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EMERGING TECHNOLOGIES AND ADVANCED TESTING & DIAGNOSTIC FACILITIES

From the Editor-in-Chief

Terminal Ballistics Research Laboratory (TBRL) came into existence in the year 1961 as one of the modern armament research laboratory, with an aim to provide facilities for applied research and technology development in the fields of high explosives, detonics, shock dynamics, blast and damage, immunity, lethality and fragmentation, defeat of armour performance evaluation of warheads, and other armament systems. The laboratory is well equipped with sophisticated instrumentation facilities like high speed photography and flash radiography, warhead arena test facility, fragment launching guns, blast measurement facility, detonics laboratory, etc. Over the years many new facilities like two stage light gas gun, environmental test facilities, shock tube, linear accelerator facility, drop test facility, ballistic test facility, explosive production facilities, etc. were added at different stages to keep pace with the latest developments in the field of armaments. One of the unique facilities which has been created in the laboratory is the Rail Track Rocket Sled, i.e., RTRS facility which is being used extensively by different national scientific programmes of the country for the dynamic test and evaluation of the components, sub-assemblies, and fully assembled systems under captive flight conditions. These test facilities helped in generating the design data of warheads at various stages of their development. TBRL is playing a vital role as a nodal lab for performance evaluation of body armour, vehicle armour, and other protection system against small arm ammunition and explosive blast. The test facilities in TBRL are unique to this laboratory in the country and also the spectrum of test article and test specifications are very wide.

The quest of learning, innovative thinking, and sincere efforts of our scientists led to the development of few important technologies which made the TBRL presence felt at national and international levels. Dynamic shock compression of materials, magnetic flux compression, shaped charges, and explosively formed penetrator and high voltage pulse power, are the few technologies which made India self-reliant in certain requirements for the national security. TBRL scientists demonstrated professional approach to master these technologies into product development which were successfully tested. Over the years, TBRL has developed various products for armament applications which include multi-mode grenade, bund blasting device, exploder for torpedo, multi-EFP based directional warheads, mechatronic fuze, safety and arming mechanism, baffles range, and riot control less lethal bullets. These products have undergone TOT to ordnance factories and private industries.

The laboratory has diversified into few ambitious projects on design and development of electronic fuzes, off-route mine system, high power microwave system, directional and tactical warheads for defeat of bunkers, tank armour, naval targets, and many explosive devices for low intensity conflict applications. The laboratory has also initiated a number of collaborations with academia, like IITs, NITs, universities, and other national research laboratories in many futuristic systems like green energetic materials, nanotechnology based armour systems, photonics for detonics, etc. Over the last 55 years TBRL has transformed itself from a humble test and evaluation centre to one of the best equipped R&D laboratory in the field of missile warhead technologies. I am sure, we at TBRL, would be able to meet the challenges of design, development, and testing of warhead systems and ammunitions to meet the requirements of new age warfare.

The indigenous warhead technologies, ammunitions, and test methodologies developed by TBRL have been covered in two issues of *Technology Focus*. I hope this issue of *Technology Focus* will be useful in generating awareness about the R&D activities of the laboratory.

Dr. Manjit Singh
DS & Director TBRL, Chandigarh

Emerging Technologies and Advanced Testing & Diagnostic Facilities

TBRL has proven self-reliance in the development of technologies for warhead systems for tactical missiles and provides state-of-the-art diagnostic facilities for assessment of terminal effects of armament systems. It has built strong technology base in the country in the field of armaments by providing requisite infrastructure and committed quality. This issue of *Technology Focus* is targeting on emerging technologies and advanced testing and diagnostic facilities established at TBRL.

TBRL has offered its expertise and evaluation facilities for ballistic evaluation of protection systems like body armour, vehicle, and structural armour. It has a full-fledged small arms ballistics range, which caters to ballistic evaluation of protection systems for the Indian armed forces, paramilitary forces, and other law enforcement agencies as per various international standards. Blast and damage studies is a unique type of test facility in India which is specialised in instrumented evaluation of any type of warhead/ammunition for its blast/shock performance in free air and underground explosions. TBRL has national test facility of Rail Track Rocket Sled (RTRS) for test and evaluation of warheads, missiles and airborne systems under captive flight conditions. A modelling and simulation facility has also been set-up in the laboratory for pursuing an experimental program on detonation wave shaping, equation of state of materials at high pressure and performance optimisation of different components of high explosive devices. Flash radiography is one of the most important facility for diagnosis of high speed events generated by detonation of high explosives.

Pulsed detonation has generated considerable interest worldwide as promising technology for propulsion applications. A big improvement over the pulsejet to make use of detonation waves is attempted to release power much higher than pulsejets, gas turbine engines or rockets. For higher accuracy, safety, and reliability, TBRL is developing electronic safe and arm fuzes for services ordnance and warheads. Mechatronic fuze for multi-mode hand grenade is already developed, evaluated and validated.

TBRL has emerged as a test and evaluation centre for design, development, and testing of warheads and armament systems with expertise and competence in technology development. In this issue of *Technology Focus* the emerging technologies and advanced testing and diagnostic facilities established at TBRL are discussed in detail.

Pulse Detonation System

Pulsed detonation has generated considerable interest worldwide as promising technology for propulsion applications. Potential advantages include higher fuel efficiency than that of currently flying systems like gas turbine engines and possibility of scaling of thrust output with operating frequency while being mechanically much simpler than gas turbine engines. Pulse detonation based engine utilises repetitive detonations of fuel-oxidiser mixture to produce thrust.

Detonation is a form of combustion wherein the combustion wave travels at supersonic speeds relative to the unburnt fuel-oxidiser mixture. Also, a constant volume combustion process is thermodynamically more efficient than a constant pressure combustion process. Hence, a propulsion system utilising detonations can theoretically have higher fuel efficiency than gas turbines while being mechanically simpler as expensive and bulky compressors can be eliminated.

For flying systems, direct detonation requires impractically large amount of energy input, hence, worldwide most of the work is being done on DDT concept, i.e., deflagration to detonation transition. DDT mode of detonation initiation involves initiating a flame kernel using a low energy spark in the fuel-oxidiser mixture and then transitioning this flame front to a detonation front some distance downstream using long tube lengths.

To reduce engine length, suitable devices are employed which reduce the length of the tube required for transition from deflagration to detonation.

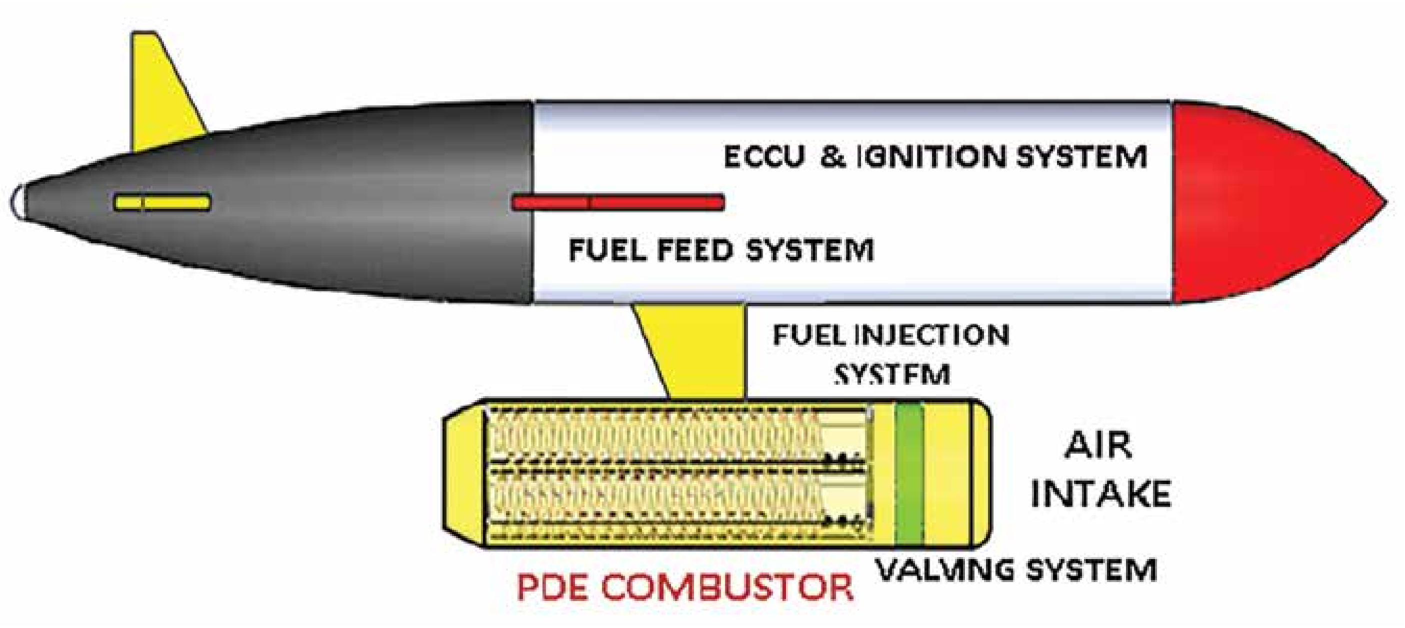
Applications
• Missile propulsion (Cruise and Anti-tank)
• Unmanned Aerial Vehicles (UAVs)
• RTRS facility propulsion for dynamic testing of payloads

Advantages	
• Light and powerful	• Simplicity and flexibility
• High specific impulse	• Few moving components
• Low cost	• Fuel efficient

A test rig was designed and established for conducting experiments with liquid fuel-air mixtures. Data Acquisition System (DAS) has been installed and commissioned. For real-time acquisition of PDS, test rig instrumentation data and digital control of fuel and air injection, ignition, and purging pulses DAS was used. After achieving single shot detonation in a single tube in liquid fuel, TBRL has achieved multi-cycle operation of 8 Hz in single PDS tube.

TBRL is working on air breathing multi-tube multi-cycle pulse detonation engine with an objective to develop an air-breathing Pulse Detonation Engine (with throttling) to generate 2.5 kN of thrust for a duration of 30 minutes.

Pressure and thrust data plot of single cycle at 8 Hz and three tube configurations for 24 Hz are shown in the graphs.

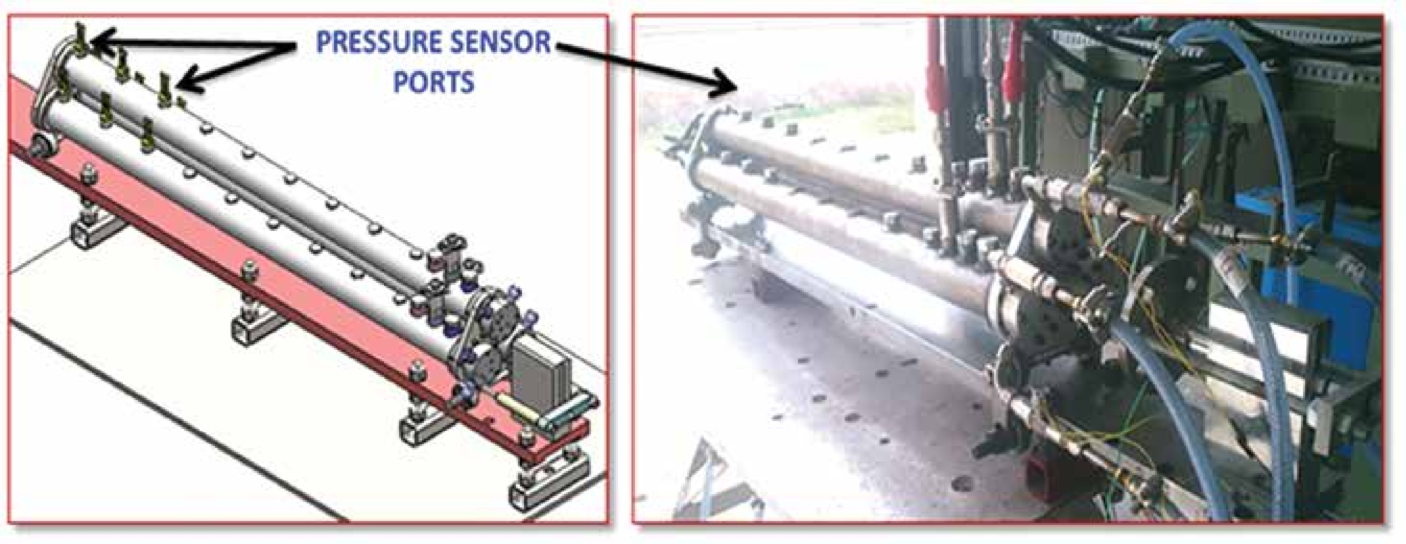


Target vehicle powered by PDE engine

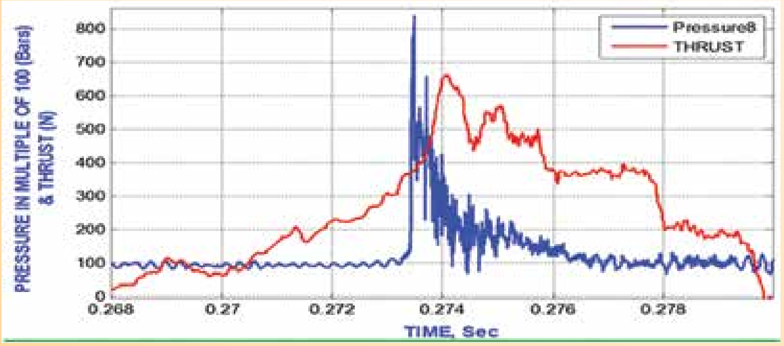
Liquid fuel test rig and diagnostics

Instrumentation test stand

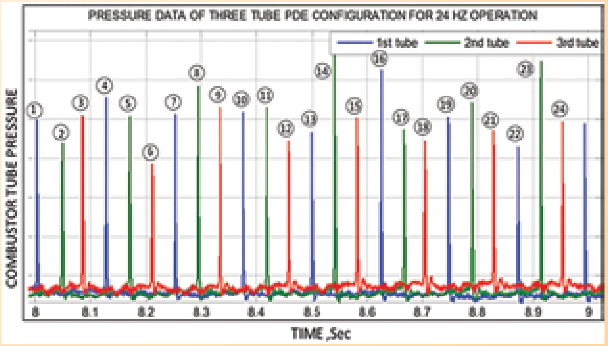
PDS tube test stand



Three tube assembly for PDE system with operating frequency of 24 Hz



Pressure and thrust data plot of single cycle at 8 Hz



Pressure data of three tube PDE configurations for 24 Hz operation

Safer, Accurate and Reliable Electronic Fuzes

TBRL has got expertise in fields of development of very safe explosive initiators. In any kind of armament, fuzes are of utmost importance and called intelligence systems. For higher accuracy, safety and reliability, TBRL is developing electronic safe and arm fuzes.

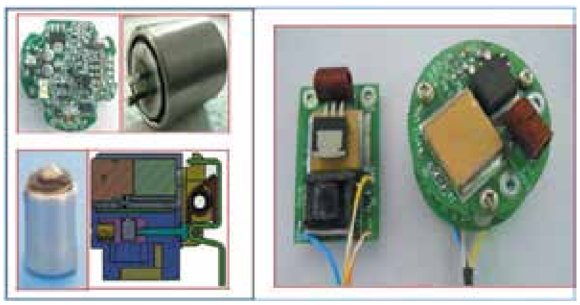
In the first stage, TBRL is developing enabling technologies and infrastructure for Electronic Safe Arm Device (ESAD) fuzes which are next generation fuzes. TBRL ia also developing mortar fuzes, artillery fuzes, impact cum delay fuzes for bombs in addition to testing techniques of fuzes.

Mechatronic Fuze for Grenade

Mechatronic fuze for multi-mode hand grenade has been developed, evaluated, and validated. It operates in three modes, viz., time delay, impact, and dual. Pre-launch safeties have been provided through mechanical components whereas post launch safeties and intelligence have been incorporated using embedded system based electronic hardware and software. The detonator is misaligned with the rest of the explosive train during storage and transportation. The fuze is powered by primary lithium battery.

The fuze has been designed to withstand accidental drop for thrower's safety. The time delay for arming and initiation of detonator is factory settable with a high precision. The fuze has a provision of self-discharge system to avoid delayed initiation after a preset delay. The Transfer of Technology (ToT) of this system has also been done in order to meet the fuze future requirements.

Mechatronic fuze



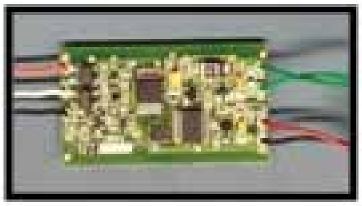
Fuze components

Salient Features

Type	Mechanical-cum-electronic fuze
Safeties	Mechanical, accidental drop, self neutralisation
Modes	Time delay, impact, dual
Accuracy	100 ms
Testability	100 % verification of functioning time
Compatibility	100 % compatible with multi-mode hand grenade

Electronic Safe and Arm Fuze for Advanced Stage Development

Development of electronic fuze for 81 mm mortar is also at completion stage and has successfully evaluated in dynamic trials. Impact cum delay fuzes are also being developed for air delivery systems and component level development and evaluation has been completed.



ISCU PCB

Fuze assembled mortar

Turbo generator

Detonator housing

Firing unit PCB

Salient Features

- Compatible with existing 81 mm mortar ammunition
- Time delay with impact backup mode of operation
- Inductive settable time delay programming
- Air driven turbo generator, RC based arming delay safeties
- Detonator based explosive train

Laser Initiation of Explosives

The technology of advanced laser initiation system has been demonstrated successfully in the year 2013 by TBRL for initiation of high explosives. The development of optical initiation method comes as a potential replacement candidate for currently used electrical method because laser initiation method is totally immune to high electrostatic discharge (spark)/electromagnetic interference, thus they are safer. Laser initiated detonators have been designed, developed, and tested successfully in field trials for firing of different high explosives like Octol, RDX, and TNT.

Laser initiators are state-of-the-art initiation technology since laser cannot be produced accidently and they also eliminate the requirement of sensitive primers. The technology of three types of laser detonators has been developed and demonstrated successfully.

Types of Laser Detonators Developed

Laser Detonator Type I– Laser DDT detonator – equivalent to electric detonator 33

a) **Laser source**: Laser diode (10 W QCW output) coupled with 400/440 µm optical fiber
b) **Mechanism**: (DDT) burning to deflagration to detonation of HMX
c) **Applications**: All types of conventional warheads where initiation time could be in ms regime, could be embedded directly in explosive charges
d) **Response time**: 5 to 6 ms

Laser Detonator Type II– (Fast DDT) – Prompt laser detonator

a) **Laser source**: Ultra-compact NdYAG laser 15 mJ 4 ns pulsed output coupled with optical fiber (diameter 1 mm fused silica glass core) tested to withstand 3000 g
b) **Mechanism**: Prompt detonation due to weak shock generated by aluminium nanoparticles mixed with HMX
c) **Applications**: All types of conventional warheads, PDE
d) **Response time**: Of the order of few hundred µs

Laser Detonator Type III (SDT)– Laser SDT detonator – equivalent to EBW

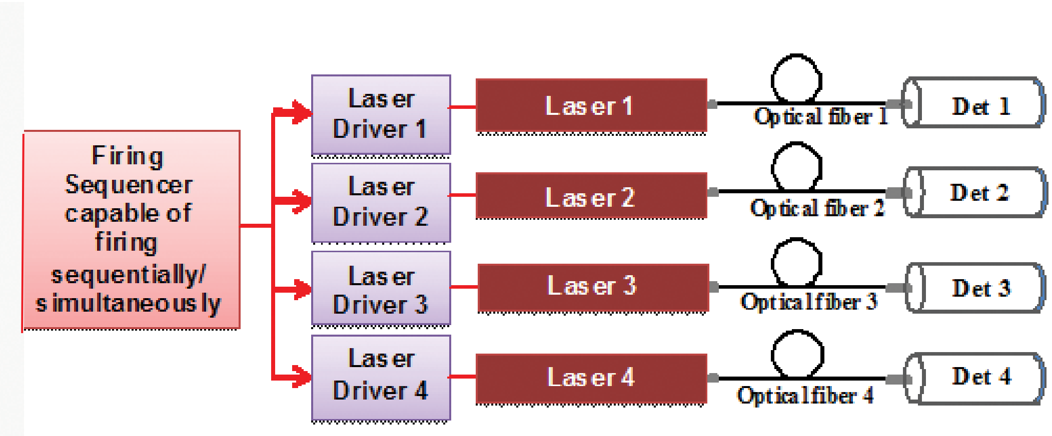
a) **Laser source**: Q-switched NdYAG laser 20 mJ, 10 ns coupled to 600/660 µm optical fiber
b) **Mechanism**: (SDT) Shock to detonation of PETN same as of EBW
c) **Applications**: All types of strategic warheads which require quick reaction time and simultaneity of number of detonators
d) **Response time**: Of the order of 3 µs, simultaneity of the order less than 30 ns for two two detonators and 70 ns for four detonators

Multi-point Laser Ordnance Initiation System

Multi-point initiation has been successfully demonstrated with simultaneous firing of multiple numbers of laser detonators. Repeatability has been established for initiation of high explosive with all these types of laser detonators. Two point laser initiation with SDT laser detonators achieved simultaneously of the order of 30 ns with each laser detonator with functional time of approx 3 µs. Four point laser initiation with SDT laser detonators achieved simultaneity of the order of 70 ns with each laser detonator with functional time of approx 3 µs. The sequencer upto eight points has been developed which can fire even 8 laser detonators of DDT type simultaneously and in any defined sequence.

Salient Features

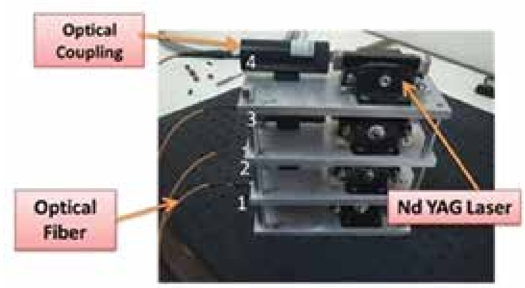
- 4-firing channels
- Programmable delay
- Programmable pulse width
- Ruggedised and field deployable
- Battery operated
- Safety key
- Immunity to fast transients
- Turn on delay
- Fast rise time



Schematic of laser ordnance initiation system

Lab demonstration unit for firing of laser detonator type II (4 channels)

Field portable laser firing unit for laser detonator type I (8 channels)



Optical block inside the firing unit for laser detonator type II (4 channels)

High Power Pulsed Laser System Facility

TBRL has been augmented with new high power pulsed laser system facility with variable pulse width, energy, and wavelength. The main application of high power laser system is for direct laser initiation of high explosives, to study the wavelength dependence of high explosives for laser initiation, to determine the laser initiation threshold energy for various high explosives and to study the laser shock generation of metal coated glass windows or metal coated explosive substrate. This laser system is very useful to study the laser interaction with nanoparticle coated reactive thin films.

High power pulsed laser system

Rail Track Rocket Sled Test Facility

Rail Track Rocket Sled (RTRS), a national test facility, has been established in 1988 in TBRL Ranges Ramgarh for dynamic testing of systems/sub-system of missiles, aerospace products like parachute systems, UAVs, wing opening mechanisms and armament systems like fuzes, warhead, bombs, etc.

Any new system development requires testing under the best possible simulated environmental conditions. These tests can be broadly classified into laboratory tests, track test, and flight tests.

Captive track testing, as used in RTRS, constitutes an optimum solution between lab test and full scale flight tests. The dynamic testing at RTRS has distinct advantage that the test item can be recovered for its post analysis after the test is over. This makes it more effective and economical for repetitive tests and analysis. The most frequently monitored parameters are velocity, acceleration, load, angle of attack, vibration, etc. RTRS facility is also utlised for evaluation of bombs/warheads in impact mode.

Initially, the facility consisted of 1.2 km long dual track of 700 mm guage. It was extended to 2.0 km in 2003 to meet the user requirements. The track has now been extended to 3.83 km along with new tri-rail parallel track of gauge 1.0 m and 1.4 m gauges options between 0.7 m to 4.86 m (outer to outer) to accommodate variety of payloads. It has culminated the RTRS facility to RTRS Penta-rail Supersonic Track. The present track has dynamic load bearing capacity of 50 tons on any point. The maximum velocity achieved so far is nearly Mach 2.

RTRS is now establishing new testing techniques for escape system testing, 1000 kg class warhead/bomb in impact mode and various fuzes like proximity, impact delay, etc.

Salient Features of Penta-rail Supersonic Track

- Length : 3830 m
- Gauges : 0.7 m to 4.8 m
- Alignment accuracy : ± 1 mm
- Load bearing capacity : 50 ton
- Max. payload (so far) : 1300 kg
- High thrust low burn time rocket motor
- Sled : Aerodynamic
- Recovery mode (achieved) : Mach 1.2
- Mode of recovery * Air brakes
  * Sand braking
  * Retro rockets
  * Parachutes

RTRS penta-rail supersonic

Test Methodology

Unit under test is made captive on a specially designed sled for testing. Cluster of rocket motors are used to generate required dynamic conditions. For carrying out the analysis, data are acquired through various ground based as well as on-board instrumentation. Data acquired with various modes are processed and analysed for performance evaluation. Besides this, photo instrumentation is also positioned along the track, covering area of interest, to record various events occuring during trials.

Applications of RTRS Facility

- Air defence target interceptor interaction simulation for proximity fuze testing.
- Terminal ballistics studies
- Performance analysis of missile sub-systems
- Evaluation of bombs and fuzes
- Evaluation of parachute and payload recovery systems

Testing of IIR seeker for Helina

Parachute testing at RTRS

Monolithic warhead testing in impact mode

Ballistic Evaluation of Materials

Ballistic test and evaluation of body armor is of great priority for any country to meet current operational needs. Since 1970s, TBRL has offered its expertise and evaluation facilities for ballistic evaluation of protection systems like body armour, vehicle, and structural armour. The laboratory has a full-fledged small arms ballistics range, which caters to ballistic evaluation of protection systems for the Indian armed forces, paramilitary forces, and other law enforcement agencies as per various international standards. The range also supports other DRDO laboratories in development of armour materials.

In recent times, need for protection systems in the wake of current national and international scenarios have grown exponentially with availability of sophisticated small arms and ammunition with higher threat levels. The test and evaluation facilities for the protection systems also have to evolve simultaneously and become globally comparable, faster, more accurate, require less manpower, cost-effective in addition to being infallible and safe.

As a result, a new state-of-the-art ballistics test facility has been established for ballistic evaluation as per global standards. The facility will cater to the enhanced needs of armed, paramilitary, and police forces as well as provide testing support to sister DRDO laboratories and other research organisations.

The laboratory has dedicated ranges for small arms and medium caliber testing facilities with state-of-the-art diagnostics and instrumentation. The laboratory has been instrumental in development of ballistic resistance standards for Indian armed and security forces.

The test facility has conducted many projects related to the test and evaluation of a variety of materials and components over the years, viz., test and evaluation of bullet proof jackets, vests, helmets, vehicle armour, observation posts, morchas, bullet, and fragment impact test on munitions, performance evaluation of 360° body armour and self-sealing fuel tanks. The scientists of the test facility are also involved in research and development of new materials for personal protection.

To cater the requirements of Indian armed forces and security agencies, a national standard for performance evaluation for body armour has been prepared along with other stake holders and submitted to Bureau of Indian Standards under the aegis of NitiAyog.

Features of the Ballistics Test Facility

- Modern, state-of-the-art testing facility specialising in ballistic evaluation of protection systems, research on high velocity impact behaviour, development of smart armours, low intensity conflict ammunition, and standardisation of ballistic test protocols. Also, test range for ballistic evaluation of personal, vehicle, structural protective armours
- Acoustic building with vibration and blast proof walls
- Climatically controlled test ranges upto 45 m
- Test procedures traceable to NIJ 0101.06, 0108.01, EN 1063, STANAG 4569 (upto Level III)
- Ballistic evaluation using test barrels as well as in-service weapons from calibre 5.56 mm to 40 mm
- Remote triggering of all weapon systems
- Dedicated ammunition reloading areas are available to cater for control and design of ammunition and range of fragments
- High-end diagnostics like IR based non-contact velocity measurement systems, optical target systems, ballistic data acquisition, and analysis systems
- Environmental chambers to evaluate service and wear life of protection systems using accelerated ageing techniques
- State-of-the-art surveillance systems and access controls, dedicated user participation areas

Equipment and Diagnostics


Projectile velocity measurement system


Universal receiver with firing system


Head forms


Reloading station


Ammunition components


Trial set-up for ballistic evaluation

New Capabilities

- Traceability to global standards of test and evaluation
- Use of standard barrels instead of conventional weapons for testing
- Controllable projectile velocity for specific threat levels
- Testing of fully engineered targets like complete vehicles, observation posts
- Minimum human intervention during trials, automatic data generation
- Service and wear life prediction of body armours

Applications

- Destructive testing: Ballistic evaluation of R&D samples of SAP/HAP for design optimisation of light weight body armours with minimum weight penalty
- Ballistic database: Sufficient experimental data generated through ballistic trials on different type of armour materials against various threat level
- Ballistic evaluation: For armours, armour materials, and bullet resistant structural materials against small arms
- Terminal ballistics: Projectile target interaction studies, trauma studies, and ricochet studies

Blast Instrumentation

TBRL is engaged in the evaluation of free air, underwater, underground explosion shock studies, and its interaction with structures. Blast and damage studies is a unique type of test facility in India which is specialised in instrumented evaluation of any type of warhead/ammunition for its blast/ shock performance in free air, underwater, and underground explosions. TBRL also provides support to sister DRDO laboratories and outside DRDO agencies for design validation and scaled down testing of various systems developed by them. It has contributed substantially in the evaluation of various construction techniques like SFRC, LRC, etc. for their blast resistant properties.

It provides support to the paramilitary forces by testing various types of bomb disposal systems designed to remove unattended explosive/IED found at public places. It has also contributed substantially in some important trials of national importance by measuring critical parameters at different locations and by generating inputs for design improvements. New test set-ups have been designed and fabricated for evaluation of boot anti-mine, protective panels, protective glasses, etc. The facility has got the full range of instrumentation for mapping blast/ground shock profiles in the near, intermediate and far off region. The facility is being upgraded by instrumented dummies for evaluating the human response during blast and quantifying the injury level.

Mine protective vehicle

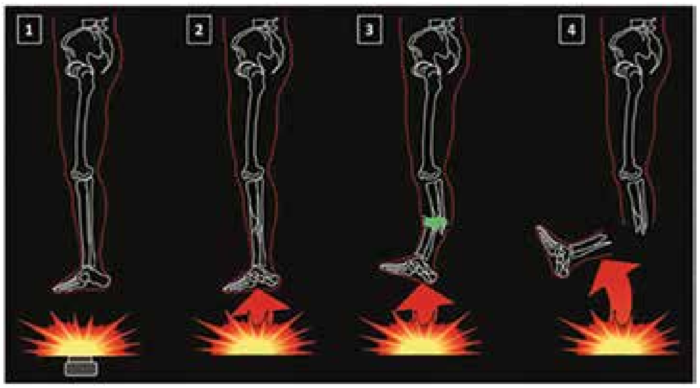
Protocol Development-Mine Protective Vehicle Testing

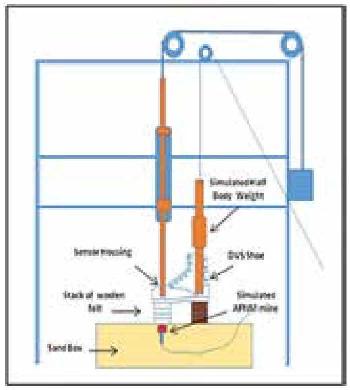
Human survivability is major concern in case of anti-vehicular landmine blast and anti-personnel landmine blast. Mine Protective Vehicle (MPV) and Mine Protective Gear (MPG) are used to protect troops against such incidents. Anthropomorphic Test Devices (ATD) are recommended by NATO to evaluate the injury to occupants of vehicle in case of anti-vehicular landmine blast and deminer during neutralisation of anti-personnel landmines. These dummies have sensors at all the critical locations like head, neck, abdomen, spine, legs, etc. to quantify the loading and evaluate the injury level.

Mine protective gear

Protocol Development-Evaluation of Threshold of Leg Amputation in case of Forefoot Landmine Blast

Severe injuries occur to lower leg in case of accidental step over the landmine. A special test set-up was designed and fabricated to simulate the actual field scenario and record the loading pressure on foot in case of AP mine blast. Trials were conducted to evaluate the threshold of leg amputation in case of fore foot landmine blastand standardisation of different pressure levels was done using varying thicknesses of shock attenuating material.





Test set-up for establishing foot injury criteria in case of AP mine blast

Research Activities

- Blast/shock evaluation of explosion caused by any type of warhead, ammunition, explosive, propellant, etc. in air, water, and underground
- Quantitative evaluation of protective systems subjected to extreme blast/shock loading
- Design evaluation of blast resistance structures
- Facility to conduct scaled blast structures interaction experiments
- Development of piezoelectric sensors for measurement of blast in intermediate region with pressure range from 1 kPa to 1.5 MPa

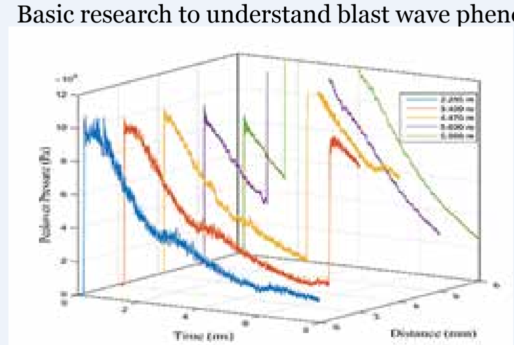
Shock Tube Facility

To carry out shock and blast related developmental work and dynamic calibration of pressure sensors at laboratory level without detonating any explosive, shock tube facility has been established in collaboration with IISC Bangalore. The facility can generate maximum 80 bar of blast pressure. A typical blast wave plot is shown.

Applications

- Blast mitigation studies
- Blast injuries studies
- Blast structure interaction studies
- Dynamic calibration of pressure sensors
- Scale down studies
- Basic research to understand blast wave phenomenon.

Shock tube facility



Blast wave

Metallurgy and Explosive Metal Working

TBRL is engaged in two domains, i.e., explosive metal working and material characterisation.

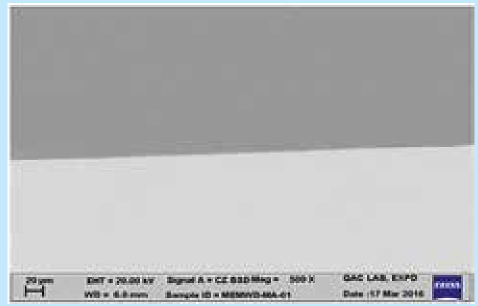
Explosive Metal working

Explosive welding is a solid-state metal joining technique for joining two dissimilar metals and has wide applications in defence and space sectors. Various trials of explosive welding of metal plates like Al-SS, Cu-SS were conducted. Along with flat metal plate joining, trials of explosive welding of bi-metallic cylinders of Cu-Al were conducted. Along with this, experimental trials of explosive shock hardening and Explosive Bulge Testing (EBT) of steel plates for naval applications were also conducted.

Material Characterisation

Material characterisation is another domain under work. TBRL is equipped with metallographic sample preparation facilities for preparing samples. Apart from this, following facilities are also available.

Aluminum (Top) joined to stainless steel (bottom)



SEM analysis of Al-SS interface shows defect free interface

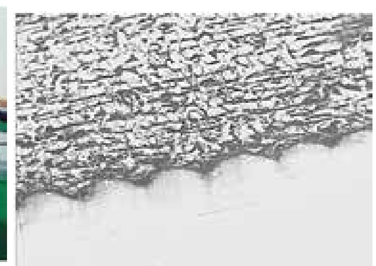
Cu (outer)-Al (inside) cylindrical joint

- **Metallurgical microscope**: The microscope having magnification of 1500 X is mainly used for studying the microstructure, interface study, grain boundaries, and other metallurgical parameters of different materials.
- **Vickers hardness tester**: Vickers hardness is important parameter used by material designers to evaluate the suitability of a material for a particular application. The equipment is used for Vickers hardness testing of metals.
- **Micro-vickers hardness tester**: It is used for precise hardness measurement like interface of explosive welded joints, brazed joints, etc.
- **Universal testing machine (20 kN)**: The machine is used for tensile and compression testing of most metals and non-metals like plastics.
- **Non-destructive ultrasonic flaw detector**: It is used for studying bonding of explosive welded plates. In addition, the equipment can also be used for analysing internal defects.
- **Surface roughness tester**: Surface roughness is an important parameter which is required for critical defence applications. Equipment for surface roughness for measurement of Ra, Rz, and Rmax values are available.

Metallurgical microscope

Micro-vickers hardness tester

Ultrasonic flaw detector on metallurgical microscope



Study of interface grain boundaries

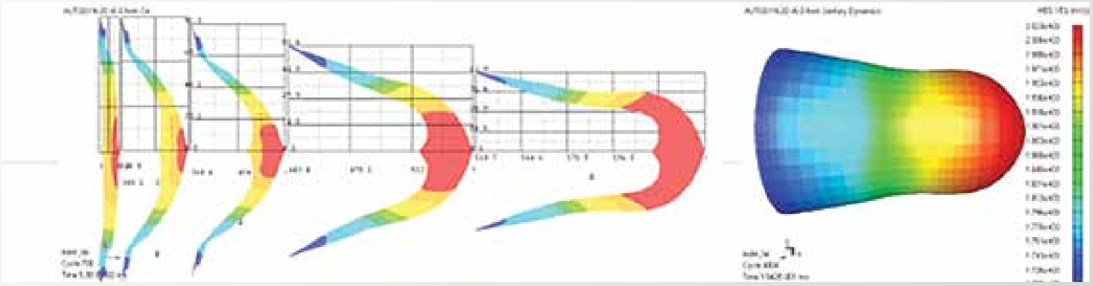
Modelling and Simulation

The process optimisation based only on the experimental work is often very time consuming process and needs many resources. Moreover, in the experiments related to explosives the resulting phenomena is extremely fast, it is over in a very short duration, high strain rates and high pressures are present and complicated shock wave/blast/material interaction takes place. Diagnostic techniques are very intricate and high experimental costs are involved. To cut down on the said requirements and to guide the further experimental program, a modeling and simulation facility has been set-up. The facility caters for problems of internal users as well as provides support for sister DRDO laboratories.

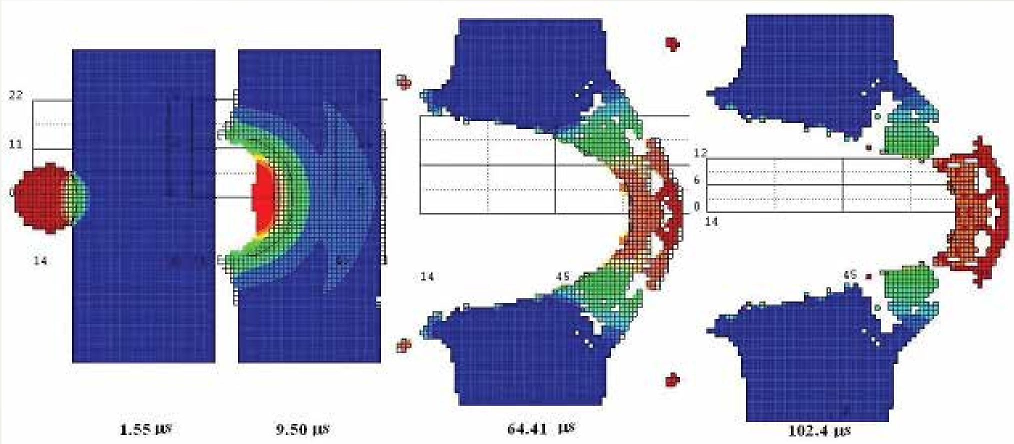
An infrastructure has been created through development of software in collaboration with academic institutes and also through commercial acquisition of non-linear software codes. At present, Autodyn 2D/3D, LSDYNA, Abaqus, SPEED are some of the non-linear finite element codes which are being extensively used. These codes allow use of different numerical solvers like lagrange, euler, euler-FCT, euler-godunov, ALE, smooth particle hydrodynamics, beam or shell depending upon the requirements. Necessary multi-CPU hardware has been set-up which allows simulation of complex 3D problems in parallel processing mode.

Over the years expertise in numerical simulation has been developed and problems related to following areas have been solved.

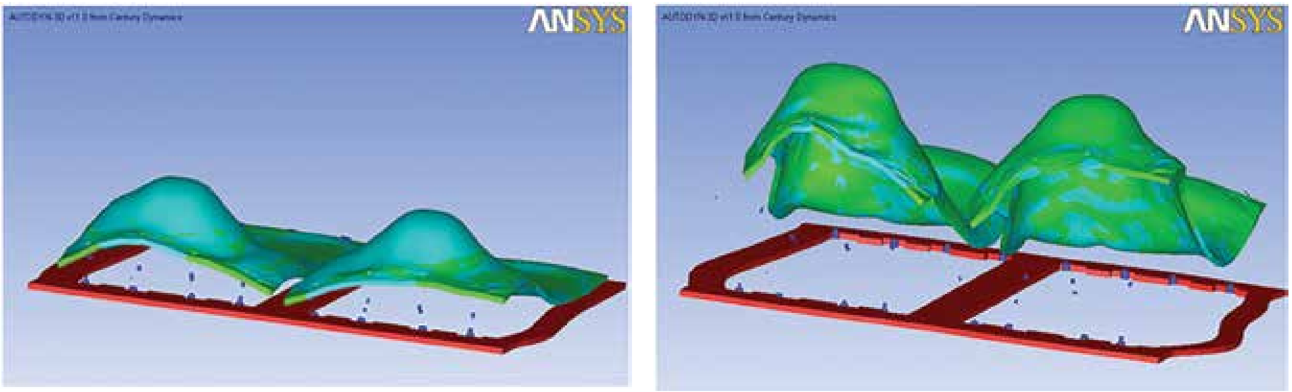
- Damage assessment of underground structures due to explosion of bombs
- Explosion of bombs-effects on structures and role of geo-media
- Hypervelocity impact behavior of futuristic armour systems
- Ballistic simulation of impact on composite laminates
- Shaped charge, EFP, and fragmenting warheads
- Possible sympathetic detonation in explosive storage buildings
- Effect of driver seat configuration in armoured vehicle subjected to buried mines



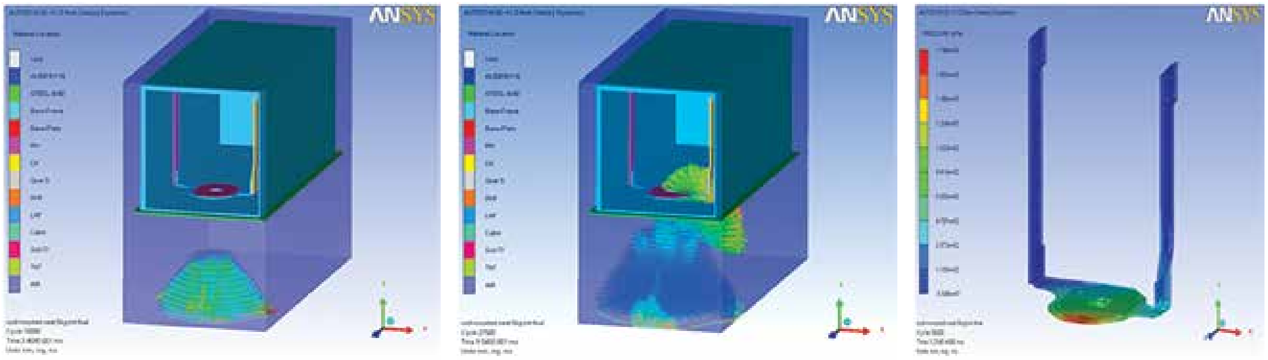
Evolution of EFP



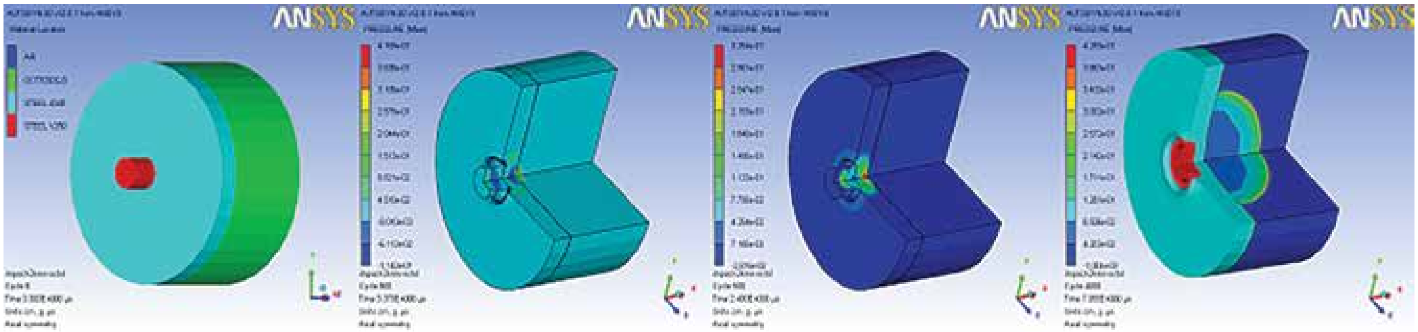
Hypervelocity impact



Explosion in the ammunition compartment



Roof mounted seat in armoured vehicle subjected to buried mines



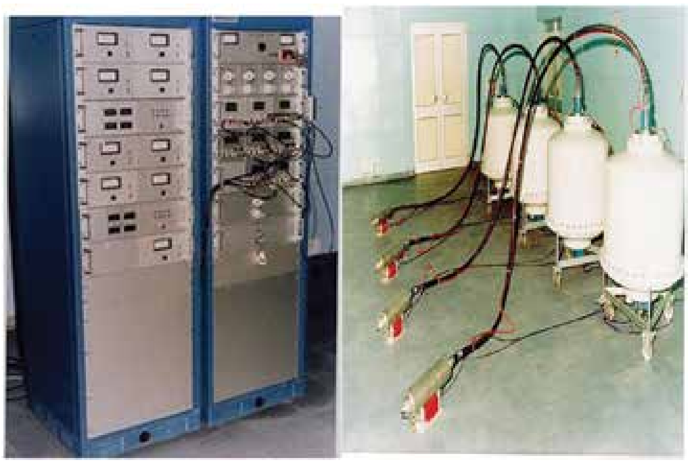
Impact on to cased munition

Flash Radiography

Flash radiography is one of the most important techniques for diagnosis of high speed events generated by detonation of high explosive and accompanied by dense smoke, intense light, debris or occurring inside the optically opaque medium. The present 480 kV facility is being used for studies on shaped charges, fragmentation of shells, shock waves, and detonics.

Salient Features

- 4 channel, 480 kV flash x-ray system
- Exposure time : 25 ns
- Penetration : 34 mm steel at 2.5 m



Flash X-ray System

Few phenomenon recorded by flash x-ray techniques are:

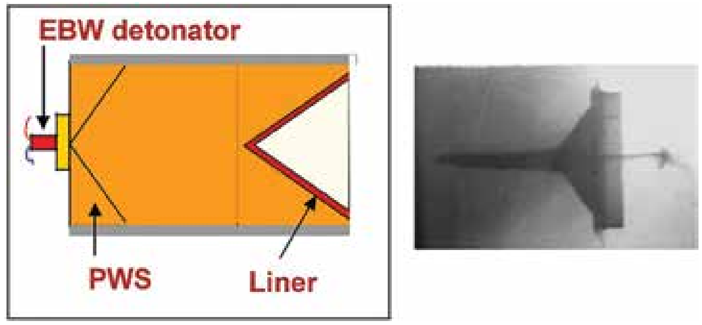
High Explosive Squash Head

High Explosive Squash Head (HESH) is basically an anti-tank ammunition. In this, explosive is fired in the direction of tank which after impact with the armour of tank gets detonated. Due to this shock wave travels in the armour which gets reflected from the open surface. The points at which these compressive and reflected shock waves meet strain forces are produced.

If these strain forces exceed the dynamic strength of the material then the material is broken from that point which hits the persons inside the tank. In the late 1970's various trials were conducted to study this phenomenon with the help of flash x-ray system.

Shaped Charge Liner Collapse and Jet Formation

Shaped charges are the cylindrical explosive devices having, generally, conical cavity at one end of cylinder which is filled by a metallic cone usually made of copper. These have both military and industrial applications to make deep holes in hard targets. Extensive study of shape charges was carried out by using 480 kV flash x-ray system which helped in basic research as well as



Shaped charge liner collapse and jet formation

in development of Shape charge based warheads. Shape charge jet moves with velocity 7-10 Km/s depending upon the caliber and angle of cone. Radiographs obtained are analysed to see the velocity, jet length, break-up time, etc. which are essential parameters in designing the shape charge based warheads. This study is being utilised at present for the design and development of shaped charge warhead of light weight torpedo to defeat double hull submarine.

Wound Ballistics

Wound ballistics is an important application which is used to study the effect of bullet on human body. Many experimental trials were conducted on a gelatin gel material whose properties are somewhat similar to human flesh by firing bullets with different caliber and velocity. With the help of radiography bullet movement profile and its penetration in gel material were studied.

Explosively Formed Projectile

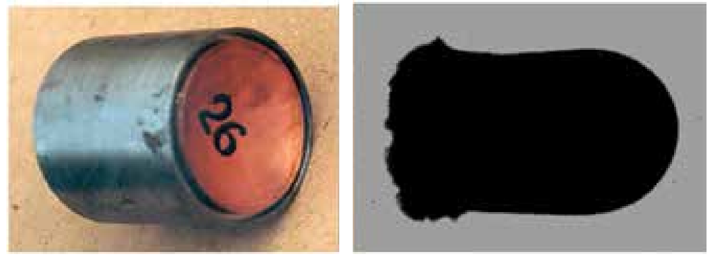
Explosively Formed Projectile (EFP) warhead is an explosive device in which a section of hemispherical liner of suitable material like soft iron, tantalum, molybdenum or copper is inserted in explosive cavity to form a high velocity projectile. These have both military and industrial applications to make deep holes in hard targets. The formation of EFP can be recorded using flash x-ray system. These records are useful for design validation.

Applications of Flash Radiography

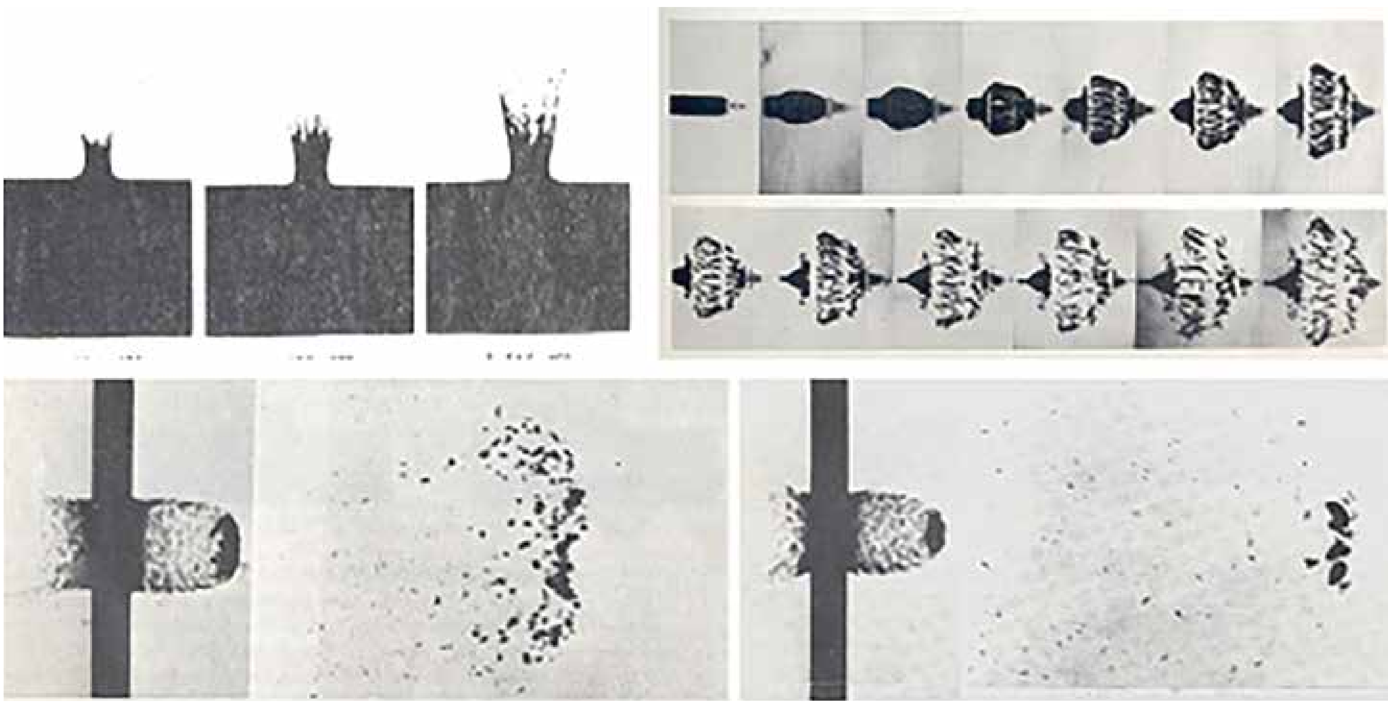
- Interior ballistics : Projectiles in bore, motion of mechanical parts, combustion and flow phenomena
- Intermediate ballistics : Projectile stability and integrity, sabot separation
- Terminal ballistics : Target penetration and perforation, fragmentation, velocity measurements
- Detonics : Detonation wave and shock wave formation and propagation, shaped charges
- Industrial : Casting, welding, power switching, quality control

- Medical : Wound ballistics, human body response to acceleration and impact
- Physical : Radiation studies, high speed photography

Terminal Ballistics Effects: Some projectile-target interactions have been recorded using 480 kV flash x-ray system. These records provide very useful input for warhead design.



Formation of explosively formed projectile



Hypervelocity impact, fragmenting shell and plate perforation

Insensitive Munitions Test Facility

TBRL has developed the capability of carrying out Insensitive Munitions (IM) compliance tests as per NATO standard and has also developed the SOP for the same.

IM Compliance Tests: The aim of this is to provide guidance on implementing the policy and requirements which has international traceability.

Scope: Provides references tests and test procedures for the assessment of safety, IM characteristics and hazard assessments for all munitions, munition subsystems and explosive devices.

Purpose : Provide a framework for the development of consolidated safety and IM assessment test program for munitions.

Application: This standard applies to all munitions, pyrotechnics munitions subsystems, fuzes, cartridge actuated devices, propulsion units, safe and arm devices, pyrotechnic devices, chemical payload and other explosive devices.

Criteria: Select the most probable, and credible stimuli that is expected to cause the greatest damage to life, property, or combat effectiveness.

Methodology of IM Assessment: The IM assessment is a process that evaluates how a munition will likely respond to the IM threats and whether it complies with the IM requirements.

The IM Assessment consists of:

- Identifying the threats
- Identifying the munition configurations
- Assessing the response of the munition to the threats
- Generating the IM signature for any particular configuration

Identifying the Threats: A number of threats to which a munition is likely to be exposed during its life cycle. Some of these threats are common to all munitions; others arise because of exposure of the munition to a specific operational or logistic environment.

Two other important aspects are:

- IM Assessment-A process to determine the compliance of a munition with the IM requirements.
- IM Signature/Reporting. A representation of the IM level of the munition, i.e., the response level to the various IM threats.

Threat Type	Stimuli	Test Procedure
Mechanical Threats	Bullet Impact (BI)	STANAG 4241
	Fragment Impact(FI)	STANAG 4496
	Shaped Charge Jet Impact (SCJI)	STANAG 4526
Combined Threats	Sympathetic Reaction (SR)	STANAG 4396
	Safety Drop Test	STANAG 4375
	Card Gap Tests	STANAG 4488
Thermal Threats	Fast Cook-off (FCO)	STANAG 4240
	Slow Cook-off (SCO)	STANAG 4382

Establishment of Shock Sensitivity Tests

Fast Cook-off Test

Representing a munition completely engulfed in a hydrocarbon fuel fire such as that resulting from an aircraft crash on a ship or road transport accident. Typically fast heating is represented by fires with temperatures exceeding 800 °C lasting upto twenty minutes. This scenario is also known as Fast Cook-Off.

Field set-up

Snapshots during the trial

Slow Cook-off Test

Representing heating of a munition by a remote heat source such as a fire in adjacent compartment or building. Typically slow heating is described by a constant heating rate of 3.3 °C/h until the munition reacts. This scenario is also known as Slow Cook-off.

Experimental set-up

Feedback for Technology Focus

We have been receiving a tremendous appreciation & good words on the contents, quality, and presentation of Technology Focus and we intend to continue with our efforts. The editorial team requests your support to further improving it. The feedback form as below would be one of the resource that would provide us your level of satisfaction and newer aspects you would want to incorporate in the Technology Focus.

Rate the ***Technology Focus*** as a medium to present DRDO's technology and product developments ?

☐ Excellent ☐ Good ☐ Satisfactory ☐ Needs improvement

Is ***Technology Focus*** highlighting developments of DRDO appropriately ? If no, kindly suggest ?

☐ Yes ☐ No

How do you rate the quality of photographs in the ***Technology Focus*** ?

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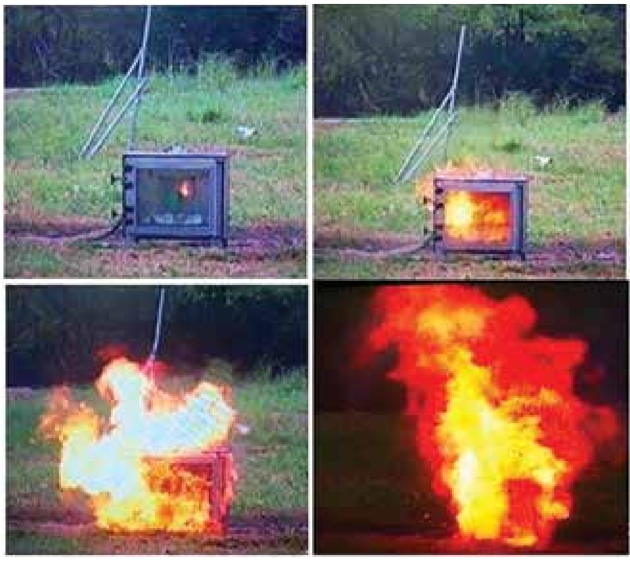


Snapshots after the trial

Trial results : Burning of propellant

Bullet Impact Test

This is a standard test procedure for determining the degree of reaction, if any, of amunition which are exposed to attack from bullets, i.e, to an impact against small arms fire like 5.56 mm INSAS, 7.62 mm SLR, 9.0 mm CARBINE, 12.7 mm AP Shot or other similar threats.

Bullet impact test

Warhead view with detonators and high speed video snapshots

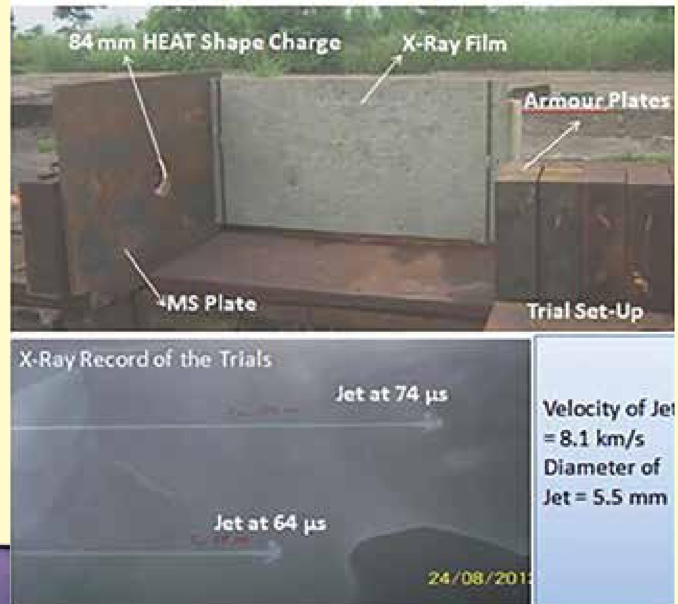
Fragment Impact Test

The purpose of the tests is to gather data and to evaluate the response of the test items to the fragment impact test conditions. This is a standard test procedure for determining the degree of reaction, if any, of a munition when hit by a typical fragment.

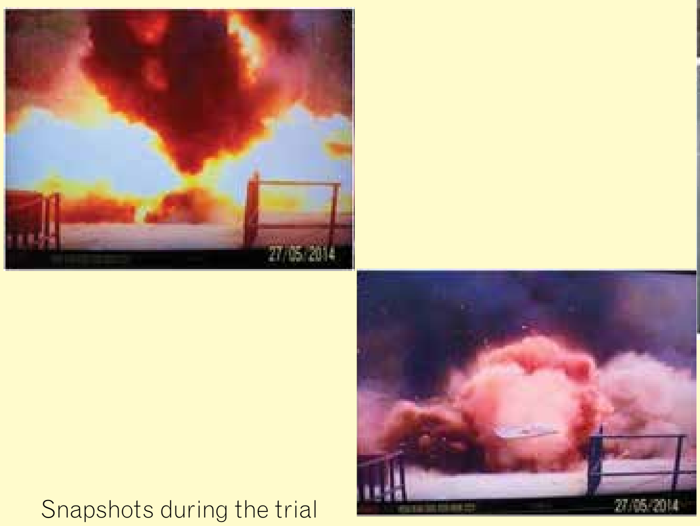
Field layout M2 aircraft gun

Shaped Charge Jet Impact Test

To ensure safety of bare and cased explosives against the jet from a shaped charge. This usually leads to the detonation of the energetic material in the target, since this mode of attack delivers the greatest concentration of power to a receptor of any of the insensitive munitions.



Measurement of jet velocity and diameter



Snapshots during the trial

Sympathetic Reaction Test

The principal factors affecting the response of a munition to the reaction of an adjacent munition are shock propagation effects reflected by the munition configuration. In addressing these factors and ensuring that they are covered for generating the worst response, which has the probability to occur in the munition life cycle.

Snapshots during the trial

Snapshots after the trial

Explosives, Shock Sensitivity Tests

The aim of this agreement is to establish test procedures which provide information on theshock sensitivity of explosive materials.

Field Layout

Experimentally calculated velocity history in propellant vs distance from interface

Witness plate after trial and large pieces of casing

Drop Test Facility

Instrumented and mechanised drop test facility is established at TBRL to study the impact of dropping the munition/warhead of weight upto 1500 kg from15 m height on the test surfaceas per STANAG 4375.

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