Andrew Samuel

The Winning Line

A Forensic Engineer's Casebook

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Andrew Samuel, BE (Mech), MEngSci, PhD, DrEngFIE Aust
Professorial Fellow
University of Melbourne
and
Principal Consultant
Engineering Investigations & Associates Pty. Ltd.
Australia

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Many times during the struggle to complete this book Eva asked why I would spend so much time and energy in writing about old case material. Here I admit publicly that it was a means of formally recording in one volume a great portion of those many boxes of legal files that used to inhabit our cupboards, having to be carted from house to house, each time we moved. So, I hope that this book will allow me to finally sever my connections with them. That alone should be dedication enough. But wait, there is more … I could never have done it (the writing and the carting) without her help, and for that I am forever in her debt.

You're the cream in my coffee,
You're the salt in my stew
You will always be my necessity,
I'd be lost without you.

An expert is a person who has made all the mistakes that can be made in a very narrow field.

Niels Bohr, Danish physicist (1885–1962)

Preface

Expert (adjective) circa 1374, from Latin *expertus*, past participle of *experiri* "to try, test". The noun sense of "person wise through experience" existed 15th century, reappeared 1825. Expertise (1868) is from French *expertise* "expert appraisal, expert's report." On-Line Etymology Dictionary (OLED)

A legal friend once confided that "when a litigation becomes difficult, I generally hire a professor to help me with the technical aspects of the argument". In this context professor is a euphemism for a highly placed or respected academic expert. Generally the "expertise" is closely connected to the special qualifications an academic expert can bring to the litigating table, but this is by no means a sine qua non for the wily litigator. Lawyers occasionally find it appropriate to use not so much the real underlying expertise of a witness but the knockout punch of the heavy string of qualifications of the expert witness. Litigation commonly reflects the John McEnroe sentiment, "winning is not everything: winning is the only thing". Litigators will generally strive to find a winning line of approach that will either deter the opponent from proceeding further with the case or that will crush the opponent should they be foolhardy enough to proceed to court. The astute expert will assist the litigation by seeking out the "technical chink in the armour" of the opposition's argument. The primary obligation of an expert is to advise a prospective client whether indeed there is a possible "winning line" to be found in the technical details of the litigation.

This book is about helping litigators find the winning line in litigations involving engineering failures. The casebook examples are based on the author's thirty-year experience in engineering litigation. There are examples of relatively simple technical evaluation to complex interactions of various strands of engineering systems. The case material includes mainly mechanical machinery failures, with some examples of attempted insurance fraud and even a very special case of how an engineering "fingerprint" helped to convict a drug smuggler. Invariably, the cases originated from insurance litigations. Therefore it is important to recognise the "real objectives" of stakeholders involved in the litigation. In general there are four major types of players and four acts in the engineering litigation drama.

The injured party – this may be an individual (as in cases of human injury or where an inventor's intellectual property is infringed by some corporation), classes of individuals (as in a case of class action[0.1]), or companies.

The cause of the injury or loss – in most cases there is a need to evaluate the root cause of the loss or injury, not for assigning blame, but as a means of disbursing the cost of compensation.

The mediators or litigators – these players in the litigation drama are the initial advisors to the stakeholders in the process of disbursing compensation.

The expert witnesses – they provide technical support to the stakeholders in the litigation drama.

Act 1: An accident or some "defining event" takes place and a financial loss is incurred or an injury is sustained by one or more persons.

Act 2: The loss assessor (a *mediator*-type player) is called in and the insurers are advised of the nature and extent of the loss or injury.

Act 3: Litigators are called in to review the situation and to advise if there are opportunities for avoiding payment or for reducing the payout by disbursing the quantum to others.

Act 4: Where appropriate, the litigators ask for experts to help identify and secure the winning line in the litigation.

So far the situation is relatively fluid and unresolved. If the experts advise and the litigators consent to take the matter further, then the real "stoush" begins. The clear and unambiguous objectives of the various parties in the litigation drama may be identified as:

(a) *Compensation* – this is the objective of the organisation or humans who suffered loss or injury;

0.1 A *class action* is a civil suit brought by one or more people on behalf of themselves and others who are similarly situated. In other words, the others are in a substantially similar circumstance where the common issues are the most critical to the lawsuit. For example, if a large number of consumers is injured as a result of an allegedly defective product, the principal issue will be whether the product caused the injury. Some examples of class actions are those brought against the manufacturers of allegedly defective or hazardous products, such as asbestos, certain vaccines, Agent Orange, tobacco, and breast implants.

(b) *Avoided payment or, at worst, reduced or deferred payout* – the objective of the insurer;

(c) *Identifying and securing the winning line for the litigators* – the objective of the experts;

(d) *Winning* – the objective of the litigator.

In these cases occasionally a serious conflict of objectives can occur where litigators and/or experts fail to recognise the real substance of a case. Securing a winning line is not necessarily a case of forensics and identifying the root cause of the accident event. In many cases the winning line involves tactical and strategic moves by the litigator well supported by an understanding expert. Identifying the technical cause of the accident may not be as helpful as building up the logical set of circumstances that led to it. These and other matters are drawn out from the many case examples presented in this book.

Chapter 1 introduces the court system and the genesis of litigation procedure. A substantial case example is presented in the introduction to illustrate the fine detail of investigation and evaluation often required for securing a winning line in a litigation. The following chapters offer documented case material in an ordered set of engineering disputes. Chapter 2 deals with a variety of mechanical failures and associated disputes. Chapter 3 introduces product liability and the laws and experiences relating to this contentious topic. Chapter 4 presents cases in which human injury was the main subject of litigation and Chapter 5 offers examples of intellectual property litigation as well as a brief introduction to information technology litigation and digital fingerprinting. Chapter 6 is about forensic investigations where disputes over insurance fraud and criminal action required engineering expert advice. In all case examples the nature and style of potential dispute scenarios are presented and each case is described with the elements of the case similar to the chickweigh case presented in Chapter 1.

The book finishes with some concluding notes, followed by a substantial bibliography and index. The appendices present relevant technical and professional information including the expert witness code of conduct.

Andrew Samuel
Melbourne June 2006

Acknowledgements

Always acknowledge a fault. This will throw those in authority off their guard and give you an opportunity to commit more.

Mark Twain

In planning this book I initially constructed a few introductory chapters and then asked several people, including technical and laypersons, to review the content and layout. The material in this book is very much a mixed lot, highly multi-disciplinary in nature. I had planned to be precise in presenting the technical content, but in addition, I wished to exercise diligence in making the material easily accessible to a variety of readers with different levels of technical understanding. The two people most instrumental in helping to make the layout and content the way it has ended up are my friend and colleague of many years William (Bill) Lewis and the love of my life, Eva Samuel. I am very grateful to both and I hope that eventual readers of the book will also appreciate their substantial input.

When I joined the staff of the University of Melbourne for the first time in 1960, my mentor and supervisor was Peter ("Le Pitot") Joubert. Like most impecunious academics of the time Peter had already developed a burgeoning consultancy in aerodynamic matters. He was also building his first boat, the planing hull Platypus, in the backyard of his home in Brighton. In allowing me to help with some of his consulting cases, Peter must have recognised in me a kindred spirit of wanting to explore the intricate details of complex engineering problems. I was also introduced to boat building, keel casting and a great variety of other matters that have helped develop my keen interest in engineering consulting.

Who can forget the Keystone Cop comedy of casting and delivering the lead keel for the Platypus to Brighton, or the effects of exploding a Shermuli orange smoke distress signal in the Brown Coal Laboratory? The testing of the large Cyclo centrifugal fan and the ferret draping quest of Alan Dowse also live in sharp detail in my memory of that time. For these and many other matters I am gratefully acknowledging Peter's substantial influence on my development as an engineering consultant.

There were many other influences that need acknowledgement. Zdzislaw Parszewski conspired with me to establish The Research Connection Pty. Ltd., which eventually became Engineering Investigations & Associates. My wonderful colleagues Bill Lewis and John Weir gave help and advice when presenting case material to undergraduate classes in engineering design. Probably the most significant influence on the formalism of forensic case presentation has come from the many lawyers and barristers I had advised on engineering matters. It was their regular insistence that the case material should be drawn out to permit easy and clear presentation to court that helped develop my reporting style. For this and many other matters I am grateful to Robert Abrahams, John Bushby, Frank Traugott, Robin Shute and several others whose names have left my increasingly fading memory. Invariably there will be errors and for those I take full responsibility.

Andrew Samuel
June 2006

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Introduction

Discourage litigation. Persuade your neighbors to compromise whenever you can. As a peacemaker the lawyer has superior opportunity of being a good man. There will still be business enough. Abraham Lincoln

For certain people after 50, litigation takes the place of sex. Gore Vidal

A friendly solicitor once told me that "insurance companies make money from collecting premiums and not from paying out compensation". At the time I was a little irritated by this "friendly" observation because it affected me personally. Now, with substantial hindsight, I recognise this advice as a wise and Lincolnian observation.

Engineering litigation of any significance is rarely initiated by individuals. In the most common scenario the decision to litigate is determined by the legal advice offered to insurance companies. It is the insurer of the plaintiff (the person or persons suffering loss) who will initiate litigation either against the plaintiff (on possible grounds of mitigation of loss) or enjoin others in the litigation process. Enjoining is a process of bringing a [law] suit against some other party who may bear some or all of the financial loss involved in the litigation process.

If we consider the overall landscape of loss-generating situations, clearly, industrial accidents involving machinery or humans or both, represent a minuscule part of the insurance loss terrain.

Although litigation ultimately takes place in a court of law, many complex interactions present themselves that can save litigants from that ultimately most costly alternative of the court. One might even invoke the words of Samuel Johnson, who said "patriotism is the last refuge of the scoundrel". For engineering litigation this translates to, "the court is often the last refuge of the incompetent litigator or the vexatious client". Once in court, the case may be dealt with in terms of technicalities of the law rather than the real technical substance of the case. Occasionally even the apparently "rock solid" case may be overturned by some minor flaw in presentation or a discredited witness.

Two key issues that influence the procedure in engineering litigation are the nature of the engineering expert [witness] and the nature of the court hierarchy. It is useful to consider these two issues in turn.

1.1 The Engineering Expert

The etymology of expert as opposed to the non-expert lay person(s) is a useful starting point for defining the role of the engineering expert.

Expert: (circa 1374) from Latin *expertus*, the past participle of *experiri* "to try, test". The sense of "person wise through experience" existed in the 15th century, reappeared 1825. *Expertise* (1868) is from French *expertise* "expert appraisal, expert's report."

Lay: (circa 1330), from obsolete French *lai* "secular, not of the clergy" (French laïque), from Latin *laicus*, from Greek *laikos* "of the people," from *laos* "people," of unknown origin. In Medieval English contrasted with learned, a sense revived 1810 for "non-expert." *Layman* "non-cleric" is from 1432; "outsider, non-expert" (especially in regards to law or medicine) is from 1477. The gender-neutral *layperson* is attested from 1972.

Witness: Obsolete English *witnes* "attestation of fact, event, etc., from personal knowledge;" also "one who so testifies;" originally "knowledge, wit," formed from *wit* (noun). The verb is circa 1300, from the noun. Christian use is as a literal translation of Greek *martys*.

OLED (*On Line Etymology Dictionary*, www.etymonline.com)

An expert witness is needed where a court requires assistance when asked to decide on matters which are outside the knowledge of the court. Court procedure is similar to procedure in parliament in that there are two adversarial sides to some argument. The expert's role is to aid the court in making decisions on the argument put by both parties.

The expert is the only person who may offer an opinion to the court. Expert opinion can vary but, in general, when faced with engineering litigation, the clear identification of the technical parameters of the argument will aid the court in making a proper decision. Einstein was quoted as noting that

> *"if a scientist cannot explain the substance of a scientific investigation in terms sufficiently clear that a layperson can understand it, then the scientist is either a charlatan or a fool".*

Senior legal counsel and judges are by no means laypersons. Consequently, the expert should have no difficulty in explaining the technical substance of virtually any matter before the court. There are some matters in engineering situations that can lead to uncertainties. Typical examples are the nature of loads and failure models in engineering structures. In these types of uncertain situations the expert is required to offer the best possible estimate of behaviour, together with an identification of the degree of uncertainties involved.

An unfortunate feature of the expert in litigation is that the nature of the adversarial system encourages the use of professional experts as "hired guns" who might embrace the argument of the side for which they act, rather than face the technical issues in an objective way. For this specific reason the legal system has developed a professional code of conduct for experts and in all cases it is essential the expert should be fully acquainted with the substance and spirit of the code.[1.1]

1.2 The Court Hierarchy

Court: 1175, from Obsolete French, *curt*, from Latin, *cortem*, accusative of *cors* (earlier *cohors*) "enclosed yard," and by extension (and perhaps by association with *curia* "sovereign's assembly"), "those assembled in the yard; company, *cohort*," from *com-* "together" + stem *hort-*, related to *hortus* "garden, plot of ground." The verb meaning "woo, offer homage" (as at court) is first recorded 1580. Sporting sense is from 1519, originally of tennis. Legal meaning is from 1292 (early assemblies for justice were overseen by the sovereign personally); *courthouse* is from 1483. *Court-martial* is first attested 1571; as a verb, 1859. *Courtier* is from 1228; *courtly* "having manners befitting a court" is from 1450.

Hierarchy: circa 1343, from Obsolete French, *ierarchie*, from Medieval Latin, *hierarchia* "ranked division of angels" (in the system of Dionysius the Areopagite), from Greek, *hierarchia* "rule of a high priest," from *hierarches* "high priest, leader of sacred rites," from *ta hiera* "the sacred rites" (neuter plural of *hieros* "sacred") + *archein* "to lead, rule." Sense of "ranked organization of persons or things" first recorded 1619, initially of clergy, probably influenced by *higher*.

OLED

Court hierarchies vary between legal systems, but in general there is a relatively similar cluster of hierarchies for litigation in civil matters. The general structure of the court hierarchy is determined by the scale of the civil suit (the *quantum*), or the sum of money that is the subject of the litigation.

In the Australian Court hierarchy the *County Court* deals with matters in which the quantum is less than $100,000, while the *Supreme Court* deals in civil quanta greater than $100,000.

The British legal system has a new set of litigation rules, proposed by the Law Reforms of Lord Woolf [1.2] in 2003. The objective of the reform was to reduce the times involved in litigation and to streamline the heavily overloaded and slow British court system. the following simple hierarchy of actions operates in the UK, other than in Scotland, where Scottish Law applies.[1.3]

> *Small Claims* – Applies where the value of the claim is not more than £5000. Various rules of procedure do not apply (e.g. no exchange of witness statements, no disclosure and inspection of documents) and legal costs are not recoverable. Normally these claims will be determined by a District Judge in the County Court. The costs provisions are designed to discourage legal representation.

1.1 A copy of the Expert Witness Code of Conduct is provided in Appendix 1.

1.2 A brief description of the new reforms is available at www.eurolegal.org/british.

1.3 www.scottishlaw.org.uk.

Fast Track – Applies where value of claim is greater than £5000 but not more than £15,000. In fast track cases trial is to take place within 30 weeks of allocation and there are fixed trial costs.

Multi-track – Applies where value of claim is £15,000 or more. It is in multi-track cases that active case management [or more often mis-management] becomes a feature. Soon after the exchange of initial statements of case [or several months after if you are in a County Court in London] the parties attend a Case Management Conference ("CMC") in order to fix a timetable for the various stages of litigation.

At first sight, the American legal system appears a little more convoluted than either the English or Australian systems. About 95 percent of all trial cases come through the *State Trial Court* system. However, The *United States District Court* handles cases where the quantum is greater than US$ 75,000, and this is the most common type of case in this court. This procedure makes the American legal system more streamlined, permitting a speedy process of litigation that may be partly responsible for the notoriously large numbers of product liability litigations conducted in the United States.

In all countries there are higher courts of appeal, for dealing with matters where either party in a case feels aggrieved by the decision of the lower courts. In general, all court and legal systems tend to discourage appeals both procedurally and financially. Moreover, all judicial systems tend to encourage a process of case management that has its first steps grounded in peaceful settlement.

Both in Australia and America, special cases involving administrative issues relating to federal laws are heard in the Federal Courts. Typically, engineers may be involved in providing expertise for tax law evaluations, and these are heard in the Federal Court. Cases involving death are invariably evaluated initially by a coronal enquiry, and based on the decision of the Coroner, these cases may be held over for trial in a criminal court. If the result of the coronal enquiry is non-criminal and a civil case ensues, then that case is usually held over for dispute in the appropriate civil court.

1.3 Engineering Insurance and Loss Management

Mitigate: 1432, from Latin *mitigatus*, past participle of *mitigare* "make mild or gentle," ultimately from *mitis* "gentle, soft" + root of *agere* "do, make." *OLED*

"From the middle of the 19th century onwards, classical insurance sectors, such as third party liability and fire insurance, were willing to partially cover the new kinds of risk arising from the operation of technical facilities, However, the numerous and, unfortunately, expensive accidents involving machines led to a call for a made-to-measure solution to improve the coverage of the financial risks. … and so it was that engineering insurance was born."[1.4]

1.4 Munich Re (2000).

Figure 1.1 Workers with a steam engine in Russia (around 1900)

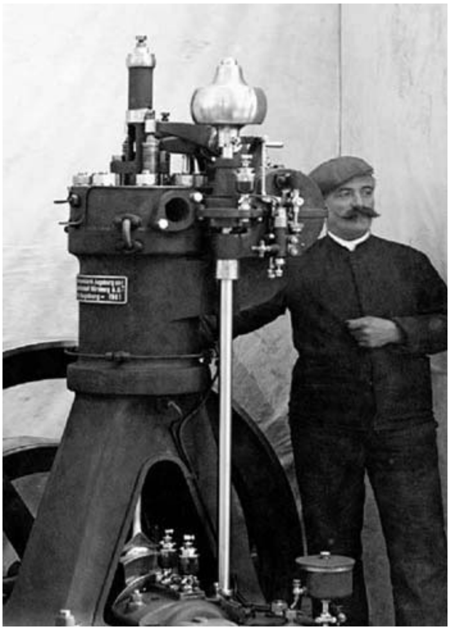

Figure 1.2 Single-cylinder 8 HP diesel engine delivered to Jaffa, Palestine (now Israel) in 1901

Figure 1.3 The collapse of the Wuppertal suspended railway in 1999 following incorrect installation during maintenance

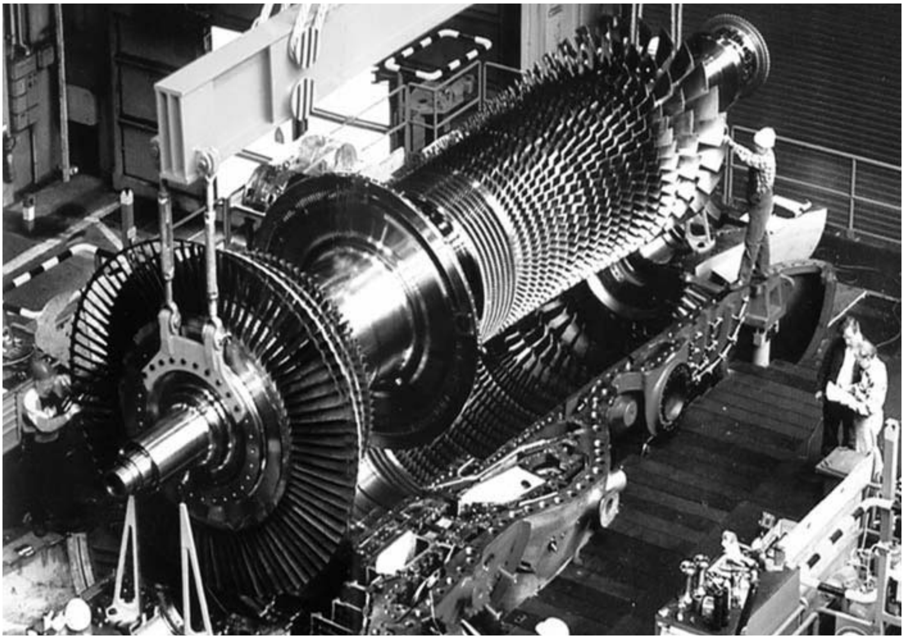

Figure 1.4 Gas turbine rotor with compressor and turbine components being installed in their housing

Figure 1.5 Sinking of an oil exploration platform (Insurance loss of $500 million)

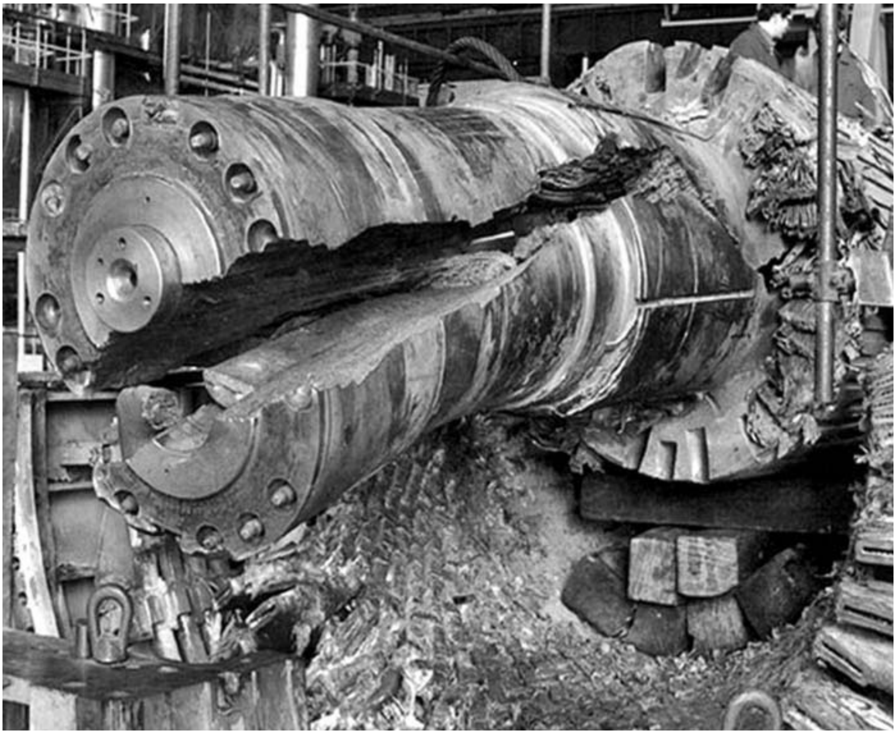

Figure 1.6 Failure of a 600 MW set with an eventual insurance loss of $40 million

Figures 1.1 to 1.6 show a very small range of the type of engineering machinery and systems insured by Munich Re, the largest and most comprehensive reinsurance organisation in the world. The company was the brainchild of Karl Thieme, about whom company history notes:

> *"36-year-old Karl Thieme, who, in cooperation with respected industrialists and bankers from Munich, founded the Münchener Rückversicherungs-Gesellschaft in Munich in 1880 and Allianz Versicherungs-AG in Berlin in 1890. In1898, one of his employees, Chief Engineer Fritz Böhrer, who had gathered extensive experience with losses in his time as technical director of a printing company, suggested something that had not been available in Germany up to that time – an innovative "insurance for machines and mechanical devices for all industrial companies, electricity, gas and water works, etc."*[1.5]

In its 100-plus years of operation Munich Re and Allianz, together with many other insurers around the globe, had to be able to assess not only the risks involved in engineering insurance, but also the underlying technologies in substantial depth. As technology developed the insurance organisations had to keep pace with these developments. It has become an accept-

1.5 Munich Re (2000).

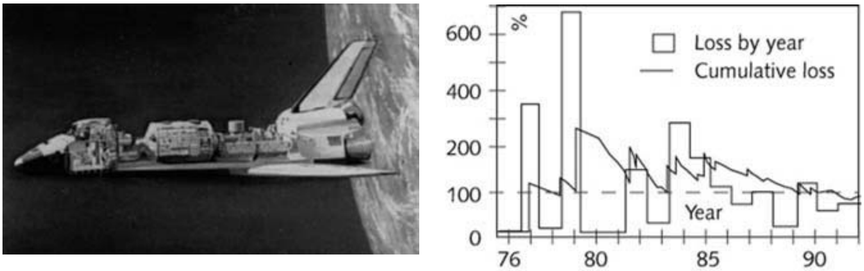

Figure 1.7 European space lab in the space shuttle together with space Insurance risk data: presented here with the kind permission of Allianz and Munich Re

ed feature of all new technology insurance that the insurer would carry some of the initial risk in hazards and loss prevention. The space industry is an excellent example of this type of *loss-leader* risk management.

The cumulative loss data in Figure 1.7 shows that in the space of about 15 years the cumulative losses have levelled off and a good estimate of the insurance risk and the associated insurance premium could be made even in this even in this volatile and substantially unknown technology.

The established wisdom of industrial insurance of machinery and technology has developed to a level where the premiums tend to keep apace with the incurred damage. Nevertheless, insurers of virtually anything are duty bound to investigate losses and wherever possible share the loss with, what I have termed, loss mitigators. Loss mitigators may be in the form of operational errors by the machinery operators, faulty components or design errors. Loss-sharing investigations often result in disputes and in some cases ultimately litigation. This then becomes the theatre of operation for the expert witness. Disputation needs the information that might be provided by *independent* assessment of the substance of the dispute. Here independence is determined by the expert's implied absence of financial interest in the outcome of the dispute. Accurate advice *without fear or favour* is the hallmark of the competent expert. Unfortunately, the expert occasionally and sometimes unwittingly embraces the collective argument of the client. This is the result of a psychological condition similar to the *Stockholm Syndrome*[1.6] and if unrecognised by the expert it can seriously influence the interplay between expert and client.

1.4 Genesis and Morphology of Engineering Litigation

The most powerful engine that drives engineering litigation is uncertainty. Were it not for uncertainty in such matters as material properties, operating loads and duty of care for clients, engineering litigation would almost certainly disappear from the court calendar. As it is, however, the participants

1.6 Kuleshnyk (1984); Kihlstrom (2004); Rothenberg (2003); Cassidy (2002); Franzoi (2002).

in an engineering dispute involve the plaintiff (the one who has suffered loss), the defendant (the initially nominated cause of the loss) and a group of umpires (usually the loss assessor in the first instance) who will initially identify the nature and scale of losses incurred and relate cause with effect. Insurers will then consider how they may pare down their losses by assigning causes to various elements and associated stake-holders in the loss process. If the case under consideration is clear-cut, then the decision of the umpire is adhered to and the matter is settled. Where the umpire's decision is not accepted by either party in the case and a dispute results, some special measures become needed for resolving the dispute.

(a) Disputation

Either the plaintiff is not satisfied with the compensation for the loss incurred, or the quantity or quality of compensation awarded against the defendant causes grief, or a mixture of these issues results in a dispute. In such events it is customary to involve an independent consultant (usually from the legal profession) to resolve the dispute. This approach almost invariably requires a further investigation of the substance of the dispute followed by some negotiation process.

(b) Investigation

Investigation requires the careful reconstruction of an event chronology associated with the event that led to the dispute. Often the timing of various stages of the event and associated decision processes by either party (plaintiff and/or defendant) can critically influence the outcome of the event (e.g. *"if only the Captain was on the bridge when the ship hit the iceberg ..."* and *"... if only we had had enough lifeboats for everyone ..."*).

(c) Mitigation

Part of the reason for conducting a thorough investigation of the various elements of the dispute is to discover if there are mitigating circumstances that might have reduced the influence of the actions or decisions taken throughout the event that led to the dispute.

Examples:

• A milk tanker rolls over while delivering milk from a farm to the dairy for processing. The tanker is damaged and 30,000 litres of milk are spilt. The loss assessor distributes the resulting $200,000 loss to the tanker manufacturer on the grounds of supplying a non-standard kingpin bolt that failed in the accident event. Later investigation showed that the tanker driver was travelling too fast for the turn where the accident took place and that the non-standard kingpin had no significant influence on the loss. The loss was redistributed to the driver contractor.

- A contractor working for *P* lops some trees on *P*'s property. One branch falls on nearby 22 kV power lines, causing damage to virtually all electrical equipment fed by the 22 kV to 415 V transformer. The loss assessor distributes the almost $1 Million loss to the contractor's public liability insurer. Subsequent investigation established that the contractor was working well outside the permissible range of his contract and, regrettably, the private contractor was a *"man of straw"* with no significant financial substance.[1.7] The losses were redistributed to the private insurers of individual property owners.

- *T*, a cleaner in a processing plant, is flashed with superheated steam from an industrial pressure cooker and later dies from his injuries. Loss investigation distributes the loss to the process plant operator. Subsequent investigation of the pressure cooker found a marginally faulty closure system and the loss was ultimately shared between the process plant operator's and the manufacturer's liability insurers.

(d) Negotiation

Once the various investigations have been completed by the loss assessors and supporting consultant investigators, the parties in the dispute are given the opportunity to settle the matter in an amicable way. The general form this process takes is that of an offer of compensation to the plaintiff. The offer is based on the established loss and the various mitigating circumstances. If the plaintiff refuses to accept the offer, or the various parties in the dispute disagree with the findings of the umpire and support consultants, the negotiation moves on to a *mediation* process.

(e) Mediation

This process is very similar to the negotiation process, but initially the matter is handed over to an independent *mediator* to assess the various issues in the case. In most cases the mediator is likely to be chosen from the legal profession, or is a technical expert with legal support. If the mediation process fails to reach a resolution in the dispute, then the *process of last resort* (the call for the *third umpire* – a sporting term[1.8]) is *litigation*.

(f) Litigation

Some cases heard in court have every right to be there, to be judged by either an impartial judge or a jury of six (half jury) or twelve good persons and true. Unfortunately there are a substantial number of

1.7 In legal terminology a man of straw is also "a person of no means," or one who deliberately accepts a liability or other monetary responsibility without the resources to fulfil it, usually to shield another party.

1.8 When in the sporting arena two umpires disagree about an incident then they can ask to view a video replay of the incident as seen from various vantage points – this process has become known colloquially as a call for *"the third umpire"*.

matters that should have been concluded at the negotiation stage or at worst the mediation stage. For these unfortunate cases imagine two very heavily inebriated persons in front of a local pub shaping up for a brawl. Each has his fists raised, daring the other to throw the first punch, which is rarely if ever thrown. Alternatively, imagine two small children in the playground stamping their feet calling *"it is so!" …, "no it is not so! …"* etc. Often this is the serious form that litigation takes, with the punch-throwing threats or the foot stamping analogies very much in evidence along the way to a final wrung out settlement. Of course, the legal profession and the professional expert witness are all very much in favour of litigation. It is invariably high drama, but the costs involved are substantial, often straining the deep pockets of the adversaries involved.

One expert colleague once remarked to me that intellectual property cases are like the *manna from heaven*. The fees continue to escalate as time and argument over the meaning and nuances of words proceeds. I have personally participated in a case heard in a supreme court over a quantum of $300,000, where the poorly advised plaintiff insisted to be heard in front of a judge and half jury. I was asked to offer a mediation report on previous investigations and other expert's reports in the case. My conclusions were in favour of an amicable settlement, with the litigant's insurers carrying the costs. In the event the case lasted two weeks in court and, on my day in court, proceedings were delayed for over an hour due to the judge's insistence on investigating why the six sitting jurors had not been paid their daily stipend. Imagine four highly paid barristers (two for each side) several clerks of court, a legion of lawyers and their article clerks, tip staff and court reporter and at least three expert witnesses hanging on for an hour at the plaintiff's (eventual) expense. That image alone should be enough to discourage even the most aggressive litigant from proceeding to court.

1.5 Negotiating with Clients and Litigation Support

Forensic: 1581, from Latin, *forensis* "of a forum, place of assembly,". From *forum*, used in sense of "pertaining to legal trials," as in forensic medicine (1845). More colloquially understood to involve careful investigation for the purposes of legal trials. *OLED*

Forensic engineering consultants are often requested by legal services through academic institutions. Well-known forensic engineers known to be informed in some specific fields of expertise may be approached directly by legal clients or occasionally individuals. Whatever the source of request for services, responsible forensic experts have a duty of care to their clients. In exercising this duty of care the expert should inform a potential client about the following matters:

(a) Specific field of expertise and experience

A useful guide for this aspect of advice is a well-presented curriculum vitae, identifying qualifications, experience and, if at all possible, case experience and some references from previous legal clients.

(b) Fee structure

In most cases the expert will have some developed fee structure that applies to the whole range of services offered. This includes investigation, travel, provision of a report for advice and/or perhaps a more formal report to be used in litigation, and court appearance. In preparing this aspect of the offer of services, it is useful to ask the potential client for a written statement of the substance of the dispute and what specific response is required form the forensic expert. In most cases the expert may be able to advise on the scale of the investigation needed and the time that may be spent on the investigation and reporting. This type of advice will help the potential client assess the relative value of hiring the specific expert.

Highly experienced forensic experts may be able to provide an outline of their proposed approach to the required investigation. This process tends to build a degree of credibility and confidence in the expert's wisdom for the potential client.

(c) Project Index

It is a sensible and useful tactic to develop a project index with an appropriate reference numbering system that will permit identifying the nature of previous projects. The project index also forms the basis of a ready reference system in legal reporting.

(d) Project Work Diary

Legal fees are commonly based on quality and quantity of time spent on projects usually in 6-minute modules (representing 1/10th of an hour). Forensic work diaries should be constructed on similar principles but perhaps a useful module for these is 0.5 hour. Each module of time spent on a project should be clearly identified for the client in terms of how the time was spent and what the outcome of this module of work represented for the results of the forensic investigation.

(e) Professional Indemnity

Professional indemnity insurance is a costly business. Premiums are determined by the scale and nature of projects handled by the expert and can be quite substantial. The premium must be paid *"in perpetuo"* to ensure cover for the full life of the outcome of the project, with cover provided *"even unto the descendants"* of the expert. For the academic expert, it may be more economical to work within the academic system where some from of indemnity insurance cover may be already in place. Naturally this arrangement requires some proportionate sharing of the fees between the institution and the expert. Needless to say, that only in moderately sized forensic engineering organisations, with a steady flow of work, is it economical to invest in professional indemnity cover.

1.6 Investigative Procedures; Data Collection

Data: 1646, plural of *datum*, from Latin *datum* "(thing) given," neuter past participle of *dare* "to give." Meaning "transmittable and storable computer information" first recorded 1946. Data processing is from 1954. Database formed 1962, from *data* + *base*.

Discover(y): circa 1300, from Old French *descovrir*, from Late Latin *discooperire*, from Latin *dis-* "opposite of" + *cooperire* "to cover up." Originally with a sense of betrayal or malicious exposure (discoverer originally meant "informant"), the modern meaning "to obtain knowledge or sight of what was not known" is from 1555.

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In each case there is considerable information available within the case structure. That does not mean to imply that the forensic expert is freely given the whole data set. In many cases within my experience not only was there some difficulty in assembling all the relevant data, but in many cases there was some reluctance and resistance to release data by one or other of parties in the dispute. In some instances the poorly informed legal client might not *"wish to cloud the judgement"* of the expert with information they see as *"not specifically relevant"* to the case in hand. In yet other cases the defendant or the plaintiff may wish to hide information they see as perhaps detrimental to their argument in the dispute. In all cases the client must be informed that only a free and unfettered access to all information can the expert offer unbiased objective opinion. Some examples:

- A new design of an automatic hydraulic levelling system was introduced into the agricultural machinery market. The system suffered large numbers of in-service failures and one farmer lost virtually a whole year's wheat crop due to poor germination resulting from seeding at the wrong and uneven depth. The farmer sued the manufacturer and these failures were initially attributed to the use of inappropriate materials for a cylinder oil seal. Only after some reluctance on the part of the defendant was it revealed to the forensic investigator that they had made an apparently, to them, *"insignificant"* design change to the previously successful levelling cylinders to make them easier to manufacture.

- An Alfa Romeo motor car was completely burnt out due to an inexplicable electric fire. The owners claimed compensation under fire insurance cover. Insurance investigation suggested that the fuel line in the engine compartment may have been at fault and the insurers sued the makers of the car. Only after some reluctance on the part of the owners was it revealed to the forensic investigator that they had installed an immensely powerful sound amplifier and the installation involved a poorly insulated pair of power wires leading to the battery and switch in the dashboard. This pair of wires led through a poorly drilled hole in the metal frame of the door and each time the door was opened or closed the burred edges of this hole rubbed against the lead wires. Eventually a short circuit in these wires caused the fire that burned out the car. After some litigation betveen the various parties, the claim was settled.

- A ski hire company was sued by a skier for allegedly providing him with incorrectly adjusted release bindings and ski boots with worn heels. This skier suffered injuries in an accident when his bidings failed to open. He sued for damages, claiming the accident was due to the faulty boots. Close investigation revealed that the hire docket issued to this skier was not filled out correctly at the time of hire and the case was settled by the hire company's public liability insurance.

1.6.1 Discovery

Of the many ways of assembling all the relevant information in a dispute, the most aggressively litigious mode is discovery. This is a legal term that involves a court order to the opponents in a dispute to release previously withheld documents or information. Under discovery a computer may be seized and its data files interrogated for such information. Discovery should be the last resort to information gathering in a dispute.

1.6.2 Data Mining

This term formally relates to a branch of information technology within which specialist software techniques are used to relate large volumes of information within a data base. The objective of data mining is to predict trends and behaviour based on logged performance. In the context of litigation I have used the term to describe the data gathering process that seeks to correlate large volumes of information for predicting plausible event scenarios.[1.9] Unless a plausible event scenario presents itself to the forensic expert, the case must rest only on the stated claims of the parties to the dispute. Clearly, if the forensic expert is to accept the stated version of events, then the nominated wisdom of the expert has little or no influence on the outcome of the dispute. In several instances identified in the case material in this book it is the careful reconstruction of events that permitted the development of a plausible event scenario and ultimately the winning line in the dispute.

1.9 Berry and Linoff (2000); Fayyad *et al.* (1996); Giudici (2003); Han and Kamber (2000); Hand *et al.* (2000); Hastie *et al.* (2001); Nemati and Barko (2003); Rud (2001); Weiss and Indurkhya (1997); Witten and Frank (1999).

1.6.3 Standard Codes of Practice

In engineering litigation the codes of practice can guide the path of the dispute to resolution. While the codes of practice have no formal legal standing, they encapsulate the collective wisdom of experts in some specific discipline. In cases where a design or operational procedure failed to adhere to the recommended code of practice, the forensic expert needs to discover the reasoning (if any) behind the variation from the code. Codes of practice are available from a variety of sources. *Standards Australia* and *American Society for Mechanical Engineering* have comprehensive catalogues of codes available for direct purchase on line. The International Standards Organisation (ISO) website states they have *"in excess of 14,000 codes for industry, Government and Society"*.[1.10]

With such a plethora of codes available, it would seem improper not to search for appropriate and applicable codes of practice at the commencement of a forensic investigation.

1.7 Reviewing the Evidence and Building a Case Chronology

Evidence: from *evident*, originally from Latin, *videre* "to see." *Evidence* (circa 1300) is Late Latin. *evidentia* "proof," originally "distinction." After 1500 it began to oust witness in legal senses.

Document: circa 1450, "teaching, instruction," from Middle French *document* "lesson, written evidence," from Latin *documentum* "example, proof, lesson," in Middle Latin "official written instrument," from *docere* "to show, teach" (see *doctor*). Meaning "something written that provides proof or evidence" is from 1727; the verb meaning "to support by documentary evidence" is from 1711.

Chronology: 1593, from Greek, *chrono-* combing form of *chronos* "time" + *logy* combining form of logos "word."

Veracity: 1623, from Latin *verax* (genative of *veracis*) "truthful," from *verus* "true."

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A useful start to a forensic investigation is to place all the stages of the event into chronological order and to associate with each stage all the available documented or oral evidence. Oral evidence, other than that presented by an eye witness, is regarded as *"hearsay"* in legal terms and therefore inadmissible in court, but in generating the evidence chronology it can point the way to exploring some follow-up evidence paths for the forensic expert. If at all possible the participants in the event should be interviewed and the interviews turned into evidence by asking the interviewee to swear an affidavit to attest to the veracity (unassailable truth) of their statement.

There are many similarities in the way certain types of engineering events, leading to litigation, unfold. Typically, when investigating a failed or damaged piece of machinery, one of the following situations arises:

(a) The machinery was damaged during delivery and could not be repaired satisfactorily, or

1.10 www.standards.com.au; www.asme.org/catalog/; www.iso.org/iso/en/ISOOnline.frontpage

(b) Installed machinery failed to meet manufacturer's (or agent's) specifications, or

(c) Machinery was installed and operated successfully for some peri od, after which time it was no longer operating as expected, or some key component failed and severely damaged the operation, or

(d) Machinery was installed and operated successfully for a period, after which it was shut down for maintenance and, when restarted, it no longer functioned as expected.

These four categories of events cover almost all possible machinery failure cases. Clearly, time-dependent conditions leading up to the event under consideration can play an important, if not critical, part in the development of the outcome. When building a case chronology, the experienced forensic investigator will be able to identify important *"milestones"* in the way the specific case had unfolded. For the first-time chronology builder a useful guide to important *"milestones"* in a case is to identify key *"decision points"*, that guided various actions that led up to, and then arose from, the event under investigation.

1.8 A Typical Example – The Failed Chickweigh Line

1.8.1 The Initiating Event

The *"chickweigh"* line, operated by *Castrato Pty. Ltd.* in 1994, determined the weight of processed chickens prior to packing in appropriately identified packages. Cleaned and processed chicken carcases were carried on hangers mounted on a chain conveyor. As each hanger passed through a weigh station, the weight and location of the hanger with its chicken was logged in a computer. Further down the line, graduated collection bins would receive the various-size chickens, to be packed and labelled by weight. The time and distance required to reach the destination bin was calculated from the information collected at the weigh station. Once the conveyor had carried the chicken the calculated distance, corresponding to the appropriate grade sorting bin, it would be released from the hanger into its destination bin.

After operating successfully for some time, the chickweigh system no longer functioned reliably. This lack of reliability caused underweight chickens to be delivered to customers, with subsequent complaints and loss of custom. Moreover, to deal with the chickweigh problems, Castrato staff were forced to weigh chickens by hand, disregarding the automatic weighing system, and thereby incurring loss of time and accompanying loss of revenue.

1.8.2 The Assigned Cause by the Umpire (the Loss Assessors)

The errors in the chickweigh line were deemed to have resulted from a *"sudden extension"* of the conveyor chain, that carried the chickens through the chickweigh system. The sudden extension allegedly resulted from a shackle (link of the chain system that carries the hanger on which the chickens are supported) being caught in an obstruction during a maintenance incident. This sudden extension, alleged to be about 1.8 to 2.2 metres (6 to 7 feet), had required the removal of this same length of chain from the packing conveyor. However, even after the removal of the length of conveyor chain, assessed as the extension length, the chickweigh line still failed to operate reliably.

1.8.3 The Evidence

On Wednesday 14 December 1994, I inspected the plant in the company of *Neville Marriner and Associates* (*NM*), Loss Adjusters and *Peter Contralto* of *PLC* Pty. Ltd., electrical engineers. While at the plant I took the following measurements and records:

(a) The motors driving the chickweigh line were two 1.1 kW (unlabelled) A\C motors driven through a 2.2 kVA variable-frequency drive. The motors were both in the coolroom area of the plant and mounted on a simple welded structure supported on three 1-metre long rods of 16 mm diameter each.

(b) The chain drive of the chickweigh line was measured at several points to establish an average value for inter-shackle length and chain

Figure 1.8 Chickweigh line chain and shackle arrangement

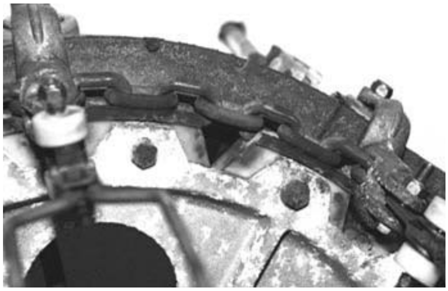

Figure 1.9 Chickweigh line corner pulley showing shackles fitting into slots on wheel

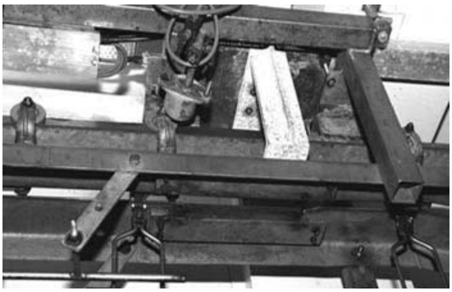

Figure 1.10 Chickweigh line weighbridge, showing proximity sensor

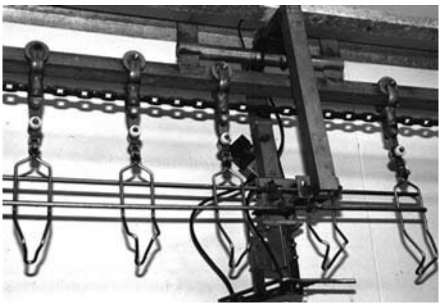

Figure 1.11 Chickweigh line chicken support and release station

link size. The corner wheels of the conveyor were inspected to establish the fit of the drive chain in the driving tabs on these wheels. (Refer to photos in Figures 1.8 and 1.9)

(c) The weighbridge of the chickweigh line was inspected, as well as its relationship to the rest of the packing line. Shackle and chicken support clevis arrangements were inspected and measured. (Refer to photos in Figures 1.10 and 1.11)

(d) Chain links were closely inspected and found to have substantial wear at the end of the links where they experience most rubbing during operation. (Refer to photo in Figure 1.12)

1.8.4 – Evaluation

(a) Chain extension

Figure 1.13 shows (schematically) one link from the chickweigh line conveyor chain. All measurements were taken with a Mitutoyo digital vernier calliper. Figure 1.14 shows the schematic layout of two shackles on the line and the inter-shackle distance as measured. The inter-shackle distance corresponds to eight links of the chain. Figure 1.15 shows the centre distance *CD* between two links. It had been alleged that there was a loss of approximately 2 metres of chain in the whole length of the conveyor (approximately 150 metres), representing 13 mm per metre of chain.

Referring to Figure 1.15, the centre distance between links of the worn chain is found from

$$CD_{links} = 2(A - B)$$

and hence the centre distance between two shackles (8 links) is

$$CD_{shackle} = 16(A - B).$$

From the measured values of the worn links

$$A = 40.8/2 = 20.4 \text{ mm}; B = 7.5 \text{ mm}$$

Hence, we can evaluate the worn inter-shackle distance:

Figure 1.12 Close-up of chain showing substantial wear at the end of the link

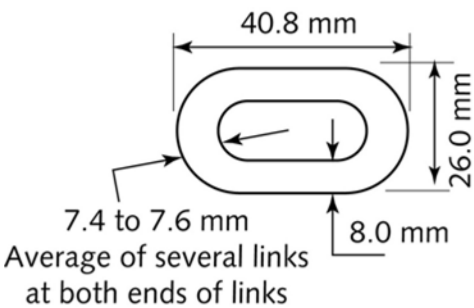

Figure 1.13 Chain link measurements on chickweigh line

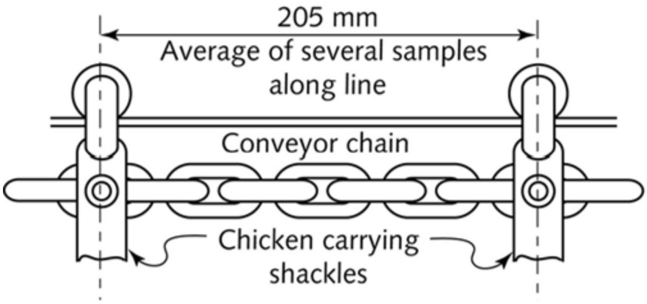

Figure 1.14 Inter-shackle distance on chickweigh line

$$CD_{shackle/worn} = 16\ (20.4 - 7.5)$$

$$= 206.4 \text{ mm (205 measured)}$$

The original inter-shackle distance in a new (non-worn) chain would be

$$CD_{shackle/new} = 16\ (20.4 - 8) = 198.4 \text{ mm}$$

The difference spread over 8 links corresponds to

$$(206.4 - 198.4)/8 = 1 \text{ mm wear per link}$$

$$= \mathbf{40\ mm\ wear\ per\ metre\ of\ chain}$$

Comparing this to the alleged 13 mm per metre of chain extension needed to account for the length removed from the chain, it is clear that the extension of the chain can be fully explained by the wear in the links. In this case the extension, calculated from measured chain link wear, is more than three times the alleged lengthening of the chain causing the weighing problems. However, it was evident that not every link had worn equally or was worn as those measured during my inspection. In addition, only the delivery half of the chain will influence errors experienced at the weighing station, causing misregistration betwen the sorting bins. The return half of the chain has no influence on the weighing process.

Having found a plausible explanation for the conveyor chain extension, the alleged structural extension of the chain needed to be addressed.

(b) Loads and elastic deflection of chain

Figure 1.16 shows the dual motor drive schematically. The second drive motor effectively doubles the torque available at the drive wheels, and correspondingly doubles the force available to drive the chain of the chickweigh line.

As a further check on the alleged process of chain extension, the static deflection of the chain under load was evaluated. For this evaluation the maximum force acting on the chain under load was estimated from the maximum available forces supplied by the motor drive. The following information was available from data at the plant:

Motor power = 1.1 kW

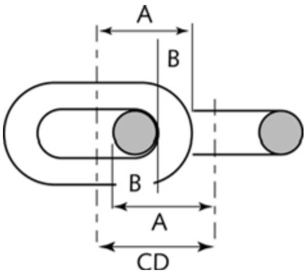

Figure 1.15 Centre distance between two links

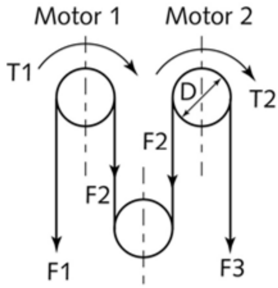

Figure 1.16 Dual motor drive (schematic only)

Motor speed = 1440 r.p.m.
Speed reducer = 225:1
Output speed N = 1440/225 = 6.4 r.p.m.
Drive pulley D = 0.52 m diameter

The greatest available driving force on the chain is found from

$$F1 = 2(\text{power} \times 60)/2\pi \times \text{N} \times \text{D}) = 3158 \text{ N}$$

If we consider the force $F3$ to be zero (a conservative assumption, since there is a lot of friction in the chain drive system) then this value $F1$ is the greatest load available to statically deflect the chain.

The average stress acting on the chain link section is

$\sigma = P/a$, where

$P = 3158$ N

$d = 8$ mm (the link section diameter)

$a = \pi d^2/4 = 50.24 \times 10^{-6}$ m^2, yielding

$\sigma = 31.4$ MPa

This is a very low stress to be acting on a chain link made of even moderate-strength steel, although, in general, chain links are made from high-strength steel.

Figure 1.17 shows schematically one link under load. The highest local stress is at point A in the chain (incidentally this is also the point of highest wear as the chain is pulled around the corner wheels). The value of this stress may be (conservatively) estimated as[1.11]

$\sigma_{max} = (34.4P)/\pi^2 rd$, where

r = inner radius of the link (refer to Figure 1.13),

$\sigma_{max} = 250$ MPa

1.11 Timoshenko (1983), pp. 362–383.

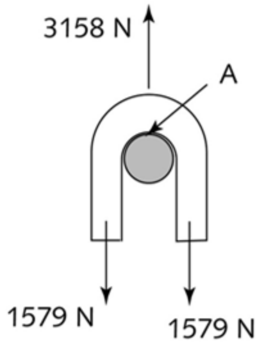

Figure 1.17 One chain link under load (schematic only)

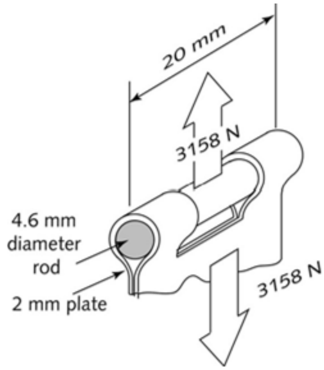

Figure 1.18 Support clevis under load (schematic only)

Under these low levels of stress the elastic extension of the link will be negligible and fully recoverable once the load is removed. Neither the average stress nor the maximum stress exceed the elastic limit for even a low-grade, mild-steel chain. Consequently I estimated that the chain could not have suffered any permanent deformation, even if the full load, available from the dual motor drive, were to be applied to the conveyor chain.

Finally, one of the scenarios for chain deformation, proposed by the plant operator, was a shackle caught in some obstruction while the conveyor was running. To eliminate this cause, it was necessary to calculate the load on the most highly stressed component of the shackle. Figure 1.18 shows a shackle schematically. The most highly loaded component is the 4.6 mm rod through the chain link on which the shackle is being carried (refer also to Figure 1.14).

The shearing stress on this rod was found from

$\tau = P/2\,a_2$, where

$a_2 = \pi \times 4.6^2/4$ mm^2, yielding

$\tau = 95$ MPa

This stress is much too low to fail or seriously deflect this component and, hence, it is entirely plausible that the chain may be stopped by the shackle being caught in an obstruction. However, this process could not apply any larger load to the chain than was estimated previously from motor torques.

1.8.5 Opinion

- The extension in the chain, due to excessive wear in links, far exceeds that claimed due to *sudden overload*;
- The stress in the chain links, even when subjected to the full load available from the motor drive (a very conservative estimate), does

not exceed the yield stress in common mild steel. Chain of better quality steel is even more unlikely to suffer permanent deformation under the available loading;

- Due to the measured elongation in the inter-shackle distance (approximately 8 mm – refer to Section1.8.4 above) the shackles will not mate correctly with the carrier tabs on the corner wheels. This effect will cause the shackles to ride up on the edge of the corner wheel until the next shackle becomes partly disengaged from the drive tabs. At this point the following shackle will *"jump"* into the vee between the drive tabs, causing some vibration in the conveyor line. This vibration effect will take place once for each shackle at each corner wheel. The result would be a general vibration and jerkiness in the conveyor system (refer to Figure 1.9);

- There are 12 x 900 mm bins along the packing line (refer to Figure 1.11), corresponding to 12 x 40 x 0.9 = 432 mm error in shackle location by the time a shackle reaches the last bin in theline. This distance significantly exceeds the length of the push-rods on the air cylinders used to dismount chickens from the line. Since the chickweigh system operates on the count of shackles passing the proximity sensor on the weighbridge (refer to Figure 1.10), this error in shackle location will inevitably result in chickens being dropped in the wrong bin or missed being dropped altogether.

1.9 Identifying and Securing the Winning Line

The *chickweigh case* example is typical of many engineering disputes. It has a problem situation (the faulty weighing) that had been attributed to some initiating event. In this case it is unclear how the alleged *"cause"* for the fault, such as shackles being caught in some obstruction, was generated.

- The operators of the line made an insurance claim under a product liability insurance policy;

Table 1.1 FMEA table for the chickweigh packaging and conveyor system

Failure type	*Possible causes*	*Risk level*	*Contributing causes*	*Action to correct*
Weighing fault	*Improper calibration*	*High*	*Wear and tear*	*Calibrate*
	Improper maintenance	*High*	*Low maintenance effort*	*Regular recorded maintenance*
Chain extends	*Overload*	*Very low*	*Wear and tear*	*Realign system*
	Wear in links	*Very high*	*Wear and tear*	*Replace chain*
Vibration in system	*Change in inter-shackle distance*	*Very high*	*Wear and tear; Improper fit in corner wheels*	*Realign corner wheel carriers*

- The loss assessor for this insurer (let us call them insurer *A*) examined the situation and decided that the best way to mitigate the situation (soften/reduce the insurance claim) would be to assign some of the causes for the loss to the servicing agency (*Contralto*) responsible for the maintenance of the line;
- The maintenance company had their own public or professional liability insurers (let us call them insurer *B*). The loss assessor of insurer B examined the situation and as a mitigating effort decided to assign some of the causes to the operators of the line;
- The line operators (*Castrato*) had their own insurance for public liability (let us call them insurer *C*);
- This case then developed into a three-cornered dispute between insurers *A*, *B* and *C*.

In this case it was insurer *B* who called in the forensic investigator to resolve the dispute. As a first step in attempting to evaluate the problem in terms of potential causes (the probable event scenario) I drew up a simple *Potential failure modes and effects analysis Table.*

Failure modes and effects analysis, or FMEA,[1.12] is a method for identifying the potential failure modes that a product or process may encounter, assessing the risks associated with these failure modes, associating priorities with failure modes according to their hazard level, and prevention as well as most likely detection, should the failure occur. The output of an FMEA cycle is the *FMEA* table, which documents how vulnerable a product or process is to its potential failure modes. The FMEA table also shows the level of risk attached to each potential failure mode, and the corrective actions needed (or already completed), to make the product or process more robust.

Based on Table 1.1, it was relatively easy in this case to focus on the root causes of the failure in the weighing line. In almost all disputes about engineering failures the initial evaluation of potential failure sensitivities and probable failure scenarios can lead to identifying the *"winning line"* of argument. Of course, it is mandatory that the winning line be backed up by careful evaluation of all possibilities.

1.10 Legal Constraints on Expert Advice

Advice: 1297, *auys*, from Old French, *avis* "opinion," from Old French, *ce m'est à vis* "it seems to me," or from Vulgar Latin, *mi est visum* "in my view," ultimately from Latin, *ad*- "at" + *visum*, neuter past participle of *videre* "to see" (see *vision*). The unhistoric -d- was introduced in English 15th century, on model of Latin words in *ad*-. Substitution of -c- for -s- is 18th century, to preserve the breath sound and to distinguish from *advise*.

Opinion: circa 1300, from Old French, *opinion* (12c.), from Latin *opinionem* (nominative of *opinio*) "opinion, conjecture, what one thinks," from stem of *opinari* "think, judge, suppose, opine," from Proto-Indo-European *op*- "to choose." *Opinionated* "obstinate" is attested from 1601.

1.12 See for example: Willis (1992); Huang *et al.* (1999); Hendershot (2000); Lee (2001).

Credit: 1526, from Latin, *creditum* "a loan, thing entrusted to another," from past participle of *credere* "to trust, entrust, believe." The commercial sense was the original one in English (creditor meaning "honor, acknowledgment of merit," is from 1607.

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As noted earlier, the forensic expert is the only one permitted to offer opinion in a judicial inquiry. The opinion supported by carefully constructed argument represents the winning line. The key qualification of acceptable opinion is credibility, in the original sense of *"honour, acknowledgement of merit"*. This is the *"pass key"* of the forensic expert.

A minor, but useful constraint on forensic expertise pertains to the language of the report. Perhaps in the most succinct terms this constraint may be stated as *"engineers engineer, lawyers apply the law"*. When reporting findings and opinions, forensic engineers should carefully avoid terminology that can carry some form of legal currency. Typical examples are *"merchantable"* and *"duty of care"*. Since these terms carry considerable legal weight their presence in a forensic report gives the impression of *"group think"* influence by the briefing solicitor and can seriously damage the technical credibility of the report.

1.10.1 The Format of the Expert Witness Report

Affidavit: 1593, from Middle Latin *affidavit*, literally "he has stated on oath," third person singular perfect of *affidare* "to trust," from Latin *ad*- "to" + *fidare* "to trust," from *fidus* "faithful," from *fides* "faith." So called from being the first word of sworn statements. *OLED*

The format and content of the expert's report takes on the nature of an affidavit. Often the legal affidavit is developed from this report. The affidavit, presented to the opposition to *"our side of the dispute"*, must accept the affidavit (or in most cases the expert's report) as the *"whole truth and nothing but the truth"* sworn statement of the expert. For these reasons the expert's report becomes the guidebook for cross examining the expert in court by the *"other side"*.

(a) Avoiding dangerous statements

All the words in an expert's report present challenges for the *"other side"*. The challenge is to dispute the meaning and/or veracity of the words in the expert's report. The following types of statements should be avoided:

- *Sweeping statements* – statements that have an inclusive sense without the necessary statistical information to support them. In cross-examination these types of statements present useful footholds for the opposition in discrediting the expert. Some examples are: *"this feature of the design will jeopardise the safety of all trucks used by earthmoving contractors"*, *"any wheelchair-bound adult will be safely transported with this locking system"*, *"skiing is a dangerous sport and all skiers must accept the risk of injury when learning to ski"*, *"This is established industrial practice …"*

- *Unsourced references* – mostly these are assertions of constraints imposed by some authority without the inclusion of the *"chapter and verse"* to support the assertions. Some examples are: *"… this is contrary to the Australian Design Rules…"* (opposition will ask which specific rules?), *"ASTM standards identify this substance as nickelic hydroxide…"* (opposition will ask about the specific ASTM standard).

- *Snake oil assertions*[1.13] – any assertion that carries overtones of established expertise. Some examples are: *"In my long standing experience…"*, *"I have considerable experience in these matters …"*

(b) Referencing

Elements of technical argument in a forensic report must be identified by reference paragraph numbers. This format permits the legal argument to be developed in an orderly manner making strict references to paragraphs in the expert's report.

(c) Opinion

In litigation, and specifically in court, the expert is the only person permitted to offer an opinion. In general, it is assumed that the expert's wisdom and understanding developed through long-standing experience, guides such opinion. In reporting, it is mandatory that opinion be offered only with considerate care. Wherever possible let the facts speak for themselves.

(d) Layout

The layout of the report must be easily accessible to anyone. Judges and senior counsel are highly intelligent people, but in the sense of technical expertise they must be given the consideration of being laypersons. Hence the readability of the expert's report should take precedence over its technical content. The facts and assertions must be transpatrently presented. For these reasons the format should be developed as follows:

- *Contents list* – for brief reports this may be unnecessary, but in most expert's reports it is useful to alert the reader where matters may be found in the report.

- *Introduction* – brief statement of the originating events that led to the dispute, the details of the counsel appointing the expert and the specific nature and substance of the opinion asked for by briefing counsel.

- *Précis of the dispute* – condensed description of the substance of the dispute and its initiating events.

- *Executive summary of findings and opinions* – in many cases this may be as far as the opposition might read into the report, accepting the expert's detailed analysis and presentation of facts as being true.

- *Qualifications* – condensed curriculum vitae that supports the averred expertise of the expert witness.

1.13 See the introductory section of Chapter 3 and www.interhack.net/people/cmcurtin/snake-oil-faq.html.

• *Briefing materials and investigations* – briefing materials supplied by briefing counsel and any other information and facts discovered through direct investigation by the expert. This material is best presented in a tabular form capable of being referenced in the body of the report.

Background history of the dispute – a full description of matters leading to and relevant to the dispute and its initiating events, including the case chronolgy.

• *Evaluation of information and analysis* – this is the main body of the report. It will contain the expert's evaluation of the information available and in many cases it will also make reference to the results of detailed analysis. Actual data and analytical evaluations should be placed in appendices attached to the report. This will increase readability of the report.

• *Concluding comments and opinions* – this is where the expert has the opportunity to stumble if not careful in avoiding the types of assertions listed in paragraph (a) above. A helpful reminder for the unwary are the words of clichéd wisdom of the *Dragnet*[1.14] televison serial as spoken by the legendary Joe Friday, *"All we want are the facts, ma'am"*.

1.10.2 The Expert Witness Code of Conduct

Ethics: 1602, "the science of morals," plural of Middle English *ethik* "study of morals" (1387), from Old French *ethique*, from Late Latin *ethica*, from Greek. *ethike philosophia* "moral philosophy," feminine of *ethikos* "ethical," from *ethos* "moral character," related to *ethos* "custom". The word also traces to *Ta Ethika*, title of Aristotle's work. *Ethic* "a person's moral principles," attested from 1651. *OLED*

Ethics are the bases of all forms of codes of conduct. None are more formalised than the code of conduct for experts in court. The code of conduct prepared by one expert witness collective states that:[1.15]

"• An expert witness has an overriding duty to assist the Court impartially on matters relevant to the expert's area of expertise.

• An expert witness should state the facts or assumptions upon which his opinion is based. He should not omit to consider material facts which could detract from his concluded opinions.

• An expert witness's paramount duty is to the Court and not to the person retaining the expert.

• An expert witness is not an advocate for a particular party."

The article goes on to note the main challenges for the expert in litigation as:

1.14 Original television police drama serial, written by and starring Jack Webb as Sgt. Joe Friday.

1.15 www.expertwitnesses.com.au

> *"Expert witnesses face a range of ethical dilemmas and conflicts in their work. A lawyer often seeks narrow and specific expertise, when in some cases that is not always possible and an expert who can consider more general principles must suffice.*
>
> *Then there are the companion requirements of being thorough and perceptive on the one hand, and impartial and objective on the other. There is a real need to look beyond the obvious, to see the whole situation (as far as this is possible) and to tell it all, without 'filtering out' evidence that may not suit the lawyer's case. If a case is weak, early knowledge of this is valuable to the lawyer.*[1.16]
>
> *Where there is a heavy reliance on expert evidence in a case and the evidence of a particular expert is accepted, there is a danger that this can usurp the role of the trier of fact. The courts are well aware of this danger and experts should be alerted to its potential. Judges decide cases, not experts."*

Although most legal systems, reliant on the advice of expert witnesses, have som form of conduct code, one of the most comprehensive codes of conduct has been drawn up by the Supreme Court of New South Wales. This document is provided in Appendix 1.[1.17]

1.11 The Cases

In the following chapters of this book there are 30 cases presented, some relatively simple, others quite complex, drawn from a variety of cultures and technologies. To provide a degree of consistency in reading through the cases a common format has been adopted for their presentation.

The Case Culture

This introductory section of each case presents the setting within which the case was conducted.

Defining Event

Full description of the background to the event that defined the ensuing dispute.

Parties to the Dispute

These are the main characters in the dispute drama.

The Client

Usually the client is a briefing solicitor acting for one of the parties in the dispute. It is always useful to keep in mind the real client in the case.

1.16 Ptolemy was the most influential of Greek astronomers and geographers of his time. He propounded the geocentric theory that prevailed for 1400 years. He is now recognised as having 'filtered' out astronomical observations that did not fit his faulty theory.

1.17 See also Boatright (2007); De Fina (2004); Fledderman (2004); Grover (2003); Gutheil et al. (2003); Kardon et al. (2003); King (2001); Pope et al. (2000); Unger (2000).

The Expert's Role

In general, with experienced legal clients, the expert's role in the dispute drama is well defined. Most often the expert is asked to respond to clearly identified issues in the case. Ocasionally, when the party appointing the expert is uncertain of the nature and substance of contributions an expert might bring to the negotiating table, the appointment is informal. Many of my cases commenced with a telephone call from a solicitor friend who asked me if I could look at a case dispute and offer some advice in progressing it to negotiation. In cases like that I would review the dispute initiating material and prepare a simple FMEA table to signal the most likely causes of the initiating event. In some cases I would perform simple *"back-of-the-envelope"* calculations to assess the magnitude of some critical element of the case argument (e.g., alleged failure conditions, as in the chain extension of the chickweigh line). In general, these initial evaluations lead to a hint of the likely winning line, if indeed one exists, of argument for our side of the dispute.

Lessons Learnt From the Case

Probably the most important outcomes of these cases are the lessons learnt by all parties to the dispute. These lessons may be summarised under the following headings:

- *Underlying causes to the dispute and its defining event* – these causes may be attributed to a variety of sources including:

  – technical defects in machinery,

  – errors in design, often attributed to the lack of consideration given to all possible failure modes,

  – human error in machinery operation,

  – maintenace errors,

  – insufficient attention to contractual detail,

  – poorly written contract or intellectual property protection,

  – subversion of insurance cover,

  – attempted fraud or crime.

- *Consequences on parties in the dispute* – these consequenes may be short-term or longer-term effects.
- *Short-term consequences* include:

  – serious financial loss (where the plaintiffs refuse to settle in the face of strong argument for the defence and, possibly, defence is awarded costs against the plaintiff),

  – monetary fine or incarceration (where fraud or crime is proven).

- *Longer-term consequences* for all parties include:

  – better care in contracting between parties with established operating relationships,

– greater care in reading and interpreting contracts and drafting of intellectual property protection.

The Outcome

Case material is presented in descriptive terms or as complete case reports in some cases. Readers interested in the minutiae of case arguments and opinions presented by an expert must read the full case report.

Technical Analysis

Wherever appropriate the technical analysis is presented in the body of the report. Where the analysis is substantially involved, the material is presented in an appendix to the report.

1.12 Chapter Summary

In this chapter I have reviewed all of those elements of forensic investigations that might influence the outcome of engineering disputes and ultimately litigation. These elements are:

- The role of the engineering expert.
- The court and judiciary system.
- Engineering insurance and loss management issues.
- Some scenarios for case progression and evidence gathering and the notion of "data mining".
- Working through the evidence with FMEA to discover the probable event scenario and the ultimate winning line of argument.
- The format and content of the expert witness report.

The common format for case material presented in the following chapters is explained. A sample case, the *Failed Chickweigh Line*, is pesented in some detail.

2

Cases of Machinery Failure

Machine: 1549, "structure of any kind," from Middle French *machine* "device, contrivance," from Latin *machina* "machine, engine, fabric, frame, device, trick" (cf. Spanish, *maquina*, Italian, *macchina*), from Greek, *makhana*, Doric variant of *mekhane* "device, means," related to *mekhos* "means, expedient, contrivance," from Proto Indo European *maghana-* "that which enables," from base *magh-*" to be able," have power. Main modern sense of "device made of moving parts for applying mechanical power" (1673) probably grew out of 17th century senses of "apparatus, appliance" (1650) and "military siege-tower" (1656). *Machinery* (1687) was originally theatrical, "devices for creating stage effects"; meaning "machines collectively" is attested from 1731. The verb is from 1915. Machine for living (in) "house" translates Le Corbusier's *machine à habiter* (1923).

OLED

2.1 The Cases

In this chapter case material is presented about disputes resulting from the failure or damage sustained by machinery of various types. In each case a background is sketched for the dispute to provide the reader with a *raison d'être* for the origin of the dispute. There are eight cases presented in this category, each involving the failure of a key component of machinery. In all but one case the failure of these key machinery components was identified as the defining cause of the dispute. In one special case, that dealing with a paper coater damaged in transit, the defining event of the dispute was the manufacturer's claim that the cost of repairs to the damaged paper coater would be substantially greater than the purchase of the original machine.

These eight cases are, in order of presentation:

Heavy Theatre Lights are Dropped From a Great Height – in this sample case the failure of a key component of the winching system, used for raising and lowering theatre lights, caused an accident. The plaintiff (theatre administrators) alleged that winch failure was caused by the supply of faulty components by the suppliers of the winch motors and gearboxes. Investigation of the failure identified faulty winch drive specifications as the prime cause of the accident. The underlying cause was traced back to a cost-cutting decision by local government and poor advice from the original engineers responsible for the mechanical services in the theatre.

The Main Bearing Breaks on a Tunnelling Machine – In this case a complex piece of machinery, a tunnel boring machine (TBM) was purchased in a tendering process by a local government agency for an underground rail loop. The machine specified to work in hard rock tunnelling for approximately 3000 hours. After almost 900 hours of operation the main cutting head of this machine weighing about 30 ton broke off. The assigned underlying cause of this accident was a failed main bearing that supported the head of the machine. Investigation into the mechanics of the failure found that the real cause of the accident was a design weakness in the main bearing support system. Further investigation of the history of the purchase of the tunnelling machine showed that the government agency responsible for the purchase of the tunneller made a serious error of judgement in accepting the cheaper tender for the machine ahead of a tender from a slightly more expensive but substantially more experienced hard-rock tunnelling machine manufacturer.

Brinelling Induces Unacceptable Vibrations in a Very Large Bottle Filler – A beverage manufacturer discovers a faulty filling machine and seeks to investigate the possibility of similar failures in other similar machines in their several large plants. Initial evaluation assigns the cause of the failure to a faulty bearing. Deeper investigation identifies the defining failure as being due to an installation error.

A Milk Tanker Takes a Spill – As suggested by the title of this case, a milk tanker overturns and spills its load while negotiating a bend in a country road. Initial examination of the trailer hitch shows that the kingpin hinge in the trailer hitch is of a non-standard design. Loss assesors assign the cause of the accident to this non-standard kingpin. Subsequent investigation of the accident shows that the underlying cause was poor judgement by the driver when negotiating the turn. Moreover, the kingpin bolt's failure in these conditions saved the prime mover from sustaining substantial damage.

A Paper Coating Machine is Damaged in Transit – The manufacturer clams that repairs to the damaged machine must be performed in America. The ultimate costs claimed against transport insurance are substantially greater than the cost of a completely new machine. Insurance loss assessors seek to investigate alternative means of repair to the machine. Investigation shows that local repairs are appropriate.

A High-speed Compressor is Damaged by Faulty Bearing Replacement – This is a case of poor judgement exhibited by maintenance engineers in attempting to repair specialised bearings on a high speed air compressor. Investigation into this case suggests that although outsourcing maintenance may save on overheads for a manufacturer, the cost of litigation resulting from incompetent maintenance can exceed these savings.

Two Large Vehicles Roll Over – Both of these cases are the result of weaknesses in design considerations. In the first of the two a weakness in re-designed track rod clamp causes a large fertiliser spreader to roll over. In the second case a weakness in the design of a steering knuckle on a tipper truck is exacerbated by its use in a specially hazardous environment.

A Large Paper Machine Dryer is Damaged and Discarded Prematurely – Paper-making industries are very conservative in both maintaining machinery in top-notch conditions and in the operational safety of their machines. The defining event for this case was an unexpected accident in which a large drying drum was damaged. On advice from non-destructive testing experts and based on the conservative estimate of the damage the drying drum was replaced under a machinery insurance claim. Subsequent insurance assessors questioned the need for replacing the drying drum, when repair options may have been available. The ensuing investigation suggested that the paper machine operator used the defining event as a means of an opportune replacement of the dryer with one of significantly improved performance.

Much of the information for case material is drawn from the author's experience in litigation consulting as an expert witness. Cases are presented as fully as possible without disclosing the real names of participants. To avoid the painfully obvious ploy of using initials to replace proper names, in each case various groups of names have been invented, drawing on the world of music, sport, theatre and horticulture. No apologies are offered for this approach, since it makes the cases a little more readable.

2.2 Heavy Theatre Lights are Dropped From a Great Height

2.2.1 The Case Culture

Flying battens are substantial steel girders that hold a host of specialised stage equipment used in the sound and light management of theatre performances. The *Erewhon City Concert Hall* (*ECH*) had several such flying battens, weighing in excess of a 100 kg each, mounted high above its stage. These flying battens are raised or lowered during performances by means of a motorised cable and winch system operated from a central control panel. Figure 2.1 is a general view of the concert hall stage. In this image the flying battens are used to carry sound reflectors to improve the acoustics of the auditorium. Figure 2.2 is a simplified schematic partial view of the flying batten and winch system.

The *ECH* was an ambitious project by the Erewhon City governors, and the original specifications for the flying battens called for hydraulic winch motors. However, as often happens with major civic projects experiencing serious cost overruns in an election year, the hydraulic motors were replaced by cheaper geared motors. Although this may seem a trivial change in the cost of such a large project, there were in fact 90 such motors involved in the whole art centre project, of which the concert hall was only one element. In total the initial cost difference between hydraulic and geared motor winches was of the order of US$ 1 million.

2.2.2 Defining Event

Sometime after the opening of the concert hall during a rehearsal one of the flying battens fell to the stage from a height of about 20 metres. Fortunately no one was injured, but an investigation of this accident was demanded by the insurers of the whole art centre complex, as well as occupational health and safety authorities. A brief technical evaluation of the failed winch system by an independent consultant, called here *Goalie Material Testing* (*GMT*), revealed the following:

1. The winch motors and gearing were specified by the technical staff of the art centre complex architects *Forward* Ltd.
2. All winching equipment was imported from an American supplier, let us call them the *Ruckman* Corporation.
3. Original specifications of the flying battens called for a maximum loading of 200 kg and the system has been tested satisfactorily under static loading to nearly 500 kg.
4. Hardness tests of the shafts of the gearing system showed both input and output shafts to be 30% below specified values in material tensile strength.

Figure 2.1 A general view of the concert hall stage

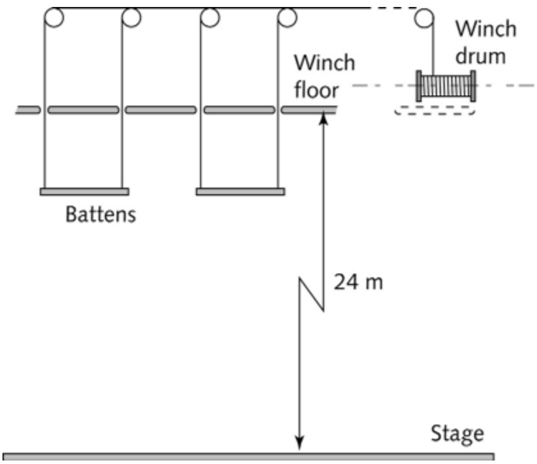


Figure 2.2 Schematic partial view of the flying batten and winch system

5. American ASME standards for shaft design. This evaluation showed the shafts to be undersized by approximately 8%.
6. The failed winch shaft was found to have failed in fatigue and machining roughness on this shaft was identified as the originating cause of the eventual failure.

Based on the above findings writs were issued by the art centre insurers against thirteen defendants, including the original architects of the centre, the technical staff and specifiers and suppliers of the winch system, *Forward* and *Ruckman*.

2.2.3 Parties to the Dispute

- *ECH insurers* – the plaintiff in this case took on the role of injured party on behalf of ECH administrators.

- *Forward Ltd.*, the original architects of the concert hall – the major defendant in the case had the responsibility for the design and specification of the failed winching system.

- *Ruckman Ltd.*, subsidiary defendant, supplier of the failed winch equipment – they were enjoined in the case through the main defendant *Forward*.

2.2.4 The Client

- *Centre and Pocket Ltd.*, Lawyers acting for ECH on the advice of GMT – they briefed me on the background to this case and requested expert engineering opinion about the identified faults in the winch drive system.

2.2.5 The Expert's Role and Associated Investigation

In general, the expert is required to respond to specific questions relating to the technical substance of a dispute. In this case the technical substance was evident, the winch had failed to perform as expected and there were continuing safety issues with all the winches – although no one had been injured in the first accident, there was very high risk of injury should other flying battens be dropped unexpectedly.

My personal involvement in this case commenced after the GMT evaluation as well as after the issue of the various writs against the thirteen defendants. Figure 2.3 shows a winch motor attached to a worm gearbox, from which the winch drums are driven. The smaller diameter component attached to the motor is a separate armature brake. This device is intended to stop the motor from over-revving or freewheeling in case of a power failure. Figure 2.4 is a view of the winch floor and Figure 2.5 is a typical winch motor shaft with the worm screw attached to it. At the time of my involvement in this matter, virtually no expense had been spared to investigate the mechanical issues identified by Goalie Ltd. My brief was to evaluate the whole system of winches and winching systems in addition to that found by Goalie Ltd. I suspected that my involvement was supposed to heavily reinforce the Art Centre insurer's case against the thirteen defendants and specifically against Ruckman, the American suppliers of the winching motors and gearboxes.

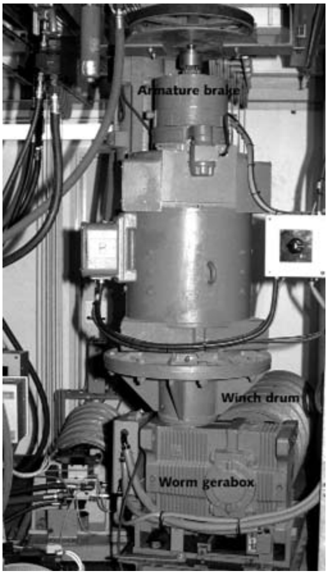


Figure 2.3 A winch motor and gearing system. The motor drive is attached to a worm gearbox

Figure 2.4 Winch floor showing the main winch drums and part of the pulley system

Figure 2.5 Typical motor shaft and worm screw

As requested by my brief, I inspected the winch systems, the failed components and the various technical reports by GMT (there were several) as well as the writ issued against the thirteen defendants. In general, where human injury or life is placed at risk, design specifications should call for a fail-safe system rather than a safe-life system. The fail-safe design, in the case of the flying batten winches, would require the system to be safe even when some critical part of it, such as a motor shaft, should fail. With a worm drive at the output end of the winch motor the designers may have assumed that the worm gearbox was not capable of being “back driven”. In other words, should the motor shaft fail, the torque on the winch drums would not be sufficient to drive the worm gear/worm screw combination. The evidence of the fallen flying batten showed this assumption to be false. In any case there was no evidence that any tests or calculations were conducted to support the above assumption.

In elevator design the cabin of the elevator is brought to a halt should the cable system fail. This is a fail-safe design where elaborate braking systems are included in the design of the elevator cabin guidance system. In the art centre winching system the design did call for a disc brake system to be installed on the motor armature. The armature brake supplied by Ruckman was, in fact, a drum brake (see Figure 2.3). However, none of the design specifications or the eventual supply and documentation of acceptance of the winch system had any evidence of fail-safe design considerations.

2.2.6 Lessons Learnt

Original design specifications for the winch system at ECH called for hydraulic motors. Perhaps intuitively, or from the wisdom of experience, the architect’s engineering staff considered the fail-safe behaviour required of the winch system. Hydraulic motor drives would have provided that feature of the design. Unfortunately this key issue was not explicit in the documentation. As a consequence, there was no clearly identifiable reason why a cost-cutting review of the specifications should not change from an expensive hydraulic drive system to a cheaper geared electric motor drive. That too would have sufficed had the specification stipulated that braking should be installed on the winch side of the drive.

2.2.7 Outcome

Unfortunately for the art centre insurers, my report on this matter turned out to be unacceptably damaging to their case. The mitigating element of the case was that the art centre authority could not fully deny responsibility in accepting the design specifications when it clearly neglected the issue of fail-safe provisions. The matter was eventually settled out of court.

2.3 The Main Bearing Breaks on a Tunnelling Machine

2.3.1 The Case Culture

> *"The modern era of machine tunnelling was born in the early 1950s. The designers of machines and the contractors who used them thought they were developing completely new techniques and new equipment. However, a view of machine tunnelling history from a clearer perspective shows that the tunnellers of the 1950s were redeveloping methods that had their origins in methods that existed more than 100 years earlier.*
> *The publication of the scholarly and well researched Handbook of Mining and Tunnelling Machinery,*[2.1] *brought the background of mechanized tunnelling into focus for the first time. Had the designers of 35 years ago been able to read the history of developments that had preceded them, their designs undoubtedly would have been affected materially."*[2.2]

In modern urban environments, tunnelling is probably the most effective way of constructing underground passage-ways for sewers, underground rail services or for cable ways. The scale of underground works has been increasing, ever since tunnelling machines, colloquially called *moles*, have been built. In Chicago the Tunnel and Reservoir Project (TARP) consists of a series of tunnels and reservoirs, some dug as deep as 360 feet, constructed parallel to Chicago's river systems. The system, when complete will extend more than 130 miles. TARP is being constructed using a tunnel boring machine that cuts a hole 33.5 feet in diameter through bedrock deep beneath Chicago's surface.

In Norway's Lillehammer a giant underground dome was built for the olympic hall of the XIIth Winter Games in 1994 using tunnelling machinery. This is the largest ever underground cavern with a net area of over 10,000 m^2 capable of seating 5100. Figure 2.6 indicates the scale of tunnelling machinery used in major earth works.

2.3.2 The Defining Event

Some years ago the city of Mytown's rail transport authority (*MRTA*) decided to extend the suburban rail system in their city to include a loop around its busy central business district. Due to the existing urban development, an underground loop was the only feasible solution. After a tendering process *Caster-Pollux Pty. Ltd.* (*CP*) won the contract for the construction of four single-track tunnels, on two levels, feeding into the city's other surface suburban train lines. The tunnelling plan called for 10 km of tunnels and the mechanical removal of 900,000 m^3 of rock and earth. *CLF* was chosen as the contractor largely because they had an established record of experience with such major earth works. Unfortunately, CP was also an

2.1 Stack (1982)

2.2 Robbins (1987)

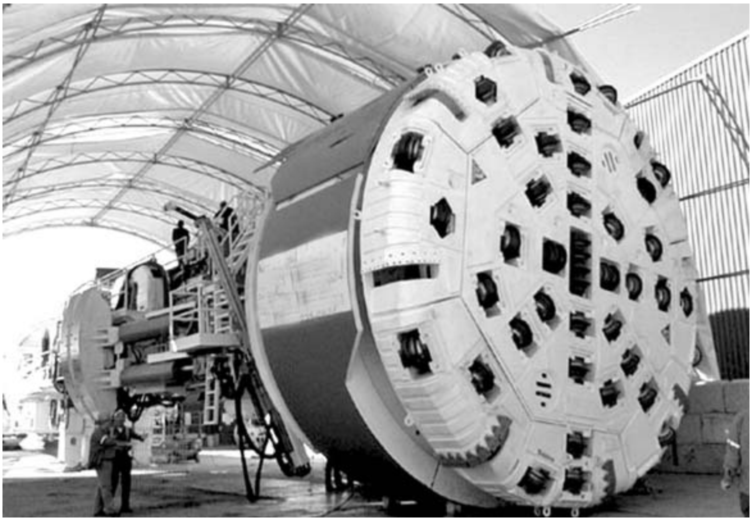


Figure 2.6 Full-face tunnelling machine just before entering tunnel portal

independent entity formed from a "quango",[2.3] somewhat constrained in their contracting by long-standing, conservative, government-established procedures. Subsequent events suggested that they chose the tunnelling machine based on economic considerations, rather than internationally proven reliability.

Based on underground surveys, it was estimated that the tunnel would take approximately 3000 hours to dig and having specified the rock characteristics (based on the said surveys) tenders for a tunnelling machine were called. The favoured tenderer was *Rawaj Pty. Ltd.* providing a tunnel boring machine (TBM) for approximately AU$ 2 million, or about 10% of the estimated total contract cost. Several tenderers, including Rawaj, had international reputation and expertise in tunnelling. However, there is always considerable uncertainty about the nature of the rock composition through which tunnels are dug. TBMs are usually purpose-built for a specific contract. Once the contract is concluded the machine is retired or rebuilt for a further application. In general, the salvage value of a TBM is insignificant in terms total contract cost of digging and constructing a tunnel. Some TBM manufacturers design machinery to meet the specified rock characteristics, while others choose to design machines that are so robust that they can withstand considerable variability in rock strength and distribution. The former approach yields lighter and less costly TBMs, while the latter approach results in a more expensive but commensurately more robust design.

After about 900 hours of operation the main bearing of the machine broke and the whole cutting head of the machine, weighing about 30 ton,

2.3 An organization or agency that is financed by a government but that acts independently of it.

fell off.[2.4] Fortunately for all concerned, the accident event took place near one of the main ventilator shafts and the machine head was recovered with minimal need for reversion to blasting and old-fashioned mining procedures. The cost of repairs was estimated at approximately AU$ 500,000. As well, there were substantial delays in construction and correspondingly substantial costs incurred in *liquidated damages.*[2.5] As a quango, CP would need to rely on government financing to bail them out, should the insurance loss be influenced by issues arising from defective contract planning or project management. It would have been inconceivable that CP would actually pay any liquidated damages to the government (CP was being financed by the government) and it was the travelling public that would have had to bear the discomfort of the resulting transport delays. Hence, facing an election year, the government of the time expressed the need for urgency in sorting out the root causes of the disaster, and getting the contract back on the rails.

2.3.3 Parties to the Dispute

- *CP* and their insurers – they saw themselves as plaintiffs in this case against Rawaj, the TBM supplier.
- *Rawaj* and their insurers, the defendants.
- The city of *Mytown* and specifically the transport authority *MRTA*, to whom CP was the main contractor for the rail loop project.

2.3.4 The Client

The government asked for an expert evaluation of the causes of this disaster. Due to the specialised nature of tunnelling there are very few experts one is able to call on with confidence. In fact, there are very few experts in the large-scale tunnelling business who are able to offer advice that is seen by a court to be free of conflict of interest. This is due to the fact that most of the available expert specialists work for tunnelling machinery or contracting companies. As noted earlier, experts are in the "credibility business" from a legal point of view. Conflicts of interest are easily discovered and brought to the notice of the judiciary, should the dispute proceed to litigation. In this case a highly experienced local expert was available, who could be relied upon to give unbiassed advice on the event. Unfortunately this expert, *David*, had worked consistently as advisor to both *CP* and for a large and internationally reputable tunnelling machinery supplier *Swallows Pty. Ltd.*, who just happened to be the "losing bidder" for the supply of a tunnelling machine for this contract.

Initial assessment of the causes of the damage to the tunnelling machine was carried out in house by *CP*, advised by their consultant *David*, who realised that there was a possible conflict of interest and asked for an inde-

2.4 Ton is a US unit of mass = 907.2 kg, or just slightly less than the SI unit of tonne.

2.5 "Liquidated damages" provides for the payment of a certain fixed amount in the event of a breach of a contract, including time delays.

pendent consultant to be appointed. As a design specialist I was appointed by CP to review the substance of the case, with the understanding that David would provide some "coaching" in the specialities relating to tunnelling machine design.

2.3.5 The Expert's Role and the Investigation

At first sight the damage could be attributed to one or more of several causes, acting singly or in combination, namely:

- Unexpected variations in the rock through which the tunnel was being dug.
- Faulty bearing material.
- Faulty adjustment or installation of the bearing.
- Inappropriate or faulty operational procedures.

  There were elements of the operation that could be called into question also. The cutting blades on the face of the machine required regular inspection and maintenance. These large rolling cutters had their own set of bearings to permit rotation as the cutting face of the machine was rotated. Should any of the blades be stopped for some reason (such as their own bearing failure) they would be soon worn down and the result would be a highly uneven load distribution on the cutting head of the machine. This uneven load would then transmit to the main bearing itself. So it would seem that there were issues of maintenance and inspection to contend with. These issues included some element of cost saving on the part of the contractor, since the cutters and their associated bearings were a very costly "consumable" item in the contract. In a tunnelling context TBMs are occasionally referred to as the "Box Brownie" part of the contract, making reference to the Kodak approach of selling the camera cheaply and recouping costs by the profits made on the sale of consumables – the film and developing.
- A design fault in the TBM.
- Some totally unexpected, unprepared-for cause (usually referred to in insurance terms as an "act of God").

The last two possible causes were originally seen as unlikely to be helpful to the dispute since design faults are very difficult to establish and there were no clearly identifiable indicators of an unexpected act of God. As a part of these early deliberations, the bearing manufacturer was called upon to answer for issues relating to the material and the mounting instructions for the bearing. It is useful to consider the possible failure scenarios due to the several causes listed above.

- *Unexpected variations in the rock through which the tunnel was being dug* – This could result in incorrect bearing specification, as the estimated loads on the bearing may have been less than conservative for this highly probabilistic load application. There were rock mechanics studies of the site prior to calling for tenders and the contractors were fully acquainted with the range of likely rock properties in the proposed tunnel. In spite of this, tunnelling is almost always fraught with considerable uncertainties in the distribution of rock properties. Moreover, the design of the rail loop tunnel called for steering by varying the thrust across the face of the cutting head. Quite apart from minor directional modifications there were four 90° "corners" to be negotiated by the machine as it completed the loop. Investigation of this aspect of the operation required the estimation of loads on the bearing and a calculation of its L_{10} life.[2.6]

• *Faulty bearing material* – bearings used on tunnelling machines are specially constructed bearings that require special attention to fitting, pre-loading, sealing and lubrication. The vibrating loads due to the rock cutting process introduces some special design requirements to cope with fatigue. Unusually harsh operating conditions in the tunnel can impose special material, sealing and lubricating requirements on the design. A maintenance report of the bearing appearance at failure was available for inspection. In addition the metallurgy of the bearing had to be checked against the manufacturer's specification.

• *Faulty adjustment or installation of the bearing* – recommendations for installation of these special bearings are normally provided by the manufacturer. Often there are sample mounting configurations provided from existing machinery. Designers may vary from these recommendations, but in general the fit (tolerances on the mounting inner and outer diameters) and the maximum misalignment (angular deviation from the vertical plane) need to be addressed in the design. Variations from these design requirements can result in early failure of the bearing. Investigation of this aspect of the accident required design calculations on the mounting arrangement of the bearing.

• *Inappropriate or faulty operational procedure* – an operator's log was available for each shift (eight hours) and these needed careful examination to determine if anything in the operation could have predicted the early failure of the bearing.

Figure 2.7 is a schematic view of a tunnelling machine operating in a tunnel. Figure 2.8 shows the operating stroke of the TBM schematically. The machine head is placed against the rock face by "walking" the machine for-

2.6 L_{10} life is a probabilistic measure of bearing life. It is the time after which (all other things being equal) 90% of these bearings are still operating successfully (are alive). For smaller bearings the L_{10} life is found by direct laboratory testing. However, for the size of bearings used in tunnellling machines, it would be inconceivable to test sufficient numbers to get a direct measure of the L_{10} life. Consequently this value must be estimated from load figures and formulae provided by the manufacturer.

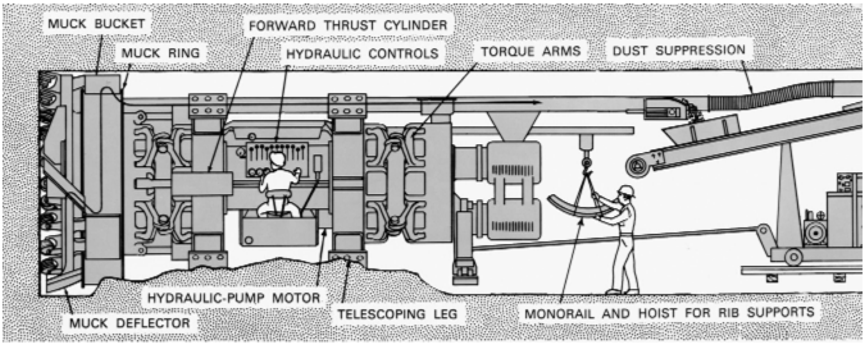


Figure 2.7 Schematic view of a TBM operating in a tunnel

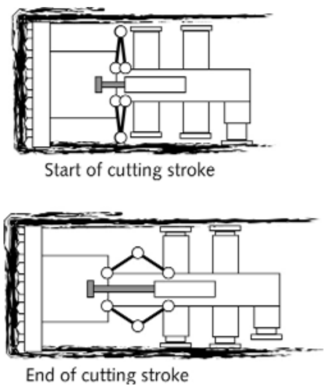


Figure 2.8 Schematic view of a TBM operating stroke

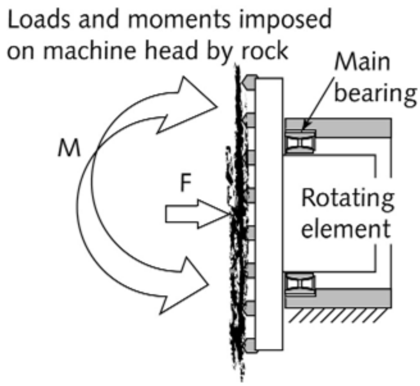


Figure 2.9 Schematic view of the main bearing indicating terminology

Figure 2.10 Broken main bearing of the MRTA tunnelling machine

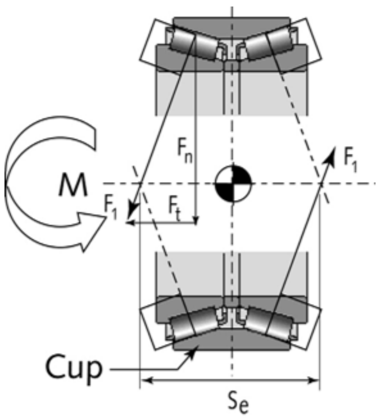


Figure 2.11 Schematic view of the main bearing indicating terminology

ward on its hydraulic supports. In this condition the main hydraulic rams of the machine are fully contracted. The hydraulic supports of the machine are then extended to grip the walls of the tunnel. Following this step, the cutter head is rotated at approximately 5 r.p.m. while the main hydraulic rams push the head forward into the rock face. Figure 2.9 is schematic view of the head of the tunnelling machine, indicating the nature of loads imposed on the head by the rock face. These loads are a combination of a thrust force, F, and a moment, M, the former varying in magnitude and the latter varying in both magnitude and direction as a result of variations of rock strength in the tunnel. Figure 2.10 is a photograph of the failed bearing with a 1.7 m tall person to provide an idea of the scale of the failed component.

Figure 2.11 is a schematic view of the TBM main bearing, a double row taper roller bearing manufactured by the Torrington Corporation, estimated to cost $20,000 in 1975, at the time of the accident.

In single row taper roller bearing terminology the outer race of the bearing is known as the *cup* and the inner race including the roller assembly as the *cone*. These terms are assigned to the bearing due to their overall physical shapes. In the *MRTA* failure it was the front section of the outer race (part of the cup) of the main bearing that broke away to permit the cutting head to fall out of its support. Figure 2.11 also indicates the types of loads acting on the bearing. Quite apart from the direct thrust load imposed on the bearing, resulting in the direct forces F_1 being carried on the outer race (cup), the moment M on the machine head induces extra varying loads on these bearing cups. The weight of the machine head, outside the central plane of the bearing results in an added moment being carried by forces on the bearing cup.

Figure 2.12 Bearing roller and part of the failed bearing cup. The notch was used for establishing material properties

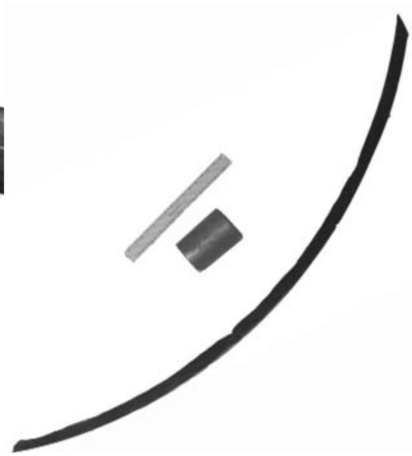


Figure 2.13 Part of the bearing broken away during the accident, with a roller and a 300 mm ruler to indicate scale

A small sample of bearing material was taken from the broken section of the bearing and examined by a metallurgy laboratory. It was found to match the maker's specification for this bearing. Having reviewed the operator's log and the bearing material it was now necessary to estimate bearing life and operating loads.

The tunnelling machine had the following specifications:

- Total mass = 250 ton
- Cutting diameter = 23 ft 2 inch (7.08 m)
- Cutter head mass = 30 ton
- Bearing housing = 15 ton
- Ring erector = 6 ton
- Main bearing diameter = 85 inch (3.35 m)
- Normal bearing thrust[2.7] = 350 ton (7.6×10^5 lb force)
- Bearing type Torrington S-34887-C double row tapered roller bearing.

Figure 2.12 is a close-up of a bearing roller, together with part of the bearing cup that broke away during the failure of the bearing. Figure 2.13 shows the complete broken part of the bearing cup representing approximately 120° of arc or about the arc length corresponding to 1/3rd (16) of the total number of bearing rollers (this bearing had 48 rollers in each row).

Of course, the housing itself is part of the design of the machine into which this type of bearing is fitted. In general, these types of bearings are used in applications requiring robust and reliable behaviour with substantial bearing stiffness, which is associated with the capacity of the bearing to withstand overturning moments. In Figure 2.11 the following nomenclature has been used:

- S_e is the "effective spread" provided by the bearing geometry, or the distance at the centre line of the machine, which is the moment arm for resisting overturning moments. For the application under consideration the value of S_e was 48.4 inch (1229 mm);
- F_1 is the reaction load at the bearing due to the overturning moment M acting on the bearing;
- F_n and F_t respectively are the normal and axial components of F_1. The axial components cancel out and the resisting moment of the bearing becomes $F_n \times S_e = M$.

The relevant overturning moments resulting from the statistical estimates of the operating conditions for the machine were taken as:

5% of the time $M = 7 \times 10^7$ inch-lbs (8×10^6 Nm)

30% of the time $M = 4 \times 10^7$ inch-lbs (4.5×10^6 Nm)

2.7 This is a nominal value only. The actual thrust for calculating bearing loads is based on a statistical assessment of the median (most commonly occurring) thrust at various distances from the machine centre, expressed as a moment acting on the machine cutting head.

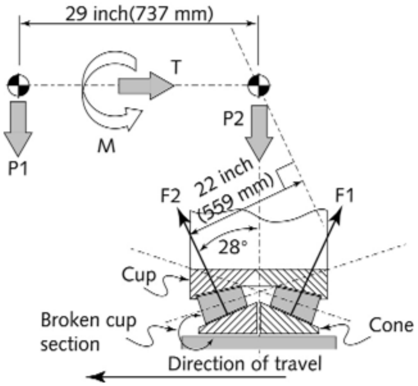


Figure 2.14 Detailed load model of TBM bearing used in analysis of retaining ring deflection

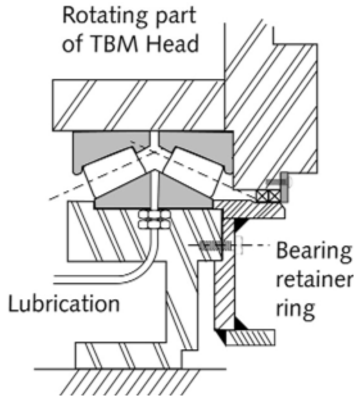


Figure 2.15 Original design of bearing mounting. This partial view shows the relatively flexible retainer ring

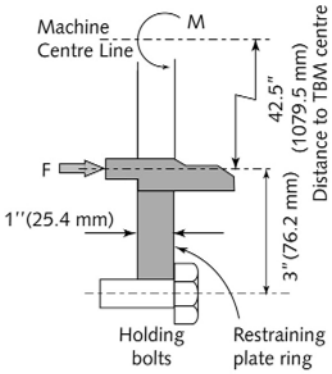


Figure 2.16 Bearing retainer ring dimensions used in analysis of deflection

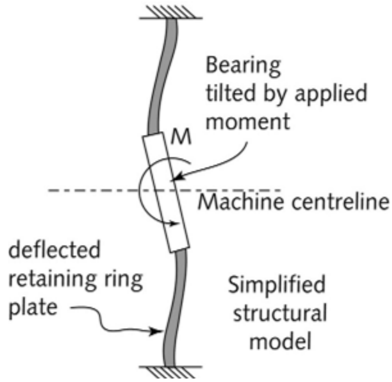


Figure 2.17 Simplified model of the retainer ring deflection

65% of the time $M = 2.7 \times 10^7$ inch-lbs (3×10^6 Nm)

Henry Timken patented the first taper roller bearing in 1898, because he recognised the need for a rolling element bearing capable of carrying a combination of thrust and radial loads. The Timken Company was responsible for developing bearing life formulae based on an observed level of damage to the bearing surface.[2.8] When the Torrington Company (now part of the Timken organisation) supplied the S-3487-C bearing to the tunnelling machine manufacturer, they carried out a life calculation using the above load conditions. After confirming their estimates of bearing loads it

2.8 Interested readers can find detailed information about bearing life calculation at www.timken.com/products/bearings/fundamen/calculate.asp; www.bearings.machinedesign.com/guiEdits/Content/BDE_6_1/bdemech6_60-1.aspx; www.epi-eng.com/BAS-BearingLife.htm.

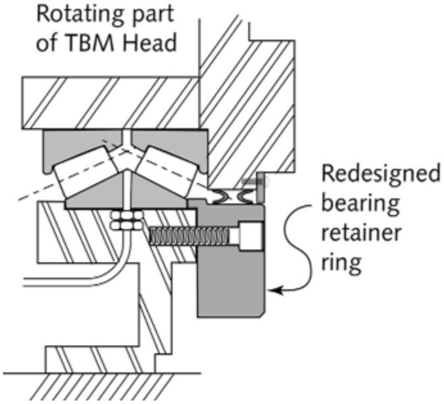


Figure 2.18 Bearing mounting with redesigned retainer ring

was found that their conservatively calculated life of 21,000 hours far exceeded the operating requirements of the contract in dispute.

Figure 2.14 is a schematic representation of the various loads acting on the bearing and in turn on the retainer ring designed to maintain the bearing in its mounting within the deflection limits specified by the manufacturers. Torrington's specification for this bearing was a maximum tilt of the central plane of the bearing of 0.5 minutes of arc. Consequently it was necessary to investigate the mounting geometry and its flexibility.

Figure 2.15 shows part of the sectional drawing of the TBM with its original bearing mounting configuration.

Figure 2.16 shows a partially dimensioned section through the retainer ring and Figure 2.17 is a simplified structural model adopted for the evaluation of flexure of the retainer ring. It was modelled as a simple constant-thickness annular circular plate with a built-in outer edge (the holding bolt pitch circle), with a moment applied at the annulus.[2.9]

Using even the smallest estimated moment (3×10^6 Nm) acting on the bearing, the flexure of the retainer ring permitted the bearing to deflect by approximately 2 minutes of arc. This value exceeded the manufacturer's safe recommendation of 0.5 minutes of arc by a factor of four for about 65% of the operating time. The rest of the time the flexure was greater than this conservative value. It was estimated that the outside edges of rollers in the front row of the bearing "rode" on the front lower part of the cup that eventually broke away, permitting the head to fall off.

2.3.6 Lessons Learnt from This Case[2.10]

Figure 2.18 shows (approximately to the same scale as the original retainer shown in Figure 2.15) the sectional drawing with the modified bearing retainer. Clearly, the new retainer ring has been substantially increased in thickness, as a result of this investigation. Fortunately, there was sufficient space available in the original design to permit the replacement of the original retainer with this substantially thicker retainer ring.

2.9 Readers interested in the detailed calculation of flexure should refer to Young, (1989) p. 435, Article 10.2.

2.10 For his wisdom and guidance in the tunnelling project I am indebted to David Sugden.

When faced with the complex and interwoven threads of information initially presented to me I found it hard to imagine that the accident might have been caused by a design error. After all, I was investigating an accident involving the machine of a highly reputable manufacturer with respected international expertise in tunnelling. Only after assembling and reviewing all the various ways in which the accident might have been initiated did it become necessary to examine the detailed design of the machine. In the words of Sir Arthur Conan Doyle, as spoken by Sherlock Holmes *"... when you have eliminated the impossible, whatever remains, however improbable, must be the truth."*

2.3.7 Outcomes

A relatively short-term outcome was that the machine was capable of repair and return to operation within a few months. The supplier of the TBM was successfully sued for the costs involved in repairing the TBM. Unfortunately for CP's insurers, there was sufficient uncertainty about the actual operating conditions of the machine and this brought into some doubt the range of forces specified in the CP tender for the TBM supplier. As a consequence the liquidated damages component of the dispute was settled out of court.

A longer-term outcome of this case was that Swallows initiated a substantial research programme on the direct measurement of forces experienced by tunnelling machines while excavating hard rock.[2.11] When I first became involved with this case I was offered the opportunity to be "brought up to speed" about the design and manufacture of tunnelling machinery. Part of this process involved a visit to the Swallows factory in Seattle California. There I met Dick Swallows, the chief designer and CEO for the company. At that time Swallows had considerable numbers of tunnelling contracts in progress and they were very interested in collecting hard rock data from wherever tunneling was going on. During this brief interview I was asked to initiate a programme of instrumentation on the repaired Rawaj machine. Dick was interested in rock mechanics and my interest was the design of machinery. I remarked that *"we will also measure the forces on the cutters during this process".* Dick said, as he calmly wrote out a cheque for US$50,000 (the first installment of our research programme) *"why bother?; we already make these maches as strong as we can".*

2.3.8 Technical Analysis

A key aspect of the technically evaluating the deflection of the bearing retaining ring was the estimation of the statistical distribution of loads acting on the machine head during the excavation of the tunnel. This estimate was based on rock mechanics data available from the drilling surveys taken by CP when initially quoting for the tunnelling contract.

2.11 See Samuel and Seow (1984).

2.4 Brinelling Induces Unacceptable Vibrations in a Very Large Bottle Filler

"Filling and capping are tasks of central importance in beverage and food production for only once the containers have been filled and capped using a method which is suitable for the product and at the highest technological level can the best product be manufactured for the consumer. We regard it as our duty to create the conditions for the right filling technology.

With a programme of rotary fillers which is rich in variety, Krones is offering the correct solution for a broad product spectrum. Especially designed to suit product demands, the individual equipment components guarantee an optimum output and the best product treatment.

Mechanical, electronic, volumetric, gravity or vacuum filling systems and a multitude of system variants provide the correct solution for each individual application. The product summary shown here provides you with the entire filler series at a glance. It goes without saying that the different variants have been adapted to suit the different container types such as glass bottles, PET bottles or cans.

After filling comes capping – and Krones can supply the correct capping technology for your container, meaning that the filling and capping process can be carried out perfectly using a continuous system, using intelligent solutions and the most modern technology." Krones AG[2.12]

2.4.1 The Case Culture

Although there are many manufacturers providing automatic packaging machinery for a variety of beverages, few are able to provide machinery for the high-volume packaging of beer. The company involved in this particular case, let me call it The *Bittersweet Lager Company* (*BLC*), produces approximately 1.4 billion *stubbies* annually at its plant located at *Tattaly*, a small country town in Northern Australia. A stubby is a 350 ml bottle designed for efficient packaging. There are few packaging machinery suppliers capable of delivering this rate of throughput reliably even with several machines operating simultaneously. At the Tattaly plant there are three production lines, each with its own washer and filler machine supplied by

Figure 2.19 A 350 ml Stubby

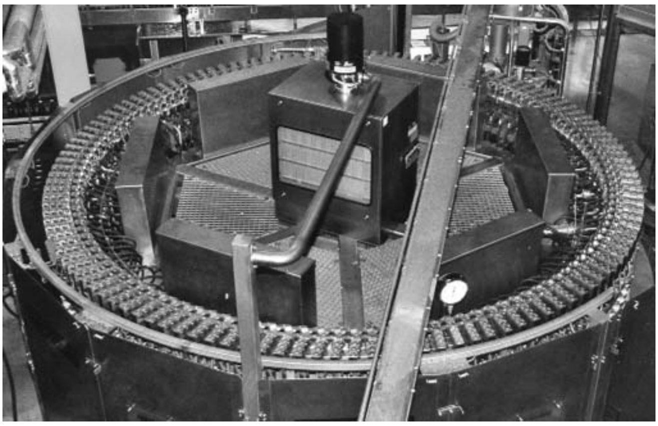


Figure 2.20 A general view of the bottle filler operated by BLC at their Tattaly plant.

2.12 http://www.krones.de/krones/en/104_110_ENG_krones_group.htm.

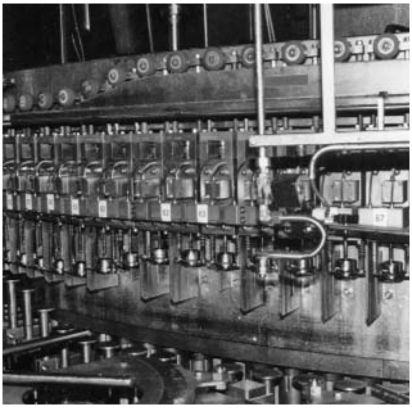


Figure 2.21 Close up view of filling stations

Figure 2.22 Bearing damage. The upper photo shows the damage to the inner (fixed) race. The lower photo is that of the damage to the moving (outer) race

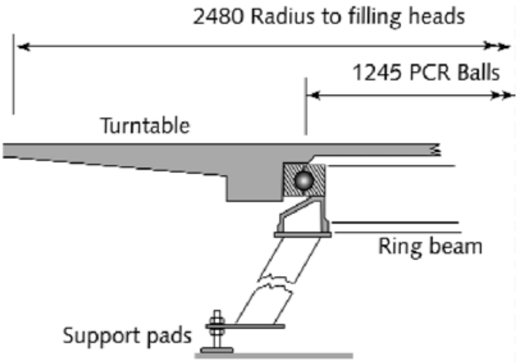


Figure 2.23 Schematic section of filler showing bearing mounting arrangement (not to scale)

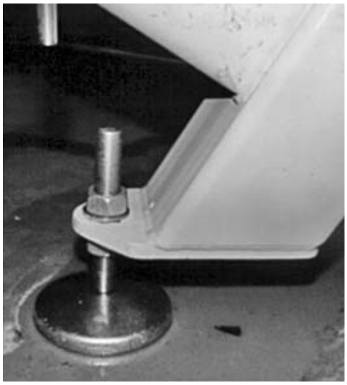


Figure 2.24 Photograph of a typical leg support pad

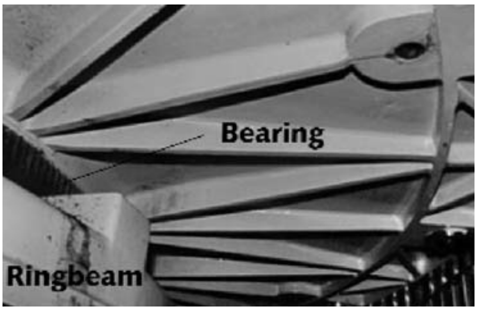


Figure 2.25 Photograph under turntable

Figure 2.26 Ball and spacer arrangement

GBF corporation. Figure 2.19 shows a typical stubby bottle, Figure 2.20 is a general view of the bottle filler at Tattaly, Figure 2.21 is a close-up view of filling stations and Figure 2.22 is a sample photo of the typical damage observed on the bearing races. Figure 2.23 is a schematic section through the filling machine showing the location of the failed bearing, nominally a KD600 *slewing -ring* bearing, with full details of its life and loading curves available from the *Rothe Erde Large-Diameter Antifriction Bearing Catalogue*. Figure 2.24 is a close-up photo of one of the legs and levelling pads on which the filling machine is supported. Figure 2.25 is a photo showing the underneath of the machine turntable and Figure 2.26 shows a photo of the balls and spacers of the bearing. These balls are made of hardened steel and in their travel inside the bearing they exert substantial local loading on the bearing surface. If the bearing race has any surface imperfections or some foreign particle imposed on it from lubricating grease contamination, the passage of these hardened balls over these imperfections or foreign matter will generate an exaggerated jarring loading on the bearing surface. On first inspection the surface damage to the bearing shown in Figure 2.22 was suggestive of this type of initiating process.

The problem with vibration in a large high speed filling machine is the resulting bottle misalignment during filling and the consequent underfill as well as the failure to achieve proper closure on the crown seals of bottles. Operators at Tattaly were alerted to the problem when these faults began to occur regularly.

Before dealing with the technical issues involved in this bearing failure, it is essential to provide a clear picture of some company strategies that would influence and possibly constrain the outcome of this case and the way in which the investigation might be reported by the expert. As one of the largest beverage companies in the world, BLC has many plants with similar filling lines, all of them supplied by the same GBF. The occasional failure of one packaging machine would be relatively easy to absorb into general maintenance by BLC. In addition, it is most likely that GBF would compensate BLC for the cost of repairs. This was certainly the case with the first failure of the bearing. With their multitude of large continuous-flow production lines, it was not so much the one failure at Tattaly that concerned BLC. It was the odds that this was not simply an isolated case but perhaps a symptom of some more substantial underlying problem with all their bottle fillers. BLC had invested heavily in GBF machines in its several plants. Moreover, they were reliant on GBF for the supply and service of these unique large-volume bottle filling machines. To some extent BLC and *GBF* were *in bed together* as far as the continued success of developing fast and reliable bottle fill processing plants were concerned.

2.4.2 The Defining Event

Table 2.1 shows a gross event chronology for the vibration problems experienced at Tattaly. A failure, such as the one described in Table 2.1, can send

Table 2.1 Event Chronology

Date	Event
Late 1993	During a substantial upgrade of the Tattaly plant of BLC, a new high-speed GBF filling machine was installed and commissioned.
Early 1994	A plastic leg support on the new filling machine broke and as a result the machine received substantial vertical jarring. GBF replaced the broken support and the machine appeared to be operating successfully.
Late 1996	Serious problems were experienced with misalignment between bottles and filling stations on the machine. This resulted in several recurring maintenance outages, which were eventually traced to the damaged main bearing on the machine. The bearing was replaced in January 1997 and the machine had been operating successfully since then.
1997	Continuous monitoring of lubricating grease in all BLC plants was initiated in 1997. This monitoring revealed unacceptable levels of metal particles in the Tattaly machine lubricant a few months after the bearing had been replaced. This investigtion was commisioned by the technical staff at BLC to establish the real cause of failure of the main bearing on the GBF machine and to estimate the likelihood of similar failures occurring in other similar machines at other plants operated by BLC.

shivers up the spine of any high volume filling machine operator. This would be especially so if the operator had invested considerable capital in several packaging lines all closely dependent on similar machines. Every minute that the filling machine sits idle during unscheduled maintenance, production is shorted by 4250 stubbies. As a consequence, this investigation was intended to offer clues to the failure scenario with the original bearing. In addition there was substantial concern about the likelihood of an incipient second failure with the Tattaly machine and similar failures in other BLC operations.

Figure 2.26 is a photograph of the 35 mm diameter balls and the plastic spacers used in the machine bearing. The bearing outer ring has a slot that permits the entry of balls into the bearing during assembly. Lubricant grease is pumped into the bearing at regular time intervals and there is a location on the bearing where the "new" lubricant extrudes "older" used lubricant from the bearing. Samples are taken from the extruded lubricant daily and analysed for metal content. When the content of metal shards in the grease exceeds some level specified by the manufacturer, the bearing is deemed to be near incipient failure. A few months after the failed original bearing was replaced by GBF engineers, the lubricating grease monitoring process showed up with unacceptably high metal particle content. It was this event that initiated the investigation described here.

2.4.3 The Client and Possible Parties to the Dispute

My client was *George Melissande*, the technical manager of BLC operations, who asked for an independent investigation into the causes of failure in the

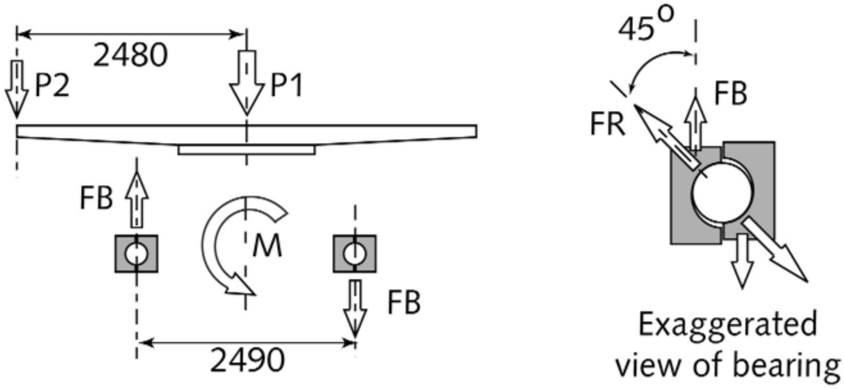


Figure 2.27 Loading on bearing

Rothe Erde slewing-ring bearing as well as an assessment of the overall reliability of the bearing. In essence this case was in the early stages of disputation planning. Had my investigation uncovered some form of design or material fault, then BLC may have initiated a dispute with GBF concerning the whole batch of bottle fillers and washers operating in all BLC plants. Had my investigations found a fault with the bearing material or its specification on the machine at Tattaly, the resulting disputation may have involved the bearing manufacturer.

2.4.4 The Expert's Role and the Investigation

The expert was asked to investigate the failure of the bearing and offer opinion about probable failure scenarios and if at all possible identify underlying causes for the failure and to evaluate the reliability of the bearing. The investigation focused on the following issues:

(a) *Was the bearing overloaded?* – The GBF company had a strong reputation for supplying beverage filling machines to the packaging industry. There were several such machines in operations around the world and also within BLC's many plants. The other machines were still operating successfully without the type of problem experienced with the machine at the Tattaly plant.

Although the bearing loads were not expected to be incorrectly assigned by the manufacturer, it was necessary to check both the load and the deflection on the companion structure to eliminate this mode of failure. As well as the static load on the bearing there was a small but significant out-of-balance load on the bearing due to the effect of the filling station loads over approximately 100° of arc on the machine circumference. This arc corresponded to 50 filling stations out of a total of 168, where the stubby bottles were pulled down from the filling heads by pull-down cams. Figure 2.27 shows the bearing loading schematically.

$P1$ = 70 kN (estimated by manufacturer)

P2 = 14 kN (provided by *BLC* maintenance staff)

Taking moments about the centre of the machine turntable (refer to Figure 2.27) gives

$$P2 \times 2480 = M = FB \times 2490,$$

$$FB = 14 \times 2480/2490 = 13.9 \text{ kN}.$$

As a result the load carried by half the balls is (70/2 + 13.9) kN or approximately 49 kN. This load is distributed over 100 balls and hence the load per ball is 490 N in the vertical direction. The actual load normal to the bearing surface is found from the vector diagram indicated on the exaggerated view of the bearing in Figure 2.27, yielding

$$FR = 490/\cos 45^\circ = 686 \text{ N}$$

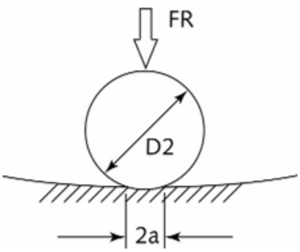
Contact loading of the balls on the bearing surface is evaluated using the appropriate equations from Young (1989), Article 13.1 (also referring to Figure 2.28). E_1 and E_2 are elastic moduli for the sphere and the substrate respectively and for the bearing and ball $E_1 = E_2 = 210$ GPa, μ_1 and μ_2 are Poisson's ratios for the ball and substrate respectively and for the bearing $\mu_1 = \mu_2 = 0.3$. K_D is a factor to allow for the relative curvatures for the two surfaces in contact. Here the conservative estimate for $K_D = D2 = 0.035$ m. Evaluating the various constants and the maximum local stress results in

$$a = 0.43 \text{ mm}$$

$$\text{Maximum } \sigma_1 = 1.77 \text{ GPa}$$ [2.13]

Accordingly, the worst contact stress occurs at the edge of the contact area and is approximately 0.133 (Max σ_1) = 235 MPa. This is well below the allowable stress for the bearing material in its hardened state.

The estimates above were made with the simplistic approximation that bearing load is distributed evenly on all the balls in the bearing. Although this would be the case under normal circumstances, if the machine were to experience a substantial vertical impact, then a severe localised load could



$$a = 0.721\sqrt[3]{FR \times K_D \times C_E}$$

$$Max\ \sigma_1 = 1.5\frac{FR}{\pi a^2}$$

$$C_E = \frac{1-\mu_1^2}{E_1} + \frac{1-\mu_2^2}{E_2}$$

Figure 2.28 Contact loading of sphere on surface (dimension units in these equations are measured in metres)

2.13 See also Timoshenko and Goodier (1983), Article 140; Samuel and Weir (1999), Section 2.7.

indeed cause local yielding of the bearing surface. The originally supplied machine levelling pads were made of solid polypropylene. These pads were replaced with the metal pads (see Figure 2.24) when one of the plastic pads collapsed during commissioning of the machine. From the evidence of the bearing damage it appeared highly probable that the failed bearing was indeed subject to this type of damage.

Brinell hardness is obtained by indenting a surface with a small hard metal sphere and measuring the size of the indentation. Hence the permanent deformation of the bearing surface locally due to the imposed contact stress of a ball is referred to as Brinelling. Once Brinelling damage has been imposed on a bearing surface, total deterioration of the bearing soon follows. As balls pass over the damaged section, the bumps experienced under load leads to further Brinelling and the type of overall bearing deterioration seen in the machine at the Tattaly plant is commonly experienced.

Bearing life calculations were made using the life formula and life data available from the maker's catalogue.[2.14] Using the life formula for Rothe Erde bearings the estimated life of the bearing under investigation was estimated at approximately 200 years. Based on these results it is certain that the bearing in the filling machine at Tattaly was very much under-loaded and life overload was unlikely to have been the cause of the observed bearing failure. Naturally there are several other technical issues which could shorten the life of a bearing and these are all noted in the Rothe Erde bearing catalogue. Only one of these issues was considered as relevant to this investigation, namely the behaviour of the companion structure on which the bearing is mounted.

(b) *Was the bearing properly mounted or had the companion structure of the bearing suffered some unexpected or unacceptable deflection during installation or commissioning?* – This last question is an expression of the commonly observed engineering paranoia when an unexpected machine failure is encountered (i.e., "*Was it dropped?*", or "*Has someone hit it with a hammer?*"). As it happened, in this case there some was cause to be concerned about a random accident event. The machine did suffer some vertical jarring when a plastic support pad under one leg of the machine collapsed during installation.

The design of the Rothe Erde Series KD600 slewing-ring bearings is based on a relatively frail structural component being supported on a stiff companion structure. Considerable care needs to be taken to minimise bearing deflection under load and the companion structure of the bearing needs to withstand the loads without undue deflection. The flatness of the supporting surface under the bearing race is to be paid particular attention, as is the tension in the hold-down bolts which ensure conjoint operation of the bearing race with its companion structure. From my discussions with

2.14 *Rothe Erde Large-Diameter Antifriction Bearings*: Hoesche Rothe Erde.

maintenance staff at the BLC plant, none of these issues was discussed or advised by *GBF* engineers when the new bearing was installed in January 1997.

Figure 2.25 is a photograph of the underneath of the machine turntable. This photograph indicates the robust ring beam structure used to support the machine bearing. Simple calculations of deflection in the ring beam under normal loading showed these deflections to be negligible.[2.15]

(c) *Was there something peculiar about the bearing material that may have resulted in this failure? – Intico Pty. Ltd.*, an independent approved testing authority had carried out hardness testing on the failed bearing. However, these tests were all conducted on the parent metal and the actual bearing surface was not tested for hardness. As noted earlier, the bearing was supplied by Rothe Erde, a company supplying bearings to the heavy lifting industry. This bearing was designated as a series KD600 slewing -ring bearing, and it is the type of bearing commonly used in large machinery such as cranes that rotate intermittently.

There were samples available from the bearing to be tested for material properties. This was performed by a metallurgical testing laboratory, *STS*, who identified the material as a *45-Cr-2 steel* (a European designation for this chromium steel, designed specifically for surface hardening). The Society of Automotive Engineers (*SAE*) designation for the same steel would be *SAE-5147*. *STS* advised that the desirable surface hardness for this steel should be in the range 55-61*HRC*, corresponding to a Brinell hardness of 550, when induction hardened.[2.16]

The bearing surfaces of the turntable bearing had been induction hardened, a widely used process for the surface hardening of steel in which components are heated by means of an alternating magnetic field to a temperature within or above the transformation range followed by immediate quenching (rapid cooling). When steel is heated above its transformation temperature (720°C), the carbon changes the steel's crystalline structure to an austenite, one of the allotropes of iron, also known as gamma iron. The harder, more brittle steel is then quickly cooled or quenched. The core of the component remains unaffected by the treatment and its physical properties are those of the bar from which it was machined, whilst the hardness of the case can be within the range 350 to 550 Brinell hardness. Carbon and alloy steels with a carbon content in the range 0.40–0.45% are most suitable for this process. The author used a *Churchill* portable Brinell hardness tester to measure the hardness of the bearing surfaces. Both inner and outer race surfaces were tested for hardness, with the results showing that both surfaces had a hardness below 400 Brinell.

2.15 These simple deflection calculations are presented in Appendix 2.

2.16 A primer on material properties and testing methods is given in Appendix 2.

Table 2.2 Potential failure mode evaluation

Potential failure mode	Description	Information available	Likelihood
1	Overloading; design fault	Life curves for given application shows the bearing is underloaded; highly reputable supplier	very low
2	Lubrication failure	Inspection showed the lubricating grease on the bearings was clean and contained no metal particles	very low
3	Material fault; manufacturing error	Material softer than expected, strength still well above levels of concern (refer bearing life calculations)	Medium to low
4	Bearing mounting fault or companion structure deflection	Mounting examined and structure deflections estimated (refer to calculations of companion structure deflections)	Very low
5	Random accident during installation or commissioning	A machine support disc that collapsed during commissioning may have imposed a undue local load on the bearing surface (Brinelling action)	High

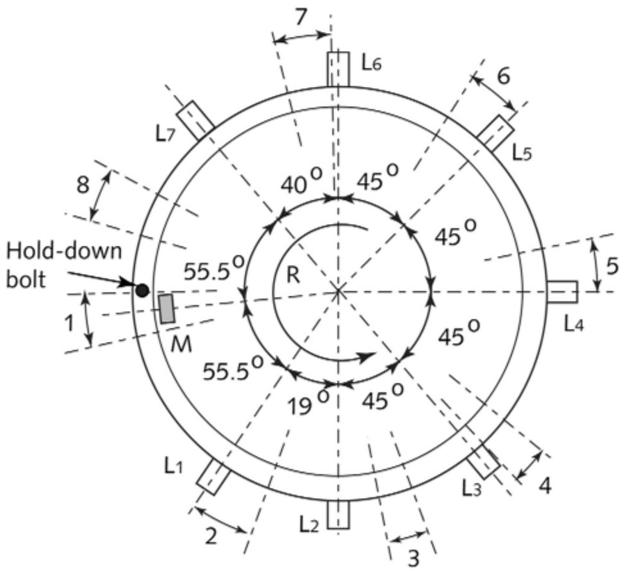


Figure 2.29 Layout of machine showing leg and bearing damage locations on the inner (fixed) bearing surface. The L numbers represent support leg locations, M is the motor drive location, R is the machine rotation direction and the damage locations numbered 1 to 8 were measured arbitrarily from the first hold-down bolt near the location of the motor drive

Table 2.3 Bearing damage survey (refer to Figure 2.29)

Location	Position relative to hold-down bolt 1 (Degrees of arc)	Arc length (mm)	Description
1	11	240	Severe chatter, with very deep indentations; this is the most extensive damage; heaviest near hold-down bolt 1
2	54–73	415	Very light, sporadic surface damage; mostly surface discolouration
3	99–107	175	Very light discolouration; few minor surface indentations
4	137–147	218	Very severe damage, with deep indentations; most severe near hold-down bolt 15
5	179–189	218	Severe chatter; less than at locations 1 and 4, but quite deep grooves; worst near hold-down bolt 19
6	223–232	196	Relatively light damage; less than at location 5; heaviest at midpoint between hold-down bolts 23 and 24
7	257–266	196	Very light damage; mainly surface discolouration, with a few shallow indentations
8	310–320	196	Heavy damage; deep indentations of the same order as at location 4

Table 2.2 is consolidated statement of the probabilities of potential failure modes considered in the initial investigation. Table 2.3 gives a detailed description of the inner (fixed) bearing surface damage. In detailing the damage, the locations are referenced with respect to the hold-down bolt holes in the inner race. There were 36 hold-down bolt holes spaced at 9.73 degrees of arc apart. Hold-down bolt hole designated number 1 was located arbitrarily just ahead of the drive motor location. This survey was conducted in order to establish if there was any pattern of correlation of damage with machine leg or hold-down bolt locations. There was no such correlation apparent in the damage locations observed.

Notably, the outer race is not loaded as heavily as the inner race, since both principal curvatures of the surface are of the same sign as the curvature of the bearing ball. Moreover, the ball path on the outer race is considerably longer than the ball path on the inner race (larger radius to contact surface). Hence the number of load cycles seen by the outer race are smaller than those seen by the inner race during the bearing life. These observations were supported by the fact that the outer race surface appeared to be less damaged than the inner race surface.

Finally, if the failure of the bearing were due to an event such as material, lubrication or companion structure failure, the outer race would be uniformly damaged rather than in a few specific locations. It is this set of randomly spaced failure locations on the outer bearing surface that presented the strongest evidence for a jarring initiated failure event, leading to the eventual failure of the whole bearing at series of specific locations.

2.4.5 Lessons Learnt and Recommendations

Probably the most salutary lesson from this case was the rather complex and convoluted nature of the relationship between the two protagonists BLC and GBF. As noted earlier, it was very much in the interest of both companies to ensure the continued and reliable operation of these filling machines. The investigation did not uncover any sinister underlying flaw with the Tattaly machine. As a consequence the following recommendations were offered to BLC technical staff:

1. Advise GBF about the nature of the failure event together with the information about this investigation. In my opinion BLC were entitled to some compensation in addition to the replacement bearing, considering that GBF were responsible for supplying the machine originally with unsatisfactory leg supports. The resulting jarring and damage initiation of the bearing appeared to be a machine design fault which should be borne by the machine supplier. This issue is supported by the evidence that the surface hardness of the bearing appeared to be 34% lower than expected.
2. Examine all other GBF machines for possible jarring which could initiate early failures similar to that experienced in the machine at Tattaly. This could be done in the following ways. A vibration survey of these machines could reveal unaccounted for resonances in their vibration spectrum. Continuous monitoring of lubricant grease could reveal unacceptably high metal content, providing a warning of incipient failure. In both of these cases the bearing could be removed and examined for surface damage during scheduled maintenance shut-down. Alternatively, and this is probably the most expensive option, the bearing of each machine could be scheduled for removal and full inspection for surface damage or brinelling at scheduled maintenance shut downs.
3. Request full life design data information for all the slewing-ring bearings in GBF designed filling machines operating at BLC plants. This design data should be available from GBF or Rothe Erde. It would provide some degree of appreciation of probable machine reliability for BLC technical staff if they had a clear understanding of how design decisions associated with these bearings were reached.
4. Monitor bearing lubricant for metal content on a regular basis to ensure that the bearings operate without shedding metal particles.

2.5 A Milk Tanker Takes a Spill

In many countries the bulk processing of food products is carried out in plants separated by substantial distances. The transportation of food products is a service requiring specially designed transport equipment. This case concerns the transport of raw milk collected from dairy farmers and transported to a food processing plant using a large milk tanker truck.

2.5.1 The Case Culture

Port Campbell is a small picturesque seaside township located on the doorstep of the world-famous Apostles along the Great Ocean Road in Victoria. *Cherry Transport* has its centre of operations there because it is in the heartland of the Victorian dairy industry. The town of Cobden is located in central Victoria where a large milk processing pant is operated by *YumYum Foods*. Milk tankers are used to transport large volumes of milk from dairy suppliers to milk product processing plants such as *YumYum*. Collection of milk is performed by the tanker driver using a stainless steel tanker trailer driven by a prime mover. The connection between the trailer and prime mover is achieved by the operation of a device called a *greasy plate hitch*. The tanker used in this case was carrying approximately 23,000 litres of milk to be processed into cheese by YumYum Foods. Cherry Transport was the tanker operator and Alan Cherry, a nephew of the owner, drove the tanker when it rolled over while negotiating a bend in the Port Campbell to Cobden road and spilled its milk contents, as well as sustaining some damage to the tanker and the greasy plate hitch.

2.5.2 Defining Event

In large transport accidents the police are routinely asked to attend the scene, interview the driver or any witnesses and subsequently file a report of the accident. The police report of this accident simply stated that the tanker trailer had rolled over and the prime mover was facing in the direction of travel. Road conditions at the time of the accident were described as slightly wet with clear visibility. As would be expected, the driver claimed to be travelling at 25 km/h, a speed he deemed appropriate to take the bend with the tanker.

When the service histories of the tanker and prime mover were routinely examined by the loss assessor for Cherry Transport's insurer, it was discovered that at some time prior to the accident event the kingpin bolt of the greasy plate hitch was replaced by *Blunt Engineering*. The replaced kingpin bolt was of a non-standard design, manufactured by Blunt Engineering to expedite the service of the greasy plate hitch when a standard bolt was not available during service. The damages claim was issued by the solicitor acting for the insurer of Cherry Transport against Blunt Engineering, claiming that the non-standard kingpin bolt was the major cause of the accident. The quantum of the claim included AU$ 9000 for repairs to the Louiswille prime mover, AU$ 33,000 for repairs to the tanker trailer and AU$ 3000 for the lost milk. The total claim, not including costs of litigation, was AU$ 45,000.

2.5.3 Parties to the Dispute

Although this was a *small* claim that under normal circumstances would have been handled by Cherry's insurer, the failure of the non-standard kingpin bolt gave the impression that an engineering failure had contributed to the accident. Consequently, Cherry's insurer sought to distribute their losses by suing Blunt's insurers. It is a sad fact of life that almost invariably these cases devolve into a loss sharing fight between two or more insurance companies.

2.5.4 The Expert's Role and the Investigation

Defence counsel for Blunt's insurers sought my services as a consultant and asked me to respond to the following:

(a) What was the most likely scenario for the accident resulting in the roll over of the Cherry Transport tanker?;

(b) In what way did the kingpin bolt influence the outcome of the accident?

(c) Finally, could it be established whether the non-standard kingpin bolt may have adversely contributed to the outcome of the accident?

In what follows, the operation of the greasy-plate hitch will be reviewed and an accident scenario constructed. Figure 2.30 is a general view of the tanker. Figure 2.31 shows the trailer hitch mounted n the back of a prime mover. A schematic cross sectional view of the greasy-plate swivelling arrangement is shown in Figure 2.32. The kingpin bolt in the centre of the greasy-plate ties the rotatable top plate to the fixed bottom plate. The spring permits some limited vertical movement between the two plates. The trailer quick-fit hitch is fixed to the top plate and the tanker hitching pin is

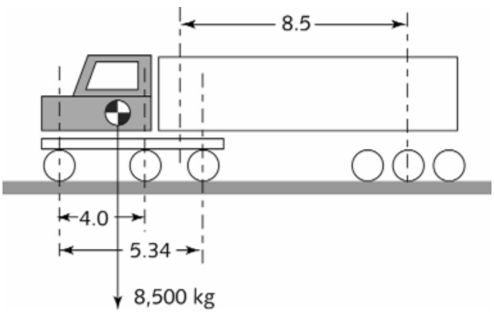


Figure 2.30 General view of the tanker

Figure 2.31 The trailer hitch mounted on a prime mover

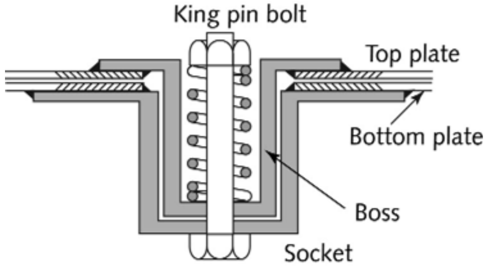


Figure 2.32 Greasy-plate arrangement (schematic, not to scale)

Figure 2.33 Hitching pin mounted on tanker trailer

received in the vee-shaped entry during the trailer hitching process (Figure 2.33). Shear loads are carried during transport by the two cup-shaped components of the top and bottom plates. Rotation of the top plate and cup on the bottom plate and inside the bottom plate cup by grease lubrication. The only time the kingpin bolt would experience any substantial loading beyond the force developed in the spring is when, due to unexpected vertical displacement the spring coils become fully compressed. Figure 2.34 shows the damaged kingpin bolt recovered after the accident. Also shown in this figure are schematic sketches of a standard kingpin bolt and one like that manufactured by Blunt as a replacement for a standard bolt. The major difference between these two types of bolts is that in a standard bolt the head of the bolt is integrally made with the body of the bolt, while in the manufactured replacement the body is machined and the head is welded on as indicated in Figure 2.34. Note that the damaged kingpin bolt has its bolt head missing and it is also slightly bent.

After the accident the loss investigator found the kingpin bolt to be a non-standard type of bolt manufactured with the head of the bolt welded on rather than formed normally. Metallurgical examination of the damaged bolt confirmed the suspicion of the loss investigator that the bolt head welded on by Blunt had been torn off the bolt stem in the accident. In subsequent statements by Blunt Engineering it was admitted that they replaced the worn original kingpin bolt with one of their own manufacture. This action was taken as a means of speeding up the delivery of the reconditioned trailer hitch. A report of the examining metallurgist alleged that the manufactured bolt had only about one third the strength of the replaced kingpin bolt.

One aspect of constructing this particular traffic accident scenario was that of modelling the behaviour of the tanker in the turn. In this case the initial modelling was conjectured as indicated by the model pictures in Figure 2.35. The conjectured chronology of the tanker rollover was as follows:

(a) Driver takes the turn faster than appropriate to the road conditions;

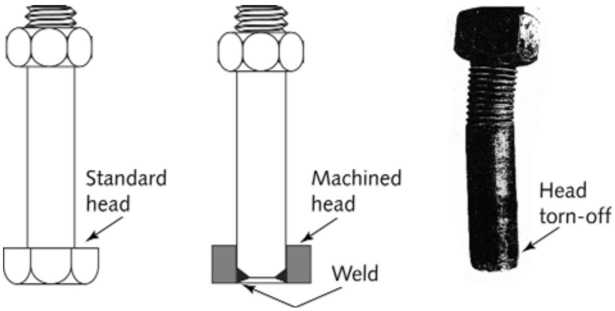
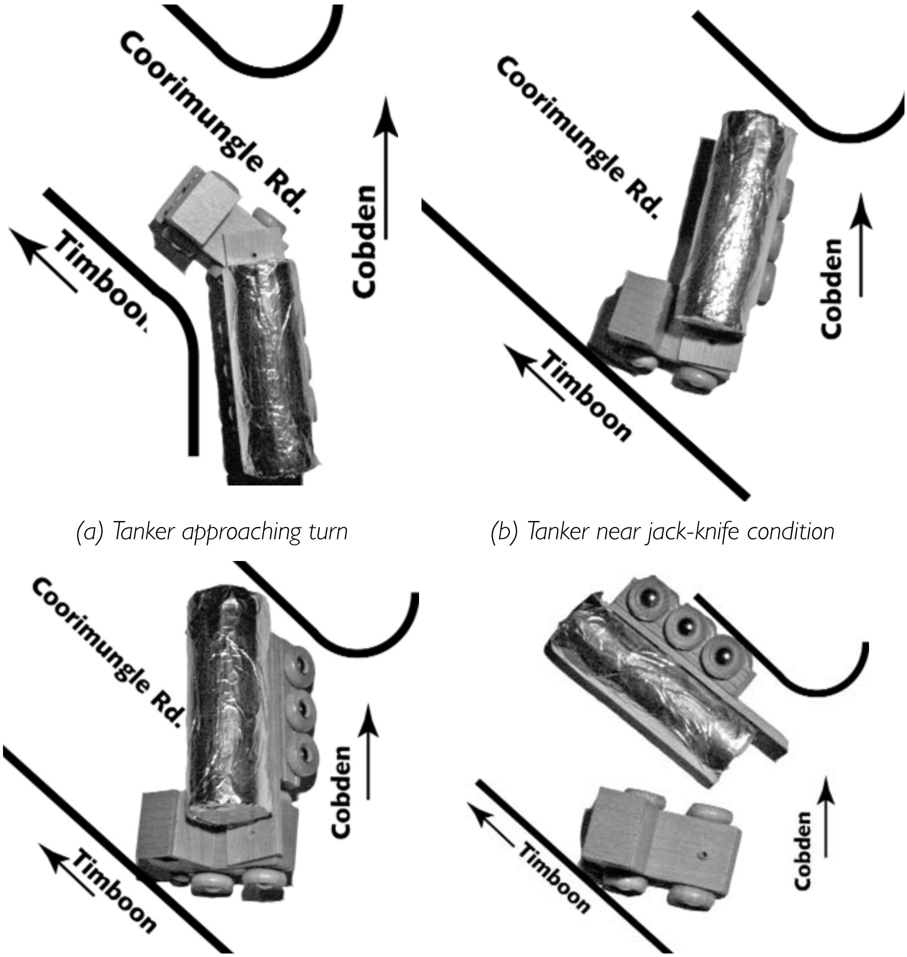


Figure 2.34 The damaged king-pin bolt and schematic sketches of a standard bolt and one similar to that manufactured by Blunt



(a) Tanker approaching turn
(b) Tanker near jack-knife condition
(c) Commencement of rollover
(d) Final locations of tanker and prime mover

Figure 2.35 Model demonstration of the tanker rollover process (not to scale)

(b) Tanker trailer begins to slide on wet road;

(c) Inexperienced driver applies brakes;

(d) Tanker trailer rolls and tears out kingpin bolt from the bottom plate of the hitch. Trailer and prime mover settle in locations indicated in the photo of Figure 2.35 (d). This was confirmed by the police report of the accident scene.

A professional road traffic modelling expert, *Peter Bitterman*, was consulted about the conjectured scenario depicted in Figure 2.35. In his report Bitterman stated:

> *"Under conditions of good tyre/road surface friction the most likely form of instability is rollover. This involves large centrifugal forces acting laterally at the centre-of-gravity of the trailer and exceeding the stabilising influence of the vertical loads between the trailer tyres and the road surface. The University of Michigan Transportation Research Institute (UMTRI) Roll Model was used the simulate the transport vehicle and to estimate its rollover limit."*

The results of this simulation showed that at at 25 km/h the trailer wheels would lift but the vehicle would remain stable. The same analysis showed that at 30 km/h the vehicle would roll over. Bitterman went on to conclude:

> *"Under conditions of poor tyre/road friction, and combined braking and cornering, the most likely forms of instability are jackknife and trailer swing.*
> *Trailer swing involves the rotation of the trailer about the turntable while the prime m over continues in its path. In a left turn the trailer would always swing to the right and may swing far enough to damage the right side of the cab.*
> *… the police report … clearly shows damage to the right hand corner of the cab only …"*

Figures 2.36 and 2.37 show schematically (again conjectured) the two phases of the rollover. In the first phase the tanker trailer will lift the rear of the prime mover producing substantial tension on the kingpin bolt. Once the spring (see Figure 2.32) had been fully compressed, the edge of the top plate would have become the fulcrum about which the rollover moment acted on the bolt. This second phase of the rollover was the most probable reason the kingpin bolt was torn from its location. The two phases were most likely only a fraction of a second apart.

Taking moments about the ground reaction in Phase 1 of the rollover

$$F1 = (8555 \times 9.81 \times 2.5)/4.7 = 44.4 \text{ kN}$$

In Phase 2 of the rollover the moment acting on the top plate due to the rolling over of the trailer is $F2 \times 0.45$ Nm. $F2$ could have been estimated from the conjectured centrifugal forces acting on the rolling trailer at various road speeds and turn diameters. However, a simpler approach was to recognise that the bolt had indeed been torn out from its location and the twisting moment responsible for this was as indicated in Figure 2.37.

$$F2 \times 0.45 = 8{,}500 \times 9.81 \times 2.5$$

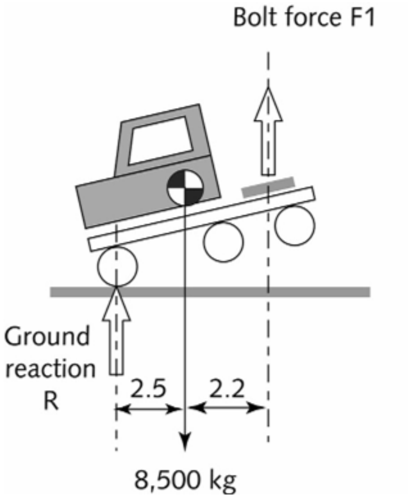


Figure 2.36 Phase 1 of the roll

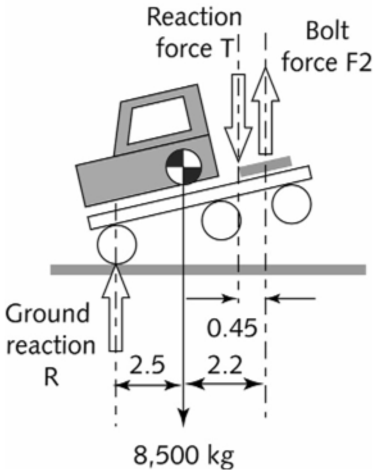


Figure 2.37 Phase 2 of the roll

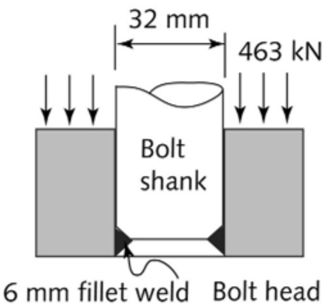


Figure 2.38 Schematic view of bolt head under load

$F2 \quad = 463$ kN

Figure 2.38 is a schematic view of the bolt head under load during Phase 2 of the roll. The stress developed in the weld is given by[2.17]

$\tau \quad = (1.21 \times F2)/(L \times h),$

$L \quad =$ weld length $= \pi \times 0.032$

$h \quad =$ weld height $= 0.006$

and $\tau \quad = (1.21 \times 463 \times 10^3)/(\pi \times 0.032 \times 0.006)$

$= 0.93$ GPa.

This is a very large shearing stress that would have easily failed the weld holding the machined head of the bolt onto the shank. However, the standard bolt originally used in the hitch was a *Duraflex* CS1045 steel bolt with a tensile strength of 440 MPa.[2.18] In the event that a standard kingpin bolt had been used in the hitch during the accident the failure criterion for this standard bolt would have been the tensile strength of the bolt shank.

Maximum tensile load on the bolt:

$\sigma_{Max} = F_{Max}/(\pi \times D^2/4) = 463 \times 10^3 /(\pi \times 0.036^2/4) = 455$ MPa

2.17 See for example Samuel and Weir (1999), Section 4.4.

2.18 This information was provided by Cherry technical staff.

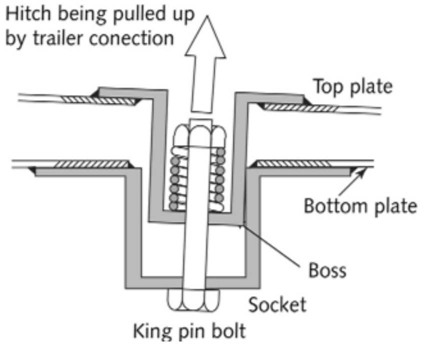


Figure 2.39 Greasy-plate hitch at its extreme displacement

This calculation does not take into account the failure of the bolt at its thread, where the root diameter is smaller than the shank diameter, and stress concentrations are introduced by the thread elements. The significance of the calculated stress on the bolt is that it would have failed in any circumstances whether it had been a standard bolt or a modified manufactured bolt. This bolt is not expected to carry substantial loading at any time other than when the hitch spring (refer to Figure 2.39) is fully compressed. In this condition the load is taken by the kingpin bolt head and nut as well as the metal bases of both boss and socket components. Under sufficient loading the thread on the kingpin bolt may shear off, the head of the bolt might be pulled through the base of the socket, or the kingpin bolt might fail in tension. These failure modes are listed in order of greatest to least likelihood, estimated from the engineering mechanics of the greasy-plate assembly. In the Cherry Transport accident, the kingpin bolt head was welded on to the bolt stem, as indicated in Figure 2.38, and it was the fillet weld of this construction that became the weakest part of the greasy-plate assembly.

2.5.5 Lessons Learnt and the Outcome

In this case as in many similar examples, the careful reconstruction of a failure scenario was an essential part of the defence for Blunt. When the large load acting on the kingpin bolt was applied to a standard bolt, it became evident that no bolt of the size used in this application would have been able to withstand the load acting in Phase 2 of the rollover. In fact, had the bolt been able to withstand this load, it is entirely feasible that the momentum of the tanker trailer would have carried the prime mover with it in the rolling process. If that happened, the prime mover would have suffered significantly greater damage than was the case in this accident. In fact, one might consider the failure of the bolt head acting like a fuse in an electrical circuit, preventing a more substantial damage.

In this case the winning line was that of recognising the fine detail of the accident scenario. This case was (as in most cases) settled out of court as a result of the above evaluations and the additional evidence provided by the transport dynamics model.

2.6 A Paper Coating Machine is Damaged in Transit

Paper with a clay or other coating applied to one or both sides is coated paper. The coating is intended to fill in all the micro-scale irregularities produced when randomly distributed cellulose fibres are compressed into the basic paper web. Coated paper generally produces sharper, brighter images and has better reflectivity than uncoated paper. The coating can be dull, gloss, matte, or other finishes. Many coaters use an *airknife* to aid the coating process where the coating is applied to the substrate and the excess is 'blown off' by a powerful jet from the airknife. Figure 2.40 shows a schematic view of the airknife coating process.

2.6.1 The Case Culture and the Accident Event

Sometime in the early nineties *Busyboard*, a paper maker, set up a new paper coating line in their preprint business at Coolaroo in the state of Victoria, Australia. Paper coating lines consist of several special types of machinery with purpose-built transfer mechanisms for the paper to be coated. In this case, Busyboard decided to out-source the manufacture and installation of the whole line to the *Holker Corporation* of Ohio. Holker had substantial expertise in paper coating lines and they contracted to supply, and install the several components of the line including an airknife coater. The total contract cost for the supply delivery and commissioning of the coating line was US$ 2.18 million. The airknife coater included in this contract was costed by Holker at US$ 253,000.

The machinery for the coating line was packaged and delivered as marine cargo to the port of Melbourne in late 1994. One package, that containing the airknife machine, was found be seriously damaged on delivery to

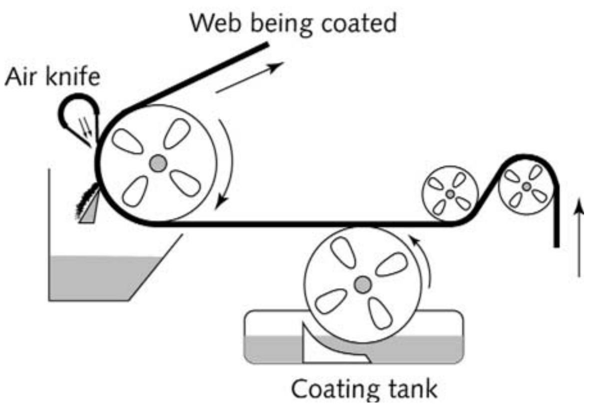


Figure 2.40 Schematic view of the coating process and the role of the airknife

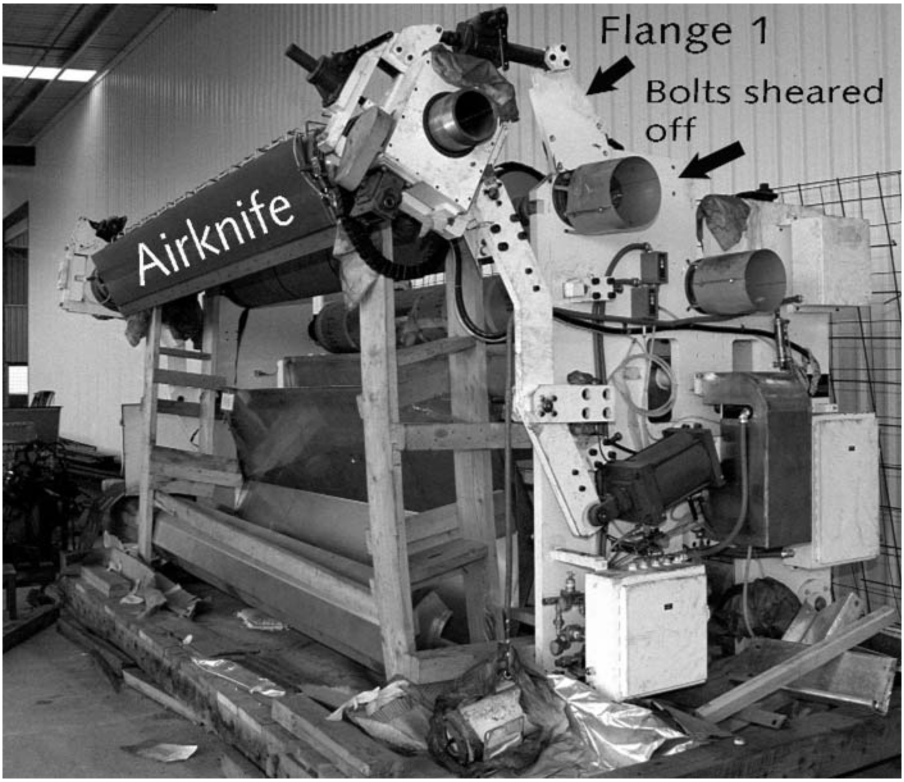


Figure 2.41 General view of the partially unpacked airknife machine in its damaged packaging

Coolaroo. Marine surveyors examine ships' cargoes, investigate accidents at sea and prepare accident reports for insurance purposes. Because the airknife package was damaged somewhere in transit, either on the docks during handling, or on board the ship that delivered it, *Captain Joseph Porter*, a marine surveyor, was appointed to inspect the damage and to report on it to Holker's insurers.

In addition an independent assesor, the engineering firm, *Telfer Ltd.,* was appointed to inspect the damaged machine and advise Holker about the nature and extent of the damage. Based on Telfer's assessment, Holker would then estimate the cost of repairing the damaged machine. Interestingly, the repairs to the damaged machine were estimated by Holker at US$ 520,000. This incredible cost figure included US$ 133,000 for packaging and return air freight (to Ohio and back to Melbourne), on the basis of Holker's insistence that the machine could be properly repaired only in their own works in Ohio. Moreover, once repaired, Holker disavowed any warranty or guarantee of performance for the repaired machine.

2.6.2 The Nature of the Dispute and Stakeholders

It is useful to put in context the claim on Holker's insurers resulting from the damage to the airknife coater. Reviewing the above figures, the supply and air freighting out a brand new airknife coater with full warranty from Holker would have cost US$ 200,000 less than the claimed repairs to the damaged machine. Of course, there may have been some issues of timing and possible liquidated damage implications in the Busyboard contract with Holker that motivated the incredibly expensive claim. Recall here that Holker's complete contract with Busyboard included full commissioning of the coating line. Consequently, one could interpret the denial of warranty and guarantee of performance for the repaired airknife coating machine as impinging only on Holker themselves rather than Busyboard. After all, Busyboard were entitled to receive a fully commissioned coating line as agreed by the original contract suggesting immunity from the implied lack of warranty or guarantee of performance.

The major stakeholders in this prelude to a dispute were the marine insurers of the transport company and Holker's liability insurers. There may have been a subsidiary party to the dispute, namely Telfer Ltd., the independent damage assessors. Their assessment of the damage would require evaluation, considering that they may have been influenced by the time and ultimate performance constraints imposed on the repairs and return to service of the machine.

2.6.3 The Role of the Expert and the Investigation

Early in 1995 Porter commissioned me to investigate the damage to the machine and to report on the possibility and implications of repairing the damaged airknife coating machine locally. My task was to review the available evidence and to report on the assessed need to air freight the machine back to Ohio for repairs.

Figure 2.41 shows the partially unpacked airknife machine. Figures 2.42 through 2.45 show closer views of various elements of the airknife machine. On first inspection it appeared that the machine in its crate had suffered a substantial bump. The most easily apparent damaged items were found to be as follows:

1. The airknife support system at the front of the machine appeared to have suffered the most serious dislocation. This is identified in Figure 2.41, where Flange 1 is seen to be displaced from its intended location. The four holding screws, designed to retain the airknife support system in its intended location, had been sheared off due to the impact received in the accident event. Figure 2.44 is a close up photograph of the airknife support head, indicating the original location of Flange 1. In fact, all the eight (four on each side) 15 mm diameter cap screws holding these support flanges on both sides of the machine had been sheared off flush with the machine frame.

2. Various support rollers had been displaced from their bearings and some had bent shafts. Almost all bearings supporting rollers had been shattered due to the impact on the machine.
3. Pneumatic actuating cylinders had been damaged (see for example 2.43).
4. The air delivery chamber (seen in Figure 2.42) had impacted on one of the support rollers and may have become damaged. This needed careful evaluation in the repair of the damage.

There was no doubt that the machine had suffered substantial damage, but its repair prognosis had to be be seen in the light of:

(a) The type of event that could have caused the damage (hypothetical accident scenario)

Figure 2.42 View along air delivery nozzle, with airknife blades removed

Figure 2.43 View showing roller dislodged from its bearing and damaged air cylinder

Figure 2.44 Airknife support head and its various adjustments. The arrows show where the flange bolts sheared off

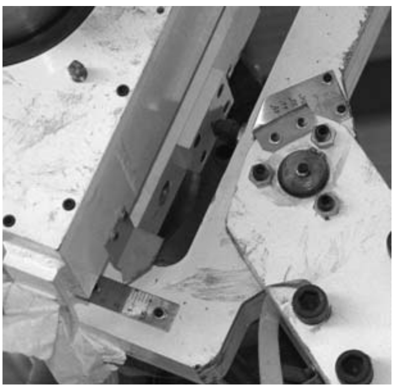


Figure 2.45 Close up of support head indivating gap and attitude adjustments

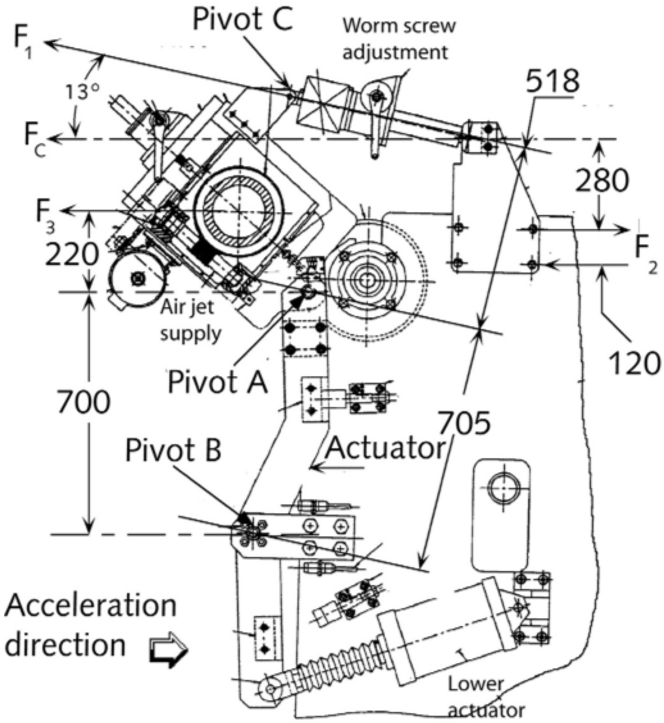


Figure 2.46 Side view of the airknife coater indicating some of the major features of adjustment to the machine

(b) The likely consequences of the accident for the overall machine assembly

(c) The likely risks for the machine operator, working with a repaired machine in a critical position of a continuous production facility.

(a) The Accident Scenario – Figure 2.46 shows a side elevation of the airknife machine taken from a copy of drawings supplied by the Holker Corporation. The measurements were scaled from the drawing, using comparative dimensions measured on the actual Holker machine on site. Figure 2.47 is a simplified mechanism view of the moving parts of the airknife machine. The lower actuator is a pneumatic cylinder and in principle the air in this cylinder will act as a pneumatic spring until the lever arm pivoted at B hits a machine stop (see Figure 2.47). The following nomenclature is assigned to the analysis:

F_1 = force acting on Flange 1 eventually causing it to shear the 15 mm diameter mounting cap screws;

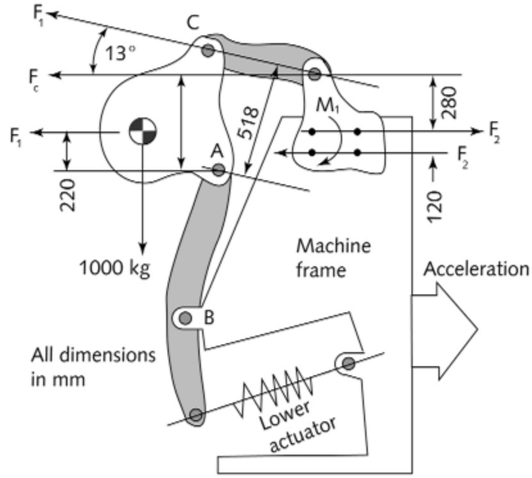


Figure 2.47 Simplified mechanism schematic of the major moving parts of the airknife machine indicating acceleration of the crated machine

F_2 = resisting force provided by bolts during shearing off;

= timp x 2 x A (noting that F_2 is provided by two bolts acting in line), where

t_{imp} = impact shear strength of the 15 mm bolt. From markings on the bolt head this has been estimated to be an SAE (Society Automotive Engineers) grade 3 medium carbon steel bolt with an approximate tensile strength of 700 MPa. The resulting shear strength under impact loading is estimated at 200 MPa;

A = the section area of the bolt material. This is estimated from the thread root diameter of the 15 mm thread (14 mm root diameter) as 1.54×10^{-4} m^2;

$F_2 = 2 \times 200 \times 10^6 \times 1.54 \times 10^{-4} = 61.6$ kN

The moment provided by the impact shearing of the 4 x 15 mm bolts is

$$F_2 \times 0.12 \text{ Nm} = 7.4 \times 10^3 \text{ Nm}$$

This moment is generated by the inertia force of the airknife assembly. Referring to Figure 2.46, the assembly will commence rotating about pivot C, under the action of the applied rearward acceleration on the packaged machine. This rotation will cause the actuating lever to move out to its outboard position about pivot B, where it will be stopped by the mechanical stops. When the lever comes to a sudden stop, the airknife assembly inertia load will be experienced in the screw jack connecting the pivot C to the actuator mounts. The magnitude of this impact load will depend on how suddenly the actuating lever is stopped. Judging by the sturdy design of this lever, I estimate that when it hits the stops the inertia load of the airknife can experience several times the acceleration of gravity ($1\,g = 9.81$ m/s^2). At this point the airknife inertia load, F_3 will act about pivot A. This force is generated by the inertia of the airknife assembly when a sudden acceleration a is applied to it by the impact on the machine crate. The moment due to the inertia of the airknife assembly, acting about pivot A, is hypothesised to be of sufficient magnitude to shear the bolts in the support flanges on both ends of the airknife machine frame. The airknife assembly mass was estimated at 1 ton. Hence we get (referring again to Figure 2.47)

$$1000 \times a \times 0.220 = 2 \times M_1 = 2 \times 7.4 \times 10^3$$

$$a = 67.3 \text{ ms}^{-2} = 6.9\,g$$

This is a relatively low level of acceleration due to an impact load. It could well have been produced by the front of the machine (in its packaging) receiving a severe blow. Moreover, the damage at the rear of the machine is also consistent with a rearward acceleration of the machine package. The idler roll is resting substantially forward of its original mounting position and all the indications of its damage suggest that the machine was accelerated suddenly (hit) in a rearward direction. The four bolts holding the machine to its package base seem to be intact. If the machine were dropped on its front, one would expect the rear pair of these bolts to be, at least partially, dislodged from the package base. The only conclusion one can draw from these estimates is that the machine package either hit something during loading or unloading, or a heavy load impacted on it while stationary.

(b) Consequences of the impact on overall machine assembly – Considering the analysis of the events leading to the damage, the following repair scenario was recommended:

1. All bearings and bearing mounts in the main frame side plates must be replaced. They would have taken the brunt of the impact load.
2. All rotating elements of the machine must be checked for run out. There is clear evidence that some rollers may be bent at their mounting into the side frame of the machine.
3. All damaged and broken parts must be replaced with equivalent new components.
4. The airknife assembly gap (refer to Figure 2.42) must be checked for gap size consistency (± 0.025 mm recommended by Holker) and if necessary replaced. The lips of the airknife were packaged separately and they were undamaged.
5. The machine must be disassembled and the frame checked for any misalignments of the various bearing housings and mountings. Due to the sturdy design and construction of this machine it is entirely

possible that the machine frame is intact.

6. The machine stops will need to be readjusted to ensure proper operation. These stops are of a relatively simple and robust design, and they did not appear to be damaged.
7. The sequencing of the programmed logic controller is unlikely to be affected in any way by the damage to the machine. However it should be checked out and put through its programme according to the operating manual, once the machine is reassembled.

Taking the above analysis into consideration, it was estimated that the total damage to the airknife machine was relatively superficial and easily repaired either on site, or at a local repairer's workshop.

(c) The likely risks for the machine operator, working with a repaired machine in a critical position of a continuous production facility – The Holker airknife machine is not some delicate instrument with a complex program of operation. In general its complexity could be compared favourably with simple mining or earth moving machinery. The Holker machine handbook notes:

"Please keep in mind that this coater uses a jet of air travelling at speeds in excess of 200 m/sec. to uniformly meter coating across a 2.9 m wide substrate, which is itself travelling at 8 m/sec. We have observed air stream non-uniformities caused by internal scratches in the airknife as small as .025mm, that are capable of effecting coating uniformity. Our airknife coaters are the product of 35 years of painstaking development. Each piece of the equipment is manufactured to tolerances at either plus or minus 0.127 mm for standard parts, or plus or minus 0.025 mm for critical parts."

The standard tolerance of ±0.127 mm (±0.005 inch) is not particularly accurate and corresponds to the general tolerances given on most engineering parts. This corresponds to general machining tolerance on part sizes up to 3 m in size (refer to *Australian Standard 1654–1974*, *Table 5 – Numerical values of standard tolerance grades 6 to 12*) This type of general tolerance can be easily achieved in most machine shops.[2.19] The tolerance of ±0.025 mm (±0.001 inch) is a fine machining tolerance on part sizes up to 800 mm. These would be again easily achieved by any competent machine shop operator.

The most critical element of the whole airknife metering operation is the setting up of the airknife jet location and attitude. After describing the nature of coating inconsistencies resulting from poor adjustment of the airknife, the Holker manual notes mysteriously *"… adjust the airknife position and gap according to accepted practices …"*.

Clearly, all the information available indicates that the operator has significant influence on the proper operation of the machine and the ultimate

2.19 See also ASME DImensional Standard B4.3-1978; http:// isotc213.ds.dk/standard.htm (Published standards of ISO Technical Commitee 213).

quality of the coating performance. There are in fact two adjustments provided for the operator on the airknife at both sides of the machine (refer Figures 2.43 and 2.44), one to adjust jet angle and the other to adjust the jet location relative to the paper surface. As can be seen in Figure 2.44 these adjustments are robust and the scales of adjustment are marked in relatively coarse increments. From the above analysis of the operation of the machine, it may be concluded that for the Holker machine repaired to its original specifications and properly checked out for mechanical operation the risk of diminished performance below the original manufacturer's guarantees is extremely low.

2.6.4 Lessons Learnt and Outcome

The Holker airknife machine is a relatively simple device requiring considerable skill and care by the machine operator to provide a high quality consistent coating on paper board. The relevant adjustments on the machine are simple and robust. The programme is relatively simple and in any case it has not suffered any damage. The mechanical components suffered serious damage and the machine required to be thoroughly checked out prior to recommissioning.

Given the precautions of checking and replacing irreparable parts, as well as checking out the operation of the assembled machine, there appeared to be no reason why this machine should not be returned to satisfactory service. The repairs and checking required are well within the capacity of any competent machine shop operator, of whom there are several in Melbourne.

In this case the winning line of argument rested on the degree of robustness and level of observed precision in the operation of the airknife machine. The warranty issue was a *"red-herring"* since the delivery and successful commissioning of the coating line (including the airknife coater) were Holker's responsibility. Their contract with Busyboard called for Holker to be responsible for the satisfactory operation of the complete coating facility. In attempting to collect substantial marine insurance and disawowing responsibility for the operation of the repaired airknife, Holker may have been trying to cover themselves against their own possible lack of due diligence in repairing the machine to its new condition. Ultimately the operation of the complete facility rested with Holker. Possibly, they may have been able to claim liquidated damages against the marine insurer for the time delays involved in repairing the airknife. But, in the event, the on site repairs to the machine did not delay the installation of the coating line.

This is a case of identifying the elements of the repair process and assessing the risk of operating the repaired machine based on technical expertise of a suitable engineering machine shop operator. This case was resolved by repairing the machine on site.

2.7 A High-speed Compressor is Damaged by Faulty Bearing Manufacture

2.7.1 The Case Culture and the Defining Event

Air conditioning units are designed to operate unattended for long periods of time. In general, the most robust part of such systems is the compressor unit. This case concerns a modest size (60 horsepower, or approximately 45 kW) industrial air conditioning unit. This unit was supplied to *Hercules Pty. Ltd.* in about 1980 by *Electra Pty. Ltd.* a local importer of industrial air conditioners. The unit was commissioned and installed by Electra, who agreed to provide regular servicing for the unit. The unit ran successfully for nine years, at which time it was stripped down and a bearing replaced. After restarting the unit ran for a few hours and then stopped. This maintenance process was repeated several times, with the machine failing only after a few hours of running time. After about the third failure, Hercules threatened Electra with a suit to cover complete replacement of the unit as well as loss of production resulting from unacceptable working conditions without the air conditioner.

2.7.2 Parties to the Dispute and the Client

Nominally this was a dispute in planning between Hercules and Electra's liability insurers. In the ensuing process of collecting the evidence for this case it was discovered that Electra outsourced the repairs of its air conditioning compressors to an engineering firm *Flybynight Ltd.*. Had the case come to court, it is probable that Flybynight would have been enjoined in the dispute.

My client was Electra's insurer, and I was asked to broadly investigate the failure and provide opinion on the matter.

2.7.3 The Expert's Role and the Investigation

This type of general investigation is often referred to as a *"fishing expedition"* in case the expert can find an appropriate failure scenario and some way in which the insurer might share out their financial loss. My first task then was to collect the failed components and to examine all the maintenance documentation available.

Figure 2.48 is a sectional drawing of the compressor. The shaded component is the high-speed pinion running at approximately 20,000 rpm. This pinion is hollow and carries a smaller diameter shaft inside it. The impeller of the compressor is attached to this inner shaft. The apparently strange design of this impeller drive system was dictated by manufacturing economy and weight saving considerations. The pinion gear cut on the outer shaft is expected to last considerably longer than the simple sliding bearings on the unit. Simple sliding bearings were used in the design to save on space and inertial loads that might be imposed by rolling element bearings. The most critical part of this construction is seen to be the thrust bearing

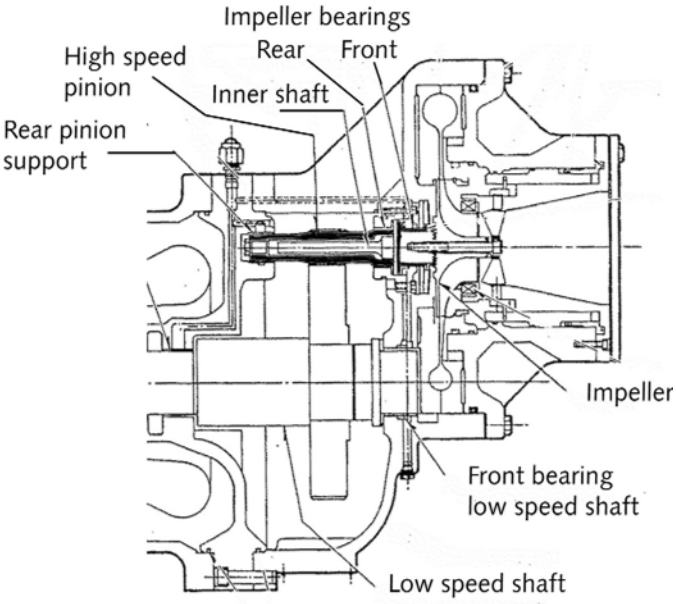


Figure 2.48 Sectional drawing of airconditioning compressor

at the rear of the impeller. Figure 2.49 shows the arrangement of the thrust bearing and the thrust face on the high-speed shaft schematically. Figure 2.50 shows the assembled high speed pinion and journal as well as the inner shaft that carries the journal and impeller.

Just prior to this investigation the compressor unit was found to have seized and the inner shaft of the high-speed pinion fractured in torsion. On inspection, the Babbitt[2.20] alloy bearing shell was found to have shattered (see Figure 2.52) and the thrust face of the shaft was found to be heavily worn (Figure 2.51). In the first major overhaul of the compressor the original inner shaft of the high-speed pinion together with its thrust face and journal was replaced by what was thought to be an equivalent component The original design is seen in Figure 2.53 and one of the replacement designs is seen in Figure 2.51. In the several following maintenance episodes various alternative thrust faces were tried by Electra (Figure 2.54). Apparently they realised that something was grievously wrong in their design of the replacement thrust face.

It is evident from Figure 2.54 that when overhauling the original bearing Electra chose to replace the original hydrostatic bearing with an angled pad design. There was no evidence suggesting the reasoning behind this decision, but it may be conjectured that obsolescence of the unit or inability to get replacement parts could have been responsible for the decision. From

2.20 Soft, white metal, an alloy of tin, lead, copper, and antimony, used to reduce friction in bearings, developed by the US inventor Isaac Babbit in 1839.

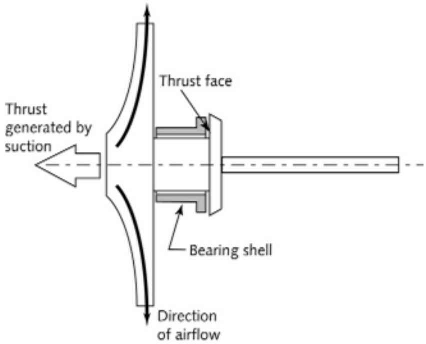


Figure 2.49 Schematic arrangement of the high-speed shaft and bearing

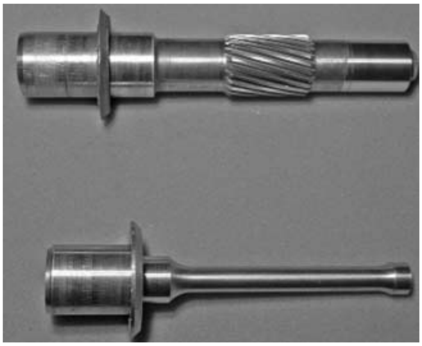


Figure 2.50 High-speed pinion assembly and separated inner shaft

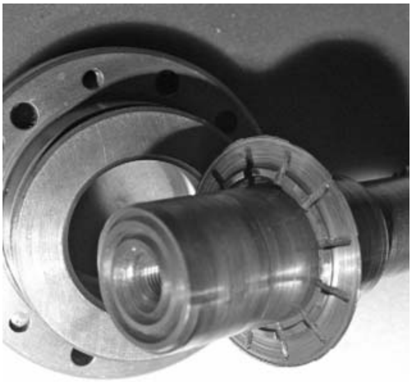


Figure 2.51 Heavily worn thrust face on high-speed journal

Figure 2.52 Components of bearing shell recovered from seized compressor

Figure 2.53 Nominally worn thrust face of high-speed shaft replaced in overhaul

Figure 2.54 Original thrust face compared to various alternatives tried by Electra

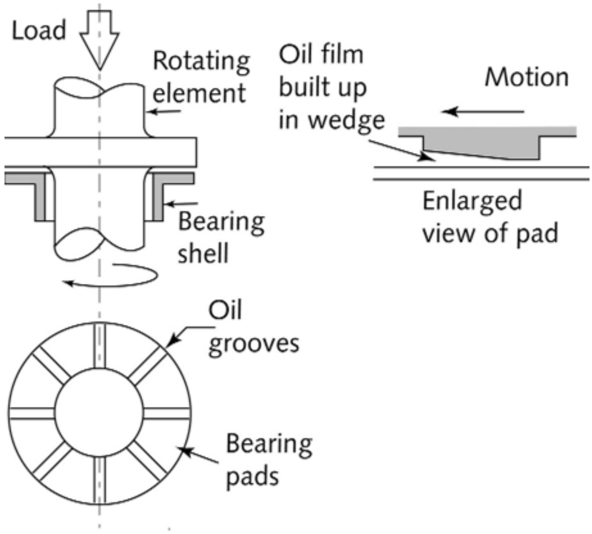


Figure 2.55 Angled pad thrust bearing geometry (schematic only)[2.21]

the several failed attempts at replacing the bearing it is also clear that Electra's design approach was one of trial and error rather than informed analysis. A reference to Neale's handbook on thrust pad design would have enlightened Electra to the real nature of angled pad thrust bearing design (refer to Figure 2.55). Moreover, tables in that publication would have advised them of the proper geometry for the loads and speeds encountered in the compressor. In the event the rather crude attempt at concocting such a bearing resulted in the ultimate seizure and failure of the compressor.

2.7.4 Lessons Learnt and the Outcome

This was not one of those large quantum cases that are fought out by insurance companies, occasionally dramatised by the media. Nevertheless it contained substantial lessons for the engineering litigator. The repair of the air conditioner could have dragged on with substantial manufacturing losses incurred ultimately by insurers of Hercules or Electra. If the air conditioning unit was not easily replaceable, or parts were no longer available, then the almost insignificant cost of contracting an expert designer would have been the simplest solution to the problem. In the event nobody would admit to the root cause of the problem and mediation was sought. The advice given to Electra was that they should use a three-dimensional coordinate measuring machine to record the geometry of the original bearing system and manufacture an exact replica. This geometry functioned satisfactorily for several years originally and there was no reason why it would not continue to do so.

2.21 Neale (1995).

2.8 Two Large Vehicles Roll Over

Two cases and their associated investigations are described here. Although they both involve the rollover of large industrial vehicles, both due to steering failures, neither involves any human injury. They are presented here as cautionary tales to illustrate the importance of care in advising maintenance procedures to mechanics and machine operators when inspecting and repairing vehicles exposed to harsh operating conditions. Both cases concern only the technicians involved in maintaining or repairing the vehicles. The cases were fought out between insurers for these technicians and the insurers of the vehicles damaged. Although neither case involves a dramatically large quantum (both claims were less than AU$ 300,000), both are interesting because they are the results of poor engineering design decisions.

2.8.1 Case Culture (a) – A Flipped Fertiliser Spreader

Modern mechanised farming makes use of computer-controlled spreading of fertilisers due to the cost of fertilisers, as well as the need to apply carefully controlled amounts of farming chemicals for optimum production. In some cases large-scale farming involves satellite thermal imaging to assess where and how much fertilising is needed.

The *Bigbrother Co.* of the United Kingdom make an excellent range of tractors for use in mechanised farming. Figure 2.56 shows a type of tractor manufactured by Bigbrother for the attachments of various farm implements. In the background a typical trailer may be seen in this figure. The procedure used in controlled spreading of fertilisers is to attach such a trailer to the tractor and control spreading by programmed opening of distribution gates on the trailer. *Fillary Engineers* of Coleraine in Australia manufacture and market a range of computer automated fertiliser spreading trailers. Farmers interested in purchasing these types of machines need to apply to Fillary, who will import the Bigbrother tractor and attach the Fillary trailer to it, usually subject to the purchasing farmer's specifications of size and various optional fittings.

2.8.2 The Accident Event and Parties to the Dispute

In 1999 *Old-McDonald Farm* purchased a fertiliser spreader system from Fillary, and then proceeded to use it for a period of about nine months. During this period the Old-McDonald farm had experienced an unusually wet season and the tractor was used in very muddy conditions. It was during a normal fertiliser spreading operation that the driver lost control of the tractor and it flipped over, causing substantial damage and completely destroying the fertiliser trailer. Fortunately the driver was not hurt in this accident.

Initial evaluation of the accident indicated that a mechanical steering failure caused the flipping of the tractor and trailer. Consequently, Old-McDonald made a warranty claim against Fillary, whose liability insurers

Figure 2.56 Typical four-wheel-drive RS232 Bigbrother tractor

sought to distribute their loss and asked for an independent evaluation of the steering failure. Their loss assessor recognised the mechanical failure as a possible design fault with the Bigbrother tractor's steering mechanism.

2.8.3 The Role of the Expert and the Investigation

When the steering linkages of the flipped tractor were examined, it was found that the steering knuckle had been pulled out of the main steering track rod. This track rod is a heavy tubular component that connects the steering arms of the two front wheels on the tractor (see the item marked Z in diagram (b) of Figure 2.57). Three-degree-of-freedom ball joints on the steering knuckle (item marked E in diagram (a) of Figure 2.57) allow for the necessary motion freedoms required for steering the front wheels. The screw adjustment of the steering knuckle permits the camber of the front wheels to be adjusted. Camber is the angle the plane of the wheel relative to the vertical plane and is used to control steering forces.

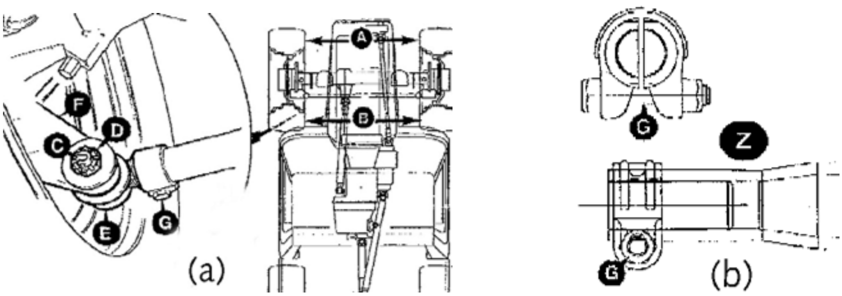


Figure 2.57 Maintenance instruction diagrams for the RS232 tractor

Figure 2.58 Original design of track rod (worn sample from Fillary)

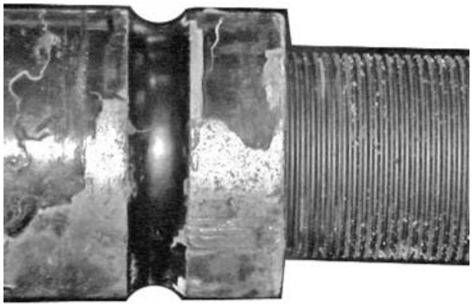


Figure 2.59 Redesigned track rod end as found on flipped tractor

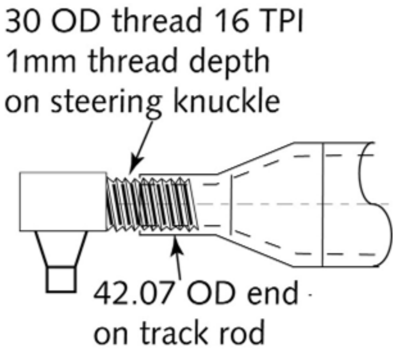


Figure 2.60 Sketch of track rod and knuckle arrangement (schematic only)

Figure 2.61 Worn knuckle (top) and new knuckle (bottom)

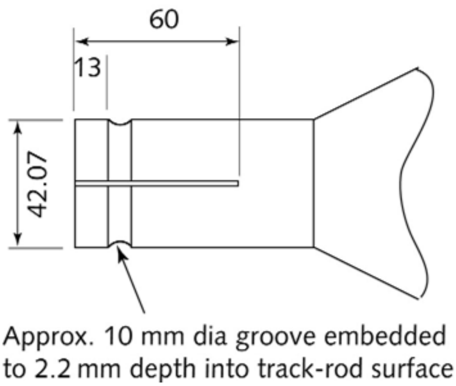


Figure 2.62 Sketch of track rod end as found on flipped tractor

Figure 2.63 Modified track rod design with improved clamping bolt locator

Tractors, as well as other farm implements are regularly redeisgned to meet customer requirements. No doubt, the Bigbrother design team responded to a need for greater transmission power, probably for driving the tractor in heavy mud, when they substantially increased the size of the front differential on the RS232 tractor. This design change called for a redesign of the originally straight track rod, to permit it to pass around the now much larger differential. The new design also made use of substantially heavier tubing with increased wall thickness. To accommodate the original steering knuckles the tubing was swaged[2.22] down to the original smaller diameter tube at the end. However, the wall thickness of the heavier tubing was retained. Figure 2.58 is a photo of the original design for track rod and steering knuckle. This photo is of a worn sample track rod, found in the Fillary scrap box. It was intended for comparison with the new track rod design. Figure 2.59 shows the track rod end taken from the flipped tractor. On inspection, this track rod end had one transverse slot cut in it for clamping the steering knuckle thread and it had a circumferential groove for the clamping bolt. Figure 2.62 is a schematic sketch of this new track rod end.

The advice offered to maintenance staff for adjusting the camber on the front wheels of the tractor is taken from the Bigbrother maintenance handbook for the RS232 tractor (refer to Figure 2.57).

"2 Check Wheel alignment (see Figure 2.57 – diagram (a))

2.1 Ensure that the wheels are pointing straight ahead. Measure the distance ***A*** *between the leading edge of the front wheel rims at hub height. Measure the corresponding distance* ***B*** *at the trailing edge.*

Distance ***A*** *should be less than distance* ***B*** *by 0 to 5 mm. If required, adjust as detailed below.*

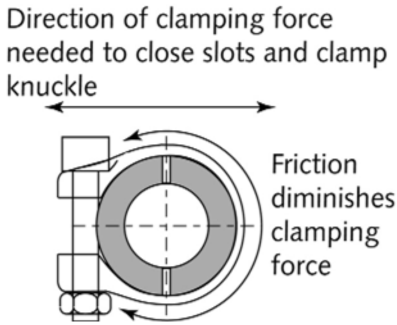


Figure 2.64 Schematic view of tube clamp with the clamping bolt oriented in the least desirable direction

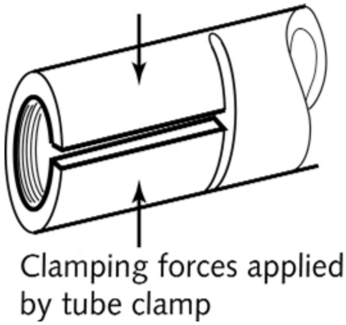


Figure 2.65 Schematic sketch of a pipe clamp designed to permit better grip on the steering knuckle thread

2.22 A mechanical deforming process is a process that is used to reduce or increase the diameter of tubes and/or rods.

*2.2 Disconnect the left hand end of the track rod **E** from steering arm **F**.*

2.3 Position the wheels so that the wheel alignment is in the middle of the limits specified at step 2.1.

*2.4 Screw the left hand end of the track rod in or out as required until the taper rod end **E** aligns with the taper of the steering arm **F**.*

*2.5 Refit track rod end and firmly tighten nuts **D** and nut/bolt **G** which must be positioned horizontal as shown at **Z** and not vertical (see Figure 2.57 – diagram (b)).*"

From Figure 2.59 it is evident that the locking bolt of the tube clamp used on the new track rod end is constrained to be oriented at right angles to the tube axis by the bolt groove. However, the bolt is not constrained to be located at any specific orientation relative to the slot in the tube end (refer to Figure 2.62). It is this slot that should permit the clamping together of the tube end onto the steering knuckle thread. If the clamp bolt is not at right angles to these slots, the clamping force will be partly dissipated in clamp friction, the worst case being when the bolt is parallel to the plane of the slots (refer to Figure 2.64).

In addition, due to the heavier gauge tube wall thickness of the new track rod, the tube clamp required substantially larger clamping force to clamp the tube onto the steering knuckle screw end. Even when modified (as seen in Figure 2.63) with two transverse slots and a more carefully designed clamping bolt locator, the design was inadequate to hold the steering knuckle screw firmly along its full length. The effect of the poor clamping arrangement was that dirt was able to enter the track rod end and lodge in the thread of the stearing knuckle. There was some evidence of dirt embedded in the slots on the track rod end.

The failure of the flipped tractor's steering was attributed to the following failure scenario.

(a) When the steering knuckle was clamped into the heavy track rod tube end, only the few screw threads near the ball joint end of the knuckle were clamped firmly. This meant that the end of the thread distant from the ball joint was permitted some slight movement inside the track rod end.

(b) Abrasive soil and dirt embedded in the clamping slot was fed into the small space between the screw thread and the track rod end. Eventually the motion of the screw and associated abrasion wore away the thread to such an extent that it was capable of being pulled out of the track rod end under the steering loads. Figure 2.61 shows the nature of wear experienced by the steering knuckle thread in this process.

A more appropriate design for clamping the track rod end to the steering knuckle thread is seen in the sketch of Figure 2.65. This design permits clamping of the thread along substantial part of its length and would have avoided the problem experienced with the RS232 tractor. Interestingly, the design shown in Figure 2.65 is well known and used in many engineering applications, though perhaps not in the farm machinery industry.

2.8.4 Case Culture (b) A Tip Truck Tips Over

Tip trucks or *"tippers"* are commonly used in the earth-moving and construction industry. The *Safedrive Company* of Sweden makes a well-known range of trucks, including tippers. *Mr. Soprano*, a hire company proprietor purchased a Safedrive tipper in 1985, for the purpose of hiring it out with a *Bobcat*[2.23] to earth-moving contractors. Approximately thirteen years later in 1998 Soprano decided to replace the tipper with a newer truck. In the event the truck was sold to a *Mr. Baritone*, an earth-moving contractor. As is usual in such cases the sale was accompanied by a roadworthiness inspection. This is a mandatory inspection for all used vehicles in Australia. When completed, and any faults found have been corrected, a roadworthy certificate is issued. Inspections are carried out by authorised mechanics. The mechanic in this case was a motor vehicle repairer operating a business called *Two-Ten Autos*.

2.8.5 The Accident Event and the Client

Approximately two months after the transfer of the tipper from Soprano to Baritone, it was involved in an accident while carrying a full load of earth fill from a building site. In the accident it was rolled over and suffered so much mechanical damage that it had to be completely written off by Baritone's insurance company. Baritone, who was the driver, was also injured in this accident, but this case is only concerned with the issue of the rolled tipper. This issue was fought out between Baritone's and Two-Ten Autos' insurers. When reporting on the accident, the driver claimed that at some point he lost control of the vehicle due to a loss of steering, drove off the sealed road onto the soft shoulder and there the vehicle rolled over. When the steering was inspected it was found that one of the ball joints on the steering arm had been pulled out from its socket. Moreover, it was also

Figure 2.66 A type of tipper produced by Safedrive

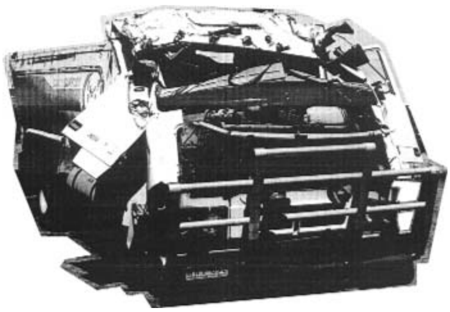


Figure 2.67 The damaged tipper owned and driven by Baritone

2.23 A trade name for a compact skid loader used in earth moving and construction.

found that this ball joint was so badly worn that it could be easily pulled out of its socket. Baritone's insurers claimed that Two-Ten Autos were negligent in the roadworthy inspection and they should have been able to detect the wear in the ball joint.

My initial involvement in this case was through *Dogwood and Dogwood (DD)*, the counsel acting for Two-Ten Autos' liability insurers. DD provided me with the background to the accident and three expert's reports reviewing the matter and offering contradictory opinions about causal links in the accident as well as the culpability of Two-Ten Autos as a result of their issue of the roadworthy certificate on Baritone's tipper. I was asked to offer opinion that might resolve the conflict between these reports.

2.8.6 The Role of the Expert and the Investigation

Figure 2.66 shows a typical tipper and Figure 2.67 is a photo of the damaged Safedrive tipper. Figures 2.68 and 2.69 show the steering linkage used on the tipper. Standard steering mechanisms use a simple Ackerman-type steering linkage based on the kinematics of the four-bar chain.[2.24] This linkage is designed to permit the outer steered wheel in the steering circle to roll further than the inner steered wheel, thereby eliminating tyre slip and wear. Figure 2. 70 shows a schematic sketch of the Ackerman linkage. On right-hand-drive vehicles the input to the steering linkage is provided by the steering link, normally a short link with two ball joint ends (see the link marked A in Figure 2.68). It is this link that failed on the Safedrive tipper, causing the whole steering linkage to become free to move under the steering forces generated by the ground reaction on the tyres. Once the vehicle left the sealed road and moved onto the soft shoulder of the road, the front wheels would dig into the soft soil and turn at some steep angle to the direction of motion. The wheel dug into the dirt and became a pivot about which the vehicle rolled over. Police photographs at the scene showed the

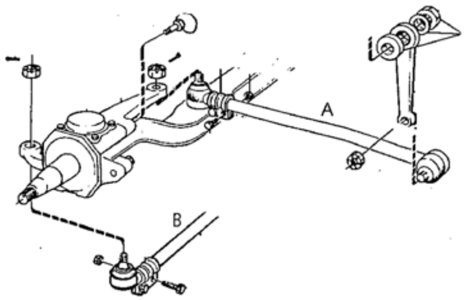


Figure 2.68 A schematic view of the steering linkage of the tipper. The link marked A is the steering linkage and B is the drag link

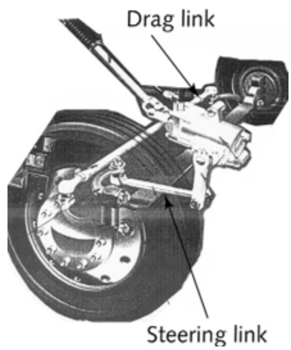


Figure 2.69 Artist's impression of the steering linkage showing both steering and drag links

2.24 See for example Uicker et al. (2003).

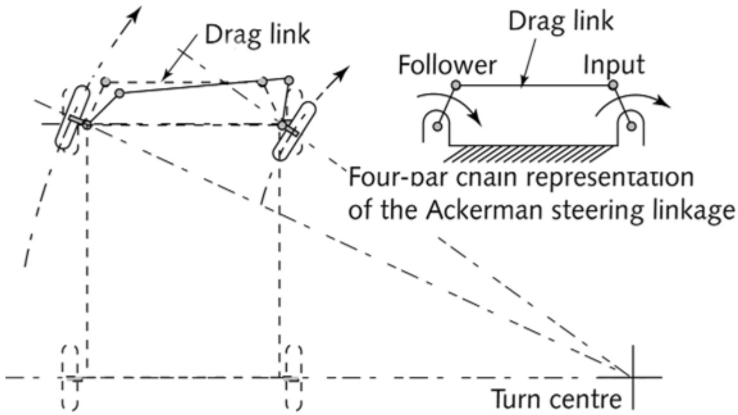


Figure 2.70 Schematic sketch of the Ackerman steering linkage

heavy gouging left in the soft shoulder by the wheels during the accident. In this case there was sufficient evidence to support the above accident scenario. The rolling occurred in a matter of seconds and the driver did not recall the technical detail of the accident chronology, other than losing steering control just before the vehicle rolled.

Figure 2.71 shows the two major parts of the failed ball joint. The socket was found to be completely filled with local clay and had to be cleaned out for full metallurgical examination. Figure 2.72 shows the ball joint at the other end of the failed steering link. Figure 2.73 sows a schematic sketch through a typical ball joint used on Safedrive vehicles. In the investigation of the accident the nylon bushes were not recovered. Figure 2.74 shows some parts of the sealing boot recovered from the failed joint. Sealed ball joints are generally expected to last for many years. If the sealing boot remained intact then it would be reasonable to expect such joints to last the full lifetime of the vehicle. The dispute in this case resolved into the following two issues:

Figure 2.71 The failed ball joint on the steering link. The socket had been cleaned out for this photo

Figure 2.72 The ball joint at the other end of the steering link. Note the damaged grease boot

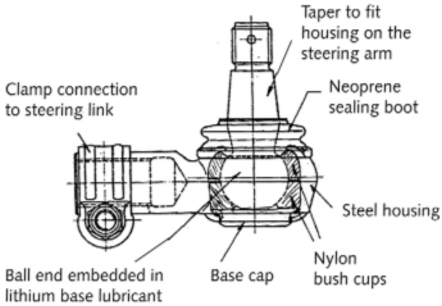


Figure 2.73 Typical ball joint (not to scale) The nylon bushes were missing from the failed joint

Figure 2.74 Sealing boot parts recovered from the failed joint

(a) Was the ball joint faulty at the time of the roadworthy examination by Two-Ten Autos? If this was the case, then could they have detected this fault during the roadworthy inspection?

(b) Did the ball joint fail as a result of some random event in use by Baritone?

In this case I was asked to resolve the above issues based on the reports of three other experts, identified here as *E1*, *E2* and *E3*.

The E1 Report

This report examined the accident site and drew conclusions from gouge marks left on the soft shoulder of the road, from examining the damaged vehicle after the accident and from interviews with the driver Baritone.

The most significant issues in this report were:

1. The allegation that

"Based on Mr. Baritone's statement that he was totally without steering whilst the truck was still completely on the sealed part of the road it is evident that this loss of steering is responsible for the vehicle veering to the left."

2. A figure in the E1 report showed clear marks and measurements of the gauges in the soft shoulder part of the road where it was alleged that the skewed front wheels of Baritone's truck gouged the soft shoulder (these figures were taken from police photographs of the accident scene).

3. Figures of other skid marks in the E1 report allegedly indicated that the wheels were still straight (aligned with the axis of the vehicle) as it left the road.

4. The report went on to estimate the wear on the steering linkage ball joint in the range 0.6 to 1.6 mm on the diameter.

From the above information I estimated that the vehicle may well have been veering off the road, but that the steering may or may not have been fully lost at the point where the vehicle left the sealed road. There is no clear evidence in favour of accepting the loss of steering on the sealed part of the roadway. Moreover, I also estimated that any standard inspection of the steering ball joint would not be able to detect the level of wear indicated in this report.

The E2 Report

This report dealt, albeit briefly, with the dynamics of the overturning process experienced by the vehicle during the accident. I had no disagreement with the factual content of this report. However, this report alleged that

> *"Had the driver lost concentration momentarily, and the vehicle commenced to veer off the sealed road, then there would be some evidence (in tyre track marks on the road) of the driver attempting to recover from this. Since there was no such evidence of attempted recovery, the veering off the road had to be the result of lost steering."*

I asserted that had the vehicle lost steering while on the sealed road, there could not be any evidence of an attempt to recover direction. Moreover, I also noted that there was absolutely no evidence (other than the report of the driver) as to why the vehicle had commenced to leave the sealed road. In fact I suggested that an equally compelling scenario for the accident might well have been as follows:

> A steering ball joint is badly worn and requires only a relatively small but finite force to dislodge the ball from its socket;
>
> The vehicle veers off the sealed road and hits the soft shoulder – for whatever reason;
>
> Leaving the sealed road with a heavily laden truck, almost any rut or bump or other surface irregularity can provide the mechanical shock necessary to dislodge the ball from the steering knuckle socket;
>
> The wheels begin to skew heavily and the vehicle rolls.

Since the ball joint required some force to fit the ball into the joint during assembly, it seemed doubtful that the ball simply *"fell out of its socket"* and caused loss of steering. The recollection of the driver was likely to be influenced by many factors. At the speed he was travelling the accident may have taken some seconds. Consequently it may not be clear as to which came first, the loss of steering or the skewing of the front wheels causing the rolling of the vehicle.

The E3 report

This report dealt with the wear on the steering knuckle ball joint and noted that:

> *"… the level of wear observed in the E1 report could well have taken place during the interval between the time the roadworthy certificate was issued and the date of the accident (estimated as 73 days)."*

This report went on:

"The vehicle was approximately 13 years old and had done over 118000 km. If the wear on the ball joint was excessive enough to be a hazard for steering, the tyres of the vehicle would have indicated inappropriate wear and normal service would have alerted the driver to this problem during normal service.

If a nearly 2 mm wear had existed in the steering link ball joint then the movement translated through the mechanism to the steering wheel on the Safedrive tipper would have been approximately 46 mm. A steering wheel requires approximately 30 mm to activate the servo valve on the power steering. Adding these two measurements we see that under these conditions the overall movement required to activate the servo valve and begin turning the wheels would be 76 mm. It is inconceivable that an experienced truck driver or a roadworthy tester could have overlooked such a slack."

Since there was no such warning mentioned in any of the reports, I had to concur with the findings of the E3 report in relation to the responsibility of the roadworthy test two months prior to the accident.

2.8.7 Evaluation of the Available Information

(a) The Flipped Fertiliser Tractor

In this case the failure resulted from both poor design as well as inappropriate maintenance management. The maintenance manual provided by Bigbrother failed to alert the uninitiated mechanic to the dangers presented by the improper clamping bolt location. This was seen as an example of failure to communicate. The design of the tube clamp was seen to be based on faulty reasoning. It neglected to account for the increased wall thickness in the track rod end. Moreover, the design failed to allow for appropriate deflection of the tube end to permit proper gripping of the steering knuckle thread. As noted earlier, Figure 2.65 shows a schematic sketch of a pipe clamp design that would have resulted in a better grip on the steering knuckle thread. Bigbrother design staff should have been aware of such a design and the consequences of the poor clamping action offered by their adopted design. This failure to appreciate the influence of a relatively minor design change on performance was seen as a result of insufficient field testing by Bigbrother.

(b) The Rolled Tipper

1. The steering ball joint was indeed worn as would be expected for a 13-year-old tipper with 118,000 km on its odometer. The wear was not sufficiently excessive to be easily detected by any other than a detailed examination of this component.

2. Normal servicing would have detected undue or inappropriate wear on tyres if the steering ball joint wear was of concern. This condition may have led to a detailed examination of the steering ball joint. Since no such concern had been expressed during the roadworthy test or any subsequent servicing, I suspected that this condition was not of sufficient concern to initiate an investigation.

3.The accident scenario proposed by the E2 report was in some doubt. There was no evidence to support the allegation that the steering was lost prior to the vehicle leaving the sealed surface of the road.

4. The assembly conditions of the steering ball joint would not easily permit the ball to simply fall out of its socket. I accepted that should the neoprene sealing boot be destroyed, the abrasive wear on the nylon bushes in the ball joint would have destroyed it very rapidly. Under such conditions the nylon bush may well fracture and dislodge, permitting the ball to fall out of its socket or be pulled out by a very small force.

5. In the type of use that the vehicle experienced in its life, damage to the sealing boot protecting the grease packing lubricant of the ball joint could be relatively easily sustained. That type of damage would have caused the destruction of the nylon bush very rapidly. Had the rubber boot been worn or damaged at roadworthy inspection time, that would have been easily detected by Two-Ten Autos. Since it was not, I had to agree with the E3 report that the damage, if indeed that was the prior cause of the accident, was sustained during the 73 days following the roadworthy examination.

7. Based on my experience with tip truck and general dirt handling operations in the building industry I considered it entirely reasonable to find wear of the nature experienced in the failed ball joint within the time period of 73 days. The heavy scoring on the surface of the failed ball element (see Figure 2.70) was consistent with very erosive material being incorporated into the joint during tipping operations. This type of heavy localised wear was also consistent with erosive clay soil with embedded small rocks being incorporated into the exposed ball joint.

8. Steering link ball joints are serious safety-critical components in any vehicle. In tip trucks operating in rough ground operations consistent with soil tipping and concreting operations it should be mandatory to carry out regular examinations of such joints. It would seem that Baritone did not carry out such examination in spite of the highly erosive nature of the work to which the Safedrive tipper was exposed.

9. The failed ball joint is oriented in the vertical direction with the sealing boot uppermost (see Figure 2.67 – it was the joint nearer the wheel that slewed and rolled the tipper). Once the boot had been damaged the ball joint would become a convenient receptacle for any dirt landing on its surface. In the conditions of operation to which the Safedrive tipper was exposed it is not surprising that failure of this joint occurred so rapidly. It was my considered opinion that roadworthiness evaluation of a vehicle would be related to operational history of the vehicle. That type of inspection can only evaluate the operational care with which the vehicle was used in the past. It is certainly not able to predict the safety of a vehicle under any future operating conditions. That had to be the ultimate responsibility of the vehicle operator.

2.8.8 Lessons Learnt and Outcomes

The Bigbrother tractor failure case was resolved in an out-of-court settlement. Both parties to that dispute agreed that some faults existed on both sides. Specifically there were serious design problems with the new track rod and its clamp mechanism. Also, there appeared to be a breakdown in communication between Bigbrother and Fillary. However, Fillary should have been aware of the problem with the new track rod design and should have alerted Bigbrother to their difficulties with it. There was some evidence that this type of communication between Bigbrother and Fillary had taken place. Hence the various modifications to the design of the clamping arrangements observed.

By contrast, the Two-Ten Autos case was eventually fought out in the High Court of Victoria in front of a judge and half jury of "six good persons and true". Having one's day in court is a powerful stimulant to anyone feeling a sense of unjust injury. As it transpired, Mr. Baritone was unwisely advised by his lawyers to make such an appearance in court. The case ran for two weeks with barristers and support staff in attendance as well as the other official complement of the court. Experts were called and eventually I was placed in the dock to give evidence in support of my report on this matter. The opposition barrister, *Mr. Alto*, commenced his questioning by almost sycophantically running through my list of qualifications. This is a common gambit used by barristers intending to lull the expert witness into some false sense of security. As a rule this approach usually terminates in what the cross examiner considers to be a *"hard question"* that might dislodge, or partly discredit the expert's opinion. The main point of Mr. Alto's cross-examination may be summarised in the following exchange:

Mr. Alto:

> *"In your report you state that:*
> *The failed ball joint is oriented in the vertical direction with the sealing boot uppermost. Once the boot is damaged the ball joint becomes a convenient receptacle for any dirt landing on its surface. In the conditions of operation to which the Safedrive tipper was exposed it is not surprising that failure of this joint occurred so rapidly.*
> *Why is it then that we do not see large numbers of Safedrive tippers rolling over?"*

AES:

> *"That is, I presume, because there are not too many thirteen-year-old Safedrive tippers operating in the specially rough conditions experienced by Mr. Baritone's tipper."*

This case was won by Two-Ten Autos' insurers and Baritone's insurers were also asked to pay costs. These costs added to the eventual cost of compensation for Baritone should be enough to discourage anyone from such litigation.

2.9 A Large Paper Machine Dryer is Damaged and Discarded Prematurely

Paper making is a process in which wet pulp (a mixture of cellulose and water) is compressed and dried. Drying is achieved by passing the wet blanket of pulp, roughly the consistency of very thick and wet blotting paper, between successive sets of rollers, much like the process used on old fashioned clothes wringers. Each successive set of drying rollers removes some proportion of the moisture from the paper web. In some special cases a very large roller is used to remove the last bit of moisture and to add a glaze to the paper surface in contact with this roller. This special roller is known as a *Yankee dryer* or *machine glaze* roller.

When the paper sheet enters the paper machine dryer section, it contains about 50% water. It must be dried to less than 10% water for a finished product. The dryers are rotating steam-heated cylinders approximately 1.3 to 1.8 m in diameter and slightly longer than the width of the paper sheet. A typical paper machine has 40 to over 100 such steam cylinders, depending on the line speed; the faster the line speed, the longer the drying section. Typical machines are over 100 m long and in excess of 10 m in height. The Yankee dryer is about 4.5 m in diameter and it is expected to remove about 30% of the moisture from the paper. Using a Yankee dryer, a paper machine can be shortened and the drying sections reduced in size. With the appropriate operating parameters, a Yankee dryer can permit substantial increases in paper production.

2.9.1 The Case Culture

Figure 2.75 shows a typical paper machine installation. The *Primrose* paper company operates a number of paper mills in Australia. Their Marigold plant operates two large machines, one of which is equipped with a Yankee dryer section. Marigold No. 1 machine dryer, referred to as *MG#1*, is a large grey cast-iron pressure vessel running at a temperature of about 110°C. This temperature is continuously controlled by the steam pressure inside the vessel. Two *service* rollers press onto the dryer at chosen locations

Figure 2.75 General view of a typical paper machine installation

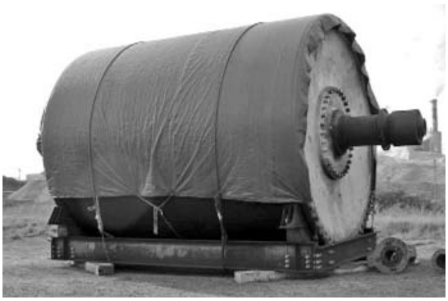


Figure 2.76 The discarded Yankee dryer stored on a field float at Marigold

on its circumference. The surface pressure between the service roll and the dryer surface *"nips"* the wet paper sheet and wrings out some of the moisture from it. In paper machine parlance the wringer action of the service roll on the dryer surface is referred to as the *nip*. Stringent quality control of the paper sheet thickness demands that the pressure in the nip should be uniform across the width of the paper sheet. The dryer surface is regularly ground to remove any longitudinal (parallel to the dryer axis) irregularities that result from wear on the dryer. Service rolls are covered with a hard polyurethane coating, providing some compliance for the paper passing through the nip. Service roll coatings are also regularly serviced by the *Inca* Rubber Company.

2.9.2 The Accident Event and Initial Evaluation

Sometime late in 1990, the surface of MG#1 was reground to remove some minor surface irregularities and crowning resulting from wear. While this maintenance work was in progress the dryer section was bypassed and the paper machine continued to produce unglazed paper, albeit somewhat slowed by the dryer section having been removed from service. At the same time the service rolls were also recoated by Inca to match the by now pristine surface conditions of MG#1. Shortly after restarting the dryer section, the elastomer coating on one of the newly coated service rolls delaminated, peeling back a large section of its 25-mm-thick coating, all of it passing through the nip. Although the machine was shut down within seconds of this disaster, MG#1 runs at 500 rpm and the peeled back service roll coating was passed through the nip several times during this shutdown.

Careful examination of MG#1 and the whole Yankee dryer section revealed the following damage:

1. MG#1 suffered surface indentations and run out (axial deformation of the surface) to a maximum of 1.4 mm. This measurement was taken by *Tictactoe* Inc., a regular maintenance contractor to *Primrose* Paper. Although this is a small amount, considering the scale of the dryer drum, it is significant in paper making terms where permissible dryer surface errors are measured in microns.

2. Bearings and bearing support structures suffered substantial damage including permanent deformation of the bolts holding the bearing blocks on MG#1.

3. Metallurgical examination of the dryer in or near the vicinity of the surface damage showed no visible cracks or incursions into the dryer surface. Using a penetrant dye (a normal non-destructive testing method for surface cracks[2.25]) the metallurgist, Andrew Maurel, found some porosity and small surface plugs that had been in the vessel since manufacture. MG#1 was manufactured in England in 1949 by Antigua Ltd. as a gravity casting in grey cast iron. Then it was normal practice to

2.25 See for example Stanley et al. (1995); Grandt (2004); Mix (2005).

weld small surface plugs into casting defects before machining the outer surface.

4. Acoustic examination by an expert, *Dennis Mesa*, found that there was substantial sensor response in the damaged vessel when it was pressurised during testing. This was a regular testing procedure used in normal operational maintenance of the vessel by Mesa. On this occasion he found unusually high acoustic emission responses emanating from the damaged region of the vessel. Acoustic emission testing is a specialised process requiring skilled interpretation of results. It is commonly used for locating incipient failure in large pressure vessels.[2.26] In the case of MG#1, incipient failure appeared especially threatening because the vessel was made of a highly brittle material and evidence from other Yankee dryer failures suggested an explosive failure as a distinct possibility.

5. Magnetic particle and penetrant dye testing of the vessel surface found many indications of surface damage. The *Discovery* Corporation, an independent testing authority called in by Primrose Paper to evaluate the damaged vessel, found about 20 such indications on the surface of the damaged vessel, all of the order of less than 5 mm in length. In metallurgical terms, a *crack* has a specific meaning. It has length and depth. An *indication*, on the other hand, signals the possible presence of a crack without actually identifying its depth or significance. *Discovery* reported that none of the indications was aligned with the axis of the vessel.

6. Mesa also used penetrant dye and magnetic particle testing on the vessel surface, albeit by *long-distance* (in subsequent reports it was noted that Mesa was on the phone in the USA while an unidentified technician carried out the tests). Mesa's tests alleged that there was

"at least one substantial indication about 10 mm long parallel to the axis of the vessel, within the area of the surface damage. This indication was identified as Indication A."

7. Yet another independent investigator, *Niblick*, reported that the passage of the hard elastomer sections of the service roll through the nip corresponded to the damage found on the vessel surface.

8. The *Joyfoot* company has a long history of supplying paper machinery to the paper industry. One of Joyfoot's specialists in Yankee dryers, *Edward Holst*, was asked to examine the evidence for damage suffered by the MG#1 vessel. Holst strongly advised Primrose Paper operations staff to discard the vessel and replace it with a new one from Joyfoot.

9. On the evidence and advice offered to them, Primrose Paper operations decided to discard the vessel and replace it with a new dryer vessel. Figure 2.76 shows the discarded vessel at the Marigold plant.

2.26 See for example ASTM (1989); Sachse et al. (1991); Dimentberg et al. (1991).

10. Internal inspection of the vessel found no bulge in material corresponding to the external indentation on the vessel surface. This measurement was taken with a straight edge inside the vessel and a light shining onto the straight edge on the vessel surface. The report noted that there was
"… no visible light through straight edge contact with inside surface of vessel. Straight edge was placed on the surface at a location corresponding to the external deformation of the vessel."

2.9.3 Parties to the Dispute and the Client

Primrose paper replaced the MG#1 allegedly advised by various experts. they sued Inca for the cost of replacement as well as substantial loss in production incurred during the time the Yankee dryer section was idle. Inca's insurers appointed counsel, *Messrs Flat and Hound*, to investigate the loss and the history leading up to it.

My appointment to investigate the case came to me with a somewhat cursory enquiry from briefing counsel in the form of *"have a look at these papers and see what you think"*. I did not find this unusual. In the most complex of cases I am regularly approached by briefing counsel in this way. I will elaborate on the reasoning behind this cursory approach later. For now, let me say that my initial response to the Primrose Paper MG#1 dryer accident may be summarised in my assertion to counsel that *"this dryer vessel is built like a brick dunny"!* This response was partly a result of my initial *"back-of-the-envelope"* calculation of shell strength and a brief survey of the documentation provided to me by counsel. Using back-of-the-envelope calculations to appraise the investigation-worthiness of a case is a useful ploy for weeding out cases eminently unworthy of further investigation. On initial reading of the voluminous literature provided to me I formed the opinion that there appeared a case to be answered by Primrose and their advisers. This opinion was supported by the apparently hasty action by Primrose to replace the MG#1 with a new one. Moreover, the specifications of the new MG#1 showed it to be a substantially improved dryer over the discarded one.

- Primrose appeared to have a legitimate claim against Inca, on the grounds that they caused the accident in the first place.
- Inca's insurers, on the other hand, were entitled to a full disclosure of how the decision to replace the old MG#1 with what appeared to be a much better new one.
- Ultimately the various advisers to Primrose would be also drawn into the dispute.

2.9.4 The Role of the Expert and The Investigation

Primrose Paper ordered a new vessel from Joyfoot and had it installed in 2002 at the Marigold Plant. The replacement cost of the vessel was estimated at AU$ 5 million. In addition, the loss of production for Primrose while the Yankee dryer was out of action was estimated at a further AU$ 5 million. This sum of AU$10 million was the approximate claim faced by the insurers of Inca Rubber for the delamination of the failed service roller.

My brief was to advise and offer opinion on the following matters:

(a) Engineering protocols followed by a responsible paper product manufacturer and paper machine operator in the position of Primrose Paper, in evaluating the damage to MG#1.

(b) Whether the opportunities for repairing the MG#1 as an alternative to replacing it was a serious option for consideration by a responsible paper machine operator in the position of Primrose Paper.

(c) Whether Primrose Paper have followed protocols appropriate to a responsible paper machine operator in their position in their investigations of the opportunities for repairs to the MG#1 rather than choosing to replace it.

The voluminous reports supplied to me demanded that I draw up a simplified case chronology. In addition to the immediate events preceding and subsequent to the accident event, Primrose documentation showed evidence of a substantial history of concern with MG#1. This historical material is also included in the case chronology.

Case Chronology

The sequence of events leading up to and immediately subsequent to the accident event in which the Yankee dryer MG#1, of number 1 paper machine at Primrose Paper's Marigold plant was damaged is shown inTable 2.4.

Background History of MG#1

The original vessel was manufactured by Antigua Ltd. in England in 1949. Various documents relating to its manufacture identify the material of the shell as a "Nickel Grey Cast Iron" with the following properties :

- Outside diameter = 14 ft; Inside diameter = 13 ft 8 inch
- Face width = 200 inch
- Ultimate tensile strength = 23.5 tsi (using UK tons = 363 MPa)
- Modulus of elasticity E = 18.1 x 10^6 psi (125 GPa)
- Coefficient of thermal expansion α = 6 x 10^{-6} / °F
- Poisson's ratio μ = 0.26
- Temperature difference from inside to outside shell surface during normal operation at 500 m/min surface speed = 90°F
- Approximate weight of structure = 80 tons

Regulatory and statutory background

The original design of the vessel was according to the standards operating in 1949, namely the SAA[2.27] Boiler Code. The requirement for unfired grey

2.27 Standards Association of Australia.

Table 2.4 Event chronology

Event number	Date	Event description[2.28]
1	1949	MG#1 manufactured by Antigua Ltd in England
2	1960	Primrose operations concerned about throughput of No. 1 paper machine and an investigation is launched to discover if MG#1 pressure may be increased to 60 psi (414 kPa). Antigua design specification was for 50 psi (345 kPa) tested hydraulically at 100 psi (690 kPa). Makers, Antigua and DLI[2.28] agree to this, but recommend hydrostatic testing to 120 psi (828 kPa) and maintaining centreline shell thickness at 2inch (50.08 mm) Thickness established by acoustic testing and is found to be 2.14 inch (54.4 mm) Hydrostatic testing declined by Primrose operations.
3	1970	MG#1 reground to correct crowning errors using abrasive belts on the service roll. Approximately 0.035 inch on diameter removed (i.e. 0.5 mm on radius)
4	1980	More concern about the possibility of increasing MG#1 pressure to 60 psi. DM of University of Melbourne contracted to carry out fatigue degrading investigation of vessel due to service roll nip pressures (500 pounds per lineal inch – pli). This investigation finds MG#1 to be sound in this regard and safe to operate. Again, due to requirements of hydrostatic testing to formally approve operations at the increased pressure MG#1 remains operated at 50 psi.
5	1999	Primrose operations concerned about Yankee dryer losses incurred due to in-service failure of such dryers. Data from Arkwright International provides some information. No lives lost, but some machine damage and downtime.
6	9/99	MG#1 profile measurements suggesting a regrind is needed.
7	10/99	MG#1 acoustic emission tested using only four sensors. Found to be sound.
8	3/01	MG#1 ground to correct profile. Again approximately 0.5 mm removed on shell thickness.
9	3/01	Newly coated service roll is installed on No. 1 machine to provide nip on MG#1.
10	4/01	Service roll delaminates and allegedly irreparably damages MG#1.
11	4/01	Post-accident acoustic emission test performed and results suggest incipient failure in shell near alleged damage imparted by service roll delamination.

2.28 A guide to units of measurement is provided in appendix A3.

2.29 DLI, Department of Labour and Industry, was in 1960 the Australian Government authority for the acceptance testing of pressure vessels.

Table 2.4 Event chronology (continued)

Event number	Date	Event description
12	4/01	*Metallurgical examination of shell surface by Maurel. Some surface porosities found, all relating to repairs on the original shell due to casting imperfections only. In its conclusion Maurel's report states that:* *"The cylinder and plug microstructures were found to be in good condition, with no evidence of microstructural degradation being identified.* *The cracking defects were found to be entirely casting related, with no indications consistent with in-service crack propagation being identified.* *Examination of regions remote from the crack revealed the presence of other linear crack-like indications (albeit on a microstructural scale). It was considered that indications of this type may well be found to be present over much of the surface of the cylinder.* *..., it follows that it may well prove unreasonable to condemn the cylinder as a consequence of primary crack indications."*
13	4/01	*Magnetic particle and radiographic examination of shell reveals no cracks, just some indentations. Surface examination also reveals the depth of these indentations to be, at worst 1 mm. The total out of roundness allegedly attributed to the accident event is no greater than 1.4 mm (Tictactoe report).*
14	4/01	*Joyfoot prepares quotation for replacement MG #1. The test pressure is specified for the proposed new dryer is 148 psi, corresponding to an operating pressure of 74 psi (510 kPa).*
15	4/01	*Letter from Ed. Holst of Joyfoot condemns damaged MG#1 based on acoustic emission results as well as Mesa's identification of crack-like indications and especially Indication A.*
16	7/01	*Niblick report identifies service roll delamination as the main culprit for damage to MG#1.*

cast-iron vessels was that the shell be designed for dominant, "maximum" stress only. This rule is in line with the normal failure criterion for brittle materials of which grey cast iron is one. The maximum stress operating in MG#1 was circumferential stress (or *hoop* stress) pertaining to the stress due to internal pressure. This rule neglects other stresses such as thermal stresses due to moderate temperature differences across the vessel shell and centrifugal loading due to modest rotational speeds. Consequently, the factor of safety implicit in the permissible working stress was 10. It was also a requirement that the vessel be hydrostatically tested at twice the operating pressure. In the case of MG#1 this was at 100 psi (699 kPa). The vessel was tested at 100 psi hydrostatic pressure at Antigua's works in November 1949.

The current standard for pressure vessel design is SAA 1210-1997 and this standard also defines a safe working stress for low-temperature unfired grey cast-iron vessels, so that the implicit factor of safety is 10 (SAA 1210-1997, Australian pressure vessel code for cast iron 40 (40 MPa – Table 3.3.1(C) page 69). The current authority for the operation of low-temperature unfired pressure vessels is the Licensing Branch of the Victorian Work Cover Authority. They require the vessel to be inspected and reported on regarding safe operating conditions every three years. An inspection certificate must be filled out and copies sent to the Authority for registration. The two certificates available from this inspection identify the vessel as having an operating pressure of 0.414 MPa (60 psi).

Service History and Operation-Related Issues

The vessel was ground in 1975 and also in 2001, removing about 0.5 mm from its shell centre line thickness on each occasion. Due to concerns about the possibility of operating the vessel at 60 psi, to increase its performance, the thickness was monitored by acoustic means at regular intervals. These readings show the wall thickness varying over a modest range, the lowest value recorded as 47 mm.

2.9.5 Evaluation of Information by the Expert

Shell stresses and operating factors of safety[2.30]

Operating working stress at the time of design and manufacture of MG#1 was 3200 psi (22.4 MPa). In light of the actual tensile strength of the shell material this working stress represents a factor of safety of 363/22.4 = 16.2. This is a considerably in excess of the SAA Boiler Code operating factor of safety of 10 for unfired pressure vessels in grey cast iron. At the time of design of this vessel in 1949 the only stress evaluation used for shell thickness specification was hoop stress. Since this neglects any centrifugal loads and any thermal loads, the larger factor used by the makers suggests some suitable degree of conservative design. Moreover, the extra thickness in the shell due to the conservative factor may also account for the nip load imposed by the service roll during normal operation. An alternative view might be (without any formal evidence) that the makers in early discussion with Primrose Paper may have considered using the vessel in the upgraded mode with 60 psi internal pressure. In subsequent correspondence Antigua seemed quite comfortable about operating the vessel at the higher pressure.

In correspondence relating to upgraded pressure loads Antigua had advised the need to maintain central shell thickness at 2 inch There were several acoustic thickness surveys conducted on the shell throughout its service life, with considerable variation in thickness as measured by the acoustic surveys, the lowest value being 47 mm, or significantly less than the suggested 2 inch for safe operation at 60 psi. Since the original design

2.30 Formal calculations for this case are presented in Appendix 2.

had a wall thickness of of 2 inch (50.8 mm) some doubt must be cast on the veracity of the acoustic thickness measurements. In spite of these uncertainties, Primrose operating staff were prepared to operate the vessel at the higher pressure of 60 psi. Ultimately the documents and correspondence suggest that the only reason for abandoning this pressure upgrading of the vessel was due to the cost and risk involved in hydrostatic testing in situ.

I calculated the operating stresses prevailing in the vessel just prior to the time of the accident event (refer to Appendix 2). I estimated the stresses in the shell to be 18 MPa (assuming the thickness is 50 mm); this now represents a factor of safety of approximately 20 over the actual tensile strength of the shell material. It is also well below the tensile working stress permitted in the original design code (22 MPa) or even the current SAA 1210 Australian pressure vessel code for cast iron 40 (40 MPa – Table 3.3.1 (C) page 69 of the relevant standard). This simplified calculation and the above correspondence and documented interest of Primrose to operate the vessel at increased pressures might suggest a degree of opportunistic haste in choosing to discard the allegedly irreparably damaged MG#1.

Non-destructive Testing and Evaluation of the Vessel Immediately Subsequent to the Accident

Acoustic emission (AE) testing subsequent to the accident event showed that the vessel had some grain boundary movement initiated since the previous test in 1999. These results are fairly common in grey cast iron and particularly so when the structure has suffered some local deformation. All information relating to AE testing suggests that while it is certainly an indicator of internal structural events, it is by no means a reliable indicator of the scale without other forms of non-destructive testing. Neither the magnetic particle inspection nor the radiographic tests subsequent to the accident event showed up any cracks in the shell to support the *AE* test concerns expressed by Mesa. Moreover, the evidence from the Primrose visual inspection of the internal surface of the vessel found no bulges or deformation corresponding to the location of the external damage. Because the vessel is a thin-walled pressure vessel (defined as having shell thickness smaller than one tenth diameter – in this case $t = D/85$), this finding is inconsistent with any substantial damage to the shell.[2.31]

AE tests at best identify the location of possible incipient failure or material defects. However, they need to be supported by other forms of examination, in particular ultrasonic tests, to establish the scale of the damage if any. Since this was not performed in the case of the damage to the shell of MG#1 it is most imprudent to assign any significance to *AE* results alone.

Since the internal surface of the shell showed no deformation (bulge under the external indentations) it is most likely that the shell had suffered superficial surface damage only.

2.31 See for example Timoshenko and Woinowski-Krieger (1959); Timoshenko and Goodier (1983).

Alternative Courses of Action Open to Primrose Subsequent to the Accident

There were several additional courses of action which Primrose should have taken to investigate the consequences of the damage caused by the accident event in order to decide whether it was appropriate to replace or repair. A responsible paper machine operator in the position of Primrose would be expected to follow the following courses of investigations:

(a) Ultrasonic evaluation of the three-dimensional structure of the damaged area to determine the scale of the grain boundary movements identified by the AE tests. These types of tests are commonplace in the pressure vessel industry for the examination of large-scale porosities in welds.

(b) Grinding out the local indentations and re-testing with AE and other non-destructive testing methods.

The option of repairs to the vessel was very much on the agenda of Primrose operations staff. This intent is evident in the correspondence provided to me in the documentation. All of these correspondence documents deal with various repair options. The only document that makes direct reference to MG#1 being *"beyond economic repair"* is the one from Ed Holst of Joyfoot, noted in the event chronology above. Based on the scant information available about the health of the vessel at the time this opinion was offered, one cannot disregard the self-serving nature of this opinion.

Further Investigations and Mediation with Other Experts

Following the initial investigation of the soundness of the allegedly damaged MG#1, several follow-up investigations were launched by both Inca Rubber's and Primrose's insurers. Dennis Mesa performed further AE tests under pressure on site at Marigold. He also performed magnetic particle and penetrant dye tests. In his report of these tests he alleged that there were two *crack-like* indications, identified as indication A, approximately 10 mm in length and indication B, approximately 20 mm in length. It was also alleged in Mesa's second report that indication B was actually present in the tests performed shortly after the accident and that it has grown in time from 10 mm to its current size. Both indications were allegedly aligned with the axis of the vessel.

I was asked to help carry out non-destructive tests on the surface of the discarded vessel as a means of validating Mesa's findings. These validation tests were performed by a local NATA[2.32] approved testing authority, *ATTAR*. They were asked to find any surface indications on the damaged surface of the vessel. None could be found other than those reported by the metallurgist Maurel and the Discovery Corporation. The disputing parties agreed that a joint examination of the vessel should occur in the presence of Mesa and ATTAR.

2.32 National Association of Testing Authorities.

This joint investigation took place in 2005 and it too failed to find the indications A and B allegedly found by Mesa. Further evidence of opportunistic replacement of MG#1 by Primrose came from the operational records of the paper maker. It was found that the new MG#1 was not only capable of operating at substantially higher pressures and temperatures than the discarded vessel, but that it was actually being used in this enhanced operational mode. This new production schedule allowed Primrose operations to remove half of the steam dryers on machine No. 1 from service and use the new Yankee dryer in their place. In addition the throughput on machine No. 1 had been increased by about 10% due to the new dryer, yielding a healthy increase in profitability for Primrose Paper.

2.9.6 Lessons Learnt and the Outcome

It is worthwhile to review and elucidate on the rather casual approach taken by counsel in appointing me to investigate this matter (see Section 2.9.3). I should note that, in my experience, briefing counsels are, in general, very conservative people. Years of litigation experience has taught many of them to consider the opportunities of a case not so much from the optimistic view of maximising gains for their clients, but from a more pragmatic consideration of minimising the losses incurred. This approach is broadly based on my earlier assertion that, in a protracted litigation, much in the same way as in a war, neither side can hope to sustain a win, but each may minimise their losses. Technical experts, on the other hand, may see mainly the overwhelming value of their finely tuned technical argument for their side of the litigation. This narrow view often fails to see the bigger picture.

There are many mitigating factors, other than technical issues, that might intrude into a judgement in court. Judges, in general, favour the injured party, even when they may have exploited their injury in some seemingly opportunistic way. In the Primrose and Inca litigation, there was no doubt that Inca had injured Primrose by supplying a poorly coated service roll. As well, Primrose was duly advised, by the best technical advisors available to them at the time, that the damaged MG#1 should be replaced. The mitigating factors in awarding damages here could be seen to be the following:

In Favour of Primrose

(a) MG#1 was damaged by the improperly coated service roll delamination. For this damage Inca was clearly responsible. There were production losses, damage investigation costs and substantial engineering costs involved in possible repairs or replacement.

(b) There was considerable uncertainty about the nature and extent of the damage incurred by MG#1. In addition there was evidence from other failures in other plants of considerable risk from an explosive failure of grey cast iron vessels when operating under pressure. One can appreciate the conservative view that the risk of returning a repaired MG#1 to service may involve some operational risk.

(c) There would be operating losses incurred even if the damaged MG#1 could be repaired.

In Favour of Inca

(a) Failure by Primrose to seek additional advice to confirm and support Mesa's AE tests and his allegations about the existence of some significant cracks in the vessel shell.

(b) Trustingly accepting the undeniably self-serving advice of Ed Holst from Joyfoot, that the allegedly irreparably damaged MG#1 vessel should be discarded, bearing in mind that they (Joyfoot) would be the providers of the replacement vessel.

(c) Most significantly, disregarding the findings of the metallurgist Andrew Maurel about the apparently superficial damage to the MG#1 vessel.

(d) Disregarding the lack of a bulge on the inner surface of the vessel, corresponding to the damaged outer shell depression.

The level of any award against Inca would need to be adjusted for the improved operating features of the new MG#1. It is an accepted rule of insurance that one should not be able to gain profit from a loss. Insurance will not replace a written-off used tricycle with a new Lear jet. Operating records showed that the new MG#1 was being operated at substantially greater throughput rates than was available with the discarded dryer.

From the above discourse it is clear that, if a winning line in this dispute were to be found, it would not be based entirely on technical matters relating to the soundness or otherwise of the damaged MG#1. Consequently, technical investigations of the soundness and repair opportunities available for the discarded vessel were, at best, likely to result in diminishing returns for the defence. An offer of compensation was made to Primrose at an early stage in the dispute. This offer was rejected. Eventually the case went to mediation and a further, more attractive offer was made by Inca's insurers. This second offer was also rejected by Primrose's insurers on the advice of their counsel. As a matter of procedure, when a mediation offer is refused, and the case is pursued to court, should the court's award be less than the mediation offer, costs of proceedings are awarded against the plaintiff (in this case Primrose). Naturally this procedure is meant to discourage vexatious litigation. In an unprecedented legal move, Mesa and Ed Holst, for Joyfoot, were enjoined in a counter-suit by Inca's counsel, for providing inappropriate and incorrect information to Primrose about the soundness and possible repair of MG#1. The vessel was discarded on the basis of this inappropriate advice.

2.9.7 Yet More "Legal Foot Stamping" in This Case

When faced with the unassailable fact that a case is unwinnable, litigators and their expert advisors have been known to exhibit kindergarden-style behaviour of children arguing some point of difference. The procedure involves virtual foot stamping and making respective statements such as

" … my facts show your case to be failing, you are in the wrong …"

" … no I'm not …"; *"… yes you are …"* etc.

All of this is usually accompanied by more and more detailed reports and the invocation of more and more experts. This case of *Primrose v. Inca* had evolved over a period of 3 years into just this style of virtual foot stamping. The following steps in this process demonstrate this evolution:

(a) In 2001 Primrose's vessel was accidentally *"bumped"* as a result of Inca's inadequately surfaced service roll. Metallurgical examination immediately following the accident suggested that repairs were possible.

(b) Several *"experts"* were called in to examine the vessel and based on their advice, despite the advice of the metallurgist, the vessel was condemned and replaced.

(c) In 2003 Engineering Investigations & Associates (EI&A, the author's consulting company) do some back-of-the-envelope calculations and estimate that the vessel was heavily overdesigned (*"built like a brick dunny"*). In my opinion the vessel could indeed have been repaired and returned to service at a fraction of the cost of replacement. Attention was drawn to the fact that there did not appear to be any serious shell deformation.

(d) In 2004 Primrose's experts retort with a deconstruction of EI&A's estimates and spend substantial sums in mapping the inside of the vessel to find the *"bump"* that would signal serious shell deformation.

(e) In 2005 experts of both sides meet at the Marigold plant to locate the *"cracks"* in the shell that made Primrose's experts condemn the vessel. No cracks are found and the experts withdraw to write more reports.

(f) In late 2005 Primrose's main expert pronounces that *"… even if the cracks are not present, there would be substantial and unquantifiable residual stresses imposed on the shell of the vessel due to its substantial deformation."*

(g) In 2006 EI&A contracted a NATA-approved testing authority to carry out a mapping of the inside of the vessel as well as to measure residual stresses in the shell.[2.33] These tests show that surface variations inside the vessel are substantially greater in the undamaged parts of the shell. Moreover, surface variations on the internal surface of the shell are

2.33 Residual stress measurement is a regular feature of damage assessment. The method uses a strain rosette mounted on he damaged surface, followed by staged drilling through the centre of the rosette, while strains are monitored. See for example ASTM E837 Standard Test Method.

well within generally accepted machining tolerances. Residual stress measurements showed that the shell has only highly localised residual stresses in the outer 0.5 mm of the surface. Moreover, these stresses abate to insignificant values below that level. Specialised heat-treating authorities advise that even these relatively insignificant stresses may be relieved by on-site heat treatment.

(h) Primrose's experts request all data to be delivered to them in raw form. I had no doubt that this data would be used for generating further reports and more virtual foot stamping.

At the time of writing this case continues.

2.10 Chapter Summary

Eight examples of industrial accidents involving machinery failures were presented in this chapter. In reviewing the investigative threads common to all the cases presented perhaps the most compelling item was that each had an easily identifiable line of defence (*the winning line*). In these cases the expert is asked to respond to issues raised by counsel, who already had the benefit of having read through the documentation and case history. These issues raised by counsel would reflect their own well-considered assessments (their hunches) of where the weakness in the arguments of the other side might lie. The expert's role was then to investigate and wherever possible reinforce the hunches of the briefing counsel. Of course the expert must evaluate the evidence from an investigation in the harsh light of all factors, not just those that might support the client's case. These points were clearly drawn in the presentation of the cases in this chapter.

Another common experience with all the cases presented was the often confused collection of information provided to the expert. Some helpful tools for sifting through this information have been presented here. The construction of case chronologies provided essential background to the more complex cases presented. The preparation of an FMEA table helped to identify the most likely mode of failure in some cases where there were several alternative probable sources of failure. The construction of a hypothetical failure scenario helped in focusing attention on specific technical elements of these cases.

3

Cases of Product Liability

Liable, Liability: 1542, "bound or obliged by law," from Anglo-French: *liable*, from Old French: *lier* "to bind," from Latin *ligare* "to bind, to tie." *Liability* "condition of being liable" is from 1794; meaning "thing for which one is liable" is first attested 1842.

Contract: circa 1315, from Latin *contractus*, past participle of *contrahere* "to draw together," metaphorically, "to make a bargain," from *com-* "together" + *trahere* "to draw". Contractor in the modern sense is from 1724.

Tort: circa 1250, "injury, wrong," from Old French *tort* (11th century), from Middle Latin *tortum* "injustice," noun use of neuter of *tortus* "wrung, twisted," past participle of Latin *torquere* "turn, turn awry, twist, wring, distort" (see *thwart*). Legal sense of "breach of a duty, whereby someone acquires a right of action for damages" is first recorded 1586.

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There was only one catch and that was Catch-22, which specified that a concern for one's safety in the face of dangers that were real and immediate was the process of a rational mind. Orr was crazy and could be grounded. All he had to do was ask; and as soon as he did, he would no longer be crazy and would have to fly more missions. Orr would be crazy to fly more missions and sane if he didn't, but if he was sane he had to fly them. If he flew them he was crazy and didn't have to; but if he didn't want to he was sane and had to. Yossarian was moved very deeply by the absolute simplicity of this clause of Catch-22 and let out a respectful whistle.

"That's some catch, that Catch-22," he observed. *"It's the best there is,"* Doc Daneeka agreed. Joseph Heller, *Catch-22*.

Product liability is the issue that probably causes the greatest concern to inventors, manufacturers and designers of products. It has been claimed[3.1] that the current product liability laws of the United States of America will stifle future innovation. One is tempted to note that *"if necessity is the mother of invention, product liability law is the mother of all persecutors of inventiveness"*. There are many horror stories about product liability suits bandied about in engineering design classrooms. Some are real, such as the successful case against a screwdriver manufacturer when a person was injured while using the tool to open a paint can. This was a case of *strict liability* in North America. Other stories are based on *urban legends*, such as the *"poodle in the*

3.1 Hales (2005).

microwave", claiming that the unfortunate poodle exploded while its owner was attempting to dry it in the microwave oven.[3.2]

A basic distinction should be drawn between product liability cases that result in human injury and those that result in a product failing to deliver on the maker's promises. The former represent cases in the law of torts, while the latter are cases in the law of contract. Strict liability in torts cases includes negligence, and must be seen to involve elements of *mens rea*. This term is from the Latin concatenation of *mens*: mind+ *rea*: involvement or connection – a legal concept in strict liability of having evil intent even through negligence – *Did not intend to cause the result that happened, but failed to exercise a reasonable duty of care to prevent that result (which includes failing to become aware of the risk of that result).* The above is defined as the tort standard of negligence.[3.3]

The engineering product liability cases discussed in this chapter fall into the *"failing to deliver on maker's promises"* category. Some makers believe in the notion of *caveat emptor* – let the buyer beware – in which the contract between supplier and buyer carries equal responsibilities of supply and acceptance of a product and its promised functions. This tactic has little or no currency where the product is a commercial item (e.g. kitchen appliances or motor cars) easily available with many competitors. Failure of the supplier to compensate for faulty products is managed satisfactorily by various government organisations responsible for administering trade practice laws. In most such cases government involvement is unlikely to be necessary, since competition and warranties provide suitable safeguards for the consumer. A special distinction must be drawn between warranties, guarantees and *"vapourware"* or *"snake oil"* when reviewing product specifications. The words *"warrant"* and *"guarantee"* both derive from French, meaning *"to protect"* or *"protection"*. Manufacturers will offer such protection by documents identifying the clear guidelines and specifications for their product. It is the responsibility of customers to read such documents with considerable care to avoid unreasonable expectations from such protection. *"Vapourware"* or *"snake-oil"* promises often accompany some products. The informed consumer should be able to recognise these types of promises and treat their value with the disdain they deserve. Matt Curtin's *"snake oil warning signs"* website[3.4] is devoted to exposing false promises from encryption software vendors. The warning signs offered by this website have wide-reaching currency for any consumer product and they may be readily identified in warranty promises.

3.2 Strict liability – liability even when there is no proof of negligence. Often applicable in product liability cases against manufacturers, who are legally responsible for injuries caused by defects in their products, even if they were not negligent.

3.3 See for example *Oecd* (1995); Rossmanith (1996); Hart and Kinzie (2001); Raines et al. (2001); Nottage (2002)

3.4 www.interhack.net/people/cmcurtin/snake-oil-faq.html

Vapourware is software or hardware or product features offered by a vendor well in advance of release. The term implies deception, or at least a negligent degree of optimism. It implies that the announcer knows that product development is in too early a stage to support responsible statements about its completion date, feature set, or even feasibility. Some examples of snake oil warning signs in warranty documentation are listed below. Although they are specifically related to encryption software, they have relevance to all consumer product warranties.

"Trust Us, We Know What We're Doing" – This message, either stated directly or implied by the vendor, is perhaps the biggest warning sign of all. If the vendor is concerned about the security of their system after describing exactly how it works, it is certainly worthless.

Technobabble – If the vendor's description appears to be confusing nonsense, it may very well be so, even to an expert in the field. One sign of technobabble is a description which uses newly invented terms or trademarked terms without actually explaining how the system works. Technobabble is a good way to confuse a potential user and to mask the vendor's own lack of expertise.
And consider this: if the marketing material isn't clear, why expect the instruction manual to be any better? Even the best product can be useless if it isn't applied properly. If you can't understand what a vendor is saying, you're probably better off finding something that makes more sense.

Secret Algorithms (read also as secret ingredients) – Avoid software that uses secret algorithms. This is not considered a safe means of protecting data. If the vendor isn't confident that its encryption method can withstand scrutiny, then you should be wary of trusting it.

Revolutionary Breakthroughs – Beware of any vendor who claims to have invented a "new type of cryptography" or a "revolutionary breakthrough". True breakthroughs are likely to show up in research literature, and professionals in the field typically won't trust them until after years of analysis, when they're not so new anymore.

Experienced Security Experts, Rave Reviews, and Other Useless Certificates – Beware of any product that claims it was analysed by "experienced security experts" without providing references. Always look for the bibliography. Any cipher that they're using should appear in a number of scholarly references. If not, it's obviously not been tested well enough to prove or disprove its security.

Unbreakability – Some vendors will claim their software or product - with *"lifetime guarantee of performance"* is *"unbreakable".* This is marketing hype, and a common sign of snake oil. No algorithm is unbreakable, nothing lasts forever – and what is the *"lifetime"* of a product? Even the best algorithms are susceptible to brute-force attacks, though this can be impractical if the key is large enough.

"Military Grade" – Many crypto and product vendors claim their system [product] is *"military grade."* This is a meaningless term, since there isn't a standard that defines *"military grade",* other than actually being used by various armed forces.

In cases where there is no clear-cut guidance available on the interpretation or application of warranties, engineering litigation may be necessary. When preparing an expert report in a product liability case pragmatic natural language is an essential feature of the reporting style. Engineers must avoid legally emotive terminology such as *"merchantable"* or *"duty of care"*. These terms will be seen by a court as counter-productive as well as diluting the technical substance of the argument presented. Nevertheless, engineering experts should be aware of the meaning of these terms in the context of responding to legal inquiry about technical matters.

Duty of care requires that everything reasonably practicable has been done to ensure that the product meets it's maker's specifications;

Merchantable implies that the product is fit to be placed on the market.

Cases presented in this chapter represent products and processes designed to meet some specific purpose. Guarantees of performance offered by their suppliers or manufacturers for these products and processes were provided by promises, some written, some oral, and some implicit or assumed through long association and trust. Technical investigations invariably hinged on how well the products met their intended purpose in the light of manufacturing specifications. Moreover, all the technical investigations followed the format of the earlier cases of building a feasible event (failure) scenario, to establish the technical nature of the failure and to seek the fundamental causes for the products failing to meet their specified behaviour.

3.1 The Cases

In this chapter there are seven cases presented, each resulting from some machinery or product failing to meet the expectations of customers. Although these are all cases in product liability, each is a case in the law of contract.

Failed Hydrostatic Levelling Causes Poor Seed Germination – In this matter a technical service provider was asked to solve a problem in farming operations for a farm machinery manufacturer. Both the manufacturer and the service provider failed to appreciate the complex nature of the problem they were trying to solve in cooperation. The resulting product failure was identified as a combination of poor specification and poor design.

Poor Surface Treatment on Playground Equipment Injures Child – The designers of this playground equipment erred on the side of caution with respect to weather protection. Unfortunately they also erred on the side of poor design in their choice of weather protection coating. In this case the playground supervision and maintenance were also partners to the accidental injury of a child.

Vibrating Sorter Fails to Sort Rubber Foam – A case where long-standing established relationships between supplier and client lulled both into a sense of trust. This trust resulted in a lack of diligence about contracting the supply and delivery of a special machine for sorting particles of foam rubber by size.

Snap-freezer Fails to Freeze Pasta – The three parties to this dispute all thought that the other two would be responsible for making this snap freezer work. The ultimate failure of this system was found to be a result of misplaced trust and poor design.

Non-absorbent Fibreglass Causes Tank Failure – Partners in the manufacture and supply of fibreglass water tanks failed to recognise their respective roles in the partnership.

Wheelchair Transporter Fails to Secure Wheelchairs – This was a case of both not reading the fine print in a contract and poor quality management.

Shrinking Brake Seal Collapses Aftermarket Venture – A cautionary tale for all "backyard" inventors. In this case what appeared to be a lucrative venture was scuttled by a combination of poor technical specification, poor design and misplaced trust in technical competence.

Cases are presented in a format similar to that in Chapter 2. In cases 3.6 and 3.7 the complete expert's report is also included in the presentation.

3.2 Failed Hydrostatic Levelling Causes Poor Seed Germination

3.2.1 The Case Culture and the Defining Event

Mechanical cultivating is commonly used by farmers when planting crop on a commercial scale. These cultivators operate by machining grooves in the earth with tines[3.5] mounted on a frame, while being dragged along behind a tractor. Seed and fertiliser are delivered into the narrow trenches formed by tines, and once the seed has been deposited, these trenches are refilled by a device called a *prickle chain* attached to and dragged along behind the cultivator frame. A critical engineering component on a cultivator is the height adjustment system provided for controlling the proper depth at which the seeds are deposited. Relatively small variations in seed depth can result in crop failure through improper germination.

A seed planting cultivator, type *Condor600*, manufactured by *Carter, Strauss, Neptune* Pty. Ltd. (*CSN*), had installed on it a specially designed height control system manufactured by *Truscott Hydraulics*. This height control system made use of two sets of hydraulic actuators operating as composite sets of *phasing actuators*.

Figures 3.1 and 3.2 show two cultivators in their different modes of operation. The first is a cultivator folded for transport. The Condor600 is made in several frame widths, the largest being 17 m, carrying 93 tines.

Figure 3.1 Cultivator folded for transport

3.5 Sharp pointed forklike tools used for creating the narrow seeding trench into which the seeds are sown. A flexible chain rake is mounted behind the cultivator for refilling the seeding trench after the seeds have been sown.

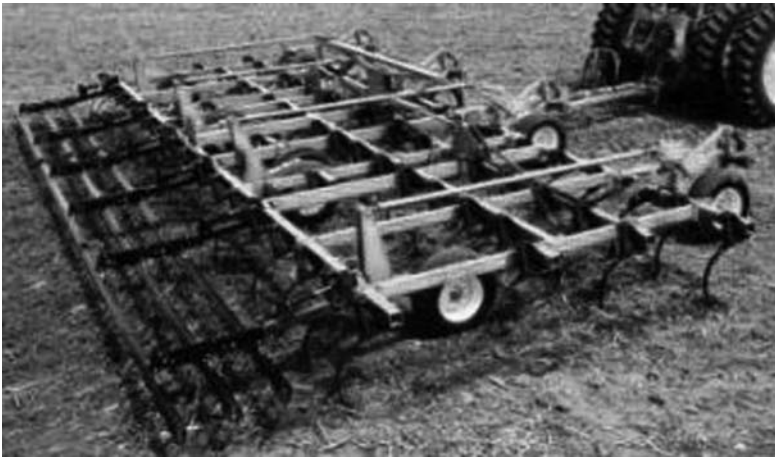

Figure 3.2 Cultivator with prickle bars

Maximum permissible transport width of these large machines is determined by farm gate access and road width. The maximum folded width of the Condor600 cultivator is 7.5 m. The two outrigger sections that fold up are referred to as "wings", and folding is assisted by two hydraulic folding actuators.

Figure 3.2 shows a cultivator in the field, and in this mode of operation the phasing cylinder sets are designed to maintain the two wing frames at the same level as the central frame during cultivation passes over the field. A number of designers and manufacturers of control hydraulics manufacture phasing actuator sets, and the Condor600 was originally fitted with phasing cylinder sets produced by *Rasputin Hydraulics*. The Rasputin phasing cylinders worked well but had some apparently minor but consistent problems. Before commencing a seeding pass over a field, the tine sets on the cultivator needed to be set to the same level. This process is called *phasing* and is performed by the cultivator operator at the start of a seeding programme as well as at regular intervals during the whole programme.

Phasing with the Rasputin phasers was achieved by setting all tines on a level surface and opening sets of poppet valves in the hydraulic lines connecting hydraulic cylinders. Due to the dusty conditions experienced in most tillage operations, the poppet valves often got stuck and had to be removed for cleaning. Eventually, farmers began to submit regular complaints about this problem to CSN representatives, and in response CSN commissioned Truscott Hydraulics to design a phasing system that would overcome the failing poppet valve problems experienced in the field.

In response to this request, Truscott produced a design that had an internally machined spiral groove in the phasing cylinders (refer to Figure 3.3). In addition, even though the original Rasputin phasing pistons had double seals, the Truscott phasing pistons were designed with a single seal (refer to

Figure 3.3). This arrangement was designed to permit internally equalising oil pressures when all pistons were raised to the top of their respective cylinders, where the single seals all rested on the spiral grooves. Several phasing sets of Truscott's new design were delivered to CSN in mid 1989. After some field testing by CSN, the Condor600 equipped with the new Truscott phasers was released for sale. By late 1989 substantial numbers Condor600 failures were reported to CSN. This failure of the Condor600 cultivators was originally associated with substantial numbers (more than 100) of hydraulic cylinder seal failures in the Truscott phasing sets. Eventually the failure of phasing cylinder sets became the basis of a dispute where several farmers sued CSN, who, in turn, sued Truscott Hydraulics. The plaintiffs (farmers) cited the failure of the Truscott phasing cylinders for poor germination of several crops, allegedly caused by poorly controlled sowing depth.

3.2.2 Parties to the Dispute and the Client

Although this turned out to be a type of minor "class action" by a whole group of farmers operating Condor600s fitted with Truscott phasers, the main plaintiff issuing a writ against CSN was *Dandelion Pty. Ltd*. CSN regarded the Dandelion suit as one in which they too were injured by the poor performance of the Truscott phasers. Consequently, CSN issued a writ against Truscott seeking damages for the failure of the phasing sets. Truscott's liability insurers, *Messrs Pork and Beans*, appointed a loss assessor, *John Darcy*, to review the problems with the Truscott phasers. Ultimately it was Darcy who approached me to help with the technical issues in this case. My brief from Darcy was to examine the Truscott phasers and to evaluate the nature of their various failures. Initially I was provided with copies of the several writs, defence responses and drawings of both the original Rasputin phasing cylinders and Truscott version that replaced them.

3.2.3 The Role of the Expert and the Investigation

Height control in the mechanical tillage industry is a consistent problem.[3.6] Tischler's empirical study investigated the effect of many different factors that influence height control on cultivators. He identified the following major factors that influence seed placement depth:

Tyre pressure and axle load – some farmers mount the seed box on the cultivator frame, and this load varies as the box empties.

Ground conditions – waviness, and compaction strength. In a private communication Tischler noted that he had seen farmers cultivate by lifting the tyres clear of the ground and running the cultivator on the tines, successfully following land contours.

3.6 See for example Morrison and Gerik (1985); Swan et al. (1987); Gupta et al. (1988); Tischler and Moore (1992); Lee et al. (2000 a) and (2000 b).

Table 3.1 Phasing cylinder hydraulic areas

Phasing set		Cylinder diameter (inch)	Cylinder area (inch^2)	Rod diameter (inch)	Annular area (inch^2)
4 inch diameter set	Master	4.00	12.566	1.375	11.081(S1)
	Slave 1	3.75	11.045(S1)	1.375	9.560(S2)
	Slave 2	3.50	9.622(S2)	1.25	
5 inch diameter set	Master	5.00	19.635	1.5	17.868(S1)
	Slave 1	4.75	17.721(S1)	1.5	15.954(S2)
	Slave 2	4.50	15.904(S2)	1.5	

Frame flexure – this is probably the most significant contributor to seed depth variation.

Operator error in height setting.

As a result of these variations, phasing cylinders need to be regularly calibrated for height alignment in the field. This calibration process requires cultivator tines to be placed on level ground, while the phasing cylinders are allowed to equalise their individual pressures. Truscott phasing sets were designed to overcome the clogging poppet valve problem experienced with the original Rasputin phasers. Truscott cylinders had machined into them some spiral *phasing grooves* that would allow pressure equalisation. A detailed review of the operation of these phasing grooves showed them to be the principal culprit in the failure of the Truscott phasing cylinders.

Phasing Cylinder Operation

Phasing cylinders installed on various tillage machinery are used to adjust and maintain the height of the agricultural tool (disc plough, seeding tine) relative to the machine axle during tillage operations. The phasing cylinder set is designed to maintain constant relative height across the machine width. In principle this relative height maintenance is achieved by matched hydraulic areas in a master/slave set of cylinders. Referring to Figure 3.4, note that the hydraulic area of each succeeding cylinder in the phasing set is made equal to the annular hydraulic area of the preceding cylinder. This condition is illustrated in Table 3.1, where the hydraulic areas in succeeding cylinders in the phasing set vary by no more than 1%. Matching areas for each set are indicated by the connecting arrows. In the field, when commencing to cultivate a set of tillage rows, the phasers are calibrated and set to maintain some specific tilling depth.

The operator actuates the master cylinder in the set to some desired setting, after which the set is "locked" by the check valves provided in the hydraulic line at or near inlet A and outlet B. Since oil is incompressible,

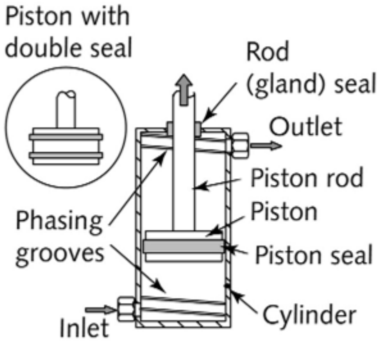

Figure 3.3 Phasing cylinder

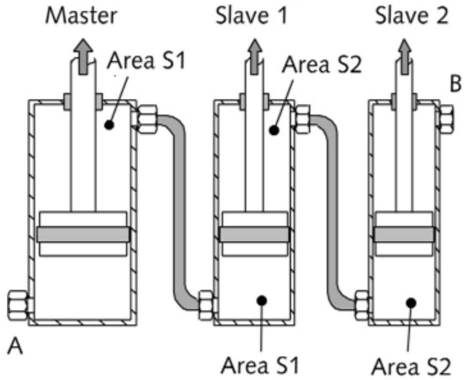

Figure 3.4 Phasing cylinder set

the matched hydraulic areas in the phasing set are supposed to ensure that movement in any of the pistons in the set will be reflected by a corresponding movement in all the other pistons.

During tilling, phasing cylinders will become out of phase due to various reasons (some are enumerated below). The standard operating procedure is to "rephase" or recalibrate phasing sets regularly during use. With the Truscott phasing sets, rephasing is achieved by raising pistons to the top of the cylinders, where the piston seals rest on the phasing grooves that permit the flow of oil between cylinders in the set and thereby permit pressure equalisation in the three cylinders.

The provision of phasing grooves in their cylinders was based on Truscott's reasoning that the grooves would allow oil to "flush" through them and even when contaminated by dust they would not become blocked. This had been borne out by empirical testing during manufacture of the cylinder sets. The spiral grooves provided in the phasing cylinders were originally equivalent to a 25 mm pitch thread. Truscott manufactured the phasing cylinders by machining cold-drawn steel tubing followed by fitting the two ends to complete the assembly. As a way of "helping" production staff ensure that phasing grooves were provided at the top of each cylinder, the cylinder tubes had mirrored phasing grooves machined into them at both ends (refer Figure 3.3).

In April 1996 Truscott supplied some "test sets" of the new phasing cylinders to CSN and advised that they should be tested on machinery in the field. Apparently this is normal operating procedure in the agribusiness. The uncertainty of operating conditions in agricultural equipment precludes full knowledge of all the loads to which the equipment is liable to be exposed. While substantial over-design is often used to cater for these uncertainties, it is always difficult to estimate the worst credible accident that might befall equipment. Hence the need to gather test data in the field for prototypes before releasing machines to the market. With the new

Truscott phasing cylinders, field testing was particularly important, since cylinders with grooves machined into their internal wall surface was a new concept without the benefit of substantial experimental evidence for their successful (or otherwise) operation.

Failures Experienced with the Truscot Phasers

In November 1996 Truscott were advised that CSN experienced some seal failures on their phasing cylinders. Initially, Truscott management were determined to provide in-service technical support to CSN and to work on the failing Condor600 machines in the field to eradicate the problems with seals. On careful examination of the installation of phasing cylinders on the Condor600 machine, several manufacturing or design errors were found. These are now enumerated as explained by Garry Truscott, the manager and inventor of the Truscott phasing cylinders.

(a) Tine height adjustment and seal failures – When the operator of the cultivator sets up the machine before going into the field, the heights of the several tine sets are adjusted to be level. This is usually achieved by adjusting the output ends of the phasing cylinders under load.

In the Condor600 the adjustment system is indicated schematically in Figure 3.5. To adjust the tine set, the operator would turn the top nut (welded to the piston rod end) and the attachment plate would move up or down on the thread machined into the piston rod end. Note that this procedure requires the piston with its fixed rod to rotate inside the cylinder. With the original Rasputin phasing sets this procedure would be harmless since the cylinder walls of those sets were smooth. However, in the Truscott phasing cylinders, this adjustment would damage the piston seals if the seals were resting on

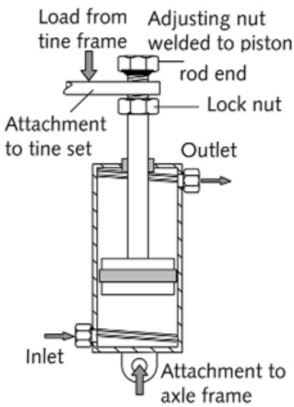

Figure 3.5 Phasing cylinder adjustment

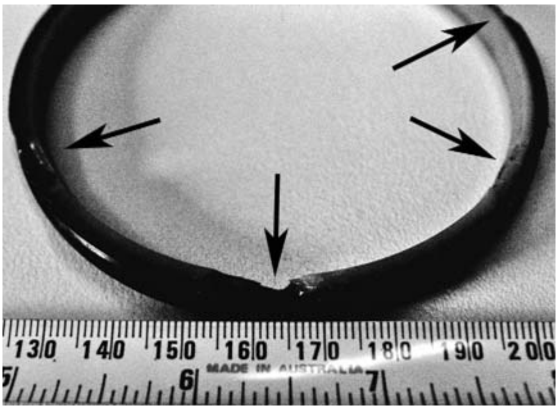

Figure 3.6 Seal damage

the relief grooves during this adjustment. There was significant evidence that this style of seal damage was experienced with the Condor600. Figure 3.6 is a photo of a seal removed from a failed Truscott phasing set.

In the first instance, Truscott reasoned that the soft seals used in their phasing sets would be "chewed" by the phasing grooves either during tine adjustment or during transport, when the pistons were lifted to the top of the cylinder. Figure 3.7 indicates schematically the imagined initiation of these types of seal failures. After many seal replacements these failures were finally attributed to the repeated passage of the seals over phasing grooves and seal edges being caught by the edges of grooves. Figure 3.8 shows this assumed process. Tillage machine operators linked the seal problems on the Condor600 to the following major effects in the field:

(b) Out-of-phase operation and loss of seed depth control – several machines were found to have failed in this way.

(c) Wheel lift during tilling – consequent failure to control the cultivator either in direction or seed depth was reported by several operators. Figures 3.9 and 3.10 illustrate these problems schematically.

As well as the above problems experienced by tillage machine operators there were other complaints about the design of the Truscott phasing sets.

(d) Height setting in operation – The master cylinder of the phasing set was expected to be maintained at some desired height by the various check valves in the hydraulic supply line. Due to leakages in the system, possibly due to early seal damage, machine operators chose to maintain master cylinder height by using spacers inserted between the piston rod ends and the top of the cylinder. The arrangement is shown in Figure 3.11 schematically.

(e) Operation of the phasing cylinders during machine transport – During tillage the phasing cylinders are expected to be height controlled by

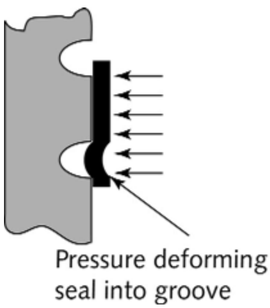

Figure 3.7 Initiation of seal damage

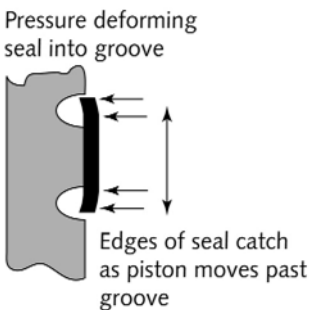

Figure 3.8 Alternative seal damage action

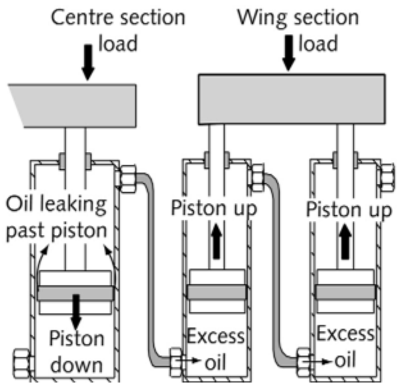

Figure 3.9 Out-of-phase error due to seal leakage

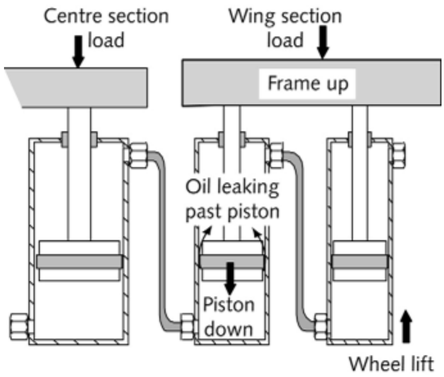

Figure 3.10 Wheel lift error due to seal leakage

the hydraulics. During machine transport the cylinders are expected to be protected from bumps and other sudden load changes by mechanical stops similar to the doughnuts inserted on the master cylinder. On several of the failed Condor600 machines a mechanical stop was imposed by inserting a bolt into a plate attached to the tine height adjustor (Figure 3.12).

Both of these mechanical height-limiting arrangements imposed substantial eccentric bending loads on the master cylinder piston rods, causing some of them to be bent in service. The single piston seal of the Truscott design permitted the piston to pivot about the seal and exacerbate oil leakages in the phasing set, as well as occasionally damaging the internal wall of the cylinder. In addition, this process also placed extra load on the seals, increasing their likelihood of failure.

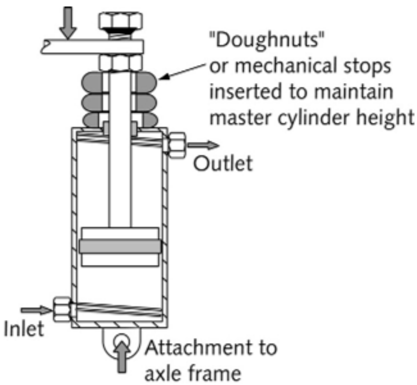

Figure 3.11 Mechanical master cylinder height limit

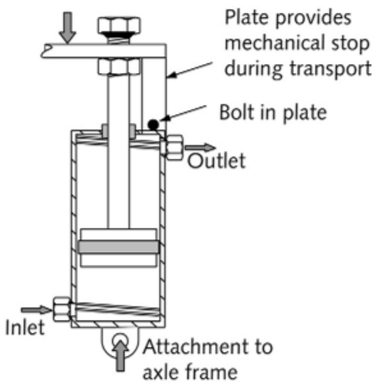

Figure 3.12 Mechanical height limit during transport

3.2.4 Evaluation of Information and Lessons Learnt

1. In principle the operation and behaviour of agricultural equipment appears to be fraught with significant uncertainties. There appears to be no consistency about quality assurance, other than the expectation that all equipment requires considerable field testing. CSN have a reputation for manufacturing reliable agricultural machinery. They have survived in a difficult marketplace for more than 30 years and have several successful products to their credit. It is inconceivable that the Condor600 machine was produced with less engineering care than any of their other products. Although they had a reputation to protect, they must have been aware of the uncertainties and difficulties to be experienced in the field with newly released cultivators.
2. Truscott responded to a special need in the industry with their new design of phasing cylinders. They did some of what was expected of any manufacturer when supplying to less than adequate specifications. Their brief from CSN was *"to design phasing cylinders that would not suffer from the seized poppet valve problems experienced with the Rasputin phasing cylinders".* They appeared to have exercised considerable concern and support for CSN customers, given the limited specifications provided to them for the supply of the new phasing cylinders. The real culprit in the development of the new spiral-grooved phasing cylinders appears to have been inadequate initial testing and undue haste in attempting to provide a "quick fix" to reported difficulties experienced in the field with other phasing cylinder sets.
3. There appeared to be some lack of care in the fitting of phasing cylinders to the Condor600 machine. The height adjustment system for tines was less than ideal. Moreover, the mechanical transport stops are clearly of poor design, since they impose eccentric loads on the phasing cylinder piston rods, as well as a twisting load on the piston and piston rod assembly.
4. Truscott appear to have made many of the changes necessary for their phasing cylinders to be suited to a wide range of applications. One feature of these types of hydraulic height controls, essential for their successful operation, is the cleanliness of the oil supply. Perhaps this is an area of design to be addressed in future manufacturing applications.
5. The need for mechanical stops on the master cylinders indicates that the height control was inadequate from the beginning. Seal failures might have exacerbated the problem, but clearly, they were not the primary cause of it.
6. The inclusion of mirrored phasing grooves on the inside of their hydraulic cylinders was a serious design error by Truscott. Hydraulic cylinders have a history of reliable operation with smooth internal

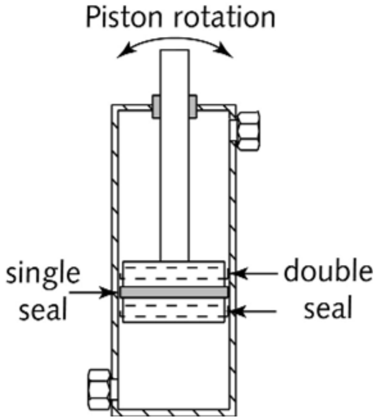

Figure 3.13 The basic problem with the Truscott phasing cylinder design

cylinder walls. Even the inclusion of the "real" phasing grooves was a dangerous new concept with hydraulic cylinders. The inclusion of a second set of grooves in the probable operating area of the pistons had substantially increased the risk of seal failure with the Truscott design.

7. Figure 3.13 shows scehmatically the basic problem with the Truscott design. In the original Rasputin design the piston had two seals separated by some distance on the piston. The piston rod seal (at the top of the cylinder) is usually formed by twin o-rings. These o-rings are suffciently compliant to permit some movement of the piston rod under load. Truscott's design required a single piston seal to be located on the spiral phasing grooves during rephasing. A double seal design would not permit rephasing with the helical phasing grooves. As a consequence of this simple design decision, the piston was permitted to pivot as indicated in Figure 3.13. The heavy dynamic loading acting on the piston would result in some back-and-forth motion of the piston during tillage operations. If the piston seal was sitting partially or fully on a phasing groove under these conditions, almost certain damage to the seal would be incurred.

3.2.5 Outcome and Concluding Comments

On evidence, there seemed to be no specific fundamental fault with the notion of the spiral rephasing grooves or the rephasing procedure offered by the Truscott phasing cylinders. In practice the grooves did appear to detrimentally influence the operation of the phasing cylinders when fitted with soft seals. It is a feature of new design ideas, that they require extensive testing and development before one can depend on their reliable operation. In the specific industry where Truscott Hydraulics was operating, the agricultural engineering industry, field performance is so critically influenced by uncertainties of operating conditions, that bench testing is unlikely to yield significant useful data on design reliability. Consequently, potential failure mode evaluation must be obtained from extended experience in field-testing. The evidence available in this case indicated that Truscott and CSN did not carry out the requisite amount of field testing on the new phasing cylinders before releasing them to the market.

Once the new phasing cylinders commenced to fail in the field, Truscott Hydraulics appear to have made concerted effort to change their design to help overcome their problems. The very brief development time devoted to each design change was certainly less than would be expected for the design changes made by Truscott Hydraulics in this period. This may have been a consequence of the pressure of attempting to help farmers with severe time constraint on their respective seeding programmes. With the evidence available it is difficult to determine how much influence CSN exerted on Truscott Hydraulics to respond to the various problems. The resulting expedient but unsuccessful design changes must have exacerbated the dissatisfaction of farmers with the Condor600 machine. This exacerbation cannot be blamed entirely on Truscott Hydraulics. CSN field service staff should have been able to recognise the severe shortcomings of the Truscott phasing cylinder seals on inspection of the failed sets. A full recall of the machines or some alternative arrangement for repairs should have been instituted at the first experience with the seal failures in April 1997.

The whole procedure of interaction between the parties involved in the delivery of the Condor600 machine to operators appears to be open to failure. Truscott Hydraulics were not given proper engineering specification for the design and delivery of phasing cylinders. CSN may have pressured Truscott Hydraulics for delivery or design development of the new phasing sets. In the event, both parties failed to carry out sufficient field testing to determine potential failure modes.

In view of the above it was recommended that:

> A properly supervised and recorded test programme on the Truscott phasing cylinders must be performed in the Truscott Hydraulics plant. These tests need to accord with a qualified testing authority such as NATA (National Association of Testing Authorities) or Lloyds or Standards Australia.
>
> The Condor600 machine needs to be examined by a professional engineer capable of evaluation the operating loads imposed on the phasing cylinders.
>
> CSN should provide substantiated accurate data on all cylinder failures in the field, including dates, seal types, action taken to correct failure, soil conditions and loads on the machine. The salient dimensions of each machine must be provided for an engineering evaluation of the structural integrity of the phasing cylinder systems on these machines.

This matter was settled with several farmers in confidential out-of-court settlements.

3.3 Poor Surface Treatment on Playground Equipment Injures Child

3.3.1 The Case Culture

An Australian Government warning about playground safety notes:[3.7]

> *"Children using playground equipment are most often injured by falls. Common injuries include fractures, spinal injuries and head injuries. The higher the drop, the more likely it is that the injury will be severe, particularly if the ground beneath the equipment is hard, rather than loosely filled with mulch or sand. To protect children, it is important to teach them how to use the equipment safely and sensibly limit their play to equipment appropriate for their age and abilities and to supervise them at all times.*
>
> *Equipment in a public playground generally caters for children of all ages. Your child might be at risk of injury from a piece of equipment designed for older children. Make sure your child only uses equipment that is appropriate for their age, strength and coordination."*

A North American Consumer Product Safety Commission offers a Public Playground Safety Checklist in *CPSC Document #327. Is your public playground a safe place to play?*[3.8]

"Each year, more than 200,000 children go to U.S. hospital emergency rooms with injuries associated with playground equipment. Most injuries occur when a child falls from the equipment onto the ground. Use this simple checklist to help make sure your local community or school playground is a safe place to play.

> *Make sure surfaces around playground equipment have at least 12 inches of wood chips, mulch, sand, or pea gravel, or are mats made of safety-tested rubber or rubber-like materials.*
>
> *Check that protective surfacing extends at least 6 feet in all directions from play equipment. For swings, be sure surfacing extends, in back and front, twice the height of the suspending bar.*
>
> *Check playgrounds regularly to see that equipment and surfacing are in good condition.*
>
> *Carefully supervise children on playgrounds to make sure they're safe."*

This case is not so much about injury as it is about the design of the playground equipment. In a sense it is case in which one might almost invoke the *mens rea* (unwitting evil intent) clause of product liability. *All Saints* is a Catholic primary school in a north-eastern suburb of Melbourne. The school decided to refurbish their ageing playground and chose to include a *"swingring"* in which the child is intended to swing from ring to ring. In this

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3.7 www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/pages/Child_safety_playground_equipment

3.8 www.cpsc.gov/cpscpub/pubs/327.html

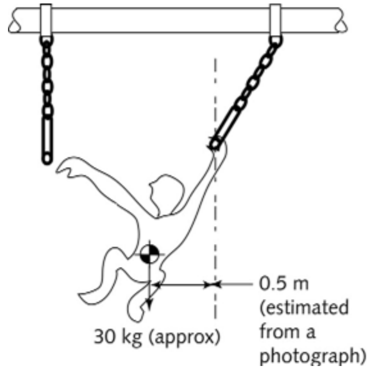


Figure 3.14 Child on swingring (schematic)


Figure 3.15 Typical swingring installation

design the "rings" were wire coat-hanger-shaped handles called *trek handles*. Several trek handles were each connected by a short length of chain to a long horizontal bar. In the past the handled parts of playground equipment were either painted or galvanised. In an effort to reduce maintenance it was decided to treat the trek handles of the swingring with a plastic coating. Figure 3.14 shows the arrangement schematically. Figure 3.15 shows a typical swingring installation. In many such installations nowadays the handles are made of some solid plastic such as polypropylene. In 1992 (the time of this accident) playground equipment materials were mostly basic steel and timber. This case concerns an accident in which a 9-year-old child *James Smith* was injured by falling from a playground equipment called a swingring.

3.3.2 The Accident Event, Parties to the Dispute and the Client

The accident occurred on 10 February 1992, while James was using the swingring on which the *"rings"* were roughly triangular-shaped *trek handles* (the manufacturer's description). The whole swingring was coated with a product called *"Beta 1627 Plastisol"*, which is applied in a dip coating process. Plastisol is a polyvinyl chloride (PVC) base product supplied by *Alpha Chemicals*.

The swingring was designed and constructed by *Hilltree Engineering* who, in turn, contracted the coating to *Carborandum Coatings* (trading as *Dipsheet Pty. Ltd.*). In particular it had been alleged that the lower horizontal grip surface of the track handle was responsible for precipitating the accident. The suit was initiated by *NNL* insurers acting for James and All Saints school as their public liability insurers. In this suit a writ was issued against Carborandum Coatings, who provided the plastic coating on the trek handles. Carborandum Coatings had product liability insurance with *Happy Days* insurers and the dispute was in mediation when I was asked by counsel acting for Happy Days to offer expert opinion in this case on the several matters and these as well as my responses are listed below.

1. Was the coating procedure used on the trek handles appropriate to the application?
2. Would it have been appropriate to apply an adhesive primer on the trek handles prior to coating?
3. For what length of time would the plastic coating be expected to adhere to the trek handles with or without adhesive primer?
4. To what extent or degree could the plastic cover twist under the action of James' hand, given that it did not tear?

3.3.3 The Expert's Role and Investigation

In responding to the issues raised by my client, my initial approach was to inspect the playground, the equipment and associated standard recommendations available on this matter. By the time I became involved in the case, the swingring device had been removed and was not available for inspection. In an interview with *Ed Dantes* of Dipsheet about the trek handles and the coatings used I was advised as follows:

- Dipsheet did not know the whereabouts of the faulty trek handle which featured in the accident.
- The trek handles were made of approximately 12-mm-diameter round bar, supplied by Hilltree with a hot-dip galvanised or zinc-coated finish prior to dipping in the Plastisol product. Dantes did not recall which coating was specified by Hilltree on the trek handles prior to Plastisol coating.
- Currently the trek handles are being Plastisol coated by *Handle Protection Ltd.*, who claim it is being applied over a zinc coating.

Based on review of all information my responses to the issues raised by my client were as follows:

1. The appropriateness of the coating procedure used on the trek handles – Dipsheet provided a service-for-a-fee to Hilltree in dipping the trek handles. They did not act as "designers" of the playground equipment and in this sense it was not really their role to determine if the coating to the handles was appropriate or otherwise. In retrospect, there is little doubt that the coating as applied was not appropriate to the eventual use of the product. Some mechanical testing would be needed to determine the mechanical behaviour of the product once applied to the trek handles.

There are three Australian Standards which reference plastic coatings on pipes and playground equipment, namely *AS 2518*, *AS 1924.1* and *AS 1924.2*.[3.9] *AS 2518* refers to polyethylene rather than PVC, coatings, but I was unable to find either an Australian Standard or an International Standard which deals with PVC coating. This may be due to the prod-

3.9 These standards are fully described in the reference list.

uct/process being relatively new and not often used in structural applications. Nevertheless, *AS 2518* does identify the techniques needed for surface preparation and bond strength testing. *AS 1924.1 clause 2.15* deals with protective coatings for playground equipment. It identifies only one type of plastic coating and that is baked acrylic enamel.

AS 1924.2 clause 2.2.3 refers to *"Ribbed Plastic Coverings":*

"Where ribbed plastic coverings are used to provide a slip-resistant surface on any handgrip or other part, these coverings shall be obtained by any of the following methods:

(a) Shrinking ribbed plastic sleeve to the core.

(b) Wrapping or bonding ribbed plastic sheet to the core.

(c) Suitably texturing core before coating it in liquid or powder coating material."

2. *The appropriateness of using an adhesive primer* – With Plastisol, an adhesive primer would tend to promote better bonding between the metal bar and the plastic. Unfortunately the mechanical working of the surface coating by the gripping and twisting motion during play could still result in partial or full debonding. This is particularly the case with a galvanised/zinc-coated inner core surface. Mechanical testing would be needed to to evaluate this issue.

3. *The approximate length of time for which the plastic coating would be expected to adhere with or without adhesive primer* – Without mechanical working of the surface I would estimate the coating would adhere indefinitely with or without adhesive primer. With mechanical working the time depends on the quantity and severity of mechanical working that is applied to the coating. If, for example, larger (heavier) children or even young adults were to use the trek handles the de-bonding could accelerate. Testing of the coating would help reveal the answer to this question.

4. *The extent or degree to which the plastic cover could or would have twisted, given that it did not tear* – Plastic generally, and PVC particularly, does not have a "yield point". This means it will tend to deform "plastically" once loaded. Hence the degree of deformation suffered without tearing would be quite considerable. I would estimate that, if the bonding failed, the coating may be rotated almost fully without tearing.

Referring to Figure 3.14 the moment exerted on the trek handle by James was approximately $(30 \times 9.81 \times 0.5) = 147$ Nm. With dynamic loading of the swinging child the moment could increase to at least double this value. The shear area available for the bond between the coating and the metal to withstand this moment was estimated from the child's hand width multiplied by the perimeter of the trek handle. This value was estimated at $70 \times \pi \times 12$ (the last figure is an estimate of the diameter of the trek handle) $= 2.64 \times 10^{-3}\,\text{m}^2$. The resulting shear stress in the bond is therefore estimated at 0.95 MPa (low figure) to as high as 1.9 MPa (high figure). The tensile strength of the cured Plastisol was supplied by Alpha Chemicals as 7.5 MPa, with an elongation of 550%. The applied local shearing stress by the child playing on the bar is uncomfortably high and would result in quite substantial local deformation and mechanical working of the plastic, even though not necessarily fracturing it.

I concluded from these notes that the coating and coating procedure used on the cylindrical section trek handles was not generally regarded appropriate for parts subject to mechanical working, such as the hand grips of playground equipment. Moreover, the galvanising/zinc coating would result in a smooth surface which would undoubtedly exacerbate the debonding between the plastic and the metal bar.

The size of the handgrip remains in question. I had not been able to inspect it, nor have I been able to ascertain the actual diameter used. *AS 1924.2* recommends hand grip of no less than 13 mm diameter. Even with such a size the available surface area for bonding is quite small and the likelihood of debonding on a smooth surface quite high. Inspection of the failed part or testing of a similar part would have permitted a more definite conclusion on this issue.

3.3.4 Lessons Learnt and the Outcome

Undoubtedly the major contributing party to this accident was Hilltree Engineering, the designer of the swingring equipment. All Saints must carry some of the blame in allowing an improper piece of equipment to be installed in their playground. The child could certainly lose his grip on the trek handle for a variety of reasons. As a useful overview of these, a potential FMEA[3.10] table, Table 3.2, was constructed for the likely loss of grip on the trek handles during play. All Saints maintenance staff should have inspected the handles regularly. This is a situation particularly referred to in the loss assessor's report, stated that several other trek handles had loose plastic coverings.

In attributing a share of the blame for this product failure it must be noted that Hilltree determined the size and finish of the trek handles and (most probably) the type of finish to be used on the surface. Galvanising/zinc coating prior to Plastisol coating indicates an obsessive concern with weather protection. In the kitchen utensil industry Plastisol is used on drying racks, with black wire cores. However, there it is not exposed to mechanical working in the same way as should have been expected with the trek handles. Hilltree designers should have considered this factor in their design. Moreover, the use of a relatively thin (12 mm) circular section trek handle was a serious design error. This was the decision that substantially failed to consider the nature of the use to which the trek handles would be exposed. Informal discussion with Hilltree Engineering revealed no attempt on their part to investigate the grip issue any further than considering what was being used (albeit uncoated) in

3.10 Potential failure modes and effects analysis.

Table 3.2 Failure modes and effects analysis for the trek handles

Failure type	Possible causes	Risk level	Contributing causes	Investigation required
1. Structural				
Handle deforms or breaks	*Design fault or deterioration of material due to weather exposure*	*Low*	*Improper choice of material or size; Coating faulty or damaged in service*	*Inspect failed part*
2. Loss of grip in use				
Handle slippery	*Weather or surface contamination*	*Low (dry) High (wet)*	*Rain or dew; Other surface contaminant*	*Inspect part at accident*
Plastic coating deforms	*Mechanical damage*	*High*	*Mechanical working of plastic*	*Inspect failed part; Test similar part*
• *plastic metal bond breaks down;*	• *improper or inadequate bonding*	*Very high*	• *improper preparation of surface prior to coating;* • *mechanical breakdown of bond*	• *Inspect failed part;* • *Mechanically test similar part*
	Surface chemistry effects	*Very low*	*Decomposition of plastic*	

other playgrounds at the time. Presumably, Hilltree engineers had examined the grip diameter of uncoated playground equipment and then allowed for the coating thickness, maintaining trek handle sizes recommended for children.

Dipsheet may be also seen as part of the problem in offering their coating service independent of the nature of surface finish (this issue is related to bonding strength). A responsible coating supplier should have explored the nature of the use to be made of their product. Notwithstanding this issue, Dipsheet were not acting as experts in playground equipment design and in this sense they should not take a full share of the blame for the accident which, was mainly caused by debonding through mechanical working of the surface coating. Weakness in evaluating use and serviceability in deciding on the design of trek handle grips by Hilltree and the poor maintenance at All Saints were matters I referred to above in my suggested invocation of *mens rea* in this case. While these matters were not necessarily "evil intentioned", considering the use of the equipment they certainly deserved substantially greater care and attention.

The public liability insurers for Hilltree and Happy Days for All Saints settled the matter with the injured party.

3.4 Vibrating Sorter Fails to Sort Rubber Foam

In matters of product liability a lack of expertise in contract drafting can turn out to be the major cause of a dispute between customer and supplier. In general, all parties to a contract should be advised to be sure to read the fine print. Customer requirements (and also unfortunately expectations) are often unarticulated when negotiating a contract with a supplier. Occasionally suppliers make preposterous performance claims (*vapourware* or *snake oil*) in their brochures, such as *"money back satisfaction is guaranteed"*, or *"we only use the best materials"*. However, even with reputable suppliers of products it is advisable to read the product specifications and try to interpret these in terms of the eventual use of the product. In essence, it is these specifications that form the basis of the contract between the seller and buyer. If a dispute about performance ensues, then any mediation action proceeds first to reading *the fine print*, or properly interpreting the specifications, while paying careful attention to the way the product was being used by the purchaser.

This case is one in which the purchaser did not fully specify the nature of their application to the supplier and the supplier's specifications implied promises that their product ultimately failed to fulfil. This situation was exacerbated by the fact that both supplier and purchaser had a long-standing relationship of mutual trust built up between them. As a result both were under the mutual impression that *they must know what they are doing*.

3.4.1 The Case Culture and the Defining Event

Carbon Black Recyclers (CBR) is a business built on shredding up used rubber tyres into granules to be used in packaging. Shredded granules of rubber are sorted into a variety of sizes using vibratory sorters for sale. CBR have built up a long-standing relationship with *Ockers Ltd*., a local importer and supplier of vibrating sorters made by the North American *Vortex Corporation*. CBR had purchased several Vortex sorters from Ockers in the past and they operated successfully for some years.

In 1994 CBR suffered a serious factory fire in which all of their Vortex sorters were irreparably damaged. Once they had recovered from the fire, CBR built a new larger plant in which they were planning to continue their tyre-shredding business. In addition, they expanded into the shredding of discarded foam rubber. For this activity they purchased from Ocker a new Vortex sorter. After a brief period of use this sorter was returned to Ocker, with the claim that it *"failed to meet its specifications"*.

3.4.2 Parties to the Dispute and the Client

Although the quantum of the dispute in this case was not large, of the order of AU$ 20,000, there was a substantial element of future business for Ockers to consider in negotiating with CBR. Nevertheless, Ockers counter-sued CBR for breach of contract as well as damage to the supplied Vortex sorter. Counsel for Ocker's insurers briefed me to prepare a report for

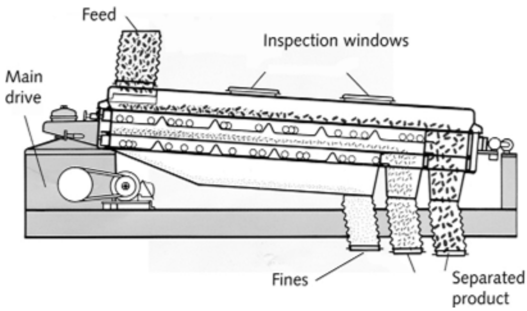


Figure 3.16 Schematic view of the operation of the Vortex separator

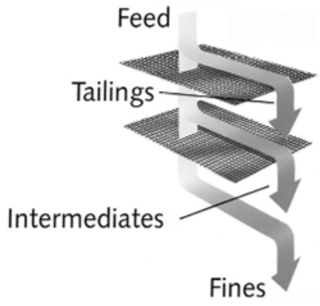


Figure 3.17 Schematic view of the separation process

mediation. My brief was to investigate the claims on both sides of the dispute and to offer opinion to help mediators resolve the matter.

3.4.3 The Expert's Role and the Investigation

Figure 3.16 shows the operation of the Vortex separator (in principle a large industrial sieve). Figure 3.17 is a schematic of the way separation takes place in the machine.

Machine Characteristics Specified by CBR

(a) *Volumetric efficiency of the separation process* – This is a measure of the proportion of acceptable particles generated by the separation process. The figure specified by CBR was not less than 90% (this implies less than 10% fines and oversize particles).

(b) *Oral exchanges between CBR and Ocker, reported in interviews with Ocker staff* – It was generally agreed that both parties understood that the sorting process was intended for relatively soft foam rubber particles. However, it was agreed by both parties (in verbal communications) that CBR would be the agent for performing acceptance tests and general commissioning of the Vortex separator supplied by Ocker.

Promises Made by Ocker

(a) *Mechanical specifications* – All machine specifications related to mechanical parameters such as crank diameter, crank revolution rate, screen area, motor power and speed, rather than any performance characteristics relating to the way in which the machine would separate particles during the screening process. These specifications were offered in the product brochures describing the mechanical operation of the Vortex separators.

(b) *Implied performance characteristics (overtones of snake oil)* – Ocker brochures for the Vortex machine listed 16 industries where these separators have been successfully used, including "Plastics: Plastic pellets, polyethylene, polystyrene, polypropylene, PVC, etc." The overall impression intended by this list was one of substantial expertise with a vast range of products.

The Substance of the Dispute

In their writ issued against Ocker, CBR made the following specific claims:

"(a) The screening machine was not reasonably fit or at all fit for the particular purpose in that rubber particles are not screened or sorted into an output of uniform size, rather the machine allows rubber particles of different sizes and shapes to be mixed together.

(b) The screening machine does not correspond with the description of a machine which sorts and screens rubber particles into an output of consistent size and shape."

In addition there were some general claims about the poor quality of manufacturing, including *"improper welding"* and *"geometric irregularities"*.

Ocker, on the other hand, responded with a writ against CBR based on the following specific counter claims:

"(a) CBR chose the machine fully specified mechanically by Ocker brochures and detail design drawings supplied to CBR.

(b) CBR were responsible for the choice of screen mesh (this feature determines operating efficiency in separation) and they were responsible for testing the machine with their product.

(c) The machine was returned to Ocker in a damaged condition."

The Vortex Sorter

Based on my examination of machine specifications available from Ocker technical brochures I found that the operation of the machine depended on the following:

- *Proper choice of machine type* – this determines the available screen area, screening rate, and drive motor power.
- *Proper choice of screens* – this determines separation of particles during screening.

The Vortex machine supplied to CBR was a general purpose separator, of a mild-steel construction, designed to be used with timber-frame screens (for lightness). However, even with a given machine type there are many different choices of screen type and discharge arrangements available. In the case of the CBR machine there were three screen surfaces used (two removable and one fixed) and discharge occurred over the end of the first screen for oversize material (see Figures 3.14 and 3.15). Clearly the specific operation and screening action of the supplied machine would have been critically determined by the screens chosen for the machine. The hole sizes provided in the screen would separate the screened material into three separate streams of sizes, namely, *oversize*, *desired size* and *undersize* components, as well as *fines*.

Figure 3.18 General view of the Vortex machine as returned to Ocker

Figure 3.19 Closer view of the machine showing the fixed screen

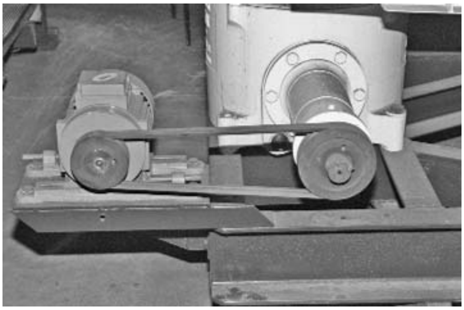


Figure 3.20 Drive motor mounted on the machine frame

Figure 3.21 Close-up view showing some of the weld runs on the machine frame

The screening action was dependent not only on particle size distribution, but also on the shape of particles to be screened. For example, a long thin particle may or may not fall through the screen holes depending on the attitude it presents to the screen during its travel from the inlet end of the screen to the outlet. Moreover, due to the random nature of the screening process, one would expect some statistical distribution of particles in all three streams of output from the screening machine.

Figures 3.18 to 3.20 show various views of the Vortex machine rejected by CBR on return to the Ocker plant. Figure 3.21 is a close-up view of some weld runs on the machine frame.

Interviews with Ocker staff indicated that they relied on CBR expertise in the choice of the specific machine supplied to CBR as well as for the testing regimen used by CBR to evaluate the operation of the Vortex separator chosen by them for their specific screening task.

On several measurements taken on the rejected machine the width measurement was found to vary by no more than 3 mm and the diagonal measurement was found to be within 3 mm. In sheet-metal work on a dimension of nearly 2500 mm (the physical size of the machine supplied to and rejected by CBR) a tolerance of 3 mm cannot be regarded as excessive. Australian Standard 1100.201-1992 gives guidance on general tolerancing of machined components in the range of 1000 to 2000 mm as ± 1.2 mm (medium series) and ± 3 mm (coarse series). The bed of the specific machine, a welded sheet-metal construction, was found to be well within these recommendations.

Inspection of welding on the machine frame and sides indicated better than adequate weld quality (refer to Figure 3.19). On the whole my inspection of the rejected machine indicated that its general construction complied with the description and specifications given in the *Ocker Product Description and Product Specification Brochure*. The general appearance of the machine was clean, but it seemed to have been left to rust in the open. The missing gearbox bolts and drag link ends indicate either improper operation or attempts at unauthorised maintenance modifications at some stage of its life at CBR.

3.4.4 Lessons Learnt and Outcome

As already noted above, size and shape will affect the screening process, more or less, independently of each other. Nowhere in the *Ocker Product Description and Product Specification Brochure* is there any mention of separation quality for rubber particles. Moreover, the choice of screens, and the ensuing screening performance, is critically product dependent. Almost invariably the ultimate screening performance is determined by the client's choice of screens and machine mechanical parameters (power and speed generally). In the case of the Vortex machine supplied to CBR, they chose the screens on the basis of considerable experience both with other Vortex machines and the product to be screened. Consequently, this particular claim appears to shift blame for CBR's failure in making the right machine and screen choices.

The *Ocker Product Specification and Product Description Brochure* clearly defines and identifies the mechanical characteristics of the Vortex machine supplied to CBR. I have compared the mechanical characteristics of the machine with its *Product Description and Product Specification* and found it to be consistent with those descriptions and specifications.

There were mitigating circumstances for both sides of this dispute. Both CBR and Ocker had colluded in this deal where promises and expectations were not fully articulated by carefully specifying product performance. CBR failed to fully identify their expectations from the separator with their relatively new product. Ocker failed to fully and clearly identify the substantial uncertainties that might exist with attempting to separate a product with which they had no experience.

Ocker had hopes of continuing with sales of more Vortex machines to CBR, who, in turn, would need to have some level of interaction with Ocker in planning CBR's growing and changing sorting needs. Ultimately the dispute went to mediation and was resolved by mutual agreement.

3.5 Snap-freezer Fails to Freeze Pasta

3.5.1 The Case Culture

Freeze-drying of foodstuffs is one of the spin-off processes of space exploration. Most food contains large quantities of water (more than 30%) and by removing this water, avoiding sublimation to ice, the food may be preserved almost indefinitely. This procedure is performed by freezing freshly prepared food at a pressure below atmospheric to draw out the water content. When properly processed, freeze-dried food may be stored for unlimited periods and eventually reconstituted with almost no loss of flavour or character by adding water. Freeze-dried food has been the staple diet of astronauts on space exploration missions ever since the late 1960s. Probably the most amazing product is *"astronaut icecream"*, freeze dried in three flavours,which may be consumed at room temperatures on the warmest day without melting it.

Fresh pasta is a foodstuff with a high water content and therefore easily perishable. Its spoilage is due both to the metabolic activity of micro-organisms (bacteria, yeast, moulds) which can easily grow in the product and to various enzymatic activities. The presence of micro-organisms is unavoidable and all preserving processes applied throughout the production process can only restrict their number and effects without eliminating them. So the shelf life of fresh pasta is substantially determined by the level of the microbic count remaining in the product at the end of the preparation process. Snap freezing is a process in which the temperature of freshly prepared pasta is rapidly lowered below the triple point of water.[3.11] In this state the frozen pasta is packaged in air-tight packaging, occasionally including oxygen-excluding substances, and can be stored for considerable periods without perishing.

3.5.2 The Defining Event and Parties to the Dispute

Pavarotti Pasta has been making home-made pasta to supply their *Conditori* restaurant and a few special customers for a number of years. When Mr Pavarotti retired, his son, *Domingo Pavarotti*, decided to commercialise the business and to commence making pasta on a larger scale for supermarkets. Domingo was aware that commercial pasta needed to be either freeze-dried or snap-frozen for packaging, the latter process being the cheaper system to set up. A local refrigeration contractor, *Carreras Heating, Ventilation and Airconditioning (Carreras)*, were commissioned to design and install a snap-freezing system at Pavarotti Pasta. The whole system was manufactured and installed by Carreras in late 1995. Some minor *teething* problems with this installation were attended to by Carreras in the first part of 1996. Shortly thereafter Pavarotti became dissatisfied with the installation and issued a writ against Carreras, claiming that:

3.11 The temperature at which all three phases, liquid, solid and vapour, are in equilibrium. For water this is at a fraction of a degree Celsius above zero at atmospheric pressure.

(a) Motors installed in the snap-freezer for driving the various conveyor systems overheated and on many occasions were stopped by their thermal cutouts.

(b) Black ice formed on the conveyor belts inside the freezing tunnel and this jeopardised the hygiene of the whole system.

(c) There appeared undue wear on the conveyors, with some fine metal particles being shed onto pasta as it passed through the tunnel.

An essential component of the snap-freezer installation was the conveying system used to transport pasta through the freezing tunnel. For reasons of hygiene this conveyor was constructed with a double-dipped galvanised machine frame and a conveying mesh of grade 304 stainless steel. Grade 304 is the most versatile and most widely used stainless steel, available in a wider range of products, forms and finishes than any other. The 304 grading is a designation of the American Iron and Steel Institute (*AISI*), and contains 18% chromium and 8% nickel, the remainder being iron and other trace elements. The conveying mesh was supplied by *Callas Wire Mesh (Callas)*, an internationally respected conveying wire mesh supplier, and they recommended their special spiral woven mesh to Carreras.

For reasons unclear, Carreras engineers decided that the major culprit in this dispute was Callas, as they were responsible for having recommended and supplied the most visible component of the whole snap-freezer system. As a consequence of this apparently arbitrary evaluation Carreras issued a writ against Callas, based on the following claims:

(a) The conveying belts recommended and supplied by Callas were entirely unsuited to the application at Pavarotti.

(b) Ice and hoar frost built up on the conveyor due to the mesh being too finely woven for this application.

(c) The black ice formed in the freezing tunnel was due to inappropriate material choice for the conveyor mesh supplied by Callas.

3.5.3 The Role of the Expert and the Investigation

Counsel acting for the product liability insurer of Callas, *Josh Moses*, invited me to investigate the claims of Carreras and offer opinion regarding the design and operating reliability of the installation at Pavarotti. In addition I was asked to pay specific attention to the suitability of the wire mesh supplied by Callas to Carreras.

Figure 3.22 is a schematic elevation of the freezing tunnel conveyor system. Figure 3.23 shows some schematic detail of the pasta conveyor. Figure 3.24 shows photographs taken inside the freezing tunnel (the transfer end of the freezer conveyor) and Figure 3.25 shows the drive system just outside the freezing tunnel. The return conveyor design was necessitated by the need to have both input and delivery of frozen pasta at the same loca-

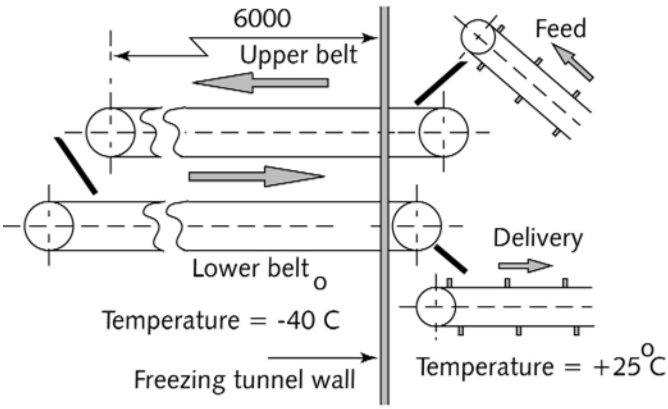


Figure 3.22 Schematic elevation through the freezing tunnel conveying system

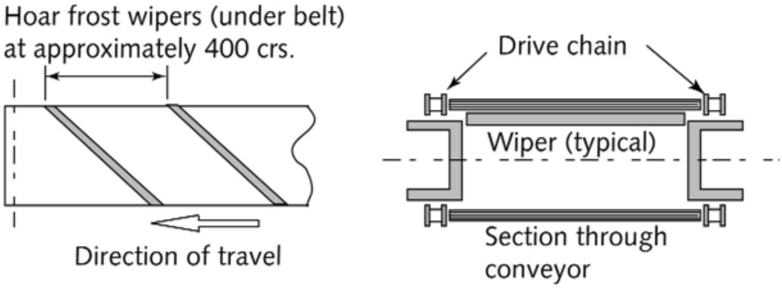


Figure 3.23 Schematic views of the conveyor belt and conveyor frame

tion. Figure 3.24 shows the transfer end of the pasta conveyor inside the freezing tunnel. Figure 3.25 is a photograph of the arrangement of wipers beneath the conveyor belt. These were introduced by Carreras to combat the hoar frost that continued to form beneath the conveyor mesh.

My brief from counsel was to investigate the design of the freezing system and to offer opinion about:

1. Suitability of the conveyor belt supplied by Callas for this application and in particular the capacity of these wire mesh belts to withstand the temperatures experienced in the conveyor system.
2. Appropriateness or otherwise of the design of the conveyor system and the ability of this system to fulfil the requirements of its use at Pavarotti Pasta.
3. General design of the conveyor system, considering its use in a food-related application.
4. Features of the conveyor system designed to prevent or deal with any build up of water or ice and any design modifications necessary to

Figure 3.24 Transfer end of conveyor inside the freezing tunnel

Figure 3.25 View underneath the conveyor belt showing hoar frost wipers

prevent such build-up, with specific reference to the presence of black ice on parts of the conveyor.

5. The design of the drive system of the conveyor given the very special nature of the application in the food industry.

Drive Motors

The following calculation establishes the approximate power requirements of the drive motors (each conveyor inside the freezing tunnel is driven by its own drive motor of 370 W).

Friction power requirements (data supplied by Callas):

Belt area (top only) = 6 x 0.564 = 3.384 m^2

Belt mass = 31.29 kg/m^2 gives 3.384 x 31.29 = 105.9 kg

Total driven mass at the top of each conveyor includes 2 x 6 m drive chain of mass 0.6 kg/m

Total driven mass = 2 x 6 x 0.6 + 105.9 = 113.1 kg

Friction coefficient (dry steel on dry steel) = 0.4

Speed of top conveyor belt = 0.103 m/sec

Power to overcome friction only

= 113.1 x 9.81 x 0.4 x 0.103

= 45.7 W

Ice carrying power requirements – For a conveyor designed to work in a freezing tunnel at – 40°C, exchanging materials at ambient conditions, one would expect that at the exit from the freezing tunnel the conveyor will be below the dew point. Hence condensation will form, resulting in frost and ice forming on the conveyor, once it returns into the freezing tunnel. Due to the close weave of the belt it is expected that it will be fully encrusted in ice almost immediately after it starts to operate. In the following I have calculated the weight of ice corresponding to the full belt area on top of each conveyor.

Top area of each belt = 3.384 m^2

Belt thickness = (approx.) 0.006 m

Ice volume (conservative estimate)

= 3.384 x 0.006 = 0.0203 m^3

Ice weight = 0.0203 x 1000 x 9.81 = 199 N

This adds only about 20% to the friction power requirements, hence is of no real consequence.

Ice-breaking power requirements – Once the conveyor ices up, as the belt passes over the pulley at the inner end (inside the freezing tunnel), the ice will need to be broken. This breaking process is independent of the radius of curvature of the pulley, since whatever the radius, excepting unnaturally small radii, ice breaking will be determined by the chain pitch (refer to Figure 3.26).

Based on a conservative estimate of the tensile strength of solid ice (σ_T = 100 x 10^5 Pa), and considering the conveyor belt to be made up of sheer ice, the force needed to break the ice as each chain is bent away from the horizontal is calculated from simple bending theory.

Breaking tensile stress σ_T = Moment/Section modulus

Section modulus of ice sheet (based on conveyor belt cross-section):

Belt section = 564 mm wide (b) x 6 mm (d) deep

Modulus = $b \times d^2/6$ = 564 x 6 = 3384 mm^3 = 3.38 x 10^{-6} m^3

Chain pitch = 12.7 mm

Moment = 12.7 x 10^{-3} x F Nm

σ_T = 100 x 10^5 = (12.7 x 10^{-3} x F)/(3.38 x 10^{-6})

F = (100 x 10^5 x 3.38 x 10^{-6})/(12.7 x 10^{-3}) = 26.6 N

This breakage occurs every time a chain link passes over a sprocket.

Rate of breakage

= 103 (belt speed)/12.7 (chain pitch) = 8.1 per second

Power to break ice

= 8.1 x 26.6 = 216 W

Adding this to the friction power of 45.7 W brings the power requirement to 261.7 W. Noting that as well as breaking ice for half the sprocket circumference, any ice retained in the gap between sprockets will be crushed as the conveyor mesh straightens out for its return journey on the underside.

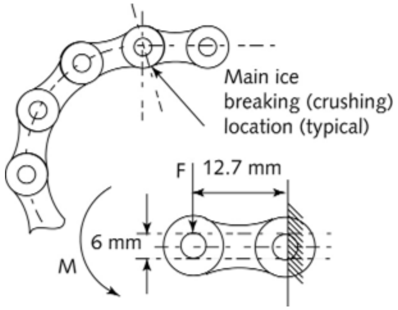


Figure 3.26 Built-up ice needs to be broken as conveyor belt and chain wind around pulleys

Ice crushing and frost scraping power requirements – Although the estimate of power based on friction and "ice breaking" is somewhat conservative, there are two other matters about the drive which a competent designer would need to consider.

Ice crushing will occur as the conveyor belt passes over the head and tail pulleys. Ice will have formed inside the belt interstices, as already alluded to above, and as the belt is stretched and rolled over the pulleys, this ice will be crushed by the surrounding metal mesh. Because ice is a brittle material, its crushing strength will certainly exceed its tensile bending strength. Consequently the force and corresponding power required to crush the ice under these condition will actually exceed the force and power needed to break it in bending. Adding this crushing power to that estimated above will bring the motor power close to its maximum available.

Finally, the hoar frost and ice formed on the underside of the conveyor belt is scraped off by metal scrapers (refer to Figure 3.22). The friction forces imposed by these scrapers are difficult to estimate, but they may add up to more than the friction power already calculated above.

Conveyor Belt and Transfer System Design

If this conveyor system were designed as the transfer mechanism in any plant other than one handling food products, it would be satisfactory. However, the sliding surfaces will inevitably cause metal particles to be rubbed off and they will no doubt contaminate the food matter on the lower conveyor belt. Welds on the belt tensioner system and the transfer chutes indicate significant corrosion. This could be caused by improper welding techniques, or by incorrect use of materials. In either case the result is less than adequate from a hygiene point of view.

The overall design of the conveying system is very poor. There are many nooks and crannies, which are difficult to clean or disinfect adequately. The use of exposed chains and shaft ends (see Figure 3.24) is another weakness of the design in terms of hygiene. Material scraped off from the underside of the belt as it moves along can fall down (and through the mesh) onto the return belt taking frozen pasta to the delivery conveyor.

Black Ice

One significant component of stainless steel is nickel (Ni, usually in proportion 6% to 22%), depending on the type of stainless used. Type 304 (the belt material) has around 8% to 10% Ni. Nickel is a transition element (refer to periodic table of chemical elements) and forms various oxides, a hydrated form of which, nickelic hydroxide (NiOOH), is black. This compound forms in the presence of air and some oxidising agent. The oxidising agent could be from salt compounds in the pasta or from traces of the lubrication oils or greases in the bearings of the conveyor.

On the Galvanic table[3.12] of materials in sea water, stainless steel 304 is listed as number 36, zinc (as used in hot-dip galvanising) at number 4 and

3.12 http://www.eaa1000.av.org/technicl/alodine/galvanic.htm; see also Kutz (1998); Schweitzer (1996); Rehrig (2002).

graphite as number 88. The lower the number the more reactive the material and when any pair of materials are interconnected in a salt solution the one with the lower number will preferentially corrode. In this application there were at least two possible forms of Galvanic corrosion. Zinc on the rubbing surfaces of the machine frame was in contact with the stainless-steel conveyor drive chain. The material used in the bearings as well as on the rubbing surfaces was a graphite based lubricant. Both had the possible action of precipitating some form of galvanic reaction in the stainless steel.

Health regulations

An investigation of existing standards and/or health regulations pertaining to hygiene or the adequate design of conveying means or mechanical handling apparatus in the food industries revealed the following.

The Australian National authority responsible for these regulations is the Australia and New Zealand Food Authority. A phone call to this authority revealed that they mainly deal with food identifications and food quality. They have no specific regulations regarding hygiene in food-handling industries. The Victorian authority is the Department of Human Services, Food and Water – Public Health Division. A further call to this authority resulted in a response similar to that from the National Authority.

A search of the Australian Standards data base resulted in only one relevant standard dealing with hygiene in the food industry, namely AS 2996-1987, *Cleaning and Sanitising Plant and Equipment in the Egg Handling Industry*. A review of this standard showed it to pertain only to whole and processed egg handling. Egg products, such as pasta, do not rate a mention.

3.5.4 Lessons Learnt and Outcome

Based on the above data and investigations I concluded the following:

1. *Suitability of the conveyor belt supplied by CWM for this application* – Conveyor mesh belts supplied by Callas Wire Mesh to Carreras were entirely suited to this application. In fact it was a case of a slight "overkill" in that the Callas belts supplied could carry a much larger load than the pasta load imposed by Pavarotti Pasta. However, the prime requirement seemed to be that the belts' surface should not make any significant marks on the soft pasta. Consequently a closely wound mesh belt was required.
2. *Appropriateness or otherwise of the design of the conveyor system* – There appeared to be several problems with the mechanical design of the conveyor system.

   (a) Conveying belts passed between ambient and freezer conditions constantly accumulating frost and causing excessive load on the drive system. As a result the drive motors were expected to operate continuously near or occasionally above their rated performance. This was a substantial weakness in a design where lengthy stoppages could not be tolerated.

(b) Stainless steel conveyor drive chains were carried on a galvanised machine frame, exposing the conveyor system to substantial rubbing wear as well as possible Galvanic corrosion. The mesh belt supplied by Callas did not have a heavy load to carry. The drive chain was designed to be carried on several pulleys rather than a continuous rubbing surface. Clearly, with the loading experienced at Pavarotti, continuous support was unnecessary.

(c) Exposed bearings and lubricating materials created an unhygienic environment and exposed the stainless steel to the formation of black NiOOH through Galvanic action.

3. *General design of the conveyor system, considering its use in a food-related application* – As well as the above noted problems with this design, two other matters were seen as serious weaknesses in the design specific to the food-related industry.

   (a) Scraping hoar frost from the conveyor belt caused contaminated particles of metal to fall on frozen pasta on the return conveyor. This could have been prevented with some form of shielding between the two conveyors.

   (b) Corrosion of welded components of the machine frame possibly due to corrosive cleaning or Galvanic action presented an unhygienic environment for food handling.

4. *Features of the conveyor system designed to prevent or deal with any build-up of water or ice and any design modifications necessary to prevent such build-up, with specific reference to the presence of black ice on parts of the conveyor* – These issues have been dealt with in the responses above.

5. *The design of the drive system of the conveyors given the very special nature of the application in the food industry* – This has been dealt with in the responses above.

The case described here is very common in industries where specialist consultants are used to design and construct mechanical equipment. Although Carreras were experienced and competent in the freezing technology, they appeared less than competent in the design of the conveyor system. They asked advice from Callas about the conveyor belt, but simple though it may seem conceptually, the actual mechanical construction of the conveyor was fraught with various pitfalls in this application. Once caught out in their inexperience with the mechanical construction they chose to blame Callas, the supplier of the major component, namely the wire mesh belts. The matter was settled by Carreras' insurers, without any involvement on behalf of Callas Wire Mesh.

3.6 Non-absorbent Fibreglass Causes Tank Failure

3.6.1 The Case Culture and the Initiating Event for the Dispute

Water conservation is a worldwide issue for anyone concerned with environmental sustainability. This is a particularly important issue in water-deprived countries such as Australia. Many rural communities use water tanks connected to roof catchment areas to boost their meagre water reserves. Within the last few years there has been a growing interest in urban communities for the installation of underground water tanks to catch rain water or even *"grey water"* for irrigation. *Sherman Tanks* is a business providing fibreglass tanks to a wide range of household and small industrial users. Tanks are formed up from fibreglass-reinforced plastic resin (FRP). Each half tank is made in a former in which glass fibre and resin are mixed and deposited with a spray gun called a *gun roving spray-up gun*. *"Roving"* is a thick bundle of glass fibre formed into a long continuous yarn, passed into the gun, where it is chopped into short lengths, mixed with resin and blown out onto the surface of the mould.

For a number of years Sherman have been importing their fibreglass gun roving, *Hybon 6000* from the *PPG* Corporation[3.13] in North America. In late 1999 Sherman marketing were approached by a local supplier, *I. M. Better Ltd.* (*IMB*) and offered a substantially cheaper product, *Gun Roving Ruger B59 (B59)*, to replace the imported Hybon 6000. In addition, IMB also supplied two pallet loads of B59 roving (96 packs, sufficient for the manufacture of several FRP tanks) to Sherman operations staff for a trial of the new glass fibre product. Shortly after adopting the new B59 roving, Sherman had several large water tanks collapse while being transported to customer's site. IMB spent some time investigating the problems but eventually claimed that the problem was with Sherman's manufacturing process and not with their B59 product. I was asked to prepare an expert witness report for mediation in this dispute and the complete report is presented in the next section.[3.14]

3.6.2 Expert Witness Report in Gun Roving Dispute

Contents

3.13 Pittsburg Paper and Glass.

3.14 The advice of John Bushby in preparing this expert's report is gratefully acknowledged.

- *The claims of Sherman in relation to being unaware of the influences the changed behaviour of B59 roving had on the manufacture of water tanks in comparison to the previously used Hybon 6000*
- *The pleadings of IMB in their defence*

Analysis of Information

Concluding Comments and Opinion

Introduction

1. This report has been prepared for *Bing Ding and Wong* (*BDW*) Lawyers of 22 Johnson St., Melbourne, 3000, acting for their client *I. M. Better Ltd.* (*IMB*), in a dispute between IMB and *Sherman Tanks* of Rosebud, Victoria (*Sherman*). The dispute concerns the supply of certain *"gun roving"*, B59, used for spray deposition of glass-reinforced resin in the manufacture of fibreglass reinforced plastic (*FRP*) water tanks. The gun roving was supplied by IMB to Sherman as a replacement equivalent in performance to the previously used Hybon 6000.
2. Sherman's alleged purpose in purchasing the gun roving from IMB was to replace gun roving Hybon 6000, previously supplied by PPG Industries Inc. – Pittsburgh USA to Sherman. The replacement was intended to support local industry and to permit the manufacture of FRP water tanks at a reduced cost.

Précis of the Dispute

3. The following is a brief précis of the matters relating to the dispute addressed in this report:

   (a) In about December 1999 Sherman changed their supplier of gun roving from PPG and Hybon 6000 to IMB and B59.

   (b) It seems that Sherman's major concern in acquiring B59 as an alternative to Hybon 6000 was that the new product, B59 should have closely similar properties to the Hybon 6000 product.

   (c) Between January and April 2000 IMB supplied Sherman with B59 gun roving. This B59 gun roving was used by Sherman to manufacture numerous fibreglass water tanks. Subsequently a number of these tanks collapsed either during delivery or on site, requiring replacement. As a result Sherman suffered financial loss, for which loss Sherman holds IMB responsible.

   (d) IMB's defence against the alleged responsibility for the failure of Sherman's FRP tanks includes the assertion that gun roving placement in manual spray-up of fibreglass tanks is critically influenced by the skill of the gun operator and the manufacturing conditions prevailing at the time of manufacture.

   (e) In particular, Sherman's manufacturing protocols, as a responsible manufacturer in their position, made it mandatory that they carry out tests involving the manufacture of sample sheets of FRP prior to going into full-scale production of FRP tanks.

(f) Moreover, Sherman staff did not carry out continuous quality control of their tanks during manufacture and as a result they failed to ensure that proper manufacturing protocols in relation to quality assurance and continuous quality management were followed.

4. I have been asked by BDW to advise and offer opinion on the following matters:

(a) Manufacturing protocols of a competent manufacturer in the position of Sherman and whether those protocols were followed in their dealings with IMB.

(b) The influence any departure from those protocols would have on losses suffered by Sherman due to the failure of their tanks.

(c) Supplier protocols of a competent supplier in the position of IMB in supplying the B59 gun roving to Sherman and whether those protocols were followed by IMB in their dealings with Sherman in this matter.

(d) Key differences between the two types of gun roving, the subjects of this dispute, and the influence these differences have on their fitness for purpose as gun roving to be used in the manufacture of FRP water tanks.

Executive Summary of Findings

5. Based on my examination of the history of supply of B59 gun roving by IMB to Sherman, it is my considered opinion that Sherman did not follow the accepted protocols for a competent manufacturer in applying continuous quality assurance standards. Moreover, IMB did follow supplier protocols appropriate to a competent supplier, and their supply-chain performance cannot be held to blame for the losses suffered by Sherman.
6. Based on my examination of the strength specifications for the two gun rovings, namely B59 and Hybon 6000, I find that the two products have almost identical strength characteristics.[3.15]
7. I have been advised that a soluble glue (size) is used to bind glass fibres into the bundled yarn of the roving. In addition a major uncertainty in the use of gun rovings is associated with the specific chemistry of the size used to bond the glass filaments together in the roving. This uncertainty might well influence the way in which the wetting of the roving takes place during fibreglass spray-up.
8. Had Sherman followed accepted manufacturing protocols of a competent manufacturer, they would have detected any differences in size chemistry and wetting through characteristics of the B59 gun

3.15 Comparison of published mechanical properties for the rovings is presented in Table 3.5.

roving that might influence the strength and rigidity of their water tanks during early trials of the product.

9. Sherman should have carried out early trials of the B59 gun roving before proceeding to full-scale manufacture of water tanks. There is no evidence that Sherman ever conducted any trials on the new B59 roving. Had they conducted such trials they would not have incurred the failures of the many tanks claimed in the writ against IMB.
10. Taking account of the manufacturing process and quality control processes followed by Sherman at their premises, I have formed the view that the failures of tanks manufactured in the period January to April 2000 are directly related to insufficient pre-production testing of the new B59 roving as well as to poor quality control procedures followed at the plant.

Briefing Materials and Investigations

11. Table 3.3 lists the briefing material supplied to me by BDW. I have inspected and read all the material in the documentation relevant to this matter, including the *Expert Witness Code of Conduct*.
12. On Tuesday 5 August I attended the premises of Sherman in Rosebud in the company of TR, a member of IMB's technical staff. I was shown around by JF, managing director of Sherman, who authorised me to view the construction of a tank in the plant. Figure 3.27 shows a typical Sherman FRP water tank, Figure 3.28 shows a typical gun roving applicator gun and Figure 3.29 is a view of the weighing station at the Sherman plant. Tank forming takes place on a weigh bridge, which is used to continuously weigh the mould as it is being formed during spray-up.

Table 3.3 Information and documents supplied to me

Item	*Date*	*Description*
1	*2000*	*B59 gun roving product information prepared by IMB*
2	*2000*	*PPG data sheet for Hybon 6000 spray up roving*
3	*02/05/99*	*Customer acceptance standard CAR95 prepared by IMB for B59 continuous roving designed for spray-up operations*
4	*03/2000*	*IMB test data for glass contents in laminates using both B59 and Hybon 6000*
5	*07/09/01*	*Letter from counsel acting for Sherman detailing damages to water tanks constructed by Sherman using B59 gun roving*
6	*29/11/02*	*Writ xxx2/02 against IMB as pleaded by Sherman*
7	*21/02/03*	*IMB's defence pleadings*

Figure 3.27 Sherman FRP water tank

Figure 3.28 Gun roving spray gun

Figure 3.29 Weighing station used in quality control

Figure 3.30 Spray-up of tank in progress

13. Figure 3.30 is a general view of the spray-up operation. The process involves one or more expert gun operators standing inside the half tank mould and laying down the inside tank skin around the inside cylindrical surface of the tank mould. Once this surface is completed down to and including the lower corner of the tank form, other operators proceed to roll out the glass resin mix to clear out any bubbles in the laminate.
14. Once the side wall is complete, a further spray-up operation completes the bottom layer of the half tank.
15. The glass resin mix is deposited according to the skill of the operator of the spray gun and according to a total deadweight system continuously monitoring the mass of the tank mould, the operators standing in the mould and the mass of glass being deposited.
16. At no time was a depth gauge used or the wall thickness of the tank being moulded checked during my inspection of this operation.

Table 3.4 Event chronology

Event	Date	Description
1	December 1999	Sherman decide to change their supplier of gun roving from PPG Industries Inc. to I. M. Better Ltd. (IMB).
2	February 2000	IMB supply two pallets of B59 gun roving (the new roving) to Sherman for trials to establish properties and to check performance of this gun roving compared to their experience with Hybon 6000 (the roving being abandoned in favour of B59).
3	January to April 2000	IMB supplies large quantities of gun roving to Sherman, who use it to manufacture about 59 tanks, 38 of which collapse and require replacement and 21 of which show damage and require repairs.
4	March to April 2000	Sherman discover that B59 has a faster wet-out than the previously used Hybon 6000. The implication of this issue is that Sherman claim B59 to be different in nature and composition from Hybon 6000 and that these differences cause substantial changes in the manufacture of fibreglass tanks.
5	April 2000 onwards	Sherman find that the resin did not absorb the B59 roving as readily as the previously used Hybon 6000. This difference resulted in thinner tanks than was the case with the previously used Hybon 6000. Several tanks collapse and require replacement or repair.

Background History

17. Table 3.4 sets out the chronology of events relating to this matter.

Evaluation of Information

(a) The claims of Sherman in relation to being unaware of the influences the changed behaviour of B59 had on the manufacture of water tanks in comparison to the previously used Hybon 6000.

18. In paragraphs 6(e) and 6(f) of Sherman's claims it is stated that:

> *"6(e) Sherman required gun roving to be supplied to it which matched, was of the same composition as, and/or had the same characteristics as, that previously supplied to it by PPG;*
>
> *6(f) Sherman required gun roving which was the same composition, and had the same characteristics, as PPG Hybon 6000;"*

19. In paragraph 10 of Sherman's claim it is stated that:

> *"10. In or about March and April 2000 Sherman discovered that the gun roving was defective and/or was not adequate, and/or fit, for the purpose for which it was acquired ("the defects").*
>
> *Particulars*
>
> *(a) The gun roving had a faster wet-out than the PPG Hybon 6000 previously used by Sherman;*

Table 3.5 Published properties of B59 and Hybon 6000

Property	B59 dry	B59 wet	Hybon 6000 dry	Hybon 6000 wet
Flexural strength average (MPa)	176.5	156	181	182
Flexural modulus (GPa)	7.47	6.8	7.9	6.6
Tensile strength (MPa)	91	83.5	88.9	87.6
Glass content (% by wt)	30–33	30–33	32	332

(b) the gun roving was different in nature, and composition, from the PPG Hybon 6000;

(c) the gun roving was not properly absorbed by the resin supplied by FGI and as a result the tanks manufactured by Sherman had a glass content of approximately 40% and a resin content of approximately 60% which resulted in a thinner tank and a tank which had substantially less flexural strength than it would have had had the resin content been higher;"

(b) The pleadings of IMB in their defence

20. In paragraph 6(c) of their defence IMB plead (bolding mine):

"(c) Without limiting the generality of this denial, it says further that the defendant supplied the raw material for commercial use subject to and in accordance with a 'Disclaimer of Liability' upon which it will rely at trial in the proceeding herein.

Particulars

The aforesaid 'Disclaimer of Liability' is published by the defendant's Product Information Data Sheet in the following terms:

Disclaimer of Liability

This data is offered solely as a guide in the selection of a reinforcement. The information contained in this data sheet is based on actual laboratory data and ***field test experience****. We believe this information to be reliable, but do not guarantee its applicability to the user's process or assume any liability arising out of its use or performance.* ***The user, by accepting the products described herein, agrees to be responsible for thoroughly testing any application to determine its suitability before committing to production.*** *It is important for the user to determine the properties of its own commercial compounds when using this or any other reinforcement.*

Because of numerous factors affecting results, we make no warranty of any kind, express or implied, including those of merchantability and fitness for *a particular purpose. Statements in this data sheet, shall not be construed as representations or warranties or as inducements to infringe any patient or violate any law, safety code or insurance regulation."*

Analysis of Information

21. Considering the information contained in the two product specifications, namely B59 roving and Hybon 6000 roving, Table 3.5 lists the relevant properties – average values.
22. Clearly, the differences in strength and flexural properties between the two products are marginal. It seems that the main difference may be the size (binding material) used for consolidating the glass filaments in the roving until it is deposited from the gun as fibreglass spray-up.
23. Interviews (informally) with manufacturers of the guns used in delivering the mix of glass and resin during the spray-up process has revealed that considerable skill is needed to generate an even distribution and a predictable behaviour of the eventual fibreglass laminate resulting from the spray-up process.
24. Fibre reinforced spray-up plastics are widely used throughout the FRP industry for the manufacture of swimming pools, tanks and marine hulls. While the process or manufacture for these products has become generally accepted, in all cases the protocols followed by responsible manufacturers of FRP products conduct manufacturing trials of new and previously untested materials of construction to establish product performance.
25. Between January and March 2000, IMB supplied two pallet loads of B59 roving to Sherman for pre-production testing. The proper protocol for a responsible FRP product manufacturer in Sherman's position would have made use of these pallets of B59 roving to establish pre-production mechanical properties for FRP laminates produced with this new and yet untested manufacturing material. I have seen no evidence of any mechanical properties obtained by Sherman from such almost mandatory pre-production tests of the B59 roving. Moreover, I have seen no evidence of any mechanical property specification for the tanks being produced by Sherman. Yet the generic mechanical properties of FRP spray-up laminates are widely available throughout the FRP industry .
26. I have been supplied with a simple and useful thickness gauge that is widely available throughout the FRP industry to ensure that consistent thickness of glass resin mix is achieved in spray-up operations. Many glass manufacturers including IMB provide such thickness gauges to their customers freely.
27. I have seen no evidence that Sherman made any use of a thickness gauge in their manufacturing process. The use of such a gauge would

have ensured that a consistent thickness of glass resin mix was being delivered during the spray-up manufacture of their FRP laminate tanks.

28. Discussions with technical staff at IMB offices on 12 June indicated that in their experience, while inspecting Sherman operations using B59 roving, gun operators using the B59 roving did not make use of such thickness gauge during the manufacture of FRP tanks.
29. In the pleadings of Sherman *"Particulars paragraph 6(j) it is claimed that the tanks had a flexural rigidity of 38 N.m [sic]"*. The proper unit of flexural rigidity is the force required to impart unit deflection. In the SI system of units this mechanical property is measured in newtons/metre. If the flexural rigidity of a tank was indeed 38 N/m then it would take only a load of 3.8 kg to deflect the tank wall by a metre and that would be a very flexible tank indeed.
30. Based on the pleadings of Sherman as noted in paragraph 30 above, they appear to have a deep misunderstanding of the nature of stiffness and strength characteristics of fibre-reinforced plastic laminates. Typically the amount of resin or glass content in the laminate does not directly determine these mechanical characteristics of the laminate. It is the distribution and orientation of glass through the laminate section that critically influences these matters.
31. Figure 3.31 is a photograph of the rolling-out process applied to the wet FRP matrix on completion of the spray-up. This is a manual process relying on the skill and experience of the spray-up operator. This process can introduce considerable unevenness into the glass fibre distribution in the FRP matrix. Figure 3.32 illustrates some hypothetical sample distributions of glass reinforcement through a fibre reinforced plastic laminate.
32. Hypothetically, in a 3 mm tank wall a 0.5 mm unevenness; i.e., even distribution over 2.5 mm of the wall (say) would have the effect of reducing bending rupture strength in the ratio of $(2.5/3)^2$. This is a reduction of bending strength to about 69% of that of an evenly distributed glass section of 3 mm thickness. Stiffness reduction is even worse, with the reduction of the order of $(2.5/3)^3$. This would be about 58% of expected stiffness. In other words, a relatively small (16% in the example) unevenness in the distribution of glass through the laminate will

Figure 3.31 Roll-out of the FRP matrix

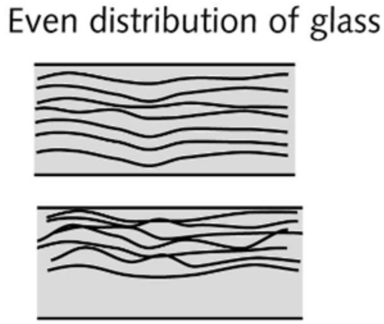


Figure 3.32 Hypothetical glass distribution in tank wall (schematic)

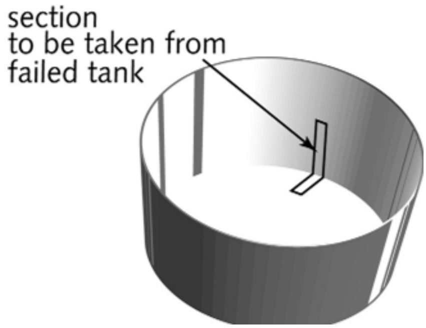


Figure 3.33 Key section of tank to be tested

have a significant influence on the mechanical properties of the laminate (31% reduction in bending rupture strength and 42% reduction in stiffness in the example).

33. In paragraph 10(c) of Sherman's pleadings it is claimed that the roving was not properly absorbed by the resin and the proportions of the glass and resin in the mix with the new roving was 40% and 60% respectively rather than 30% and 70% as was the case with the previously used roving.
34. "Wet-out" is a term that relates to the time required for the resin to penetrate through the glass fibres in the resin glass mix as it is sprayed onto the tank moulds during spray-up. Consequently, it would be expected with faster wet-out that the resin would behave in a way that seemed less viscous in seeping through the glass roving during deposition than would be the case with slower wet-out.
35. It is my opinion that as a result of a faster wet-out a larger proportion of the resin would seep through to the inside surface of the tank as it was being sprayed onto the tank former or mould. Moreover the main result would be that the distribution of glass in the glass-resin mix would be different to that with a slower wet-out.
36. Based on the above evaluation I have formed the opinion that it was the uneven glass-resin distribution in the tank walls of the failed tanks that was the major contributor to the failure of these tanks. An examination of samples of laminate (as shown schematically in Figure 3.33) taken from the walls of the failed as well as from those of sound tanks would help in confirming this opinion.
37. My general impression of tank manufacture at the Sherman Rosebud plant was that the spray-up operation is very much dependent on operator skill and experience. Material placement in the tank is based on a continuous weighing process and hence there is no absolute certainty about the thickness or glass/resin distribution in the tank wall. These matters are critical to tank strength and stiffness.

Concluding Comments and Opinion

38. A responsible manufacturer in the position of Sherman would have carried out extensive tests on a new raw material used in the production of one of their core products such as the FRP water tanks.
39. The pre-production testing of raw materials of FRP construction should be a mandatory quality control measure when using gun roving for an FRP spray-up operation. This is due to the considerable uncertainty that exists in the manufacture and resulting mechanical properties of FRP spray-up products.
40. In the pleadings of IMB, in relation to any guarantees of performance of the B59 roving supplied to Sherman they draw special attention to the uncertainties of the FRP spray-up manufacturing process.
41. Moreover, IMB, following appropriate supplier protocols of a competent supplier of products to the FRP manufacturing community, did provide two pallets of B59 roving to Sherman for evaluation prior to Sherman commencing full-scale production of FRP tanks.
42. Based on the above evaluation of evidence presented to me I have formed the opinion that Sherman did not follow appropriate manufacturing protocols of a responsible manufacturer of FRP products. This is especially relevant, as they offer substantial guarantees to their customers about the structural performance of their water tanks.
43. Sherman has shown no evidence of carrying out pre-production establishment of mechanical properties of FRP spray-up laminates produced with the new B59 roving. Moreover I have not been shown any technical specifications required of mechanical properties to be achieved in satisfactory tanks produced by Sherman. Only by comparing the mechanical properties required of satisfactory tanks with the mechanical properties consistently produced by the spray-up operation at Sherman could we properly establish the acceptability or inappropriateness of the manufacturing processes used by Sherman. In the absence of the above-noted evidence, it is my opinion that inappropriate manufacturing protocols and poor quality management are the root cause of the tank failures experienced by Sherman.
44. Consistent reproduction of mechanical properties in FRP laminates resulting from gun spray-up operation is critically dependent on gun operator expertise and well-defined and consistent quality control procedures. Despite the fact that Sherman has recently gained ISO9001[3.16] accreditation, I saw no evidence of any continuous quality control procedures being followed during the tank manufacture at my inspection on 5 August.
45. Sherman technical staff advised me that the completed tanks are checked for wall rigidity after manufacture. Although this may be a

3.16 ISO9001 is a continuous quality management standard.

key characteristic of the tank mechanical properties, it does not provide a direct evaluation of tank wall rupture strength.

46. Sherman technical staff provided the information that the Rosebud plant of Sherman is capable of manufacturing 30 to 40 tanks per day depending on orders. Based on this information the failures reported in the pleadings of Sherman correspond to a very brief period of production in the order of only a few days.
47. It is my considered opinion that a prudent and responsible manufacturer of FRP laminate products would carry out extensive testing and evaluation of a new glass reinforcing product. Only after such testing would such a prudent and responsible manufacturer commence full-scale production of FRP laminate products.
48. Furthermore, as the failures of their tanks occurred after only a brief time of experience with the new roving (the subject of this matter), it is my opinion that their failures were a direct result of insufficient operator experience with the new roving and ineffective quality control procedures during tank spray-up.
49. My considered conclusion is that they now have the requisite experience to maintain consistent tank laminate behaviour. I also conclude that their claims against IMB are based on simple lack of experience in using the B59 product and inappropriate quality control procedures for the spray manufacture of FRP laminate of consistent mechanical properties.

3.6.3 Lessons Learnt and the Outcome

The real winner in this case was experience. As Soren Kierkegaard famously remarked *"Life must be understood backwards; but …. it must be lived forward."* I suspect he too was talking about experience. In this case both parties were culpable. IMB represented themselves as fibreglass experts and caring providers of gun roving. It was insufficient to simply "contract themselves out of responsibility" by their disclaimer. If they really cared for their customers, then their technical staff should have participated in the initial evaluation of the FRP performance of their product. In essence, IMB technical staff should have been more aware of the uncertainties in the application of the gun roving in FRP products than their customer Sherman.

Sherman technical staff, on the other hand, were culpable because they went ahead and commenced-full scale production without the proper safeguards of pre-production testing.

This matter was settled at mediation by mutual consent. There were clear motivating factors for mutual settlement on both sides. Sherman were keen to continue manufacturing tanks with the B59 roving. IMB, on the other hand, were keen to avoid even a shadow of any unfavourable publicity with their B59 product.

3.7 Wheelchair Transporter Fails to Secure Wheelchairs

3.7.1 The Case Culture and the Initiating Event

In a guest editorial to the September/October 2000 issue of the *Journal of Rehabilitation Research and Development*, Professor Douglas Hobson, Director of Rehabilitation Engineering Research Centre at the University of Pittsburgh noted:

> *"The Americans with Disabilities Act (ADA) and Individuals with Disabilities Education Act (IDEA), have provided, among many other things, more opportunities for all persons using wheelchairs to gain better access to public transportation. … Because many people either elect to or must remain in their wheelchairs while riding in a vehicle, a number of issues related to the safety and security of the wheelchair-seated person are raised, especially in the event of a vehicle collision ….*
>
> *One critical design aspect of the occupant protection system is the relationship between the vehicle seat, the occupant, and the occupant restraint (lap belt, shoulder belt, and air bag). First, the seat is securely fastened to the vehicle and designed to hold the occupant in a limited range of body positions relative to the occupant restraint device(s). Second, this system is designed to limit and control the motion of the occupant relative to the interior of the vehicle during an impact event. When a person substitutes a wheelchair for a regular vehicle seat this protection system no longer functions as designed and the wheelchair occupant may be at significant increased risk of serious injury."*

The matter described in this section concerns the safe transport of wheelchair bound adults between their homes and sheltered workshops in and around Melbourne. Wheelchair transport vehicles (WTV) are commonly purchased by City Councils for sheltered workshop transport within their areas of influence. A major supplier of WTVs is *Tiergarten Ltd.,* an internationally respected organisation better known for the manufacture of semi trailers and tankers for road transport. WTVs represented a small segment of their regular market. Tiergarten would be supplied with a transit van and they would be responsible for the provision and installation of securing means for wheelchair bound passengers. Tiergarten's quality management system for these installations was partly imposed by ISO9001 as well as Australian Standard AS 2942.[3.17] Under these standards, Tiergarten was required to perform regular quality tests on their installation, including tests in a *"crash laboratory"* to ensure that the structural integrity of the wheelchair constraints met AS 2942. It was during one these regular test regimes that Tiergarten technical staff were advised of the structural failure of their securing system. A key feature of the securing system was a type of railing that provided the anchorage for the seat belts used in the

3.17 ISO9001 is a continuous quality management standard; AS 2942-1987 is a standard devoted to and titled Wheelchair Occupant Restraint Assemblies for Use in Motor Vehicles.

Tiergarten's wheelchair securing system. It was these anchorages that were reported to be failing in designated crash tests.

Anchorage railing was supplied to Tiergarten by Spender Ltd., an importer of a great variety of structural elements designed for the securing of cargo in transport (typically, hold-down equipment used for securing cargo in trucking and aircraft). Spender had been the supplier of anchor track to Tiergarten since 1991. The original track supplied was a Canadian product called *E-track*. Sometime in 1997 the Canadian supplier advised Spender that they have chosen to discontinue supply of E-track. As a result Spender sourced a local replacement product also called E-track, but of a slightly different design to the originally supplied Canadian E-track. They advised Tiergarten of this change in 1997. Spender continued to supply the Canadian E-track to Tiergarten until their supplies ran out, after which they commenced delivery of the locally made E-track. The crash test failures occurred in 2000, and as a result of their failed crash tests with the newer E-track, Tiergarten issued a writ against Spender. I have been asked by Messrs *Bing Ding and Wong* (*BDW*), acting for the product liability insurer of Spender, to investigate this matter and to prepare a report for mediation. The resulting report is presented fully in the next section.

3.7.2 Expert Witness Report in the Matter of Tiergarten and Spender

Contents

Introduction

1. This report has been prepared for *Bing Ding and Wong* (*BDW*) Lawyers of Melbourne, acting for their client *Spender Pty. Ltd.* (*Spender*), in the matter of *Spender and Tiergarten Industries Pty. Ltd.* (*Tiergarten*). This matter concerns the supply of certain cargo securing tracks, known as an *E-track*, supplied by Spender to Tiergarten from about 1991 until about 3 April 2000.

2. Tiergarten's alleged purpose in purchasing these cargo-securing tracks was that they would be used in the design and construction of transport vehicles for wheelchair-bound handicapped persons.

Précis of the Matter

3. The following is a brief précis of the matters addressed in this report:

   (a) In about late 1991 Tiergarten approached Spender for the purchase of a cargo-securing track known as E-track. Spender supplies similar tracks to a wide range of transport industries for securing cargo during transport.

   (b) Spender offered Tiergarten two alternative tracks, one made from Australian steel and one made from Canadian steel. Tiergarten chose to purchase the E-tracks made from Canadian steel.

   (c) Sometime in late 1997 Spender advised Tiergarten that the E-track made from Canadian steel was no longer available and that Spender could continue to supply Tiergarten with E-track made from Australian steel.

   (d) Tiergarten continued to accept the E-track made from Australian steel in lieu of their previously chosen E-track made from Canadian steel. This state of affairs continued until early 2000, at which time Tiergarten issued writs against Spender for supplying E-tracks made from Australian steel when in fact they had earlier contracted to be supplied with E-track made from Canadian steel.

   (e) Tiergarten has claimed that the E-track made from Australian steel is inferior in performance to the originally contracted E-track made from Canadian steel. This claim is made partly based on performance tests of these tracks to Australian Standard AS 2942 as seat belt anchorages for wheelchair-bound persons during transport. As a result Tiergarten further claims that due to modifications needed to the E-track made from Australian steel and due to vehicle recalls they have suffered financial loss for which they claim Spender is responsible.

   (f) Spender disputes these claims on the basis that they informed Tiergarten of the changed supply of E-track, and Tiergarten failed to make appropriate design changes when the change in supply occurred.

4. I have been asked by BDW to advise and offer opinion on the following matters:

   (a) Manufacturing protocols of a competent manufacturer in the position of Tiergarten and whether those protocols were followed in their dealings with Spender and what influence departure from those protocols would have on the losses they suffered in this matter.

(b) Supplier protocols of a competent supplier in the position of Spender in supplying materials and equipment to a manufacturer and whether those protocols were followed by Spender in their dealings with Tiergarten in this matter.

(c) Key differences between the two types of E-track, the subjects of this dispute, and the influence these differences have on their fitness for purpose as seat belt anchorages in vehicles designed to transport wheelchair-bound persons.

Executive Summary of Findings

5. Based on my examination of the history of supply of products by Spender to Tiergarten, it is my considered opinion that Tiergarten did not follow the accepted protocols for a competent manufacturer in applying continuous quality assurance standards. Moreover, I aver that Spender did follow supplier protocols appropriate to a competent supplier and that their supply-chain performance cannot be blamed for the losses suffered by Tiergarten.
6. Notwithstanding the clear and timely advice provided by Spender to Tiergarten about the changes in the supply of E-tracks, the differences in the two E-tracks are so overwhelming, both in appearance and in documentation of orders and invoices, that any manufacturer following competent quality assurance procedures would have detected these and taken appropriate action.
7. The central holes in the E-track made from Australian steel represent a serious structural weakening of this product in comparison to the E-tracks from Canadian steel, which had no central holes. This structural weakness is so significant that any competent manufacturer following widely accepted quality assurance protocols would have detected this weakness and would have taken appropriate action.
8. The design and construction of seat belt anchorages is a safety critical issue bound by the relevant Australian Design Rule (ADR 0504)[3.18] and Australian Standard AS 2942-1994 (originally AS 2942-1987). Any change in the E-tracks used for seat belt anchorages have imposed on them mandatory verification requirements by ADR 0504 and AS 2942. The manufacturing protocols followed by a competent manufacturer in the position of Tiergarten would demand that the seat belt anchorage design must be verified at the time when the change in E-track supply occurred. Tiergarten's loss is a direct result of their failure to follow such a protocol.

Briefing Materials and Investigations

9. Table 3.6 lists the briefing material supplied to me by BDW. I have inspected and read all the material in the documentation relevant to

3.18 The Australian Design Rules set out design standards for vehicle safety and emissions. They have been developed through a consultative process involving government, industry, employee and consumer representatives.

Table 3.6 Briefing materials suplied to me

Item	Date	Description
1	1997	A bundle of representative example invoices relating to the purchase of both the Canadian and Australian E-track
2	1987	Australian Standard 2942-1987 – wheelchair occupant restraint assemblies for motor vehicles
3	08/1992	Crashlab's special report SR 92/386.
4	19/04/2000	Crashlab- Test Report: TR2000/ 042.
5	04/09/2000	Letter of Metlabs (metalurgical test results on E-tracks) to Tiergarten
6	11/09/2000	Crashlab test report TR2000/299.

Table 3.7 Further material obtained through direct inspection or by investigation

Item	Date	Description
7	05/2003	Obtained Australian Design Rule 5/04 relating to seat belt anchorages (provided in the Addendum to this report)
8	05/2003	Track specifications for both Canadian and Australian E-track (provided in the Addendum to this report)
9	09/2003	Colour photographs of Crashlab tests performed in August 1992
10	17/10/1997	Purchase order number TP LP 5544
11	30/10/1997	Spender delivery docket to Tiergarten order number TPLP5544
12	30/10/1997	Spender invoice number 28678 drawn on Tiergarten for order number TPLP5544
13	12/12/1997	Spender invoice number 28936 drawn on Tiergarten for order number TPLP5618
14	01/09/1997	Fax from Spender to technical manager at Tiergarten

this matter including documents in the possession of the Plaintiff (Tiergarten) and the Defendant (Spender). Table 3.7 lists further material that I obtained through direct inspection or by investigation.

Background History

10. Table 3.8 sets out the sequence of events relating to this matter.
11. It seems that after due consideration, Tiergarten chose to purchase the E-track product made from Canadian steel from Spender, who subsequently continued to supply this product until late 1997.

Table 3.8 Sequence of events relating to this matter

Event	Date	Description
1	1991	*Spender is asked to supply E-track to Tiergarten for design and construction of transport vehicles for wheelchair-bound adults*
2	1991	*Spender offers two types of product to Tiergarten for consideration in their design and construction. These are a product from Canadian steel and a similar product made from Australian steel.*
3	1992	*Tiergarten informs Spender that they have chosen the product made from Canadian steel for their design and construction of the transport vehicles. Spender commences supply of the product made from Canadian steel to Tiergarten*
4	08/92	*Crashlab carries out tests on the product made from Canadian steel. Two sets of tests are performed, both on the product made from Canadian steel. One test involves a special Tiergarten design combining lap and rear restraint. This restraint system fails during side impact tests due to the seat belt clips pulling out from the slots in the E-track.* *The second Crashlab tests involve a 6-point restraint system, namely 4-point anchorage for the wheelchair and a separate 2-point anchorage for the lap belt of the occupant. These tests succeed and Tiergarten adopts this design.*
5	10/97	*Spender informs Tiergarten that E-track made from Canadian steel is no longer available and will supply the product made from Australian steel instead. Tiergarten continues to order E-track from Spender.*
6	04/00	*Tiergarten orders new Crashlab tests on their design now with the product made from Australian steel. This arrangement is shown to fail due to the seat belt clips pulling out of the track slots during side impact tests*
7	09/00	*Metlab carry out tensile tests on both types of E-tracks, namely the product made from Canadian steel and the product made from Australian steel*
8	09/00	*Tiergarten engineers design modifications for the product made from Australian steel. The modified product is tested by Crashlab and is found to succeed.*

12. I make reference to the *Statement of Claim* of Tiergarten paragraph 4(e).

    "the Plaintiff required the Defendant to supply the product manufactured from Canadian tensile steel and not local Australian steel, because the Product manufactured from local Australian steel had failed compliance testing ..."

13. I have not been able to find any evidence of compliance testing of the product made from local Australian steel prior to April 2000.

Evaluation of Information

(a) *The claims of Tiergarten in relation to being unaware of the change in supply of E-track from Spender*

14. In paragraph 13 of Tiergarten's claim it is stated that:

> *"The Plaintiff did not know until about 3 April 2000 of the fact that the Defendant had been supplying it with the Product manufactured from local Australian steel and not Canadian tensile steel."*

15. Paragraph 14 (b) of Tiergarten's claim in its Particulars makes reference to the clear differences between the two types of E-track supplied by Spender, namely the product made from Canadian steel and the product made from Australian steel:

> *"The local Australian made Product did not pass Australian compliance testing. Further, the local Australian Product differs in thickness of material, thickness of track, type of holes, position of holes, material, finish and yield strength from the Product made from Canadian tensile steel."*

16. Purchase order number TP LP 5544, dated 17 October 1997, lists two items with the same part number, 40838-10-01, having different unit costs (*$31.65* and *$33.55*).
17. This purchase order originated at Tiergarten and it is clear that they were aware of the different length of the product ordered from Spender in October 1997. The use of the same part number for the two different products may be due to an internal error at Tiergarten. Nevertheless, the different length of the two different products should have alerted Tiergarten about a change in the supply of the products from Spender in October 1997.
18. Spender delivery docket for Tiergarten order number TP LP 5544 and Spender invoice number 2867, dated 29 October 1997 and 30 October 1997 respectively, also for Tiergarten order number TP LP 5544 both list the delivery and invoicing of two consignments of E-track with part numbers 40838-10-01, of length 3.048 m, at a unit cost of $31.65 and 40838-10, of length 3.66 m, at a unit cost of $33.55.
19. Delivery docket of Spender to Tiergarten order number TP LP 5618 and Spender invoice number 28936, dated respectively 9 December 1997 and 12 December 1997, both list a consignment of E-track part number 40838-10 of length 3.66 m at a unit cost of $33.55.
20. It is clear from the above documents that Spender was making reference to two different part numbers and two different lengths when supplying E-track to Tiergarten orders. I have been advised by BDW that part number 40838-10-01 refers to the product made from Canadian steel, while part number 40838-10 refers to the product made from Australian steel.

21. Manufacturing protocols of a competent manufacturer would demand that some form of quality assurance procedure be followed at the point of acceptance of products used in manufacturing. This procedure would be especially required when the products being supplied are to be used in a safety critical design and construction such as seat belt anchorages for wheelchair transport vehicles.
22. On their website, *www.tiergarten.com.au*, Tiergarten list equipment for disabled access as one of their products. They also list the motto *"quality without compromise"*. In this sense Tiergarten is representing itself as designer and manufacturer of products committed to quality assurance. It is widely accepted in manufacturing that competent manufacturers would use quality assurance systems equivalent to those prescribed by the ISO 9000 series of standards, including stringent acceptance audit systems.
23. ISO 9000 is a widely accepted set of standards for quality management. Currently more than 90 countries, including Australia, have adopted ISO 9000 as their national standards. When a product or service is purchased from an organisation that follows the appropriate ISO 9000 standard, important assurances are provided that the quality of what is to be received will be precisely as described and detailed in the manufacturer's or service provider's documents. In addition, the year 2000 revision of the standard's quality objectives, including continuous improvement, provides the customer with increased assurances that their needs and expectations will be met.
24. An essential part of the ISO 9000 standard is the use of acceptance audit systems. Within such an audit system, it is mandatory to follow up changed conditions of supply. Had Tiergarten used such an acceptance audit system the changes in the conditions of supply of products from Spender should have been readily detected in December 1997.
25. The fax from Spender to technical staff at Tiergarten, dated 1 September 1997 advises:

    "As advised only 3.66 m long locally made E-track is now stocked @ 33.50 per length Part No 40838-10"

26. This fax further confirms that the part number used for the Australian product is 40838-10 and its length and part number clearly differs from that of the product made from Canadian steel.

(b) The pleadings of Spender in their defence

27. The following is a précis of the pleadings of Spender in relation to the supply of the relevant products.

    27.1 The plaintiff has pleaded, at paragraphs 11 and 12 of the statement of claim, that Spender supplied the Canadian product until *"about April 1997"*, after which the Australian product was provided.

27.2 At paragraph 24 of the defence, Spender pleads as follows:

"The defendant informed the plaintiff that:

(a) E-track product manufactured in Australia was available to it; and

(b) E-track product manufactured in Canada was not available to it:

during conversations in or about September and/or October and/or November 1997 between technical staff on behalf of the defendant and technical staff of the plaintiff. By, a facsimile transmission sent by the defendant to the technical manager of the plaintiff on or about 1 September 1997 the plaintiff was informed by the defendant that only the Australian made product was stocked by the defendant. A copy of this facsimile transmission may be inspected at the offices of the solicitors for the defendant".

27.3 At paragraph 27 of its defence, Spender pleads that the Australian product replaced the Canadian product pursuant to agreements between the parties, as follows:

"The Agreements are partly orally, partly in writing and partly to be implied.

To the extent they are oral, the defendant refers to and repeats the particulars under paragraph 24, and says that employees of the plaintiff responded by stating that the plaintiff agreed to purchase the Australian made product. The plaintiff will provide further particulars of these conversations after discovery by the plaintiff.

To the extent they are in writing, the defendant refers to each purchase order from the plaintiff to the defendant and each invoice and delivery docket from the defendant to the plaintiff relating to each purchase of the Australian made product in and after October 1997.

To the extent they are implied, the defendant relies on the conduct of the plaintiff in ordering the Australian made product from the defendant in and after October 1997 in circumstance where:

(a) As at September 1997, the Canadian made product was not available and the Australian made product was available to the defendant.

(b) The Canadian made product had a different product code to that of the Australian made product.

(c) The plaintiff had been informed by the defendant of matters referred to in (a) and (b) above.

(d) The Australian made product visibly, differed from the Canadian made product including in thickness of material, thickness of track, types of holes, position of holes, and finish and

(e) The plaintiff was or should have been aware of the matters referred to in (a), (b) and (d) above."

27.4 At paragraph 28 of the defence, Spender pleads that the plaintiff was negligent and caused its own loss because it should have been aware of the matters pleaded in paragraphs 20 and 23, but despite that, it:

(a) Continued to manufacture its wheelchair restraint system from the Australian made product and to sell that system to its own customers;

(b) Should have but did not assess or test the Australian made product to see if it was fit for the purpose, including any requirement that it satisfy the alleged compliance requirements or the Australian standards;

(c) Should have but did not re-design its wheelchair restraint system in a manner which was fit for the purpose; and

(d) Should have but did not choose an alternative E-track vertical product which was fit for its purpose."

Analysis of Information

28. Figure 3.34 is a photographic comparison of the two types of E-track. The one marked E-track (a) is the originally supplied Canadian product and the other marked E-track (b) is the Australian product. Figure 3.35 shows the two types of track installed in tranport vehicles. The modification made by Tiergarten to E-track (b) is also seen.
29. Referring to the photograph in Figure 3.34, I have been advised that the track identified as E track (b) in this photo is the product made from Australian steel.
30. Referring to the mechanical properties of the two E-tracks (Table 3.9), on tensile strength and yield point the the two products are closely matched. Only in elongation at failure is there a substantial difference. Tests conducted by Metlabs (a material testing authority) in September 2000 (Doc. No. 000810/2) showed that the tensile strength of both track materials exceeded their specified values.
31. The Crashlab tests on the product made from Canadian steel were carried out according to the Australian Standard AS 2942-1987. This

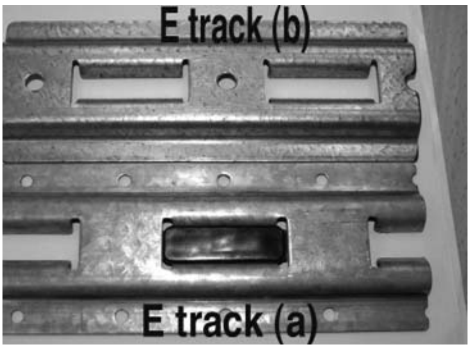


Figure 3.34 Two types of E-track. E-track (a) is the Canadian product and E-track (b) is the Australian version

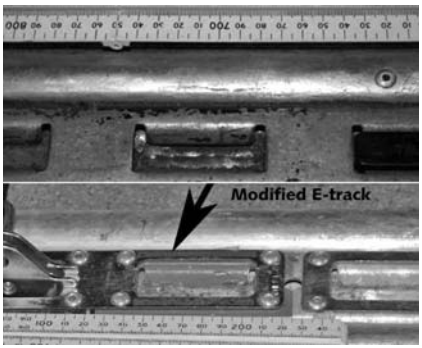


Figure 3.35 Two types of E-track mounted in transport vehicles. The lower photo shows the modification to the Australian product

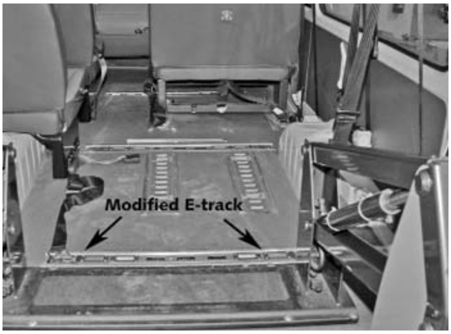


Figure 3.36 Modified E-track installed in a transport vehicle

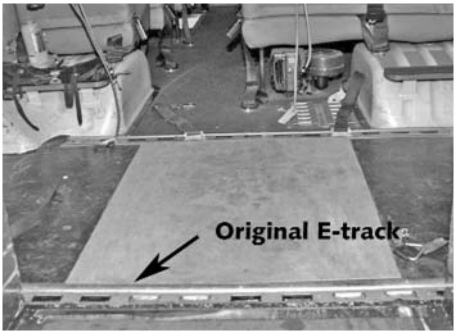


Figure 3.37 Original E-track installed in a transport vehicle

Table 3.9 Mechanical properties of the two types of E-track[3.19]

E-track type	Yield point minimum MPa (psi × 10^3)	Tensile strength minimum MPa (psi × 10^3)	Elongation in 50mm(2 inch) minimum %
E-track (a)	255 (37)	360 (52)	18
E-track (b)	280–330 (40.4–47.7)	330–380 (47.4–54.9)	27

was the appropriate standard operating at the date of these tests. The track met the standard's requirements.

32. A new amended version of the AS 2942 was published in 1994 and a further amendment to that standard was published in 1998. Neither of these newer standards materially change the relevant loading, anchorage and test methods identified in the earlier edition of the standard. Hence, there was no specific necessity for Tiergarten to carry out subsequent testing of their restraint system, unless there was a material design change, or a change in the material being supplied by Spender.
33. Once Tiergarten manufacturing staff became aware of the changes in supply (see paragraphs 16 to 18 above) it became mandatory for them to carry out further compliance tests on the products being supplied by Spender in late 1997. The fact that they failed to do so speaks to Tiergarten's failure in following manufacturing protocols expected of a competent manufacturer in the position of Tiergarten.
34. Crashlab tests were carried out on the product made from Australian steel in April 2000 (refer to Crashlab report TR2000/042). These tests found that this product failed to meet the standard's requirements. Failures reported by Crashlab in their April 2000 tests showed

3.19 Refer to the introduction and also to the Primer on Mechanics in Appendix 2.

that the seat belt clips inserted into the track, designed to restrain the wheelchair under crash conditions, pulled out of the track during testing under side impact loading.

35. The photos of Crashlab report TR2000/042 show that the product made from Australian steel (E-track (b))was mounted by the edges of the track during these tests (See also the photographs in Figures 3.36 and 3.37). The central holes in the product made from Australian steel appear to represent a significant structural weakness in the track, particularly when considering the type of loading placed on the track during side impact. This type of impact places unevenly distributed loads on the track elements as indicated in Figure 3.38, a schematic view of the seat belt clip inserted into E-track experiencing side impact loading. Clearly, in the arrangement shown, the seat belt clip will tend to slide closer to the left edge of the track slot due to the clearance between the clip and slot engagement. In this way more of the seat belt clip will be in contact with the left edge of the track slot than with the right edge and uneven loading on the track results.
36. The uneven loading on the track during side impact further exacerbates the structural weakening of the track by its central holes and severe bending of the track locally and disengagement of the seat belt clips is the most likely failure mode. The results of the Crashlab tests, report TR2000/042, clearly show this effect in the failure mode of the product made from Australian steel.
37. When Crashlab tests in April 2000 found that the product made from Australian steel failed to meet AS 2942 during side impact loading, Tiergarten designed and installed a modification to the tracks. The modification was a rectangular plate installed around the track slots where the seat belt clips engage. These modifications were designed to strengthen the track slots at their engagement points with the seat belt clips and to basically overcome the failures experienced in the earlier Crashlab compliance tests (Refer to Figures 3.36 and 3.37).

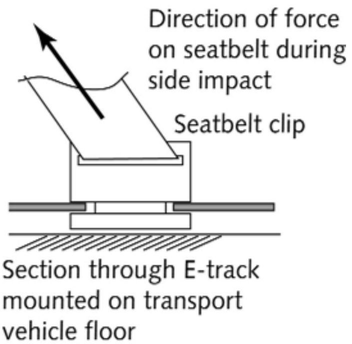


Figure 3.38 Force on seatbelt during side impact

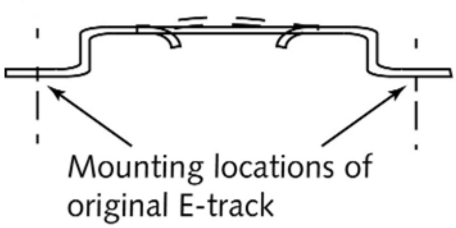


Figure 3.39 Mounting arrangement of originally supplied E-track

38. Further Crashlab tests followed in September 2000, to evaluate the modifications made to the product made from Australian steel. These tests showed that the modified track met the requirements of AS 2942 in that it no longer deformed so severely or allowed the seat belt clips to disengage during side impact loading.
39. On Wednesday, 14 May I attended the premises of *Manic Motors*, Campbellfield Victoria, to inspect a wheelchair transport vehicle fitted with the modified E-track made from Australian steel. Figure 3.36 is a photograph of this E-track fitted to the wheelchair transport vehicle.
40. The modifications to the track are made up of several small plates fitted to the upper surface of the track, in an attempt to increase its thickness and thereby provide greater resistance to the seat belt clip disengaging during testing at the levels of acceleration demanded by AS 2942. The plates are rivetted to the track as seen in the close-up photo in Figure 3.35.
41. Notably, the modified E-tracks have been mounted in the transport vehicle by their edges. Also, as noted above in paragraph 35, in the Crashlab tests the various tracks were all mounted by their edges during testing.
42. Considering the two track types shown in Figure 3.34, the most significant structural difference between the two tracks is the central hole in the product made from Australian steel when compared to the product made from Canadian steel.
43. I have been advised by Spender technical staff that E-track (b), made from Australian steel, was available with and without the central holes. These central holes are designed to act as drainage holes in applications where cargo is exposed to to the weather .
44. Given that the tracks were safety critical in the application planned by Tiergarten, the fact that they chose to purchase the apparently structurally weaker track, when a structurally stronger one (one without the central drainage holes) was available, speaks to a serious weakness in their competence as designers and manufacturers.
45. Because the tracks were supplied without edge holes (in many transport truck applications the tracks are welded to the chassis of the truck) it would have been a simple matter to mount the tracks via the already present central holes. Had Tiergarten taken this approach, then the seat belt securing arrangement, using the E-track made from Australian steel, would have been structurally stronger than the edge-mounted product made from Canadian steel under the same seat belt anchorage loading conditions.
46. A widely accepted industrial practice in continuous quality management is the regular quality testing of products. With safety-critical

components on motor vehicles and especially in relation to seat belt anchorages ADR 5/04 makes such regular testing mandatory.

48. By analogy with ADR 5/04 for motor vehicles, it would have been mandatory for Tiergarten to test seat belt anchorages in wheelchair transport vehicles when the change of supply of tracks from Spender commenced in October 1997.

Concluding Comments and Opinion

49. There were several clearly identifiable differences between the two products supplied by Spender to Tiergarten. Documentation in the form of invoices and delivery dockets shows differences in part numbers, product lengths and unit costs. These matters have been referred to in paragraphs 16 to 18 above. There were also clear visually detectable differences between the two products. Tiergarten refers to these differences in paragraph 14(b) of their *Claims*.
50. Given that there was a failure to carry out proper acceptance quality assurance audits of the documentation relating to the two different products, Tiergarten should have detected the clear visual and structural differences when the change in product delivery advised by Spender occurred in late 1997.
51. The failure of Tiergarten to test the new tracks, when they were first supplied by Spender, is contrary to accepted industrial practice. Continuous quality assurance is a clear requirement of responsible and competent manufacturing, especially in relation to a safety critical product. This failure is also contrary to the clear requirements of ADR 5/04 with respect to seat belt anchorages.
52. The choice of the product, made from Australian steel with their central holes, when an equivalent track without these holes was available, indicates a significant weakness of Tiergarten engineering staff in understanding and appreciating the considerable structural influence these holes would have on the performance of the tracks in the duty to which they were intended.

3.7.3 What Has Been Learnt and the Outcome

ISO-9000-based quality management is an ordered and caring procedure adopted by manufacturers who take professional pride in their products and the way they deal with their customers. Unfortunately, the large volume of detailed minutiae of information collection, practical safeguards and documentation involved in the ISO 9000 procedures tend to deter many manufacturers from following these procedures "by the book". A key element of the ISO 9000 prescription for continuous improvement in manufacturing quality is the ultimate elimination of all error from administrative procedures. This requires a *snail trail* to be generated whenever an error occurs and error correction procedures are launched. The snail trail is the trail of evidence that is designed to grant the error correcting investigator the capacity to pinpoint the location of the original error and to make appropriate changes to prevent it from occurring in the future.

The experience with their change in E-track deliveries would allow Tiergarten to follow a trail of evidence back to where and how they were able to overlook the clearly signposted changes in delivery. Spender marketing staff also learnt the hard lesson that one cannot deal with customers while completely removed from their manufacturing operations. In cases such as this, the notion of *caveat emptor* simply does not constitute good business. Interestingly. the modification made to the Australian E-track cost significantly more to accomplish than would a change of mounting arrangements using the central holes in the new E-track. Curiously, Tiergarten was averse to a change in mounting arrangement because this meant a complete review of safety testing.

Ultimately the failure to appreciate the structural consequences of their aversion to change may be encapsulated in the old cliché often quoted in the various armed services: *"we never have the time to do it right but we always seem to find the time to do it again."* The matter was settled at mediation.

3.8 Shrinking Brake Seal Collapses Aftermarket Venture

Aftermarket is the term applied to the market offering spare parts and service to manufactured products outside the sphere of influence of the original manufacturer of the product. The automotive aftermarket industry is concerned with manufacturing, remanufacturing, wholesaleing, distribution and retailing of all vehicle parts, accessories, tools, equipment and services, *except those products which are used in the manufacturing of original equipment*.

Brothers *Kostas and George Koumas* ran a brake repair shop *KGK Ltd.* for the servicing and replacement of automotive brake cylinders. Among their customers the largest single group requiring brake replacements were the taxi community. Kostas and George did some preliminary calculations and found that by making their own wheel cylinders, locally, rather than purchasing them directly from importers, they could make a substantial financial killing in the aftermarket business for brakes. KGK have already invested in machine tools to service brake cylinders where they could get away with repair rather than replacement. They even had a little manual testbench for evaluating the performance of repaired brake cylinders. All of their repairs used proprietary product neoprene brake seals specially manufactured and imported by *RPB Ltd*. Of course, KGK were not averse to a little "reverse engineering". They saw the RPB brake seals as the only stumbling block to their venture into the large-scale aftermarket brake cylinder field. A medium to large manufacturer facing the need to source components for a new product would generally consult material specialists, industrial designers or anyone who can advise them about their planned product.

GKG knew that the component they were seeking was an elastomer (an artificial rubber product). What they did not appreciate was the complexity of attempting to manufacture such a product. In the event, they did not have anyone to advise them about the quality issues involved in their planned new product.

3.8.1 The Case Culture and the Defining Event

KGK approached a reputable rubber product manufacturer, *Dunpac Ltd*., for the supply of brake seals. After several meetings with Dunpac, during which the nature of the application of the planned newly manufactured KGK brake seals was fully discussed, Dunpac agreed to design and manufacture the seals for KGK. A key feature of the agreement between KGK and Dunpac was based on some sample RPB seals and the agreement that Dunpac would supply seals to KGK that were *"just like the RPB seals"*. Here we seem to run into a natural weakness of the type of agreement between the two parties KGK and Dunpac. Brake seals are a safety-critical item in the operation of motor vehicles. The Australian Design Rules, operating at the time of this contract between KGK and Dunpac, stipulated that the brake seals must meet SAE test requirements.[3.20] Unfortunately, there was no mention of any such testing in the agreement between KGK and Dunpac. No doubt there were verbal promises made, not the least of which was the reputation of Dunpac in the processed rubber industry. Equally unfortunately, as Samuel Goldwyn had famously remarked, *"a verbal contract is not worth the paper it's written on."*

KGK then went ahead and invested further funds in casting patterns and numerically controlled machine tools. They ordered a large batch of brake cylinder castings, as well as professionally designed branded packaging. Once the first batch of Dunpac brake seals arrived the new brake cylinders were assembled and briefly tested for leaks on a test-bench. Several brakes were installed, at no charge, in taxis waiting to have brakes repaired. This act was seen as a "loss leader" by KGK, the costs to be recouped when all the taxi contingent would change to the newer locally made KGK brake cylinders.

Two events rapidly conspired to thwart KGK's venture into what they hoped would be a lucrative aftermarket field. The first was an immediate reduction in the cost of imported brake cylinders by the local importer and wholesaler. The much more serious second event ensued when the taxis, issued with the newly manufactured KGK cylinders, all had brake failures shortly after installation of the new brake cylinders. Not only did this second event hurt KGK immediately, but it also lost an immense amount of marketing good will. When the failed cylinders were disassembled and examined it was found that the Dunpac brake seals had shrunk in use. To prove the influence of the shrunken Dunpac seals, KGK reassembled the

3.20 Society of Automotive Engineers, World Headquarters 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA.

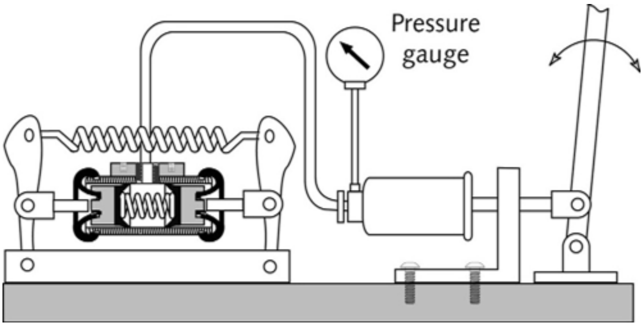


Figure 3.40 Brake cylinder leakage test rig (schematic)

failed brake cylinders with some seals originally obtained from RPB. These reassembled brake cylinders were exposed to bench testing for extended periods and found to function satisfactorily. Figure 3.40 shows the style of test rig used by KGK to test their brake cylinders for leakage. After this shattering experience with their new brake cylinders, Kostas and George sought professional help in their quest to continue with production, while hoping to be compensated by Dunpac.

3.8.2 Parties to the Dispute and the Client

My involvement in this minor disaster was initiated by a personal visit to the KGK brake emporium for the repair of brakes on my motor vehicle. While settling my account, Kostas Koumas, recognising a kindred engineer, lamented the misfortunes of their planned business venture. He and George then took me into their by now derelict *"factory"*, set up for machining and assembling brake cylinders. I was struck by the passion they appeared to have for preferring Australian-made products ahead of those imported from overseas. This passion, coming from a pair of Greek migrants, aroused in me such a *pro-bono* feeling that I agreed to examine their problem and offer technical opinion on possible recovery from their situation. I did have a minor vested interest in following up the failure of KGK's business venture. At the time I had a responsibility for preparing engineering design projects for my courses at the University of Melbourne and I assessed the KGK case as one well suited to student exploration.

Ultimately this turned out to be the case with a project on the engineering design and manufacture of brake cylinders. The following brief description of this case is based on a combination of my investigation coupled with some student group investigations. In essence, the dispute in planning was between KGK (the plaintiff) and Dunpac (the probable defendant). My brief was to review the events leading up to the failure of the brake cylinders and to offer opinion in relation to a writ issued by KGK's lawyers against Dunpac.

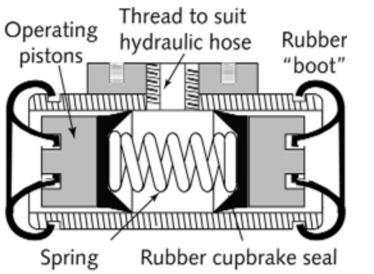


Figure 3.41 Brake cylinder (schematic)

3.8.3 The Role of the Expert and the Investigation

Figure 3.41 shows a schematic section through the brake cylinder. These cylinders range in size from 60 mm to 100 mm in length. The seal cups, contracted to be made by Dunpac, had a complex chemical formulation. In the first batch they produced for KGK, the rubber cup brake seals were found to shrink approximately 15% to 25%, by volume when exposed to the brake fluid for extended periods. On examination, the brake fluid used in the taxi brakes that were found to leak, was Castrol Anti-Corrosion oil type TS23-2-01, a diacetone alcohol (2 methyl-2-pentanol-4-ona), which is a ketone and an alcohol (25%). The data sheet provided by Castrol lists its use as a power transfer medium. In my experience such fluids are used in hydraulic rams and other power control equipment. In this sense they are designed to operate in more demanding conditions than the brake cylinder application.

When the original RPB seals, the models for the Dunpac seals, were immersed in this oil they were actually found to expand in volume by between 5% and 10%. The Dunpac seals were found to always shrink in volume. The substance of the dispute between KGK and Dunpac may be summarised by their respective claims and pleadings.

(a) KGK's Statement of Claim

1. KGK made contact with Dunpac to get a quotation for the manufacture of "rubber cup brake seals" and "boots"[3.21] needed as parts of the aftermarket brake cylinders to be manufactured.
2. Dunpac had an established reputation for the manufacture of rubber products. In this case it was clear that KGK went to them for their expertise in this area. At no time did Dunpac disabuse KGK of their belief in their competence in rubber chemistry and the formulation and manufacture of rubber components.
3. Most of the discussion between KGK and Dunpac seemed to centre around the production volume for the components. There was no mention of the complexity of rubber product chemistry or testing for functionality of the product, i.e., the cups must not shrink if prime safety-critical functionality – no leakage– was to be maintained.
4. KGK asked Dunpac if they needed technical drawings prepared, but Dunpac technical staff responded that, *"samples of components to be manufactured would be sufficient."*

3.21 Softer rubber sealing elements on the outer ends of the brake cylinder assembly.

5. Technical drawings would need to specify the material to be used and in this case Dunpac appeared not to require this information. This point is further evidence of the implied competence of Dunpac in the manufacture of the rubber[3.22] brake cylinder components.
6. In all discussion between KGK and Dunpac there was no mention of any functional testing.
7. KGK placed an order with Dunpac for rubber cup brake seals in October 1987.
8. The internal geometry of the KGK cylinders is a direct copy of brake cylinders provided by suppliers to motor vehicle manufacturers. There is no special internal feature of a KGK brake cylinder which would adversely affect the operation of the brake seal cups and boots as compared to some other brake cylinder.
9. In May or June 1988 Dunpac had advised KGK that they had satisfactorily tested the sample rubber cup seals submitted to them by KGK as models of cups to be manufactured and they were ready to manufacture rubber cup brake seals matching the samples supplied by KGK.
10. In late 1988 KGK went into full-scale production of brake cylinders with the brake seal cups made by Dunpac. By early 1989 their sample release of brake cylinders to taxi drivers were returned due to failing by leakage. The brake seal cups manufactured by Dunpac did not function properly – they had all shrunk and the brake cylinders in which they were installed leaked.

(b) The Pleadings of Dunpac in Their Defence

11. Dunpac technical staff advised KGK that they had not previously manufactured brake seals. They agreed that they could develop a suitable product, with both parties involved in the process, including appropriate pre-market testing of the product. Dunpac technical staff also advised that the components could be developed from samples.
12. In their pleadings Dunpac claim that: *"these discussions related to … seal shape … importance of fit … and shrinkage problems."* (This was a clear admission by Dunpac that they were aware of the possibility of shrinkage).
13. The paragraph in the pleadings goes on to claim that Dunpac technical staff advised KGK of the need for both parties to test components and that *"only testing by KGK would confirm functional operation of the seal."*
14. KGK did not provide Dunpac technical staff the Castrol Anti-Corrosion brake fluid in which to test rubber components.

3.22 Although "rubber" is the term used in the description of brake seals and boots, the actual nature of these products is better described by the more general term "elastomer"

> *"Development … was … implied from trade custom and practice … it is customary … in the automotive industry:*
>
> *(i) to provide full specifications …*
>
> *(ii) to test components in assembly to confirm function."*

(c) Additional Evidence in This Dispute – Analysis of the Seal Material
Product analysis was performed by Dunpac laboratories. Their test data only appears to identify the polymer type in the seal cups. There was no information sought or given regarding the other constituents of the cup and its likely behaviour in the oil environment to which it was to be exposed. This appears to be cavalier behaviour with components which were to be used in safety-critical brake systems.

The appropriate motor vehicle standard that applied to the performance of rubber brake seals in 1988 was SAE-J1601, March 1985, *Rubber Cups for Hydraulic Actuators.* SAE-J1601 clearly identified that no shrinking was permitted, but swelling of 5% to 20% by volume was acceptable.

The originally supplied RPB cups supplied by KGK to Dunpac were manufactured by *Schlechtpoor Ltd.* Documentation provided to me by counsel acting for KGK showed that Dunpac had access to the Schlechtpoor formulation of the RPB rubber cups. This documentation shows the complex nature of rubber formulation and that carefully selected additives can modify the behaviour of the polymer to make it swell rather than shrink.

3.8.4 Lessons Learnt and Outcome

KGK had a genuine enthusiasm for initiating a market venture in manufacturing aftermarket brake cylinders and they were poorly advised by Dunpac technical staff. Moreover, given the claimed expertise of Dunpac in the rubber industry, the first batch of rubber cup seals provided by them to KGK showed serious disregard for the safety-critical nature of the product.

Placing aside any emotional considerations for KGK (Greek migrants claiming to be motivated by improving our balance of trade in the automotive aftermarket industry), they were clearly far less experienced at medium -scale manufacturing than Dunpac technical staff. KGK should have been advised to consult technical standards as well as testing authorities to establish the appropriate regime of continuous quality management for their planned product. No doubt, they had some reluctance for committing the necessary time and resources to this type of planning, having already spent substantial part of their financial reserves on setting up their "factory".

Ultimately, there were sufficient numbers of errors in judgement on both sides of this contractual failure between KGK and Dunpac. KGK were advised by counsel to cease proceeding with their suit against Dunpac.

Perhaps the most relevant and ultimately kindest, cliché one could apply to the KGK experience is that well-known quote from Alexander Pope: *"Fools rush in where angels fear to tread."* Some cultures are well known for inventing solutions to problems. This type of innovation is particularly prevalent in rural societies where there is limited access to expert technical help. Farmers needing to solve a problem with implements, under the pressure of a planting or harvesting timetable, will invent solutions to specific technical problems.[3.23]

Manufacturing brake cylinders to the automotive aftermarket industry cannot be seen as innovation intended to solve a specific technical problem. KGK's intention was more evidently designed to solve what they saw as an economic problem. For this they needed not only technical advice, but expert business advice as well. The apparent fact that they chose to avoid seeking either expert technical or business help with their venture speaks to their inexperience in medium-scale manufacturing. The fact that they chose to enter a field of manufacturing safety-critical components, without referring to standards or testing authorities, speaks to KGK being nothing less than foolhardy.

There were elements of "snake oil" in the discussions between KGK and Dunpac; *"trust us, we know what we are about."* Releasing the product before substantial and satisfactory bench tests were performed completely scuttled the business before it started. Perhaps the most valuable lesson to be learnt from this case is the care and attention to detail needed when planning a business venture in manufacturing.

3.10 Chapter Summary

In this chapter seven cases dealing with failures in technical contracting are presented. It is interesting to identify the common threads and issues that appear not only in these cases but in virtually all similar cases. In all of them the winning line was the capacity to recognise and draw out these issues.

Issue (a) Failure of diligence in articulating and specifying product performance requirements expected from the product.

Issue (b) Drafting defective technical contracts based on trust developed over long association with the supplier of technical service. In these cases *Issue (a)* is again commonly experienced.

Issue (c) Failing to recognise the cooperative diligence essential to technical ventures where both supplier and client will benefit from such cooperation.

Issue (d) Failure to recognise implicit *"snake oil"* promises such as *"trust us, we know what we are about"*.

In two cases complete technical expert reports are presented to indicate the format of such presentations.

3.23 See for example Australian Academy of Technological Sciences and Engineering (1988).

4

Case Examples of Human Injury

Recompense injury with justice, and recompense kindness with kindness. Confucius (551 BC–479 BC)

If an injury has to be done to a man it should be so severe that his vengeance need not be feared. Niccolo Machiavelli (1469–1527)

Niccolo Machiavelli's writing in the 15th century foreshadowed the practice of paying less for a death than a permanent disability injury. Of course he could not foresee the economic "vengeance" inflicted in litigation by those suffering injury or by the relatives of anyone killed by their injuries. No other law receives such clear and helpful explanation for intending litigants as does the law pertaining to compensation for personal injury. There are a plethora of web sites dedicated to explaining to laypersons the various types of litigations that may result from personal injuries.[4.1] A Google search of personal injury law will return over 50 million English pages of information relating to this item. A Similar search for law books dealing with personal injury lists over 25,000 books on this subject.

Yet, in principle, the issues of personal injury are quite simple. In exploring this topic, any cases of person-to-person injuries, specifically those resulting from arguments or fights between individuals or groups of people, are excluded. Conceptually, in the injury event a person is somehow connected with a machine and in operating this machine suffers injury. There is always some initiating event and there are underlying causes for this event. Ultimately, at one end of the spectrum of possibilities, either the machine was at fault or, at the other end of this spectrum, the human was at fault in operating the machine. All human–machine injury cases lie within spectrum of possibilities. In this simplified definition of personal injury, "machine" is a generic definition, and it may be as simple as a can opener or as complex as an aircraft carrier.

4.1 injury-law.freeadvice.com; consumerlawpage.com and many others.

The major contribution an expert can bring to a personal injury case is that of assigning probable causal relationships to the initiating event in which the injury occurred. Before developing the issues of how specialist experts might deal with assigning underlying causes, contributing causes and mitigating circumstances to an initiating event, it is interesting to speculate on how damages might be awarded. How do we value an eye, a leg or an arm? How can we assign an appropriate loss to a shortened life, or indeed a lost life? In reality, we all make judgements associated with such values every day of our lives. Whenever we embark on a journey in a motor vehicle and buckle our seat belts, we assign some level of risk to surviving the journey. We intuitively assign some level of trust to the expertise of the designers of seat belt anchorages that will restrain our body mass in an impact. Indeed, a serious impact is rarely considered by motor vehicle passengers when embarking on a journey. This is the case, in spite of the fact that a motor vehicle is, by a wide margin, the least safe mode of transport. The US National Transportation Safety Board[4.2] reported in 2004 that 95% of all transport-related deaths have resulted from road transport, with passenger automobile transport fatalities being the largest representative in the total.

In *Priceless: On knowing the Price of Everything and the Value of Nothing.*[4.3] Ackerman and Heinzerling remark:

> *"How do you put a price tag on a human life, you ask? Number-crunchers at think tanks such as the Harvard Center for Risk Analysis, the AEI-Brookings Joint Center for Regulatory Studies, and the Cato Institute have for the most part focused on workplace data. Dangerous jobs at construction sites, nuclear plants, and coal mines tend to pay more than low-risk ones; economists maintain that this wage difference indicates the price people are willing to pay to avoid death. Through some fancy math involving comparing risks to wages, that works out to be about \$5 to \$6 million."*

Engineering designers take the pragmatic view that one can never fully design out failure from any piece of equipment. To put this notion in a positive sense it is recognised by all designers that 100% safety of any equipment can be achieved only at the expense of infinite resources. This notion places all equipment design on a *"fuzzy"* footing of making judgement about probabilities. A common approach adopted by conservative designers of machinery is to use the concept of *"most credible accident"*. This notion requires the assessment of the most credible set of loading conditions that the critical components of a machine might be subject to in an accident. Typically, seat belt anchorages are subjected to crash tests with dummies of credible scale and mass and at credible speeds. Structures are designed with credible loads, usually assigned by authorities with substantial experience in credible worst loads.

4.2 www.ntsb.gov/Pressrel/2005/050909.htm.

4.3 Ackerman and Heinzerling (2004).

Of course, it is inconceivable that designers should foresee all possible failure scenarios. But in assigning structural strengths, or safe operational sequences, all credible accidents should be considered. When an accident happens (the initiating event) and someone is injured, expert reconstruction of the accident scenario should take into account all possible underlying causes and contributing causes. One approach is to draw up a *fault tree* associated with the accident (the accident is considered to be the *top event*) and examine all the possible paths through the resulting fault tree diagram, to assess how the underlying and contributing events influence the top event. An alternative approach to evaluating potential hazards and risk is the *event diagram*. Event diagrams list all the several events that might contribute to the initiation of the top event. In this analysis, probabilities are associated with each contributing event, permitting a table of risk levels to be associated with each contributing event. In practice these probabilities are drawn from operating experience. Both approaches owe their existence to concerns about containment of radiation from nuclear power plants.[4.4] A further alternative approach to evaluating risk associated with equipment failure is *potential failure modes and effects analysis* (FMEA).[4.5]

These approaches are all associated with the avoidance of the top event (the accident). In personal injury cases the accident has already taken place and the expert is faced with *reverse-engineering* these analyses to assess the most likely accident scenario. Some of the cases considered in this chapter will provide examples of these analyses. However, they are introduced here to indicate the connection between failure analyses and some elements of personal injury law.

4.1 Some Elements of Personal Injury Law

As a precursor to the cases, it is useful to review some of the elements of personal injury law, that might impact on the advice provided by an expert. When someone is injured by either the malfunction of a machine or by the misuse of a machine, several issues need to be explored for an appropriate source of compensation. As an aid in this exploration four participants are identified in the delivery of goods and services associated with the operation of the machine.

> *Proprietor (P)* – the person or organisation responsible for the proper adjustment and maintenance of the machine. In addition, this is the person or organisation responsible for providing appropriate operating instructions and arrangements associated with the safe operation of the machine.
>
> *Operator (O)* – person or persons in charge of operating the machine, and, in general it is expected that the operator will have some specialist skills associated with the operation of the machine.

4.4 See, for example, Isermann (2006); Hoang (2003); Evans and Evans (2001).

4.5 See also Hawkins and Woollons (1998); Pelaez and Bowles (1996).

Designer (D) – person or organisation responsible for the design of the machine as well as its *operating language*. In this context, it is noteworthy that all machines *speak to us* in their operating language. The terminology introduced here is frequently used in industrial design. Most commonly, the displays and control devices of machines have expected performance characteristics. As an example, when accessing a cold-beverage vending machine, we expect it to deliver a cold beverage that is safe to handle. Also, when operating a motor vehicle, a turn of the steering wheel in a given direction is expected to turn the vehicle in the same direction. Similarly, when passing through an entrance to a social club, we would expect the sliding door entrance to permit safe entry to the establishment. In this context, one would not expect the proprietor to provide special instructions in the operation of the entrance.

External Influence (EI) – this is the participant in the personal injury drama that is generally held responsible for some form of unpredictable machine behaviour. Examples are unexpected variations in material properties in a manufacturing process and unexpected changes in traffic, road or terrain conditions when driving an automobile. A most common form of *EI* is unexpected material behaviour when exposed to extremes of temperature, or unexpected environmental conditions.[4.5]

There are several forms of personal injury drama might take.

O is injured and sues P – This is probably the most common type of personal injury matter. *O* sues *P* under either work place occupational health and safety law or under personal liability law. In such matters, the expert's task is to assess if the injury was caused by a machine fault (possibly a fault by *D*), work place fault, misuse by *O* or misadventure due to *EI*.

P is injured by the machine – In general, this type of injury is a result of some unexpected machine behaviour or misuse (typical examples are exploding grinding wheels, automobile engine fire, injury from exposed moving parts or failure in machine guarding).

Collateral injury – Some bystander is injured by the machine. Although rare in an industrial situation, this can certainly occur most commonly in motor vehicle accidents. Typical examples are passengers injured due to poor construction or poor design.

Compensation for personal injury may be claimed under *tort law* or under *strict liability*. A tort is committed where a person violates his/her duty to others, created under general (or statutory) law,[4.6] resulting in personal injury. The four elements that must be present in a typical tort lawsuit are:

4.5 See for example Eberhart (2003); Gordon (1976, 1979)

4.6 General law refers to the expectations of a "reasonable" person

(1) The existence of a legal duty owed by a person to others (e.g. P to O, or D to P);

(2) The breach of the duty by one person (negligence);

(3) The breach of duty being the initiating cause of damages suffered by a person;

(4) Damages incurred by a person.

Strict liability often applies when people engage in inherently hazardous activities, such as using explosive blasting in demolition in an urban environment, or keeping wild circus animals. If the blasting injures someone, no matter how careful the blasting company was, it is liable for the injury. Similarly if wild animals escape and injure someone, the fact that the circus used the world's strongest cages and the highest standard of care imaginable will not free them from responsibility.

In the *human–machine fraternity* (*HMF*), including *P*, *D*, *O,* some human roles tend to overlap. In many cases *P* and *O* are the same person. On occasions *P* and *D* are the same person. In even rarer instances all three are embodied in the same person, but in that trivial example there is no case to answer except perhaps due to some external influence. In general, there is an implicit contractual relationship between *D* and *P*, often time limited by warranties. However, should there be any serious design fault encountered, even after the warranties expire, litigation may ensue between two or more members of the HMF.

This very brief introduction to elements of personal injury law is not intended to serve as a law reference. My intention is to alert engineers to how the law might serve to support personal injury compensation. Interested readers might find it useful to refer to more substantial law references.[4.7]

4.2 The Cases

Sliding Door Knocks over Elderly Woman – Mrs. Eileen Dover was injured in a fall when the sliding door of the entrance to a services club for the elderly malfunctioned. The public liability insurers for the club sued *Matadoor Pty. Ltd.,* the installers of the sliding door controller. In treating *Matadoor* as the primary contributor to the accident, they failed to take into account the complex nature of the case.

Paraplegic Girl is Accidentally Burnt During Diathermy – This is essentially a malpractice case against a chiropractor, *Dr. Hyde*, whose personal liability insurers attempted to off-load the loss against the supplier of the infrared heater.

4.7 See for example Prosser et al. (1984); Lunney and Oliphant (2000); Hepple et al.(2000); Weir (2004).

Two Skiers Attempt Sslippery Tactics in Seeking Compensation for Injuries – Both cases concern injuries sustained by novice skiers on the ski slopes. Both cases turned out to be failures in understanding the mechanics of skiing.

Industrial Pressure Cooker Kills Cleaner – *Mr. Karamazov* was a cleaner at *Danny Bhoy's*, a wholesale manufacturer of pies. While cleaning an industrial pressure cooker he was accidentally flashed with superheated steam and died from his injuries. In this case there were contributing factors from both the UK manufacturer of the pressure cooker *Jackson and Ripper Pty. Ltd.* as well as the employer *Danny Bhoy Pies*.

Front-end Loader Crushes Mine Mechanic – *Dennis Gibbon*, a hydraulic maintenance mechanic, was killed when a heavy bucket of a front-end loader descended on him while he was attempting to remove a hydraulic line. This case turned out to be one of death by misadventure. However, *Tarabell Goldmine*, the owners of the front-end loader, were duty-bound to investigate the case on behalf of their employee.

4.3 Sliding Door Knocks over Elderly Woman

4.3.1 The Case Culture and the Defining Event

The *South Park Services Club* (*SPSC*) in Sydney provides light entertainment, in the form of risqué floor shows and poker machines, as well as meals for its mostly elderly members. On Tuesday, 21 December 1999, *Mrs. Eileen Dover* decided to take her granddaughter to the club for lunch and a bit of a flutter on the "pokeys". At the club's Einbahn St. entrance one had to ascend a step before encountering the large double sliding entry doors. Eileen was walking with a cane and as she slowly approached the entry doors her young granddaughter ran ahead and entered the club foyer. As she was passing through the wings of the sliding doors, one wing struck Eileen and she fell on the tiled floor, breaking her hip in the fall. There were various conflicting accounts of how the fall was initiated, but ultimately the case was handed over to *Arfur and Daily Pty. Ltd.* (*AD*), SPSC's public liability insurers.

The operation of glass sliding doors is quite common in many industrial installations, where clients of the installation need to move through such doors without the need to apply opening or closing action to the doors. Typical examples are hospitals, shopping centres and service stations. The doors installed at the SPSC are certainly representative of such doors. The mechanism used for opening and closing these doors is a *Matadoor type 300* heavy-duty actuator. Figure 4.1 shows the schematic operation of automatic sliding doors and Figure 4.2 shows a schematic sequence of door controller operations.

In Figure 4.1 the upper diagram shows the sliding door pair fully closed. The entry sensor is not shown, but it is usually located above the centre of the doors. The entry sensor has a broad three-dimensional sensing range.

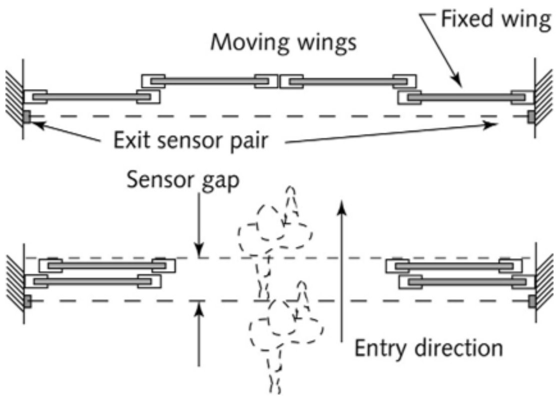


Figure 4.1 Schematic plan view of sliding door entrance, indicating a person passing through in the lower diagram

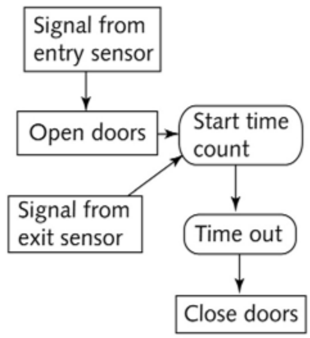


Figure 4.2 Schematic view of sliding door entry control sequence

In contrast to this, the counter-intuitively named exit sensors are located near the entry surface of the sliding door pair. As may be observed from the control diagram in Figure 4.2, the exit sensor signal triggers a count-down sequence that permits the door controller to determine when to commence the closing sequence. Figure 4.2 is a simplified representation of the control schematic, from which acceleration and braking sequences have been excluded. The sensor gap is determined from the expected time taken by the slowest member of 95%[4.8] of the population in passing through the doors before the closing sequence is initiated. When several people pass through the entry, the time count is restarted each time the exit sensor is triggered.

4.3.2 Parties to the Dispute and the Client

After assigning a loss assessor to review the events associated with Dover's injuries, AD decided to sue Matadoor Pty. Ltd., the installer of the sliding door controller. My involvement in this case arose when Matadoor's insurers appointed *Free and Easy Lawyers* (*FE*) to deal with this law suit. FE appointed me to look into the matter and asked me to offer opinion on the following issues:

(a) Whether the installation and operation of the automatic doors at the time of the accident met the requirements of Australian Standard *AS 4085-1992, Automatic Sliding Doors*.

Table 4.1 Briefing materials and information used in this investigation

Item	*Date*	*Description*
1	*10/12/201*	*Statement of Claim*
2	*Various*	*Service reports of Matadoor on various dates through 1999*
3	*4/4/2000*	*Expert's report by J. Smith*
4	*July 2000*	*Report of SPSC maintenance manager*
5	*18/7/2000*	*Eye witness report of incident by Guy Fawkes, an employee at SPSC*
6	*Undated*	*Statement of Mrs. Eileen Dover*
7	*April 2003*	*Interview with Kevin Bacon, manager Matadoor operations*
8	*29/7/2003*	*Inspection of the Einbahn St. entrance of SPSC*
9	*1992*	*Australian Standard 4085-1992, Automatic Sliding Doors*

4.8 This value excludes only the upper and lower 2.5% of the population. Note that here we need only concern ourselves with the slowest 2.5%.

Figure 4.3 General view of the SPSC entrance

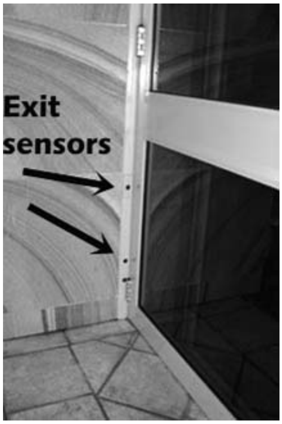


Figure 4.4 Close-up view of the exit sensor

(b) Whether the accident was in any way causally related to the proper operation of the door operator installed and serviced by Matadoor.

(c) Whether the protocols followed by Matadoor in their dealings with SPSC were appropriate to a responsible contractor in their position.

(d) Possible accident scenarios and possible causal relationships of the accident to the proper or improper operation of the Einbahn St. entrance automatic doors of SPSC.

4.3.3 The Investigation

Table 4.1 lists the briefing materials and information used in this investigation. In April 2003 I was able to interview Kevin Bacon, the manager of Matadoor operations and this interview yielded the operating description for the Matadoor 300 heavy door actuator. Service reports and the report of the SPSC maintenance manager yielded the history of the club entrance.

Sometime in 1998 SPSC contracted *Tom Dooley Pty. Ltd.*, a commercial building company to carry out building renovations at the club. The Einbahn St. entrance doors were replaced during this renovation. The door panels were manufactured and installed by *Flyweight Aluminium* of Newcastle in August 1999. Matadoor removed and stored the door actuators and then reinstalled them on 5 August 1999.

Mrs. Dover is an elderly disabled person who walks with the aid of a walking stick, probably due to a stroke she has suffered sometime prior to her accident at SPSC. Mrs Dover was walking through the Einbahn St. entrance on 21 December 1999. She was walking slowly, as would be the case with someone walking with the aid of a walking stick. While still in the space between the moving panes of the automatic doors, the doors commenced to close on her. Subsequently the door struck her and she fell, suffering injury.

Figure 4.3 is a general view of the Einbahn St. entrance to SPSC. There are two sets of exit sensor pairs installed on this entrance, the lower pair catering for small animals accompanying club members. Figure 4.4 is a close-up view of one side of the entrance showing the location of one member of each exit sensor pair. The exit sensors are located so that they meet the requirements of AS 4085. However, the glass in the doors was measured at 8.66 mm, substantially contributing to the total door mass of between 60 and 65 kg.

Figure 4.5 shows the measurements taken on the glass door and frame. Figure 4.6 shows the space available between the plane of the exit sensors and the inside surface of the moving door frame (sensor gap). During my inspection of this arrangement on 29 July I found that I could stand with part of my anatomy protruding into this space and the doors would attempt to close on me. This experience is also validated by the report of Dr. John Smith (an expert for SPSC's public liability insurers) who similarly experienced the closing of the doors while standing in between them.

4.3.4 Evaluation of Information and Lessons Learnt

The mass of the moving wing of the sliding door was calculated from data provided by Flyweight Aluminium for the door frame and from Pilkington Glass for the mass of the safety glass installed in the frame.

Mass of frame = 11 kg

Door frame size = 2.2 m x 1.1 m = 2.4 m^2

Mass of glass (8.6 mm safety glass from manufacturer's estimate of 20 kg/m^2) = 48 kg

Total mass of door = 59 kg

However, this mass does not allow for door hangers and parts of the operating mechanism attached to the moving frame. Hence a conservative (low) estimate of the moving wing is between 60 to 65 kg. In all force and momentum estimates the average of this figure (62.5 kg) is used.

From the operating manual of the Matadoor 300 actuator, this mechanism accelerates the door to 0.25 m/sec speed (approximately 1 km/hr). Hence, the frame travelling at this speed will exert 62.5 x 0.25 = 15.6 new-

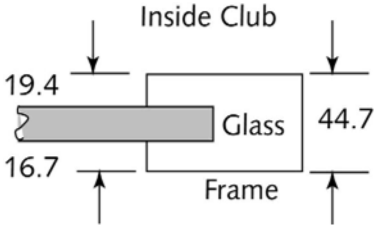


Figure 4.5 Glass dimensions measured by digital vernier calliper (mm measurements)

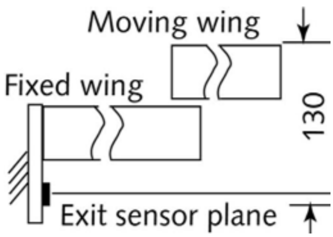


Figure 4.6 Sensor gap space (mm measurements)

ton second (an impulse measure) on the body it strikes. In practical terms, this is about the impulse exerted by a 3 kg sledge hammer travelling at 18 km/hr. Admittedly, the door is not "ballistic" (freely moving, as the hammer would be), because it is being driven by a chain drive system. Nevertheless, the heavier the door the larger the inertial opposition it requires to sense an obstruction in its path and consequently to generate an emergency stop.

There are several elements of the door operation that could have been responsible for the accident suffered by Mrs. Dover. Figures 4.7 and 4.8 respectively show substantially simplified fault tree and event diagram representations of the sequence of events associated with this accident. In order to make these representations accessible to a wide audience they have been simplified by omitting timer sequencing and the internal mechanisms of the door actuator. The fault tree identifies those major aspects of the entry operation that might critically influence the presence of hazards (in this case the injury of a relatively frail person). It isclear from this diagram that the maladjustment of the actuator (something for which Matadoor might be held responsible) is only one element of a complex interacting set of events that will generate the accident.

The event diagram of Figure 4.8 identifies the same elements of the entry identified in the fault tree representation. However, in contrast to the fault tree representation, the event diagram explores the likelihood of the accident being caused by a specific failure in the event chain. It is necessary to interpret the meanings of *"succeeds"* or *"fails"* associated with events intuitively. For example *"failure"* of the door mass must be interpreted as being *"too large to initiate early trigger of an emergency stop sequence"*.

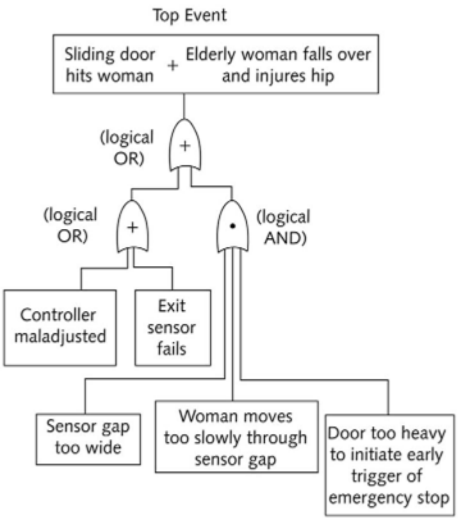


Figure 4.7 Fault tree diagram for sliding door failure

Fault tree diagrams focus on the events contributing to the delivery of the top event. Event diagrams focus on the same final outcome with special regard for the probable failure or success of each contributing event. From the event diagram of Figure 4.8 it is clear that even when the initiating event is a maladjusted actuator, the outcome is substantially influenced by all the other contributing events. The construction of these diagrams alerts the investigator (and client) to the nature of complex interactions that influenced the delivery of the accident under investigation.

4.3.5 Concluding Opinions and Outcome

1. The accident that befell Dover on 21 December 1999 is incontrovertible. She fell and hurt her right hip. However, the events leading to the accident may be reconstructed in a variety of ways.
   (a) The photoelectric exit sensors may have been faulty. A person may pass through the doors slowly, and if the photo sensors do not detect the presence of this person the doors would then close on that person. In this case the fault is one that could and should have been detected by the regular service agency of the entrance (not Matadoor);
   (b) The exit gap may have been incorrectly gauged for a specially slow speed through this gap, such as a frail person moving with the aid of a walking stick;
   (c) Dover's granddaughter passed through the doors ahead of Dover, opening the doors. Dover in following her granddaughter may have been sufficiently close behind her that her presence may not have activated the infrared entry sensors above the door. Additionally, combined with this scenario, she may have been slow in moving through the doorway, or may even have slightly halted past the exit sensors, while part of her anatomy was still in the way of the sliding wings of the entry and hence was struck by the closing doors.
2. The doors installed at SPSC were much too heavy and this fact could have exacerbated the effect of a door striking a frail elderly person. This is an issue of which SPSC should have been aware because retired elderly people form a large percentage of the clientele attending this club.
3 The surface of the floor near the doors appears to be tiled and hence slippery under some conditions. This is poor design when providing for the ingress and exit of anyone, not just some frail people.
4. As there is no simple way to prevent automatic doors

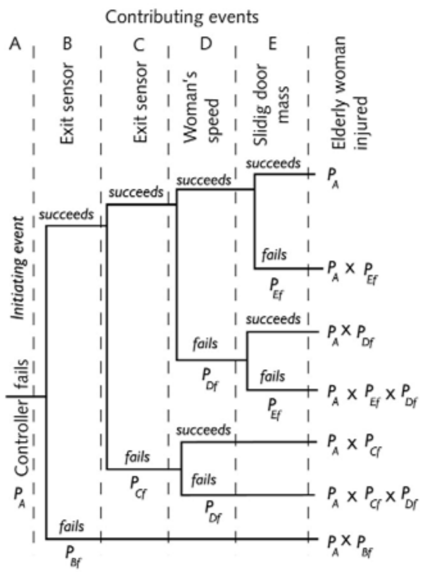


Figure 4.8 Event diagram for sliding door failure

occasionally striking people who are moving through them, it would have been been prudent to install safety railing at both the entry and exit locations of these doors. If such railing were installed, Dover's accident could well have been avoided.

5. The issue of increasing the closing force from 130 N (as required by Australian Standard 4085) to 160 N is not a serious one. A force equivalent to 13 kg (130 N) could be quite sufficient to overbalance an elderly and frail person.
6. Finally, based on my investigation and having given due consideration to the evidence provided to me, I have formed the opinion that the work carried out by Matadoor has met all quality requirements expected from such an operator of technical services. Their installation had no influence on the accident that befell Dover.
7. The operation of the Einbahn St. entrance doors of SPSC appears to meet the requirements of Australian Standard *AS 4085-1992, Automatic Sliding Doors*. However, this standard is a general standard for automatic doors in many locations. It is not designed to safeguard elderly frail handicapped persons walking slowly with the aid of a walking stick.

This case was resolved in an undisclosed out-of-court settlement. There were some issues taken with the expert's reports on both sides of the argument, but ultimately the case was judged as unwinnable by SPSC's public liability insurers.

Public liability is an area of the law that has become a veritable minefield of litigation. For many years in Australia the cost of public or personal liability of insurance was of the order of 0.1% (i.e., one could take out public or personal liability insurance of AU$ 10 million for a premium of about AU$ 1000). The main reason for this low premium was that negligence, a concern in tort, based on the *duty of care*, was very difficult to establish. In recent times there has been a significant change in the law relating to public liability and specifically in the case of negligence.[4.8] As a result, many small businesses, including riding schools, children's party entertainers and buskers, have stopped operating for fear of encountering public liability claims. In the USA the issue of negligence has been coupled with strict liability. Consequently, the cost of this type of insurance has been and continues to be very high.

4.8 See for example the excellent Briefing Paper 11/2002 by Roz Luzusic at www.parliament.nsw.gov.au/prod/parlment/publications.nsf/0/06EC3841B9567F9BCA256 ECF007 A414

4.4 Paraplegic Girl is Accidentally Burnt During Diathermy

Diathermy = Heating by electrodes placed at some distance apart (from Greek *dia-* "apart" + from Greek *therme* "heat") *OLED*

4.4.1 The Case Culture and the Defining Event

Physical chiropractors make use of deep tissue heating to stimulate tissue growth. There are many medical electric devices that provide this type of service. In fact, there is a whole theory of health improvement systems, based on electrical impulses, explored by various natural healing organisations.[4.9] Whether one believes in these types of healing techniques or not, they exist and are used by a wide range of medical therapy establishments. Diathermy is a process of soft tissue heating by electromagnetic waves of various lengths and with various levels of current passing through the tissue. In surgery, diathermy is used as either a cutting tool or to cauterise blood vessels to stop bleeding. The invention of diathermy has considerably reduced the workload of surgeons by allowing them to cauterise small arteries that would previously have had to be tied manually.

The diathermy of concern in this case involves the medical therapy of soft tissue using diathermic heating. Magnetic short-wave diathermy relies on electromagnetic induction. This is a process in which an electric current is generated (induced) in a conductor as it moves through a magnetic field. Devices used are either a coil placed around the body region to be treated or a *pancake* coil placed near a body part. As alternating current in the coil generates alternating magnetic fields, eddy currents are induced in soft tissues, producing heat. This method is effective for treating muscle spasm, pain from intervertebral discs, joint diseases and bursitis (inflammation of lubricating surfaces in joints). It is also a deep heating agent for joint diseases with minimal soft tissue coverage (e.g. knee, elbow, ankle).

Applying diathermy to tissue with a functioning nervous system appears to be a harmless process. During treatment, should the heat become unbearable, the patient can readily switch off the apparatus or remove the heat source. Unfortunately this case is concerned with a paraplegic girl, whose nerves responsible for feeling in the lower limbs have been destroyed by a spinal injury. In such cases soft tissue requires regular physical stimulation to avoid complete atrophy.

The subject of this case is *Jacqui Frey*, a 19 year old T-1 paraplegic.[4.10] She was attending the physical therapy centre, operated by *Dr. Jake Hyde*, for regular diathermy treatment of her buttocks and lower limbs. Jacqui has been attending the Hyde therapy centre on a weekly basis until Thursday 21 October 1993, when during a diathermy session her buttocks were severely injured, sustaining third-degree burns.

4.9 See for example Poesnecker (1996).

4.10 T-1 paraplegics have damage to the spinal cord at the level of the first thoracic vertebra.

4.4.2 Parties to the Dispute and the Client

The device used in Jackie Frey's treatment sessions was a type P250 short-wave diathermy machine, serial number ER1766. Because Jacqui was unaware of her burns, having no feeling in her buttocks, it was her parents who noted the severe injury later that day. On advice from their solicitor they issued personal injury proceedings against the Hyde therapy centre, and specifically against Dr. Hyde. A personal injury case against the Hyde therapy centre would have been handled under public liability insurance. The case against Dr. Hyde was invoked under medical malpractice law. Patricia Danzon notes in the introduction of her paper on malpractice economics:[4.11]

> *"Physicians and other medical providers are subject to a negligence rule of liability. To prevail, a plaintiff must show that he or she sustained damages that were caused by the failure of the physician to take due care, defined as customary practice of physician in good standing with the profession, or a significant minority of such physicians. In a simple model, with perfect information and homogeneous physicians, a negligence rule of liability with an appropriately defined due care standard should induce complete compliance: there should be no malpractice, no malpractice claims and no malpractice insurance.*
>
> *The malpractice experience is seriously at odds with this prediction. The incidence of negligent injury is not trivial – roughly one per hundred hospital admissions … From 1975–1985 the frequency of malpractice claims per hundred physicians at roughly 10 percent a year, claim severity (average amount per paid claim, including jury verdicts and out-of-court settlements) rose twice as fast as the consumer price index, and malpractice premiums increased sharply. From 1985 to 1989 claims costs and premiums stabilized, but are beginning to rise again. There have been no major changes in the basic common law rules defining medical liability that could explain this increase in claims.*
>
> *This discrepancy between the simple theory and actual experience raises two related issues. First, what goes wrong? Second, if the system does indeed operate imperfectly, does it yield benefits in terms of injuries deterred that outweigh the high cost of operating a liability system?"*

In the case of *Frey v. Hyde* public liability insurers were invoked first and they chose to issue a malpractice writ against Dr. Hyde under negligence. Dr. Hyde's personal liability insurers issued a writ against the suppliers of the model P250 diathermy machine, *Sly and Grogg Pty. Ltd. (SG)*. My clients and instructing solicitors, *Jalleson and Miques (JM)*, acting for Frey, asked for a review of events leading to Frey's injuries with specific examination of the P250 machine and its operation.

4.4.3 The Role of the Expert and the Investigation

1. General

The substance of this investigation is directed at determining if the P250 machine or any similar diathermy machine could have been responsible for

4.11 Danzon (1991).

the burns suffered by Frey (*the plaintiff*) during her treatment at the Hyde therapy centre on 21 October 1993.

As noted earlier, diathermy is a process of producing heat in body tissue by passing a high-frequency electric current through the parts being treated. Due to the very high (27.12 MHz[4.12]) frequency involved, there is no muscular or nervous reaction caused by this electric current. Heating results from the resistance of body tissue to the passage of the electric current. Body tissue is a relatively poor conductor, hence the heat generated is not readily dissipated to the atmosphere and tends to stay within the tissue for some time once it heats up. This type of heating is commonly used in industrial applications, where it is referred to as dielectric heating. Typical applications are heating of thermosetting glues, drying fibrous material, fast jelling of foam rubber and pre-heating of plastics prior to moulding.

The heat in diathermy is generally applied by placing the body part to be heated between two plates, or electrodes. These electrodes are essentially the plates of a large capacitor (condenser) which get charged up by the diathermy machine. The electric current is passed by the resulting electromagnetic field created between these electrodes. A metric of the current that the substance between the electrodes is capable of passing is its *dielectric constant* or *permittivity*. Permittivity is measured in relative terms by comparing the passage of current between the electrodes in vacuum to the current passed when some other substance is placed between the electrodes. Typically air has a relative permittivity of 1.00059 and water 78.2. Hence we can see that when water is placed between the two capacitor plates the current passed will be approximately 78 times that passed when air is between the same electrodes.

2. Legal Requirements

The Australian Authority for accrediting all medical equipment is the *Therapeutics Goods Authority (TGA)* in Canberra. In a telephone interview with an officer of the TGA I was advised that there are no specific laws governing the manufacture, distribution and use of muscle or nerve stimulators such as diathermy machines. Consequently, there was no particular legal or procedural regulation in force at the time the P250 machine was either manufactured, sold or used. There were in 1993 Australian standards relating to Medical Electrical Equipment and these are listed below:

Australian Standard AS3200.1-1990: Approval and test specification – Medical electrical equipment, Part 1-1990: General requirements for safety;

International Electrotechnical Commission Standard (IEC) 601-2-10 1987 Part 2: Particular requirements for the safety of nerve and muscle stimulators;

Australian Standard AS3200.2.3-1992 (previously IEC 601-2-3:1991): Approval and test specification – Medical electrical equipment Part 2.3: Particular requirements for safety – short-wave therapy equipment.

4.12 Megahertz = 10^6 cycles per second.

Standards do not carry the force of common law, although they are often used as the basis of contractual agreements, where there are no specific laws relating to the quality standards of machinery. Moreover, there are no specific laws governing the testing, servicing or safety of medical electrical equipment in the State of Victoria, nor were there any such laws in force at the time of the injury suffered by the plaintiff. Nevertheless, these standards and some of their specific requirements demonstrate the level of concern expressed by the Standards Association for quality assurance in the construction and use of these machines. Any responsible professional manufacturer distributor or user of such machinery would need to consult these standards, and indeed comply with their requirements in order to fulfil the necessary quality of care associated with their manufacture, distribution and supply. The following clauses of these various standards have special relevance to the Frey v. Hyde case:

AS3200.1-1990: Part 1-1990: General requirements for safety – Clause 6.8 Accompanying Documents

6.8.1 General

Equipment shall be accompanied by documents containing at least instructions for use, technical description and an address to which the user can refer. The accompanying documents shall be regarded as a component part of equipment.

6.8.2 Instructions for use

(a) General information – Instructions for use shall contain all information necessary to operate the equipment in accordance with its specification. This shall include explanation of the function of controls, displays and signals, the sequence of operation, connection and disconnection of detachable parts and accessories, replacement of material which is consumed during operation.

(b) Instructions for use shall include indications of recognized accessories, detachable parts and materials, if use of other parts or materials can degrade minimum safety.

No instruction manual was available with the P250 machine under investigation. Further investigations and inquiries to SG, the machine supplier, discovered that no instruction manual was available either during use or at the time of purchase of the P250 machine. In fact, SG noted that they supplied the P250 machine, Serial Number ER1766, to the Hyde therapy centre as a pre-owned machine, in an overt attempt to divest their responsibility for its subsequent operation.

Consequently the P250 machine did not comply with *AS3200.1-1990: Part 1-1990* on this aspect alone. In addition, the operator of the machine (the Hyde therapy centre) did not observe basic operational care for the patient in failing to ensure that the machine was operated properly. For proper operation of the P250 machine an operating and maintenance manual would have been mandatory. In this context, any machine with adjustable controls, even a simple household machine (such as a food processor or dish washer) must be considered unfit for commercial sale without an instruction manual. The issue here is one of acceptable level of risk in machine adjustment. The P250 was not some simple vending machine whose control features would *"speak to the operator"* in unmistakable terms. In spite of its simple appearance, it was a complex machine whose improper adjustment could place patient safety in serious jeopardy. Consequently, the operator of the P250 machine was seriously derelict in continuing to operate such a machine without proper instructions being available to users.

AS3200.2.3-1992 Part 2.3: Particular requirements for safety – short-wave therapy equipment.

6.8 Accompanying Documents – 6.8.2 Instructions for use

Additional Item: In particular advice shall be given on:

... for equipment having a rated output power in excess of 10 W:

(c) Patients should normally not be treated with short-wave therapy when they have reduced thermal sensitivity over the proposed area of treatment, unless the physician in charge of the patient is notified.

(d) Short-wave therapy should not be applied to patient through clothing.

Closer examination of the P250 machine showed it to require *"tuning"* adjustment to ensure that the induction current generated in soft tissue is limited to specified levels. Without a manual there was no indication of how the accuracy of the output power could be ascertained by the operator, whether the output circuit was properly tuned or if there is some way of establish the proper tuning of it. As the patient moves during treatment the tuning can change and this could cause substantial variations in heating.

AS3200.2.3-1992: For equipment having a rated output power in excess of 10 W the following additional sub-clauses apply:

51.101 The equipment shall incorporate means (an output control) to enable the output power to be reduced to less than 50 W or 20% of the rated output power, whichever is the lower, other than by de-tuning of the output circuit.

51.102 The equipment shall be so designed that the output circuit cannot be energized unless the output control is first set to the minimum position. This requirement shall also be met after the interruption and restoration of the mains supply.

51.103 Equipment shall be provided with an adjustable timer which de-energizes the output circuit when a preselected operating period has elapsed.

No such features were available on the P250 machine operated by the Hyde therapy centre. Although the machine predated the standard, the requirements of the standard appear to be based on a rational avoidance of the most obvious hazards with the operation of such machines. At the Hyde therapy centre diathermy machines were often operated unattended by the physiotherapist. This unattended operation was the condition experienced by the plaintiff according to documentation supplied to me.

Figure 4.9 The P250 diathermy machine that was used by the Hyde therapy centre

Figure 4.10 A typical treatment area at the Hyde therapy centre

3. On-Site Examination

In December 1993 I visited the premises of the Hyde therapy centre to examine the P250 machine and its operating environment. The following notes relate to the operating environment and rooms where the P250 machine was used:

The treatment room was approximately 2.5 m x 3.5 m in size with two treatment areas separated by a curtain. It appeared cramped and I had some difficulty in moving around the couch on which patients would be treated during therapy. Figure 4.9 shows the P250 machine identified as the one used in treating Frey. Figure 4.10 is a general view of the treatment area in which Frey received her diathermy treatments. According to documentation, Frey's diathermy treatment had the following regular routine:

1. The machine would be set to some current and frequency level by the physiotherapist;
2. A mechanical timer would be set to a predetermined period with an alarm for when the set time had elapsed;
3. Frey would lie on a treatment bench fully clothed and the P250 electrodes would be placed in the area of her buttocks. She was provided with a hand bell to seek help in case of any emergency;
4. The physiotherapist would leave Frey on her own during the treatment period. When the timer alarm sounded (or if Frey were to sound her emergency bell) the physiotherapist would return to the treatment area and switch off the machine.

There are at least two aspects of the treatment received by the plaintiff which are of questionable quality in terms of patient care. Firstly, the electromagnetic field between the electrodes can significantly vary with deflection of the soft rubber and terry-towelling heat insulation used. As a test of this effect, I placed my arm between the electrode pads and found I could increase the current indication several fold by applying a load to the electrode pads. I could also feel an increase of heat on my arm as I applied the load to the electrode pads.

Secondly, the recommendation of the standard regarding treatment through clothing recognises a serious hazard with short-wave therapy. As already noted earlier, the relative permittivity of the material between the electrodes can vary nearly 80-fold between air and water. Hence the current passed in a region inhabited by water (sweat for example, is in fact salty water with a relative permittivity much greater than that of pure water) is likely to be much higher than that passing through air or low-conductivity tissue material. Local sweating could have seriously increased the current passing through the area near the buttocks of the plaintiff when the sweating could not be absorbed by the terry-towelling in direct contact with the skin. Regarding diathermy treatment of the plaintiff, the only evidence of the nature of instructions given to Dr. Hyde is from the statement of Mrs. Suzanne Frey, the mother of the plaintiff:

"I had previously told Dr. Hyde that Jacqui's sensory levels are nil in the area of her backside and legs."

On the day of the accident the Hyde therapy centre was unusually busy. This situation may well have exacerbated the poor attention paid the plaintiff during her treatment. On examination, the condition of the P250 machine used in this case was found to be only fair to poor. On the dials of the machine there is no clear indication of it being switched on, nor is there a clear indication of how the dose relates to current or power. The electrode pads are best described as "care-worn" with some of the insulation perished through use or age and in some places the material was completely eroded.

4.4.4 The Outcome and Lessons Learnt

In retrospect, this was a simple case of professional negligence, that is, a case of breach of contract in tort law. The physiotherapist and the physiotherapy centre represented themselves as a professionals in providing a level of care for their patients. As in all medical procedures, all forms of therapy carry associated risks. The pain and suffering incurred during treatment is, in most cases, compensated by the benefit of an improved well-being or quality of life for the patient. This was certainly not the case for Jacqui Frey.

One might almost suspect that there is some element of *snake oil*[4.13] about the use of diathermy in physiotherapy. A fault tree analysis might well show that the whole treatment process administered to Jacqui Frey was fraught with many hazards, most of them associated with the way the P250 machine was used. Of these events a machine failure was just one component. This case resulted in a protracted battle between several insurers, scheduled to be heard in the Supreme Court of Victoria in 1995. On the eve of the court hearing it was settled by Hyde's personal liability insurers.

4.13 Refer to the introduction to product liability in Chapter 3.

4.5 Two Skiers Attempt Slippery Tactics in Seeking Compensation for Injuries

Ski(n): 1885 (there is an isolated instance from 1755), from Norwegian *ski*, related to Old Norse *ski* "snowshoe," literally "stick of wood," cognate with Old English *scid* "stick of wood," obsolete English *shide*. *OLED*

Two similar cases are presented in this section. Injuries sustained by the two plaintiff skiers are slightly different, as are the circumstances preceding their injuries. However, their attempt to recover compensation from a snow field operator in tort law negligence contains some significant similarities.

4.5.1 The Case Culture

Skiing is a risk sport. Participants engaged in the sport accept that there are significant risks involved in donning a pair of skis and schussing down slopes, usually at high altitudes. For many skiers the adrenaline rush of the danger associated with the sport is a major factor in its enjoyment. In addition, there are risks in the way ski equipment (boots and skis) are fitted to one's feet. The dynamics of skiing demand that ski bindings[4.14] should be properly adjusted to permit safe release before the limbs are damaged, either in direct bending, or in torsion. Binding adjustment is deemed to be *proper* when the binding will release under dynamic loading in a way that bones of the lower limbs (tibia and fibula) and the knee joint are protected from injury. The fitting of boots and skis to individual skiers, as well as the proper adjustment of bindings, is a procedure requiring skill and considerable appreciation for the dynamics of skiing.

There are many books and learned articles written on ski dynamics. Regrettably, they are read mostly by physiotherapists, orthopedic surgeons and ski binding manufacturers.[4.15] It would certainly reduce or avoid disappointment among skiers if beginners were to read up on ski dynamics before attempting to learn to ski. This caveat applies to all forms of snowfield learning, including professionally managed ski classes, but especially to *seat of the pants* style of learning by simply putting on skis and getting out on the snow.

It is probably the apparent ease of acquiring the necessary skill in the sport, exhibited by younger (children and teenage) skiers, that seduces the first-time adult skier to try and ski without proper instruction. In addition, even when in the care of an instructor, physical fitness plays a very important part in the way learning proceeds. As an example, no untrained and unfit person would attempt to perform even the simplest gymnastic routine on the high bar or parallel bars. Yet the risks in these specialist sports compare favourably with skiing. The two cases described in this section were entirely motivated by a serious poverty of appreciation for these matters.

4.14 The spring-loaded mechanism that fixes the ski boots to the ski.

4.15 See for example Elling (2003); Lind and Sanders (2004).

4.5.2 The Defining Event, the Client and the Expert's Role

The Figgles Ski Incident of Michael Small

Michael Small (*MS*) was a 42-year-old slightly overweight lawyer, who decided to take a course of ski lessons from *Buller Ski Lifts* (*BSL*), the lift operating service provider at Mt. Buller, the main downhill ski field located in North Central Victoria. The BSL ski school had a graded approach to teaching turning with skis, using skis of increasing lengths as a skier's skills built up. The two key skills required for skiing are turning and stopping and these skills are initially developed on very short skis called *figgles*. In 2001 the January edition of the *Utah State University Department of Journalism and Communication News*[4.16] reported:

> *"The origins of skiboards go back a long away says Stephen Wood, a writer for The Independent (London). Austrian mountain guides would cut a pair of old skis down to 70 centimeters in length and carry them in their backpacks in late spring. To traverse a snow field they would strap them on their boots. The boards then, were known as figls, which is a contraction of the German word firngletier, kind of meaning 'slush-glider.'*
>
> *In 1989, Atomic produced the first skiboards and called them figgles."*

It was on a figgles ski that Michael Small began (and ended) his brief skiing career. While in a class of figgles skiers, he attempted to follow the instructor down a very gentle slope of about 15 degrees to the horizontal (some skiers might derisively refer to such a slope as *almost uphill*). As he was attempting to turn, Small caught one of the edges of his skis against an obstruction (this could have been some ice or just some built-up snow on the smooth surface of the slope) and toppled over, seriously damaging his knee joint in the process. In the fall, the figgles skis remained attached to Small's boots. Having observed release bindings on longer skis, Small chose to attribute his injuries to the fact that figgles skis do not have release bindings attached. He saw this as a failure in ski design and a failure in BSL's care for their customers, and decided to sue BSL for negligence. My instructing solicitors, *Biddlemore and Nevins* (*BN*), asked me to examine the figgles skis and offer opinion about the following matters:

(a) *Release bindings on a full-length Alpine ski* – What are the loads and moments required to undo ski release bindings on a full length Alpine ski adjusted to suit the height weight and skill of Small?

(b) *Binding loads* – Estimate whether these loads and moments would be sufficient to actuate a release binding if such a binding were to be fitted to the shorter ski.

4.16 newscafe.ansci.usu.edu/archive/jan2001/0110_skiboards.html.


Figure 4.11 Typical snow plow stance

The Damaged Boot Incident of Alan Oldwell

Plow: Old English *plog*, *ploh* "plow, plowland (a measure of land)," possibly from Scandinavian (cf. Old Norse *plogr* "plow"), Old Church Slavonic *plugu*, Lithuanian *plugas* "plow" are Germanic loan-words, as is probably Latin *plovus*, *plovum* "plow," a word said by Pliny to be of Rhaetian origin. Replaced Old English *sulh*, cognate with Latin *sulcus* "furrow." *OLED*

Snow plow is the term used to describe the stance taken up by beginner skiers when taking their first introductory "steps" on a pair of skis. This stance permits both turning and stopping, the two key elements of survival for first-time skiers. Figure 4.11 is a photograph of a skier using the typical snow plow stance. Regrettably, often left unexplained to first time skiers is the basic principle of the snow plow, that the ankles must be turned inwards to make this stance do what it is designed to do, namely to safeguard the skier from "catching" the outer edge of their skis.

Alan Oldwell (*AO*), a 39-year-old heavily overweight photographer, decided to spend a weekend with friends in the snow fields of *Perisher Valley*, part of the Kosciuszco mountain range of in New South Wales. Having no ski gear of his own, he chose to hire skis, boots and ski-poles from the *Matterhorn Ski Hire Centre* (*MSHC*) at Jindabyne, a small snow field township on the way to Perisher.

At this point it is worth recording the statement of the accident as described by AO:

"Approximately 3 days before my accident on the 3rd September 1995, I attended the ski hire shop with my friend Jules prior to lunch with a view to hiring some skis. Jules had her own equipment. My recollection is that the shop was reasonably busy.

My recollection of the fit out was that the staff member was keen to fit me up with a pair of boots and that was essentially all he attended to. I did not think this was strange because I had no prior experience of being fitted up for boots and skis and did not give it much attention. He asked me about my shoe size and basically he fitted me up with the first pair of boots that he handed me. I do not recall signing any documentation. The staff member did not weigh or measure me. My height is 177 cm and at the time I weighed approximately 94 kg. He was aware I was a novice skier because told him that I had not skied before and so did my companion Jules. I do not recall him asking me about any physical impairments or disabilities. It took him about five minutes to fit me up with the boots. The boots were not fitted in the skis at the ski shop. This hap-

pened back at the lodge where we were staying. I do not recall signing any contract at the ski shop. The fit out was done in great haste.

My recollection of dealing with the hire shop staff member was that he was essentially concerned with whether or not the boots fitted me and whether they were comfortable, to which I replied yes but he never slipped me into proper skis with the boots on. However I was not used to this process and did not think it was anything unusual.

When Jules and I returned to the shop the guy who had served us was serving someone else and he was very busy. When we asked for further assistance we were assured by him that everything was fine and that there was nothing further which needed to happen I remember Jules turning to him and laughingly saying that "this bloke makes a million bucks a year and he will sue you if anything goes wrong". Jules was still somewhat concerned that the boots had not been properly weighted for my height and size.

I had the accident on the third day after hiring the gear. I found with the boots and skis that I could not stop properly or snow plow because I could not get the skis on the right angle to snow plow which was in turn because the boots were hooked up on the wrong section of the rear part of the ski binding so I could not stop. I experienced three days of going faster and faster and not being able to stop. The other thing I noticed was that my feet were becoming black and blue because the boots were actually too small. I think that the boots were actually a size too small."

In the accident AO suffered a serious knee injury when one of his ski release bindings did not release during a fall. In the remainder of his statement AO notes that:

"… Basically what I was trying to do was to throw myself down on the snow and stop myself that way …"

As a novice skier, AO was probably unaware that this type of behaviour (throwing oneself down to stop) is very common among beginner skiers. In addition, he may not have been advised to check his release binding before going out to ski. This is essential advice given to all skiers, whatever their standard of skiing. Most beginner accidents on skis occur in the morning when the leg muscles are cold and the most common type of accident with these types of skiers is the wrenching of the lower leg or knee due to a slow twisting tumble. Often with such cases the release bindings will not release because there is insufficient dynamic impact load to activate them. When read by someone much more experienced in skiing than the plaintiff AO, there were several curious (thought-provoking) elements of the hire process described in his statement.

1. It is an essential part of the ski hiring service that the order in which the fitting takes place is:
   (a) Boots are fitted to the feet

4.17 See, for example, ISO 11088:1993(E) *Assembly, adjustment and inspection of an alpine ski-binding-boot (S-B-B) system*.

(b) Skis are chosen to match the height weight and experience of the person hiring the equipment

(c) Boots are fitted to bindings on the chosen skis and the release bindings are, in turn, adjusted to release according to an ISO scale based on height, weight and expertise.[4.17]

Although AO may not have observed this being done in the hire shop, this is a service *drill* rarely left unattended.

2. Clearly, the hire staff may have been concerned to fit the appropriate boots to AO. As a general rule the tighter the boot the better the coupling between the feet and the release binding. The fact that AO's feet were becoming bruised is a sad but expected experience of most skiers, including experts, when returning to skiing after some period of layoff.
3. Snow plow is a beginner's means of slowing down on a ski slope. Even for experts this procedure applies substantial torsional loading to the legs.

If AO threw himself over the ski to stop and the binding on the ski did not release, then the substantial torsion applied to his knee by the ski would almost certainly cause injury. On the other hand, there may have been many reasons for bindings not releasing in AO's fall. In the event, AO chose to explore a public liability suit against MSHC, whose insurers hired *Biddlemore and Nevins* (*BN*) to defend the case against MSHC. In this case my instructions from BN were similar to those in the case of Michael Small. Here, however, apart from establishing binding release loads, there was also a concern about the way AO's boots were fitted into the bindings.

4.5.3 The Investigation

MS and the Figgles Ski

As a first step in this investigation it was necessary to compute the dynamics of tumbling over one's ski during a forward fall. Although not the most common type, this is the type of fall in which MS allegedly sustained injury. A ski hire agreement issued by BSL indicated the height and weight of MS, as well as his estimated skiing expertise and appropriate ski binding settings. Based on this ski hire agreement MS had the following hiring data:

Height (H) 1710 mm; Weight (W) 70 kg; Skiing expertise DIN rating 2; Release binding setting 5.5 DIN[4.18]

ISO 11088 Table B.1 recommends DIN 5.5 release binding settings for the mass and height of MS. This also corresponds to the DIN setting designated on the ski hire agreement issued by BSL. The corresponding static torque settings identified in ISO 11088 are:

4.18 Deutsche Industrie Normen (German Industrial Standard), see ISO 11088:1993(E) Assembly, adjustment and inspection of an alpine ski-binding-boot (S-B-B) system (relevant parts of this standard, including Table B1, provide release value selection based on the skier's weight).

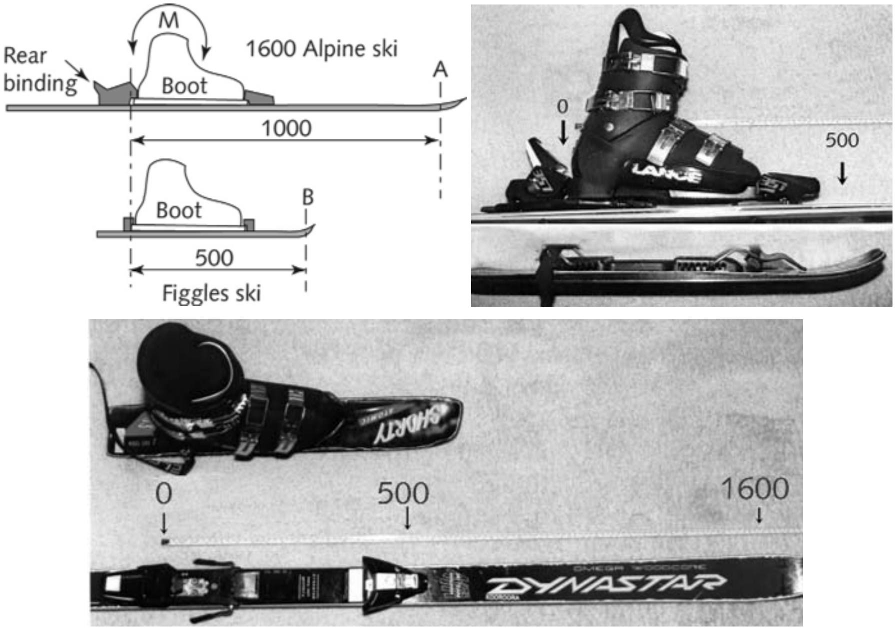


Figure 4.12 Relative dimensions of a standard Alpine ski and a figgles ski and elevation and plan photographs of the ski used by Small. The photo also shows the boot used by Small fitted to a standard 1600 mm Alpine ski

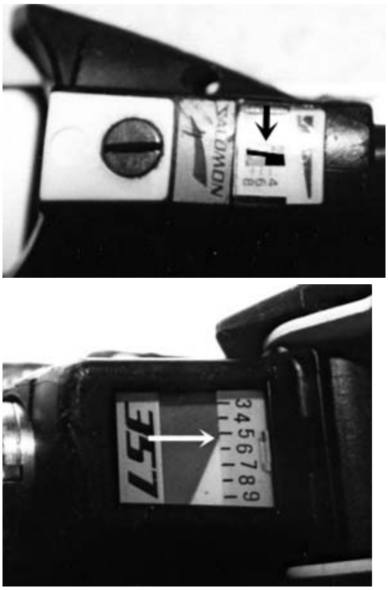


Figure 4.13 Toe and heel binding settings for Small on a 1600 Alpine ski (see arrows)

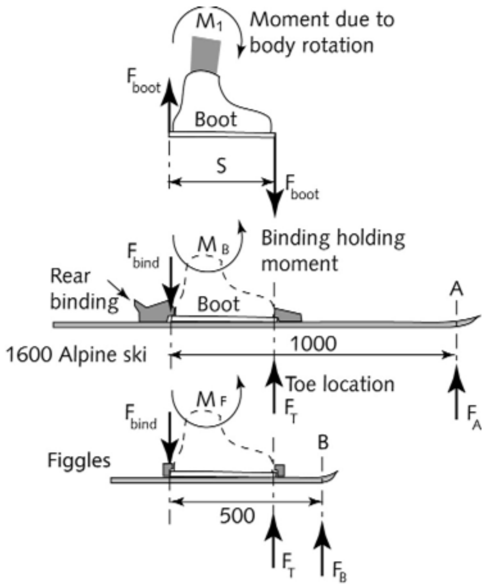


Figure 4.14 Schematic forces and moments acting on the figgles ski used by Small. A 1600 mm Alpine ski is shown for comparison

M_z = 48 Nm to 65 Nm

M_y = 170 Nm to 250 Nm

M_z is the rotational torque needed to release the binding under transverse loading. This is the torque loading that might apply to the vertical axis of the tibia.

M_y is the rotational torque applied in the vertical plane to release the binding. This is the type of loading experienced by a skier whose forward release fails to open in a serious fall, and this is the type of loading consistent with the type of injuries claimed by MS. Figure 4.15 shows the two moments acting on the ski boot.

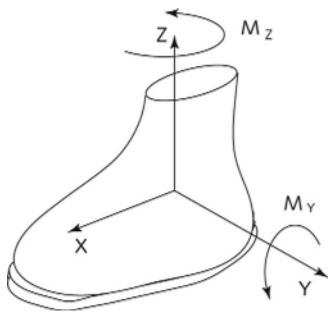


Figure 4.15 Coordinate system used by ISO 11088

Comparison of the Two Skis

The standard Alpine downhill ski hired to MS was 1600 mm long (nominally). The figgles ski, alleged to be responsible for MS's injuries, was 630 mm long (nominally). Figure 4.12 shows the two skis schematically as well as photographs of the two skis indicating the differences in bindings.

During forward motion on the snow, the curved-up tip of the alpine ski will smooth the snow in front of the ski. When forward pressure is applied to the ski by the moment M_y, exerted by the skier during a forward fall, the moment arm, available for generating sufficient release torque, is the distance between the heel registration of the ski boot in the release binding and a point near the tip, designated point A. Point A is the location on the alpine ski where the tip commences to turn upwards. Measurement on the alpine ski hired to MS indicates this distance between the heel registration of the ski boot in its binding and point A to be 1000 mm, shown in Figure 4.12. For the shorter figgles ski, the moment arm for generating a potential release torque is the distance between the tip of the ski (designated point B in Figure 4.12) and the heel registration of the ski boot in its binding. This distance was measured to be 500 mm.

Figure 4.13 shows photographs of heel and toe release bindings for the 1600 mm ski hired to MS. These photographs show that the bindings were indeed adjusted to be in accordance with the recommendations of *ISO 11088 Table B.1.* Figure 4.14 shows schematically the forces generated on the ski boot and Alpine ski at the instant just before binding release, when the body moment M_{body} reaches the value of the release torque M_y (Figure 4.15). The forces acting on the leg (knee and tibia) are calculated from the release moment applied to the boot sole length (S) as seen in the free body diagram of the boot in Figure 4.14. The sole length of the boots issued to MS by BSL was 310 mm. Based on the ISO recommended release torque M_y and the moment arm S, I estimated the forces acting on the tibia and knee in a forward fall, at the instant of release from the binding, as

$$F_{boot} \times S = M_{body} = M_y \ = 548 \text{ N} < F_{boot} < 807 \text{ N}$$

The force acting on the front of the ski, provided by the snow, F_A, can be calculated by taking moments about the toe location T.

$$M_y = F_{boot} \times S = F_A \times (1000 - 310) = 246\text{N} < F_{boot} < 362 \text{ N}$$

This force is distributed over the relatively small area of the ski tip during a forward fall and I estimate that about half the front of the ski will be still on the snow (by considerable bending) during such a fall. The average width of the ski is 80 mm and, consequently, the area of the ski on the ground during such a forward fall is $0.5 \times 1000 \times 80 = 0.04 \text{ m}^2$. The ground pressure is therefore estimated as

6.6 kPa (264/0.04) to 9.1 kPa (362/0.04)

Under normal operation, the snow loading under the Alpine ski used by MS is found from his total mass as

$$70 \times 9.81/(1.6 \times 0.08 \times 2) \quad = 2.7 \text{ kPa}$$

and for the shorter ski as

$$70 \times 9.81/(0.63 \times 0.08 \times 2) \quad = 6.8 \text{ kPa}$$

The same rule of conjecture may be applied to the figgles ski as that used for the Alpine ski in estimating ground pressure under the tip in a forward fall, namely that half the ski remains in contact with the snow in a forward fall (this is a very conservative estimate, since the figgles ski is not nearly as flexible as the Alpine ski). The estimated ground area over which the putative release loads would need to act is $0.25 \times 0.08 \text{ m} = 0.02 \text{ m}^2$. Hence, the ground pressure at or near the tip of the short ski necessary to generate the necessary moment to release the (putative) binding on the short ski is estimated at:

44.8 to 65.8 kPa.

These ground pressures are quite unsustainable on normal snow, and suggest that the skier will tend to dig into the snow and tip over the front of the ski in preference to releasing a binding. From this relatively simple evaluations of loads acting on the short ski in a forward fall, it seems clear that a release binding on the short ski would be of no practical value.

The Mechanics of Forward Release and Tumbling

A fall during skiing is a complex combination of forward and sideways rotation of the skier. In this simplified analysis of the mechanics of a fall, I have considered only a forward rolling action over the front of the ski. The intention of this simplified analysis is to demonstrate that, in such a forward tumbling fall, even if release bindings were installed on a figgles ski, they would not release the skier.

The release moment values have been experimentally determined to permit the skier being released from the binding in a forward fall. However, due to the dynamic nature of the forward release, the skier will experience some forward rotation θ while developing the forward moment, M_y, nec-

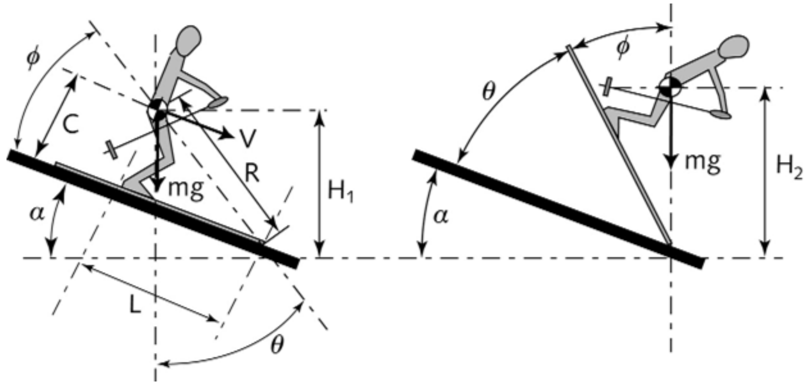


Figure 4.16 Two schematic views of a skier on a slope of angle α to the horizontal. In the right-hand diagram the skier has been rotated forward to a position where the vector of his weight is just aligned with the vertical through the tip of his ski (tumbling condition)

essary to relelease the binding. The following analysis examines the rotation angle θ experienced by the skier in a forward rotating fall. Consider the skier moving with forward velocity V on a slope that makes an angle α with the horizontal. Consider further that the front of the ski hits an obstruaction in the snow. As a result, the skier will commence to rotate forward on the ski until sufficient momentum, M_y, is developed on the binding to relaease the skier. In this process, the forward momentum of the skier will be converted to rotational momentum, resulting in the forward rotation θ of the skier before the binding releases. There will be a combination of θ and α, where the skier will no longer be released, but instead will tumble roll over the tip of the ski. This condition is indicated schematically in the right-hand diagram of Figure 4.16. Should the value of θ be such that the skier's centre of mass rotates to be vertically above the ski tip, the skier may tumble rather than be released from the binding. I refer to this condition as the tumbling condition.

The left-hand diagram of Figure 4.16 shows a skier on a slope just prior to an impact which an obstruction. The right-hand diagram in Figure 4.16 shows the condition necessary for the skier to tumble over the tip of the ski (tumbling condition). Both diagrams are schematic only and not to scale.

We can estimate the conditions necessary for tumbling over the front of the ski in preference to releasing the binding set to a forward release torque of M_y. These calculations were performed for several values of slope angle α, since the angle of the slope, on which MS was skiing at the time of his fall, is uncertain. From my experience at Mt. Buller, and from the copies of the photographs of the slope provided to me, I estimated the slope on which the accident occurred somewhere between 10 and 30 degrees to the horizontal.

The values of θ can be calculated as follows (refer to Figure 4.16):

R is the distance between the centre of mass of the skier and the point at the ski tip about which the tumbling rotation will take place.

C is the distance to the centre of mass and L is the ski length from heel binding to the point designated A in Figure 4.12.

$$R = \{C^2 + L^2\}^{0.5}$$

$$\phi = \tan^{-1}(C/L)$$

$$\theta = 90 - (\alpha + \phi)$$

$$H_1 = R \sin(\alpha + \phi)$$

In this analysis the distance C was taken as half the height of MS (0.855m). Table 4.2 lists the calculated values of θ for several values of α.

From energy principles we can estimate the moment developed at the boot of the skier when experiencing a forward fall of the type described here and depicted schematically in Figure 4.16. When the tip of the ski hits an obstruction, the skier will rotate forward and in this process the release moment M_y needs to be generated at the ski boot to release the skier from the binding. As a conservative estimate, I have assumed that the impact acceleration experienced by MS, a novice skier, was approximately $2g$. This is a relatively low acceleration tumbling fall, typical of the type experienced by beginners. The work done by the moment M_y in rotating through the angle θ is that required to rotate the skier through the same angle θ. Noting that there are two boots and referring again to Figure 4.16,

$$2M_y\theta = 2mg(R - H_1)$$

In this highly simplified analysis the boot moment developed is independent of forward velocity. The real skiing situation will be very different, and forward velocity will be an important determining factor in generating the forward release moment on the bindings. However, this analysis was intended only as a comparative evaluation of how a release binding might behave, when installed on a figgles ski. It is clear from Table 4.2 that the angle θ available before the tumbling condition is reached with a short ski is significantly less than would be the case for a standard Alpine ski. On a slope of 30 degrees a skier of the stature of MS with a short ski would almost tumble over merely under the action of gravity while standing still.

Based on the curves in Figures *B.1* and *B.2* in *ISO 9462:1993(E)*, the forward release moments recommended for a skier of the height and weight

Table 4.2 Parameters of ski dynamics

Slope angle α degrees	*M_y for Alpine ski (Nm)*	*M_y for figgles ski (Nm)*	*Alpine ski θ degrees*	*figgles ski θ degrees*
10	298	119	39.3	20.3
15	263	90	34.3	15.3
20	226	61	29.3	10.3
25	189	32	24.3	5.3
30	151	1.8	19.3	0.3

of MS is in the range 170Nm to 250 Nm. Table 4.2 shows that the release moment generated with the Alpine ski remains in this range until the slope angle is increased to 30 degrees to the horizontal. By contrast, the figgles ski never develops sufficient release moment.

The Faulty Equipment Hired to Alan Oldwell

The following international standards are relevant to ski equipment:

ISO 9465:1991(E) Alpine ski-bindings – Lateral release under impact loading – Test method.

ISO 8061:1991(E) Alpine ski-bindings – Selection of release torque values.

ISO 11088:1993(E) Assembly, adjustment and inspection of an alpine ski-binding-boot (S-B-B) system.

ISO 9462:1993(E) Alpine ski-bindings – Safety requirements and test methods.

ISO 5355:1997 Alpine ski boots – Safety requirements and test methods.

The setting of ski bindings is based on a standard table of values recommended by ISO 11088 Table B.1. The settings are referred to as *DIN* (Deutsche Industrie Normen – German Industrial Standards) values determined as suitable for *reasonably safe* skiing. Of course, no amount of standardisation can cater for the considerable uncertainties that exist in skiing. Variable terrain and snow, changes in diurnal temperature and weather conditions, skier skill and physical fitness are all matters that contribute to the complexity and challenge of skiing as a sport. Consequently, safety of the skier can be only regarded as *reasonable* within the experience of the international standard used to define the DIN settings.

Skier-specific DIN settings are based on skier physique (height and weight) and ability. According to Table B1 in ISO 11088, a setting of DIN

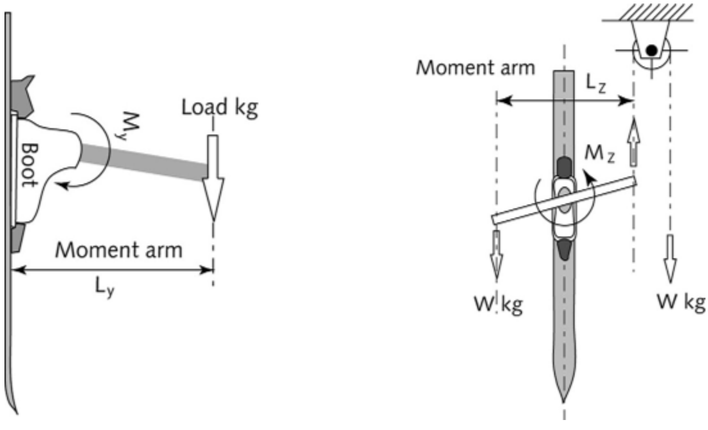


Figure 4.17 Schematic arrangements for testing Oldwell's skis for both overturning moments and twisting moments

6 with a boot sole size of 311 mm corresponds to a skier mass between 79 to 94 kg and a height of 1.79 to 1.94 m. These values also correspond to the following values of static release torques (refer to Figure 4.15):

Twist	M_z	= 58 Nm
Forward lean	M_y	= 229 Nm

When a skier falls during skiing, release from the bindings can occur in a complex combination of twist and forward release. The whole matter of release is a delicate balance between staying attached to the ski during the complex dynamic process involved in making turns on the slope while attached to a twisting and bending beam (the ski) and being released from it during a fall. It can be almost as dangerous, if not more so, to be released prematurely from a ski during a skiing manoeuvre. Figure 4.17 shows the schematic arrangements designed to test AO's skis for the two release moments and Figure 4.18 shows the ski under test in the author's laboratory. For these tests the release bindings were adjusted to the value specified by Table B1 in ISO 11088. Several static loading tests were performed on both right and left skis with the following results:

DIN setting		= 6	
Boot sole length	S	= 311 mm	
Forward release mass		= 22.7 kg (50 lb)	
Forward release arm	L_y	= 0.998 m	
Release moment	M_y	= 22.7 × 9.81 × 0.998	= 222 Nm
Twisting moment arm	L_z	= 0.48 m	

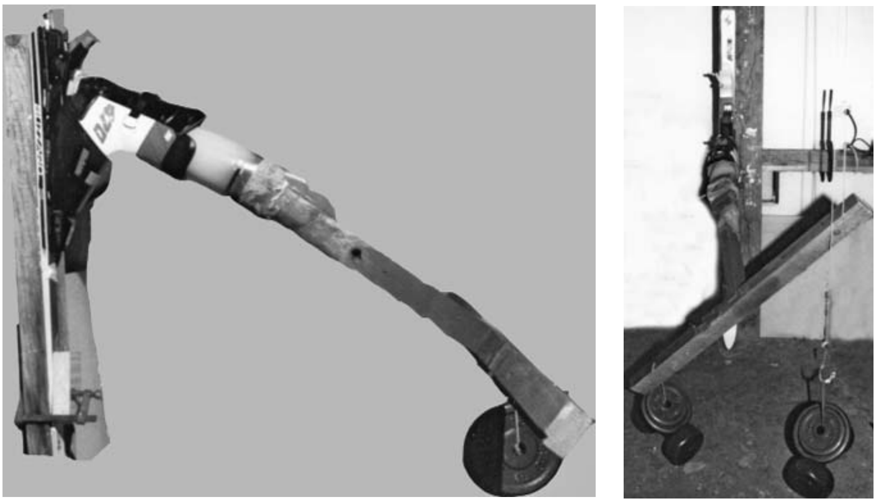


Figure 4.18 Ski being tested for overturning moment and twisting moment. The prosthetic leg, matching the boot size used by AO, was kindly provided by a rehabilitation unit of the Caulfield Community Hospital in Melbourne

Twisting release load $= 13.6$ kg (30 lb)

Twisting moment $M_z = 13.6 \times 9.81 \times 0.48 = 64$ Nm

Although ISO 1108 specifies the selection of release torque values for Alpine ski bindings, ISO 9462 deals with the various uncertainties that impact on the release torque settings. This latter standard also offers upper and lower bounds on the torque settings (tolerances). According to these tolerance graphs the range of values for these release moments, corresponding to a DIN setting of 6 are as follows:

Forward release moment $M_y = 208$ Nm to 270 Nm

Twisting moment $M_z = 53$ Nm to 69 Nm

Clearly, the values of release moments found for AO's skis with the recommended settings lie well within the ranges of values judged appropriate by Table B.1 in ISO 11088 for release moments corresponding to his physique and skill level.

In the dispute under investigation a further complication arose due to the claim by AO that the failure of the release bindings to operate during his fall was due to a worn heel pad on his right ski boot. Figure 4.19 shows the nature of wear on the heel of the boot. When skiers walk in these boots (on the way to the ski slope, for example), due to the restricted bending afforded by the boot heel, most of the wear takes place on the heel. For this rea-

Figure 4.19 The worn heel pad on AO's right boot

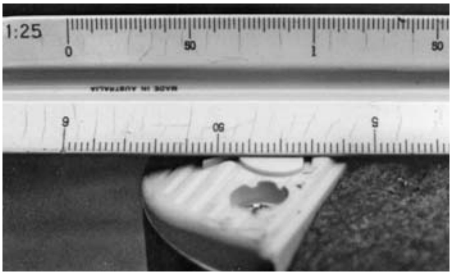


Figure 4.20 A new heel pad on a ski boot similar to AO's right boot

Figure 4.21 The right ski boot under forward release moment test

Figure 4.22 The right ski boot just before forward release

son, most ski boot manufacturers provide a replacement heel pad that may be installed on the worn boot. The photograph of Figure 4.20 shows a typical replacement heel. This photograph also shows that the new heel pad has a slight bevel upwards away from the heel plane. This bevel is intended to overcome the point loading, and consequent substantial initial wear on the heel, that would be experienced by walkers in ski boots without the bevel on their heel pads.

Photographs in Figures 4.21 and 4.22 show the worn ski boot under forward release test and just prior to forward release respectively. It is clear from these photographs that the heel is lifted clear of the ski during forward release (see the arrows in the figures). Consequently, it is unlikely that heel wear would play any part in the mechanics of forward release.

4.5.4 Outcomes and Lessons Learnt

The Figgles Ski of Michael Small and Buller Ski Lifts

On review of the evidence it appeared that BSL acted within the accepted industry regime of ski school operators. Dynamic analysis of the figgles ski in comparison to a standard Alpine ski showed that even at very low speeds a skier with the figgles ski will tumble in preference to being released from any release bindings set to the appropriate ISO recommended values.

Having been provided with this analysis, as well as other substantial evidence from other experts in human factors and ski school operators, and in spite of the overwhelming evidence against proceeding with this case, MS chose, with unrelenting determination, to proceed to court. The case was heard in the Supreme Court of Victoria in front of a judge for a period of five days. Apart from the several experts and legal teams on both sides of this case, an *EAD*[4.19] skier was flown in from Canada to give evidence about skiing and ski school operations. The EAD skier, a gold medalist in giant slalom, had two artificial below-the-knee limbs. His evidence was addressed to the robust nature of the sport. MS declined an offer of compensation in a mediation hearing. He had his day in court but ultimately lost the case and was required to pay for all costs.

Alan Oldwell and the Matterhorn Ski Hire Company

Interestingly, all the evidence in this case supported MSHC's actions in providing the correct ski boots (well fitted according to AO's statement) and an appropriate choice of DIN setting for the release bindings. The release tests supported the DIN setting and showed these settings to be appropriate for the physique and skill level of AO. Considering all this evidence in favour of MSHC, it was a most unfortunate revelation that the ski hire agreement issued by MSHC staff did not record the height, weight, skill level and DIN setting requirement for AO. Although this may have been an oversight committed in error, MSHC's insurers wisely chose to resolve the issue in an out-of-court settlement.

4.19 Elite Athletes with Disabilities.

4.6 Industrial Pressure Cooker Kills Cleaner

Encyclopedia Britannica identifies a pressure cooker as a

"hermetically sealed pot which produces steam heat to cook food quickly. The pressure cooker first appeared in 1679 as Papin's Digester, named for its inventor, the French-born physicist Denis Papin. The cooker heats water to produce very hot steam which forces the temperature inside the pot as high as 266° F (130° C), significantly higher than the maximum heat possible in an ordinary saucepan. The higher temperature of a pressure cooker penetrates food quickly, reducing cooking time without diminishing vitamin and mineral content … Modern innovations in pressure cooker design include safety locks, pressure regulators …"

Mountaineers and ski enthusiasts are well aware of the effect of altitude and reduced atmospheric pressure on cooking. At an altitude of 2000 m the atmospheric pressure has dropped to about 0.7 bar and water will boil at approximately 90°C. At this altitude, it takes approximately 5 minutes to prepare a soft-boiled egg that would require only 3 minutes at a pressure of 1 bar (sea level). M. Papin was motivated to improve matters by the invention of the pressure cooker in 1679,[4.20] although he was more concerned with using the device as a retort for cleaning laboratory implements. Domestic application of pressure cooking was adopted very much later. One of the earliest patents for pressurised cooking in the US was granted to J. K. Hawkins in 1910 (*US947062 – Pressurized Cooker and Canner*). However, the idea of increasing steam temperature, by increasing the pressure in a sealed vessel, is so generic in nature, that patents relating to its use abound in the patent literature. Pressure cooker patents are still being granted for devices that include various modifications of the original concept. As well, there is a constant stream of patents continuing to be approved for various locking and safety devices.

Figure 4.23 An early design of industrial pressure cooker and a current form of industrial pressure cooker being used as a horizontal autoclave

4.20 MacLachlan (1974).

4.21 See, for example, US4932550 (1990), US6523459 (2003), US6708837 (2004), and others at http://patft.uspto.gov/netahtml/.

Figure 4.23 shows two examples of industrial vessels that permit heating steam to temperatures above 100°C, by sealing the vessel. The subject of this case is a similar industrial vessel designed to pressure cook batches of meat products in pie manufacture.

4.6.1 The Case Culture and The Defining Event

Danny Bhoy Pies (*DBP*) produce a variety of meat pies and other pastry products. In 1986 they purchased an industrial pressure cooker, colorfully titled *JustMix*, from *Jackson and Ripper Ltd.,* a UK manufacturer of industrial cooking equipment. DBP planned to use the JustMix cooker as part of their batch production meat pie line. This 1-metre-diameter cooker was fitted with a camlock system of lid closure, as well as various electrical controls and interlock devices to ensure safe operation. The cooking pressure in the vessel was set to 10 kPa, and it was heated by means of super-heated steam being passed through a jacket surrounding the vessel. In industrial steam-heating, processes-temperature is often controlled by controlling the pressure of the steam used for heating. This control is permitted by the direct relationship between steam pressure and temperature. It was this relationship that was exploited in the invention of the household pressure cooker. Recall the variable mass mounted on the opening of the cooker's lid. This mass was calculated to generate the appropriate pressure (and corresponding temperature) in the cooker during operation.

Pressure is relatively easy to regulate by appropriate opening and closing of valves. This was the type of temperature control used in the JustMix cooker. If the pressure in the vessel exceeded the set value, a relief valve would activate and vent the excess pressure to atmosphere. Batch cooking time was set on an electronic timer. Once the set time expired, the heating was switched off at a shut-off valve and the vessel was allowed to cool. As a result of the cooling process the pressure inside the vessel would fall to atmospheric. Safety interlocks were so arranged that the vessel could not be opened until the pressure inside the vessel had reached atmospheric pressure. Figure 4.24 shows the control circuitry schematically.

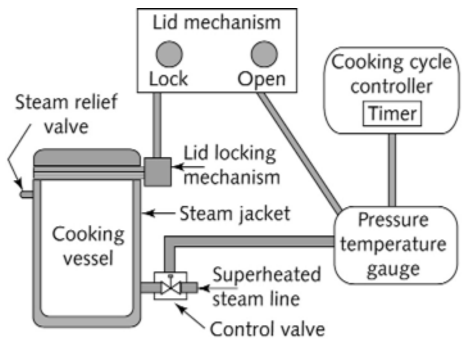


Figure 4.24 Schematic diagram of the JustMix cooker and controller

Josef Karamazov (*JK*), a Ukrainian teacher with almost no English language skills, was employed in 1988 by DBP as a night-shift cleaner, while he was learning the language in an *EASL*[4.22] programme at a technical college. On all accounts JK was regarded as a conscientious worker with a strong ethic of providing value in his work for the wage paid by DBP. This information was provided by his company evaluation record. On the night of 23rd January 1993 JK was scheduled to clean out the JustMix cooker. He had done this many times previously as a regular part of his cleaning schedule. His regimen of cleaning was explained to him by the shift foreman during his induction in 1988.

1. The cooker would be partially filled with water and the cooking cycle timer was set to 10 minutes.
2. The lid would be closed and the lid lock mechanism would be actuated by pressing the lid lock control button. These two actions (lowering and locking the lid) occurred in sequence once the lid lock control button was depressed by the operator.
3. On completion of the cooking cycle, the cooker would be opened and washed out with the hot water remaining in the vessel.
4. The lid lock release button could be pressed at any time after the completion of the cooking cycle. This button controlled the operation of the lid lock hydraulic system. It would only operate once the pressure in the vessel had reached atmospheric pressure. Once the cooking cycle time had elapsed, JK would press the release button several times to check if the vessel had "depressurised". This was a procedure advised to him by the shift foreman earlier.

Shortly after such a release check on the night of 23rd January 1993, as JK was walking away from the vessel to attend to other work, the lid of the JustMix cooker flew open and JK was covered with 110°C steam. He was treated for the severe burns inflicted on him in this accident but he died from his injuries three days later.

4.6.2 The Client and the Expert's Role

There was a routine occupational health and safety investigation of the accident and Mrs. Luba Karamazov was offered a worker's compensation settlement. She was advised by her solicitors *Boris, Mancash and Burnblack* (*BMB*) to sue DBP for negligence. My briefing came from BMB, after various investigations of the operation of the JustMix cooker revealed some problems in its lid lock control mechanism. By the time I was briefed there were four sets of defendants.

1. Defendant No. 1 was Danny Bhoy Pies, for their part in operating an unsafe work environment.

4.22 English As a Second Language.

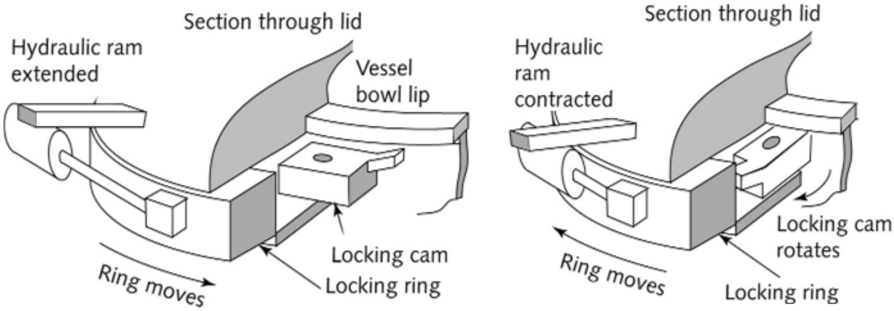


Figure 4.25 Schematic sketch of the lid locking mechanism showing the locking cam (there are several of these around the vessel's perimeter) both fully locked and fully unlocked

2. Defendant No. 2 was *Jackson and Ripper Pty Ltd.* (*JR*) the UK manufacturers of the JustMix cooker.
3. Defendant No. 3 was *Rattus and Dreck Ltd.* (*RD)* a UK manufacturer responsible for the design and manufacture of the lid lock mechanism on the JustMix cooker. RD was a subcontractor to Jackson and Ripper.
4. Defendant No. 4 was *Frost Leaf Controls* (*FLC*), the designer and manufacturer of the controller for the JustMix. FLC was also a subcontractor to Jackson and Ripper.

My brief asked for an examination of the lid locking mechanism and its controller, including an opinion about the safety of the operation of the JustMix cooker at Danny Bhoy Pies. There were several expert investigations conducted to discover the way this accident could have occurred. One investigator discovered that the operation of the lid closure mechanism was faulty. Under normal operation of the lid lock controller, the lid closure required that the lid lock control button be depressed by the operator until closure was completed. If the operator released the lid lock control button before full closure, the lid locking cams would not rotate fully into position under the lip of the vessel. Only close inspection of the closure mechanism would reveal this condition. As a result of this discovery, the manufacturer and the several subcontractors were enjoined to the suit against DBP.

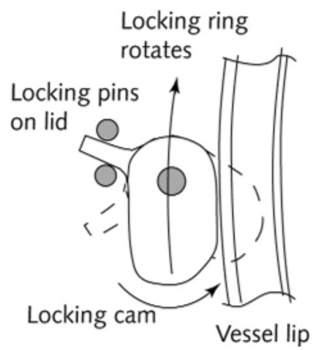


Figure 4.26 Plan view sketch of actual lid locking cam from drawings of the JustMix cooker (not to scale)

4.6.3 The Investigation

Figure 4.25 shows the operation of the lid locking mechanism schematically. Figure 4.26 is a plan view of one of the actual cams used in locking the lid down during pressurised cooking. On close examination of the control circuitry of the JustMix cooker and the lid locking system, the following was found:

1. The cooker's electrical control circuit was designed to protect the cooker cycle against the unclamping of the lid if the temperature in the cooker exceeded 98°C.
2. Further protection was supposed to be provided by a pressure sensor set to prevent operation of the lid opening button when the pressure exceeded the pressure switch set point (atmospheric pressure).
3. Once the lid lock control button was depressed, the lid would be lowered by a pneumatic system, following which the lid locking hydraulic system would operate the 20 locking cams around the periphery of the vessel. These cams would engage with the vessel lip as indicated in Figures 4.25 and 4.26.
4. After the cooker was installed at DBP, Defendant 1 installed a 2-second delay timer into the lid locking cycle. This was intended to permit the lid to seat securely before the lid's locking cams could be actuated.

Examination of the cooker and its lid after the accident revealed that, if the operator released the lid close button before the lid clamping operation was completed, the lid would be incompletely clamped. Consequently, it was entirely possible that under pressure the lid could open, as it did for JK, venting super-heated steam and boiling water. The mechanical system employed for closing and locking the cooker's lid required the operator to press the lid close button until the lid closing cycle was completed. Then, after a 2-second delay, the lid's locking mechanism would be actuated hydraulically and 20 locking lugs would be rotated into their locking position and clamp the lid until the lid open button would be pressed.

In the opinion of another expert engaged by Defendant 1, a design fault in the electrical circuit allowed incomplete lid closure to occur. It was further alleged by Defendant 1 that a *"better and safer design"* would have allowed the clamping operation to be completed automatically when the lid close button was pressed and not be dependent on the finger pressure of the operator being maintained on the button.

According to my inquiries from DBP as well as my briefing attorneys, by the time I was briefed in 1995, the cooker had been *"sold for scrap"*. On further inquiry from a legal source[4.23], it is my understanding of these events that Defendant 1 may have *"breached confidence"* in these investigations, but may well have considered the matter sufficiently well explored by other experts to permit disposal of the cooker.

All the investigations of other experts in this case concentrated on the following factors:

4.23 For this information I am indebted to my friend and legal advisor Mr Gabor Fleiszig, of Fleiszig and Fleiszig Solicitors, Melbourne

(a) Structural integrity of the cooking vessel (TS Ltd.) – This was found to be well within specifications.

(b) Post-accident appearance of the cooker (report by Crusoe and Associates Ltd.).

– The locking cams of the lid lock mechanism appeared to be in good condition (i.e., not worn noticeably)

– Because wear on the locking cams could have substantial impact on the lid closure process, this assessment needed careful examination. As the vessel was no longer available for inspection, legal argument might ensue about the nature and veracity of this opinion. It is specifically this issue that I referred to as *"breaching confidence"* in the investigation when Defendant 1 disposed of the vessel

– The lid closure cycle depended on the operator holding the close button pressed until the cam lock mechanism had fully engaged the cams in the lid. If the operator did not maintain button pressure during this cycle the quick lock cams would not fully engage, presenting a serious hazard to pressurised operation of the vessel

(c) The actions of the deceased just prior to the accident (all reports).

4.6.4 Evaluation of the Investigation

There is very little doubt about the mechanism of the failure of the JustMix vessel. It failed to remain closed under pressure while being cleaned by the deceased. It seems more than likely that either the lid closure cams were not properly engaged with the lid when the deceased closed it for pressurising, or the cams were sufficiently worn to permit the vessel to open under pressure. This latter condition could not be checked since the vessel was no longer available for inspection. However, if one accepts the opinion of other expert investigators, the locking cams were in reasonable operating condition after the accident.

The effect of using the release button to check if the vessel had cooled sufficiently to permit opening had some influence on the initiation of the accident. When JK pressed the open button and *"nothing happened"*, something actually did happen. The hydraulics received an *"open"* signal and may have initiated an opening cycle. However, the temperature interlock signalled to prevent opening. This is a common feature of all interlock systems that a small time delay takes place during servoing, depending on the servo stiffness (responsiveness) of the controller. As can be seen in Figure 4.26, each locking cam had a *"lead-in"* chamfer to permit smooth operation during the locking cycle. Even a very slight servo delay in the response of the hydraulic closure system to the temperature interlock could have dislodged the locking cams to a configuration where the lead-in chamfer of the cams would be bearing on the edge of the vessel bowl's lip (see the right-hand diagram in Figure 4.25). At 110 kPa (operating pressure) the load on the 1-metre-diameter lid would have been approximately 8.8 ton. It is quite conceivable that subjected to this substantial load, with the locking arrangement configured as conjectured, the lid may have been blown open.

In the absence of the vessel the above-conjectured mechanism of failure cannot be verified or discarded, but it does offer a plausible mechanism for the failure of the locking system. In spite of this there remain several unanswered questions about the events leading to the accident. Moreover, none of the investigators considered these matters in offering a purely technical opinion.

A curious anomaly arose from the reports of the condition of the locking cams and the lid lock mechanism. The technical report of *Crusoe and Associates* states that *"the cams showed no significant wear"*, while suggesting that *"the cams would be well lubricated from animal fats generated by the product in the cooker"*. This latter observation signifies reduced friction at the cam/vessel lip interface during the latching process, possibly exacerbating the opening of the lid if the vessel lip was bearing only on the lead-in chamfer of the locking cams. Notably, this configuration would also result from an incomplete closure of the lid. In addition, even if the cams showed wear or scoring, there was no evidence of any close inspection of the underside of the vessel lip. It is that surface that would have shown up local damage resulting from a locking mechanism failure. A facsimile message from an expert hired by Defendant 2 (JR) offered the conflicting opinion that *"the cams were worn and covered with animal fats"*. In the absence of the vessel, one could conjecture this to have been an opinion attempting to share responsibility for a possible design fault (from JR) to one of maintenance (DBP).

The manufacturer JR, and others (Defendants 2, 3 and 4)

The cooker, a simple jacketed pressure vessel, operated as a pressure cooker. When over-pressure occurred, venting of the vessel would follow. In a domestic cooker the complete, or partial, closure of the lid is easy to recognise, because of registration marks commonly provided by domestic cooker manufacturers. With the JustMix, completion of the locking cycle was not easy to verify. The locking controller's dependence on finger pressure to complete the locking cycle was seen by all investigators as a serious design fault. Responsibility for this fault must rest with JR and the controller manufacturer. In addition, considering the very serious consequences of a boiler explosion (in a sense it is what happened in this accident), the system designers and installers appear to have taken a rather cavalier approach to the matter of verifying the closure of the lid lock system.

The operator Danny Bhoy Pies (Defendant No. 1)

Josef Karamazov (the deceased) was a good and diligent worker by all accounts. Nevertheless, he was an unskilled operator, with poor English language skills, in charge of a hazardous boiler. He may have been trained to do cleaning, but he may not have been made aware of the very real hazards associated with boilers, and gas (steam) explosions even at relatively low pressures.

The JustMix handbook for the operation of the cooker refers to three *CIP* (clean in place) cycles. A CIP cycle is a timer-controlled cleaning (cooking) cycle initiated from the control panel that would not require the operator to manually check if *"the cycle was complete"*. Had such a CIP cycle been initiated by JK as a routine cleaning procedure, he may well be alive today. Checking the completion of the cooking time manually by the operation of the lid lock open control button was a most dangerous procedure. The advice given to JK about this procedure by the DBP foreman clearly places responsibility for the hazardous operation on Defendant No. 1.

Risk Analysis of Industrial Accidents

Industrial accidents resulting from the operation of hazardous equipment may be attributed to one or more of the following:

1. *Operator faults –*

    1.1. Failure to operate equipment according to maker's specifications,

    1.2 Failure to read operating condition gauges correctly,

    1.3 Failure to heed or act on hazard warnings,

    1.4 Failure to take appropriate action to minimise hazard or injury.

2. *Design faults –*

    2.1 Insufficient structural integrity,

    2.2 Inadequate control interlocks,

    2.3 Failure to perform to agreed specification,

    2.4 Failure to properly identify known hazards and contingencies,

    2.5 Failure to clearly identify all operating gauges and control features,

    2.6 Failure to provide proper training programmes and manuals.

3. *Manufacturing faults –*

    3.1 Improper choice of materials,

    3.2 Improper choice of manufacturing process,

    3.3 Outside agreed tolerance specifications.

4. *Unexpected or unplanned-for events, "Acts of God", for examples –*

    Uncontrollable or unexpected environmental conditions (e.g., unexpectedly high or low temperatures or wind loads), land subsidence, lightning strike, collision with other plant equipment, being dropped while in transit.

Table 4.3 Risk Analysis

Type of cause	Probability of occurrence
Operator faults	
1.2 Failure to read operating condition gauges correctly – inability to ascertain proper lid closure.	Very high
1.4 Failure to take appropriate action to minimise hazard or injury – if the cooker was tested at commissioning, then the operator (DBP) must have been aware of the fault in the lid closure operation.	Medium to high
Design faults	
2.2 Inadequate control interlocks – the maker must have been aware of the operational weakness in the interlock with the lid closure mechanism.	Very high
2.4 Failure to properly identify known hazards and contingencies – If the manufacturer knew about the interlock weakness, then as a duty of care to the operator they should have installed a proper warning system for incomplete lid closure. In the event they did have a hardly discernible warning light on a user-unfriendly control panel.	High
2.5 Failure to clearly identify all operating gauges and control features – The poor control panel layout may have been a result of established operating procedure with the manufacturer. Given proper training and expertise we can presume the operator could be expected to learn the operation of the panel. If an unskilled labourer was expected to operate the cooker, this fault may be seen as serious. The maker should have known who would operate the cooker from experiences with other operators. The manuals and training procedure should have taken care of this issue.	Moderate depending on proper training procedures
2.6 Failure to provide proper training programmes and manuals – I note no reference to the warning light for the incomplete lid closure in the operating manual supplied to me. However, such reference may have been part of the training procedure offered to operators, including the deceased. Since the mother tongue of deceased (as with several other cleaners at DBP) was not English, the language barrier may well have exacerbated this type of event.	Moderate to high
Manufacturing faults	
3.3 Outside agreed tolerance specifications – the weakness in the interlock should have been eliminated at manufacture. This weakness made the cooker unmerchantable. While this may have been an "unarticulated" quality issue, the manufacturer's duty of care to the customer should have made it imperative that this weakness was eliminated.	High

4.6.5 Opinions and Lessons Learnt

Table 4.3 presents an evaluation of the risks associated with the operation of the JustMix cooker. Based on the probabilities of events leading to the accident, it appears that a large part of the responsibility for the accident must be borne by the designer and manufacturer of the cooker and its controls (Defendants Nos. 2, 3 and 4). The lid lock mechanism should operate quite successfully if proper interlocks were used to ensure the full closure of the vessel.

It would have been relatively simple technically to ensure that the locking mechanism operated safely. This aspect of the accident and its causes must be seen to be the responsibility of the suppliers Jackson and Ripper. Danny Bhoy Pies must also take some significant portion of responsibility as the vessel operator. An unskilled cleaner could not be expected to be aware of the full significance of hazards associated with boilers. This is regarded as part of the expertise of a technically trained and skilled boiler operator. The deceased was certainly not that.

After appropriate evaluation, the matter was resolved by a substantial out-of-court settlement to Luba Karamazov from the workers compensation insurers and public liability insurers of DBP. Some components of the settlement were recovered by retrograde litigation from the insurers of Defendants 2, 3 and 4.

4.7 Front-end Loader Crushes Mine Mechanic

When first the Fox saw the Lion he was terribly frightened, and ran away and hid himself in the wood. Next time however he came near the King of Beasts he stopped at a safe distance and watched him pass by. The third time they came near one another the Fox went straight up to the Lion and passed the time of day with him, asking him how his family were, and when he should have the pleasure of seeing him again; then turning his tail, he parted from the Lion without much ceremony. "Familiarity breeds contempt."

Æsop (Sixth century B.C.). Fables

An historical account of gold mining in Australia notes:[4.24]

> *"Australia's population and prosperity boomed in the early 19th century with the discovery of gold. News of the Rush spread around the world, bringing many immigrants to Australia to try their luck. Life on the diggings was rough and dangerous."*

Today, gold is Australia's second-largest export earner, after coal. Australia is also the world's second largest producer together with the USA after South Africa. Australia contains 10% of the world's gold resources and is presently ranked third after South Africa and USA. These days, mining is highly mechanised and most of the underground work involves carting large quantities of gold bearing ore to the processing plants. Although the social environment has improved substantially since the 19th century, mechanical mining still presents substantial dangers to its participants. This

4.24 www.canterbury.nsw.gov.au/library/homezone/gold.htm.

case is about mechanical mining and the dangers of overfamiliarity with apparently benign mining equipment.

4.7.1 Case Culture and the Accident

The *Tarabell Goldfields* (*TG*) mine is situated near the country town of *Tarabell* in North Eastern Victoria. It is the leading gold producer in Victoria and produces around 110,000 ounces per year. One of the most common pieces of mechanical equipment in the mining industry is the *Long Haul Ore Loader* (*LHOL*). This is an articulated front-end loader designed to smoothly fit through the narrow mine tunnels, while carrying substantial loads of ore. Figure 4.27 is a photograph of the R2800 LHOL, which is the subject of this case. Two key features of the LHOL are its articulated prime mover and the compact geometry of the bucket and lifting gear. Articulation permits steering the LHOL through narrow tunnels and the lifting geometry permits operation close to the ore face.

Dennis Gibbon, a hydraulic maintenance mechanic, was a contract employee of TG and had several years of experience in operating and servicing the R2800 LHOL. Apart from his work with TG, Dennis operated *Tarabell Hydraulics* (*TH*), a hydraulic maintenance service workshop, in Tarabell. His maintenance employment with TG was on a retainer that would permit TG to demand *"first call"* on his time, whenever a maintenance issue arose in the mine. This arrangement is common practice where infrastructure technology (maintenance, accounting or data base management, for example) is outsourced by manufacturers committed to *"lean manufacturing"*.[4.25]

Figure 4.27 Articulated long haul ore loader

4.25 See, for example, Gunasekaran (2001), Correll and Edson (1999), Bicheno (1994).

Machinery of the R2800 LHOL type recovers its cost to the operator by the volume of work it can produce. When the machine could no longer provide an acceptable volume of work, without major overhaul of its components, it was retired from service, and was garaged at Tarabell Hydraulics for the purposes of resale. As a contract operator, Dennis owned and operated a similar type of machine, though not exactly the same as the R2800. He was a capable serviceman with expert knowledge of the machine and its hydraulic systems. Whatever his continued relationship was with TGM, he was permitted to remove parts from (*"cannibalise"*) the R2800 machine, to maintain his own machine in working order.

The R2800 machine was constructed sometime between 1992 and 1993 by *Caterpillar-Elphinstone*, a subsidiary company of Caterpillar Australia Ltd. in Burnie, Tasmania. It was purchased by TG for mine works and, during its operation at the mine, it was properly serviced according to the recommendations of the service manuals supplied with the machine. Dennis Gibbon had at various times serviced the machine. The last known occasion of safe operation of the machine occurred on 27 October 1999 at the Tarabell Fair. At that time it was operated by a mine employee for carrying waste material and litter generated at the Fair. According to maintenance records, the machine, although no longer suitable for regular mine operation, was in complete working order at that time.

Sometime on Sunday, 21 November, 1999, Dennis went to Tarabell Hydraulics to work on, or to remove, a component from the R2800 machine. This component is a short length of lubricating hose on the lift arm of the machine and provides lubrication to the front pivot of the lift ram. Figure 4.28 is a close-up view of the lubricating hose in question. Presumably Dennis had a need for this component to maintain his own machine. Although it may appear an insignificant component, there may have been several factors that may have helped to contrive the situation Dennis found himself in. Purchase of the hose from the supplier may have been both costly and time consuming. Dennis may have had a pending contract for his own machine, generating an urgent need for replacing a damaged hose. Whatever the case it was during the process of removing this hose that Dennis Gibbon was killed.

Work on the lubricating hose was difficult without lifting the bucket to a position indicated in Figure 4.29. According to the police report of the accident, there were tools found on the machine (a shifting spanner on the hose coupling), consistent with the supposition that the Dennis was in the act of working on the coupling when the accident occurred.

At the time of the accident, a component of the electrical system had been removed from the R2800 machine. This component, described as the *stop solenoid*, permits interruption of electric supply to the engine, for the purpose of stopping the engine. As a result, the two remaining methods of stopping the engine at the time of the accident were, (a) the interruption of the fuel supply and (b) stalling the engine by reaching the hard stops on the

Figure 4.28 Close up view of the lift arm pivot lubricating hose

Figure 4.29 Bucket raised to provide access to outer pivot on lift arm

hydraulic rams. Although it is uncertain whether Dennis had stopped the engine, it was certainly stopped at the time the accident was discovered. While he was attempting to remove the small hydraulic hose, the bucket dropped down and crushed the lumbar region of Dennis, killing him almost instantly.

4.7.2 The Client and the Expert's Role

Although garaged at TH, the R2800 machine was still owned by TGM. The accident was initially considered as a work-related accident possibly covered by worker's compensation insurance. TGM's worker's compensation insurers were advised by their solicitors to seek expert opinion about the accident, with a view to identifying it as a case of *"misadventure"* on the part of the deceased. The resulting expert evidence should be provided to the coroner's inquiry into the accident. In the event that the coroner's inquiry into the accidental death of Gibbon should find the accident to be misadventure, then the deceased's personal life insurance and perhaps Tarabell Hydraulics' liability insurers would carry the cost of compensation. In effect, my brief was based on a *"load shedding"* objective by TGM's insurers. My brief from *Bamber and Eastgirth Solicitors* (*BES*) acting for their clients, TGM's insurers, asked me to investigate the accident and to offer opinion about possible accident scenarios and if possible identify the most likely root cause of the accident. In this context I interpreted my role as developing a credible scenario that lead up to the bucket of the R2800 crushing Dennis Gibbon and killing him.

4.7.3 The Investigation

My main sources of information were:

1. Interview with Kevin Twaine (KT), the works manager and close associate of the deceased at TH, the person who found the deceased on the day of the accident;
2. Statement of John Robie, the maintenance superintendent at TGM;
3. Direct examination of the machine at TH.

Figure 4.30 Bucket lowered and tilted forward (man approximately 1.8 m height)

Figure 4.31 Lift arm lowered with bucket in "crowd" position and tape indicating "pinch point" width of 120 mm

The R2800 had two main articulations using hydraulic rams. One articulation moved the main lift arms up and down and the second articulation tilted the bucket forward (*"down position"*, used for digging) and backward (the *"crowd"* position used for carrying). All motion on the linkages actuating these articulations had *"soft"* and *"hard"* stops. Soft stops were determined by the hydraulic controls of each set of hydraulic actuators. Hard stops were, as the name suggests, metal bumpers welded onto the machine for stopping a specific motion should the hydraulics' soft stop fail. As noted earlier, by the time Dennis Gibbon chose to remove the small hydraulic hose from the R2800, the electric stop solenoid was missing from the machine. Consequently, Dennis could not stop the machine from the driver's control panel. He had to devise a means of getting access to the lift arm actuator's outer joint and to stop the machine in a configuration permitting him access to the joint lubricating hose.

Figure 4.30 is a photograph of the R2800 with the bucket forward and the lift arms lowered. The man standing between the wheel and the bucket is indicative of the scale of the machine. Figure 4.31 shows the narrowest distance between the bucket and the wheel when the lift arms are down and the bucket is in the *crowd* position. Figure 4.32 is a schematic sketch of the front end of the R2800, indicating this narrowest distance (*"pinch point"*).

When the deceased was found at the site he was in a location identified as the pinch point, with the hydraulic controls of the vehicle indicating that Dennis had put the bucket in the crowd position.

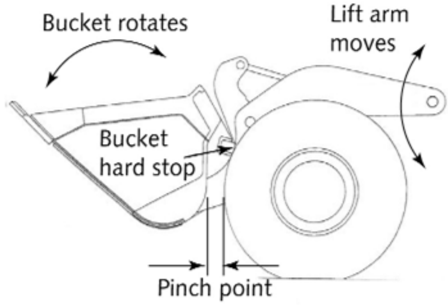


Figure 4.32 Bucket in crowd position, indicating the "pinch point"

The most plausible accident scenario is conjectured as follows:

1. Dennis Gibbon was in need of the short length of hydraulic hose available on the partially cannibalised R2800 machine at his works in Tarabell. Proceeding to the site he started the engine to provide power to the articulation hydraulics.
2. Upon raising the lift arm to the position required to gain access to the outer joint he needed to stop the engine to *"freeze"* the machine in this configuration. Having no other means of stopping the machine, Dennis used the crowd position *"hard stop"* to stall the engine.
3. It is difficult to estimate time scales associated with these actions, but at this point Dennis would have moved into position to remove the hydraulic hose and while in this location, the lift arm hydraulics gave way and dropped the arm and bucket, crushing him to death.

Examination of the machine after the accident showed the hydraulic control levers to be in locations consistent with the above accident scenario. As well, the engine was stopped and there was fuel in the tank. Later investigation found that there was some air in the hydraulic system that could well have accounted for the lift arm hydraulic ram contracting and dropping the bucket in an unexpected way.

Investigation of the weather conditions at the time of the accident showed it to be a rainy, squally, day. It seems appropriate that Dennis, being very comfortable with the operation of the R2800, felt confident in working in a hazardous location. In addition, he may have been in some haste to complete the task and get out of the wet weather. Had he thought about the possibility of the lift hydraulics dropping the bucket, it would have been an easy matter for him to *"chock"* up the lift arms with timber supports. However, this action may have seemed unnecessarily cautious to someone with his experience and expertise.

4.7.4 Concluding Opinion and Outcome

From the point of view of someone without Dennis Gibbon's expertise with the R2800, it would seem inexplicable why he would take such a risk for a small piece of hydraulic hose. However, there were extenuating circumstances that permitted the deceased to place himself into such a hazardous and risky situation. He was very comfortable in working with this machine. Also, it was raining and there was no cover over the work area. He may have thought that it ould take only a few seconds to remove the component he was interested in and, therefore, not worth going to a lot of "unnecessary trouble" to fully secure the safety of his working environment. So he chose to take the risk of working under the unsupported bucket, with only the lift hydraulics between him and the weight of the bucket. The operation guide (9DE 8715) of the R2800 machine is explicit on this matter. On page 4 of the manual in the section on Safety/Crushing and Cutting Prevention:

"Support equipment and implements properly when working beneath them. Do not depend on hydraulic cylinders to hold it up. The bucket can fall if a control is moved or a hydraulic line breaks."

The deceased was very familiar with this machine through servicing it over several years and having a similar machine of his own. It would have been a small matter to place a wooden block beneath the bucket in the forward position and the lift arms raised. Alternatively, he could have chocked up the bucket in the rearward crowd position with the lift arm raised and a timber block between the bucket and wheel on the right side of the machine, while he worked on the left side. Either of these safety precautions would have avoided the accident. The deceased was very familiar with hydraulic equipment. He must have been aware that the R2800 machine had some leakage from its rams. Under the circumstances he was taking a serious risk in operating as he did. The coroner's inquiry found this case to be a one of accidental death through misadventure by the deceased.

4.8 Chapter Summary

"They're funny things, Accidents. You never have them till you're having them." Eeyore, *Pooh's Little Instruction Book*, inspired by A. A. Milne

"… hazards are one of the main causes of accidents." From the U.S. Occupational Safety and Health Administration Booklet *"Safety with Beef Cattle"* 1976[4.26]

The chapter introduces the legal background to human injury disputations and some of the law relating to injury compensation. Five cases of human injury disputes are presented in some detail. All could have been avoided with better hazards management. Perhaps that is the key characterisation of this chapter. All situations involve some forms of hazard. Care and attention to managing these is the most effective path to avoiding accidental human injury.

When faced with evaluating the causes and assigning responsibilities, *"fault tree"* and *"event tree"* diagrams provide some measure of guidance, even in the absence of computed probabilities. For conjecturing failure scenarios, *"potential failure modes and effects analysis"* and a *"risk analysis table"* are useful tools. The chapter reviews the background to such procedures and the associated bibliography (identified in footnotes) provides a substantial list of references for further reading.

4.26 Petras and Petras (1993).

5

Cases Involving Intellectual Property

Necessity, who is the mother of invention.
Plato*, The Republic*

Patent (noun): 1376, "open letter or document from some authority," shortened form of Anglo-French *lettre patent*, also in Middle Latin (*litteræ*) *patentes*), literally "open letter" (1292), from Old French *patente* (adjective), from Latin *patentum* (*nominae patens*) "open, lying open," present participle of *patere* "lie open, be open," (see also Greek *petannynai* "to spread out," *petalon* "leaf," Old Norse *fadmr* "embrace, bosom," Old English *fædm* "embrace, fathom").

"The Letters Patent were ... written upon open sheets of parchment, with the Great Seal pendent at the bottom ... [while] the 'Litteræ Clausæ,' or *Letters Close*, ... being of a more private nature, and addressed to one or two individuals only, were closed or folded up and sealed on the outside." [S.R. Scargill-Bird, "A Guide to the Principal Classes of Documents at the Public Record Office," 1891]

The adjective sense of "open to view, plain, clear" is first recorded 1508; the verb "to obtain right to land" is attested from 1675. The meaning "copyright an invention" is first recorded 1822, from earlier meaning "obtain exclusive right or monopoly" (1789), a privilege granted by the Crown via letters patent.

OLED

Patents offer a means of securing a monopoly (exclusive control of a commodity or trade) for exploiting an invention. There is an apocryphal[5.1] legend about a lone inventor coming up with an idea, patenting and exploiting it to gain unimaginable wealth. Regrettably, as most would-be inventors rapidly discover, even clever ideas require considerable investment to take them from conception to market. As an example, for every unit of cost for creating an embodiment of an idea (a working model, for example), 10^3 units of cost will be spent on creating a marketable prototype and 10^6 to 10^7 units of cost will be spent on a manufacturing system for mass producing it. In addition, there is a substantial time scale, usually on the order of decades [5.2] involved in this process. Somewhere along the way the idea will need protection from market predators and this where the intellectual property content of the original idea and its embodiment need to be iden-

5.1 Of doubtful authenticity.

5.2 See for example Mensch (1975).

tified. Some level of protection for intellectual property is afforded by patenting or registering and invention. The most commonly recognised patent is the type defined by the US Patents and Trademarks Office as a *"utility patent"*:[5.3]

> *"Utility Patent – Issued for the invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof, it generally permits its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application filing, subject to the payment of maintenance fees. Approximately 90% of the patent documents issued by the PTO in recent years have been utility patents, also referred to as 'patents for invention.'"*

A substantially different (and lesser) form of protection is offered by a *"design patent"*, also called a *"design registration"* by some patent offices:

> *"Design Patent – Issued for a new, original, and ornamental design for an article of manufacture, it permits its owner to exclude others from making, using, or selling the design for a period of fourteen years from the date of patent grant. Design patents are not subject to the payment of maintenance fees."*

The term "ornamental" in a design patent refers to shape, (from Latin *ornamentum*: equipment, trappings, embellishment) devoid of any scale.

There are many other forms of intellectual property protection offered by patents and trademark offices around the world, but the cases in this chapter deal only with utility and design patents. Moreover, patent protection and patent laws are specific to a country or region of the world, and patents and trademarks offices provide a wealth of specific information about their protections and jurisdictions. The cost of patenting is substantial, considering that initial and maintenance fees can add up to several thousand dollars per country or region covered by the patent. By contrast, commensurate with the lower level of protection offered by a design patent or registration, it is significantly cheaper than a utility patent.[5.4]

A design patent is a relatively simple document that describes the design and provides careful drawings of the shapes or embellishments being protected by the patent. As there is no scale provided for the shapes or embellishments this patent is intended to protect all possible scaled versions of the design.

A utility patent contains technical descriptions and drawings of the "*new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof*", as well as several claims for the performances and applications of the subject of the patent document. When a patent is being defended or challenged in a court of law (usually by intending or actual infringers of the patent) it is the technical descriptions and the several

5.3 www.uspto.gov/web/offices/ac/ido/oeip/taf/patdesc.htm. In Australia these are called "innovation patents" and I am idebted to Rob Melvin of IP Australia for information relating to Australian patents and patenting.

5.4 See also www.ipaustralia.gov.au/, www.patent.gov.uk/, www.jpo.go.jp/.

claims of the patent that are most likely to be open to attack. A patent may have as many as 50 or more claims in manufactured devices, but in patents describing chemicals or drugs, hundreds of claims are not uncommon.

Perhaps the most important element of the patenting process is the question of what is patentable. In order to be eligible for patent protection, United States patent law requires that an invention be (similar rules of patentability apply in other countries):[5.5]

New or Novel: The invention must be demonstrably different from publicly available ideas, inventions, or products (so-called prior art). This does not mean that every aspect of an invention must be novel. For example, new uses of known processes, machines, compositions of matter and materials are patentable. Incremental improvements on known processes also may be patentable.

Useful: The invention must have some application or utility or be an improvement over existing products and/or techniques.

Non-Obvious: The invention cannot be obvious to a person of "ordinary skill" in the field. This specific requirement of patentability demands that the invention must have been arrived at by one or more inventive steps. If person, skilled in the art of the field of the ionvention, would have been prompted to modify the closest prior art in such a way as to arrive at something falling within the terms of the claims, then the invention does not involve an inventive step.

There are two important patent terms that need to be defined here. These are *priority date* and *prior art,* and experts offering support in patent litigation should be familiar with the precise meaning of these terms.

Patent Priority Date

In patent litigation this is the date when the patent was first applied for. This refers to the priority date of an issued patent or a patent application. A continuation application is a new patent application that contains, at least in part, subject matter which is either an extension of the subject of the earlier patent application, or closely related to it. If the subject matter is sufficiently related, the later filed application may claim the benefit of the priority date of the earlier filed patent application.

Prior Art

This term refers to all that information available and relevant to the patent applicant in the public domain. To assess the validity of a patent application, patent offices explore the prior art that was disclosed before the invention occurred or before the filing date.It is this aspect of a patent application that determines if the "inventive step" in moving from the prior art to the current subject of the patent application was indeed novel and not obvious to someone skilled in the prior art.

5.5 See www.uspto.gov.

5.1 The Role of the Expert in Patent Litigation

Patent prose is a mixture of legalese and technical terminology. In drawing up a patent document (the task of the patent attorney) the following issues need careful consideration:

1. *Technical soundness* – The patent document must describe the invention and its application in as broad a technical manner as possible, taking care to maintain the content of the description unassailable from any technical challenge.
2. *Inclusiveness* – In terms of the various possible embodiments and uses to which the idea or product may be applied the patent should embrace as many of these as possible in its description. These descriptions, in general, deal with *means* (ways of achieving certain results) rather than *ends* (embodiments).
3. *Claims* – The claims section of a patent describes specific elements of the patent and their relation to the patent as a whole, still, as far as possible, in terms of means rather than ends.
4. *Preferred embodiment* – This is described in technical terms that are intended to convey a generic (broadly applicable) description rather than specific geometric features of the invention. This description also attempts, wherever possible, to concentrate on means rather than ends.

A major stumbling block in patent litigation is the wording of the patent. One might almost assert that this is the only stumbling block in drafting and defending a patent. Should the patent need defending in court, the element of the patent that will be most open to attack is its technical wording, the descriptions of its novelty and breadth of application and the technical description of its preferred embodiment.

It is the expert's role to evaluate the veracity and technical soundness of the patent wording, independent from the possibly implied meaning of the wording and drawings. When a patent is being challenged in court, the judgement will be based on validity and infringement.

(a) *Validity* – A validity challenge disputes the novelty and the mythical *"inventive step"* embodied in the patent claims. Novelty is primarily examined by reviewing all available prior art and comparing it to the main technical claims of the patent being challenged. It is the expert's task to define or dispute the nature and content of the inventive step that was taken by the patent holder in moving from the prior art to the current invention. It is also the expert's task to define what might be seen as "obvious" when considering the nature of the novelty embodied in the patent.

In this context, the expert must consider how a mythical entity called a *"reasonable person of general understanding and skill in the art"* would proceed to invent the ideas embodied in the patent. When examining and presenting arguments on *"obviousness"* in the invention, the expert must be careful to pretend to be a *"non-inventive skilled worker"* in the art under consideration. Consider the Australian Federal Court judgement of Sackville J in *Minnesota Mining & Manufacturing Co. vs. Tyco Electronics Pty. Ltd*.[5.6]

"One of the 'criticisms', levelled at Professor Samuel's evidence by 3M was that he was over-qualified and therefore could not be regarded as a non-inventive skilled worker in electrical connectors."

(b) *Infringement* – This aspect of a patent is probably the most difficult to judge. Claims of patents are often written in complex convoluted language describing and claiming monopoly over several interconnected means of achieving a desired outcome. The expert's task is to subdivide a complex claim into individual parts, commonly referred to as *integers*, each describing some specific means identified by the claim. A useful reference to an example of such a subdivision into integers is Claim 1 in *Minnesota Mining & Manufacturing Co. v. Tyco Electronics Pty. Ltd*. [5.7] Once a complex claim has been subdivided into its integers, infringement may be judged by comparing the patent and the infringing idea on each integer in the claim.

5.2 The Cases

The Case of the Trailer Connector Plug – This was a design patent infringement matter. Designer of the infringing item was sued by the original manufacturer. In essence, the matter was resolved by recognising that the design patent holder was attempting to patent not only shape but also function.

A Small Electronic Connector of Major Proportions – The case of *Minnesota Mining & Manufacturing Co. v. Tyco Electronics Pty. Ltd.*, eventually ruled in favour of Tyco by the Federal Court of Australia. In this case the ruling was largely determined by the fact that 3M's patent was attempting to gain monopoly on a simple generic idea used in many other applications.

A Silage-wrapping Machine – This case involved a mechanical device used to wrap hay for winter feeding of stock. It was resolved by the manufacture of the machine licensing the infringing importer of a closely similar machine.

Energy-absorbing Roadside Barrier – Hollow plastic roadside barriers are placed in position and filled with sand or water to weigh them down. This was a case of failing to recognise the dynamic performance of such barriers in a barrier–vehicle collision.

Information Technology Piracy and Digital Fingerprints – This is a brief review of the history of protection available for digital information.

5.6 See www.wptn.com/patent_vol4is7/pat_001_vol4is7.htm (Australian Federal Court Ruling in the case of Minnesota Mining & Manufacturing Co. v. Tyco Electronics Pty Ltd.).

5.7 Op cit.

5.3 The Case of the Trailer Connector Plug

5.3.1 The Case Culture the Dispute and the Client

Trailers are required to have at least running lights, turn signals and brake lights. To provide the power and a hook-up for these, the tow vehicle's wires are connected to the trailer via connectors available in various configurations. Various connectors are available from four to seven pins to allow for the transfer of power for the lighting as well as auxiliary functions such as electric trailer brake control and backup lights. Connector design commonly caters for weatherproofing and avoiding unnecessary protuberances or dangling leads either in the trailer or the vehicle.

Certain characteristics of these trailer connector plugs are recommended by industry standards. In Australia the industry standard appropriate to this case in 1993 was *Australian Standard 2513-1982; Electrical Connectors for Trailer Vehicles*. Functions and operational requirements of electrical trailer connectors are specified by *AS2513*. Although engineering standards such as *AS2513* do not carry the force of common law, in general, compliance with standards will ensure that a wide range of engineering experience is incorporated into the design.

Figures 5.1 and 5.2 show typical trailer connector installations. The number of different types of connector designs available from motor spare suppliers is substantial. One specific manufacturer, *Luxative Pty. Ltd.* (*LPL*) had a trailer connector design registered in Australia in 1992. *Fireup Motor Spares* (*FMS*), a Queensland wholesaler, devoted to supplying various after-market fittings to motor vehicle resellers such as Autobarn, commenced importing a trailer connector manufactured in Asia, by *Cheepian Industries*. The Cheepian design had many similarities to the design registered to *LPL* and they chose to sue *FMS* for infringement of their registered design. My briefing solicitors were *Porter and Cable Lawyers* (*PCL*), who asked me to consider the two designs, as well as other prior art, and to offer opinion

Figure 5.1 Typical trailer connector installed on a trailer

Figure 5.2 Trailer connector with cover open

Table 5.1 Relevant information supplied by PCI for this investigation

Item	Description	Referred to as
1	Australian Certificate of Registration of a Design No. 98557	CRD98557
2	Australian Standard 2513-1982; Electrical Connectors for Trailer Vehicles	AS2513
3	Typical trailer connectors imported by FMS (the respondent) from Cheepian Industries	Cheepian design
4	Typical trailer connector marketed by Luxative Australia (the plaintiff)	Luxative design
5	Typical trailer connector marketed by Ulmen Australia	Ulmen design
6	Metal trailer connectors identified as prior art	Metal connectors
7	Several auto spare part dealer and supplier catalogues	Referred to by individual company name

regarding the originality of the Luxative design as well as the similarities and differences between the Luxative and Cheepian designs. PCL supplied me with the writ sworn by Luxative against FMS as well as other documentation in this case listed in Table 5.1.

5.3.2 The Investigation

Design Comparisons

Figure 5.3 is a specification of the Type 2 trailer connector, the subject of this dispute, as described by AS 2513-1982. Figure 5.4 shows diagrams of the Luxative design as described in their design specification *No. 98557* for a *"Trailor Connector Base"* dated 5 November 1987. Figure 5.5 shows two views of the Cheepian connector as measured from samples supplied to me by FMS. Design registration *CRD98557* notes that:

> *"Monopoly is claimed in the shape and/or configuration … as illustrated in the accompanying representations"*

Figure 5.4 is a rear view taken from the CRD98557, with measurements added by the author. The measurements are approximate only and they are taken directly from the Luxative design, as these measurements do not appear in CRD98557. Figure 5.4 also shows a partial right side view of the the Luxative design clearly illustrating the appearance of the hinge housing as well as the shape of the lifting lip (front lip) on the cover of the Luxative connector base.

In addition, Figure 5.4 shows a perspective view of the Luxative design (as registered) taken from CRD98557. Note particularly the appearance of the two mounting holes in the *"as-registered"* design. In this registered embodiment the mounting holes have a countersunk lead-in. This indicates that a countersunk head screw or bolt would be used for mounting the connec-

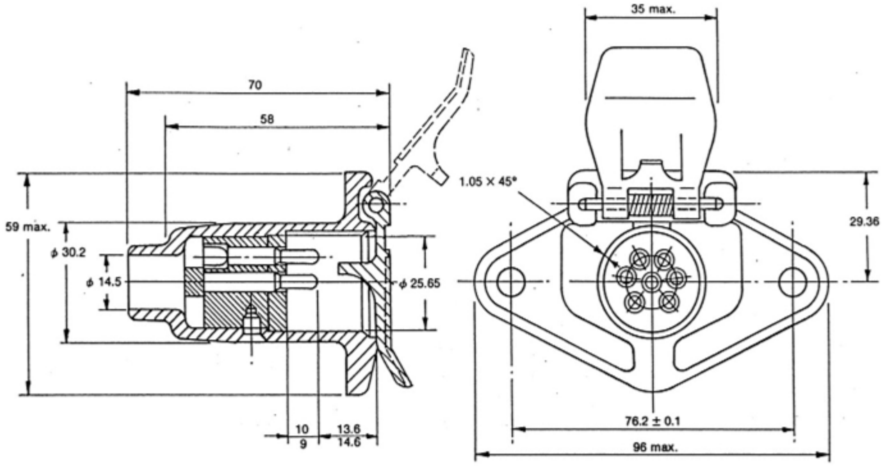


Figure 5.3 Type 2 trailer connector design specification from AS 2513-1982

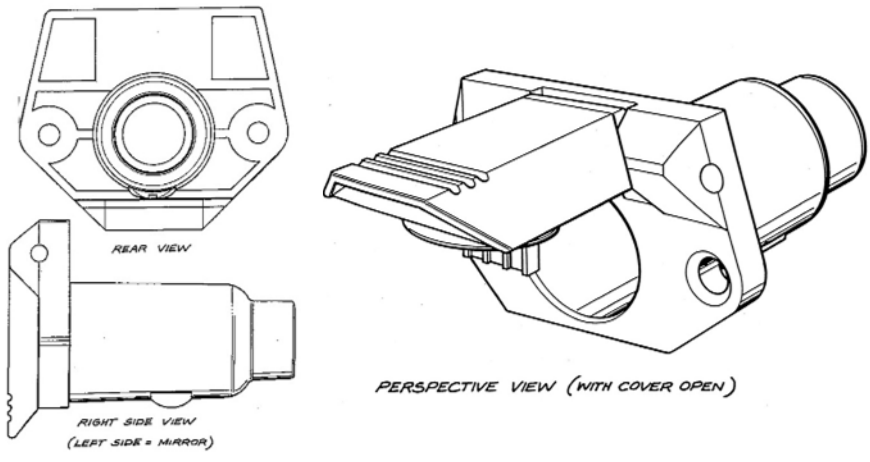


Figure 5.4 Drawings of the Luxative design taken directly from their registered design specification

tor on the trailer. A countersunk head screw has a tapered head commonly used in engineering and automotive applications requiring a conical surface on the part to which such screws are mated. However, in the embodiment sample provided to me, the Luxative design had counterbored holes, with cylindrical surfaces, and in this sense the sample embodiment differed from the original registered design.

Figure 5.5 shows the approximate rear and right-side views respectively for the Cheepian design connector. Clearly, there are significant shape differences in both the rear view and in elevation (right-side view). The

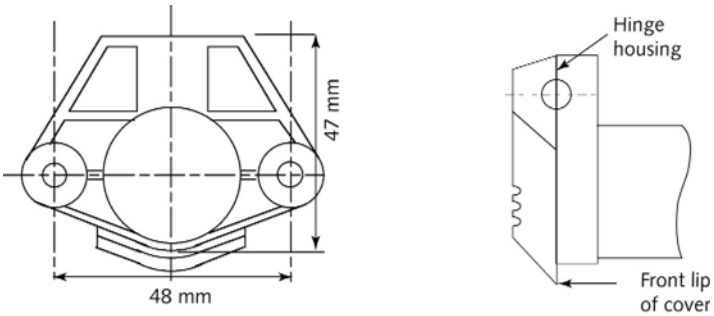


Figure 5.5 Drawings of the Cheepian design produced from direct measurements by the author. The left-hand diagram is a rear view and the right-hand figure is a side view

Cheepian design has a curved lower profile compared to the Luxative design, which has a flat lower profile. In addition, the front cover lips on the two designs differ considerably. The upward slope on the Cheepian connector lip is quite different from the downward sloping lip of the Luxative design. Although these differences may appear minor, they have serious implication for the design as a whole.

The two designs have similar operational characteristics, due to the functional requirements specified by AS2513-1982. The centre distance dimension of the two mounting holes (48 mm in Figures 5.4 and 5.5) and the height over the front part of the connector body (47 mm in Figures 5.4 and 5.5) are closely similar for both connectors. Apart from these two dimensions, most likely dictated by requirements of standardisation, the design of the two connectors is distinctly different.

Both the shape of the lower profile and the shape of the cover lip for the Cheepian connector have been designed to reduce the material content in the device over that which is required for the Luxative connector. A comparison of the two connector bodies on a chemist's beam balance showed the Luxative connector to be approximately 15 g heavier than the Cheepian connector. This difference in the masses of the two connectors represents a significant saving in material and cost in favour of the Cheepian design. Consequently, FMS have chosen to import an apparently cheaper and superior design in competition with a less material-efficient local product. As well, the front of the Cheepian design is more streamlined than that of the Luaxative design. Although this difference is relatively minor, it does make the Cheepian connector easier to clean than the Luxative connector.

Although not part of the design infringement dispute, it is interesting to contrast some of the operational differences between the two connectors. In the Cheepian design the front cover is shorter than that of the Luxative design due to the upward sloping lip on the cover. This results in requiring a larger force to open the Cheepian connector compared to that needed to open the Luxative connector. This assertion assumes that the return springs on the cover of both types of connectors are made approximately equal in stiffness.

The hinge designs on the two connectors are also functionally different. On the Luxative connector the front cover is designed with a chamfer which lifts away from the hinge as the cover is lifted. In contrast to this, the hinge housing is permitted to rub on the cover in the Cheepian design. As a result of this design difference, the cover of the Luxative connector was securely returned each time it was opened, while the Cheepian connector cover remained partially open after most actuations. In this sense, from an operational point of view, the Cheepian Connector is inferior to the Luxative connector.

The Australian Standard AS2513-1982

Functions and operational requirements of electrical trailer connectors are specified by AS2513. Although engineering standards such as AS2513 do not carry the force of common law, in general, compliance will ensure that a wide range of engineering experience is incorporated into the design. In some cases, such as the *Pressure Vessel Code* the *Crane and Hoist Code* and the *Welding Code,* the certificating authorities require compliance with these standards. Inquiries showed that trailer certificating authorities (the *Australian Road Transport Authority* and the various road transport bylaws introduced by State Authorities) make no reference to trailer connector requirements. There are three types of connector identified by AS2513 and the Luxative and Cheepian connectors most closely match the specifications given for the 7-*pin Type 2 connector*. In fact, the 7-pin Type 2 connector illustrated in AS2513 most closely resembles the *metal connector* samples supplied to me by FMS. AS2513 specifies certain elements of the trailer connector design as mandatory, namely:

> *1.5 CONSTRUCTION REQUIREMENTS (7-PIN CONNECTORS).*
>
> *1.5.1 Contacts. – Contacts shall be of the pin and tube type. The diameters of the pin and tube shall be such as will permit them to be connected with a moderate push and also ensure a good electrical contact. Split elements shall have the ability to spring back to their original diameter after disengagement from their mating element.*
>
> *All contacts in the socket shall be isolated from other contacts and from the connector body (where metallic).*
>
> *1.5.2. Socket. – The rear terminals of the socket shall each be capable of receiving one conductor of at least 2.5 mm^2 cross-section.*
>
> *1.5.3 Socket Cover. – The socket shall be provided with a hinged cover which shall*
>
> *(a) close automatically when the plug is disengaged from the socket to effectively prevent the ingress of dust, liquid splash or other foreign matter into the socket and*
>
> *(b) incorporate a lip or other design feature which will latch onto and retain the plug in the socket when the plug is inserted fully into the socket.*

1.5.4 Mounting.

1.5.4.1 Socket. – Provision shall be made on the socket for securely mounting the socket on the rear of the towing vehicle.

Other requirements specified by AS2513 involve force of engagement and disengagement of plugs as well as the force to be withstood by the latching security lip included in the cover of the socket. These requirements determine the necessary clearance and contact areas of the plug and socket, and spring stiffness of the pin and tube connectors. The security lip requirements determine the size and strength of the security lip. This latter aspect is closely similar in all the sample connectors supplied to me.

The centre distance between mounting holes for attaching the connector base to a trailer is specified in AS2513 as 76.2 ± 0.1 mm (see Figure 5.4) for a 7-pin Type 2 connector. The overall height is specified for the same connector as 59 mm maximum. Neither the Luxative connector nor the Cheepian connector meet this hole centre distance requirement, although they both meet the overall height dimension requirement. Standardisation in the location of mounting holes on trailers may have caused the close similarity in the mounting hole centre distance dimension in the two connectors. Overall connector body height may well be dictated by similar standardisation requirements. The fact that these dimensions are specified in AS2513 may in itself have precipitated the choice of similar values in an attempt to match a market demand.

Prior Art

Prior art in patent specifications relates to a combination of functions for a specific product. It will also relate to the specific means of achieving a certain function or combination of functions (embodiment). The functional requirements of the trailer connector base may be identified as follows:

(a) A means for making electrical contact between plug and socket – this is clearly specified in AS2513.

(b) A mating means for securely interconnecting the bodies of the plug and socket – although there is plenty of freedom for the embodiment of this means, invariably it is achieved by two cylindrical surfaces mating. In AS2513 two types of cylindrical surface are noted for this means. Circular cylindrical surfaces are used in Type-1 and Type-2 connectors, while rectangular section cylinders are used for mating Type-3 connectors.

(c) A means for securing the plug to the socket once the plug is inserted. This means is clearly indicated as a securing lip in AS2513 and various forms of this securing means abound in the electrical connector industry.

(d) A means for securely covering the socket when the plug is removed. AS2513 clearly identifies this with a spring loaded cover. Again, similar types of covering means abound through the electrical connector industry.

(e) A means of electrical cable entry. This is specified in AS2513 and is closely similar in all the connectors supplied to me.

(f) A means for securely mounting the connector to the trailer. AS2513 indicates this means by two or three holes for all connectors. Nevertheless, the type of bolt used for achieving the connection is not specified anywhere.

All of the functions of the connector exist in one form or another throughout the electrical connector industry. Considering the specific instances of 7-pin trailer connectors and the embodiments used by others for achieving a favourable combination of these functions, AS2513 identifies several embodiments for the functions of the 7-pin trailer connector dated 1982. The following embodiments are indicated in the various catalogues supplied by PCL.

Luxative describe three embodiments for the 7-pin trailer connector, namely *H3514*, *H40975* and *H1715* dated 1988.

Pollak (USA) indicate no less than seven alternative embodiments for a 7-pin trailer connector.

FMS indicate three alternative embodiments for the 7-pin trailer connector in their catalogue, namely *65-95515*, *65-40975* and *65-94907* (undated).

Menbers (Italy) offer no less than 32 alternative embodiments for the 7-pin trailer connector in their catalogue dated September 1983. Admittedly the differences between some of these alternative embodiments are minor, however, the range emphasises the myriad of embodiment possibilities.

Cole-Hersee (USA) indicate four alternative embodiments for the 7-pin trailer connector in their catalogue dated 31 March 1988.

Whatever the function or combination of functions of the product, embodiments will vary between designs. This is what makes for variety and choice in the whole design process. In design we recognise two types of quality. First of all there is basic quality which refers to the product meeting at least the basic functioning requirements of the product, reliably and consistently. Secondly, there is *excitement quality*, or *value-for-money*. This second form of quality is essentially what drives the choices purchasers make between two products which are almost identical in function, such as motor cars or trailer connectors. Purchasers will identify the value of a product in terms of their own value systems or through the value systems developed by marketing specialists. A more costly, but lasting, product may fare better than a cheaper limited-life product. National pride (*Made in Australia*) may be one component of the value system used by a purchaser. The most successful design will provide both types of quality. Market pressures will determine the eventual survival of a product.

The Registration of the Design

Embodiment of a design and *value-for-money quality*, built into the design, result from the considerable intellectual skill of the designer; this intellectual property must be safeguarded by a copyright. In this sense the Luxative design, as registered in CRD98557, stands as a copyright for that design. CRD98557 protects only the geometric and value-for-money quality features of the Luxative design. A purchaser may choose the Luxative connector over the Cheepian connector when comparing the two connectors in terms of value-for-money quality, all other things being equal.

The Cheepian connector has clear advantages over the Luxative connector in its material-efficient and somewhat more streamlined design. It also has some functional inferiorities compared to the Luxative design. In these aspects it must be regarded as a different design embodiment. Consequently, I consider that technically, the Cheepian connector has not infringed CRD98557, rather it constitutes a different product with some better and some worse features all of which may themselves be subject to a copyright process.

The Luxative Versus Lumen Connector Comparison

The *Auto Parts and Accessories Journal of Australia* dated March/April 1992 carries an advertisement for *Lumen Australia* in which Lumen apologise to Luxative for infringing CRD98557 with the some of their Lumen products. I have not sighted all of these products, however, I did compare the Lumen 7-pin connector supplied to me by PCL with the corresponding Luxative connector. Quite in contrast to the Cheepian connector, the Lumen connector is identical to the Luxative connector in every detail (other than the name stamped on the outside). Consequently, it must be regarded as the same product as the Luxative connector and may well be regarded as having infringed the copyright of CRD98557.

The Lumen apology and royalty arrangements with Luxative must be regarded as having no relevance to the Luxative v. Cheepian dispute. The Cheepian connector contains substantive differences in intellectual content and must be regarded as a different embodiment of the functions required by the automotive industry for trailer connectors.

5.3.3 The Outcome and Lessons Learnt

Based on the above arguments about function, it would seem that the Luxative design is capable of being a registered design under the *Designs Act 1906 (as amended)*.

In the Design Act 1906 (amended) the definition of *"design"* requires (among other things) that the features of shape, configuration, pattern or ornamentation which constitute the design features that, *"in the finished article, can be judged by the eye"* (see Ricketson, 1984, p.456).

Ricketson continues:

> *"…the Franki Committee, which took the view that this should be the eye of the court."*

I have formed the opinion, that the court would find it hard to pick the difference between the registered article and the actual Luxative product. This opinion is further reinforced by the fact that the registration CRD98557 gives no scale to the drawings and representations registered therein. I have now taken the measurements of several features and find that the actual scale of the registered representation compared to the Luxative product is somewhere in the range of 1.75 to 1.88. This scaling also includes the length of the barrel and it to seems to be approximately to the proper scale when comparing the registered design and the Luxative product. Further comparisons between the imported connector and the representations registered in CRD98557 indicate the following :

(a) *Front view* – The Luxative registration shows an irregular hexagonal shape for the connector. All edges are approximately straight and the dust cover shape is so arranged that the lower section blends into the rest of the hexagonal shape of the connector. The angles on the design were estimated from the registered representations in CRD98557. In this sense the imported product is quite different in shape. The angles are steeper, the lower part of the connector base is curved as is the dust cover. The cover lower lip is stepped away from the lower curved profile of the connector body and this step is clearly a different shape or "ornamentation" than is the case for the design registered in CRD98557. The hinge support of the front cover in the registered design is heavier in proportion to the rest of the design than is the case for the imported product. In general, the registered design in CRD98557 appears bulkier than the imported product. Without the proper scale on the representations in CRD98557 it is hard to estimate the weight differences, but I would suggest that the imported product is significantly lighter than the design in CRD98557 by virtue of its shape. The imported product looks a more elegant, less bulky design. It is also easier to clean on the outside than would be the case for the Luxative design as in CRD98557. These are matters the "eye of the court" can evaluate by inspection.

(b) *Barrel body* – The main notable difference between the imported barrel and the design registered in CRD98557 is the absence of the complicated fastener seen in the Luxative design for the retention of the 7-pin electrical connector held in the barrel. Instead, a screw is used for the purpose of retaining the electrical connector. It is entirely unclear from the representations offered in CRD98557 how this connector retainer should work. In this sense it may be regarded as too general to be of any use in the design registration process. This shape is certainly not infringed by the imported connector.

(c) *Side view* – The design registered in CRD98557 has a front cover with its bottom lip sloping downward towards the front of the article. For this to function properly, the bottom of the front cover is squared to match the alignment of the base of the connector. In the imported product the front cover is chamfered to slope downward towards the rear of the connector body. This is the aspect of the imported product which gives it a more streamlined appearance than the Luxative design. Although a function may not be registered as part of a design, the shape in the imported product appears to be the result of good functional considerations. The resulting appearance is more elegant than is the case for the Luxative design.

(d) *Front cover raised looking into the barrel* – Due to the rounded base of the imported connector this aspect of the connector is again more elegant and less heavy looking than the registered design. Due to this streamlined feature, the barrel appears more centrally located in the imported connector than in the Luxative design.

For engineers dealing with intellectual property matters the key reference is Professor Ricketson's excellent text on the subject *"The Law of Intellectual Property"*.[5.8] This book teaches the idea of design registration, with many readable examples and the tests that a design must fulfil to be registrable. The meaning of design has been dealt with in 5.3.3 above. On the matter of designs where there are many instances of embodiment already in use Ricketson offers (465):

> *"… where there were a great number of designs, novelty or originality might be satisfied by quite small differences. Thus, in one New South Wales case dealing with designs for chairs, Jacobs J. said:*
>
> *'I think that it is most important to bear in mind in relation to such an article as a chair, that one cannot and should not expect to find some startling novelty or originality. The element of novelty or originality will of necessity be likely to be within a small compass. I do not mean thereby that any difference of shape, outline, proportion or placement of components will thereby constitute novelty of design, but provided I can see a substantial difference from the fundamental form and from the development in the trade up to the time of the application for registration, then I do not think that it is sufficient to point to a number of elements of similarity to past design in order to show that the design is not new or original.*
>
> *… I do not accept … that novelty and originality of design in such articles can only exist when some quite different style or type of chair is invented. To accept such a proposition would deny to designers the benefit from that subtlety which represents great skill and much thought and experience.'"*

Although intellectual property law is the domain of expertise belonging to patent lawyers, engineering experts must not shy away from drawing

5.8 Ricketson (1948).

attention to evidence that supports a specific opinion. In the case of Luxative v. FMS/Cheepian, the above judgement is highly relevant to the opinion offered about the importance of small differences in the design of the two connectors. The two connectors had imposed on them the functional requirements of the standard AS2513 mitigated by the special requirements of industry standardisation. As a result it was unlikely that they would differ substantially in shape or in operating function. The relatively small differences in shape invoked some functional differences between the two designs and these differences, when technical attention was drawn to them, were sufficient to dissuade the disputing parties from pursuing this matter. The case was resolved in an undisclosed out-of-court settlement between the disputing parties.

5.4 A Small Electronic Connector of Major Proportions

Crimp: 1638; Old English had *gecrympan* "to crimp, curl," but the modern word is probably from Middle Dutch or Late German *crimpen/krimpen* "to shrink, crimp." To put a crimp in (something) is 1896, U.S. slang.

Insulation: 1538, "make into an island," from Latin *insulatus* (see *insular*). Sense of "cause a person or thing to be detached from surroundings" is from 1785. Electrical/chemical sense of "block from electricity or heat" is from 1742. *Insulation* "insulating material" is from 1870.

OLED

5.4.1 The Case Culture, the Dispute and the Client

Anyone working with electronics, telephony or just plain electrical fittings, would be aware of the myriad of electronic connectors available on the open market. Electronic hobbyists provide easy access to such products through shops such as Tandy or Radio Shack or Dick Smith Electronics (in Australia the latter is occasionally affectionately, though outrageously, referred to as the *"electronic Dick"*). Over the last few decades electronic cable connections have moved away from screwed or soldered connectors to entirely *"tool-free"* connectors, where a clamping of the connector onto

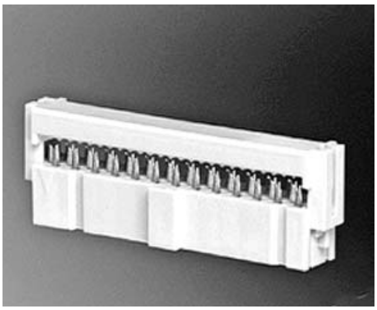


Figure 5.6 A flat ribbon cable connector ready to be crimped

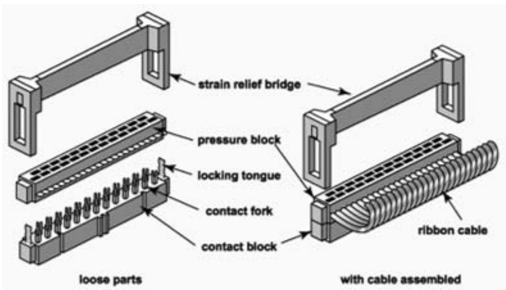


Figure 5.7 Assembly procedure for flat ribbon cable connectors

Figure 5.8 Typical RJ14 telephone connector

the wire results in a secure connection. This type of connector is particularly popular in low voltage telephony or data communication cabling, where multiple connections need to be made securely and reliably. Typical examples are flat ribbon cable connectors, nowadays rarely seen outside the confines of the computer tower. Figure 5.6 shows a sample flat ribbon connector and Figure 5.7 is a schematic view of the assembly process for such connectors. The flat ribbon cable is an assembly of conductors coated with an insulation layer, forming the flat ribbon. In the assembly of the cable with the connector, the ribbon is placed between the *pressure block* and the *insulation displacement* contact forks in the lower part of the connector. Once the connector and cable are properly aligned, the pressure block is compressed onto the cable, the contact forks penetrate and displace the insulation and secure connection is achieved between each conductor and its corresponding contact fork. This process is commonly referred to as *crimping*. The cable is then wound through the *strain relief* bridge to prevent any strain being placed on the connection in the connector block.

Key features of the connector are insulation displacement connection and strain relief. These two features are common to many connectors in the electronic and communication industry. The insulation displacement feature has only limited numbers of embodiments, usually forks or spikes driven through the insulation (see for example the RJ14 telephone connector, Figure 5.8), but the strain relief feature has many embodiments.

This case is mostly about the strain relief feature included in the connector for which the Minnesota Mining and Manufacturing Company (*3M*) was granted Australian Patent Number 624486 (*the Patent*). The Patent was granted on 11 June 1992 and has a priority date of 14 April 1989. The complete specification for the Patent describes the invention of the Patent as relating to *"a connector for insulated conductors such as cables, particularly for electrical telecommunication cables."*

On 27 July 1999, 3M commenced a proceeding in the Australian Federal Court against the respondent, *Tyco Electronics Pty. Ltd.* (*Tyco*), alleging infringement of the Patent by Tyco by selling or otherwise disposing of the product known as *"AMP Stack Mark IV Ten Pair Connector Module"* (*the Tyco Product*). On 5 October 1999, Tyco filed a cross-claim for declarations that the Patent is invalid and for an order that it be revoked.

My briefing counsel was Dr. Frank Traugott of *Malleson Stephen Jaques*, Solicitors (*MSJ*). It was MSJ's Sydney office that sought out the University of Melbourne for expertise in this specific patent litigation. MSJ supplied

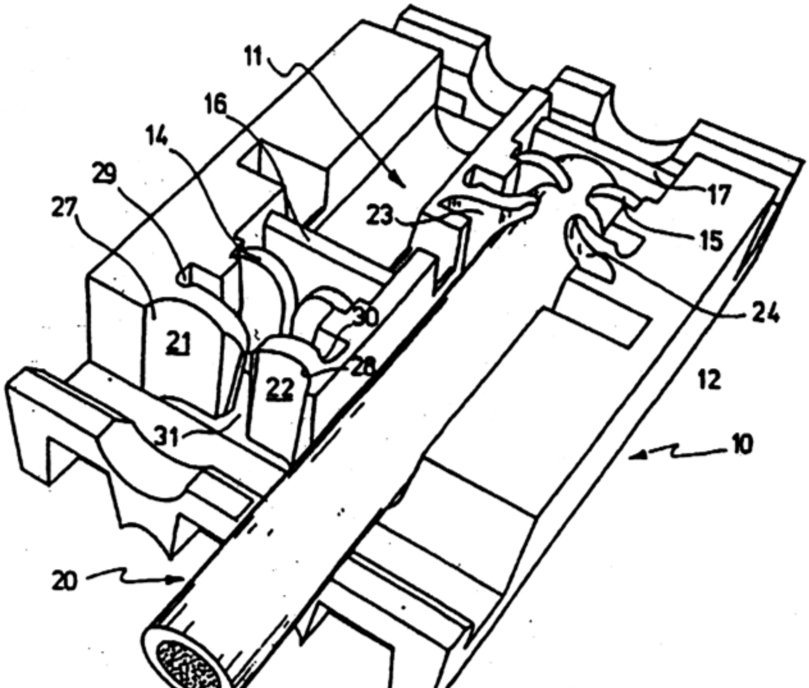
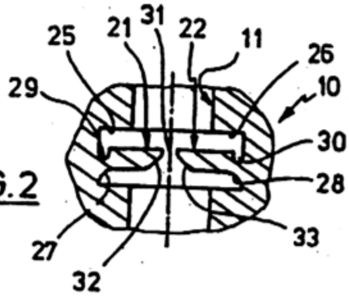


FIG. 1

FIG. 2



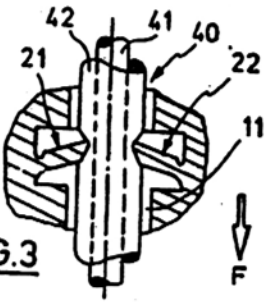


FIG. 3

FIG. 4

Figure 5.9 schematic sketches of the 3M invention taken directly from Australian Patent Number 624486

me with a copy of the Patent and a sample of the Tyco Product. I was asked to examine the Tyco Product and the Patent and offer opinion about

(a) the novelty of the Patent at 13 April 1989;

(b) whether the Tyco Product falls within the description of the claims of the Patent.

5.4.2 The Investigation

In patent litigation the first task of the expert is to examine the patent and the article allegedly infringing it. In this case the 3M patent shows several schematic sketches of preferred embodiments of the invention as well as claiming certain operational means protected by the patent. Figure 5.9 is taken directly from the Patent and shows a general view of the 3M connector with some embodiments identified for the strain relief elements of the invention. In subsequent litigation concerning this patent, it was the nature of these strain relief elements that caused the greatest concern.

In this case description only the summary of the invention and the first claim of the Patent are examined in any detail. The complete text of the judgement determined by Sackville J. in the Federal Court of Australia in September 2001 is available for interested readers. That judgement details all the evidence in this case as well as considering all the significant elements of the Patent, its validity and the infringement claims.

Summary of the Patent

"The invention includes an integrally molded basic body of plastic material having one or a plurality of passageways adapted to receive insulated conductors. In the connector according to the invention, flexible tongues are formed at opposing walls. The tongues, extend in a plane approximately perpendicular to the longitudinal axis of the passageway. At the free ends of the tongues, a relatively narrow slot is formed, the most narrow portion of the slot being adjacent the open upper side of the passageway and it has a width smaller than the diameter of the smallest cable to be placed in the connector. The lower portion of the slot having a larger width so that by this, a movement of the cable out of the passageway is resisted. ***It is further essential to the invention that the tongues are shaped or are connected to the walls of the passageway such that the tongues are uni-directionally resiliently deformed toward one end of the passageway and toward the contacting element within the passageway.*** *In other words, the ends of the tongues face toward the free end of the cable or opposite to the extraction direction so that an effective strain relief is achieved.*

With the known connectors it may occur that the cables move out of the passageway as soon as the cover on the passageway is opened. This danger increases with increasing diameter of the cable. With the connector according to the invention, however, the strain relief increases with increasing diameter, the flexibility of the tongues being adapted to retain cables within a large diameter *range. Depending on the elasticity and the strength of the insulating material, the tongues mold into the insulating material more or less whereby the cable is effectively secured against displacement out of the connector. The deformation of the tongues and the embedding into the insulation are such that a cutting into the insulation and thus an elimination of the strain relief is avoided.*

As already mentioned, it has to be assured that the tongues are deformed in a predetermined manner when the cable is pressed into the slot. In this connection, an embodiment of the invention provides that deflecting surfaces are formed on the tongues adjacent the slot which cause the tongues to be deformed resiliently by a cable such that the ends of the tongues face toward the cable end within the passageway. Different modifications for the deflecting surfaces can be used. According to an embodiment of the invention, the deflecting surfaces can be defined by chamfers formed at the side of the tongues oppositely located of the cable end. The chamfers form oblique surfaces which converge toward the cable end. They assure that both tongues are deflected toward the cable end.

According to a further embodiment of the invention, the width of the slot between the tongues continuously increases toward the bottom of the passageway. According to a further embodiment of the invention, the edges of the slot can include saw-tooth-like projections by which a movement of the cable out of the slot is effectively restricted.

If possible, the tongues should be deflected in total upon an insertion of the cable into the slot. ***An embodiment of the invention provides that the wall of the tongues facing away from the cable end merge into the wall of the passageway through a radius while the opposite wall of the tongues have a relieving flute adjacent to the wall of the passageway.*** *By such a hinging of the tongues to the passageway walls, the tongues can be relatively simply and uni-directionally deflected toward the cable end as the cable is pressed into the slot.*

The entrance portion of the slot is funnel-like enlarged in an upward direction in order to facilitate the insertion of the cable." [Emphasis added by Sackville J.]

Claim 1

"A connector for an electrical cable, particularly for electrical telecommunication, comprising a housing of plastic material including a basic body, at least one transverse passageway having an axis being formed in said basic body, a contact element disposed in said passageway, and flexible retaining elements integrally formed with said basic body are positioned in said passageway, said retaining elements being resiliently deformed when a said cable is introduced into said passageway to retain said cable against outward movement, said retaining elements comprising tongues being formed on opposite walls of said passageway in a plane approximately perpendicular to said axis of said passageway, the free opposing ends of said tongues forming a narrow slot having the most narrow portion of said slot adjacent the open upper side of the passage-

way and having a larger width than the upper portion of said slot, and said tongues being joined to the walls of said passageway by means for affording deflection of said tongues such that said tongues are resiliently deformed toward one end of said passageway and toward the contact element within said passageway when a wire is inserted into said passageway."

This is a complex claim with several elements of the claimed invention interwoven through it. One witness (Dr. Stark for 3M) broke the claim up into ten separate parts he identified as *integers*.

"*1 A connector for an electrical cable, particularly for electrical telecommunication, comprising a housing of plastic material including a basic body.*

2 At least one transverse passageway having an axis being formed in said basic body.

3 A contact element disposed in said passageway.

4 Flexible retaining elements integrally formed with said basic body are positioned in said passageway.

5 Said retaining elements being resiliently deformed when a said cable is introduced into said passageway to retain said cable against outward movement.

6 Said retaining elements comprising tongues being formed on opposite walls of said passageway in a plane approximately perpendicular to said axis of said passageway.

7 The free opposing ends of said tongues forming a narrow slot,

8 Having the most narrow portion of said slot adjacent the open upper side of the passageway and having a width smaller than the diameter of the smallest cable to be placed in the connector.

9 The portion of said slot adjacent the bottom of said passageway having a larger width than the upper portion of said slot.

10 Said tongues being joined to the walls of said passageway by means for affording deflection of said tongues such that said tongues are resiliently deformed toward one end of said passageway and toward the contact element within said passageway when a wire is inserted into said passageway."

Integers 1 to 3 dismiss the contact elements (specifically the insulation displacement features of the invention), and integers 4 to 10 deal specifically with the strain relief means represented by several preferred embodiments shown in Figure 5.9 (Figures 2, 3 and 4 in the Patent). The question of validity depended on whether the strain relief means were "obvious" to a skilled worker in the art of designing such connectors. The question of infringement depended on whether the design of the strain relief means in the Tyco product matched every integer (integers 4 to 10) in the patent. The following is an excerpt from my first report on the matter of the strain relief means described in the several integers of Claim 1 of the patent.

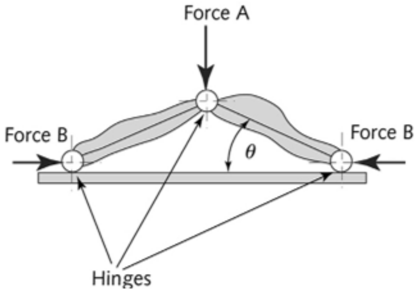


Figure 5.10 Standard toggle mechanism force amplifier

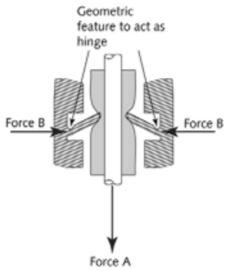


Figure 5.11 Toggle mechanism applied as strain relief in the Patent (see Fig. 3 in Figure 5.9)

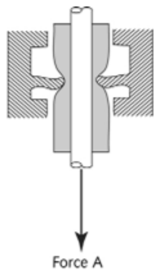


Figure 5.12 Penalty for fingers being too resilient

"My investigation relating to the Patent and the Tyco product has considered the following:

In the first instance I examined the claims of the Patent and found that its main claim relates to the process of holding an electrical cable captive securely inside the connector, to prevent interruption to the transfer of data or electrical supply. The capture and restraint offered to the withdrawal or release of the insulated conductor cable is in the form of a pair of elements that are ***resiliently deformed*** *when the cable is inserted into the connector.*

The connection of the electrical conductor is made by insulation displacement, *a process that has been well established by 13 April 1989. In the three years 1986–88 there were 73 US patents granted dealing with insulation displacement. Moreover, in the same set of three years there were a total of 495 US patents granted for electrical connectors. The impression gained from this cursory examination of the US patents database is that electrical connectors are continually being developed and novel features patented at substantial rates.*

Returning to the claimed novelty of the Patent (Australian Patent Number 624486) I found that the pair of elements (tongues in the Patent) restraining the conductor from being released, once captive, operate very much like a simple mechanical toggle. The toggle mechanism is described on page 819 of the 15th edition of the New Encyclopedia Britannica, published in 1974, viz 'toggle mechanism, combination of solid, usually metallic links (bars), connected by pin (hinge) joints that are so arranged that a small force applied at one point an create a much larger force at another point.'

Figure 5.10 shows a typical toggle mechanism schematically. The relationship between Force A and Forces B may be found from equilibrium of forces and simple geometry as Force B = Force A/(2 tan θ*).*

As this simple equation indicates, the mechanism is a 'force amplifier' from Force A to Force B. As the angle θ *reduces, so the amplification increases, and as* θ *tends to very small values, the amplification from Force A to Force B increases without limit.*

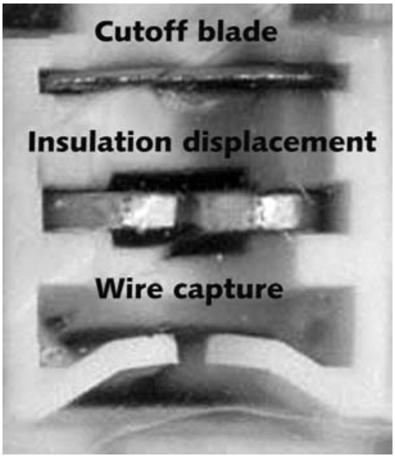


Figure 5.13 Photomicrograph of one segment of the Tyco product

There is a penalty to pay for the gain in force amplification. For relatively small values of the angle θ, that would be the case where large force amplification is required, as may be used in mechanical clamps (for example), any inaccuracy in the mechanism or flexibility will permit it to 'flip' through the horizontal and thereby release the Force B. Consequently there is a limit to the gain in amplification possible with such a mechanism. This limit is determined by the flexibility of the arms, the accuracy of the hinges and in general the capacity of the toggle mechanism to maintain Force A above the line joining Forces B in Figure 5.10.

In the Patent the arms that hold the conductor in place are resiliently deformed when the conductor is compressed into the plug. The arms of the cable restraining means are referred to as 'tongues' in the Patent. When the insulated cable is inserted into the connector, these 'tongues' are deformed towards one end of the cable containment chamber by the end geometry of the 'tongues' (towards the top of Figure 5.11 above). This deformation is also assisted by the local thinning out of the 'tongues' near the walls of the containment chamber. The local thinning of the material may be considered as 'hinges' about which the 'tongues' are permitted to rotate as shown schematically in Figure 5.11.

Now when Force A (the pull-out force) acts on the cable, the 'tongues' and the containment chamber body will act exactly like the toggle mechanism indicated in Figure 5.11, thereby amplifying the restraining forces B acting on the insulated sides of the conductor, and further restraining the cable.

As explained above, there is a penalty to contend with in the operation of such a toggle mechanism. If the angle of deformation of the 'tongues' is insufficient, or if the material of construction is sufficiently resilient (after all the Patent claims resilient deformation of the 'tongues') the 'tongues' can 'flip' through the line joining Forces B and release the cable (this is shown schematically in Figure 5.12).

Figure 5.13 shows an enlarged photo of one module in the Tyco product. The 'insulation displacement' feature is similar to many other products as well as the one described in the Patent. The cable capture feature has a pair of 'arms' that are angled inwards towards the insulation displacement feature. The effect of these arms is to hold the cable in a way similar to the operation of the 'tongues' described in the Patent, except that these 'arms' do not rely on any geometric feature to bend them inwards. In this way they are different from the cable capture feature described in the Patent. These 'arms' will still operate as a toggle mechanism for preventing the cable being released from them."

The Patents Examined

1. US Patent No. 4,836,803 as well its equivalent German Patent No. 3,622,164 (Seidel)
2. US Patent 4,262,985(Muehlhousen)
3. US Patent No. 3,902,154 and its equivalent German Patent No. 2,456,977 (McKee)
4. US Patent No. 4,057,314 and its equivalent German Patent 2,637,378 (Mathe)
5. US Patent No. 3,845,455 and its equivalent German Patent No. 2,446,670 (Shoemaker)
6. Australian Patent Application No. 55799/80 (Bryant)
7. Australian Patent No. 565,276 (Khatri, Wilkinson)
8. Great Britain Patent No. 1,396,790 (Gore)
9. US Patent No. 4,514,027 (Seidel)
10. US Patent No. 4,343,529 (Reavis)
11. US Patent No. 4,236,778 (Hughes)
12. Spanish Utility Model No. 294,749 (Elzaburu)
13. US Patents No. 4,412,374, (Forberg One), No. 4,171,857 (Forberg Two), No. 4,533,196 (Forberg Three)
14. US Patent No. 4,615,576 (Gerke)
15. US Patent No. 4,775,330 (Teichler)
16. Australian Patent No. 609,486 (App. 17379/88)(Nichols)
17. Australian Patent No. 509,783(Mathe-Kasper)
18. United Kingdom Patent No. 2,201,306A (Ranger)
19. US Patent No. 4,169,645 (Faulconer)
20. US Patent No. 4,722,699 (Heng et al.)
21. US Patent No. 3,708,779(Enright et al.)
22. US Patent No. 4,127,312(Fleischhacker et al.)
23. US Patent No. 4,210,379 (Vachhani et al.)
24. US Patent No. 4,349,239 (Roberts-Wassericin)
25. US Patents No. 3,496,522 (Ellis One), granted 17 February, 1970, No. 3,611,264 (Ellis Two), granted 5 October, 1971, No. 3,631,378 (Ellis Three), granted 18 December, No. 1971, 3,798,587 (Ellis Four), granted 19 March, 1974

Patent Review

1. *US Patent No. 4,836,803 and its equivalent German Patent No. 3,622,164 (Seidel)* (quoted as insufficient prior art to The Patent) –

"A wire holding device for locating wires in an electrical connector, comprising at least one passageway into which a connection wire to be held can be moved essentially normally of its length through an outwardly enlarging entrance slot toward a closed end of the passageway. A first barb adapted to be resiliently urged aside by a wire upon the introduction thereof extends from a sidewall of the passageway adjacent the entrance slot. A second barb extends from the sidewall opposite the first barb and is adapted to be resiliently urged aside by the wire upon the introduction thereof, the free end of the second barb, …"

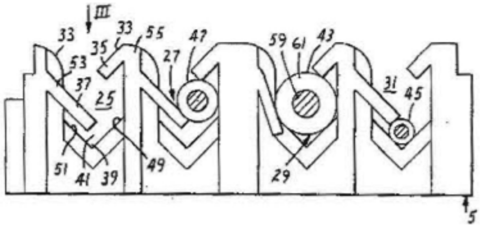


Figure 5.14.1 After US Patent No. 4,836,803[5.9]

The *wire holding* means, or retaining means for wires of varying diameter, behave in an analogous way to the strain relief means in The Patent. The operation of the angled *"barbs"* (identified as 37 and 35 in Figure 5.14.1) is to *"resiliently deform"* when wires of various diameter are inserted into the plug. Although the retention action is parallel to the axis of the cable or wire being retained, it is a trivial step to make the same action operate in a plane normal to the axis of the wire or cable as is done in The Patent.

2. *US Patent No. 4,262,985 (Muehlhousen)* (quoted as insufficient prior art to The Patent) –

"… The wire-retaining slots … in the index strip and index-strip portion of the connector module have flexible inwardly curved flanges … adjacent to one end of the slot. Each corresponding pair of flanges, which depend from adjacent slot-defining upright members …, deflect inwardly into the wire-retaining slot during wire indexing to securely grip an inserted conductor, … the deflected flanges being capable of biasing toward each other to create an even tighter grip on a conductor when conductor pull out from that end is attempted …"

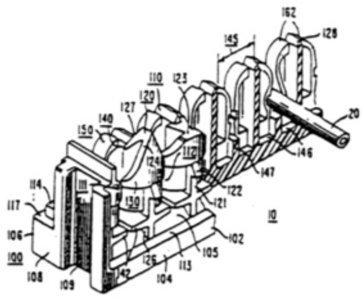


Figure 5.14.2 After US Patent No. 4,262,985

This patent describes *"flexible inwardly curved flanges"* that retain the cable but again the retention means is parallel to the axis of the cable. However,

5.9 In this review Figures are identified by their patent numbers as shown in Figure 5.14.1

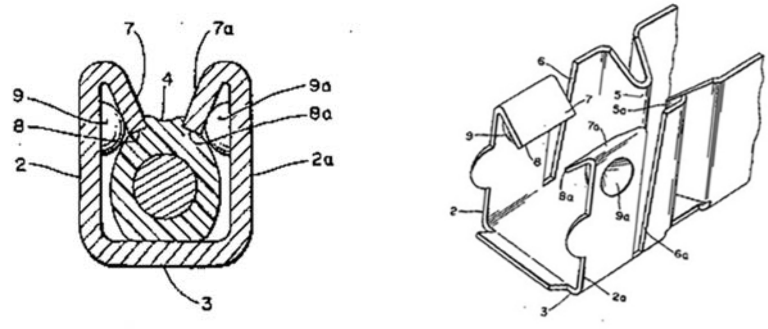


Figure 5.14.3 After US Patent No. 3,902,154

the method of retention – the retaining force gets larger as the wire is displaced outwardly from its normal position – has strong similarities in concept to the toggle action of The Patent.

3. *US Patent No. 3,902,154 and its equivalent German Patent No. 2,456,977 (McKee) –*

   "A relief wire terminating system with particular regard to a strain relief means provided as an integral part of the system. At the rearward or termination portion of the system, side walls define a channel for receiving an insulated wire. At the rearmost extremity, a tab extends from the top of each wall at an angle, downward and inward into the space. The tabs terminate in edges defining a wire passing space between them and below them, a wire restraining space. The tabs act on the wire to take up strain."

This patent teaches us about the application of *"tabs"* extending downward and inwards to hold the wire into the "wire retaining" part of the channel. The operation of this strain relief means is identical in concept to that of The Patent. Again the retention is parallel to the axis of the cable, but a trivial step away from having the cable retention means normal to the cable axis.

4. *US Patent No. 4,057,314 and its equivalent German Patent 2,637,378 (Mathe) –*

   "An electrical connector is provided with a plurality of contacts, each of the contacts having an insulation opening terminal element of sheet metal construction to electrically contact an insulated conductor. The contact is advantageously constructed for receiving an insulated stranded conductor, but is equally applicable for receiving an insulated solid conductor. Each contact includes an active portion, of either male or female configuration, a terminal element portion, and an intermediate portion connecting the active and termi-

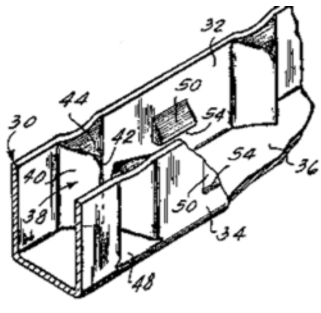


Figure 5.14.4 After US Patent No. 4,057,314

nal element portions. The terminal element portion preferably includes an elongate open channel of U-shaped cross-sectional configuration having side and bottom walls, the sidewalls including opposite portions dimpled in to provide inner detents forming, and separated by, a conductor-receiving notch for opening the insulation of the conductor and electrically engaging the underlying exposed conductor. A plurality of different embodiments of a detent are offered, each of which advantageously- includes an enlarged wiping surface, a notch entrance and a smooth portion adjacent the notch entrance to prevent snagging, and possibly severing, of the individual strands of a stranded conductor."

Figure 5.14.4 shows the *"detents"* (identified as 44 in the figure) that act as either insulation displacement devices or as cable retention means, depending on the relative size of the opening between the detents and the diameter of the cable insulation. Although these *"detents"* or dimples are solid elements in the wire receiving channel, they act in a manner very similar to that described in The Patent for strain relief.

5. *US Patent No. 3,845,455 and its equivalent German Patent No. 2,446,670 (Shoemaker) (quoted as insufficient prior art to The Patent) –*

"Conductor-in-slot connecting device comprises a first formed tubular member having an axially extending open seam and having sidewalls on each side of the seam. A second tubular member is formed from material in the sidewalls of the first tubular member and has a second open seam. When wire is moved laterally of its axis and into both of the open seams, the edges of the second tubular member penetrate the insulation of the conductor and establish electrical contact with the conducting core. The edges of the first tubular member penetrate the insulation only and function as a strain relief for the conductor."

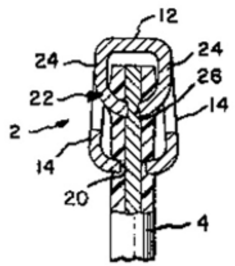


Figure 5.14.5 After US Patent No. 3,845,455

Figure 5.14.5 is a section through the "tubular members" and the *"resiliently deformable fingers"* formed by the sidewalls of the slit tubular member. As seen in the figure, one set of edges act as insulation displacement means and the second, longer fingers act as strain relief means. Here the cable retention means (strain relief means) act normal to the axis of the cable just as the strain relief fingers act in The Patent.

6. *Australian Patent Application No. 55799/80 (Bryant) –*

"… a connector comprising a base member of insulating material having longitudinal open channels with ridges formed in their sides which frictionally securely grip the insulation of tapped and tapping wires when moved transversely of their axis into said channels …"

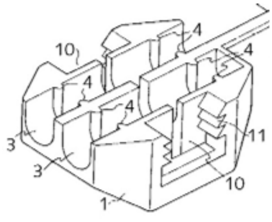


Figure 5.14.6 After Australian Patent No. 55799/80

Figure 5.14.6 shows one half of an electric plug device with strain relief detents in "longitudinal open channels" (items 4 in the figure) that *"frictionally securely grip"* the cable insulation, when the cable is inserted into these channels. The essence of this claim is to provide strain relief similar to the ideas described in both US Patent No. 4,057,314 and in The Patent.

7. *Australian Patent No. 565,276 (Khatri–Wilkinson)* – This invention describes an electric plug specifically for telephone cables using insulation displacement to make the connection between the cable and the plug. In addition, the patent teaches us about

   "pairs of fingers (see 17 in Figure 5.14.7) extending inwardly from the cover and base portions [of the plug]. The length of these fingers such that when the housing is assembled the ends compress and grip the segments of insulated cable passing therebetween."

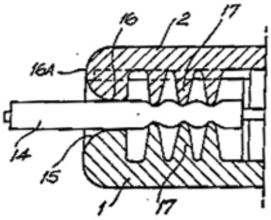


Figure 5.14.7 After Australian Patent No. 562,276

These *"fingers"* act in a way similar to the *"detents"* described in US Patent No. 4,057,314 and in Australian Patent Application No. 55799/80. They also mimic the action of the resiliently deformable fingers in The Patent. Additionally, the gripping is normal to the axis of the cable and the fingers deflect by virtue of the plug components compressing on the insulation during plug closure.

8. *Great Britain Patent No. 1,396,790 (Gore)* – Part of this patent refers to strain relief as described in the patent:

   "The present invention is particularly concerned with electrical fittings having a casing of insulating material built up of at least two separately formed parts, hereinafter referred to as casing members, that are detachably secured together and the invention has for its principal object the provision of a casing for an electrical fitting having associated with a cable entry improved means for reducing the risk of strain being imparted through a cable to electrical connections within the casing."

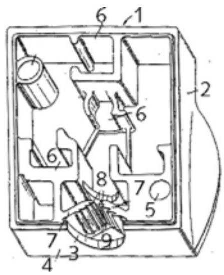


Figure 5.14.8 After Great Britain Patent No. 1,396,790

As seen in Figure 5.14.8, the *"resiliently deformable"* fingers or *"tongues"* (identified as item 7 in the figure) act in an identical way to the strain relief system described by The Patent (the patent in suit). In essence, the radial force acting on the cable being held will increase as the cable is moved outward from the body of the plug. The *"resiliently deformable"* tongues deflecting inwards during this action, cause this increase of force.

9. *US Patent No. 4,514,027 (Seidel)* – Although this patent describes some features similar to that taught by US Patent No. 4,836,803 (Seidel's ear-

lier patent) in addition it describes *"inwardly deflecting tabs"* (identified as item 76 in figure 5.14.9) that grip the conductor securely when inserted into the grooves (or channels) formed in the body of the connector. This aspect of the patent is similar in action to Seidel's earlier patent, with the additional feature of the detent (identified as item 78 in the figure) that provides further grip on the cable insulation when the connector is assembled. In this patent, as in Seidel's earlier patent, the gripping action is parallel to the axis of the cable. Nevertheless, if an attempt is made to pull the cable out of the connector the cable gripping force will increase.

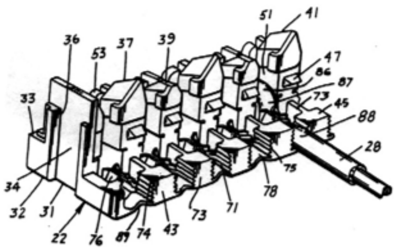


Figure 5.14.9 After US Patent No. 4,514,027

10. *US Patent No. 4,343,529 (Reavis)* – Figure 5.14.10 shows a detail with an electrical cable inserted into the terminal block and held there in a channel by the cutting edges of tubular member (identified as item 6 in the figure) that provide the insulation displacement means in this connector. The cable is also held in place by the flared skirts (identified as item 40 in the figure) that dig into the insulator of the cable.

Although this patent makes no direct reference to strain relief, the skirts (item 40) act in an identical way to the *"resiliently deformable tongues"* of the patent in suit (The Patent), providing toggle action retention means of the cable against any pullout force.

11. *US Patent No. 4,236,778 (Hughes)* – The subject of this patent is similar to that of US Patent No. 4,343,529 (Reavis) and it cites an earlier patent of Reavis et al. (US Patent 4,141,618) as prior art. On examination, US Patent No. 4,141,618 only makes reference to a slotted barrel shaped connector for insulation displacement means. There is no reference to strain relief means or any means for holding the insulation on the cable

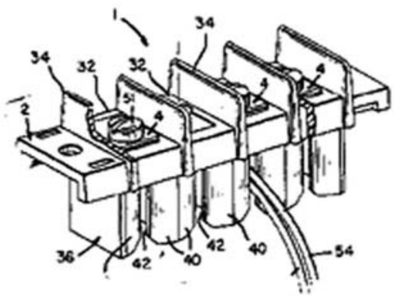


Figure 5.14.10 After US Patent No. 4,343,529

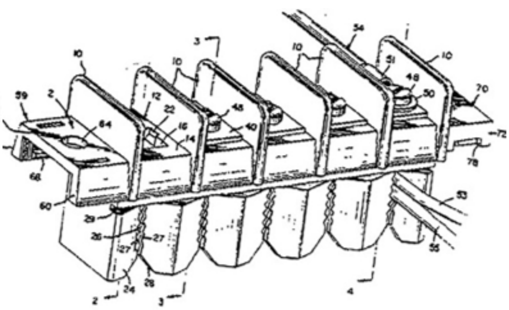


Figure 5.14.11 After US Patent No. 4,236,778

against pullout forces. However, US Patent No. 4,236,778 does make reference to the deformation of the edges (identified as item 27 in the figure) in a *"resilient hinge like manner"*. These edges act on the insulation of the inserted cable in an identical way to that described in the patent in suit (The Patent).

12. *Spanish Utility Model No. 294,749, (Elzaburu)* – This patent refers to the fingers (identified as item 28 in Figure5.14.12) as means for guiding cables into the connector described by the patent. The connector is specifically intended for the splicing of electric cables. Clearly, the action of these "fingers' will be that of retaining the cables against pullout forces, acting as a toggle mechanism similar to that described *by the patent in suit* (The Patent).

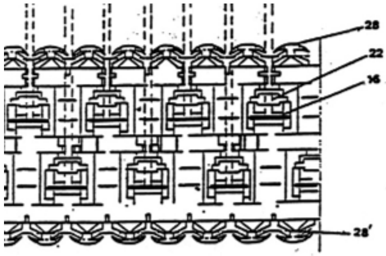


Figure 5.14.12 After Spanish Utility Model No. 294,749

13. *US Patents No. 4,412,374, No. 4,171,857 and No. 4,533,196 (Forberg)* – These patents make no reference to strain relief, but the insulation displacement means described have the action of *"resiliently deformable"* fingers that cut into the insulation, down to the wire, for making contact. This action, although used in a different context of making a contact rather than offering strain relief, mimics the operation of the *"resiliently deformable tongues"* of the patent in suit (The Patent).

14. *US Patent No. 4,615,576 (Gerke)* – The insulation displacement contact system described in this patent is similar to that described in US Patent No. 4,171,857 (Forberg), which is cited as prior art. The novelty claimed in this patent is the opposing torque produced on the cable during insulation displacement by the opposing pairs of insulation displacement blades (see item 2 in Figure 5.14.14). It is clear that some resilient deformation of these blades will take place during cable insertion in order to

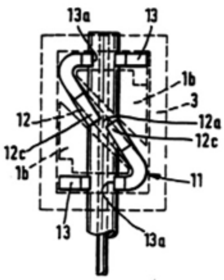


Figure 5.14.13 After US Patent No. 4,412,374

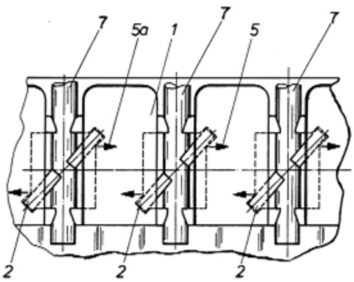


Figure 5.14.14 After US Patent No. 4,615,576

permit the system to work with varying diameter conductors. Hence the action (at least in part) still mimics the resiliently deforming tongues of the patent in suit (The Patent).

15. *US Patent No. 4,775,330 (Teichler)* – This invention refers to *"cutting and clamping contacts"* that use insulation displacement on electric cables to make contact. The blades of the *"cutting and clamping contacts"* behave in the same way as do the insulation displacement means described in US Patents No. 4,615,576, No. 4,412,374, No. 4,171,857 and No. 4,533,196. The comments relating to these disclosures are similarly applicable to US Patent No. 4,775,330. No reference is made to strain relief.

16. *Australian Patent No. 609,486 (App. 17379/88, Nichols)* – Feature 112, identified in Figure 5.14.16 represent strain relief means by providing an insulation gripping function when the connector parts are clamped together.

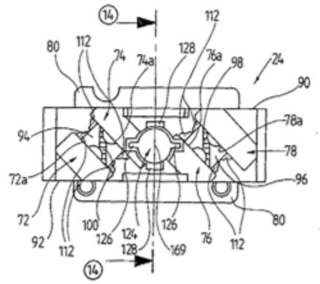


Figure 5.14.16 After Australian Patent No. 609,486

17. *Australian Patent No. 509,783 (Mathe–Kasper)* – This patent identifies strain relief means already disclosed in US Patent No. 4,057,314 and its equivalent German Patent 2,637,378. All those comments offered on those disclosures apply for Australian Patent No. 509,783.

18. *United Kingdom Patent No. 2,201,306A (Ranger)*

"An electrical plug includes: a base carrying internal recesses each incorporating an electrically conductive terminal connected to a respective terminal pin of the plug, the recesses receiving the bare ends of electric leads; and a cap including internal protrusions which mate, when the cap is secured upon (the) base, with respective recesses whereby to hold the ends of the electrical leads against the terminals. Arms (12) moulded with the base provide a cable clamp. …"

The arms 12 shown in Figure 5.14.18 behave in an identical manner (toggle action) to that described in the patent in suit (The Patent).

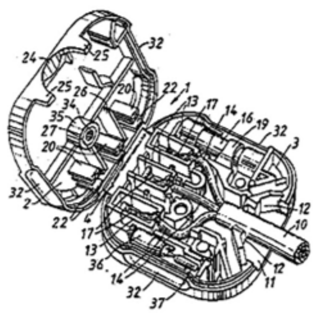


Figure 5.14.18 United Kingdom Patent No. 2,201,306A

19. *US Patent No. 4,169,645 (Faulconer)* – This patent teaches us about a connector for splicing (interconnecting) multi-strand communication cables and presents a labyrinth technique for clamping cables into the connector as well as a simple cutoff procedure for making contact with

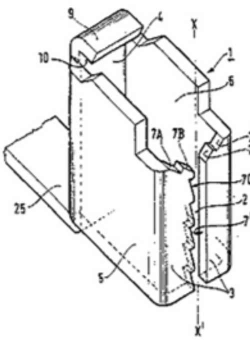


Figure 5.14.20 After US Patent No. 4,722,699

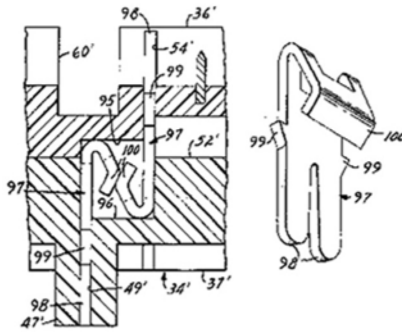


Figure 5.14.21 After US Patent No. 4,722,699

the conductor in the cable. This particular patent has no relationship to any of the features presented in the patent in suit (The Patent). No reference is made to insulation displacement or strain relief provisions.

20. *US Patent No. 4,722,699 (Heng et al.)* – Figure 5.14.20 shows the insulation displacement means described in this patent. The means are not intended as strain relief, but the operation of the preferred embodiment described is provided by the *"resiliently deformable"* means offered by faces 1 in the figure. The slot, formed by the edges 7c and 7′c in the figure, mimic the action of the resiliently deformable fingers described in the patent in suit.

21. *US Patent No. 3,708,779 (Enright et al.)* – Figure 5.14.21 shows one preferred embodiment described in this patent. Tabs, identified as 100 in the figure, are intended as contact means for making electrical contact between two parts of the splicing connector described. Although used in a different application (that of making contact rather than strain relief) these tabs also mimic the action of the resiliently deformable fingers of the patent in suit. Moreover, this patent was assigned to 3M, the suitor in this matter. Hence they had to be aware that the intellectual property associated with this type of plug component was in the public domain before the publication of the patent in suit.

22. *US Patent No. 4,127,312 (Fleischhacker et al.)* – This patent describes a connector for a plurality of telephone cables. It uses a clamping arrangement for strain relief (not noted in the patent although implied by intent), The insulation displacement means described and the plurality of cable connections have similarities to the connector in the patent in suit, but there is no explicit mention of the strain relief means.

23. *US Patent No. 4,210,379 (Vachhani et al.)* – Figure 5.14.23 shows the preferred embodiment for cable clamping means. Item 42 carries one cable end. The split cylindrical element 32 provides the insulation displace-

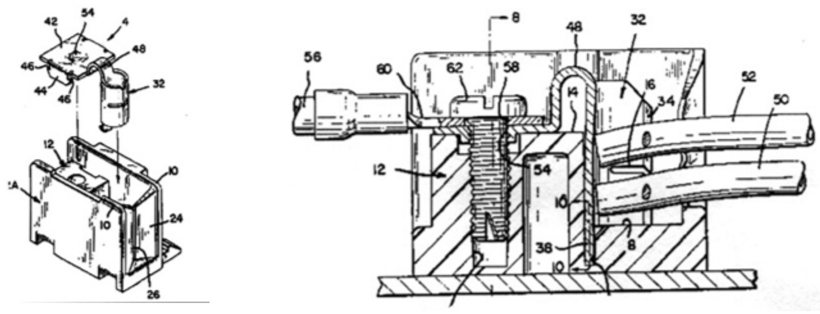


Figure 5.14.23 After US Patent No. 4,210,379

ment means for a second sets of cables. The flanges 24 *"resiliently deform"* around the cable insulation and the resulting slot 26, when deformed will offer strain relief for the cables. The patent describes this as:

"One slotted flange 24 …, will have its slot 26 in alignment with the barrel slot 34 to grip opposite sides of the wires and provide a strain relief. More specifically, the wires are inserted transversely of their lengths into the flange slot 26, the sides of the slot gripping the wires. The slot sides diagonally converge. If an inserted wire is pulled in a direction outwardly from the barrel terminal, the slot sides will tend to pivot into mutual alignment, narrowing the slot 26 to improve the grip on the wire and prevent its pull out from the terminal."

This patent, assigned to AMP in 1980, describes an embodiment identical to the strain relief action provided in the patent in suit, predating The Patent by a considerable number of years.

24. *US Patent No. 4,349,239(Roberts–Wassericin)* – This patent describes cable connection means as indicated in Figure 5.14.24. Insulation displacement means are similar to many other examples in the patent literature. The strain relief, provided by *"ridges"* 35 that *"capture"* the terminated ends of the cable into terminating slots, is implied, but not explicitly mentioned in the patent.

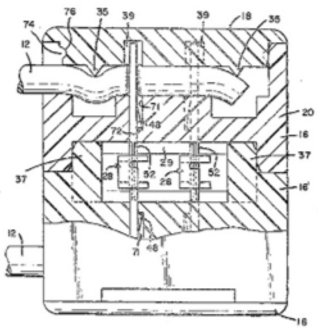


Figure 5.14.24 After US Patent No. 4,349,239

25. *US Patents No. 3,496,522 (Ellis One), No. 3,611,264 (Ellis Two), No. 3,631,378 (Ellis Three) and No. 1971, 3,798,587 (Ellis Four)* – All four Ellis patents have been assigned to Bell Laboratories, as was the more recent *Muehlhousen, US Patent No. 4,262,985.* These four patents make claims about insulation displacement connections through the use of insulation piercing clips mounted in terminal blocks. Major differences between the four patents are the geometric arrangements of the blocks or housings containing insulation piercing clips. In terms of wire

retention or strain relief means, these patents are not relevant to The Patent.

Discussion of the Patents

This examination is about an invention. In this context I define invention as *"the conception of a new means to fulfil a need"*. Additionally, it is helpful to identify a broad classification of inventions.[5.10]

(a) Primary Inventions: These are the most difficult and novel, and represent those inventions where there is nothing in nature or previous knowledge to suggest a solution to a problem. Typical examples are the wheel and axle and the Arabic number system with the artefact zero.

(b) Secondary Inventions: These are still moderately difficult and involve major innovative problem solving. Typical examples are the telegraph, the telephone and the zip fastener.

(c) Easiest inventions or Discoveries: These can be subdivided into three classes, namely:

(c1) Observations of phenomena which could be usefully applied;

(c2) Improvements on prior inventions;

(c3) A new use of an existing invention.

The strain relief means described in the schedule of patents all fall into the type (c). The first application of the toggle action for strain relief could be classified as type (c1), the rest are all of type (c3). From the schedule of patents examined it is not possible to determine when the toggle action strain relief system was first applied. However, it is clear that the notion predates the patent in suit by a substantial margin.

In the schedule of patents examined, the following are direct applications of toggle action strain relief means as described by the patent in suit:

(a) gripping applied parallel to the cable axis – US Patent No. 4,836,80 as well as its equivalent German Patent No. 3,622,164; US Patent No. 4,262,985; US Patent No. 3,902,154 and its equivalent German Patent No. 2,456,977; US Patent No. 4,514,027.

(b) gripping applied normal to cable axis – US Patent No. 3,845,455 and its equivalent German Patent No. 2,446,670; Great Britain Patent No. 1,396,790; US Patent No. 4,343,529; US Patent No. 4,236,778; Spanish Utility Model No. 294,749.

The following patents disclose strain relief using gripping by rigid detents that in part mimic the gripping action described in the patent in suit: US Patent No. 3,902,154 and its equivalent German Patent No. 2,456,977; US Patent No. 4,057,314 and its equivalent German Patent 2,637,378; Australian Patent Application No. 55799/80; Australian Patent

5.10 This classification follows Bailey (1949).

No. 565,276; Australian Patent No. 609,486 (App. 17379/88); Australian Patent No. 509,783.

The following patents disclose insulation displacement means that act like toggle action for gripping the conductor: US Patents No. 4,412,374, No. 4,171,857 and No. 4,533,196; US Patent No. 4,615,576.

There is trivial a difference between the application of toggle action gripping parallel to the cable axis and normal to the cable axis. Moreover, the application of toggle action to grip the insulation, once it has been disclosed for gripping the conductor in insulation displacement systems is also a trivial improvement.

In an earlier report (dated 29 June 2000) I identified other prior art relevant to these discussions (see Figure 5.15) and that report must be read in conjunction with the current report.

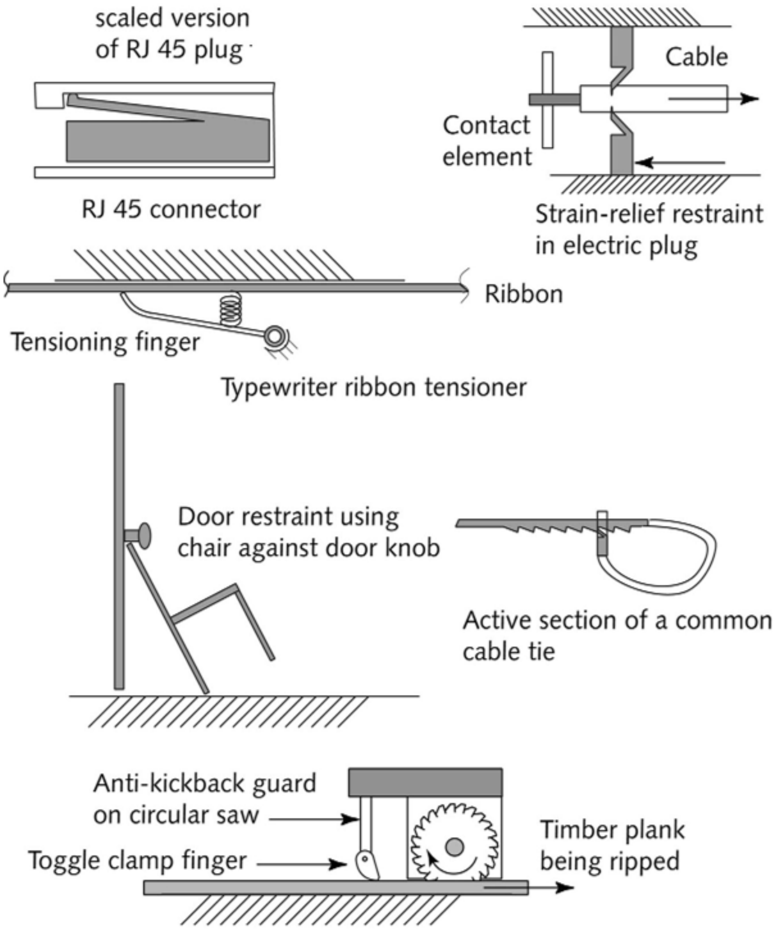


Figure 5.15 Toggle action applied in other prior art applications

5.4.3 Concluding Opinion, the Outcome and Lessons Learnt

Based on the above investigation I concluded that the features described in the Patent (Australian Patent No. 624486) are not novel, since they have been in the public domain for some considerable time.

As a result of this opinion I was asked to affirm separate affidavits on both validity and infringement. In due course the case was heard in the Federal Court of Australia, before His Honour Sackville J., who, after considering the evidence, found in favour of Tyco on both validity and infringement. The reasons for this judgement are set out in document FCA1359, dated 29 September 2001.[5.11]

Following this judgement 3M appealed and the appeal was heard in front of the full bench of the Federal Court (Heerey, Emmett and Dowsett JJ) detailed in document FCAFC 315, dated 23 October 2002. In their judgement Their Honours, Heerey, Emmett and Dowsett, upheld the case in favour of Tyco on infringement, but overturned the judgement on validity. The issue of validity was assessed from the point of view of the wire retention means in the 3M patent being "obvious", when considering the vast body of toggle action designs available in other applications. Therefore, it was argued that to make the simple step of applying this idea to wire retention was obvious nd not really inventive. However, in paragraph 118 of their reasoning Their Honours stated:

> *"…The Patent identified a new feature able to provide wire retention and strain relief. It was different from anything previously known in this area, although aspects of it may have been known, and the underlying principles were well-known. The idea was to design a feature which provided both wire retention and strain relief using plastic tongues, designed to deform resiliently. With the benefit of hindsight, it may be possible to say that each of the steps taken in the design was logical, but that does not mean that the claimed inventive step was obvious. The evidence does not lead us to that conclusion. … Patent provided 'an elegant solution to the problems posed ...' and that the solution was 'simple, effective and efficient'. We find no difficulty in adding the epithet 'inventive'. In our view the patent does not fail for obviousness."*

5.11 www.wptn.com/patent_vol4is7/pat_001_vol4is7.htm.

5.5 A Silage-wrapping Machine

Silage: "fodder packed in a silo," 1884, alteration (probably by influence of *silo*) of *ensilage* (1881), from French *ensilage*, from *ensiler* "put in a silo," from Spanish *ensilar* (see *silo*).

Silo: 1835, from Spanish *silo*, from Latin *sirum* (nominative of *sirus*), from Greek *siros* "a pit to keep corn in." Or, alternately, the Spanish word is from a pre-Roman Iberian language word represented by Basque *zilo*, *zulo* "dugout, cave or shelter for keeping grain." Meaning "underground housing and launch tube for a guided missile" is attested from 1958.

OLED

5.5.1 The Case Culture, the Dispute and the Client

Silage is the term used for the feed produced by controlled fermentation of high-moisture herbage. When silage is stored under anaerobic conditions (in the absence of oxygen) lactic acid is produced and will halt the fermentation process. If silage is undisturbed it will keep for extended periods. High-quality silage is very palatable, and excellent results can be achieved in modern farming with properly maintained silage material. The conservation of silage made from grass and forage crops has increased in popularity in recent years because it is a cost-effective way of providing a reliable, nutritious winter feed from known resources and is less weather-dependent than haymaking. Baled silage is a relatively recent farming practice, first used in Australia and New Zealand in the 1970s, and only became possible following the development of suitable plastic films by the petrochemical industry.

The *Edberg Corporation of Sweden* (*EDS*) was the manufacturer of an automatic bale-wrapping machine, the *Wrapsil-991*. This machine had been designed and constructed according to Australian Patent No. 571,087 granted to Kenneth Williamson (the *Williamson Patent*), inventor, with a priority date of 25 May 1984. The patent applicant, *Eighth Millieu Nominees Pty. Ltd.* (*EMN*) granted a licence to EDS to manufacture and import into Australia these silage wrappers. Due to long winters in the nordic climate

Figure 5.16 The Wrapsil-991 completing a bale wrapping process

Figure 5.17 The Wrapsil-991 ready to wrap the next bale

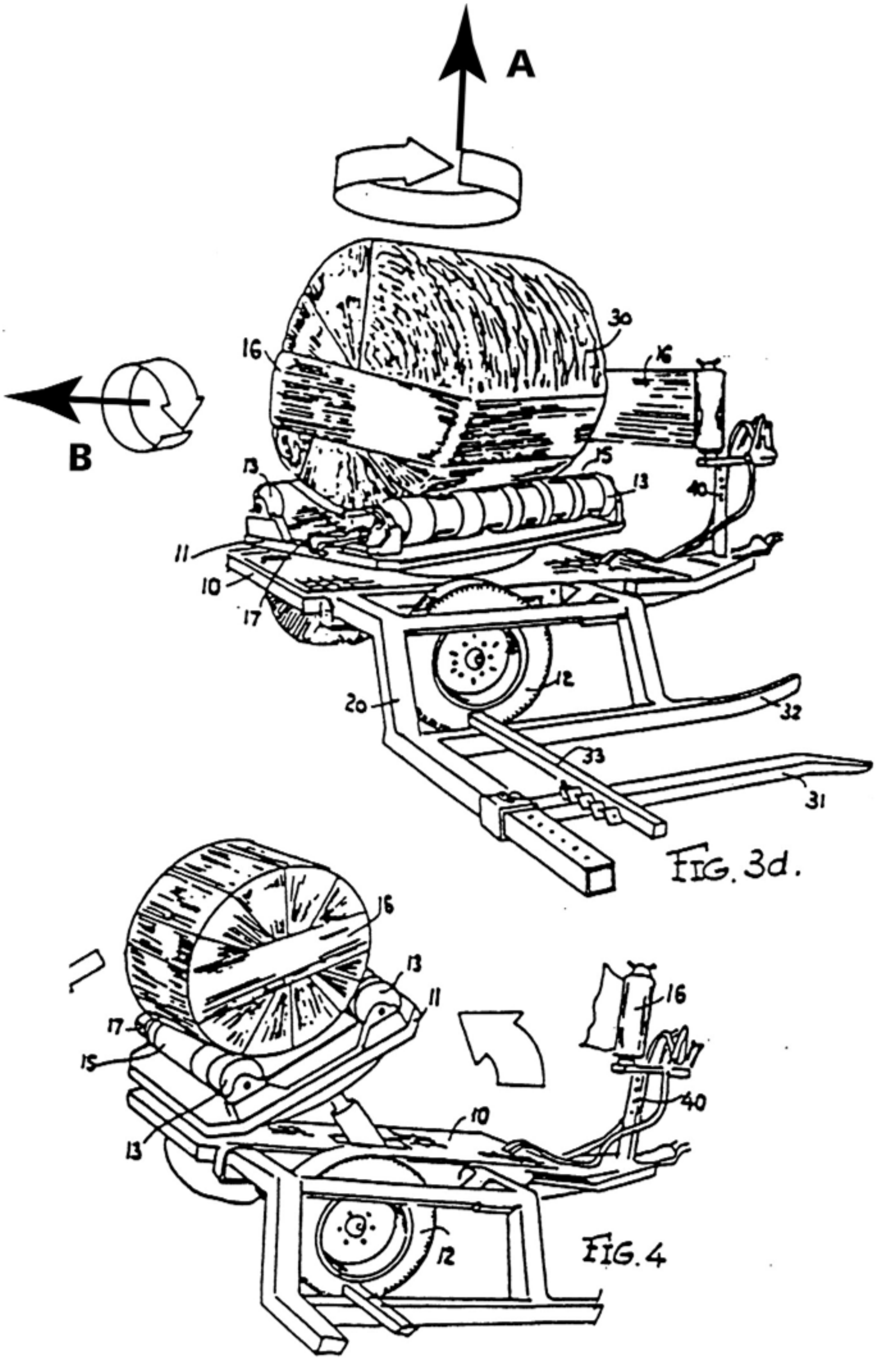


Figure 5.18 Key features of the Williamson Patent illustrated schematically in preferred embodiments

silage wrapping is big business there, and it seemed most appropriate and convenient to license the manufacture of the Wrapsil-991 to EDS. The Australian agent and distributor for the Wrapsil-991 was the *Differential Packaging Group Ltd.* (*DPG*). In 1997 DPG discovered that an Irish manufacturer *Tom Dooley Ltd.* (*TD*) was importing a silage-wrapping machine into Australia. On examination, DPG observed that the TD machine was very similar in appearance and operation to the Wrapsil-991 machine. In fact, the only difference noted between the two machines was their colour, the Wrapsil-991 being predominantly red and the TD machine predominantly green.

On advice from their solicitors *Francis and Bacon, Lawyers* (*FBL*), EMN issued a writ of infringement in the Federal Court of Australia against the Australian distributor for TD. In consequence, on advice from their solicitors, TD issued a counterclaim on validity against EMN. My brief, from FBL, asked for an examination of various patents in evidence, as well as the two machines (the subjects of this dispute), and my opinion on infringement and validity. I was also asked to offer opinion about the similarities and differences between the TD machine and Wrapsil-991.

5.5.2 Investigation

Figures 5.16 and 5.17 show views of the Wrapsil-991 machine. Figure 5.18 is one taken directly from the Williamson patent and it illustrates a key feature of the patent schematically.

The Complete Specification Number 571087 describes the invention as *"Improvements relating to the wrapping of hay bales".* The description goes on (from lines 29 onwards on page 2 of the specification) :

> *"There is provided according to the present invention a method of forming hay silage comprising the steps of supporting a hay bale on a support, said support being adapted to rotate said bale about two axes simultaneously, rotating said bale about two axes by rotation of said support, applying a sheet of impervious plastic film material to said bale by wrapping the plastic film material around the bale in overlapping close fitting fashion during said rotation of said support and said bale, wherein the plastic is self adhering to form a close fitting airtight package completely enveloping the hay bale, the hay being substantially sealed from the atmosphere for sufficient period of time whereby the formation of silage within the package occurs."*

This paragraph in essence embodies all the major claims of this invention, namely:

(a) Handling and support of the hay bale for the purposes of wrapping a plastic film around it to make an air-impervious package;

(b) Rotation of the package about two axes simultaneously to effect the wrapping;

(c) Use of self-adhering overlapping plastic film wrapping to effect the complete covering of a bale;

(d) Use of a wrapping process which results in essentially *"double wrapping"* the hay bale.

The invention makes the following claims:

"1. A method of forming hay silage comprising the steps of supporting a hay bale on a support, said support being adapted to rotate said hay bale about two axes simultaneously, rotating said hay about two axes by rotation of said support, applying a sheet of impervious plastic film material to said bale by wrapping the plastic film material around the bale in overlapping close fitting fashion during said rotation of said support and said bale, wherein the plastic is self adhering to form a close fitting air tight package completely enveloping the hay bale, the hay being substantially sealed from atmosphere for sufficient period of time whereby the formation of silage within the package occurs.

2. A method according to claim 1 wherein said two axes are mutually perpendicular.

3. A method of forming hale silage substantially as herein described having reference to the drawings.

4. Apparatus when used in the method according to any one of claims 1 to 3 including a turntable for rotatably supporting a hale bale, said turntable being rotatable about a substantially vertical axis, the turntable including rotatable support means thereon for rotating the bale about a substantially horizontal axis and means for wrapping the plastic film around the bale whilst it is being rotated about said axes."

Quite apart from the overall improvement in producing silage, the object of the invention, the process used is that of wrapping a large approximately spherical object in a flat sheet of plastic film. It is this process which is claimed in Claim 1 and Claim 4 above. Although Claim 2 suggests that the axes of rotation (indicated as axes A and B schematically in Figure 5.18, as Figure 3d, taken from the patent) should be mutually perpendicular, the wrapping would still succeed even if the axes were at some other angle to each other. In fact, as long as axes *A* and *B* are not parallel to each other, the wrapping will continue to succeed.

The Case for Infringement

I have sighted successive photographs of the operation of the Williamson invention and found it to be a true embodiment of the description in Australian Patent No. 571,087. On Wednesday, 15 October, I visited the premises of TD Australia in Elmore, Victoria, and examined the TD Round Bale Wrapper (hereinafter referred to as the *TD machine*).

Based on my examination and comparison of the TD machine to the Williamson invention described by Australian Patent No. 571,087, I formed the opinion that the two machines are almost identical. The two machines are certainly identical in their actions of wrapping the bale. The minor mechanical details in which the two machines differ have no relation to the bale-wrapping operation described by the Williamson patent. In essence then the Claims 1 to 4 noted above are identically applicable to both machines.

Ricketson, in *The Law of Intellectual Property*,p. 976, cites the case for the *"pith and marrow"* approach for judging infringement:

> *"… before the drafting of precise claims had fully developed, it was possible to see a more generous approach to this question by the courts. This was sometimes known as the 'pith and marrow' approach. Thus, in Clark v. Adie, a case relating to an improved form of horse clipping apparatus, Lord Cairns said:*
>
> *One mode of infringement would be a very simple and clear one; the infringer would take the whole instrument from beginning to end, and would produce a clipper made in every respect like the clipper described in the specification. About an infringement of that kind no question could arise. The second mode would be one which might occasion more difficulty. The infringer might not take the whole of the instrument here described, but he might take a certain number of parts of the instrument described; he might make an instrument which in many respects would resemble the patent instrument, but would not resemble it in all its parts. And there the question would be, either for a jury or for any tribunal which was judging of the facts of the case, whether that which was done by the alleged infringer amounted to a colourable departure from the instrument patented, and whether in what he had done he had not really taken and adopted the substance of the instrument patented. And it might well be, that if the instrument patented consisted of twelve different steps, producing in the result the improved clipper, an infringer who took eight or nine or ten of those steps might be held by the tribunal judging of the patent to have taken in substance the pith and marrow of the invention, although there were one, two, three, four or five steps which he might not actually have taken and represented upon his machine."*

In the dispute between EMN and TD, the simple and clear judgement of infringement applies. The makers of the infringing device, the TD machine, have not taken any trouble to disguise the close similarity between their machine and the Williamson invention. For example, had they chosen to do so, they could have made the two axes of rotation at some angle other than perpendicular to each other. In the event they simply chose not only to copy the substance of the invention, but also the embodiment of it.

The Case for Validity

A counterclaim was issued by TD against EMN on the grounds that the original Williamson patent contained in its inventive claims substantial matters that would in fact have been *"obvious"* to an *"average person, skilled in the art of silage wrapping"*.

There were several patents, with priority dates preceding the Williamson patent, quoted as evidence for this assertion. However, none of the patents quoted in evidence made use of the wrapping process in precisely the same way as did the Williamson invention. Therefore, bearing in mind the earlier quote from Ricketson on originality (refer to Section 5.3.3), there appeared to be sufficient differences between the Williamson invention and those earlier patents quoted in evidence as *"prior art"*. Based on these issues I formed the opinion that the case for validity could be upheld in court should the case proceed that far.

5.5.3 The Outcome and Lessons Learnt

When faced with evidence on both sides of a dispute, clients often get "cold feet" about proceeding to court. This is a regrettable condition suffered by clients in litigation, initiated by the substantial costs that might be incurred in a judgement and the substantial uncertainties where the judgement will be based on the interpretation of all the evidence by a third party, namely the judge.

In this dispute the client chose the *"soft option"* of mediation with the opposition. Ultimately the matter was resolved by TD negotiating a royalty arrangement with DPG, under which TD agreed to pay a sum (undisclosed) to DPG for every TD machine imported into Australia. Similar royalty agreements were being explored for distribution of TD machines to other countries.

5.6 Energy-absorbing Roadside Barrier

Energy: 1599, from Middle French *energie*, from Late Latin *energia*, from Greek. *energeia* "activity, operation," from *energos* "active, working," from *en*- "at" + *ergon* "work". Used by Aristotle with a sense of "force of expression;" broader meaning of "power" is first recorded in England 1665. *Energize* "rouse to activity" is from 1753; energetic of persons, institutions, etc., is from 1796. Energy crisis first attested 1970.

Absorb: 490, from Middle French *absorber* (Old French *assorbir*), from Latin *absorbere* "to swallow up," from *ab*- "from" + *sorbere* "suck in." Absorbent (noun) first recorded 1718. Absorbing in the figurative sense of "very interesting" first recorded 1876.

Barrier: circa1325, from Old French *barriere* "obstacle," from *barre* "bar". First record of barrier reef is from 1805.
OLED

Crash-barrier history almost parallels the history of automobile development. As long as vehicles moved slowly or were constrained to rail tracks there was no need to physically separate streams of traffic. With the advent of the automobile, multi-lane highways and higher speeds, traffic barriers emerged as median separators, devices designed to prevent vehicles from leaving the carriageway and to generally improve road safety. A National Council for Highway Research Publication (Chapter 5) notes:[5.12]

> *"Although it is not clear exactly when or where the first concrete median barriers were used, concrete median barriers were used in the mid-1940s on US-99 on the descent from the Tehachapi Mountains in the central valley south of*

5.12 NCRP Synthesis 244 (1997) *"Guardrail and Median Barrier Crashworthiness"*. See also Baldwin and Baldwin (2003), OECD (2003), Eligehausen (2001).

Bakersfield, California. This first generation of concrete barriers was developed to (a) minimize the number of out-of-control trucks penetrating the barrier, and (b) eliminate the need for costly and dangerous median barrier maintenance in high-accident locations with narrow medians – concerns that are as valid today as they were 50 years ago".

5.6.1 The Case Culture, the Dispute and the Client

The invention and development of tough plastics, such as polypropylene, has led the way to lighter and more mobile hollow plastic replacements for the concrete barrier.

Figures 5.19 and 5.20 show types of hollow plastic road barriers in use. Filling material used in these barriers may be water or sand. Both types of filling materials are easily available, easily disposable and free flowing, permitting rapid filling and emptying. In addition, newer styles of hollow plastic road barriers have the capacity to be moulded into shapes well suited to transport and stacking. Typically, many such barriers include holes moulded into them to accept forklift tines for easy deployment from delivery vehicles.

In Australia during 1993 to 2004 there were seven patent applications with the title *"Roadside Barrier"* and there were four patents granted with this same title. The case described in this section concerns *Australian Patent Application No. 47941/96,* dated 7 March 1996 (the *Patent Application*) and amendments pages 2, 12 and 13 thereto (the *Amendment*). The case also involves *Australian Patent Application No. 50241/93*, dated 26 October 1993 (the *Opponent's Patent*). In essence, this case contains two different but related disputes, namely:

(a) *Dispute 1* – A dispute between the patent examiners and the patent applicant, and

(b) *Dispute 2* – A dispute between the inventor of the Patent Application No. 47941/96 and the inventor of Patent Application No. 50241/93, the Opponent's Patent.

For both disputes, my client was the patent attorney firm of *Oxbold, Carter and Carter*, whose senior partner, *Richard Cranium* (*RC*) was involved in drafting the two patent applications as well as the amendment.

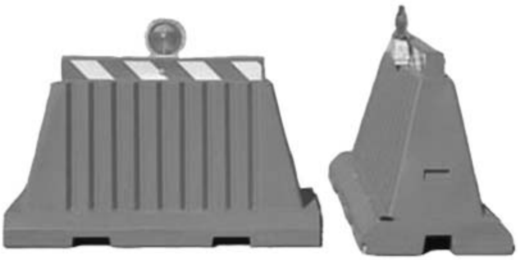


Figure 5.19 A typical hollow plastic traffic barrier

Figure 5.20 An alternative type of hollow plastic traffic barrier

Dispute 1

The role of the patent examiner includes the investigation of patent amendments submitted later than the priority date of the original application. In this case I was asked to offer opinion on the Amendment to the Patent Application. RC supplied me with a copy of the Patent Application, dated 7 March 1996 and a copy of pages 2, 12 and 13, the Amendment, filed 16 April 1998. I was asked to examine the Patent Application and the Amendment in order to offer opinion whether the amendments are entirely in line with the original inclusions and intent of the Patent Application, or if the Amendment introduces *"substantially new material"*.

Dispute 2

This was a dispute about the novelty substance of the Patent Application and a precursor to an infringement litigation concerning the Patent and the earlier priority dated Opponent's Patent. In this dispute RC supplied me with copies of Patent Applications No. 50241/93 (the Opponent's Patent) and No. 47941/96 (the Patent). In addition I was supplied with copies of statutory declarations by two experts. The first declaration, by *Mahesh Nataraj*, was dated 24 December 1997 (the *Nataraj Declaration*). The second declaration by *Anthony Perkins* was dated 16 February 1998 (the *Perkins Declaration*). I was asked to comment on whether European Patent No. 490,748 (the subject of the Opponent's Patent, Australian Patent Application No. 50241/93) contains the features contained in Claim 1 of the Patent and whether the barrier described in the Patent might be significantly different structurally from the barrier described in the Opponent's Patent.

5.6.2 The Investigation

The Patent

The Patent Application describes the invention in its abstract as:

> *"A roadside barrier of a type comprising an elongated container configured to receive and hold a volume of fluent material, said container comprising a pair of side walls, said side walls having sufficient rigidity to allow the container to stand alongside a roadway and sufficient resilience to deform upon impact by a vehicle and to recover their shape after at least some impacts; characterised by at least one port extending between sidewalls."*

Page 2 of the Patent Application reads between lines 10 and 20 as (mostly a repetition of the patent abstract stated above):

> "10. *This invention in one broad form provides a roadside barrier of the type comprising an elongated container configured to receive and hold a volume of fluent material, said container comprising a pair of side walls, said side walls having sufficient rigidity to allow the container to stand alongside a roadway and sufficient resilience to deform upon impact by a vehicle and to recover their shape after*

at least some impacts;characterised by at least one port extending between sidewalls.

It is preferred that the barrier of this invention also incorporates an inter nal frame positioned within the container."

Page 12 of the Patent Application further identifies the innovation in its claims as:

"Claim 1: A roadside barrier of the type comprising an elongated container configured to receive and hold a volume of fluent material, said container comprising a pair of side walls, said side walls having sufficient rigidity to allow the container to stand alongside a roadway and sufficient resilience to deform upon impact by a vehicle and to recover their shape after at least some impacts; characterised by at least one port extending between sidewalls.

Claim 2: The barrier of claim 1 wherein the port is sized to receive a fork of a forklift.

Claim 3: The barrier of claim 1 comprising two ports located to receive the forks of a two-forked forklift."

Figures 5.21 and 5.22 show views of a preferred embodiment of the invention described by the Patent.

The Amendment

Page 2 of The Amendment describes in a general way the intention of the invention:

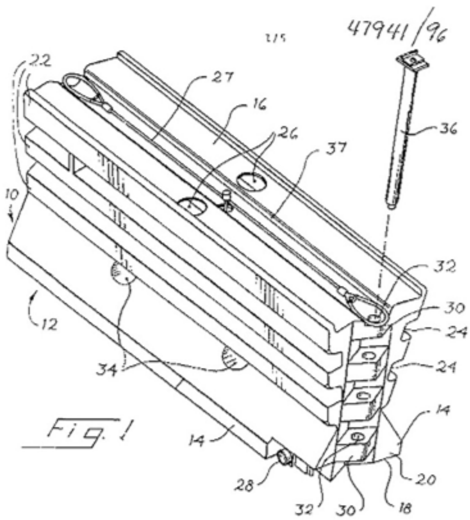


Figure 5.21 General view of one preferred embodiment of the invention described in the Patent

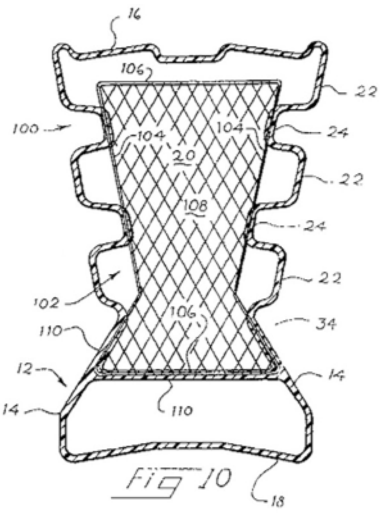


Figure 5.22 Sectional view of one preferred embodiment of the invention described in the Patent

"Accordingly, it is an object of this invention to provide an improved energy absorbing barrier which is light in weight, and which can be built at lower cost using less expensive materials that allow a barrier of greater length to be used.

This invention in one broad form provides a roadside barrier of the type comprising an elongated container configured to receive and hold a volume of fluent material, said container including: –

a pair of side walls, a bottom wall and a top wall, said side walls having sufficient rigidity to allow the container to stand alongside a roadway and sufficient resilience to deform upon an impact by a vehicle and to recover their shape after at least some impacts;

wherein said barrier includes an upper part and a lower part, said side walls being, in said lower part relative to said upper part, downwardly and outwardly inclined;

and wherein the container further includes a plurality of ports intermediate said bottom wall and said top wall, said ports forming wall means integrally joining said side walls to strengthen said lower part."

Pages 12 and 13 of The Amendment go on to elaborate on the invention through the claims:

"Claim 1: A roadside barrier of the type comprising an elongated container configured to receive and hold a volume of fluent material, said container including:

a pair of side walls, a bottom wall and a top wall, said side walls having sufficient rigidity to allow the container to stand alongside a roadway and sufficient resilience to deform upon an impact by a vehicle and to recover their shape after at least some impacts;

wherein said barrier includes an upper part and a lower part in said 'side walls' being, in said lower part relative to said upper part, downwardly and outwardly inclined

and wherein the container further includes: a plurality of ports intermediate said bottom wall and said top wall, said ports forming wall means integrally joining said side walls to strengthen said lower part.

Claim 2: A roadside barrier according to claim l wherein said wall means integrally joins said side walls in said lower part.

Claim 3: A roadside barrier according to claim 1 or 2 wherein each of said ports is sized to receive a fork of a forklift.

Claim 4: A roadside barrier according to claim 1 or 2 wherein there are two of said ports located to receive the forks of a two-forked forklift.

Claim 5: A roadside barrier according to any preceding claim wherein at least one of said side walls defines an array of longitudinally extending ridges separated by longitudinally extending channels.

Claim 6: A roadside barrier according to any preceding claim further including a pair of end walls spaced along the longitudinal direction, each comprising at least one mounting element configured to secure the container to another similar container.

Claim 7: A roadside barrier according to any preceding claim further including at least one fill opening for supplying said fluent material to the container, and a drain to allow the fluent material to be drained from the container."

The Integers of Claim 1 in the Patent and the Opponent's Patent

Integer 1 – A roadside barrier.

The Opponent's Patent describes the invention contained therein as a *"dividing block for road traffic diversion"*. The intent is very similar to that offered in the patent, namely a type of roadside barrier.

Integer 2 – An elongated container configured to receive and hold a volume of fluent material.

The Opponent's Patent makes only passing reference to the use of water as possible ballast to increase stability of the device (line 26, page 4 of the translation: *"Additionally, a further increase of the stability of the blocks can be achieved by filling them with ballast. To this end, it is proposed that they could for instance be partially filled with water."*

Integer 3 – Said container comprising a pair of sidewalls.

Integer 4 – Said sidewalls having sufficient rigidity to allow the container to stand alongside a roadway, and

Integers 3 and 4 essentially describe both devices, that of the Patent and that of the Opponent's Patent in general terms;

Integer 5 – Sufficient resilience to deform upon impact by a vehicle and to recover their shape after at least some impacts.

Because the patents offer no scale, it is difficult to assess the relative structural rigidity of the two devices, namely the device described by the Patent and that described by the Opponent's Patent. The latter goes to considerable length to describe the structural elements of its disclosure (see Figure 5.23 for a schemtic sketch of one preferred embodiment of the opponent's invention). In a similar way the Patent offers some description of the internal frame to provide resistance to bending of the barrier. It is unclear whether this bending is to be sustained in an impact or during transport of the filled barrier. Clearly, both barriers described by the two patents may be made capable of withstanding similar impacts without permanent deformation. This can be done by suitable choice of materials of construction and appropriate scaling of wall thickness.

Integer 6 – Characterised by at least one port extending between sidewalls.

This feature is present in both preferred embodiments described by the two patents. The location of the transverse port is such as to make the sidewalls it connects act in unison for the purpose of resisting deformation. In the Opponent's Patent the ports are located in the upper section of the container. In the barrier described by the Patent these ports appear to be located in the lower section. The operation of the internal frame of the Patent is such as to make the upper section sidewalls act in unison to resist deformation. In order to properly assess the influence of these matters on the resilient (elastic) deformation of either device, it would be necessary to conduct proper analyses of impact performance.

The Declarations of Nataraj and Perkins

Mr. Nataraj is a civil engineer with expertise in structural behaviour. Moreover, he has worked for the *Road Traffic Authority* and in this capacity he is clearly experienced in the use and application of the roadside barrier described in both patents. In his declaration Mr. Nataraj deals with the likely structural behaviour of the various containment devices described in these patents. In general terms his arguments seem reasonable, but I challenge the notion that one can assess the structural behaviour of anything described in a scale and material independent patent.

In addition, the purpose of the road barrier is not only to provide a division between two streams of traffic, but also to act as a means of energy-absorption in case of impact. To this end the dynamic behaviour of the *"fluent"* material contained in the barrier is much more important than the structural behaviour of the walls of the containment vessel.

Figure 5.24 shows schematically the energy-absorbing behaviour of the barrier containment vessel and its fluent contents. As the barrier vessel is impacted, the fluent material contained will squirt upwards into the available empty space (the vessel is usually partially filled to permit this type of behaviour). There will be a dynamic momentum exchange to absorb

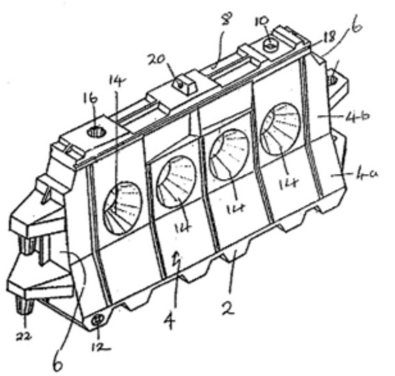


Figure 5.23 General view of one preferred embodiment of the invention described in the Opponent's Patent

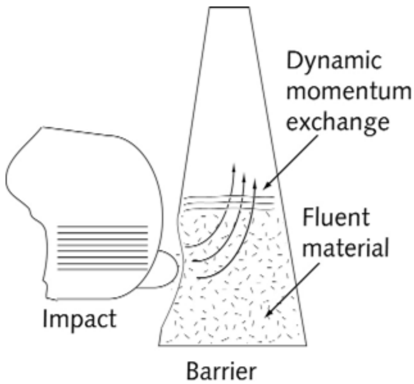


Figure 5.24 Schematic view of barrier and fluent content behaviour during impact

momentum of the horizontally moving fluid body and to create a vertically (approximately) moving fluid body. This aspect of the behaviour of the invention has not been considered by either of the declarants or the patent attorney.

Mr. Perkins' expertise lies in the plastic moulding industry. His declaration deals mainly with the property of a plastic that permits it to be resiliently (elastically) deformed. The Perkins declaration also neglects the dynamic behaviour of the material contained in the vessel during impact. Moreover, the Perkins declaration is very general in its content and also fails to admit that the behaviour of the plastic barrier will entirely depend on material choice and the choice of wall thickness scale. Since none of this is discussed or taught by the various patents, no conclusion about relative behaviour may be reached.

5.6.3 Opinion, the Outcome and Lessons Learnt

Page 2 of The Amendment to the Patent contains the words additional to the description offered in the original patent application:

> *"said side walls being, in said lower part relative to said upper part, downwardly and outwardly inclined"*

It may be seen from both Figures 5.21 and 5.22 (Figures 1 and 10 in the original patent application) that the intent of invention was to substantially include *"downwardly and outwardly inclined walls"* at the lower part of the energy-absorbing barrier, namely wall 110 identified in Figure 5.22.

The Amendment goes on to further include the extra wording

> *"wherein the container further includes a plurality of ports intermediate said bottom wall and said top wall, said ports forming wall means integrally joining said side walls to strengthen said lower part."*

The Patent Application described the presence of two ports for the purpose of permitting the entry therein the twin forks of a forklift. These ports are clearly indicated in Figure 5.21 (identified as 34 in the figure). As the container is designed to hold a fluent material, it must have been the intent of the invention that these ports extend through the body of the container from wall to wall, being integrally joined to these walls. If it were otherwise, the fluent material would leak out through these ports, contrary to the intent of the invention. The presence of fluent material within the container is an essential feature of the original invention. It is this fluent material that provides the major energy absorption component of the invention.

Additionally, once these forklift ports are *"integrally joined"* to the *"downwardly and outwardly inclined"* walls of the container, they will automatically add extra strength to the lower part of the container. One might conjecture that a *"plurality"* suggests more than two ports, originally taught by the Patent Application. However, even two such ports would add substantial extra strength to the sidewalls of the container.

In the original Patent Application there were only three claims and in the Amendment there are seven claims. These are now revisited and compared to the Claims of the original Patent Application.

Claim 1: A general description of the invention, largely similar to that in the original patent application, with the additional words described and dealt with above;

Claim 2: This claim further strengthens the description of the additional words describing the action of the forklift ports;

Claims 3 and *4*: These were included in the original application as *Claims 2* and *3*;

Claim 5: This claim describes a detail of embodiment clearly intended in the original application. The *"ridges"* described in this claim can be seen in Figure 5.21 (identified as item 22 in Figure 1 of the original patent application);

Claims 6 and 7: These are further detailed descriptors of the preferred embodiment in the original patent application. Both features identified in these two claims are evidently intended in the original invention.

Australian Patent Application No. 4794/96 describes an energy-absorbing roadside barrier. The figures in the patent show a preferred embodiment that has several features that would, in the normal course of events, significantly influence the successful operation of the invention. It is therefore surprising that all of these features and their required presence for the successful operation of the invention were not more specifically described in the claims of the original application. Although this omission is a weakness of patent application drafting procedure, the original invention and its intents are well enough described by the figures included in the original patent application. Based on my reading of the original patent application and its figures, I found no substantially new material in The Amendment and its wording. In my view this amendment appeared to elucidate the original intent of Australian Patent Application No. 47941/96.

In considering the issue of similarities between *Australian Patent Application No. 50241/93* (the Patent) and *Australian Patent Application No. 47941/96* (the Opponent's Patent), in all aspects of impact-resistant behaviour the barrier described in the Patent is superior to those described in the Opponent's Patent. This superiority is not merely due to any local structural issues such as wall thickness, wall angle or transverse connecting channels. In my opinion the energy absorption superiority is due to the ribbed structure, described in the Patent, which is able to contain more fluent material per unit wall height than the other proposed barrier design. In this sense the Patent has some significant, non-obvious, improvement over the Opponent's Patent.

Australian Patent Application No. 47941/96 and its amendment were accepted by the Australian Patent Office. A patent No. 677547 was granted for this invention on 16 June 1996. The allegations of infringement were never pursued beyond the evaluation presented in my reports.

5.7 Information Technology Piracy, Digital Fingerprints and IT Security

Information: 1387, "act of informing," from Old French *informacion*, from Latin *informationem* (nominative of *informatio*) "outline, concept, idea," noun of action from *informare* (see *inform*). Meaning "knowledge communicated" is from circa 1450. Short form info is attested from 1906. Info-mercial and info-tainment are from 1983.

Pirate: 1254, from Old French *pirate*, from Latin *pirata* "sailor, sea robber," from Greek *peirates* "brigand, pirate," literally "one who attacks," from *peiran* "to attack, make a hostile attempt on, try," from *peira* "trial, an attempt, attack,". Meaning "one who takes another's work without permission" first recorded 1701; sense of "unlicensed radio broadcaster" is from 1913. The verb "to pirate" and "piracy - the act of pirating" is first recorded 1574.

Digit: 1398, from Latin *digitus* "finger or toe," related to *dicere* "tell, say, point out" (see *diction*). Numerical sense is because numerals under ten were counted on fingers. *Digital* (1656) is first recorded 1945 in reference to computers, 1960 of recording or broadcasting.

Print: circa 1300, "impression, mark," from Old French *preinte* "impression," proper feminine past participle of *preindre* "to press," from Latin *premere*. Sense of "picture or design from a block or plate" is first attested 1662. Meaning "piece of printed cloth" is from 1756. The verb is circa 1384, "to impress with a seal or die;" the sense of "produce a book" (1511) is from earlier *imprint*. The meaning "to record (someone's) fingerprints" is from 1952.

Copy: circa 1330, from Old French *copie*, from Middle Latin *copia* "reproduction, transcript," from Latin *copia* "plenty, means" (see *copious*). Originally "written transcript," sense extended 15th century to any specimen of writing (especially MS for a printer) and any reproduction or imitation. The verb, in the figurative sense of "to imitate" is attested from 1647. Copyright is 1735.

OLED

5.7.1 Protection of "Soft Information"

In this chapter so far we have examined protections offered for design inventions and innovation inventions. In most cases of intellectual property, where engineering expertise is called upon to support litigation, the most common form of *"intellectual property"* is likely to be *"hardware"*, or some form of artefact. Litigations concerning inventions contained in information stored digitally, music, video and computer programs, have become increasingly common since the advent of internet and fast data communications. Digitally stored information is commonly referred to as *"soft information"*, in contrast to *"hard information"* stored on paper or in hardware.

Written information contained in books, on film or on analogue recordings, have always had the protection of copyright. Due to the ease of transmission available for digitally stored information, soft information is much more difficult to protect.

The University of Maryland's James Clark School of Engineering offers:[5.13]

> *"With the development of the Internet and multimedia processing techniques, the protection of multimedia content has become increasingly important. While cryptographic encryption is a powerful tool for access control and confidentiality*

5.13 www.engr.umd.edu/media/pressreleases/pr030706_digital-print.html *protection, the protection usually terminates once the content is delivered and decrypted. The urgent need of the research effort addressing post-delivery protections come from both national security and commercial applications."*

The article goes on:

"A crucial lesson from the 9-11 event is the importance in promoting information sharing among agencies. However, due to the potential conflict of interests, the leak of classified information shared between agencies is not uncommon …

Multimedia forensic mechanism for tracing traitors also has compelling commercial applications, such as by the Hollywood film industry in anti-piracy campaigns. Hollywood is actively seeking technologies whereby each preview copy of a new movie is individually and invisibly labelled prior to sending to Oscar voting members to prevent the leak to the market. …

'Digital Fingerprinting' is an emerging technology to protect multimedia from unauthorized redistribution. It embeds a unique ID into each user's copy, which can be extracted to help identify culprits when an unauthorized leak is found. A powerful, cost-effective attack is the collusion attack from a group of users, where the users combine their copies of the same content but with different fingerprints to generate a new version. If designed improperly, the fingerprints can be attenuated or even removed by the collusion attack."

The Faculty of Engineering went on to announce:

"Researchers have demonstrated a new forensics technology designed to help catch cyber thieves and digital pirates. The digital fingerprinting technology, which was developed by academics at the University of Maryland's A. James Clark School of Engineering, is designed to help protect digital assets and identify national security leak sources."

In an article in Forbes Magazine, dated 13 December 2004, Daniel Lyons wrote:[5.14]

"Inside the alarming pileup of business data is an even more alarming trend: The fastest-growing stockpile is made up of so-called unstructured data– e-mails, electronic checks, X rays and the like – that can't be stored in tidy rows and columns like traditional database information.

This messy stuff is growing 90% per year, versus 50% for traditional structured information, says market researcher Enterprise Strategy. And it's fueling fast growth for specialized products designed to find files in massive archives. One of those products is Centera, a box that storage leader EMC introduced in 2002. So far, says EMC, it has sold combined Centera capacity of 30 petabytes (30 quadrillion bytes) to more than 1,000 customers, making it the fastest-growing product in EMC's history.

Centera keeps track of unstructured files by giving each X ray or photo image its own 27-character digital fingerprint, which is stored in an index. EMC likens the digital fingerprint to a claim check that can be used to retrieve a file

5.14 www.forbes.com/business/forbes/2004/1213/110sidebar.html *and says the technique makes for speedy file searches. EMC says that in archives that can hold hundreds of millions of objects, where traditional computer systems might need days to find an object, Centera can accomplish the task in mere seconds."*

The truly alarming aspect of the growth of *"soft"* data storage is the technology used to access this information at very high speeds. Protecting this information in a climate of such high-speed access has driven the development of more and more sophisticated data protection technology. The first line of defence in this process is encryption. There are many encryption programs from very simple substitution codes to complicated use of *"one-time pads"* Wikipedia offers the following historical account of the one-time pad:[5.15]

"The history of the one-time pad is marked by four separate but closely related discoveries.

The first one-time pad system was electrical. In 1917, Gilbert Vernam (of AT&T) invented and later patented (U.S. Patent 1,310,719) a cipher based on teletype machine technology. Each character in a message was electrically combined with a character on a paper tape key. Captain Joseph Mauborgne (then a captain in the United States Army and later chief of the Signal Corps) recognized that the character sequence on the key tape could be completely random and that, if so, cryptanalysis would be more difficult. Together they invented the first one-time tape system.

The second development was the paper pad system. Diplomats had long used codes and ciphers for confidentiality and to minimize telegraph costs. For the codes, words and phrases were converted to groups of numbers (typically 4 or 5 digits) using a dictionary-like codebook. For added security, secret numbers could be combined with (usually modular addition) each code group before transmission, with the secret numbers being changed periodically (this was called superencryption). In the early 1920s, three German cryptographers, Werner Kunze, Rudolf Schauffler and Erich Langlotz, who were involved in breaking such systems, realized that they could never be broken if a separate randomly chosen additive number was used for every code group. They had duplicate paper pads printed up with lines of random number groups. Each page had a serial number and eight lines. Each line had six 5-digit numbers. A page would be used as a work sheet to encode a message and then destroyed. The serial number of the page would be sent with the encoded message. The recipient would reverse the procedure and then destroy his copy of the page. The German foreign office put this system into operation by 1923.

A separate notion was the use of a one-time pad of letters to encode plaintext directly as in the example below. Leo Marks describes inventing such a system for the British Special Operations Executive during World War II, though he suspected at the time that it was already known in the highly compartmentalized world of cryptography, as for instance at Bletchley Park. The final discov-

5.15 http://en.wikipedia.org/wiki/One-time_pad.

ery was by Claude Shannon in the 1940s who recognized and proved the theoretical significance of the one-time pad system."[5.16]

In the wake of these developments new terminology has invaded our language. Terms like *"information superhighway"* to denote the National Information Infrastructure in the US, *"cyberspace"*, to denote anything recorded and available on the web or on the information superhighway, *"ijacking"*, the theft or fraudulent use of personal identity information and *"cybertheft"*, to denote the use of information, often gleaned from cyberspace, without permission. This type of new terminology develops where the subject of the term is increasingly commonly encountered. Typically *"phoneslaughter"* is now an accepted new term for fatal injuries caused by vehicle drivers engaged with a mobile phone.[5.17]

It is yet unclear whether courts of law will accept such terminology as shorthand descriptors of events in copyright infringement. However, expert advisors in copyright litigation should make themselves aware of the terminology and what they denote.

5.7.2 The Expert's Role in Litigation Involving Cybercrime

Support for cybercrime litigation may involve technical expertise on many levels. Expertise in the technical issues of *information technology* (*IT*) is probably the most common type of support sought by litigators. However, because cybercrime is an emerging and constantly changing field of illegal endeavour, it is important that the IT expert be aware of the laws and protection offered for information in cyberspace.

The nature of information in cyberspace can be the initial stumbling block to the provision of IT expertise. Information may be in the form of text (articles, books and presentations), still or moving images (artwork, pictures or video), or sounds (music, talking books and training or learning programmes). IT expertise in each specific medium may require different forms of protection and copyright laws to manage the dispute encountered. However, there are some generic issues that might be addressed by the IT expert.

In an early article on cybercrime litigation Jeffrey Briggs, an intellectual property and patent litigator, wrote:[5.18]

"US copyright protection extends to original creations capable of being 'fixed' in a tangible medium. It also reserves to the copyright owner the exclusive right to make 'derivative' works from the original creation, to "perform" works such as musical compositions, and to 'publicly display' works such as motion pictures. Thus, copyright law is not limited to written works or drawings, but extends to musical performances, choreography and to computer software.

5.16 See Kahn (1967), Shannon (1949), Marks (1998).

5.17 Ackerman and Heinzerling (2004).

5.18 Briggs (1997).

Years of struggling with the application of copyright law to computer software have led the courts to develop new definitions of 'copying' that can include simply loading a program onto a computer. Now the courts are facing the consequences of those rulings as they examine the implications of millions of computer users accessing and transmitting what might be copyrighted information over the Internet.

Businesses need to worry about copyright liability in the computer age more than ever before. 'Desktop publishing' in 'multimedia' formats that can include text, still photos, drawings,motion pictures, and audio (including music created by others) all implicate copyright issues. Sharing information electronically with every computer user in the world, rather than merely a select group of inquiring customers, decreases the ability to distinguish unauthorized from authorized copying of someone else's expression. Even businesses not using computers themselves are doing business with those who use them and – the Internet – extensively, raising the possibility that their expression will be put into the stream of commerce over the Internet without their even knowing it. Interactive features that allow one to manipulate and transform images created by others also raise copyright questions. And copyright infringement can result in criminal as well as civil liability."

This article, written at virtually the "dawn" of cybercrime, illustrates the general concerns facing IP litigators. As a cautionary note the article goes on:

"Although there has been a great deal of publicity about 'on-air' theft of cellular phone numbers and similar 'cybercrime' stories, the true pervasiveness of 'electronic eavesdropping' is, in fact,greatly underappreciated. The fact is that no Information Superhighway 'vehicle' is secure from unauthorized access or manipulation.

Computer virus inhibitors, e-mail encryption, and 'firewalls' between one's own local area network and another's provide an adequate level of protection for routine company communications, at least as compared to the cost of more sophisticated protection devices. Policies respecting employee Internet use can add another layer of protection. Most 'electronic break-ins,' however, are made possible more by manipulation of human behavior (what computer 'hackers' call 'social engineering') than by new or sophisticated technology.

Thus, it is more important than ever that every company audit its confidentiality procedures with respect to sensitive information on a regular basis."

It is this key issue, identified in this last paragraph, that the IT experts should be capable of tackling. Security audits need the specialist expertise involved in IT security measures (for example, digital fingerprinting). This is the specialist area where the IT expert and litigator might best complement each other.

This very brief introduction to IT security provides only a glimpse of the vast forensic and legal minefield that has resulted from the development of cyberspace, and cybercrime. Although the information available on IT security is vast, on the plus side, most of it is available as *"soft"* information. A brief search of the "Science Direct" electronic database yielded several hundred articles on IT security and IT security auditing. A small selection of this type of information is provided in a special section devoted to IT security in the bibliography.

5.8 Chapter Summary

In this chapter the following issues were examined:

1. The nature of intellectual property;
2. Types of patents: design and innovation;
3. The patenting process and what is patentable;
4. Four cases of intellectual property litigation.

The chapter concluded with a brief overview of copyright protection for information in cyberspace.

6

Case Examples of Fraud and Crime

There is no kind of dishonesty into which otherwise good people more easily and frequently fall than that of defrauding the government.
Benjamin Franklin

Insurance: 1553, "engagement to marry," a variant of *ensurance* (see *ensure*). Commercial sense of "security against loss or death in exchange for payment" is from 1651. Assurance was the older term for this (late 16c.).

Underwrite: circa 1430, loan-translation of Latin *subscribere*. Used literally at first; modern sense of "to accept the risk of insurance" (1622) is from notion of signing a marine insurance policy. Meaning "to support by a guarantee of money" is recorded from 1890.

Liable: 1542, "bound or obliged by law," from Anglo-French liable, from Old French lier "to bind," from Latin ligare "to bind, to tie." General sense of "exposed to" (something undesirable) is from 1593. Liability "condition of being liable" is from 1794; meaning "thing for which one is liable" is first attested 1842.

Fraud: "criminal deception," 1345, from Old French *fraude*, from Latin *fraudem* (nominative of *fraus*) "deceit, injury." The noun meaning "impostor, humbug" is attested from 1850.

Crime: circa 1250, from Old French *crimne*, from Latin *crimen* (genative of *criminis*) "charge, indictment, offense," from *cernere* "to decide, to sift". Crime wave first attested 1920 (in headline in the "Times" of London).

OLED

This chapter is about litigation involving fraud and crime. In three cases reviewed the fraud element involves purposeful deception attempted against insurance underwriters. Only one case is concerned with established crime. Dishonesty against government (as advised by the quote from Benjamin Franklin) is very common even among *"otherwise good people"*. The US *"Coalition Against Insurance Fraud"* is a national advocacy organisation of consumer groups, public interest organisations, government agencies and insurers.[6.1] The Coalition's resource centre provides information about the latest law relating to insurance fraud, as well as an interesting annual compilation of the *"hall of shame"* for insurance fraud offenders. The home page of the Coalition notes that:

6.1 www.insurancefraud.org.

"Insurance fraud is an $80-billion crime wave. It's driving up everyone's insurance prices."

Apart from *Case 6.3*, for the cases reviewed in this chapter, insurance fraud was at the heart of the deception involved. Only *Case 6.4* was focused on falsely profiting from liability insurance. In *Case 6.2* and *Case 6.6* the deception was intended to devolve compensation payment from one insurer to several other insurers in an attempt to *"load shed"*. *Case 6.6* is an example of how to thoroughly bungle allegations of insurance fraud. This last case is presented mostly as a cautionary tale of covert suspicion, coupled with incompetence in getting the facts right.

6.1 The Cases

A Gardening Disaster Blows out the Power in the Whole District – A small time gardening contractor was hired to lop a tree growing near a 22 kV power line. One branch of the tree fell across the power line, shorting it out and causing damage to electrical appliances in 200 nearby residences. In the subsequent dispute the public liability underwriter of the gardener was sued for damages by the electricity generating authority. Deception was involved in identifying the location and scale of the tree being lopped.

A Screwdriver "Fingerprint" Confirms a Case Against Drug Importer – Drugs were being imported into Australia in the frames of Asian carved bas-relief artwork. The frames were prised open with a screwdriver that left an impression in the frame. The impression was matched to the screwdriver found in the suspect's premises. Expert advice was needed to establish the presence of distinguishable patterns of markings ("fingerprints") on the ends of screwdrivers.

Painter Allegedly Brakes a Leg Due to a Loose Gutter – In this case the painting contractor involved was uninsured. The dispute arose out of unsafe working conditions while fulfiling a painting contract. The deception involved in this case was an attempt by the painter to collect public liability insurance while doing "grace and favour" work for a relative.

Unsound Sound System Burns Alfa Romeo – This case involved an claim against a vehicle insurer when the vehicle was burnt out due to a short traced to sound system wiring. Deception involved the failure to report the presence of a poorly installed sound system in the vehicle.

A Builder is Accused of Stealing Tiles – A large consignment of expensive porcelain floor tiles were missing from a building site. The insurers had a suspicion that the builder may have stolen the tiles. Expert opinion was sought about the veracity of the builder being capable of delivering the tiles to the building site in his stated time frame.

6.2 A Gardening Disaster Blows out the Power in the Whole District

6.2.1 The Case Culture, the Dispute and the Client

Trees and greenery are an accepted and welcome part of the Australian suburban landscape. The State of Victoria is known as *"the Garden State"* because of its large tracts of urban greenery, occasionally referred to as the *"lungs of the city"*. The great freedom to grow large collections of trees on relatively small suburban blocks can bring with it the requisite responsibility of tree maintenance. Arboriculture is the requisite training for garden contractors offering to trim trees of substantial size. Most responsible garden contractors carry public liability insurance. However, this type of insurance cover does not release the contractor from the required duty of care when managing large trees.

Garibaldi's garden service provided tree management services in the leafy North Eastern suburbs of Melbourne in 1997. Sometime in April 1997, *Paulo Garibaldi*, the son of the proprietor, was called out to number 72 Warburton St., Doncaster to lop a tree whose branches were beginning to make incursion into the nominal exclusion zone around power supply and telephone cables passing near the property in question. The proprietor of 72 Warburton St., *Mr. Peter Parker*, contracted Paulo to lop a tree (the *Tree*)in his front yard. It was later alleged that during the lopping process, one of the branches fell across the 22 kV power line running across the nature strip outside 72 Warburton St. The resulting short circuit caused damage to electrical appliances in about 200 houses supplied by the main power transformer serving Warburton St. In the initial investigation by the insurance loss assessors it was estimated that the total cost of claims resulting from this accident event would exceed AU$ 1 million.

The insurance underwriters for Garibaldi's public liability policy were *Larson, Entwisthle and Pettyfoger* (*LEP*) and a specific exception in their insurance policy contained an exclusion that

"It is noted that this policy does not cover tree lopping over 3 metre in height."

My appointment to this case came through the company of *Biddleton, Less and Nevins* (*BLN*), lawyers for LEP. I was asked to offer opinion about whether the branch of the tree being lopped by Garibaldi was in fact more than 3 m in height above the ground. Upon reading the brief and the relevant section of the LEP insurance policy, namely the exclusion, I formed the opinion that the exclusion could be interpreted in two different ways. One interpretation could infer that the cutting point should be less than 3 m above the ground. The other, possibly more likely interpretation, would infer that the uppermost tip of the tree branch being lopped should not be more than 3 m above the ground.

By the time I became involved in this case, the tree of concern had been cut down and the ground in which it stood had been rotary hoed. One might speculate on the reason for these actions, but my conjecture is that the proprietor (Parker) may have been concerned about being sued for damages over the matter of contracting Garibaldi and not checking his public liability credentials. In any case, Garibaldi would be regarded as a *"man of straw"*[6.2] where financial recovery for damages were concerned. Consequently, compensation for the loss created by the tree lopping may well be charged to the householder's public liability cover of Parker, if he had any such cover. Alternatively, and this may have been an even more worrying possibility, compensation may have been sought from Parker's estate directly. There appeared to be an element of negligence in the whole tree lopping exercise by both Parker and Garibaldi.

On 19 May 1997 I attended the site in the company of *Stanley Dover*, acting for *Nehru Services, Loss Assessors*, to carry out a survey of the site. The purpose of the survey was to establish, as far as practicable, the scale of the subject tree, the heights at which the subject tree was being lopped and some credible scenario for the accident event. I had been supplied with the following documents and information:

1. *Letter of Commission* – A letter of commission from BLN requesting the investigation on behalf of their clients LEP, including Garibaldi's public liability insurance claim form, dated 17 April 1997. Also included was a copy of the special exclusion clause in Garibaldi's public liability insurance policy.
2. *The Nehru Report* – Initial evaluation of the loss, dated 22 April 1997, signed by Stan Dover in which he advises that the loss could easily escalate to over AU$ 1 million.
3. *The United Energy Suit* – A letter of intent of claim against Garibaldi Garden Services from United Energy, dated 16 April 1997. In this letter they advise that United Energy intends to recover any claims against it by householders whose property may have been damaged by the short circuit caused through Garibaldi's tree lopping.
4. *The Dover Photos* – Colour photographs taken by Dover during his initial assessment immediately following the accident event.

This matter became a dispute between Garibaldi's underwriters and the insurers of United Energy. Key elements of the dispute were the determination of the party or parties responsible for the short circuit and the possible enforcement of the exclusion clause in Garibaldi's insurance. One could have attempted a scaling of the tree and its branches from the Dover photos. However, foreshortening and other scaling issues would have made this approach far too error prone to be useful in a court proceedings. Consequently, I chose to adopt basic surveying procedures to estimate the most credible accident scenario. Having cleared this approach with my clients BLN, the following pages describe the process used and its results.

6.2 Man of straw, *"imaginary opponent"* is recorded from 1624. The term refers to a person who is *"hollow"* or *"empty"* with respect to the substance of the argument or dispute.

6.2.2 The Investigation

Paul Garibaldi was asked by LEP Insurers to identify the location of the tree he was lopping (see Figure 6.1). To provide a survey datum reference, Stanley Dover was photographed with a 4 m surveyor's staff in the location identified by Garibaldi (see Figure 6.2). The staff is held vertical with the aid of a plumb gauge in Dover's hand (not easy to see in the photo). Figures 6.3 and 6.4 are views of the site at 72 Warburton St. just after the accident. These figures are taken from the Dover photos. As may be observed from Figure 6.4 the tree that had been lopped by Garibaldi appears substantially reduced in scale compared to the other trees sur-

Figure 6.1 Paul Garibaldi idenfiying the location of the tree

Figure 6.2 Stan Dover at tree location with a 4 m surveyor's staff

Figure 6.3 Lopped tree just after the accident, from Dover photo

Figure 6.4 Lopped tree and surrounds from opposite side of street, from Dover photo

rounding it. This scale reduction is mostly a result of the lopping performed by Garibaldi, but partly due to photographic illusion. In the photograph of Figure 6.3 there is shown another, somewhat larger, tree just west of the tree identified by Garibaldi as the tree that had caused the accident. This second tree, seen in the photograph of Figure 6.3, also appears to have been trimmed. However, as there was no data available about this tree or its

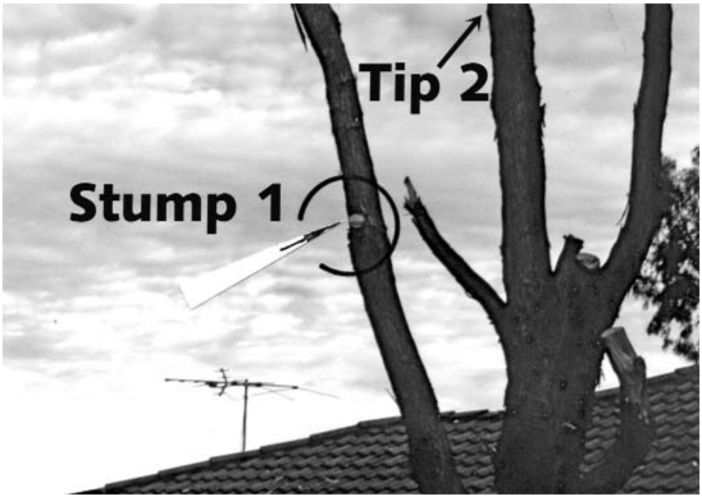


Figure 6.5 Lopped tree after the accident. The lower arrow shows the stump identified by Garibaldi as the stump (Stump 1) from which the branch causing th accident was cut. The upper arrow indicates the tip (identified as Tip 2) of the middle branch of the tree

Figure 6.6 Photo taken from same location from which Figure 6.5 was taken

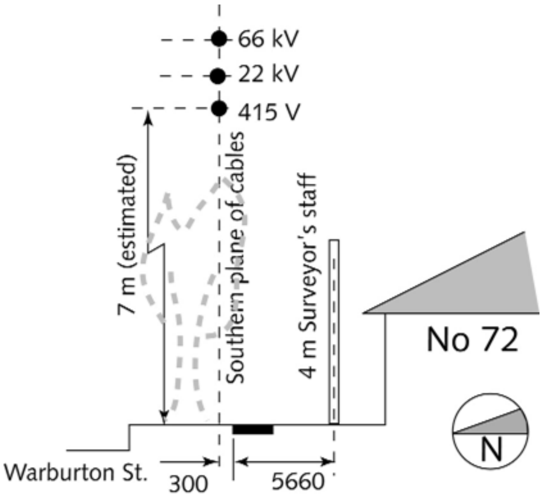


Figure 6.7 Elevation schematic for No. 72 Warburton St. indicating the various reference locations used in the survey (unless otherwise noted, all dimensions are mm, not to scale)

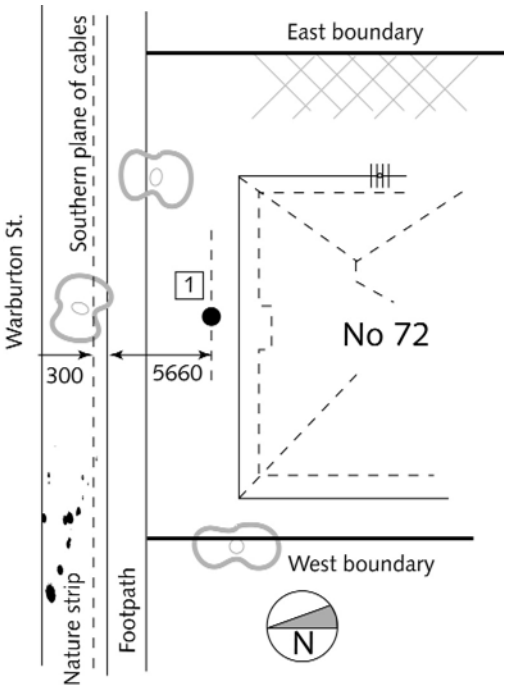


Figure 6.8 Plan view schematic for No. 72 Warburton St. indicating the reference locations of the tree (1) and the southern plane of cables (all dimensions are mm, not to scale)

participation in the accident, this investigation made no further reference to its existence. Figure 6.5 shows the lopped tree just after the accident. The arrow identifies *Stump 1*, the stump identified by Garibaldi as the one from which he allegedly cut the offending branch.

The photograph in Figure 6.6 was taken from the same location and aspect from which the Photo in Figure 6.5 was taken by Dover. Figures 6.7 and 6.8 are elevation and plan schematics of 72 Warburton St. The schematics identify the main items of interest investigated in the survey. In addition, survey reference points are identified in Figure 6.9 and they are:

1. Western eaves corner.
2. Eastern eaves corner.
3. Cut tree stump (Stump 1) location (see photograph in Figure 6.5).
4. Eastern roof ridge point.
5. Tip of TV antenna.
6. Tip 2 on the middle branch of the lopped tree (see photograph in Figure 6.5).
7. Power cable locations above tree on nature strip outside 72 Warburton St.

The Survey

Lines of sight were taken using a Sokkisha theodolite type DT20E, serial number 49854. Figure 6.10 shows schematically the survey sighting arrangement for Survey location 1. Wherever possible, elevations were

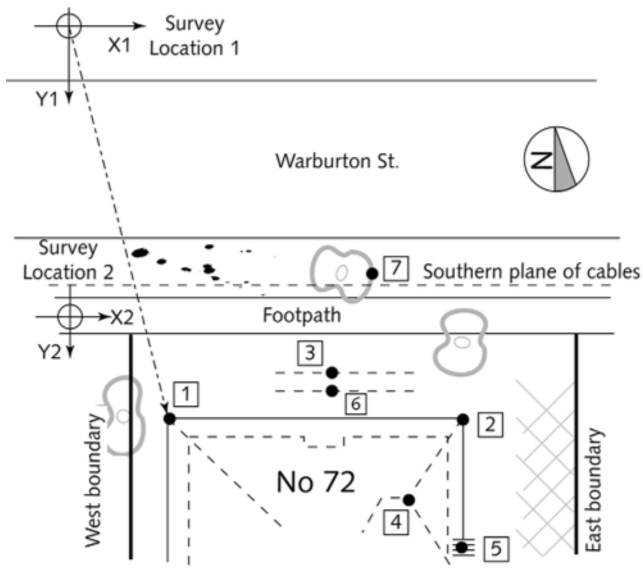


Figure 6.9 Plan view schematic for No. 72 Warburton St. identifying the various reference locations used in the survey

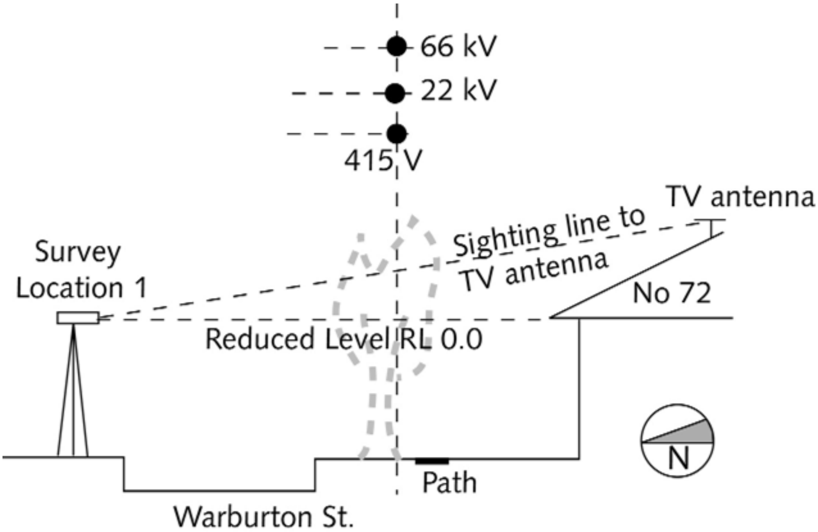


Figure 6.10 Elevation schematic showing a typical survey sighting taken from Survey location 1

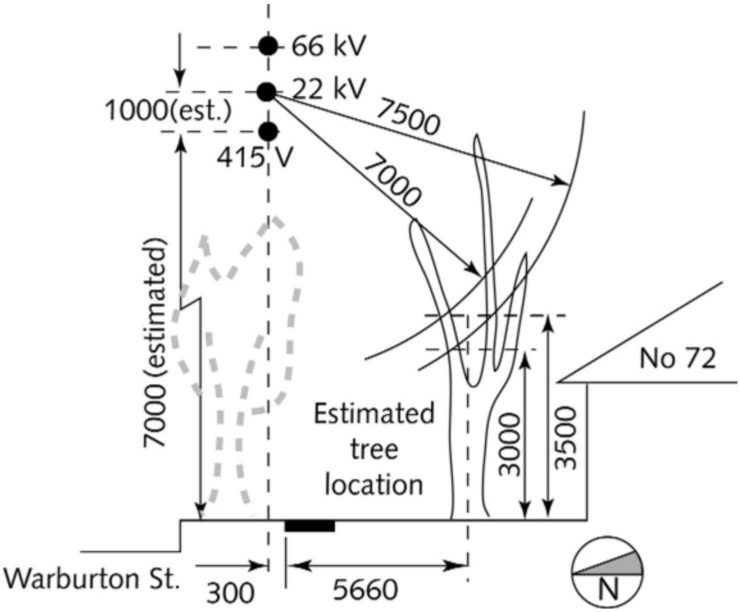


Figure 6.11 Elevation schematic showing the two trimming cut locations investigated in the survey. The lower cut is the one identified by Garibaldi and the higher one is a cut on an alternative branch (refer to the photo in Figure 6.5, all dimensions are mm, not to scale)

Figure 6.12 Spark-eroded section of 22 kV cable. Photo taken throiugh theodolite telescope

measured using a standard surveyor's 4 m staff (see Figure 6.6). The vertical height of each target was either measured by the surveyor's staff or calculated from their vertical angular elevation as measured by the theodolite. All significant target height measurements were reduced to a reference plane through the base of the tree at its alleged location. This reduction involved the addition of the survey reduced level (2300) plus the drop in ground level between the location of target 1 and the base of the tree (measured as 380 mm). I estimated the ground to be relatively level in the north-south direction at the estimated tree location. Hence, all levels calculated

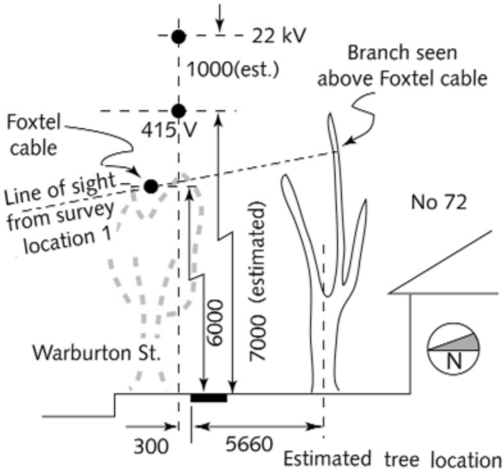


Figure 6.13 Line-of-sight schematic showing the tree branch above the Foxtel communication cable

Figure 6.14 Power cables outside 72 Warburton St. A = 415 V; B = 22 kV; C = 66 kV

Table 6.1 Key target locations

Target	Description	Elevation from reference plane (mm)
5	Tip of TV antenna	4292
4	Eastern roof ridge point	3733
7(a)	415 V cable reduced horizontally to 22 kV cable spark-eroded location	7393
7(b)	22 kV cable at spark-eroded location	8380
6(a)	Eastern roof ridge point reduced horizontally to Stump 1(see photo in Figure 6.5)	3520
6(b)	Tip of TV antenna reduced horizontally to Stump 1(see photo in Figure 6.5)	3887

from survey data have 2300+380 = 2680 mm added to them in order to reduce the measurements to the same reference plane. Horizontal distances were measured with a surveyor's 100 m steel tape. Spark-erosion of the 22 kV cable (shown in the photograph of Figure 6.12) suggests that it was involved in the accidental short circuit of April 1997. Figure 6.13 is an elevation schematic and Figure 6.14 is a photo outside 72 Warburton St., both figures showing the power cables well above the tree on the nature strip.

Table 6.1 shows the key target elevations measured or calculated from the survey. As noted earlier, all measurements were reduced to the same horizontal reference plane. In addition, two of the measurements were also transposed to the same location in the vertical plane.

Discussion of Survey Results

The roof gable line (level with target 4) and the tip of the TV antenna (target 5) provide clearly identifiable locations relative to which one can estimate the height of the limb stump of the tree (Stump 1 in Figure 6.5). Referring to Figure 6.5, it is noted that the photograph shows Stump 1 to appear to be almost level with the tip of the TV antenna (target 5), and certainly above the eastern roof ridge point (target 4). In addition, it may be noted from the same photograph that Stump 1 appears to be just slightly to the east of survey target 4.

Based on these observations it was conjectured that Stump 1 was at an elevation of between 3520 and 3887 mm. Bearing in mind that the base of the tree was approximately 300 mm above the reduced level of the survey, it was estimated that Garibaldi cut the limb of the tree from Stump 1 at an elevation between 3300 to 3500 mm above ground level.

Figure 6.11 is a conjectured arrangement of the tree being lopped by Garibaldi during the accident. The diagram is intended to demonstrate the lengths of tree branches required to enable them to touch the 22 kV cable. This diagram also confirms the estimation that Garibaldi was indeed lopping at heights outside the limits of his insurace policy.

6.2.3 The Outcome and Lessons Learnt

Several issues complicated a conclusive evaluation of this accident. First of all, there was no clear description of what actually took place at the time of the accident. Secondly, I was unable to inspect the subject tree, either standing or cut down. Thirdly, Garibaldi was ordered by LEP (his insurers) to identify the location of the tree before it was cut down. Therefore the location of the subject tree was, at best, uncertain. This uncertainty was due partly to the fact that there had been an attempt to remove the tree roots prior to my inspection. In addition, considering the apparent deceptive behaviour of both Parker (the proprietor of 72 Warburton St.) and Garibaldi, there was no reason to suspect complete honesty in the identification of the tree location during my inspection. Based only on the evidence available to me, I conjectured the following scenario for the accident:

> Garibaldi and helper were lopping the eucalypt (the subject tree) at 72 Warburton St. In the lopping process, preceding the felling of the tree, the higher branches with leafy growth were being removed. Some of these leafy branches were relatively light and short (less than 2 to 3 m in length). The type of leafy branch I refer to may be seen in Figure 6.4, which shows another, unlopped, eucalypt tree on the property (arbitrarily called *reference tree*), which was more than likely similar to the subject tree in size and growth. This reference tree is seen further to the east from the subject tree in Figure 6.4. At some point in the lopping process a long branch was encountered. This branch was most likely growing from the end of the limb on which Garibaldi identified Stump 1.
>
> The limb being cut was probably secured with ropes to prevent it from falling in the wrong place. Unfortunately, Garibaldi underestimated the length of this branch and its relative position to the power supply cables. As the branch fell, its leafy ends brushed against the 22 kV and 415 V power supply cables causing a short circuit.

Several items of evidence support this constructed scenario. There was no continued break in the power supply, hence, following the short circuit, it was not necessary to repair any damaged cables. Consequently one must presume that the cut branch only brushed against, or at worst, lightly touched the wires, rather than falling on them, as there was no structural damage sustained by the cables.

A close examination of the photograph in Figure 6.5 indicates that Stump 1 was no more than 100 mm in diameter. Moreover, the direction of cut of Stump 1 suggests that this branch was actually growing somewhat northwest relative to the tree location. Although this cut was substantially above 3 m from the reference plane through the base of the tree, it is unlikely to have been the one that caused the accident. It would need to have been approximately 7.5 to 8 m in length to do so.

A more likely branch to have caused the accident is the one cut from the end of the limb on which the Stump 1 is seen. As may be observed in the photograph of Figure 6.5, this limb appears to be significantly larger in diameter than Stump 1. I estimated that it would have been at least twice the diameter of the branch growing from Stump 1. In structural terms this means that it could support approximately eight times more load than the branch cut from Stump 1 could. This larger limb would have been a substantial growth cut at approximately 4.5 to 5 m above ground. Furthermore, an examination of the uppermost end of this branch shows it to be only partially cut, signifying that the branch, when partly cut through, probably broke under its own weight.

Examination of the photograph in Figure 6.3 shows the end of the central branch of the lopped tree to be above the Foxtel communication cable (thick black cable). Based on the angle of view in this photo, I estimated the height of this central branch to be at an elevation greater than 6 m from the ground (refer to Figure 6.13). Whatever the elevation at which the accident causing branch was being cut, Garibaldi had been lopping at heights well above the 3 m limit of his insurance policy.

In the initial report of the loss by Dover, there was a reference to the large ti tree on the nature strip outside 72 Warburton St. In a statement signed by Garibaldi, he claimed that *"most likely"* the branch being cut by him and helper fell onto this ti tree and that a branch of this ti tree had brushed against the high-tension cables, causing the short circuit. The photograph in Figure 6.14 shows that the power supply cables were well above the ti tree on the nature strip. Moreover, I considered this accident scenario, suggested by Garibaldi, to be inconsistent with the observed spark-erosion on the 22 kV cable, That type of short circuit (from the 415 V cable to ground) would not result in the heavy spark erosion seen on the 22 kV cable (refer to Figure 6.12). Finally, I noted that the alleged cut (Stump 1 in Figure 6.5) appeared to be at 3.3 to 3.5 m above ground. However, based on the geometry of the location, I estimated that the height at which the accident causing branch was being cut was more likely at 4.5 to 5.0 m above the ground.

Often with cases like this, when a public utility (United Energy) is being sued by insurers of private householders, the most common resolution is reached by some form of mutually acceptable settlement. There seemed no doubt that suing Garibaldi directly would be a futile financial gesture. In this instance he had clearly worked outside the limitations of his public liability insurance policy. However, because United Energy's insurers and Garibaldi's insurers both distanced themselves from the damage caused by the accident, it was left for householders to recover their losses from their private insurance companies. The major losers in this instance were the general public, because insurers pass on their losses to the public in the form of premium increases.

6.3 A Screwdriver "Fingerprint" Confirms a Case Against Drug Importer

Heroin: from German *Heroin*, coined 1898 as trademark registered by Friedrich Bayer & Co. for their morphine substitute, traditionally from Greek "heros" (see *hero*) because of the euphoric feeling the drug provides. *OLED*

6.3.1 The Case Culture, the Dispute and the Client

"The price of freedom is eternal vigilance", is a quote attributed to Thomas Jefferson, third president of the United States of America. Although referring to a freedom from oppression, the quote certainly applies to the approach taken by border protection authorities in most countries. In Australia, border protection is the domain of the *Australian Customs Service* (*ACS*) in conjunction with the Australian Federal Police. The ACS website provides a lucid description of the nature of *"vigilance"* they provide.[6.3]

> *"The Australian Customs Service manages the security and integrity of the Australian border and assists people and cargo to move in and out of the country.*
>
> *It works to detect and deter the unlawful movement of goods and people across the border. Protecting the Australian community by intercepting illegal goods, such as drugs and weapons, is a high priority.*
>
> *Customs uses sophisticated techniques to target high-risk aircraft, vessels, cargo, postal items and travellers. It employs about 5000 people across Australia and overseas."*

ACS use a wide range of technologies for detecting illegal imports into Australia, including gamma ray backscatter,[6.4] trace particle detection[6.5] and the now internationally acclaimed *sniffer dog*[6.6] programme. Between 2002 and 2005 ACS vigilance in container examination alone uncovered attempts to import illicit drugs with a combined street value of over AU$ 1 billion.

Jason Manchu was an alleged member of a triumvirate of drug importers caught by ACS in 1999 for attempting to import heroin into Australia. One of their methods of transport for the drug was to implant packets of heroin in the frames of large carved bas-relief artwork. On arrival in Australia, the frames of these images would be prised open and the packets of drug would be removed. Once detected by ACS, it was the domain of the Australian Federal Police to inspect the evidence and lay charges against the drug importers.

6.3 www.customs.gov.au.

6.4 Gamma ray backscatter device detects differences in density behind a solid surface.

6.5 Trace-particle detection is based on ion mobility spectrometry and is capable of detecting traces of substances in the low nanogram (10^{-9} gram) range.

6.6 Sniffer dog teams have been trained to find target odours of goods concealed in baggage, parcels, cargo containers, vessels, vehicles, aircraft and on people.

When arraigned in court on the charge, two members of the triumvirate of drug smugglers pleaded guilty as charged, but Jason Manchu chose to maintain his innocence. The only evidence tying Manchu to the drug charge was a screwdriver found in his possession (including fingerprints on the handle). In their inspection of the evidence, the police investigator, *Mark Oleander*, found several indentations in the soft timber frame of one piece of artwork used for transporting the drug. Presumably these indentations were made when the frame was prised open to remove the drug. The indentations contained an imprint of the blade tip of a screwdriver, identified as the one found in Manchu's possession.

The defence attorneys acting for Manchu, *Mostly, Grumpy and Co. Lawyers* (*MGL*), appointed me to investigate the veracity of the police allegations in relation to the screwdriver tying Manchu to the indentations in the wooden frames. For my investigation I was supplied with the following:

1. Transcript of court proceedings relating to evidence given by Mark Oleander, forensic specialist with the Australian Federal Police, evidence pages 2954–2968;
2. Several sets of forensic photographs relating to Oleander's investigation.

Figure 6.15 is a photograph of a Stanley 8 mm screwdriver, type 65-549 (the *"evidence screwdriver"*), that allegedly made the tool marks identified in the photographs of Figures 6.16 to 6.18.

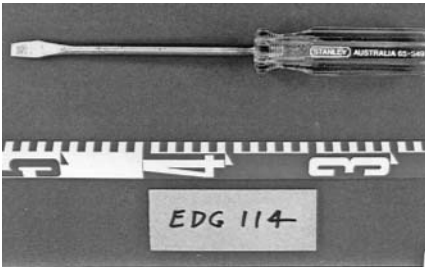


Figure 6.15 Manchu's screwdriver in evidence

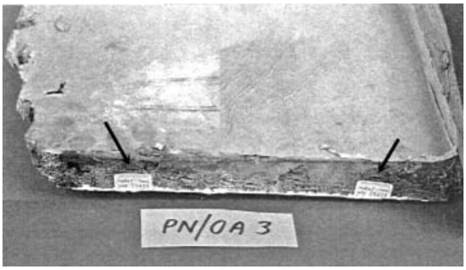


Figure 6.16 Screwdriver impressions in the edge of wooden frame

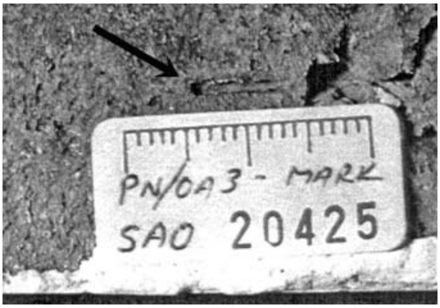


Figure 6.17 Close-up of three impressions (evidence 20425)

Figure 6.18 Close-up of one impression (evidence 20426)

I have been asked to offer opinion about the uniqueness of the markings on the evidence screwdriver, so that it might be identified uniquely as the tool that made these marks in the edge of the wooden frame.

6.3.2 The Investigation

In October 1999 a visit to the Victorian headquarters of the Australian Federal police permitted a direct inspection of the wooden frame in which Manchu had allegedly made the tool marks that tied him to the screwdriver in his possession. The photographs in Figures 6.15 to 6.18 were obtained from the evidence package provided by the Federal police.

In order to fulfil my brief I needed to investigate the following matters:

1. *The screwdriver fingerprint* – Examination was needed to discover if the pattern on the tip of the evidence screwdriver was distinguishable from the tip pattern of other similar screwdrivers.
2. *Tool marks in the evidence timber frame* – Tool marks are regular features of forensic examinations.[6.7] Although the most common application of tool mark examination is associated with firearms, police have made good use of casts for other tools of the criminal trade, including jemmies, knife blades, wire cutters and screwdrivers. Imperfections left on the operating surfaces of these tools lend themselves to identification whenever they leave an imprint (tool mark). The frame in which the evidence screwdriver had allegedly left a tool mark was identified as a soft rain forest timber similar in character to teak.

The Screwdriver Fingerprint

Screwdrivers are produced by a variety of manufacturing methods, depending on the quality of the tool produced. Most common medium- to high-quality screwdrivers are forged from a good-quality tool steel and finished by machining. The evidence screwdriver, a Stanley type 65-549, belongs to this class of tools. A visit to the Victorian branch of the Stanley Company revealed that the tips of these 56-549 screwdrivers are finished by a grinding process. This process imposes a fine but discernible pattern on the tips of these screwdrivers.

Cheaper types of screwdrivers are commonly stamped out from relatively low-quality steel and are finished by some form of cheap surface treatment. In contrast to the 65-549 screwdrivers, these cheaper products have a smooth unpatterned tip.

Figure 6.19 is a photograph of the five 65-549 screwdrivers purchased for this examination. In Figure 6.20 a composite photomicrograph is shown of the tips of these sample screwdrivers. As may be observed in this photograph the tip markings differ markedly between sample screwdrivers. These markings are produced in the final grinding process used on the tips.

6.7 See for example the website of the International Association of Firearm and Tool Mark Examiners, www.afte.org.

Figure 6.19 Sample set of Stanley type 65-549 screwdrivers

Figure 6.20 Blade tip photo micrographs of the sample set of screwdrivers

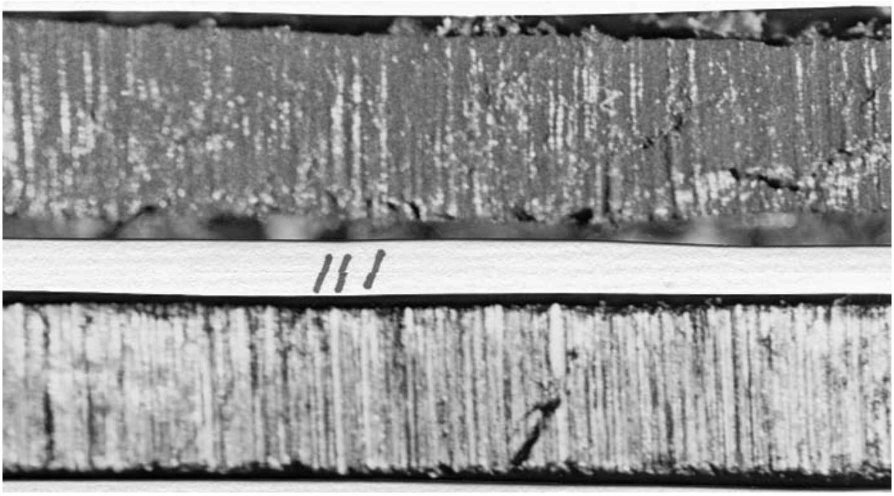


Figure 6.21 Evidence screwdriver tool mark casting impression prepared and photographed by the Author. The three lines in the photograph show corresponding features in the tool and the impression taken from the tool mark

As the grinding particles chip away the material of the tip, fine grooves are produced on the tips. It is the combination of these grooves that form the unique and clearly identifiable *"fingerprint"* for each tip.

Tool Marks in the Evidence Frame

For this part of the investigation it became necessary to prepare a timber sample with a screwdriver tool mark and to examine the result of a tool mark cast. Tool mark casts may be taken with a variety of casting compounds. Dental plaster may be used for larger, coarse markings, such as shoe prints or tyre markings. For fine imprints a special two component

6.8 Kjell Carlsson Innovation,www.carlssoninnovation.com.

casting putty, *Mikrosil*,[6.8] has been developed by Kjell Carlsson Innovation in Sweden. This product has been is designed by criminologists and formulated to give the best rendering of small details, specifically for shallow marks with small details, requiring large magnification.

Figure 6.21 is a photomicrograph of the evidence screwdriver tip and its corresponding tool mark impression, prepared with Mikrosil. Although only three lines of correspondence are identified in the two photographs, the much clearer and accurate police images contained substantially more points of correspondence between the tool mark and the screwdriver tip.

6.3.3 The Outcome and Lessons Learnt

Comparison of the evidence screwdriver blade and its impression (see Figure 6.21) indicates that the tip of the evidence screwdriver will produce tool marks identifiable by the casting method used. Similar casting impressions were observed at the offices of the Federal police during my visit in October 1999.

The photographs in Figures 6.20 and 6.21 were taken through a moderately low-magnification (10x) trinocular microscope suitable for photographing evidence. Even in these photographs there were clearly identifiable features of the tool and the impression taken from its tool mark in a piece of wood. I had no doubt that when examined under an accurate higher magnification comparative microscope, such as that available in the Federal police forensic laboratory, there will be further elements of similarity identifying the impressions in the wooden frame as those made by the evidence screwdriver.

Based on the police evidence and its veracity confirmed by my independent investigation, Manchu was ultimately found guilty as charged and convicted of drug importation. As noted earlier, only the tips of individually packaged high-quality screwdrivers, such as the type 65-549, are finished by a tip grinding process leaving the tool marks that helped to convict Manchu. Similar screwdrivers, sold in economy packs, are not finished in this way. The blade tips of these economy screwdrivers have no specific markings on them, since they are left in the *"as forged"* state. Had Mr. Manchu used a cheaper screwdriver as the tool for opening the picture frames, it would have been substantially more difficult to link him to the crime directly.

6.4 Painter Allegedly Brakes a Leg Due to a Loose Gutter

A verbal contract isn't worth the paper it's written on.
Samuel Goldwyn

Contract: circa 1315, from Latin *contractus*, past participle of *contrahere* "to draw together," metaphorically, "to make a bargain," from *com-* "together" + *trahere* "to draw".

OLED

6.4.1 The Case Culture, the Dispute and the Client

Joseph and Georgina Papageno operated a moderately successful jewellery business in an inner suburb of Melbourne in 1994. Their success was in no small part due to the business acumen of Georgina, who did the buying and general selection of goods sold in their store. In addition to running the household, she was the business and accounts manager for the store. Joseph had often remarked on his good fortune that enabled him to marry a fine woman with such business sense.

On the social side of the ledger, the Papagenos had two nice little daughters doing well at a local school. Joseph and Georgina belonged to a local social club where they were highly respected for their generous and charitable nature. In a sense there was very little to impede complete happiness for the Papageno family. Joseph also had an itinerant, part-time employed, older brother George. George Papageno did odd jobs for building contractors, including painting, external house repairs and the occasional hedge trimming of gardens. He regarded himself as an all-round handyman of many skills. George was also a regular, though not always invited, guest at his much more financially endowed brother's dinner table.

After one of these dinner engagements, later statements revealed, George remarked to Georgina that

> *"…one of your eaves lining seems to be out of line – I will drop in to fix it soon …",*

and Georgina had acceded by

> *"… that sounds OK, any time …".*

Whether this exchange constituted a contract of sorts became a matter for speculation by the subsequent loss assessors for *Comma, Dipthong and Cedilla* (*CDC*), the householder's liability insurers of the Papagenos. Insurers normally advise householders to take out such insurance as a small adjunct to the regular household insurance. Householder's liability insurance is very cheap (of the order of less than 0.1%) and most householders follow this advice.

According to a later statement by Joseph Papageno, he was awakened by a loud noise on the morning of Wednesday, 22 February 1994. This being a day when the shop opened late, Joseph was still in bed, although Georgina had already taken the girls to school. On investigation, Joseph found

George, his older brother, on the ground in the front garden, in evident pain, having apparently fallen from the roof of the Papageno house. A painter's extension ladder lay nearby, also on the ground. This was the ladder that had been used by George to access the roof. Also apparently, George had broken his tibia in the fall and needed hospital treatment.

More speculation is needed to discover how the ensuing insurance claim had been formulated by George. Perhaps one might also speculate whether there was some collusion between the brothers in the formulation of the claim. Whatever the case, George chose to sue Joseph under public liability. The quantum (the amount of the claim) was not specified, but it was not likely to be more than AU$ 20,000. It is a true testament to the cussedness (steely determination) of public liability insurers for avoiding payouts that CDC chose to fight this claim rather than offer a small, but agreeable, settlement to George.

My briefing attorneys were those regular suppliers of forensic investigations to *Engineering Investigations & Associates* (*EI&A*, the Author's consulting company), *Biddleton Less and Nevins* (*BLN*), lawyers for CDC. A writ had been issued by George Papageno (*plaintiff*) against Joseph and Georgina Papageno (*defendants*) in the County Court of Victoria. Paragraph 4 in the statement of claim, dated May 1996, alleged that:

> *"...the Defendants failed to take reasonable care to see that the Plaintiff would not be injured by reason of the state of the premises or of things done or omitted to be done in relation to the state of the premises.*
>
> ***Particulars***
>
> *(a) Requiring or permitting the Plaintiff to rest the ladder against the guttering when it was unsafe to do so.*
>
> *(b) Failing to give any or any proper warning to the Plaintiff that the state of the guttering was dangerous.*
>
> *(c) Allowing the guttering to remain in an unsafe condition.*
>
> *(d) Failing to assist the Plaintiff in clearing the guttering or in anchoring the ladder whilst the Plaintiff was clearing the guttering.*
>
> *(e) Failing to take all reasonable steps to ensure that the premises were reasonably safe for the Plaintiff.*
>
> *(f) Failing to have or instruct the Plaintiff in relation to a safe system for clearing the guttering.*
>
> *(g) Requiring or permitting the Plaintiff to climb to height of more than 3 metre using the guttering as a support for the ladder.*
>
> *(h) Requesting the Plaintiff to ascend the ladder and rest it against the guttering when it was unsafe to do so."*

Although written in easy-to-follow legal terminology, Particulars (a) to (h) are worthy of a little *"unpacking"*. Particulars (a) and (h) are both about

Figure 6.22 A ladder leaning against the Papgeno house. Note the steep roof above the porch (photo taken in 1997)

Figure 6.23 Ladder leaning against the porch gutter (photo taken in 1997)

Figure 6.24 A ladder leaning against the porch gutter, with a man ascending the roof (photo taken in 1998)

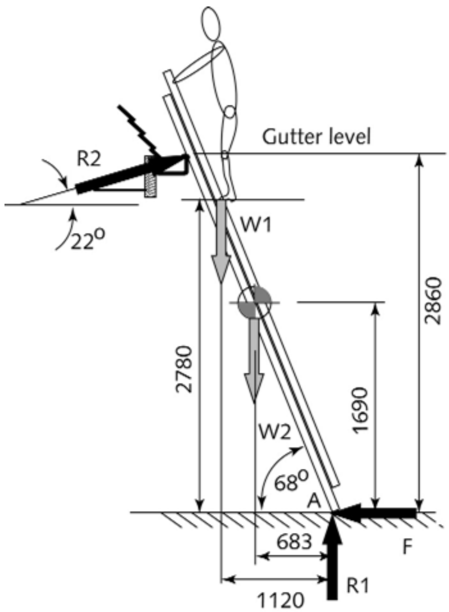


Figure 6.25 Schematic view of the extension ladder against the porch gutter (not to scale)

the unsafe guttering as well as the substance of the alleged contract between the plaintiff (George) and the defendants (Joseph and Georgina). These as well as Particulars (d) and (g) make reference to *"the ladder"*, alleging that the choice of ascending the roof via a ladder was somehow *"the fault of the defendants."*

Particulars (b) and (c) allege that the state of the guttering was *"dangerous"*, and that the defendants failed to warn the plaintiff about this *"state of danger"*.

Particular (d) also makes an implied allegation about the ladder falling or slipping while the plaintiff was involved in ascending or descending it.

Particular (e) is a general allegation about safe premises and Particular (f) alleges that the plaintiff was requested to clean guttering and that the defendants were somehow responsible for the injury suffered by the plaintiff while performing this task.

No doubt, this was a *"scattershot"* approach taken by public liability claim lawyers on behalf of George Papageno, in the fervent hope that some of these allegations might induce CDC to settle the matter. My instructions were to examine the premises of the defendants, including the guttering, and to offer opinion about the *safety* of the gutter as well as any plausible accident scenario. I note, with some amusement, that safety is hardly a term one could apply to guttering. It is a widely accepted design consideration in the building industry that guttering is a means of channelling water from the roof catchment area to the storm water drains. They are designed to support some quantity of water, not ladders or the weight of humans falling off roofs.

No experienced painter or handyman would regard a gutter as a device for anchoring a ladder. In spite of these evidently specious allegations against the defendants it was necessary to examine the guttering and to estimate the nature of loads applied to it during George's ascent.

6.4.2 Investigation Number 1 (1997)

There were two inspections of the site of the Papageno accident. On Saturday, 3 May, 1997, the first inspection, an *Oldfield's Tradesman Up'nup* industrial, dual-purpose ladder was used for ascending the Papegeno roof. Figure 6.22 shows the ladder leaning against the Papageno house, with the third rung from the top just slightly above the gutter over the porch roof. This places the height of the porch roof gutter at approximately 3 m from the ground. Figure 6.23 shows the ladder leaning against the porch roof gutter. This could well have been the configuration of the ladder when the plaintiff fell. On inspecting the gutter in question, I found it to be clean, sound and not loose or defective. Bearing in mind that my inspection took place more than two years after the accident, this situation was hardly surprising.

Having read the various witness statements, the allegations in the writ and reviewing the general condition of the Papegeno house, I had formed the opinion that George (and his attorneys) were somewhat overstating the matter. George, in an expansive mood, after a nice dinner at his brother's place, offered to fix an eaves lining. The nearest eaves lining in the neighbourhood of the porch is at the top of the porch roof. If that lining was being repaired, George had to be at some point well above 4 m from the ground. He may have slipped or fell and on the way down hit his leg against the porch metal railing. Whatever the case, his injuries did not appear to have come from a fall from the ladder leaning against the porch guttering.

6.4.3 Investigation Number 2 (1998)

Once I had completed my report of the first investigation in June 1997, I assumed, on reflection rather naively, that the matter would be settled. Imagine my surprise when about a year later I received a call from my briefing from attorneys, BLN, to investigate the Papgeno matter further. In this brief BLN were very specific about the nature of investigation required. I was asked to offer opinion about the following:

1. *What amount of weight/pressure/force would it take to compress the guttering to make it 'collapse' or 'give way' as alleged by George Papageno (the plaintiff). Would the weight of the ladder the plaintiff was using combined with his own weight be sufficient in your opinion to cause such a collapse. We estimate the plaintiff is approximately 5'10" and weighs about 12 stone.*
2. *Assuming the guttering 'gave way' or 'collapsed' would this be sufficient so as to cause the ladder to slip as alleged?*
3. *Would the guttering move back into its original shape after the incident or would such an incident leave the guttering permanently bent out of shape?*

   3.1 If the guttering would move back into its original shape, would there be any other evidence or sign that the guttering had 'given way' or 'collapsed' as the plaintiff has claimed?

   3.2 What would this 'evidence' or 'sign' be ?

   3.3 Is there any such 'evidence' or 'sign' in/on the guttering?
4. *If the guttering would not move back into its original shape after it was deformed by way of a 'collapse' or 'giving way' as claimed by the plaintiff – does an inspection of the guttering show that it has been permanently bent [out] of its original shape?*
5. *We would like you to re-attend the accident scene with the ACTUAL LADDER USED by the plaintiff and place the ladder in the exact position where the fall occurred. You should then have a person, of the same weight (and approximate height) as the plaintiff climb the ladder and you should inspect the guttering to see if the weight of this person and the ladder causes the guttering to bend, 'give way' or 'collapse' as alleged by the plaintiff (photographs should then be taken).*
6. *You should also test the guttering by forcefully bending it (and if possible meas-*

uring the force required) and then observing as to whether it moves back to its original shape.

7. *We also require your opinion as to, what angle the ladder would need to be leant against the guttering for it to slip out away from the guttering and fall to the ground.*

Well, this was more like it! These very specific questions could be addressed by a technical evaluation with relative ease. Of course, I was perplexed by the time lapse between this second investigtion and my earlier investigation when I had dismissed the case as fatuous. It now seemed that some form of *argy-bargy*[6.9] had taken place between the insurers CDC and George Papageno in establishing the true circumstances of his accident at the Papageno house. This whole process of delayed *"back and forth"* between various advising attorneys is yet another symptom of insurance collection by legal means.

What surprised me about the case was not so much the delay and the revisit of the accident, but the way in which the convoluted allegations were apparently being modified and fine tuned to explain the accident. Then, after some reflection, I formed the opinion that the legal advisors (on both sides) were not so much interested in case veracity as in winning for their client. This latter consideration is a regrettable feature of all adversarial conflict in litigation. Another plausible conjecture was that the Papagenos might have been altering their various accounts of the initiation of the accident. No matter, it was not my task to speculate on the evolution of the case and the caprices of litigation likely to impact on future liability premiums. Never mind the time lapse between the accident and its ensuing litigation and the possible contamination of the evidence during the intervening years, my task was to provide responses to the questions raised by my brief.

Figure 6.24 shows an extension ladder (identical to the one used by the plaintiff) leaning against the porch gutter and a man ascending the ladder with one foot on the roof. I had formed the opinion that this would have been the way the plaintiff may have ascended the roof on the day of the accident. The ladder used was an Oldfield's 6.7 m aluminium extension ladder (unextended), with a maximum permissible load of 1177 N. The ladder weight was 147 N and the coefficient of friction for aluminium on dry concrete was estimated at 0.7. Figure 6.25 is a schematic sketch of the ladder against the porch roof (all measurements were taken with a steel tape measure). The following is an explanation of the symbols used in Figure 6.25:

> *W1* is the weight of the person on the rung just about to ascend the roof, *W2* is the weight of the ladder, *R1* and *R2* are the ground and gutter reactions respectively, *F* is the friction reaction offered by the concrete path to the base of the ladder.

6.9 *Argle*: 1589 "to argue obstinately," from *argue*, perhaps by influence of *haggle*. Reduplicated form *argle-bargle* (sometimes *argy-bargy*) "wrangling" is attested from 1872. *OLED*

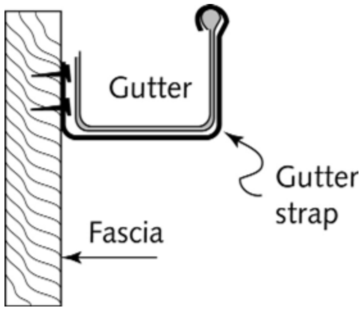


Figure 6.26 Schematic section through the porch gutter at the Papageno house

Figure 6.27 Photo showing the gutter and the locations on the gutter edge where some rubbing and deformation had occurred

Taking moments about the ground contact point A in Figure 6.25, results in the following:

$$(W1 \times 2780 + W2 \times 1690) \cos(68) = R2 \times 2680 / \sin(68), \text{ and}$$

$$W1 = 1177 \text{ N and } W2 = 147 \text{ N, yielding}$$

$$R2 = 456 \text{ N}$$

$$R1 = W1 + W2 - R2 \sin(22) = 1153 \text{ N}$$

$$F = 0.7 \times 1153 = 807 \text{ N}$$

If there is no frictional resistance offered to the ladder slipping at the gutter contact (an idealised conservative assumption) then the ladder will commence to slip when the horizontal component of *R2* is just equal to *F*. It is simple to show that this condition occurs when the angle of the ladder to the ground is about 50°. It is also easy to discover that no self-respecting tradesman would set up a ladder at this shallow angle to the ground. Figure 6.26 is a schematic section through the gutter and fascia at the Papageno residence. Figure 6.27 is a photograph of the gutter showing markings where some heavy object had rubbed the paint from the gutter edge and where some heavy object had deformed the gutter downward. This inspection took place more three years after the accident and there was no indication or evidence to suggest that the guttering was in a condition similar to that when the accident had occurred.

The load on the ladder of a person about the size and weight of George Papageno (see Figure 6.24) failed to deform the gutter in any other than elastic manner. When the ladder was removed, there was no indication or deformation to suggest permanent deformation of he gutter.

As requested by my brief, I applied the load of two persons to the ladder rung just below the gutter line (well in excess of the permitted maximum loading of 1177 N) without any appreciable deformation resulting in the gutter. Had the gutter collapsed under such a load, a most unlikely outcome, the angle of the ladder to the ground would change only marginally (refer to the geometry in Figure 6.25).

6.4.4 The Outcome and Lessons Learnt

Following my second report on this matter CDC insurance were able to dissuade the Papagenos from any further action in the matter. I have already alluded to the *"steely determination"* of public liability insurers to avoid payouts. In this case the investigation was clearly justified. No doubt, my fees and those of my briefing solicitors may well have exceeded the sum for which the Papageno case could have been settled. However, the procedure applied (by both of the disputing parties) was a type of almost no-holds-barred legal stoush. My suspicion of deceptive and collusive behaviour on the parts of the Papagenos may well have been shared by the insurers and their counsel.

6.5 Unsound Sound System Burns Alfa Romeo

Arson: 1680, from Anglo-French *arsoun* (1275), from Old French *arsion*, from Late Latin *arsionem* (nominative of *arsio*) "a burning," from Latin *arsus* past participle of *ardere* "to burn," (see *ardent*). The Old English term was *bærnet*, literally "burning;" Arsonist is from 1864.

Amplify: 1432, "to enlarge or expand," from Middle French *amplifier*, from Latin *amplificare* "to enlarge," from *amplificus* "splendid," from *amplus* "large" + the root of *facere* "make, do" (see *factitious*). Meaning "augment in volume or amount" is from 1580. Specific focus on sound seems to have emerged in the electronic age, circa 1915, in reference to radio technology. The electronic amplifier first attested 1914; shortened form amp is from 1967.

OLED

Converium, an independent international multi-line reinsurer, has a website devoted to public information about insurance fraud.[6.10] They write:

> *"It is estimated that at a minimum 10% of all property and casualty claims contain some element of fraud. The first step in identifying insurance fraud is to recognize some of the common indicators or "red flags". These red flags are facts or circumstances that will require further investigation into the nature of the claim. …The following list is meant to be comprehensive but not exhaustive.*
>
> *Insured is overly aggressive in pursuit of a quick settlement.*
>
> *Insured is unusually knowledgeable regarding insurance terminology and the claims settlement process.*
>
> *Insured handles all business in person, thus avoiding the use of the mail.*
>
> *Insured is willing to accept an inordinately small settlement rather than document all losses.*
>
> *Insured contacts agent to verify coverage or extent of coverage just prior to loss date.*
>
> *Insured is recently separated or divorced.*
>
> *Suspiciously coincidental absence of insured or family at the time of the accident.*

6.10 www.converium.com; see also Morley, et al. (2006); Viaene and Dedene (2004); Crocker and Tennyson (2002); Tennyson and Salsas-Forn (2002); Artis, et al. (2002).

Existence of multiple policies covering the same loss.

Documentation submitted is questionable, e.g., no original documentation available.

If an insurance company disputes the entitlement of an insured to make a claim, then the insured has the onus of proving the circumstances of the loss to establish that the loss falls within the scope of the insurance policy. However, if in its defence to the claim the insurer alleges that it is not obliged to pay the claim because the insured has committed a crime – fraud – then the onus, or the burden of proving the crime, is on the insurer. The onus of proving fraud is very difficult, which partly explains why in practice so few prosecutions for insurance fraud are made.

Although an insurer's claim of fraud is a civil suit, the standard of proof is the criminal standard of proof. Therefore the prosecutors of insurance fraud must prove the case of fraud "beyond all reasonable doubt". That burden has been described in mathematical terms as 90 percent certainty or more, in contrast the usual civil burden of proof, "on the balance of probability", which is 51 percent or more.

Fortunately for insurers there are other ways around the pleading of "fraud" in English law. For example, insurers or reinsurers can defend a claim by putting the claimant to "proof of loss", and challenging that proof. No fraud is alleged, but the result achieved is the same – the non-payment of the claim.

6.5.1 The Case Culture, the Dispute and the Client

Artemis Nero was an ardent automobile enthusiast. His enthusiasm focused on European cars with a particular penchant for Italian makes. He owned several models and in early 1992, Artemis took delivery of a fine red Alfa Romeo, model 33-1.7 litre motor vehicle. Unimpressed with the sound system provided by the manufacturers, Artemis arranged for an after market service to install a *"boom box"* or a substantial amplifier in the trunk of the new vehicle. Later that year, on 22 September, while driving around town, Artemis observed black smoke emanating from the engine compart-

Figure 6.28 An Alfa 33 in the showroom

Figure 6.29 Nero's Alfa 33 after burnout

Figure 6.30 View of the burnt-out engine compartment

Figure 6.31 The burnt-out driver area

Figure 6.32 View into front passenger area

Figure 6.33 View into rear passenger area

Figure 6.34 View into trunk compartment

ment of his Alfa. He and his passenger took flight from the vehicle and sought the help of the local fire department, who attended the vehicle. Unfortunately, by the time the fire truck arrived, the vehicle was well and truly alight and ultimately completely burnt out. Compensation for the vehicle was a matter for basic fire insurance and Artemis was well endowed in that department. However, a routine post-fire examination of the burnt-out vehicle by a *"well-known vehicle expert"*, *Andy Kneebone*, alleged that there may have been some manufacturing fault with the original vehicle. As a further proof of the steely determination of insurers to dispute payouts, Artemis' insurers chose to institute retrograde litigation against the manufacturer of the Alfa and their local agency *Deluca Motors*.

My brief in this case came from my regular suppliers of expert witness action, *Biddleton, Less and Nevins* (*BLN*) acting for their clients *Kangoroo Star Insurance* (*KSI*), who had already paid out Artemis Nero for the burnt-out Alfa. I had a copy of Andy Kneebone's report, which implicated the manufacturers by Andy's assertion that the fire in the Alfa had commenced in the engine bay, in his opinion due to unusually heavy petrol fumes. How Andy could have made this assertion when faced with a completely burnt-out wreck stretches one's imagination. Nevertheless, I decided to inspect the burnt-out vehicle at the wrecker's yard. Figure 6.28 is a photograph of an Alfa 33 in the Deluca showroom and Figure 6.29 is Nero's Alfa in the wrecker's yard.

6.5.2 The Investigation

After consulting an expert in fire fighting, (a member of the workshop staff at the University of Melbourne, who is a volunteer fire fighter with the Country Fire Authority[6.11]) I gained the impression that one could spot the location of the source of a fire from the most violently burnt part of the subject (in this case the Alfa). Figure 6.30 is a view into the burnt-out engine compartment. Figures 6.31 – 6.33 are views of the burnt-out interior of the Alfa. Figure 6.34 is a view into the burnt-out trunk compartment, where the power amplifier was located.

On a cursory inspection of the burnt-out wreck, there appeared no clearly identifiable location for the initiation of the fire. Deluca motors advised that the seat material and the padding of the door panels were all made of flammable materials and in a fire they would be, more or less, extra fuel. The appearance of the passenger compartments confirms this information. It is evident from the photographs that the engine compartment had suffered no greater burn damage than the passenger compartment. This observation made it difficult to support Kneebone's assertion that fuel fumes initiated the burn.

Examination of the front passenger compartment (see Figure 6.32) revealed loose wiring in the passenger side door frame. The insulation of this wiring was heavily charred. The owners identified this wiring as the power wiring for the power amplifier installed in the trunk of the vehicle (see Figure 6.34). In addition, the holes in the metal bulkheads, through which these lead wires passed on their way from the battery section to the trunk compartment, showed jagged edges. As a result of these observations I formed the opinion that a wire loom fire caused the burning of the vehicle. The wire loom is the collection of wires carrying power from the battery through the ignition lock to the various instruments in the dashboard of the vehicle. Once inside the engine compartment, the power amplifier leads would become part of this wire loom. Shorting out these power leads would result in an insulation fire within the wire loom. Moreover, I suggested that the poorly installed power amplifier leads may have initiated the loom fire.

6.11 CFA is one of the world's largest volunteer-based emergency services.

6.5.3 The Outcome

This matter was resolved by Nero's insurers accepting the loss and abandoning any further retrograde litigation against Deluca Motors.

6.6 A Builder is Accused of Stealing Tiles

Tile: Old English *tigele* "roofing shingle," Old High German *ziagal*, German *ziegel*, Dutch *tegel*, Old Norse *tigl*, a borrowing from Latin *tegula* "tile", Italian *tegola*, French *tuile*, from *tegere* "roof, to cover" (see *stegosaurus*). Also used in Old English and early Middle English for "brick," before that word came into use. The verb meaning "to cover with tiles" is recorded from circa 1375.

Steal: Old English *stelan* "to commit a theft."

OLED

6.6.1 The Case Culture, the Dispute and the Client

Porcelain is a hard ceramic substance made by heating kaolinite clay mixed with other refined materials at between 1200 and 1400 degrees Celsius. The toughness, strength and translucence of porcelain arises from the formation of mullite and glass at high temperatures within the clay mineral. Polished porcelain tiling is a preferred form of cladding for bathrooms, kitchens and entry halls of expensive housing developments. One might speculate on the *"sleight of hand"* practised by builders using such shiny surfaces to divert the eye of the observer from the many small faults that often beset large-scale developments. However, it must be admitted that polished porcelain tiling lends a special class of finish to a home.

Amok Builders were middle-level (projects of value below AU$ 10 million) developers of housing units in the inner suburban part of Melbourne in 1995. The project manager and part owner of Amok, *Costa Gavras*, allegedly delivered 280 boxes of porcelain tiles to a building site on or about 5 June 1995. The tiles, approximately AU$ 50,000 in value, were stored in styrene boxes and according to Costa, they were loaded into the Amok on-site storage shed. Later on the same day, Costa attended the building site and found that the storage shed had been breached, its lock broken and the tiles missing. Amok was insured for such matters by *CDC Insurers* and in due course CDC dispatched their loss assessor, *Robin Crusoe*, to inspect the site of the theft.

Crusoe, as befits a loyal contractor to CDC, commenced his assessment by doubting the veracity of Amok in general, and Costa in particular, about the nature and plausibility of the alleged theft. It seemed, according to Crusoe's figuring, a very convenient situation for the builder to have sold the tiles and then claimed their value from insurance, thereby off-setting any building losses he may incur in the development. In any case, Crusoe, together with many people in regular employment, had a healthy distrust

6.12 *Columbo* was a popular TV detective series between 1971 and 1978 featuring Peter Falk as Lieutenant Columbo. See also www.tv.com/columbo.

of all self employed entrepreneurs, such as Costa. As in the television crime series *Columbo*,[6.12] the culprit was already determined, it was only a matter of investigative acumen and time before CDC, guided by Crusoe, could pin the crime on him.

My brief came from my regular attorneys in residence, *Biddleton, Less and Nevins* (*BLN*), acting under instructions from their clients CDC Insurance. As a matter of course, I would not consider a brief without the opportunity to inspect the evidence and the site of the theft, or to interview the various parties involved in the case. However, and here I must accept some responsibility, I reluctantly accepted the instruction to withdraw from any inspections or interviews. This instruction was accompanied by a *"clear"* identification of Gavras' truck, which had carried the allegedly stolen tiles, Crusoe's hypotheses and suspicions about the alleged theft and some instructions about establishing the veracity of Gavras' claims.

6.6.2 The Investigation

Gavras' claim for compensation identified his truck as a *Ford Trader*. I was advised that on 27 May Gavras delivered 280 styrene boxes, filled with porcelain tiles, from 3 Westland Street, St. Albans, to the site of Amok Builders Pty. Ltd. at 330 Mattok Road, Kew. According to Gavras' statement, the delivery was made in a single trip, with a Ford Trader truck, registration number *ERB 333*. Moreover, I was further advised that Gavras unloaded and stacked the boxes of tiles by himself. The truck had been identified as a model *0409t Tipper*, with key properties provided in Table 6.2. There are two sets of properties listed in Table 6.2, one set provided by

Table 6.2 0409t Tipper properties

Property	*Maker's specification*	*BLN brief*
Kerb Mass	*2370 kg*	*1870 kg*
Tray Mass	*850 kg*	*850 kg*
Registered Tare	*2720 kg*	*2720 kg*
Gross Vehicle Mass	*4575 kg*	*4575 kg*
Nominal Payload	*2205 kg*	*2605 kg*
Wheel Base	*2505 mm*	*2515 mm*
Tyres Front	*2 x 750 x 16*	*2 x 750 x 16*
Tyres Rear	*4 x 700 x 16*	*4 x 700 x 16*
Front Axle Load	*2020 kg*	
Front Tyre Load	*2020 kg*	
Rear Axle Load	*3750 kg*	
Rear Tyre Load	*3840 kg*	

my briefing attorneys *BLN* and the other provided by *Ford Customer Advice* when I interviewed their local representative about the nominated model. The slight difference in values may have been a result of model changes since ERB 333 had been registered.

A porcelain tile, similar to that allegedly transported and allegedly stolen, was weighed at 2.65 kg. The specific gravity (S.G.) of porcelain is 2.6 to 2.9. The tiles were measured to be 10 mm thick and 302 mm square. Based on my estimate of the tray size on the ERB 333 truck (3 m x 2 m), there would need to have been two layers of 140 tile boxes (making up the 280 boxes) on the tray. I further estimated that the height of the two layers was approximately 0.61 m. Based on the above estimate of dimensions, the 280 boxes of tiles would have fitted onto the truck in a single load.

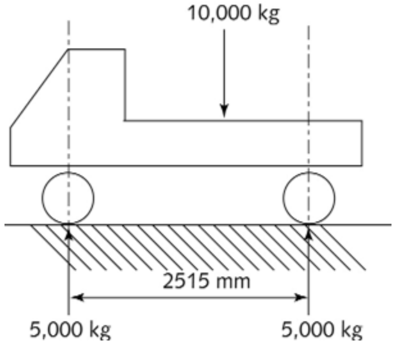


Figure 6.35 Schematic view of the transport truck

Mass of the tile = 2.65 kg, and

280 boxes of 10 tiles each = 2800 x 2.65

= 7420 kg

Adding the tare weight of the ERB 333 truck of 2720 kg, yields:

Total axle loading = 7420 + 2720

= 10,140 kg

Time to Load and Unload

At the time of this investigation in 1995, I had been advised by BLN that, according to Crusoe's statement, Gavras had no special equipment to help with loading and unloading his vehicle. As each box weighed approximately 27 kg, I estimated that the boxes were loaded one at a time by an average human operator. At a loading speed of one minute per box, a reasonable estimate, counting transit time between the shed at the Amok site and the box location on the tray, it would have taken 280 minutes or approximately 4.6 hours to unload the boxes. Even if the loading time were more efficient, involving the use of a hand trolley (for example), the total delivery would have taken the best part of a whole working day.

Load Capacity of the Truck

Referring to the axle loads recommended by *Ford Customer Advice* for the Ford Trader model 0409t Tipper (refer to Table 6.2 and Figure 6.35):

Front axle loads were exceeded by a factor of 5000/2020 = 2.5

Rear axle loads were exceeded by factor of 5000/3750 = 1.3

A factor of 2 is regarded as reasonable for the design of motor vehicle parts. Consequently, the front axle would have exceeded its design limit under such loading. Moreover, the front tyres would be flattened under this load and the vehicle would not be steerable under these conditions. The springs would have bottomed out and each bump on the road could cause irreparable damage to the front axle. It is difficult to estimate the way in which the engine would react to this loading, as such estimates are affected by both the acceleration experienced by the vehicle and the grades it needed to negotiate. Nevertheless, I estimated that the 3.5-litre engine would have had some difficulty coping with such a load and would have suffered particular difficulties when faced with flattened front tyres.

6.6.3 Opinion Offered, the Outcome and Lessons Learnt

From the above calculations and estimates, I was forced to conclude that the Ford Trader model 0409t Tipper could not have been driven with a load of 280 boxes of porcelain tiles weighing 7420 kg.

Based on this conjecture, one could speculate further that two trips may have been required to deliver the tiles to the Amok site. However, Gavras claimed that he delivered the tiles and found them stolen on the same day. Therefore, the time required to load and unload the vehicle would place this claim in serious jeopardy. Having offered this opinion, I presumed, again naively, as it later developed, that the matter would be settled between Amok, Gavras and their insurers. Just how naive this presumption was became revealed to me in the following two years of further *argy-bargy* associated with this case. My first instruction in this matter took place in October 1995. Between then and June 1998 I was asked by *BLN*, no doubt, instructed by their clients CDC, and probably at the behest of eager-beaver Crusoe (Columbo), to submit a total of four reports, all dealing with the same material and evidence uninspected. In truth, I was provided with a single piece of evidence, namely a sample porcelain tile similar to that allegedly stolen from the Amok site. All my reports offered the same doubts expressed about the delivery, unloading and eventual theft on the same day of the tiles.

In 1998 I had the sad and salutary experience of having to swear out an affidavit on this matter. By then I had realised that it doesn't pay to prejudge the, occasionally foolhardy, litigious, behaviour of insurance companies, when resolutely urged on by their loss assessor.

The case was heard in the County Court and the witness for Amok advised that the delivery vehicle was a different model to the one being investigated by eager beaver Crusoe and his retinue of misguided followers. In this instance the case was appropriately dismissed by the presiding judge and, to their added chagrin, CDC were also ordered to pay costs. I had no doubt that the costs were eventually passed on to consumers in the form of increased premiums on building site insurance. Perhaps the most important lesson learnt rom this case was that one can never overstate the importance of checking the facts and inspecting the evidence.

6.7 Chapter Summary

The five cases reviewed in this chapter all involved some form of deceptive behaviour. Some of the deceptions were real and some were in the form of allegations. In all cases the investigation is described in sufficient detail to permit evaluation by others. Important elements of the cases described are:

- Key geometric evidence may be destroyed, but photographs and surveys can still permit the close estimation of the geometry of the case.
- Expensive tools leave more readily identifiable tool marks than do their cheaper equivalents. In addition, tool mark technology is an essential part of all forensic investigations.
- Insurance fraud is very common and in many cases it is easily detected. In addition, there are *"flags"*, identifying features of insurance litigations, that permit early detection of such fraud.
- When asked to investigate and offer opinion in a dispute over property damage or theft, examination of the evidence is mandatory. This is so even when apparently carefully considered reports of other experts are available.

7

Concluding Brief on Expert Witness Reporting and Case Delivery

When I examine myself and my methods of thought, I come to the conclusion that the gift of fantasy has meant more to me than any talent for abstract, positive thinking. Albert Einstein (1879–1955)

Do not condemn the judgement of another because it differs from your own. You may both be wrong. Dandemis 1815–1882 American writer lawyer

Be not too hasty either with praise or blame; speak always as though you were giving evidence before the judgement-seat of the Gods. Seneca (5 BC–65 AD)

Provision of expert evidence is a lifelong learning experience. Each case has its special problem-solving element that provides a challenge to the expert. I would be remiss if I did not admit to finding the reporting process tiresome. In all its glory the final report of an expert is often a dreary document to read. Fortunately by the time the report is published, the exciting chase for clues and the exercise of Holmesian investigative powers is over. Nevertheless the expert must make certain the case is presented to a court in a way that documents the reasoning behind offered opinions in a clear and logical manner. Experts cannot hide behind obscure, arcane or inaccessible logic. Perhaps Miguel de Cervantes stated it most succinctly in his Preface to *Don Quixote*:

> *"Do but take care to express yourself in a plain, easy Manner, in well-chosen, significant and decent Terms, and to give a harmonious and pleasing Turn to your Periods: study to explain your Thoughts, and set them in the truest Light, labouring as much as possible, not to leave them dark nor intricate, but clear and intelligible."*

7.1 A Case Compendium

In the remainder of this concluding chapter a compendium of case material is presented in which only the source of dispute is provided. All these cases result from personal involvement or inquiries from potential clients.

My purpose in offering this compendium is to generate opportunity for discussion and hypothetical evaluation of each case. My intention is that these *"hypotheticals"* should focus on the engineering content of each case.

H1: A machine operator sues his employer for personal injury in the workplace, claiming that some of his tasks and working environments did not meet Occupational Health and Safety (OHS) requirements.[7.1]

The writ alleged that the employee was required to install a large and heavy saw blade in his machine without mechanical assistance and this had resulted in a back injury.

I was briefed by the employer's legal team and asked to investigate. The location of the *"faulty"* workplace was in Sydney, but to save on transport I was shown what the employer claimed to be a *"closely similar"* workplace in the employer's Melbourne factory. On examination, this *"closely similar workplace"* seemed well within the requirements of OHS. Moreover, the machine shown to me in Melbourne could only accommodate saw blades of a size that even a small child could lift without injury.

Question: How to proceed when asked to submit a report?

H2: You are approached by solicitors acting for a bulk milk delivery company, let's call them Marigold Pty. Ltd. Marigold have made a claim in taxation relief for the cost of structural engineering works conducted on their large tanker trailers purchased from Tiemann's. Tiemann is a trailer manufacturer supplying tanker trailers to the transport industry. The Australian Taxation Office (ATO), disputes these claims on the grounds that, in their view, the claimed engineering works were designed to add *"accessories"* to the tanker and therefore subject to normal taxation considerations. You are advised by taxation consultants that the dispute is about the addition of support legs and the structure to support the rear undercarriage. Figure 7.1 shows a typical tanker trailer.

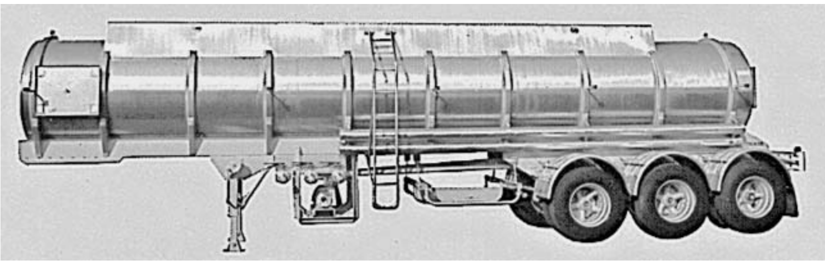


Figure 7.1 Bulk milk tanker trailer

7.1 See: www.nohsc.gov.au

Question: How would you prepare a plea for Marigold in this case?

H3: Seymour Darcy is a wheelchair-bound paraplegic, committed to an active lifestyle, including participation in his local sports club as a wheelchair racer. He has a motorised wheelchair and the chair has had many breakages. In one recent event he was almost killed when his chair collapsed while negotiating an entry ramp to a local railway station. Darcy has sought out your advice in relation to a possible suit against the wheelchair supplier for compensation.

Question: How would you advise Darcy? Would you be able to prepare a case for him in his quest for compensation?

H4: Marlene Gardiner, a 35-year-old beautician, was a keen *"mini-bike"* enthusiast. These very light-motor driven bicycles could be constructed by mounting a lawnmower engine on a bicycle frame. There are various levels of competition involving these machines and Marlene belonged to a local mini-bike sporting club. Her enthusiasm was mostly focused on constructing highly manoeuvrable light machines. One Sunday afternoon, while in the process of deconstructing a weathered lawnmower engine, she was injured by a piece of flying grinding disc. Marlene had several years of machining experience and the grinding disc in question was mounted on a small hand-held angle grinder. She had obtained the disc as part of a bulk purchase from *Heidegger Tool Imports (HTI)*. When the disc in question shattered, Marlene was wearing safety goggles, but, due to the restricted access afforded on the engine she was deconstructing, she had removed the wheel guard from the grinder. The shattered disc caused such severe facial injuries that her livelihood as a beauty consultant was in jeopardy. Marlene complained to HTI about the incident and was advised that

(a) *"you should have been more careful"*, and

(b) *"yes we have had a few of these discs shatter recently"*.

Question: How would you advise Marlene about mounting a case against HTI?

H5: Alex Kostas, an electrical contractor, was injured in a fall at *Mamma Mia's Pasta* (*MMP*) works, while in the process of making repairs to the electrical connections in the ceiling space at MMP. The fall occurred on a Sunday, while the pasta works were shut down. Alex accessed the ceiling space (at approximately 5 m above a concrete floor) by standing on a pallet mounted on the tines of a high-lift forklift truck operated by Pancho Gonzales, the works manager of MMP. In his claims against MMP, Alex alleged that Gonzales had moved the truck while he (Alex) was standing on it, causing Alex to fall to the floor, sustaining substantial injuries.

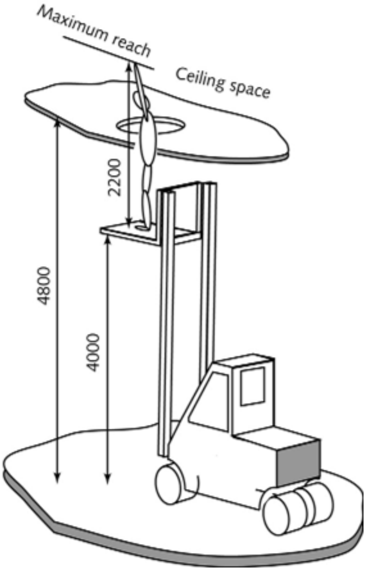


Figure 7.2 Schematic sketch of Kostas on the forklift platform. All dimensions are mm (not to scale)

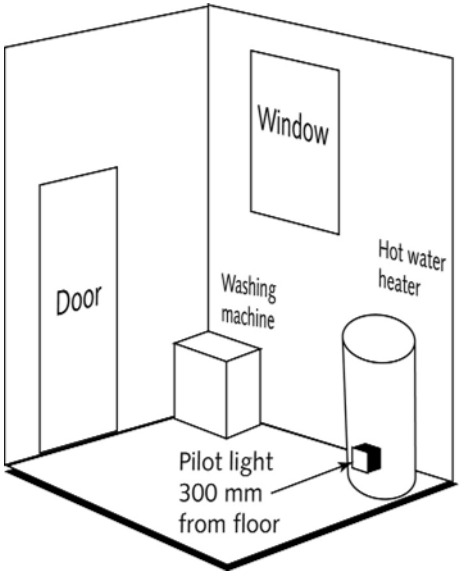


Figure 7.3 Schematic sketch of the Collins' laundry

At an initial examination of the premises you discover that Kostas could not actually reach the location of the electrical works he was supposedly fixing from the forklift platform (see Figure 7.2). His maximum reach was at 4800 mm from the floor, and the electrical connections in the ceiling space were at a height of more than 5000 mm. It would seem that Kostas had to access the ceiling space and walk on the ceiling joists to complete his work. The ceiling construction is plaster sheeting mounted on timber joists.

Question: How would you prepare the case for Kostas in his suit against MMP? Does he have a case?

H6: George Dooley, a handyman, offered to help out his friend, Tom Collins, by laying tiles in the Collins' laundry. To glue the tiles to the floor George made use of a contact adhesive made by the Cobap Pty. Ltd. According to a later account by George, as he was laying the tiles, the whole laundry seemed to be enveloped in flames and he was severely burnt. Figure 7.3 is a schematic sketch of the Collins' laundry, prepared by the loss assessor acting for the householder's liability insurers for Collins. The loss assessor also arranged for an analysis of the contact adhesive being used by Dooley and found that the active volatile constituent of the adhesive was toluene.

Question: How to prepare a case for Collins' insurer against Cobap? Do they have a case to answer?

H7: The clothes drying industry has continued to grow in leaps and bounds, mostly due to the ever increasing inner city apartment style of accommodation. In these apartments, where space is limited, clothes dryers that fold away into cupboards are a common feature of laundry furniture. *Justin Thyme* was a cabinet maker specialising in the installation of fold-away clothes dryers for the *Gizmo Corporation*, an Italian company with their head office in Milan. Justin had seen all the problems involved in managing fold-away dryers and in his spare time had made sketches and models for a new fold-away mechanism that required fewer parts and was more robust than the ones manufactured by Gizmo. Eventually he sought to commercialise this new mechanism by approaching Gizmo with his ideas. Being a cautious person, Justin had arranged for Gizmo management to sign a confidentiality agreement before he submitted his ideas for examination to the Milan head office. After approximately a year of delay in communication with Gizmo, Justin attended a trade show and found that Gizmo had on display a dryer mechanism that had many of the features of the Thyme design incorporated into it. Eventually Gizmo offered Thyme a *"compensatory"* payment of AU$ 20,000 for his ideas and advised him that they do not wish to proceed with the commercialisation of his invention.

Questions: (a) Does Justin have a genuine case against Gizmo?

(b) If yes, how would you prepare his case?[7.2]

H8: A liability claim was issued by Tyro Lawson and the Victorian Work Cover Authority against Bonmot Ltd., a blended milk product manufacturer. The subject of the claim was a Ladderweld industrial ladder (the ladder), load rate 120 kg. The ladder was involved in an industrial accident (the Lawson accident) when Lawson was in the process of loading a 25 kg bag of milk powder into a mixing machine, the *blender*. The ladder had its work platform at 1400 mm from the ground. During the incident, Lawson was required to walk up the ladder with the 25 kg bag of milk powder, and once there he was to open a metal lid on one of the two loading bays of the blender and then proceed to empty the bag into the open loading bay. As he was attempting to load the bag into the blender, the lid of the loading bay dropped down into the closed position and caused serious injury to Lawson's left hand middle and index fingers.

Question: What evidence would be needed to prepare a case supporting Lawson?

7.2 See www.austlii.edu.au (Maggbury v. Hafele); Matthew (2002).

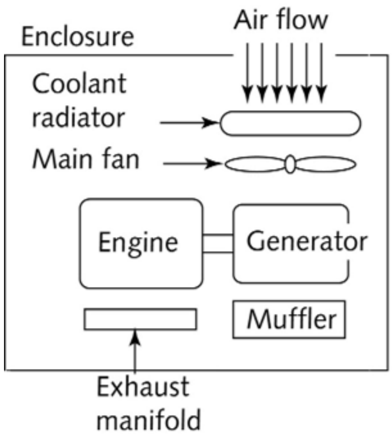


Figure 7.4 Honda generator installation schematic

H9: A dispute had arisen between *Honda Australia Ltd.* and *Roadside Fastfoods Ltd.,* a mobile food van operated by a Hungarian pastry chef Paula Chinta. The dispute concerned problems with the Honda EX5500 stationary power generator installed in the food van. According to Chinta's complaints the generator was overheating, running rough and had developed substantial oil leaks. As a result of these problems, the Chinta cold store would not operate properly and food stores were ruined on several occasions.

A sketch of the generator installation was supplied by the loss assessor acting for Honda and their insurers *Cutt and Runn Pty. Ltd.* (Figure 7.4). The sketch shows the generator installed in an enclosure. On further inquiry, the loss assessor advises that the enclosure is located inside the food van.

Question: How would you advise Honda about their defence in this suit?

H10: Kathleen Tonic, a woman of middle years, sustained severe back injuries in a single vehicle road accident. She was a back seat passenger in a vehicle driven by her brother on the way from their country property to Melbourne. The vehicle had a trailer attached and the trailer was loaded with furniture being transferred between the Tonic's country and city residences. The accident occurred when the connection between the trailer and the vehicle came adrift and the trailer draw bar dug into the asphalt of the highway, making the vehicle veer off the road and land in a ditch by the side of the road.

Police attending the scene of the accident took statements from witnesses. One witness remarked that *"I observed the trailer 'fishtailing' just before the vehicle ran off the road"*.[7.3] On examination you discover that the trailer had a fixed axle mounted on leaf springs.

Question: How would you advise the insurer of the trailer manufacturer in this case? What further evidence would you need for this advice?

7.3 *"Fishtailing"* is swinging of the trailer from side to side.

H11: Manchester coolstores is operated by the *Flybynight* family of solicitors, as part of a long-standing family business. The Manchester site has several large refrigerated sheds at various temperatures ranging from 5° Celsius to –10° Celsius. These cooling sheds are available to be used by large-scale food retailers such as *Safeway* and *Kmart* for the storage of perishable goods. The food is held in large pallets stored on several levels in the cooling sheds. Pallet handling is performed by high-reach forklift trucks. For many years Manchester coolstores had purchased their forklifts from *Ratchet Engineering*, a UK based manufacturer of material handling equipment. When Manchester took delivery of their most recent batch of 10 forklifts, their site engineer noted that metal shards were flaking off from the inside surfaces of the forklift extension towers. When a warranty complaint was issued to Ratchet's Australian agent, they were advised that *"this flaking was normal bedding down of the lifting equipment and that Manchester site maintenance staff should apply heavy grease to the lifting tower surfaces to catch the metal shards"*.

Question: How would you advise Manchester about their legal position and their recourse to warranty litigation?

H12: Warren Truss, a final-year civil engineering student at the University of Melbourne was a keen cyclist. Living in Footscray, an inner city suburb on the western side of Melbourne, he was able to ride to the university each day. This case predates the introduction of bicycle paths and Warren would ride on the roadway among various motor vehicles. On one such occasion he chose to pass a stationary stream of traffic between the inside lane and the kerb. Unfortunately the bitumen near the kerb had become very rough due to its constant exposure to heavy transport trucks that frequent this part of the city. In the event, Warren fell off his bicycle just as the traffic commenced to move and a large truck passed over one of his legs, almost severing it at the hip. Ultimately the leg had to be amputated. Student counselling advisors tried to help Warren mount a case against the transport company who owned the truck that injured him. Their insurers claimed that the poor condition of the roadway caused the accident and the city council was responsible for maintaining the road in a proper condition.

Question: How would you advise Truss about his legal position and what compensation would you seek for his injuries?

7.2 Concluding Note

The compendium of twelve hypothetical cases presented in this very brief chapter may provide opportunities for exercising engineering judgement. It has been my intention that all legal issues be left to legal counsel. Nevertheless, references are available to legal outcomes in similar cases and these should be consulted by engineers.[7.4] The judgements are clear and well explained and aspiring forensic engineers can certainly learn considerably from the material in these judgements to help in preparing case material.

7.4 See www.austlii.edu.au.

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Note: Due to the great variety of material presented in this book,this bibliography is presented under headings that identify the bibliographic material and its association with the several chapters of the text.

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Appendix 1 — Expert Witness Code of Conduct

Virtually all legal systems provide a code-of-conduct recommendation for the expert witness. In Australia the Supreme Court of New South Wales Code of Conduct is commonly used by counsel briefing expert witnesses. It is a basic requirement of the court system that the expert report affirms that this code of conduct has been read and understood.

EXPERT WITNESS CODE OF CONDUCT

Supreme Court of NSW: (Schedule K, Part 36 Rule 13C(1) and Part 39 Rule 2(1))

Application of code

1. This code of conduct applies to any expert engaged to:

   (a) provide a report as to his or her opinion for use as evidence in proceedings or proposed proceedings, or

   (b) give opinion evidence in proceedings or proposed proceedings.

General duty to the Court

2. An expert witness has an overriding duty to assist the Court impartially on matters relevant to the expert's area of expertise.
3. An expert witness's paramount duty is to the Court and not to the person retaining the expert.
4. An expert witness is not an advocate for a party.

The form of expert reports

5. A report by an expert witness must (in the body of the report or in an annexure) specify:

   (a) the person's qualifications as an expert, and

   (b) the facts, matters and assumptions on which the opinions in the report are based (a letter of instructions may be annexed), and

   (c) reasons for each opinion expressed, and

   (d) if applicable – that a particular question or issue falls outside his or her field of expertise, and

   (e) any literature or other materials utilised in support of the opinions, and

(f) any examinations, tests or other investigations on which he or she has relied and identify, and give details of the qualifications of, the person who carried them out.

6. If an expert witness who prepares a report believes that it may be incomplete or inaccurate without some qualification, that qualification must be stated in the report.

7. If an expert witness considers that his or her opinion is not a concluded opinion because of insufficient research or insufficient data or for any other reason, this must be stated when the opinion is expressed.

8. An expert witness who, after communicating an opinion to the party engaging him or her (or that party's legal representative), changes his or her opinion on a material matter must forthwith provide the engaging party (or that party's legal representative) with a supplementary report to that effect which must contain such of the information referred to in paragraph 5 (b), (c), (d), (e) and (f) as is appropriate.

9. Where an expert witness is appointed by the Court, the preceding paragraph applies as if the Court were the engaging party.

Experts' conference

10. An expert witness must abide by any direction of the Court to:

(a) confer with any other expert witness, and

(b) endeavour to reach agreement on material matters for expert opinion, and

(c) provide the Court with a joint report specifying matters agreed and matters not agreed and the reasons for any non agreement.

11 An expert witness must exercise his or her independent, professional judgment in relation to such a conference and joint report, and must not act on any instruction or request to withhold or avoid agreement.

Supreme Court rules for expert witnesses – Part 36 rule 13C

(1) For the purposes of this rule and rule 13CA: *"expert witness"* means an expert engaged for the purpose of:

(a) providing a report as to his or her opinion for use as evidence in proceedings or, proposed proceedings; or

(b) giving opinion evidence in proceedings or proposed proceedings;

"the code" means the expert witness code of conduct in Schedule K.

(2) Unless the Court otherwise orders:

(a) at or as soon as practicable after the engagement of an expert as a witness, whether to give oral evidence or to provide a report for use as evidence, the person engaging the expert shall provide the expert with a copy of the code;

(b) unless an expert witness's report contains an acknowledment b y the expert witness that he or she has read the code and agrees to be bound by it:

(i) service of the report by the party who engaged the expert witness shall not be valid service for the purposes of the rules or of any order or practice note; and

(ii) the report shall not be admitted into evidence;

(c) oral evidence shall not be received from an expert witness unless:

(i) he or she has acknowledged in writing, whether in a report relating to the proposed evidence or otherwise in relation to the proceedings, that he or she has read the code and agrees to be bound by it; and

(ii) a copy of the acknowledgment has been served on all parties affected by the evidence.

(3) If an expert witness furnishes to the engaging party a supplementary report, including any report indicating that the expert witness has changed his or her opinion on a material matter expressed in an earlier report by the expert witness:

(a) the engaging party must forthwith serve the supplementary report on all parties on whom the engaging party has served the earlier report; and

(b) the earlier report must not be used in the proceedings by the engaging party, or by any party in the same interest as the engaging party on the question to which the earlier report relates, unless paragraph (a) is complied with.

(4) This rule shall not apply to an expert engaged before this rule commences.

Appendix 2 — A Primer on Mechanics; Detailed Calculations From Cases 2.3 and 2.9

Give me but one firm spot to stand on and I will move the earth. Archimedes

Force, unaided by judgement, collapses through its own weight. Horace

A2.1 Definitions and Terminology

In this appendix I deal with technical matters relating to engineering analysis presented elsewhere in the book. The material is common to most engineering texts.[A2.1] Probably the most common (and most commonly misunderstood) concepts in mechanics are *force* and *moment*. In addition, there are concepts that represent basic mathematical or geometric building-blocks for mechanics and there are physical manifestations of these concepts. As an example, patent attorneys should take special note of the difference between a geometric concept such as *axis* and its manifestation in some geometric feature (e.g. a passageway) aligned with a specific axis.

Commonly used symbols

A, a	area, cross-section area, acceleration
D, d	diameter
E	modulus of elasticity, (Young's modulus)
F, f	force, friction factor
g	acceleration due to gravity
I_{zz}	second moment of area, mass moment of inertia
k, K	spring stiffness, kinetic energy
l, L	length dimension
m	mass
p	pressure
r, R	radius
S_U	ultimate tensile strength
S_Y	yield strength
t, T	time, material thickness, temperature
v, V	velocity, electric potential
α	thermal coefficient, angle
δ	small change in quantity, deflection of beam
ε	strain (fractional change in length)
∂, ϕ, θ	angle, twist/unit length
μ	Poisson's ratio

A2.1 Readers wishing to refer to direct source material may do well to make use of Shigley et al. (2004), or Samuel and Weir (1999).

ρ	density
π	ratio of circumference to diameter of circle
σ	direct stress
τ	shear stress

A2.2 Basic Concepts and Their Measurable or Observable Manifestations

Force (F): A force is a fundamental concept in mechanics, yet it can not be measured directly. Its manifestation is the measurable accelertion (a) of an object with a measurable mass (m), using Newton's working hypothesis:

$$F = m \times a$$

The unit of mass in *SI* is equal to the mass of the *International Prototype of the Kilogram*, a platinum-iridium cylinder kept by the *Bureau International des Poids et Mesures* at Sèvres, France. The mass of this standard kilogram in *Imperial Units* is about 2.2046 pounds avoirdupois. Even mass may not be measured directly without reference to this basic standard. Considerable care is used in establishing and calibrating standard masses and forces at the National Institute of Standards.[A2.2] Once machinery is available for the measurement and calibration of such basic concepts as mass and force, derived forms of measurements follow.

Point, Line and Plane: These are the most fundamental of geometric concepts and they originate from the basic geometric axioms of Euclid.

Point is a geometric element that has position but no extension; a point is defined by its coordinates.

Line is defined by two points it passes through.

Plane is defined by three noncolinear points.

Axis: This is a geometric concept usually represented by a line passing through a specific *point* in a *plane*.

Moment: Moment M results from a *force* F applied at some distance l from an *axis* and represented by the form $M = F \times l$. It is important to realise that moment is a *vector* quantity, with magnitude, direction and sense. Its direction is normal to the plane containing F and l and its sense is determined by the right-hand screw rule in rotating from the direction of l to the direction of F. Figure A2.1 illustrates the formation of a moment schematically.

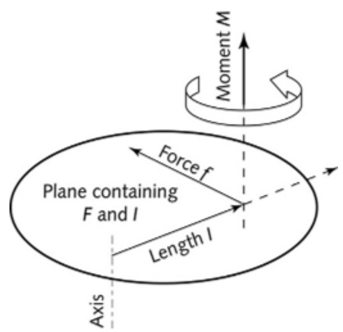

Figure A2.1 A moment about an axis

A2.2 See for example Jabbour and Yaniv (2001).

Torque (T): This is the physical manifestation of a *moment* applied to some physical object (e.g. a shaft).

Work (or *Energy*): A force F and a torque T are able to do *work* (or impart *energy* to a system) by moving. *force* and *torque* are *vector* quantities associated with both magnitude and direction. The following equations apply:

W_{linear} = $F \times l$, where l is the distance the force moves its point of application in the direction of F.

W_{rot} = $T \times \theta$, where θ is the angle through which T rotates about its axis.

Area (A): This is a *plane* region defined by two lengths l_1 and l_2 so that

$$A = l_1 \times l_2.$$

Pressure (P) = Force F per unit area A, viz. $P = F/A$.

A2.3 Material Behaviour

Most commonly encountered engineering materials behave in predictable ways. Predictions of this behaviour are based on laboratory tests on samples taken from each material. Typically, material samples are tested for strength and elastic/plastic behaviour. Figure A2.2 shows a typical test curve for an elastic material (e.g. steel). The specific mechanical properties of of interest to us are:

- *Ultimate tensile strength*, defined as the load per unit area of the test specimen (or stress with the units of *pressure*) when the specimen breaks. The symbol used for this property is σ_u;
- Elastic tensile strength or more commonly *yield strength* is the load per unit area of the test specimen when the material reaches its elastic limit and begins to deform plastically. The symbol for this property is σ_y;
- Modulus of elasticity E.

The relationship between these properties in the elastic region of the material follows the well known form for elastic materials (including springs) originally expressed by Robert Hooke (1635–1703), now known as *Hooke's law*,

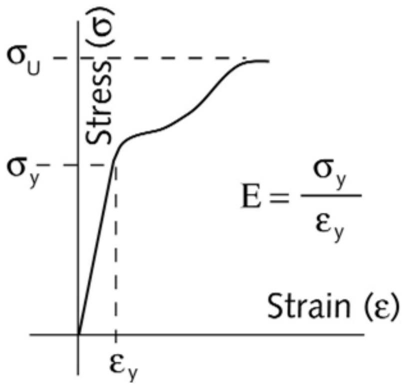

Figure A2.2 Typical stress-strain curve for elastic materials

$$\sigma = E \times \varepsilon$$

Finally, a property associated with a change in material volume when the a deformation occurs under load is Poisson's ratio (with the symbol μ). The most common use of this particular property is to express the relation between the linear elastic modulus of the material E and its shear modulus G. The *shear modulus* G is the linear relation between the shear stress τ and the shear strain experienced by the material under the applied shear stress.

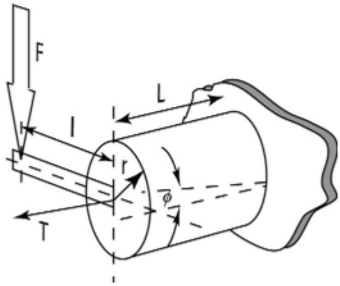

Figure A2.3 A cylindrical component with an applied torque load

$$G = E/[2(1+\mu)]$$

Rotational strain may be expressed as

$$\gamma = r\phi/L$$

with the symbols identified in Figure A2.3. The *"rotational Hooke's Law"* then becomes (similar to the linear version)

$$\tau = G\gamma$$

A2.4 Stresses and Deformation in Engineering Components

Torsion

Shear stress τ in a mechanical element (*e.g.* a shaft) varies in magnitude throughout the section of the element. Referring to Figure A2.2 the torque T (sense indicated by the arrow in the figure) is found from

$$T = F \times l$$

$$\tau_{max} = (T \times r)/I_p$$

where I_p is the *polar moment of area of the shaft*, a geometric measure associated with the capacity of the shaft component to withstand the applied torque. The shear stress τ varies linearly from zero at the shaft centre to a maximum value on the shaft surface (at radius r).

The angular rotation of the bar is (without proof)[A2.3]

$$\phi = 2TL/(G\pi r^4)$$

Tension

For a simple tensile situation where a force F is applied to a metal bar of length L and cross-section area A, the stress in the bar is (refer to Figure A2.4)

$$\sigma = F/A\,,$$

and the extension of the bar is (by simple application of Hooke's Law)

A2.3 Interested readers may wish to consult Samuel and Weir (1999), Chapter 3 for derivations of these equations.

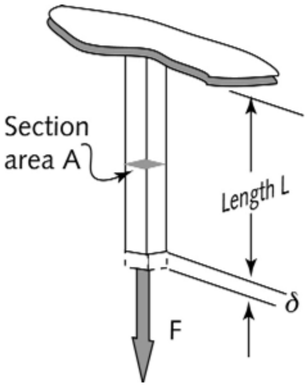

Figure A2.4 Bar under tensile loading

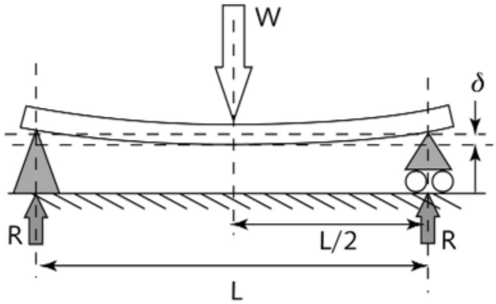

Figure A2.5 Beam under load W

$$\delta = (\sigma L)/E = (FL)/(EA)$$

Bending

Figure A2.5 is a schematic sketch of a beam acted on by a centrally located concentrated load W. The beam is resting on *"simple"* supports. The term simple here implies that the reactions at the supports act, as indicated, vertically. It also implies that the supports do not impose any moments on the beam under load. Hence $R = W/2$, and the maximum moment acting on the beam is at the middle

$$M_{max} = (W/2) \times (L/2) = WL/4$$

Figure A2.6 shows schematically the simplified mathematical model used to represent the stresses generated in the beam by the applied load and its resulting bending moment. The stresses generated in the beam oppose the moment applied as indicated in the enlarged left-hand diagram in Figure A2.6. The right-hand diagram in Figure A2.6 is a *"free body diagram"* of the section of the beam just to the right of the applied load W. The only load acting here is the reaction R as indicated. The moment generated by this load is $M = R \times L/2 =$ (as identified earlier) $WL/4$. As a result of this applied

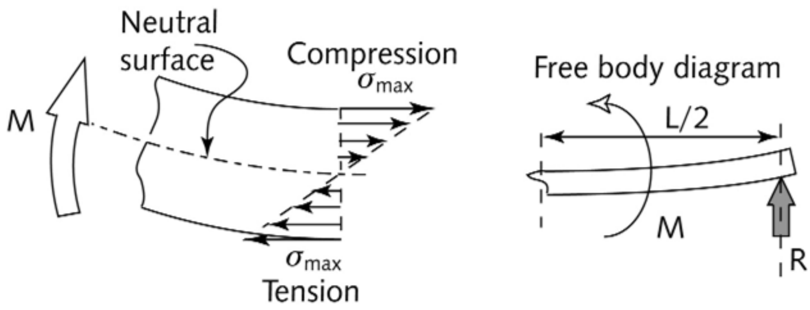

Figure A2.6 Free body diagram of one half of the beam showing the externally applied bending moment and the stress field developed internally to resist the external moment

moment the material in the beam generates an internal stress field as indicated in the left-hand diagram in Figure A2.6. This model is based on many simplifying assumptions about material behaviour under this type of loading. Interested readers may wish to follow up the derivation of the model in Samuel and Weir (1999).

The stress field generated is one of compression (conventionally assigned a negative sign) in the upper part of the beam section and tension in the lower part. The two parts of the beam are divided by a *neutral plane* where the stress is conventionally considered to be zero. The stress maximum at the lower surface of a beam width b and depth d is (again without proof)

$$\sigma_{max} = 6M/(bd^2) = 3WL/2bd^2$$

Deflection δ may be found by the application of a special form of Hooke's Law resulting in (again without proof)

$$\delta = WL^3/(4Ebd^3)$$

A2.5 Failure Predictors

Information about material behaviour under load is generally provided by laboratory tests. The nature of these tests is commonly limited to simple tension (or compression) of test bars, simple bending of test beams and *"fatigue"* testing in tension/compression and reversed bending. All materials exhibit fatigue when subjected to loading that varies with time, referred to as *dynamic loading*. For all materials the level of maximum dynamic load at which the test specimen will fail is always less than the corresponding maximum failure load under static load conditions. In this brief primer on mechanics the complex nature of fatigue loading will not be considered further. Interested readers may wish to consult appropriate references on the subject.[A2.4]

Once faced with real-world engineering components and loading conditions, we need some way of converting allowable loads, available from simplified laboratory tests to these real-world situations. This conversion process is assigned to the domain of mathematical modelling, *structural distillation*[A2.5] and failure predictors. Two most commonly used failure predictors are *maximum shear stress* (*MSS*) and *maximum principal stress* (*MPS*).

Engineering materials may be classified into *ductile elastic*, *brittle elastic* and *plastic*. Ductile elastic materials exhibit a distinct *yield point*, the stress at which the test specimen begins to deform plastically (see Figure A2.2). Brittle elastic materials do not have a distict yield point. However, both ductile elastic and brittle elastic materials have an *elastic"* region of behaviour, where the material will return to its original shape once the load is removed. Plastic materials have neither a distinct yield point, nor an elastic

A2.4 See for example Shigley et al. (2004), Samuel and Weir (1999), Carlson and Kardomateas (1995).

A2.5 Samuel and Weir (1999) Section 1.3.

region of behaviour. In real-world load situations the most highly stressed material element has a three-dimensional stress field imposed on it as indicated shematically in Figure A2.7. The stresses are designated arbitrarily as σ_1 (maximum) and σ_3 (minimum). The element shown in Figure A2.7 has been rotated into its *principal stress* orientation by geometry. In this condition there are no shear stresses acting on the faces of the material cube.

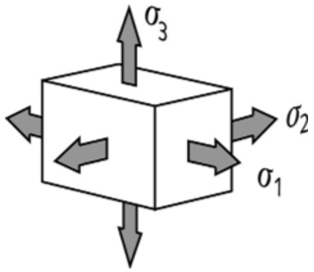

Figure A2.7 Three dimensional stress field acting on the most highly stressed material element

The *maximum shear stress failure predictor* predicts that failure will occur when the most highly stressed material element is subjected to the maximum allowable shear stress $\tau_{\text{max. allowed}}$, where

$$\tau_{\text{max. allowed}} = (\sigma_1 - \sigma_3)/2$$

This is the failure predictor used for ductile elastic materials because they all tend to fail in shear rather than in tension or compression. By contrast, for brittle materials, we tend to use the *maximum principal stress failure predictor*. This approach takes account of the fact that brittle materials almost invariably fail in direct tension. For these materials failure will occur when

$$\sigma_1 = \sigma_U, \text{ where}$$

σ_U is the tensile failure stress measured on a test bar in the laboratory.

A2.6 Fail-safe and Safe-life Design

Engineering components may fail in a variety of ways, referred to as *modes of failure*. Designers of engineering components must assess the most credible modes of failure and build the component strong enough to resist these modes. Even in predictable situations there are some statistical influences on the design due to material variations, manufacturing errors and unforseen load variations possibly due to environmental factors or even *"acts of God"*. No engineering component can be designed to be perfectly safe uder all conditions without the commitment of unlimited resources. For this reason the common approach taken by designers is to design components with a *safe life* or to be *fail-safe*.

The term fail-safe is used to describe a device which, if (or when) it fails, it does so in a way that will cause no harm or at least a minimum of harm to other devices or danger to personnel. Examples include:

Safety glass used in automobile windows, designed to shatter into very small pieces rather than the long jagged fragments created when common window glass breaks.

Luggage carts in airports in which the hand-brake must be held down to prevent the cart from stopping.

Air brakes on railway trains. The brakes are held in the off position by air pressure created in the brake system. Should a brake line split, or a carriage become decoupled, the air pressure will be lost and the brakes applied. It is impossible for the train to be driven with a leak in the brake system.

Aircraft control systems use *redundancy* (mutiple control lines to wing control surfaces) to ensure maintenance of control even when one of the control lines becomes damaged.

In safe-life design products are designed to survive a specific design life with a chosen reserve. As an example, aircraft components made from aluminium have a limited design life and need to be replaced at regular intervals.

A2.7 Detailed Calculations for Case 2.3[A2.6]

In this case a key issue was the structural deflection of the *companion structure* of the main bearing, which had suffered damage through brinelling. The bearing involved was a Rothe Erde single-row angular contact slewing ring bearing. These bearings are designed to be supported on a stiff companion structure to ebnsure that the bearing does not deflect under load. The companion structure in this case was a ring beam, identified in the photograph of Figure 2.25, and shown here schematically in Figure A 2.8. In Figure A2.9 a segment of this ring beam is shown schematically for the purpose of deflection estimation.

The ring beam was supported on several legs and the portion of the ring considered in this calculation was that where the legs were the furthest distance apart. This was over a section of the ring representing 111° of arc. As a conservative assumption, this longest arc between supports was modelled as a simply supported beam with the distributed load calculated from the

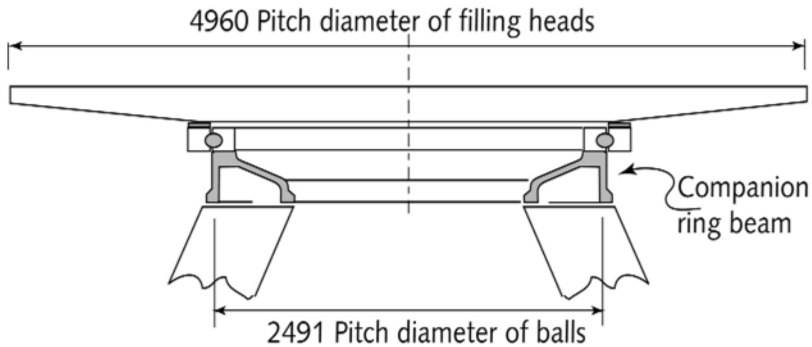

Figure A2.8 Schematic sketch of the bottle washer turntable (not to scale)

A2.6 All stress and deflection formulae used in this section are derived in Samuel and Weir (1999).

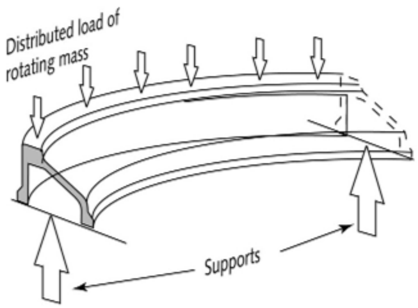

Figure A2.9 Schematic sketch of the ring beam segment evaluated for deflection

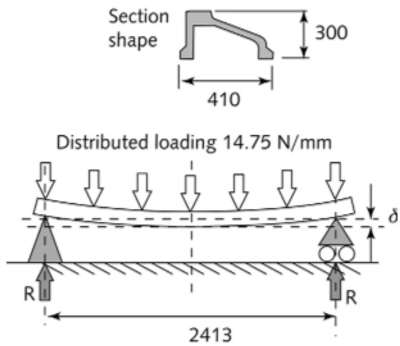

Figure A2.10 Schematic sketch of the ring-beam modelled as a simply supported beam

total load carried by the ring beam. Figure A2.10 shows this conservatively simplified model of the ring beam schematically.

Arc length $= (111/360) \times 2491 \times \pi = 2413$ mm

Static dead load (from data) = 70 kN, over total circumference.

Total circumference $= 2491 \times \pi = 7826$ mm,

Distributed "dead" load = 70 kN/7826

= 8.95 N/m

An out-of-balance load over this arc length, due to the pull-down load of the bottle washer heads, was estimated at 14 kN over the same arc, yielding:

Live load component of 14,000/2413 = 5.8 N/mm

Total distributed load over beam $w = 8.95 + 5.8 = 14.75$ N/mm

The second moment of area for the beam section was estimated from its proportions given in documents provided by counsel in this case as

$$I_{xx} = 1.26 \times 10^{-4}\ \text{m}^4$$

Maximum deflection δ_{max}(at beam centre)

$$= (5 \times w \times L^4)/(384\ E \times I_{xx})$$

where E is the modulus of elasticity and L is the beam length.

$\delta_{max} = (5 \times 14.75 \times 10^3 \times 2.413^4)/(384 \times 210 \times 10^9 \times 1.126 \times 10^{-4})$

= 0.28 mm (well within acceptable values for this bearing).

A2.8 Detailed Calculations for Case 2.9[A2.7]

Data for #1MG

Shell material is Grey Cast Iron 40,

Ultimate tensile strength = 23.5 tons/in^2

= 15.44 × 23.5 = 363 MPa

AS1210 – 1997; Table 3.3.1(C) – page 66, recommends a design tensile strength for Grey Cast Iron to AS 1830 Grade T-400 operating at temperatures less than 250°C of 40 MPa.

At 50 psi the saturation temperature of steam (steam tables) = 281°F

External temperature (according to a plant maintenance report)

= 213°F

Temperature drop from inside to outside = 281 – 213

= 68°F

Thermal conductivity of Grey Iron (Matweb data at 25°C)

= 55 W/m^2.°C/m

This converts to k_{GI} = 55 × 0.578 BTU/hr ft^2.°F/ft

= 32 BTU/hr ft^2.°F/ft

Endurance limit for Grey Iron (in reversed bending) ASTM Table 004
= 18,500psi

This value converts to S_{EGI} = 128 MPa

Wall thickness = (nominal) (2 inch) = 50.8 mm

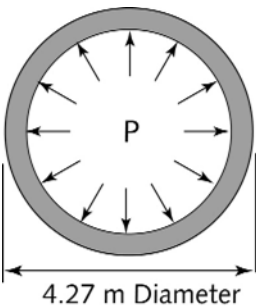

Figure A2.11 Model of pressure loading on shell

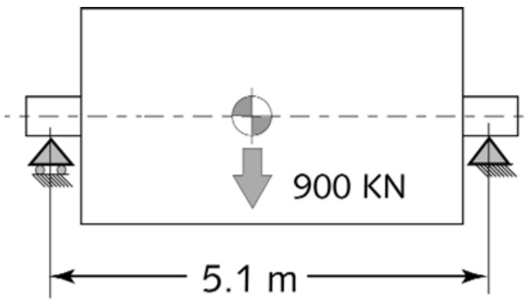

Figure A2.12 Model of beam loading on shell

A2.7 All stress formulae used in this section are derived in Samuel and Weir (1999).

Pressure loading

Pressure loading of the vessel shell is shown schematically in Figure A2.11.

Operating Pressure = (50 psi) 350 kPa

Circumferential shell stress

$$\sigma_c = P \times D/2t = 350{,}000 \times 4.27/0.1 = \mathbf{14.95\ MPa}$$

Beam loading

Beam loading of the vessel shell is shown schematically in Figure A2.12.

Wall thickness t = 50 mm

Second moment of area

$$I_{zz} = \pi \times [4.274 - (4.27 - 0.1)^4]/64$$

$$= 1.48\ m^4$$

Radial distance to centroid

$$d = 4.27/2 = 2.135\ m$$

Section modulus Z = 1.48/2.135 = 0.69 m^3

Maximum Moment M

$$= (900{,}000/2) \times 5.1/2 = 1.15 \times 10^6\ N\ m$$

Longitudinal stress in shell skin due to bending

$$\sigma_B = 1.15/0.69 = \mathbf{1.66\ MPa}$$

Centrifugal loading

Centrifugal loading operates as an extra pressure field on the cylindrical shell of this vessel. Figures A2.13 and A2.14 show the models used in this calculation. All calculations are taken for a unit length of the shell. Integration of the vertical component only of shell element loads is equilibrated by the stress load acting on the quarter shell lower boundary (σt). It is easy to show that the equilibrium equation yields (an approximation for

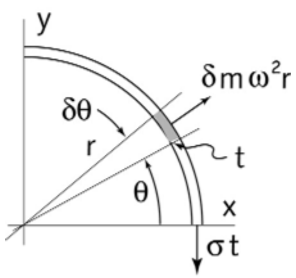

Figure A2.13 Model of centrifugal loading on quarter shell

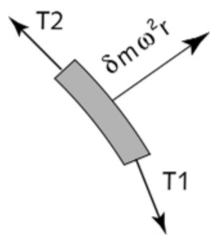

Figure A2.14 Model of centrifugal loading on shell element thin-walled cylinders where D is greater than 20t):

$$\sigma t = \rho r^2 \omega^2 t$$

Cast iron density ρ = 7300 kg/m^3

Surface speed of MG = 500 m/min or approximately 4 rad/sec

$$\sigma = 7300 \times 2.132 \times 4^2 = \mathbf{0.53\ MPa}$$

Thermal loading

Thermal stress is determined by the temperature gradient in the metal shell. This gradient needs to be estimated to ensure that the vessel stress is correctly evaluated. Heat transfer to the shell is via convective heating by the steam. Condensation will take place on the wall in a thin layer. However the majority of heat from the steam will be transferred by direct convective transfer in a thermal layer near the wall. For consistency, the heat flux through the wall must be equal to the heat flux to the wall from the thermal layer (refer to Figure A2.15). Hence

$$h \times \Delta T(\text{Steam}) = k \times \Delta T(\text{Cast Iron})/t(\text{shell})$$

where h is the assumed convective heat transfer coefficient from steam to the shell surface. In general the value of this ranges between 10 and 30 (Imperial units). For condensate, the value is about one order of magnitude greater. It can go as high as 600. Taking the lower value (average of 10 and 30 = 20 BTU/hr ft^2.°F)

$$20\ \Delta T(\text{Steam}) = 32/(1/6) \times \Delta T(\text{Cast Iron})$$

For this case the ratios of temperature gradients in steam and cast iron are:

$$\Delta T(\text{Steam}) = 9.6 \times \Delta T(\text{Cast Iron})$$

which gives a temperature rise of approximately 7°F in the shell.

If we use the higher, vastly overestimated value, of 600 for the heat transfer coefficient the same set of consistency calculations yield a temperature

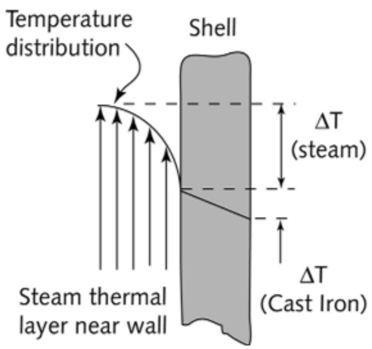

Figure A2.15 Schematic view of temperature distribution near shell wall and inside the shell.

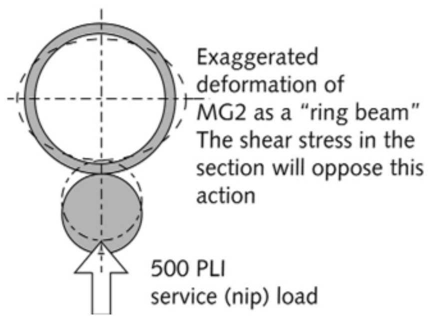

Figure A2.15 Ring beam deformation of the #1MG shell under the nip load.

rise in the shell of 51°F. The tensile hoop stress on the outer surface of the vessel is estimated from

$$\sigma = (E \times \alpha \times \Delta t)/[2 \times (1 - \mu)]$$

where E = elastic modulus; α = thermal expansion coefficient and μ = Poisson's ratio. For this particular iron, the following values hold (from data supplied by counsel):

$$E = 18.1 \times 10^6 \text{ psi} = 125 \text{ Gpa}; \mu = 0.26$$

$$\alpha = 6 \times 10^{-6} \text{ per °F}; \Delta t = 7\text{°F (low value)}, 51\text{°F (high value)}$$

Hence σ = **3.5 MPa** (low value), **25MPa** (high value)

Total loading on shell circumferentially

= (15 + 3.5 + 0.5) = **19 MPa** (low value)

= (15 + 25 + 0.5) = **40.5 MPa** (high value)

Allowable load (BS boiler code design originally) = 3200 psi = 22.3 MPa.

Fatigue loading

The line load on the shell is generated from the nip load imposed by the service rolls pressing against the shell surface. The effect of one service roll is indicated schematically in Figure A2.16. The stress generated by the line load is complex, but as an approximation I have accepted the figure estimated by finite element modelling as – 4478 psi = – 30.87 MPa. Note that the line load (a compressive load) acts to oppose the stresses generated by the pressure, centrifugal and thermal loads (all are tensile loads on the shell). Figure A2.17 shows schematicaly how the dynamic line loads vary on the outside surface of the vessel.

(a) Low thermal gradient case (more realistic case)

Mean stress = (19 + 31)/2 = 25 MPa

Fluctuation = ±15.5 MPa (inside surface stress is the worst case)

Outside surface has a compressive stress imposed on it due to the line load.

Mean stress = (19 – 31)/2 =–6 MPa

Hence the dynamic stress at the outer surface

= –6 ±15.5 MPa

(b) High thermal gradient case (exaggerated condition)

Mean stress = (40.5 + 31)/2 = 36 MPa

Fluctuation = ±15.5 MPa (again, inside surface stress is the worst case)

Outside surface has a compressive stress superimposed on the large tensile stress from other load

Mean stress = (40.5 – 31)/2 = 5 MPa

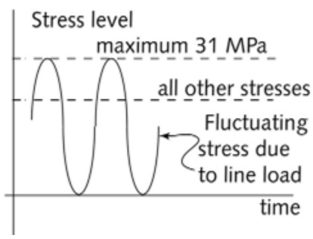

Figure A2.17 Fluctuating stress imposed on the MG shell by the nip load

Hence the dynamic stress at the outer surface

$$= 5 \pm 15.5 \text{ MPa}$$

A graphic evaluation of the design conditions for the two dynamic stress cases is presented in Figure A2.18. From each design condition the permissible mean stress (or corresponding fluctuating stress component) is found.

Case (a) (low temp. gradient)

Permitted mean stress to failure

= 132 MPa

Factor of safety = 132/25 = 5.3

Case (b) (high temp. gradient)

Permitted mean stress to failure = 189.5 MPa

Factor of safety = 189.5/36 = 5.3

Overall factors of safety

Static load – low temp. gradient = 363/19 = 19

Static load – high temp. gradient = 363/40.5 = 9

Dynamic load (both temp. gradients) = 5.3

Clearly still quite conservative design.

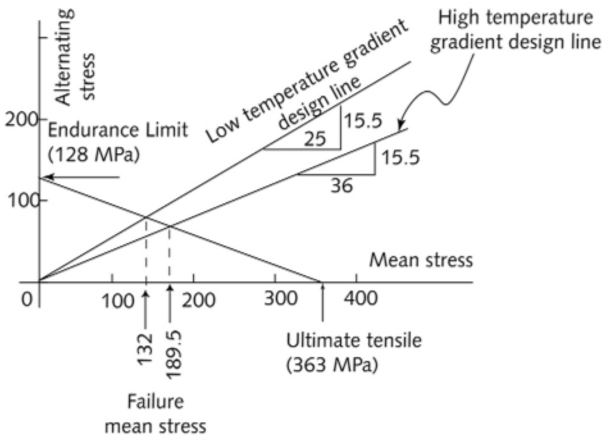

Figure A2.18 Goodman Diagram with the design conditions of the two dynamic stress cases above

Appendix 3 — Units of Measurement and Conversions

The best measure of a man's honesty isn't his income tax return. It's the zero adjust on his bathroom scale. Arthur C. Clarke

Engineers make use of measurements, in both SI (*Système Internationale*) and *"Imperial"* units. The expert's report must clearly identify the measurements and units used in any investigation or analysis. The following is a brief review of some common measuring units and their relationship to the seven fundamental SI units.

Imperial (English) units of measurement became standardised in the 13th century and initially the USA adopted the English system of weights and measures. In spite of this there remain differences in both fluid and mass units. The unit of inch, now standardised at 25.4 mm in both the UK and USA, became standardised only in 1959. In France the metric system officially started in June 1799. The unit of length was the metre, which was defined as being one ten-millionth part of a quarter of the earth's circumference. The production of this standard required a very careful survey to be done which took several years. To permit proper standardisation of measurements and units, the *Bureau International des Poids et Mesures* (BIPM) was set up by the *Convention of the Metre,* and has its headquarters near Paris, France.

The Bureau's mandate is to provide the basis for a single, coherent system of measurements throughout the world, traceable to the International System of Units (SI). This task takes many forms, from direct dissemination of units (as in the case of mass and time) to coordination through international comparisons of national measurement standards (as in length, electricity, radiometry and ionising radiation).

In all, the BIPM recognises seven basic units of measure under the International System of Units, *Système International d'unités*, or SI system, and all other measures and units are derived from these.[A3.1]

A3.1 The Seven Fundamental SI Units

- *Length* – the *metre* (m) is the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second;
- *Mass* – the *kilogram* (kg) is the unit of mass; it is equal to the mass of the international prototype of the kilogram;
- *Time* – the *second* (s) is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom;

A3.1 Source: www.bipm.org – a wonderful SI brochure is freely available from this site. See also http://physics.nist.gov/cuu/index.html for the USA version of standard system of units.

- *Electric current* – the *ampere* (A) is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length;
- *Temperature* – the *kelvin* (K) unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water;
- *Quantity of elemental material* – the *mole* is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles;
- *Luminous intensity* – the *candela* (cd) is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

A3.2 Derived Units and Dimensions

All units measuring physical quantities may be derived from these seven fundamental units. Table A3.1 lists some of the derived units and their symbols. *Area*, *density*, *force* and *pressure* are typical derived units. The SI agreed format for all the units when written as symbols is in the singular. Typically, ten metres (10 m), or ten kilograms (10 kg), rather than 10 ms, or 10 kgs. In addition, each quantity has associated *dimensions* in mass (M), length (L) and time (T). These dimensions permit the evaluation of relationships between derived units. Table A3.1 lists the dimension for all the derived units. As an example, the unit of force is the newton, derived from the definition that it is the *force* required to *accelerate* a *mass* of one kilogram at a rate of one metre per second per second (invoking Newton's law, $F = Ma$). Its dimensions then become $[MLT^{-2}]$. *Work* is the quantity derived from the definition that *one unit of work is performed* by *one Newton force* moving *one metre*. Hence the units of work are $[ML^2T^{-2}]$ (i.e. force × length). Kinetic energy is the energy of a moving body of mass m at velocity v. Hence $KE = mv^2/2$. The dimensions of KE are $[ML^2T^{-2}]$, or the same as the dimensions for *work*. Clearly, these two derived quantities, *work* and *energy*, have the same dimensions and indeed they are measured in the same units, namely joules (*J*).

In many situations there is a need to express quantities in very large or very small units. The SI system recommends standard prefixes for denoting various orders of 10 as the multiplier of the basic unit. For example, one kilowatt, denoted kW, is 1000 W. Table A3.2 lists the standard prefix set recommended by SI, virtually all prefixes differing by three orders of magni-

Table A3.1 Derived quantities and their dimensions

Quantity	Unit	Symbol	Dimensions
Area	Square metre	m^2	L^2
Volume	Cubic metre	m^3	L^3
Velocity (speed)	Metre per second	$m\ s^{-1}$	LS^{-1}
Acceleration	Metre per second per second	$m\ s^{-2}$	LS^{-2}
Density	Kilogram per cubic metre	$kg\ m^{-3}$	ML^{-3}
Concentration	Mole per cubic metre	$mol\ m^{-3}$	ML^{-3}
Specific volume	Cubic metre per kilogram	$m^3\ kg^{-1}$	L^3M^{-1}
Current density	Amper per square metre	$A\ m^{-2}$	$A\ L^{-2}$
Force	Newton	N	MLT^{-2}
Work	Joule	J	ML^2T^{-2}
Power (rate of working)	Watt (joule/second)	W	ML^2T^{-3}
Pressure	Newton per square metre, or pascal	Pa	$ML^{-1}T^{-2}$
Stress	Newton per square metre, or pascal	Pa	$ML^{-1}T^{-2}$

Table A3.2 Prefixes used to denote orders of magnitude in units

Prefix	Symbol	Power of ten	Multiplier
tera	T	12	1,000 000 000 000
giga	G	9	1,000 000 000
mega	M	6	1,000 000
kilo	k	3	1,000
hecto[1]	h	2	100
deca[1]	da	1	10
		0 ($10^0 = 1$)	1
deci[1]	d	–1	.01
centi[1]	c	–2	.001
milli	m	–3	.0001
micro	μ	–6	.000 0001
nano	n	–9	.000 000 0001
pico	p	–12	.000 000 000 0001

1. These prefixes are not recommended by SI and are included because they are still in use by some systems of units.

tude (i.e. giga is three orders of magnitude larger than mega and pico is three orders of magnitude smaller than nano).

There are some important units used internationally that have not yielded to SI standardisation. The following are some examples:

- *knot* = 1 nautical mile per hour = (1852/3600) m/s.The nautical mile is a special unit employed for marine and aerial navigation to express distance. The conventional value given above was adopted by the First International Extraordinary Hydrographic Conference, Monaco, 1929, under the name *international nautical mile*. As yet there is no internationally agreed symbol. This unit was originally chosen because one nautical mile on the surface of the Earth subtends approximately one minute of angle at the centre;
- *are* = 100 m^2, a unit still in common use in the form *hectare*, short for *hecto-are* or 10^4 m^2;
- *bar* – as a unit of pressure, approximately in multiples of standard atmospheric pressure (*atmospheres* as measured by a *barometer* – hence *bar*). 1 bar = 0.1 MPa = 100 kPa = 1000 hPa = 10^5 Pa;
- *yard* – still used in expressing distances (1 mile = 1760 yards); 1 yard = 0.9144 m; same in the US and UK;
- *pound* – for measuring quantity of substances = 0.453 592 37 kg; same in the US and UK;
- *US gallon* (liquid) – volumetric measure = 3.785 411 784 l;
- *UK gallon* = 4.546 09 l; different from US gallon;
- *Ton* – a unit of mass = 2000 lb (*short ton*) in US and 2240 lb (*long ton*) in UK;
- Note that the SI unit *megagram* (Mg = 10^6 g) is the *tonne*;
- The international unit of thermal energy is the calorie (cal) – 1 cal = 9.80665 J;
- The speed of light in vacuum = 299,752,458 ms^{-1};
- Acceleration due to gravity = 9.806 65 ms^{-2};
- Newton's gravitational constant G = 6.674 $2E^{-11}$ $m^3kg^{-1}s^{-2}$.

A3.3 Systems of Measurement and Conversion Factors

Two main systems of measurement still in use, in spite of the *Convention of the Metre.* Before the introduction of SI units internationally, there was considerable investment in the older units used in many countries. Typically road measurements (and road signage) and engineering thread sizes represent considerable commitment to specific sytem of units. As well, there are other traditionally adopted units of measure that remain in use by certain trades and professions.

Apothecary measure – This is still used in most medical dosage applications.

Table A3.3 Some common conversion factors

Quantity	SI unit	To get (other unit)	Multiply SI unit by
Mass	Kilogram (kg)	Pound (lb)	2.204 62
		Ounce (oz)	35.274 0
Length	Metre (m)	Foot (1/3 yard)	3.280 84
		Inch (1/12 foot)	39.370 1
	Kilometre (km)	Mile (5280 ft)	0.621 37
Volume	Litre (l)(=10^{-03} m^3)	Gallon US	0.264 172
		Gallon UK	0.219 969
		Cubic foot (ft^3)	3.5315 x 10^{-2}
Density	Kilogram/metre^3 (kg m^{-3})	Pound/cubic foot (lb ft^{-3})	6.242 8 x 10^{-2}
Force	Newton (N)	Pound force (lbf)	0.224 809
Moment	Newton metre (Nm)	Foot pound force(ft lbf)	0.737 562
Pressure/stress	Pascal (Pa = N m^{-2})	Pound force/in^2 (psi)	1.450 4 x 10^{-4}
		Pound force/ft^2(psf)	2.088 5 x 10^{-2}
		bar	1 x 10^{-5}
		Millimetre mercury (mm Hg)	7.500 6 x 10^{-3}
		Inch water (in H_2O)	4.014 6 x 10^{-3}
	Tonne/metre^2 (Tm^{-2})	UK ton/ft^2	9.143 789 x 10^{-5}
		US ton/ft^2	1.024104 x 10^{-4}
	Bar	Atmosphere (atm)	0.986 923
Work/energy	Joule (J)	British thermal unit (Btu)	9.478 2 x 10^{-4}
		Calorific heat unit (Chu)	5.2657 x 10^{-4}
Power	Watt (Js^{-1})	Horse power (Hp)	1.341 0 x 10^{-3}

Household measures – Recipes make use of these types of units.

Troy weights (used in jewellery, bullion and precious stone weights) – A system of units of weight in which the grain is the same as in the avoirdupois system and the pound contains 12 ounces, 240 pennyweights, or 5760 grains.

Avoirdupois – In the avoirdupois system, all units are multiples or fractions of the pound, which was defined as 0.453 592 37 kg in most of the English-speaking world in 1959. It is the everyday system of weight used in the United States. It is still widely used by many people in Canada and the United Kingdom despite the official adoption of the metric system, including the compulsory introduction of metric units in shops.

Table A3.3 provides some conversion factors for SI units. Table A3.4 provides conversions for some of the traditional units of measure.

Table A3.4 Conversions for some traditional units of measure

Unit	SI or Imperial equivalent
1 cable's length	120 fathoms; 720 feet; 219.456 m
1 chain (Gunter's or surveyor's)	66 feet; 20.1168 m
1 fathom	10 chains (surveyor's); 660 feet; 201.168 m
1 league (land)	3 statute miles; 4.828 km
1 mil (thou)	0.001 inch; 0.025 4 mm
1 point (desktop publishing)	0.013 889 inch; 0.352 778 mm
1 rod, pole, or perch	16.5 feet; 5.0292 m
1 acre	43,560 square feet; 4840 square yard; 0.405 hectare
1 barrel, liquid	31 to 42 gallons[1]
1 bushel (US) struck measure[2]	2150.42 cubic inches; 35.238 l
1 bushel, heaped (US)	747.715 cubic inches; 1.278 bushel, struck measure
1 dram, fluid or liquid (US)	0.226 cubic inch; 1.041 British fluid drachm; 3.697 ml
1 gallon (US)	231 cubic inches; 3.785 l
1 gallon (British Imperial)	1.201 US gallons
1 gill	7.219 cubic inches; 0.118 l
1 peck	8.810 l
1 tablespoon	3 teaspoons; 4 fluid drams; 0.5 fluid ounces
1 assay ton[3]	29.167 g
1 carat	200 mg
1 dram, apothecaries'	3.888 g
1 dram, avoirdupois	1.772 g
1 hundredweight, gross or long[4]	112 pounds; 50.802 kg
1 hundredweight, net or short	100 pounds; 45.359 kg
1 ounce, avoirdupois	437.5 grains; 0.911 troy ounces; 28.350 g
1 ounce, troy or apothecaries'	480 grains; 1.097 avoirdupois ounces; 31.103 g
1 pennyweight	1.555 g
1 point (jewellers)	0.1 carat; 2 mg

1. There are varieties of *"barrels"* established by law or usage. For example, federal taxes on fermented liquors are based on a barrel of 31 gallons; many state laws fix the *"barrel for liquids"* at 31.5 gallons; one state fixes a 36-gallon barrel for cistern measurement; federal law recognizes a 40-gallon barrel for *"proof spirits"*; by custom, 42 gallons compose a barrel of crude oil or petroleum products for statistical purposes, and this equivalent is recognized *"for liquids"* by four states.

2. *"Struck measure"* refers to a struck, or level, bushel. It is the only official bushel measure in the UK.

3. Used in assaying. The assay ton bears the same relation to the milligram that a ton of 2000 pounds avoirdupois bears to the ounce troy; milligrams of precious metal obtained from one assay ton of ore gives directly the number of troy ounces to the net ton.

4. The gross or long ton is used commercially in the United States to only a limited extent, usually in restricted industrial fields. These units are the same as the British "ton".

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