AD-A183 996 LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND 1/4
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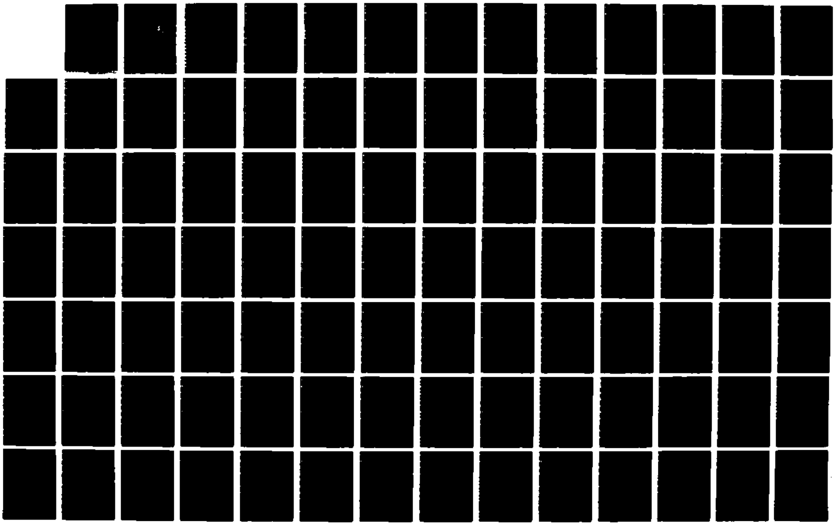

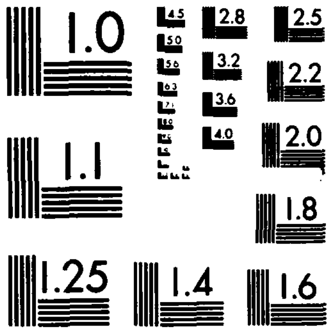
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Lightweight Towed Howitzer Demonstrator

Final Report

Volume F

Systems Engineering Analysis

(QA, Test Plans)

April 1987

Contract Number DAAA21-86-C-0047

FMC CORPORATION
Northern Ordnance Division
4800 East River Road
Minneapolis, Minnesota 55421

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The LTHD (Lightweight Towed Howitzer Demonstrator) was to be a 9,000 lb equivalent to the M198, transportable via Blackhawk helicopter, with reduced emplacement time using fewer personnel. The FMC design achieved weight reduction via a mortar-like configuration, composites structure, and hydraulic actuators. Recovery of power from the recoil system, in turn, facilitated crew reduction via hydraulic emplacement, four-way joystick tube lay, and power ramming. FMC completed Concept Development (Ph I) and two-thirds of Detailed Design (Ph II) prior to funds running out. Keywords:

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AUTHOR: Errol Quick

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E-xxxx

PRELIMINARY

PRIME ITEM DEVELOPMENT SPECIFICATION

FOR THE

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

Contract No. DAAAK21-86-C-0047
CDRL Sequence No. A003

15 APRIL 1987

Prepared For:

Commander, U.S. Army
Armament, Munitions and Chemical Command
Dover, New Jersey 07801

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Minneapolis, Minnesota 55421

TABLE OF CONTENTS

1. SCOPE

1.1 This specification establishes performance, design, development, and test requirements for the Lightweight Towed Howitzer Demonstrator System prime item.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. These documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

SPECIFICATIONS

FEDERAL

VV-F-800	Fuel Oil, Diesel
P-C-437	Cleaning Compound, High Pressure Cleaner

MILITARY

DOD-D-1000B	Drawings, Engineering and Associated Lists
MIL-F-17111	Hydraulic Fluid
MIL-F-16884	Fuel, Naval Distillate
MIL-G-3056	Gasoline, Automotive, Combat
MIL-P-116	Preservation, Packaging, Methods of
MIL-T-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5

Other Documents

STANDARDS

FEDERAL

FED-STD-595	Colors

MILITARY

DOD-STD-100	Engineering Drawing Practices
MIL-STD-130	Identification, Marking of U.S. Military Property
MIL-STD-470A	Maintainability Program For Systems and Equipment
MIL-STD-471	QA
MIL-STD-721C	Definitions of terms for Reliability and Maintainability
MIL-STD-785B	Reliability Program for Systems and Equipment Development and Production
MIL-STD-810D	Environmental Test Methods and Engineering Guidelines
MIL-STD-847A	Format Requirements for Scientific and Technical Reports
MIL-STD-882B	System Safety Program Requirements
MIL-STD-961A	Preparation of Military Specifications and Associated Documents
MIL-STD-1098	
MIL-STD-1472C	Human Engineering Design Criteria for Military Systems, Equipment and Facilities

MIL-STD-1474B	Noise Limits For Army Materiel
MIL-STD-1552A	Uniform Department of Defense Requirements for Provisioning Technical Documentation
MIL-STD-1561A	Provisioning Procedures, Uniform Department of Defense
MIL-STD-1944	Polymor Matrix Composites
MIL-STD-6083D	

Military Handbooks

MIL-HNDBK-472	Maintainability Prediction
MIL-HNDBK-759A	Human Factors Engineering Design for Army Materiel

2.1.2 Other Government documents, drawings and publications.

DRAWINGS

USA Armament Research and Development Command

12008000	Howitzer, Med, Towed, 155mm, M198
120079C	Body Assembly, Cradle (machining)
12007903	Body Assembly, Cradle (weldment)
12008200	Cradle Assembly, M39 155mm
12008100	Top Carriage Assembly
12008101	Top Carriage (machining) M39
9357756	155mm HIP Sys Interface drawing
11741626	Telescope, elbow M138
10554823	Mount, telescope & quadrant M172

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11741101	Telescope, panoramic M137
11727800	Mount, telescope & quadrant M171
12008185	Trunnion, right M39, 155mm HC
11741648	Alignment device
10554685	Mounting bracket assy for telescope and quadrant
11729606	support quadrant
11727834	Collar
11729530	M17 quadrant

Watervliet Arsenal

8768770	M198 Band
11579253	Barrel Assembly M199
11578962	Ballistic drawing, cannon 155mm, How M199

Benet Weapons Laboratory

WTV-F31771	Barrel assy, XM283 How Cannon 155mm
WTV-D30106	Thrust collar, 155mm HIP
WTV-F30077	XM283 Tube (muzzle end details)
11578887	Muzzle brake for M199 cannon
11578888	Muzzle brake (casting)

155mm Projectiles

92116352	M107 HE
9217030	M110A1 Smoke (WP)
7514317	M110 Chemical
8885162	M116 Smoke
8861029	M121 Chemical
8875850	M449 HE ICM

dwg ________	M454 Nuclear
9215220	M483A1 HE ICM (dual purpose)
9214150	M485 ILLUM
9235999-1	M549A1 HERA
dwg ________	M687 Binary
9198316	M692/M731 HE ADAM
9305300	M712 HE COPPERHEAD
9278014	M718 AT
11786215	M718E1 AT
9298316	M731 HE
9278014	M741 AT
11786240	M741E1
9331794	M804 PRACTICE
dwg ________	M825 SMOKE

PUBLICATIONS

U.S. ARMY

AR 70-44	Criteria for Air Transportation and Airdrop of Material

2.1.3 Other publications.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM-E-8-85	Methods of Tension Testing of Metallic Materials
ASTM-E-94	Guide for Radiographic Testing
ASTM-E-142	Method for Controlling Quality of Radiographic Testing
ASTM-E-238	Pin-Type Bearing of Metallic Methods
ASTM-C-393	Method of Flexural Test of Flat Sandwich Constructions

ASTM-E-407-70	Methods for Microetching Metals and Alloys
ASTM-D-695	Compressive Properties of Rigid Plastics
ASTM-D-790	Flexible Properties of Unreinforced Forced and Reinforced Plastics and Electrical Insulating Materials
ASTM-D-792	Specific Gravity and Density of Plastics by Displacement
ASTM-E-793	Heats of Fusion and Crystallization by Differential Scanning Colormetry (DSC)
ASTM-D-897	Tensile Properties of Adhesives Bonds
ASTM-D-1876	Peel Resistance of Adhesives
ASTM-D-2563	Recommended Practices for Classifying Visual Defects In Glass - Reinforced Plastics Laminates and Parts
ASTM-D-2584	Ignition Loss of Cured Reinforced Resins
ASTM-D-2734	Void Content of Reinforced Plastics
ASTM-D-3039	Tensile Properties of Fiber-Resin Composites
ASTM-D-3171	Fiber Content of Rosin-Matrix Composites by Matrix Digestion
ASTM-D-3355	Test Method for Fiber Content of unidirectional, Fiber Composites by Electrical Resistivity
ASTM-D-3410	Compressive Properties of Unidirectional or Crossply Fiber-Resin Composites
ASTM-D-3418	Transition Temperatures of Polymers by Thermal Analysis
ASTM-D-3518	Practice For In-Plane Shear Stress-Strain Response of Unidirectional Reinforced Plastics
ASTM-D-3528	Strength Properties of Double Lap Shear Adhesive Joints by Tension Loading

ASTM-D-3532	Gel Time of Carbon Fiber-Epoxy Prereg
ASTM-D-4065	Determining and Reporting Dynamic Mechanical Properties of Plastics

BOEING AIRCRAFT COMPANY

Boeing Material Specification 8 - 256F

Lockheed-Georgia Company

LG86BDR0005	Loadability/Transportability Characteristics of the USAF C-130H, C-141B, and C-5 Aircraft

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the contracting agency or as directed by the contracting officer.)

2.2 Precedence of documents. Should any conflict exist beteen the requirements of (1) the applicable documents listed in 2.1, (2) the contract, and (3) this specification, the order of precedence shall be:

a. Contract

b. This specification

c. Drawings and list of drawings

d. Military specifications

e. Military standards

f. Other government publications

g. Non-government documents

3. REQUIREMENTS

3.1 Prime Item Definition.

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3.1.1 Prime Item Diagrams. The LTHD systems breakdown structure and functional flow block diagrams are shown in Figures __ thru __.

3.1.2 Interface Definition.

3.1.2.1 Functional Interfaces -AMMUNITION INTERFACE

3.1.2.2 Physical Interfaces -

3.1.2.3 Major Components/sub assemblies.

3.1.3 Major Component List

3.1.4 Government Furnished Property List. The following items of Government-Furnished Equipment (GFE) shall be made available:

a. Fire Control Equipment -- M198 Fire Control System.

b. Cannon Assembly -- XM-284 Cannon with the following changes/exceptions:

* Lunette integral with titanium muzzle brake.
* Band is titanium.
* Center mount is taper-locked to yoke.
* Breech handle is replaced by a hex (for a wrench).
* Incorporation of autoprimer and thermal indicator.

c. Test Ammunition -- 155mm projectiles, bag and modular charges, fuzes and primers from the lists identified within paragraph ______ of this specification.

d. Test Facilities -- at Aberdeen Proving Grounds.

e. Detailed Interface Drawings -- of Government-Furnished Equipment, materials and components.

3.1.5 Government Loaned Property List. Non-applicable to this specification.

3.2 CHARACTERISTICS.

3.2.1 Performance. The LTHD shall provide and maintain the performance characteristics specified herein during and after exposure to the applicable environments specified in 3.2.5.

3.2.1.1 Firing rates.

3.2.1.1.1 Maximum rate of fire. The LTHD shall achieve the following maximum firing rates for standard-size rounds (assuming Swiss Notch will hold propellant in chamber at elevations up to 800 mils):

Firing Elevation	Maximum Rate of Fire
≤ 800 mils	4 rounds/min.
> 800 mils	1 round/min.

The LTHD shall be able to fire over-size rounds (COPPERHEAD) at a maximum rate of TBD rounds/min.

The LTHD shall be able to maintain the above specified maximum rates of fire for up to TBD minutes (to be determined by Benet Weapons Laboratory).

3.2.1.1.2 Sustained rate of fire. The LTHD shall be able to maintain a sustained firing rate of TBD rounds per minute (to be determined by Benet Weapons Laboratory).

3.2.1.2 Projectile delivery error. The LTHD shall be able to deliver the specified projectiles on target at the level of precision currently demonstrated by the M198. The delivery error associated with the LTHD material and ammunition elements shall not exceed a 3 mil CEP at maximum range, assuming "stable" Met conditions.

3.2.1.3 Range.

3.2.1.3.1 Maximum range. The LTHD shall provide fire support to maximum ranges equivalent to or better than the current M198. An rocket assisted projectile can reach a range of approximately 30 km.

3.2.1.3.2 Minimum range. The LTHD shall have a minimum range capability of 3.5 km or less (Z3).

3.2.1.4 Direct fire. The LTHD shall possess a direct fire capability which is at least equivalent to that of the M198.

3.2.1.5 Elevation. The LTHD cannon shall be able to elevate between the limits of -75 to + 1275 mils. Elevation rates shall be sufficient to allow achievement of the required firing rates. Elevation precision shall be sufficient to allow attainment of projectile delivery error specifications.

3.2.1.6 <u>Traverse</u>. The LTHD shall be able to traverse 400 mils to the right and left of the emplacement orientation. The traversal rates and precision shall be sufficient to allow achievement of the required firing rates and delivery error specifications.

3.2.1.7 <u>Firing stability</u>. The LTHD design should ensure weapon system stability under all specified firing conditions. The slide and hop reactions to firing shall not exceed those of the M198 for the respective worst case combinations of charge, gun-pointing, soil conditions and off-level weapon orientation.

3.2.1.8 <u>Fire control</u>. The LTHD design shall incorporate the M198 Fire Control System (to be provided GFE). Firing preparation activities, fire enable and post-fire activities performed by the LTHD shall be developed and defined in accordance with the functions, capabilities and limitations of the M198 Fire Control System.

3.2.1.9 Muzzel blast pressure.

3.2.2 <u>Physical Characteristics</u>.

3.2.2.1 <u>Weight</u>. The total weight of the LTHD shall not exceed 9000 pounds. This weight limit is the projected maximum load which can be tactically deployed by the UH60 BLK I MOD helicopter. The weight limit of 9000 pounds is the actual hook load, and does not include any allowance for ammunition or for slings/hardware that must be used by the UH60 to carry the LTHD.

3.2.2.2 <u>Size</u>. The LTHD size envelope specifications are identified below for the stowed, towing and firing configurations of the howitzer.

3.2.2.2.1 <u>Stowed Configuration</u>. The LTHD size limitations in a stowed configuration are driven by constraints associated with deployment from the C130 aircraft. The maximum allowable dimensions are as follows.

<u>Length</u> -- 38 feet.

<u>Width</u> -- The width shall be no greater than that of the M198 howitzer in its stowed configuration (110 inches).

Height -- The maximum allowed height for a stowed M198 howitzer is 84 inches. This height enables the M198 to clear the exit opening of the C130 as it tips and slides down the ramp during extraction via parachute.

The height allowance actually increases with the distance from the last part of the howitzer to exit the aircraft. Therefore a slight increase (to about 87 inches) in stowed height over that of the M198 is allowable on the LTHD, if the maximum height occurs further forward than on the M198.

3.2.2.2.2 Towing Configuration. The LTHD towing configuration size envelope shall be within that of the M198 which is as follows:

Length: 40'3"
Width: 9'2"
Height: 9'6"

3.2.2.2.3 Firing Configuration. The dimensional limits for the LTHD in a firing configuration should be determined via the design tradeoff process which seeks the proper balance of firing stability, survivability and operational deployment/emplacement considerations. As a guideline, the M198 firing size envelope is 37'2" X 25'9" X 9'6". The LTHD firing size envelope, while not restricted to these dimensions, should enable emplacement on a similar size piece of terrain (37-foot diameter circular area).

3.2.3 Reliability.

3.2.4 Maintainability. The LTHD shall be designed to achieve maintainability within the constraints provided herein.

3.2.4.1 Corrective-maintenance time.

3.2.4.2 Preventive-maintenance time.

3.2.4.3 Maintainability program.

3.2.5 Environmental Conitions. The LTHD system shall meet the requirements of this specification under extremes of temperature, humidity, shock, rain, dust, vibration and other environmental factors and induced factors to the extend specified below:

3.2.5.1 Natural Environment. The LTHD should be able to perform its missions and operate effectively under the natural environmental conditions described below:

Operating Temperature -- exposure to any ambient air temperature between -25 degrees F and +160 degrees F for up to 8 hours. (These temperature limits include the effects of winterization kit heating, solar radiation and internally generated heat.

Storage Temperature -- exposure to ambient air temperatures between -70 degrees F and +160 degrees F for extended periods.

Temperature Shock -- Per MIL-STD-810D, Method 503.

Humidity -- no degradation in performance during or after exposure to conditions of relative humidity up to 99% per MIL-STD-810D Procedure II.

Waterproofness -- Per MIL-STD-810D, Method 512.2.

Dust -- Per MIL-STD-810D, Method 510,Procedure 1.

It should be possible to perform all LTHD functions under adverse weather conditions (high winds, rain, snow, sleet, fog, etc.) day or night.

3.2.5.2 Self-induced Environment. The LTHD should be able to perform its missions and operate effectively under the self-induced (or interface-induced) conditions described below:

Shock --The LTHD shall be capable of operating in the sustained high shock and vibration environment associated with cross-country towing (Use MIL-STD-810D, Method 514.2 as a guide). All components shall also withstand repeated gun firing shock conditions.

Vibration -- conditions which consist of imposing sinusoidal vibrations of 0.40 inch double amplitude from 1 to 14 Hz and 4g from 14 Hz to 500 Hz at the component mounting interface. Vibration frequency will be imposed at a logarithmic sweep rate of 20 minutes per sweep cycle (from 5 to 500 to 5 Hz) followed by 20 minute dwells at each resonant frequency (maximum of 4 frequencies). Total vibration time including dwells shall be 120 minutes. Use MIL-STD-810D as a guide.

<u>Chemicals</u> -- withstand exposure to vapors of or contact with the following for durations up to 48 hours:

1) Fuel per VV-F-800, MIL-T-5624, 1 MIL-G-3056, and MIL-F-16884.
2) Hydraulic Fluid per Standard Fire Retardent Spec. MIL-STD-6083D.
3) Cleaning Agents per P-C-437.

<u>Cleaning Spray</u> -- withstand water jet spray from 12 inches away applied perpendicular to the surface.

3.2.5.3 <u>Threat-imposed Environment</u>. Vulnerability to aerial bursts should be a primary consideration for design decisions and tradeoffs involving component placement and routing of cables, pipes, and hoses. The design should reflect selective use of shrouds as an additional means of physical protection.

The LTHD shall also be able to operate on an NBC-contaminated battlefield. To the maximum extent possible, the LTHD design should use materials which do not absorb NBC contaminants and are not affected by decontaminating solutions. The design should also facilitate decontamination of the LTHD (maximize smooth surfaces, minimize sharp/inaccessible corners).

Fire retardancy is also a necessary design consideration, especially when composite materials are used.

3.2.6 <u>Transportability</u>.

3.3 <u>DESIGN AND CONSTRUCTION</u>.

3.3.1 <u>Materials, processes, and parts</u>.

3.3.1.1 <u>Materials</u>.

3.3.1.1.1 <u>Dissimilar metals</u>. Dissimilar metals as defined in MIL-STD-889 shall not be used in direct contact with each other unless suitably protected against electrolytic corrosion.

3.3.1.2 <u>Processes</u>.

3.3.1.2.1 <u>Finish</u>.

3.3.1.2.2 <u>Threads</u>.

3.3.1.2.3 <u>Nondestructive inspection (NDI)</u>.

3.3.1.3 <u>Parts</u>.

3.3.1.4 Hydraulic power requirements.

3.3.1.5 Maintenance design. The LTHD system shall be designed to permit repair or replacement by USA personnel of an <u>TBD</u> skill level using common hand tools and repair equipment.

3.3.1.5.1 Accessability. The LTHD system shall be designed to provide access to the system and ammunition functions to the degree necessary to meet the requirements of this specification. MIL-STD-1472 shall be used as a guide for determining accessability requirements for system maintenance.

3.3.1.6 Lubrication. Means shall be provided for lubrication of moving parts involving material combinations which necessiate the use of lubricant. Lubricants shall be selected from those lists in MIL-STD-838.

3.3.2 <u>Electromagnetic Radiation</u>.

3.3.2.1 <u>Electromagnetic vulnerability</u>.

3.3.2.2 <u>Lightning and precipitation static</u>.

3.3.3 Name plates and Product Markings. Newly developed equipment, assemblies, subassemblies, and parts shall be marked for identification using MIL-STD-130 as a guide. Existing LRUs (either military or commerical) and support equipment end items shall retain their existing identification.

3.3.4 Workmanship. The LTHD system shall be manufactured and assembled with a quality of workmanship which ensures all delivered items are free of defeats which might effect the life, strength, or reliability and that all requirements of this specification are met.

3.3.5 Interchangeability. Unless otherwise specified on applicable drawings, all configuration end items shall be mechanically and functionally interchangeable with items having identical part numbers from the same or other items of the LTHD system without selection or fitting.

3.3.6 Safety.

3.3.6.1 Ammunition loading safety.

3.3.6.2 Safety during non-gunnery missions.

3.3.7 Human performance/human engineering. The LTHD system shall be designed, to the maximum extent possible, to comply with the requirements of MIL-STD-1472 except where they conflict with the requirements in the following paragraphs.

3.3.7.1 Equipment hardware.

3.3.7.1.1 Noise.

3.3.7.2 Maintenance. Maintenance requirements shall comply with MIL-STD-1472.

3.3.8 Hydraulic system construction. Hydraulic systems shall be designed, constructed, installed and meet all applicable requirements in accordance with MIL-________ . Hydraulic fluid shall meet the requirements of MIL-H-83282.

3.4 DOCUMENTATION. Data delivery requirements shall be set forth in the development contract.

3.5 LOGISTICS.

3.5.1 Maintenance. Maintenance functions shall be based upon the Maintenance Allocation Chart (MAC) derived from the Logistic Support Analysis.

3.5.1.1 Levels of maintenance. Maintenance shall be performed at the decribed levels below:

3.5.1.1.1 Organization level.

3.5.1.1.2 Direct support level.

3.5.1.1.3 Depot support level.

3.5.2 Supply. The LTHD system shall complement the following supply considerations:

a. The existing Government supply system shall be utilized to the maximum extent possible.

b. Modification requirements shall maximize use of standard or preferred parts, accessories and components unless single purpose peculiar items can be shown to be more cost effective.

c. Introduction of new items into the supply system shall be held to a minimum and methods of supply/re-supply of all items shall not require development of additional supply systems/reporting procedures.

3.5.2.1 Spares. Operational spares provisioning sahll be performed in accordance with MIL-STD-1561.

3.5.3 Facilities and facility equipment. The LTHD system and support equipment shall be capable of using existing US Army facilities to the maximum extent possible. These facilities shall include but are not limited to, training facilities, operational buildings, maintenance buildings,shops, and test facilities.

3.6 PERSONNEL AND TRAINING. The LTHD system shall be designed to provide for efficient operation and maintenance support by personnel properly trained in the use and care of the system. Requirements for special aptitude and training shall be kept to the lowest level commensurate with deploying an acceptable system.

3.6.1 Personnel. The LTHD system shall be designed to be operated and maintained by a crew of _____. The functions of emplacement, displacement and speed shifting shall only involve 4 personnel.

3.6.2 Training. Training courses shall be prepared and conducted as specified in the contract, for government operator and maintenance personnel. The operator course will serve to train crew personnel to operate the system and perform daily maintenance services.

3.7 MAJOR COMPONENT CHARACTERISTICS.

3.7.1

3.7.2

3.7.3

3.7.4

3.7.5

3.7.6

3.8 PRECEDENCE.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General. Verification of the performance and physical requirements specified in section 3 shall be accomplished using the evaluation methods of analysis, inspection, demonstration, similarity, and tests. A plan to include testing, and measuring shall be prepared, as specified in the contract, and submitted for approval by the procuring agency.

Tests shall consist of ....

4.1.1 Responsibility for tests. Unless otherwise specified, the contractor shall be responsible for the performance of the quality assurance provisions as defined in this specification. Through governemt approved test plans, the contractor may use data gathered from government tests and previous validation tests for possilbe qualification purposes. The procuring agency reserves the right to witness or separately perform any tests specified or otherwise certify any or all tests and inspections. Inspection records of the examination and tests shall be kept complete and available to the procuring agency.

4.1.1.1 Determination of compliance with requirements. Vertification shall form the basis for the determination that the requirements of this specification have been met. Measurements shall be made with instruments of the labotatory precision type whose accuracy has been certified to at least one tenth of the tolerance for the variable to be measured unless not attainable with existing measuring devices. Calibration shall be in accordance with MIL-STD-45662. The contractor shall maintain a record of vertification data to determine compliance with the requirements defined herein. Any adjustments, repairs, or maintenance performed on test articles shall be logged and become part of the test record available for inspection upon request. Compliance to the requirements of Section 3 shall be verified by methods identified in Section 4 as defined in Section 6.

4.1.1.2 Standard conditions. Unless otherwise specified in the test plans, all tests shall be conducted under standard conditions of ambient temperature, atmospheric pressure, and relative humidity, as specified herein.

Actual conditions shall be reported periodically during the inspection or test period and reported as part of the test results.

4.1.1.3 Rejection and retest. When an item fails to conform to the specification, acceptance shall be withheld until the extent and cause of the failure are determined. If the item cannot meet the requirement of this specification, the procuring agency may conditionally accept an item by specifying additional corrective measures to be accomplished by the manufacturer.

4.2 Quality conformance inspections. Each of the design requirements set forth in Section 3 of this specification shall be verified by the method stated in the following paragraphs. These vertification methods are summarized in Table _____ for information.

5.0 PREPARATION FOR DELIVERY

5.1 General. For purposes of shipment, the LTHD system shall be divided into the minimum practicable number of subassemblies.

5.2 Preservation, packaging, packing, and marking.

6.0 NOTES

6.1 Intended use.

6.2 Documents required. These documents shall be supplied by the contractor under the provisions of this specification (all data items must be specified on contract Form DD 1423):

Phase II.

Product Assurance Test Plan

Material Test Samples

Level II Drawings

Reliability Stress Analysis Report

Long Lead Items List

Performance and Cost Reports

Purchase Description (as required)

Agendas

Meeting Minutes

Tradeoff Analysis Report

Quality Program Plan

Demonstrator Specification

Updated PHA

Phase III

6.3 Ordering data. Procurement documents for equipment covered by this specification shall specify the following:

a. Title, number, and date of this specification

b. Quantity of equipment on order

c. Name and address of technical directing agency

d. Serial numbers to be assigned to equipment

e. Whether or not qualification is required

f. Date required for delivery

g. Level of packaging and marking

6.4 Definitions.

6.4.1 Specification terminology.

a. Test - A method of verification of compliance with requirements denoting the qualitative determination of the properties and parameters of item (or components thereof) by technical means requiring the use of laboratory equipment, procedures, items or services to determine conformance to specified requirements.

b. Demonstration - A method of verification of compliance with requirements involving a trial or test wherein it is established that equipment can be safetly operated and maintained and conforms with the contract requirements.

c. Analysis - Analysis is the mathematical process of resolving data into its primary elements to permit logical conclusions to be formed allowing direct determination that the data analyzed satisfies the purpose fpr the analysis. Specifications, drawings, test data and other related data are used. Mathematical simulations are considered an analysis tool.

d. Similarity - Similarity as used herein shall refer to the demonstration of compliance to design requirements for the purpose of qualifying a component by displaying commonality between the component and one of similiar design, manufacture, use and environmental exposure which has been previously qualified.

e. Failure - Any incident wherein the system or any of its assemblies, subassemblies, components, or parts operates outside of limits set by the appropriate specification. Malfunction due to government furnished equipment or human error will not be considered a failure.

f. Inspection - A method of vertification of compliance with requirements for physical characteristics, without the use of special laboratory equipment, procedures, items and services to determine conformance to speified requirements.

g. Contractor - The organization that contracts to manufacture the LTHD system.

h. Procuring agency - The organization that contracts to buy the LTHD system.

10.0 APPENDIX

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dtd 14 Oct -

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR (LTHD)

~~PRELIMINARY DESIGN~~ SPECIFICATIONS

PHASE I -- JUNE 1986

Updated - Working Copy -

LTHD PRELIMINARY DESIGN SPECIFICATIONS
OUTLINE

1. PROGRAM SCOPE

1.1. OBJECTIVES

The primary objective of the LTHD project is to conceptualize, design and fabricate a 155mm technology demonstrator which can meet or exceed the performance characteristics of the M198 howitzer, but in a much lighter configuration. The demonstrator shall not weigh more than 9000 pounds. This represents a substantial reduction from the 15,760 pound weight of the M198.

The LTHD design objectives are to maximize system effectiveness, reliability, flexibility, safety, simplicity and maintainability while minimizing the overall size, weight, vulnerability and cost. The resulting LTHD design should reflect the proper balance of deployability, mobility, firepower, survivability and supportability. The specifications associated with each of these major areas are described within Section 2 of this document. The current system description is also attached for reference purposes.

1.2. GOVERNMENT-FURNISHED MATERIAL

The following items of Government-Furnished Material (GFM) have been requested:

1) Fire Control Equipment -- M198 Fire Control System.

2) Cannon Assembly -- XM-284 Cannon with the following changes/exceptions:

- o Lunette integral with titanium muzzle brake.
- o Band is titanium.
- o Center mount is taper-locked to yoke.
- o Breech handle is replaced by a hex (for a wrench).
- o Incorporation of autoprimer and thermal indicator are considered proven technology and thus beyond the scope of this project.

3) Test Ammunition -- 155mm projectiles, bag and modular charges, fuzes and primers from the lists identified within Section 2.4.2. of this document.

4) Test Facilities at Aberdeen Proving Grounds.

5) Detailed Interface Drawings for Government-Furnished components.

2. LTHD DESIGN SPECIFICATIONS

2.1. PHYSICAL CHARACTERISTICS

2.1.1. SIZE

The LTHD size envelope specifications are identified below for the stowed, towing and firing configurations of the howitzer.

2.1.1.1. STOWED CONFIGURATION

The LTHD size limitations in a stowed configuration are driven by constraints associated with deployment from the C130 aircraft. The maximum allowable dimensions are as follows.

Length -- 38 feet. M198 = 24'8"

Width -- The width shall be no greater than that of the M198 howitzer in its stowed configuration (110 inches).

Height -- The maximum allowed height for a stowed M198 howitzer is 84 inches. This height enables the M198 to clear the exit opening of the C130 as it tips and slides down the ramp during extraction via parachute.

The height allowance actually increases with the distance from the last part of the howitzer to exit the aircraft. Therefore a slight increase (to about 87 inches) in stowed height over that of the M198 is allowable on the LTHD, if the maximum height occurs further forward than on the M198.

2.1.1.2. TOWING CONFIGURATION

The LTHD towing configuration size envelope shall be within that of the M198 which is as follows.

Length: 40'3"

Width: 9'2"

Height: 9'6"

2.1.1.3. FIRING CONFIGURATION

The dimensional limits for the LTHD in a firing configuration should be determined via the design tradeoff process which seeks the proper balance of firing stability, survivability and operational deployment/emplacement considerations. As a guideline, the M198 firing size envelope is 37'2" X 25'9" X 9'6". The LTHD firing size envelope, while not restricted to these dimensions, should enable emplacement on a similar size piece of terrain (37-foot diameter circular area).

2.1.2. WEIGHT

The total weight of the LTHD shall not exceed 9000 pounds. This weight limit is the projected maximum load which can be tactically deployed by the UH60 BLK I MOD helicopter. The weight limit of 9000 pounds is the actual hook load, and does not include any allowance for ammunition or for slings/hardware that must be used by the UH60 to carry the LTHD.

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2.1.3. DESIGN

2.1.3.1. STANDARDIZATION

The design should incorporate standard military parts, materials and hardware to the maximum extent possible.

2.1.3.2. PRODUCIBILITY

The design should reflect producibility considerations in that it may be manufactured without elaborate machinery or rare skills. Exotic materials requiring special machining or treating should be avoided.

2.1.3.3. SPECIAL REQUIREMENTS

- o The LTHD design shall maintain ballistic similitude with the M198 howitzer to the extent practical.
- o The maximum impulse to be imparted to the recoil mechanism is 12,500 lbs. sec.
- o Standard hydraulic fluid shall be used per MIL-STD-6083.
- o The LTHD design shall integrate and effectively interface with the GFE items listed in Section 1.2. of this document.

2.2. DEPLOYMENT

2.2.1. AIR TRANSPORT AND DEPLOYMENT

The LTHD shall be transportable and deployable via fixed-wing aircraft and helicopters. The requirements associated with air transport and deployment are presented below.

2.2.1.1. FIXED-WING AIRCRAFT

The LTHD design shall allow it to be loaded, transported and deployed from C-130E, C-141 and C-5 aircraft. The design shall take into account all mechanical interfaces (i.e. attachment/release points) with these aircraft. It shall also permit interface with the ground support vehicles/hardware used to load and offload these aircraft.

The LTHD shall be Low Altitude Parachute Extraction System (LAPES) certified and able to withstand the deployment forces and shocks associated with air drops. It should remain aerodynamically stable during its separation from the aircraft and throughout the parachute descent. It shall remain upright upon ground impact and withstand impact shock loads of 15 to 20 g's.

2.2.1.2. HELICOPTERS

The LTHD design shall enable it to be airlifted by the UH60 Blackhawk BLK I MOD helicopter, which is expected to have a maximum lift capability of 9000 pounds. This requirement is the driver of the significant weight reduction on the LTHD over that of the M198. It shall also be possible to airlift the LTHD with the helicopters used to transport the M198 howitzer (CH-47C and larger helicopters).

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The LTHD design shall provide sling attachment points which allow stable lift operations by the helicopters designated to transport the howitzer.

2.2.2. VEHICLE INTERFACE

The LTHD shall be towable by designated tactical trucks from the Army's present inventory. This includes the M813 5-ton cargo truck and the M548 6-ton tracked cargo carrier which currently can tow the M198 howitzer. It shall also be possible to tow the LTHD with the M992 Field Artillery Ammunition Support Vehicle (FAASV).

Requirements associated with the towing vehicle interface include the following:

- LTHD ground clearance may not be less than that of its designated towing vehicles; this requires that a ground clearance of at least 10.5 inches be provided.

  A turning radius of at least TBD feet shall be achieveable with either the M813 or the M548 towing the LTHD.

  LTHD towing configuration shall minimize the risk of hitting roadside obstacles during towing; design shall limit the vulnerability of critical components to towing damage.

  It should be possible for 4 crew members to couple and uncouple the LTHD from its towing vehicle.

2.3. TACTICAL MOBILITY

2.3.1. TOWING SPEEDS AND STABILITY

The LTHD shall remain stable at the following maximum towing speeds:

- o Cross-Country ------------ 5 mph
- o Secondary Roads ---------- 25 to 30 mph
- o Improved Roads ----------- 45 mph

The LTHD should remain more stable than the M198 under all towing conditions, including rough cross-country terrain, sharp turns and towing on side slopes.

2.3.2. FIRING POSITION

It shall be possible to deploy and fire the LTHD from any position used to fire the M198 howitzer. This includes type of terrain/soil, amount of area needed to deploy the weapon, and off-level terrain allowances. These requirements are as follows:

It shall be possible to deploy the LTHD on all types of solid terrain, ranging from desert sand to rocky surfaces.

The LTHD shall be operationally deployable within a circular area 37 feet in diameter.

It shall be possible to load and fire the LTHD from the following worst case off-level weapon orientation:

Maximum terrain slope = 10-degree cant

2.3.3. WEAPON EMPLACEMENT

The LTHD shall be emplaceable by a four-person crew in 3 minutes or less (up to the point of laying the weapon), assuming it has been previously disconnected from the helicopter or truck which transported it to the emplacement site.

2.3.4. WEAPON DISPLACEMENT

It shall be possible for a four-person crew to change the LTHD from a firing configuration to a towing or stowed configuration in 3 minutes or less. This time allowance does not include attaching the LTHD to the towing vehicle or helicopter slings.

2.3.5. SPEED SHIFTING

The LTHD design shall allow a four-person crew to shift the howitzer through 6,400 mils in 3 minutes or less.

2.4. FIREPOWER

2.4.1. OPERATIONAL PERFORMANCE

The LTHD should have performance characteristics equal to or better than the M198 howitzer.

2.4.1.1. ELEVATION

The LTHD cannon shall be able to elevate between the limits of -75 to + 1275 mils. Elevation rates shall be sufficient to allow achievement of the required firing rates. (Elevation rate requirement is an output of timeline budget tradeoff analyses.) Elevation precision shall be sufficient to allow attainment of projectile delivery error specifications. (Elevation precision requirement is an output of error budget tradeoff analyses.)

2.4.1.2. TRAVERSE

The LTHD shall be able to traverse 400 mils to the right and left of the emplacement orientation. As was the case for elevation, the traversal rates and precision shall be sufficient to allow achievement of the required firing rates and delivery error specifications.

2.4.1.3. FIRING RATES

2.4.1.3.1. MAXIMUM RATE OF FIRE

The LTHD shall achieve the following maximum firing rates for standard-size rounds (assuming Swiss Notch will hold propellant in chamber at elevations up to 800 mils):

Firing Elevation	Maximum Rate of Fire
≤ 800 mils	4 rounds/min.
> 800 mils	1 round/min.

The LTHD shall be able to fire over-size rounds (COPPERHEAD) at a maximum rate of TBD rounds/min.

The LTHD shall be able to maintain the above specified maximum rates of fire for up to TBD minutes (to be determined by Benet Weapons Laboratory).

2.4.1.3.2. SUSTAINED RATE OF FIRE

The LTHD shall be able to maintain a sustained firing rate of TBD rounds per minute (to be determined by Benet Weapons Laboratory).

2.4.1.4. RANGE

The LTHD shall provide fire support to maximum ranges equivalent to or better than the current M198. The M198 can deliver rocket-assisted projectiles to 30.1 km.

The LTHD shall have a minimum range capability of 3.5 km or less (Z3).

The LTHD shall also possess a direct fire capability which is at least equivalent to that of the M198.

2.4.1.5. PROJECTILE DELIVERY ERROR

The LTHD shall be able to deliver the specified projectiles on target at the level of precision currently demonstrated by the M198. The delivery error associated with the LTHD material and ammo elements shall not exceed a 3 mil CEP at maximum range, assuming "stable" Met conditions.

2.4.1.6. FIRING STABILITY

The LTHD design should ensure weapon system stability under all specified firing conditions. The slide and hop reactions to firing shall not exceed those of the M198 for the respective worst case combinations of charge, gun-pointing, soil conditions and off-level weapon orientation.

2.4.1.7. FIRE CONTROL

The LTHD design shall incorporate the M198 Fire Control System (to be provided GFE). Firing preparation activities, fire enable and post-fire activities performed by the LTHD shall be developed and defined in accordance with the functions, capabilities and limitations of the M198 Fire Control System.

2.4.2. AMMUNITION INTERFACE

2.4.2.1. PROJECTILES

The LTHD should be capable of loading and firing all 155mm projectiles which are presently in inventory. This includes the following:

-- M107 HE

-- M110 SMOKE

-- M110 CHEMICAL

-- M116 SMOKE

-- M121 CHEMICAL

-- M449 HE ICM

-- M454 NUCLEAR

-- M483A1 HE ICM

-- M485 ILLUM

-- M549A1 HERA

-- M687 BINARY

-- M692/M731 HE ADAM

-- M712 HE COPPERHEAD

-- M718/M741 HE RAAM

-- M804 PRACTICE

-- M825 SMOKE

2.4.2.2. CHARGES

The LTHD should be able to load and fire using the following propelling charges:

- -- M3A1 GREEN BAG (Z5 or less)
- -- M4A2 WHITE BAG (Z3-7)
- -- M119/M119A1 WHITE BAG (Z8)
- -- M119A2 RED BAG (Z7)
- -- M203 RED BAG (Z8S)
- -- Unique Charge used for M454 NUCLEAR Projectile
- -- Modular Charges currently under development

2.4.2.3. FUZES

Projectile/fuze combinations fired from the LTHD should include all such combinations currently fired from the M198. This includes the following types of fuzes -- Impact/Point Detonating, Mechanical Timer, Mechanical Timer Super Quick, Electronic Timer, and Proximity.

2.4.2.4. PRIMER

The LTHD design should make allowances (weight, space and functional interface) for an automatic primer insertion capability consistent with achievement of the maximum rate of fire specifications in paragraph 2.4.1.3.

2.4.3. POST-FIRE ACTIVITIES

2.4.3.1. ROUTINE FUNCTIONS

Following each firing, the LTHD shall be readied for loading of the next round within the time budget associated with achievement of the maximum firing rate specifications. The design shall provide a self-swabbing capability between each round.

2.4.3.2. ABNORMAL ACTIVITIES

The LTHD design shall enable development of safe, effective procedures to handle misfires, hangfires, stickers and cookoff situations.

2.5 ENVIRONMENT

2.5.1. NATURAL ENVIRONMENT

The LTHD should be able to perform its missions and operate effectively under the natural environmental conditions described below:

Operating Temperature -- exposure to any ambient air temperature between -25 degrees F and +160 degrees F for up to 8 hours. (These temperature limits include the effects of winterization kit heating, solar radiation and internally generated heat.

Storage Temperature -- exposure to ambient air temperatures between -70 degrees F and +160 degrees F for extended periods.

Temperature Shock -- Per MIL-STD-810D, Method 503.

Humidity -- no degradation in performance during or after exposure to conditions of relative humidity up to 99% per MIL-STD-810D Procedure II.

Waterproofness -- Per MIL-STD-810D, Method 512.2.

Dust -- Per MIL-STD-810D, Method 510,Procedure 1.

It should be possible to perform all LTHD functions under adverse weather conditions (high winds, rain, snow, sleet, fog, etc.) day or night.

2.5.2. SELF-INDUCED ENVIRONMENT

The LTHD should be able to perform its missions and operate effectively under the self-induced (or interface-induced) conditions described below:

Shock -- operate in sustained high shock and vibration environment associated with cross-country towing (Use MIL-STD-810D, Method 514.2 as a guide). All components shall also withstand repeated gun firing shock conditions.

Vibration -- withstand conditions which consist of imposing sinusoidal vibrations of 0.40 inch double amplitude from 1 to 14 Hz and 4g from 14 Hz to 500 Hz at the component mounting interface. Vibration frequency will be imposed at a logarithmic sweep rate of 20 minutes per sweep cycle (from 5 to 500 to 5 Hz) followed by 20 minute dwells at each resonant frequency (maximum of 4 frequencies). Total vibration time including dwells shall be 120 minutes. Use MIL-STD-810D as a guide.

Chemicals -- withstand exposure to vapors of or contact with the following for durations up to 48 hours:

1) Fuel per VV-F-800, MIL-T-5624, 1 MIL-G-3056, and MIL-F-16884.
2) Hydraulic Fluid per Standard Fire Retardent Spec. MIL-STD-6083D.
3) Cleaning Agents per P-C-437.

Cleaning Spray -- withstand water jet spray from 12 inches away applied perpendicular to the surface.

2.5.3. THREAT-IMPOSED ENVIRONMENT

Vulnerability to aerial bursts should be a primary consideration for design decisions and tradeoffs involving component placement and routing of cables, pipes, and hoses. The design should reflect selective use of shrouds as an additional means of physical protection.

The LTHD shall also be able to operate on an NBC-contaminated battlefield. To the maximum extent possible, the LTHD design should use materials which do not absorb NBC contaminants and are not affected by decontaminating solutions. The design should also facilitate decontamination of the LTHD (maximize smooth surfaces, minimize sharp/inaccessible corners).

Fire retardancy is also a necessary design consideration, especially when composite materials are used.

2.6. MANUAL INTERFACE

2.6.1. CREW

The LTHD shall be operable by a crew of no more than 11 personnel. The crew will consist of a section chief, a gunner, an assistant gunner, a driver, and up to 7 cannoneers. Manual tasks associated with operations of the LTHD shall be compatible with the range of human capabilities of the 5th to 95th percentile of the U.S. Army male population.

2.6.2. HUMAN FACTORS CONSIDERATIONS

The LTHD design shall reflect human factors engineering which will allow the crew and maintenance personnel to perform their assigned tasks under the stressful conditions of a battlefield engagement. The design shall enable manual tasks to be accomplished without excessive exertion and without exposing personnel to hazardous operations. The design should provide easy access to controls, indicators and any components requiring manual interface for routine operations (i.e. loading tray, etc.).

Specific human factors requirements and guidelines for the design of the LTHD include the following:

Operation of the LTHD shall not result in any adverse effects on the crew from noise and blast overpressure. Noise and blast overpressure shall conform to MIL-STD-1474 and MIL Handbook 759. Blast/overpressure data (amplitude and duration) shall be generated for each crew position.

Elevating and traversing controls and activation mechanism design shall conform with MIL-STD-1472 and MIL Handbook 759.

Design shall enable operation, maintenance and repair under MOPP IV and Arctic conditions.

The LTHD shall be operable, maintainable and repairable by soldiers in Educational Categories 1-4 per para. 2.0 (Document # DA PE-MPA-CS).

Reach distances, visual access and lifting requirements shall be in accordance with MIL-STD-1472 and MIL Handbook 759.

Fire control and communication component design/interface shall be in conformance with MIL-STD-1472 and MIL Handbook 759.

2.6.3. MANUAL BACKUP

To the maximum extent possible, the LTHD design shall provide manual-backup operating modes for mission critical functions.

2.7. MAINTENANCE AND SUPPORT OF DEMONSTRATOR

2.7.1. RELIABILITY AND MAINTAINABILITY GOALS

The LTHD design shall maintain M198 reliability and maintainability REQUIREMENTS ~~performance~~ in accordance with MIL-STD-785B and MIL-STD-470A. Design support efforts should include correlation between types of defects and associated performance degradation.

The LTHD shall achieve the following preliminary hardware reliability requirements ~~goals~~ to match the requirements ~~performance~~ of the M198 howitzer:

Corrective Maintenance MRBF = TBD

Combat Abort MRBF = ~~TBD~~ 1100 Rounds

The LTHD shall achieve the following preliminary maintainability requirements ~~goals~~ to match the requirements ~~performance~~ of the M198 howitzer:

Mean Time to Repair ~~= TBD~~ (Organizational Maintenance) = 0.5 hours
" " " " (Direct Support Maintenance) = 2.0 hours

~~Mean Manhours to Repair = TBD~~

2.7.2. SELF-MONITORING

The LTHD design should incorporate the internal sensors, indicators, and gauges needed to enable the crew to monitor the operating condition of the howitzer. A primary function of these sensors will be to provide early indications of potential problems and thereby prevent or reduce personnel hazards and equipment damage.

2.7.3. MAINTENANCE AND REPAIR

The LTHD design should stress simplicity and allow for modular field replacement of subsystems. LTHD field maintenance activities shall be accomplished, to a large extent, by the crew members assigned to the weapon. Maintenance and repair activities shall make use of common tools and support equipment; the use of unique/special tools and equipment shall be strictly limited.

The LTHD design should enable operations in degraded modes until proper repairs can be made. The design should strive to limit the impact of component failures and crew reductions on mission performance.

The design shall minimize the time the crew must spend performing routine/scheduled maintenance on the LTHD. It shall enable manual access to LTHD components during scheduled and unscheduled maintenance without exposing personnel to hazardous conditions.

2.7.4. DEMONSTRATOR SPARES, TOOLS AND S&TE

The spares, tools and support and test equipment (S&TE) needed to troubleshoot, maintain and repair the LTHD shall be identified prior to any and all demonstration firings.

DESCRIPTION: RISK ANALYSIS REPORT

STATUS: The Risk Analysis Report was prepared 30 January 1987 and reflects well the current configuration as of 13 March 1987. One final risk analysis review of the system at Phase II completion would be recommended to ensure completeness of the analysis.

AUTHOR: Errol Quick

Risk Management
for the
Lightweight Towed Howitzer Demonstrator
(Updated Report)

Risk management begins with the identification of uncertainties at the highest level of WBS planning and continues through the task planning of the individual WBS task and subtask levels. Uncertainties, unknowns, inconsistencies, or even areas of unusual complexity are identified at each significant milestone in the design process and are evaluated as to their impact on performance, schedule, and cost. Alternatives that present near-term promises of alleviating the risk will be identified and evaluated as corrective options and, when acceptance of risk is deemed necessary, contingency plans will be developed.

The risk management process designed for the LTHD program is based on the early identification, assessment, and control of the risks associated with meeting performance criteria of critical parameters identified by the Technical Performance Measurement (TPM) process.

Prepared By:
Errol A. Quick
LTHD Systems Engineer
30 January 1987

1. Risk Identification and Assessment

The TPM process identifies the LTHD performance criteria which are critical to system success. In addition, it also associates each of these critical criteria with the WBS elements essential for achieving the required performance values. To arrive at a preliminary identification of the risk associated with these essential WBS items, members of the LTHD program team assessed the probability of failure (Pf) and consequences of failure (Cf) for each essential WBS element. Based on the team's assessment, a preliminary risk factor (Rf) value was established for WBS items noted in chart 1.

Based on the calculated risk factor (Rf), the essential WBS elements were determined to have a low, medium, or high risk. The breakdown that was used for this determination was as follows:

Risk Factor	Assessed Risk
$0.1 \leq Rf \leq 0.55$	Low
$0.55 < Rf \leq 0.8$	Medium
$Rf > 0.8$	High

2. Change in risk factors.

As we all know, the risk factors associated with corresponding WBS elements will change as the TPM criteria become fully defined, as new risk areas are identified, or as new information on current risk areas becomes available.

During the past few months we have lowered the risk of the program in a number of areas. Chart 2 was presented during the design review at ARDEC on 15 January 1987. The probability, consequence and risk factors which have changed during our TPM process are highlighted by the boxes. There have been two items added to the Chart 2 matrix: the rail assembly and the fire control linkage. One item was deleted: the claws.

3. Justification for Change in risk factors.

a. Primer Autoloader. The probability of failure due to complexity and dependence as well as consequence factors have been reduced. The operating linkage has been simplified and a capability now exists for manual cyclying. This area was previously listed as a medium to high risk (.817).

b. Cradle. The risk factor of the cradle has been lowered from (.841) to (.783) because the design utilizes readily available hand laying techniques and can be locally reinforced if needed. Testing has been added to evaluate the critical joints to minimize the risks. We are still assigning a medium to high risk to this area for our management purposes.

c. Trails. The trail design is now of conventional construction with areas being easily reinforced if necessary. Manufacturing processes are being valided by test. The risk factor has decreased from a high risk (.841) to a medium risk (.599).

d. Gimbal. Probability and consequence factors have been lowered because the design is of a conventional box beam construction. The welding procedures that will be utilized are being validated by test. Additionally, localized reinforcement is practical if necessary. The rating of medium risk has not changed.

e. Recoil Mechanism. The risk factor of (.841) has been lowered to (.683) for a medium risk rating. The main reason for lowering the factors was that the recoil system is similiar to existing designs with the added variable of the long length. In addition, the recoil system can be isolated from the other hydraulics in the event of a malfunction.

f. Inertial Rammer. Previously this item was called the flick rammer, but the name was changed to deplict its proper function. The risk factor has decreased from (.754) to (.599) based on that the long stroke inertial rammer utilizes conventional hydraulics. Testing is proposed to validate that the hydraulics circuit provides controlled ramming under all environmental extremes. The assembly still maintains a medium risk assignment.

g. Spade. The rating of the spade has decreased from a medium risk to one of a low risk. The spade design is simplified titanium weldment. The areas in contact with the ground has increased and the part can be locally reinforced if required.

4. Risk Program Management.

The Program Manager along with the project and systems engineers will still follow the elements listed in chart 2. The risk identification and tracking is the responsibility of every program team member. Should a team member identify a new element of risk or believes that a risk factor should be changed he or she will notify the systems engineer.

CHART 1

WBS Element	Description	Probability Factors Pm	Pc	Pd	Consequence Factors Ct	Cc	Cs	Avg. Prob. Factor	Avg. Consequ. Factor	Risk Factor	Rating
11100	Int/assby	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557	
11200	Cannon										
	Tube	GFE									
	Muzzel Brake	0.3	0.3	0.5	0.3	0.3	0.3	0.367	0.300	0.557	
	Breech	GFE									
	Primer Autoloader	0.5	0.5	0.9	0.7	0.3	0.5	0.633	0.500	0.817	M-H
11300	Carriage										
	Cradle	0.5	0.3	0.9	0.9	0.5	0.5	0.567	0.633	0.841	M-H
	Trails	0.7	0.5	0.5	0.9	0.5	0.5	0.567	0.633	0.841	M-H
	Gimbal	0.5	0.5	0.5	0.5	0.5	0.5	0.500	0.500	0.750	M
	Platform	0.3	0.1	0.3	0.3	0.3	0.3	0.233	0.300	0.463	
	Wheel units	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
	Recoil Mechanism	0.5	0.5	0.9	0.7	0.5	0.5	0.633	0.567	0.841	M-H
	Equilibrators	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557	
	Hydraulics	0.5	0.5	0.5	0.7	0.5	0.5	0.500	0.567	0.783	M-H
	Flick Rammer	0.7	0.5	0.5	0.7	0.3	0.3	0.567	0.433	0.754	M
	Load Tray	0.3	0.1	0.1	0.1	0.1	0.1	0.167	0.100	0.250	
	Spade	0.3	0.1	0.3	0.7	0.3	0.3	0.233	0.433	0.566	
	Claws	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557	
11400	Fire Control										
	Elevation	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
	Traverse	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	

Pm = probability of failure due to maturity
Pc = probability of failure due to complexity
Pd = probability of failure due to dependency on other items
Ct = consequence of failure due to technical factors
Cc = consequence of failure due to changes in cost
Cs = consequence of failure due to changes in schedule

CHART 2

WBS Element	Description	Probability Factors Pm	Pc	Pd	Consequence Factors Ct	Cc	Cs	Avg. Prob. Factor	Avg. Consequ. Factor	Risk Factor	Rating
11100	Int/assby	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557	L-M
11200	Cannon										
	Tube	GFE									
	Muzzel Brake	0.3	0.3	0.5	0.3	0.3	0.3	0.367	0.300	0.557	L-M
	Breech	GFE									
	Primer Autoloader	0.3	0.3	0.5	0.5	0.1	0.1	0.367	0.233	0.514	L-M
	* Rail Assembly	0.3	0.1	0.3	0.3	0.1	0.3	0.233	0.233	0.412	
11300	Carriage										
	Cradle	0.5	0.3	0.9	0.9	0.3	0.3	0.567	0.500	0.783	M-H
	Trails	0.5	0.3	0.3	0.5	0.3	0.3	0.367	0.367	0.599	M
	Gimbal	0.5	0.3	0.3	0.5	0.3	0.3	0.367	0.36[illegible]	0.599	M
	Platform	0.3	0.1	0.3	0.3	0.3	0.3	0.233	0.300	0.463	
	Wheel units	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
	Recoil Mechanism	0.5	0.5	0.5	0.5	0.3	0.3	0.500	0.367	0.683	M
	Equilibrators	0.3	0.3	0.3	0.5	0.3	0.3	0.300	0.367	0.557	M
	Hydraulics	0.5	0.5	0.5	0.7	0.5	0.5	0.500	0.567	0.783	M-H
	Inertial Rammer	0.3	0.3	0.5	0.5	0.3	0.3	0.367	0.367	0.599	M
	Load Tray	0.3	0.1	0.1	0.1	0.1	0.1	0.167	0.100	0.250	
	Spade	0.3	0.1	0.1	0.3	0.1	0.1	0.167	0.167	0.306	
11400	Fire Control	GFE									
	Elevation	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
	Traverse	0.1	0.3	0.3	0.1	0.3	0.3	0.233	0.233	0.412	
	* Linkage	0.3	0.1	0.1	0.1	0.1	0.1	0.167	0.100	0.250	

Pm = probability of failure due to maturity
Pc = probability of failure due to complexity
Pd = probability of failure due to dependency on other items
Ct = consequence of failure due to technical factors
Cc = consequence of failure due to changes in cost
Cs = consequence of failure due to changes in schedule
* = Added to list
NOTE: Claws were deleted

DESCRIPTION: PRELIMINARY HAZARD ANALYSIS

STATUS: The Preliminary Hazard Analysis is complete as of January 1987 and accurately represents (with some very minor changes) the status of the current 13 March 1987 LTHD configuration.

AUTHOR: Tom Hillstrom

PRELIMINARY HAZARD ANALYSIS

FOR

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

Prepared for the U.S. Army Armament Research and Development Center

under Contract

DAAA21-86-C-0047 CDRL A001

System Safety Hazard Analysis and Preliminary Hazard Analysis Report

per

DI-H7048B, as tailored to only address paragraphs 10.1.1 and 10.2.1

January 1987

FMC Corporation
Northern Ordnance Division
4800 East River Road
Minneapolis, Minnesota 55421

PRELIMINARY HAZARD ANALYSIS
FOR
LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR

1.0 INTRODUCTION

System safety activities are an integral part of the concept development of the Lightweight Towed Howitzer Demonstrator (LTHD). Using a systems engineering approach, safety will be a part of all future design reviews. At each design review, the Preliminary Hazard Analysis (PHA) will be a base document for identifying safety hazards and formulating corrective action using the following order of precedence: (1) eliminate the hazard, (2) provide a safeguard, (3) provide a warning, (4) provide training.

Research from a wide variety of sources was incorporated into this PHA. Material was supplied from the U.S. Army Safety Center, from records of industrial safety, MIL STD's and FMC's own, in-house safety standards and practices.

Program system safety objectives will be in accordance with MIL-STD-882B to ensure that:

1. Safety consistent with mission requirements is designed into the system in a timely, cost-effective manner.

2. Hazards associated with each system are identified, evaluated, and eliminated, or the associated risk reduced to a level acceptable to the managing activity (MA) throughout the entire life cycle of a system.

3. Historical safety data, including lessons learned from other programs, are considered and used.

4. Minimum risk is sought in accepting and using new design and materials.

2.0 METHOD

Hazards can be identified through many sources. Historical data is particularly helpful. In this context the U.S. Army Safety Center was asked to provide a record of all recent accidents on the M109 howitzer, M198 howitzer and airlift sling load accidents. These sources show a significant number of accidents being caused from dropping heavy projectiles or from the close proximity of the cannoneer to the howitzer breech. These two hazards should be significantly reduced in the new lightweight howitzer design.

Hazards are also identified by identifying sources of high energy which if not properly controlled can be dangerous. As always the analysis considers not only the primary system but also the associated support equipment, personnel, environmental exposures, and interfacing systems. Therefore the PHA includes items from the ammunition, towing and lifting vehicles.

Energy sources are hazardous and as such are fundamental to the safety analysis. Generic energy sources include kinetic, potential, chemical and electrical. Kinetic sources are represented by the moving vehicle and machinery. High potential sources include stored pressure and system mass. Chemical sources are present in the ammunition, hydraulic fluid, NBC agents and NBC decontaminates. Electrical sources are present in static electricity during helicopter lift.

The presence of an energy source is not necessarily hazardous unless system events can cause the energy to become uncontrolled. Typical causes leading to loss of control include human error, component failure and external forces such as hostile fire. Thus a typical hazard identification will begin by identifying a possible system event leading to a hazardous loss of control. A close working relationship is maintained between human factors, reliability and safety as human error or mechanical failure frequently generate hazards. Energy sources are compared to the system events which can lead to loss of control in a Accident-Risk Factor Matrix presented as Attachment 1.

The preliminary Hazard Analysis Report presents a listing of identified hazards classified by subsystem and including the following information as specified by MIL-STD-882B.

(1) System/Subsystem/Unit. Enter the particular part of the system that this phase of analysis is concerned with. For example, if this item (or items) applies to a radar system modulator, enter "modulator." If there are several modulators in the system, be sure and clearly specify which one the analysis pertains to.

(2) System Event(s) Phase. The configuration or phase of the mission the system is in when the hazard is encountered, for example, during the maintenance, during flight, during pre-flight, full-power applies, etc., or it could be encountered in all system events.

(3) Hazard Description. A brief description of the hazard, for example, "Radiation leakage from radar set wave guide."

(4) Effect on System. The detrimental results that an uncontrolled hazard source could inflict on the system or personnel.

(5) Risk Assessment. An assigned risk assessment for each hazard as defined in MIL-STD-882B, paragraph 4.5, or contractually designated classification for severity and probability of occurrence.

(6) Recommended Action. A technical description of the recommended action to eliminate or control the hazard, for example, detailed design criteria, possible protective devices or special procedures. Include alternative designs criteria, possible protective devices or special procedures. Include alternative designs and cost impact where appropriate.

(7) Effect of Recommended Action. The effect of the recommended action on the assigned risk assessment.

(8) Remarks. Any information relating to the hazard not covered in the blocks, for example, applicable documents, previous failure data on similar systems, or administrative directions.

(9) Status. The status of actions to implement the recommended, or other hazard controls.

SEVERITY

Description	Category	Mishap Definition
CATASTROPHIC	I	Death or system loss
CRITICAL	II	Severe injury, severe occupational illness, or major system damage.
MARGINAL	III	Minor injury, minor occupational illness, or minor system damage.
NEGLIGIBLE	IV	Less than minor injury, occupational illness, or system damage.

PROBABILITY

Description	Level	Specific Individual Item	Fleet or Inventory
FREQUENT	A	Likely to occur frequently	Continuously Experienced.
PROBABLE	B	Will occur several times in life of an item.	Will occur frequently
OCCASIONAL	C	Likely to occur sometime in life of an item	Will occur several times
REMOTE	D	Unlikely, it can occur in life of an item	Unlikely, but can reasonably be expected to occur
IMPROBABLE	E	So unlikely, it can be assumed occurrence may not be experienced	Unlikely to occur but possible

In category 5, above, severities and probabilities are defined in accordance with the following definitions taken from MIL-STD-882B. In general all catastrophic, category I and critical category II hazards shall be eliminated or their risk reduced to an acceptable low level.

3.0 SYSTEM DESCRIPTION

The basic LTHD consists of three major subsystems: (1) cannon, including barrel and breech, (2) carriage, including basic structure, trails, spade, travel wheels, brakes, suspension recoil and equilibration, (3) fire control including direct and indirect sights, elevation and traverse control systems.

3.1 Cannon

The cannon consists of a new, 39 caliber barrel, a modified M185 breech and a new muzzle brake incorporating the towing lunette. The barrel and breech are of conventional, steel construction. The muzzle brake is made of titanium for weight savings. The section modulii are modified to provide equivalent strength to the current, steel muzzle brake.

Prolonged firing can lead to the initiation of fatigue cracks in the bore of the barrel, generally starting at the root of the rifling grooves. Procedures similar to the current 155mm howitzers will be used to maintain a log of number rounds and zones fired. After an established number of rounds the barrel will be replaced or removed for inspection.

The M185 breech is an existing unit except for minor modifications to mount the primer autoloader. Current procedures will be used for periodic replacement of the breech ring. The breech is opened upon hydraulic command from cannoneer #1 after completion of the counterrecoil cycle. After loading the next charge the breech is closed by hydraulic command from cannoneer #1. There is a hazard of closing the breech while the cannoneer's hand is still in the breech. It is controlled because cannoneer #1 operates the control for breech closing and he is the only person exposed to the hazard. The situation is similar to all currently fielded howitzer systems. Proper precautions and the nature of the hazard should be emphasized in training.

The muzzle brake is essentially the same as the M198 but incorporates a lunette for towing. Pressure pulse in the crew area should be improved because the crew stations are further to the rear of the muzzle. Testing should be done to determine positions, protecting and maximum number of rounds which can be fired without risking hearing damage to the crew.

Cannoneer #1 may be exposed to increased blast reflected from the trails. His location should be considered in the test program. The addition of the towing lunette to the muzzle brake should pose no safety hazards as the unit is far stronger than any imposed towing loads.

For the production version the primer inserter will be mounted on the breech with a minimal modification. It holds a clip of primers and is activated by hydraulic command from cannoneer #1. It will automatically insert a new primer and cock the firing mechanism. In the event of a misfire a new primer can be inserted by a mechanical linkage. This feature is a safety advantage relative to current cannons since the cannoner will be further from the primer hole for this operation. If the apparent misfire is really a "sticker" the chamber will be full of hot gases which will escape when the primer is removed.

Firing the howitzer is normally accomplished by hydraulic command from cannoneer #1. As a safety feature to prevent inadvertent firings, the firing control must first be moved in and then moved to the side in order to fire. A lanyard ring is provided for charges which require a long lanyard. The lanyard will require a force of 10 to 20 pounds to fire.

The primer clip is removeable for misfire diagnosis. Both the front end and back end of the primer are visible to determine its condition. Removal and replacement does not cause an error in the primer count. The proper count of remaining, good primers is displayed.

3.2 Carriage

The carriage subsystem consists of the cradle trails, gimbal platform, inertial ramming load tray spade, trunnions, wheels, brakes and suspension.

The platform is constructed of composite structure. The surface is smooth, non absorbent to NBC contaminants and resistant to both high pressure water spray and supertropical bleach decontaminates. The edges of all composite structures are sealed to prevent absorption of NBC contaminants into the weave of the fabric. The strut tubes are closed at the ends to prevent infiltration of contaminants inside the tubes. The production gun will use C.A.R.C. paint.

The trails are a truss structure with composite flanges and AlSiC struts. The structures for the platforms and trails are stronger than the worst case loading which is firing at negative elevations. In a normal duty cycle the life of the units is infinite. Loss of structural integrity could only be caused by abuse or handling. In the case of overstress it is possible that layers or individual filaments of the structure could delaminate which would not be visually apparent. However, during emplacement, the gun is not being fired and any hidden structural delaminations will give clearly audible cracking noises.

The spade will be made of titanium. The static balance of the gun is such that the vertical load on the spade is much higher than the M198, 2800 pounds versus 500 pounds, which greatly increases the resistance to a catastrophic pullout. Spade area is also increased.

The gun derives its stability from the configuration of the forward pointing trails. In the static position, load is distributed evenly at three contact points: the central spade, the forward left trail and the forward right trail. Firing recoil forces increase the load on the central spade and unload the forward trails. Positive system stability is maintained even in the worst case which is firing maximum zone charge at zero elevation. Dynamic analysis indicates positive stability. System test will be used to support initial stability calculations. The spring effect caused by rapid unloading of the trails will be investigated.

The transport system consists of four tires on an hydraulic suspension.

The four tire configuration with individual hydraulic suspension provides increased tracking stability in the towing mode and reserve load capacity for the tires. Rated load for the four tires is 10,720 lbs. while actual load is only 9000 lbs. Even in the event of a sudden flat in one of the tires the remaining tire on that side will be able to carry the load for a short time at maximum speed, 55MPH, or for much longer at reduced speed.

Springing is provided through the hydraulic system. Oil is transferred between the front and rear tires to create an action similar to a suspension bogey. The use of oil provides damping to the suspension action.

The system is equipped with air over hydraulic brakes which can be mechanically locked in the park position when so desired. Loss of pressure will not destroy the park the brake hold.

Sling lift Rings are provided, two at the front of the cradle assembly and two at the rear frame. For helicopter sling lifting the unit will be supported on rubber tires at the point of sling attachment. Therefore, it will be insulated from the ground which may reduce the hazard of static electric shock due to a build up of charge on the helicopter. However, a grounding strap should be used prior to attachment.

The center of gravity is located centrally to the sling points for stable sling load operation. The large cross section of the trails will provide a natural center of air resistance which will move stably to the rear of the sling center for streamlined sling flight.

3.3 Fire Control

The standard M198 optical sights will be used and no safety related difficulties are anticipated.

3.4 Hydraulic System

In the work breakdown structure, the hydraulic subsystem is split between the carriage and fire control subsystems. However, it is convenient to address all hydraulic functions in one section of this report.

The hydraulic system consists of the recoil, equilibration, elevation, traverse ramming, primer autoloader/lanyard control, and suspension subsystems and their associated cylinders, reservoirs, and accumulators.

Standard hydraulic fluid is used per MIL-STD-6083. This is a reasonably non-volatile petroleum based hydraulic fluid which is used in many Army systems. A slight hazard could exist if absorbent materials are allowed to accumulate fluid. However this can be controlled with procedures for general good housekeeping. The materials used in the howitzer construction are non-absorbent. Disposal of this should be by current procedures to avoid environmental pollution.

The equilibration accumulators use moveable pistons to separate the oil from the gas and minimize leakage. The accumulators will require occasional recharging with nitrogen. The pressures involved are extremely high, approximately 5000 psi. There are hazards from the gas pressure and from any mixing of oxygen with the system. For the production gun, procedures and product labels must be provided for safe recharging.

The accumulators and recoil cylinders are positioned to give them maximum protection from hostile fire and are protected by the torque tube structure. In the event of a hit, the positioning of the crew should prevent any injury from pressure leaks or from the resulting loss of barrel elevation.

The equilibration and recoil systems employ dual hydraulic cylinders. The loss of one cylinder from any system will allow function but in a degraded mode with higher system operating pressure using reduced charges.

The cylinders are provided with "bear locks." In the event of loss of hydraulic pressure the cylinder will lock in position. Hoses are minimized by use of manifolds and commutator joints. There are three cylinders which support the barrel in the raised position, the elevation cylinder and the two equilibration cylinders. The loss of any one of these cylinders will not cause the barrel to catastrophically drop.

The systems are temperature sensitive and oil must be added or removed to compensate for variations. This is easily done by a bleed valve which returns oil to the reservoir or a handpump which transfers oil from the reservoir back into the system. Pressure gauge readings are used to indicate low or high oil condition. If a high or low level occurs in the equilibrator, the corrections for elevation and azimuth will require increased effort which will prompt the gunners to replenish oil. In the case of the recoil system, extremely low oil will result in the gun failing to return all the way to battery which will be apparent to the crew. The system is safe for firing maximum zone charges from the load position. If the oil pressure is so low that the cannon does not return to the load position then it will be impossible to load the next round. Thus the degradation caused by low oil will be gradual, visible and safe.

Thermal relief valves will relieve pressure increases due to thermal expansion for any locked portion of the system.

All hydraulic valves require motion in two directions in order to activate. The valves must be pushed downward to unlatch and then to the side to activate. This is done to protect against an inadvertent activation caused by grabbing or bumping into a valve. The effectiveness of this action should be evaluated in the test program.

4.0 OPERATION

This paragraph gives an operational description of deployment, emplacement, firing, speed shift, vulnerability and displacement.

4.1 Deployment

The LTHD with four wheels and hydraulic suspension provides better towing stability than the M198. For highway safety, stop, tail, and side marker per FMVSS 108 should be provided which are easily detached for field maneuvers to prevent damage. A Kevlar rope is used as a safety chain for towing. The spade effectively acts as a road wheel mud flap.

The LTHD height is minimized for LAPES, specifically from the C130, to clear the top of the exit door during parachute extraction.

4.2 Emplacement

Positioning the LTHD requires a smaller area than conventional howitzers due to the configuration's capability to focus the firing forces into an integral platform and central spades. The additional ground contact area of the forward trails combined with the ability to retract the spade, simplify emplacement in rocky terrain.

The emplacement procedure consists of the following steps which can be performed by a crew of four without any special skill or ability and with minimum training.

1. Check for minimum hydraulic pressure, pump up if necessary.

2. Disconnect highway lights.

3. Lower front wheels so that the howitzer is supported only on the front wheels. This shifts the balance of the gun so that the lunette load is reduced and the crew will be able to lift the lunette.

4. Unlock the lunette and raise above the pintle.

5. Drive the truck forward.

6. Lower the lunette to the ground.

7. First raise the rear wheels into the trails then raise the front wheels. As the front wheels are raised, the howitzer will be lowered fully to the ground. Both sides of the howitzer must operate together to keep the gun level.

8. Unlock both trails from the cradle.

9. Elevate the trails.

10. Spread the trails fully to their stops. If the trails are not fully spread, there is no safety hazard. A narrow configuration may be desired for firing from a roadway.

11. Pin the trails to the platform.

12. Lower the trails to the ground.

13. Release the barrel travel locks.

14. Extend the cannon to the load position using the hydraulic controls.

15. Equilibrate the barrel.

16. Adjust equilibration pressure

17. Elevate the barrel to 300 mils using the hydraulic controls.

If below-zero QE firing is required, a trench must be dug, or the lunette will hit the ground. The maximum trench depth is 32 inches on level ground. This is a result of the reduced trunnion height, a necessity for stability. If the trench is not deep enough and the LTHD is fired, the lunette mounted on the muzzle brake, being the low point, will dig a trench. The recoil accumulators (mounted beneath the slide tubes for protection) do not recoil and will not be damaged if the trench is of insufficient depth.

4.3 Firing

The LTHD crew positions are shown in figure 1. Locating the trunnion behind the breech at full recoil enables the section chief position to be at the focal point of operations. From this position, the section chief can see all personnel, check the fuze settings as the projectiles enter the load tray, see the prescribed tube lay, and observe the status of the cannon relative to the prescribed tube lay. In addition, all personnel are further from the muzzle brake than the M198 layout permits, which results in a reduction of the theoretical blast overpressure to which the crew is exposed.

The LTHD employs a load tray to facilitate mechanical breech access. The load tray has an important safety advantage by keeping the crew away from the recoiling mechanisms and breech area both of which are sources of accidents in the M198. The ram cycle for the projectile is controlled by hydraulic command from cannoneer #1 and there is a hazard if rams while his hand is in the breech. It is very important that this control requires both of his hands for activation. This will ensure that he does not inadvertently ram the projectile while his hand is still in the chamber for swabbing or other unplanned reasons. This control should require two buttons which are spaced far enough apart that he cannot activate them with one hand or arm.

It is possible that the hydraulic ram will not firmly seat the projectile due to low oil pressure, cold oil or projectile ballotting at the entry to the forcing cone. If the projectile falls back immediately with the retraction of the load tray the situation will be obvious. If the projectile falls back after the breech is closed there may be minor damage to the forcing cone and lands. This is not a serious hazard and can be monitored during test.

The LTHD is not equipped with a thermal warning device and it is not anticipated that the demonstrator would be subjected to extreme barrel heating. Only one set of misfire procedures is given. It is anticipated the production model would have a temperature indicator and procedures similar to the M198 would be used. The procedures for loading and firing, as well as for handling malfunctions, is shown below.

4.3.1 Loading and Firing

1. Upon completion of the last counter recoil cycle or the beginning of a new firing sequence, cannoneer #1 opens the

breech by hydraulic command.

2. If necessary, the chamber is swabbed.
3. Load the projectile on the tray.
4. Ram the projectile using hydraulic control.
5. Cannoneer #1 inserts the propellant into the chamber.
6. Close the breech by hydraulic command.
7. Advance the barrel fully to the battery position.
8. Load a fresh primer.
9. Fire upon command, either with hydraulic control or with the lanyard.

NOTE: The M198 is provided with a temperature indicator. However, the demonstrator is not provided with one. In the following procedures it will be assumed that the barrel is cool, below 170°F. If the barrel is too hot to touch by hand, stop firing and allow the barrel to cool down.

4.3.2 Misfires

1. Attempt to fire two more times.

2. If there is no recoil, keep the howitzer on target, and wait two minutes.

3. Cycle the primer inserter. Be careful to stay away from primer vent hole as a sticker will release a hot gas jet. If there is a gas jet it indicates a sticker. See the procedure for stickers.

4. Remove the primer magazine and inspect the primer. If the primer has been fired it indicates a hangfire condition. See the procedure for hangfires.

5. If the mechanism appears to be working satisfactorily but the primer did not fire, replace the primer magazine to the primer inserter, insert a new primer and fire again.

6. If the mechanism is not working properly, repair it.

7. Resume load-fire process at Step 8, insert fresh primer.

4.3.3 Hangfires

1. Wait three minutes from the last attempt to fire.

2. Replace the charge and primer and resume load-fire process from the top

4.3.4 Stickers

1. Wait two minutes

2. Combustion chamber is vented by removing the primer. Be careful to stay away from the hot gas jet.

3. Tube is depressed

4. Breech is opened hydraulically.

5. Projectile is removed (unless plan is Larger Charge)

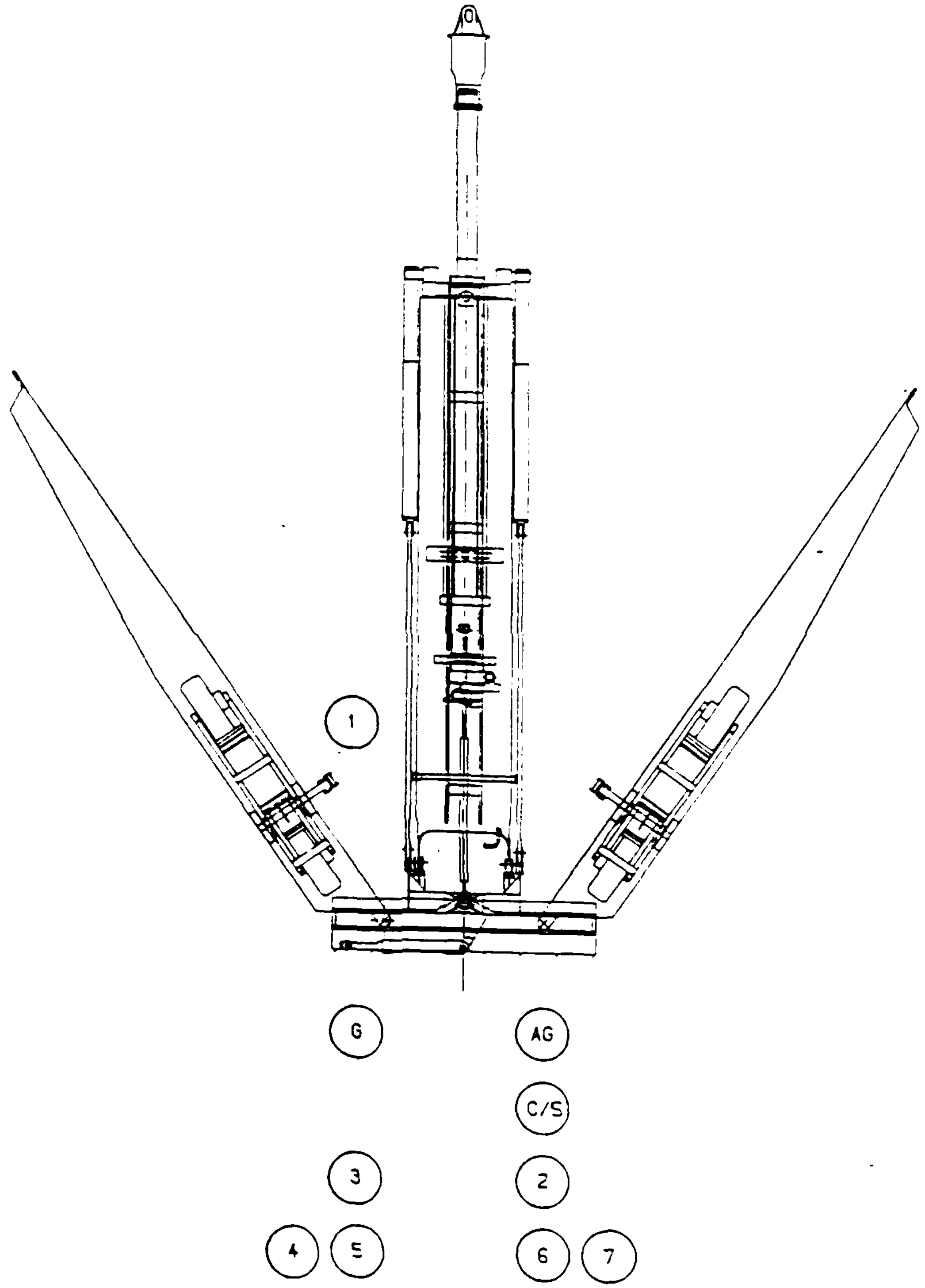


FIGURE 1. CREW POSITIONS REDUCE THE EXPOSURE TO BLAST OVERPRESSURE

6. Tube is elevated

7. Load-Fire process is resumed

   A. With new projectile, Step 3 (load projectile)

   B. With larger charge, Step 5 (load propellant)

4.3.5 Cookoff

A temperature indicator and hot tube cookoff procedures are not provided with this demonstrator. If the tube is too hot to touch by hand, allow it to cool before loading the round. Cook off is not a problem with a cool tube. Treat as misfire, hang fire or sticker.

4.4 Speed Shifting

Speed shift (3 minutes with crew of 4)

1. Move swab & bucket.

2. Traverse to 0 mils, depress to 300 mils.

3. Lower speedshift assy.

4. Put cannon weight on the speedshift assembly by raising the trails.

5. Lower the rear wheels, thus pulling the spade up out of the ground.

6. Rotate the howitzer to its new heading by pivoting about the speedshift assembly and rolling on the rear wheels.

7. Raise the rear wheels.

8. Lower the trails to the ground.

9. Equilibrate the barrel.

10. Elevate the barrel using the hydraulic system.

11. Raise the speedshift assembly.

12. Retrieve the swab and bucket.

4.5 Vulnerability to Aerial bursts

The LTHD minimizes vulnerability to aerial bursts to improve survivability through component placement and the selective use of armor by the following:

1. Designing the recoil cylinders so dynamic sealing surfaces do not interface with the outside wall. (Instead, the inside of the outer cylinder provides the orifice function). The precision surfaces are buried deeper within the assembly.

2. Providing a protective shroud for the upper recoil cylinder rod to protect it during the 3-second recoil/counterrecoil cycle.

3. Providing a protective shroud for the elevation cylinder to protect its rod surface.

4. Accumulators are housed within and protected by the torque tube.

4.6 Displacement

The displacement procedure is essentially the reverse of the emplacement procedure.

5.0 Summary of Results

This PHA considered each of the hazard sources listed on the PHA worksheet. A breakdown of the hazard categories is as follows:

HAZARD	NUMBER
Category I, Catastrophic	27
Category II, Critical	14
Category III, Marginal	5
Category IV, Negligible	0

Note: In some cases, there are more than one hazard per item. This results in more hazards than total items. In addition, in cases where there are more than one risk assessment indicated; e.g., IC to IIB, then the worst case assessment was assumed.

Recommended actions noted in block 7 of the PHA worksheet are being analyzed by the designers for incorporation into the final concept. An analysis of block 8 (Effects of Recommended Actions) in the PHA worksheet shows that all Category I risks can either be downgraded or the frequency of their occurrence can be reduced to a point where there are no major safety hazards in the system.

In the Category I hazards, after the applications of preventative measures, none are rated to occur at probability level A, frequent; B, probable; or C, occasional.

six category I items are rated to occur at "D" level probability; i.e., remote. They involve barrel rupture, NBC decontamination, vehicle collisions, crew runovers, lapes damage and ballistic errors. In all cases the LTHD is judged to be equal to or better than the M198.

The remainder of the category I items are rated as improbable, category, "E".

ATTACHMENT 1

ACCIDENT-RISK FACTOR MATRIX

PRODUCT PHASE	SHIP/ STORE	SET- UP	TRAIN	OPERATION	GROUND TRANS.	AIR TRS.	MAINT- ENANCE	DISPOS
ENERGY SOURCES								
ELECTRICAL						X	X	X
CHEMICAL								
PROPELLANT	X	X	X	X	X	X		X
PROJECTILE	X			X	X	X		X
COMPOSITES	X							X
NBC				X				
FLUIDS				X			X	X
PRESSURE								
HYDRAULIC				X			X	X
FIRING				X				
NOISE				X				
KINETIC								
TRANSPORT					X	X		
RECOIL				X				
BREECH				X				
BALLISTIC				X				
POTENTIAL								
GUN MASS		X	X	X	X	X		
CREW POSITION		X				X		

PROGRAM Lightweight Towed Howitzer Demonstrator

SYSTEM Howitzer

SUBSYSTEM Cannon

REVISION 1 DATE 30 January 1987

HAZARD ANALYSIS SUMMARY WORKSHEET

TYPE ANALYSIS Preliminary

COMPLETED BY T. Hillstrom

DATE STARTED 27 January 1986

DATE COMPLETED 12 June 1986

ITEM 1	SYSTEM SUBSYSTEM UNIT 2	SYSTEM/EVENT OPERATIONAL MODE 3	HAZARD DESCRIPTION 4	EFFECT ON SYSTEM OR PERSONNEL 5	RISK ASSESSMENT 6	RECOMMENDED ACTION 7	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK) 8	REMARKS 9	STATUS 10
1		Operation	A hot ember in the firing chamber ignites prop. charge	Fire injury minor to serious.	IC to IIIC	Provide water swab	Reduce to IE to IIIE		Open
.		Operation	Damage to propellant bag charge torn, unit charge cracked or broken	1. Loss of powder minor fire hazard	IIIC	Provide training and warnings for cannoneer #1. Section chief to observe operations.	Reduce to IIIE		Open
				2. Low ballistic path death to friendly troops.	IC		Reduce to IE		Open
				3. Low charge causes stuck projectile possible cook off in hot barrel	IC		Reduce to IE		Open
				4. Damage to ignitor pad causes delayed combustion causing possible breech blow	IC		Reduce to IE		Open
		Operation	Firing low zone charges results in a stuck projectile. Possible cook off in a hot tube	Loss of system injury, death	IB	Provide temperature monitor, procedures same as M198 for handling possible cook off situation. Provide access to primer for diagnosis	Reduce to IE	The demonstrator is not equipped with a temperature monitor. It should only be fired with a cold barrel condition.	Open
4		Operation	Misfire possible cook off in a hot tube	Loss of system injury death	IB	Provide temperature monitor, procedures same as M198 for handling possible cook off situation. Provide access to primer for diagnosis	Reduce to IE	Same as above.	Open
.		All	Lifting projectiles causes personnel injury by exceeding MIL-STD-47, MIL-HDBK-759 and NIOSH limits	Back injury trauma	IIA	Load tray to be easily accessible to facilitate two man projectile lift	Reduce to II[illegible]		Open

PROGRAM Lightweight Towed Howitzer Demonstrator	HAZARD ANALYSIS SUMMARY WORKSHEET	COMPLETED BY T. Hillstrom
SYSTEM Howitzer	TYPE ANALYSIS Preliminary	DATE STARTED 27 January 1986
SUBSYSTEM Cannon		DATE COMPLETED 12 June 1986
REVISION 1 DATE 30 January 1987		PAGE 2 OF 10 PAGES

ITEM 1	SYSTEM SUBSYSTEM UNIT 2	SYSTEM EVENT OPERATIONAL MODE 3	HAZARD DESCRIPTION 4	EFFECT ON SYSTEM OR PERSONNEL 5	RISK ASSESSMENT 6	RECOMMENDED ACTION 7	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK) 8	REMARKS 9	STATUS 10
6		All	Lifting trails or towing connection traps hands or feet	Crushing injury to hands, feet	IIIB	1. Provide lifting points 2. Maintain clearance between trails and ground	Reduce to IIID	Design provides both recommendations	Open
7		Operation	Sound level, pressure blast from firing	Loss of hearing, damage to ear drums, lungs and sinuses	IIA	Provide protection to meet units of MIL STD 1474B Through the following actions: 1. Position crew members to minimize exposure 2. Provide ear plugs and helmets with acoustical muffs 3. Limit exposure depending on number of rounds and zone	Reduce risk to IIID	Procedures and protection are similar to M198. The new cannon and muzzle brake must be tested for pressure signature	Open
8		Operation Firing	Rupture of barrel or breech due to fatigue cracking	Loss of system, serious injury or death	IA	Maintain log of rounds and zones fired. Replace barrel before catastrophic failure can occur	Reduce to ID	Procedures and protections are similar to M198	Open
9		Operation	Crew member struck by recoiling element	Injury, minor to serious	IIC to IIIC	1. Position crew away from recoiling elements 2. Reduce the need to be near recoiling elements 3. Eliminate pinching or shearing areas	Reduce to IIIC	This design keeps the crew further away and shields the recoiling elements inside the slide	Open

PROGRAM	[illegible] Towed Howitzer Demonstrator	HAZARD ANALYSIS [illegible] WORKSHEET	COMPLETED BY	T. Hill [illegible]
SYSTEM	Howitzer	TYPE ANALYSIS: Preliminary	DATE STARTED	27 January 1986
SUBSYSTEM	Carriage		DATE COMPLETED	12 June 1986
REVISION [illegible]	DATE [illegible]		PAGE 3 OF 10 PAGES	

ITEM	SYSTEM SUBSYSTEM UNIT 2	SYSTEM EVENT OPERATIONAL MODE 3	HAZARD DESCRIPTION 4	EFFECT ON SYSTEM OR PERSONNEL 5	RISK ASSESSMENT 6	RECOMMENDED ACTION 7	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK) 8	REMARKS 9	STATUS 10
		Operation Maintenance Training	Hand trapped by [illegible]	Injury, minor to serious	IIC to IIIC	[illegible] to control closure	Reduce to IIID to IIID		Open
		Operation	The [illegible] breech is closed [illegible] inadvertent firing	1. Possible death to friendly troops. 2. Injury to cannoneer due to blast or recoil	ID IIC	Require separate positive action to arm or to complete primer feed	Reduce to IE Reduce to IIE	The primer inserter complies with these recommendations.	Open
		Operation Maintenance Training	Hand trapped by [illegible] RAM	Injury, minor to serious	II [illegible] IIIC	Require two buttons at least 24" apart	Reduce to IIE to IIIE		Open
		Operation	[illegible] projectile ram velocity or force [illegible]	Minor damage to [illegible]	IIIB	Test and modify ram as required	Reduce to IIID		Open
1		Operation Training Maintenance	Materials of [illegible] become weakened [illegible] or by exposure [illegible] UV, hydraulic fluid, NBC agent or decontam[illegible] agent	Possible structural failure lead to loss of stability while firing [illegible] of system [illegible] crew [illegible]	I[illegible]	1. Physical or chemical actions leading to loss of strength should be visually evident. 2. Materials should be compatible with ozone, UV, hydraulic fluid, NBC agents and contaminants. 3. Provide training and instruction to inspect for damage. 4. Provide attachment points for crane lift, emergency towing or slinging	Reduce to IE	Maximum stress occurs during set up as gun is emplaced and raised from low QE. Cracking noises will be apparent during this procedure	Open
1[illegible]		Demo[illegible]	[illegible] products of [illegible]	Illness due to inhalation of products of combustion	IIIC	Minimize toxicity of products of combustion, provide instruction for safe disposal	Reduce to IIIE		Open

[illegible]

PROGRAM: L[illegible]weight Towed Howitzer Demonstrator

SYSTEM: Howitzer

SUBSYSTEM: Carriage

REVISION: [illegible] DATE: [illegible] January 198[illegible]

HAZARD ANALYSIS [illegible] WORKSHEET

TYPE ANALYSIS: Preliminary

COMPLETED BY: T. Hill[illegible] gm

DATE STARTED: 27 January 1986

DATE COMPLETED: 12 June 1986

ITEM	SYSTEM SUBSYSTEM UNIT 2	SYSTEM EVENT OPERATIONAL MODE 3	HAZARD DESCRIPTION 4	EFFECT ON SYSTEM OR PERSONNEL 5	RISK ASSESSMENT 6	RECOMMENDED ACTION 7	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK) 8	REMARKS 9	STATUS 10
[illegible]		Operation [illegible] NBC [illegible]	Absorption of NBC [illegible]	Injury or death	IA	System to be manufactured of non absorbent components. All spaces to be sealed or open for flush and drain. Components must resist decontaminating agent and water spray. Appurtenances (steps, storage spaces to provide smooth, rounded surfaces, minimize small openings. Use [illegible] A R [illegible] paint	Reduce to ID	Operation in an NBC environment is extremely hazardous. The Howitzer should not contribute to the hazard by trapping and holding contaminating materials.	Open
		[illegible]	[illegible]	Minor [illegible]	ID to IVD	1. Prevent collisions. Provide stop, tail and side marker lamps per FMVSS 108 for [illegible] CON [illegible]. 2. In event of a collision the nature of the equipment shall not make the result worse. All components must be adequately secured	Reduce so that any additional hazards due to towing are minimized. Reduce to ID		Open
[illegible]		[illegible]	[illegible]	Effect [illegible] range from [illegible] [illegible] death	I to IVE	Provide redundant connection such as safety chain	Reduce to IE		Open

HAZARD ANALYSIS SUMMARY WORKSHEET

TYPE ANALYSIS Preliminary

COMPLETED BY T. Hillstrom

DATE STARTED 27 January 1986

DATE COMPLETED 12 June 1986

ITEM [illegible] 1	SYSTEM EVENT / OPERATION MODE [illegible]	HAZARD DESCRIPTION [illegible]	EFFECT ON SYSTEM OR PERSONNEL 5	RISK ASSESSMENT 6	RECOMMENDED ACTION 7	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK) 8	REMARKS 9	STATUS 10
[illegible]	[illegible]	[illegible]	Effects range from II to IV [illegible] ... and death	II to IV	In event of an overturn the nature of the equipment must not worsen the situation. All components to be adequately secured. Provide lifting and towing points.	Reduce to IE	This Configuration is more stable than the M198	Open
[illegible]	[illegible]	[illegible]	[illegible] death	II	Provide training and instruction.	Reduce to IE		Open
[illegible]	[illegible]	[illegible]	[illegible]	II	The loss of one tire must not cause major instability or dramatic overload to remaining tires. Provide jacks, tools & procedure for tire changing.	Reduce to IIID	This item should be tested in development phase.	Open
[illegible]	[illegible]	[illegible]	Damage [illegible]	IIIB	Provide clearance up to the tightest turn radious of expected towing tractor. Provide for replacement or repair of damaged [illegible]	Reduce to IIID		Open

PROGRAM [illegible]   HAZARD ANALYSIS [illegible] WORKSHEET   COMPLETED BY [illegible]

SYSTEM Howitzer   TYPE ANALYSIS: Preliminary   DATE STARTED 27 January 1986

[illegible]   DATE COMPLETED 12 June 1986

REVISION [illegible]

ITEM	SYSTEM OR SUBSYSTEM UNIT	[illegible]	HAZARD DESCRIPTION 4	EFFECT ON SYSTEM OR PERSONNEL 5	RISK ASSESSMENT 6	RECOMMENDED ACTION 7	EFFECT OF RECOMMENDED ACTION (RESIDUAL RISK) 8	REMARKS 9	STATUS 10
		[illegible]	[illegible] become [illegible] the [illegible] removal of [illegible] cause the unit to [illegible] from the rear wheel. A sudden release [illegible] cause the barrel to fall	Serious injury or death of soldiers [illegible] are under the barrel	IC to III[illegible]	Test the likelihood of this occurrence provide warnings and training	Reduce to IE to IIIE		Open
[illegible]		[illegible]	[illegible] port wheels on [illegible] side [illegible] fully while the other side [illegible] lowered	Sideways instability causes tip over possible injury or death	IB	Unit to have positive side stability in worst case on 10° side slope.	Reduce to IE	Analysis indicates the unit is stable in worst case condition.	Open

0834E

[illegible] Demonstrator

DATE 10 January 1987

HAZARD ANALYSIS SUMMARY WORKSHEET

TYPE ANALYSIS Preliminary

COMPLETED BY T. Hillstrom

DATE STARTED 27 January 1986

DATE COMPLETED 12 June 1986

[illegible]	[illegible]	SYSTEM EVENT/ OPERATIONAL MODE	HAZARD DESCRIPTION	EFFECT ON SYSTEM OR PERSONNEL	RISK ASSESS-MENT	RECOMMENDED ACTION	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK)	REMARKS	STATUS
		3	4	5	6	7	8	9	10
		Operation Firing	Recoil/counterrecoil forces cause gun to tip over.	Possible severe injury or death to crew. Loss of system.	IA	Gun stability must prevent tipover in worst case. Train to establish a level area for gun emplacement.	Reduce to IE	Stability factor is positive up to 270 mil slope.	Open
26		Operation - helicopter lift	Static electric shock while making connection.	Shock, injury minor to possible severe	IIA	Provide ground strap and training instruction for use prior to making sling connection.	Reduce to IIC		Open
27		Operation Training Helicopter Lift	Crewmen slip or fall from elevated positions while rigging slings or making heli attachment.	Injury, minor to serious.	IIB	Provide non skid, stepping points. Provide sling points. Provide instruction and training.	Reduce to IID		Open
28		Operation Helicopter Lift	Highest point of equipment contacts helicopter.	Damage to helicopter ranging from minor to serious	ID	In the transport position equipment should fold as low as possible.	Reduce to IE	Barrel and trails fold to horizontal position.	Open
29		Operation Helicopter Lift	Load slips from sling.	Damage to system ranging to loss of system	IC	Provide strong, positive sling points.	Reduce to IE	Slip proof sling attachment points are provided.	Open
30		Operation Helicopter Lift	Load will not streamline.	Unstable load may strike helicopter or lead to loss of stable flight possible loss of system	IC	The center of wind resistance must lie behind the center of gravity.	Reduce to IE	Large cross section of trails provides a good center of resistance.	Open

0834E

PROGRAM Lightweight Towed Howitzer Demonstrator

SYSTEM Howitzer

SUBSYSTEM Recoil System

REVISION 1 DATE 30 January 1987

HAZARD ANALYSIS SUMMARY WORKSHEET

TYPE ANALYSIS Preliminary

COMPLETED BY T. Hillstrom

DATE STARTED 27 January 1986

DATE COMPLETED 9 March 1986

ITEM	SYSTEM SUBSYSTEM UNIT	SYSTEM/EVENT/ OPERATIONAL MODE	HAZARD DESCRIPTION	EFFECT ON SYSTEM OR PERSONNEL	RISK ASSESS-MENT	RECOMMENDED ACTION	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK)	REMARKS	STATUS
1	2	3	4	5	6	7	8	9	10
31		Operation Helicopter Lift	Load Oscillates.	May strike helicopter causing loss of system	IC	Center of gravity must be central to support points.	Reduce to IE	This item requires consultation with people responsible for the helicopter lift operations. Aerodynamic or balance characteristics may need to be tested.	Open
32		Operation Helicopter Lift	Latched components - barrel or trails come loose during transport	Movement causes system instability leading to possible crash	IB	Provide secure latches, sling attachment points should hold the equipment in the stable position.	Reduce to IE		Open
33		Operation Training - Lapes	Shock loads from extraction or drop damages equipment	Possible loss of system	IA	In the transport configuration equipment must resist shock loads.	Reduce to ID	1. Composites will give audible cracking noises during set up if damaged. 2. Maximum stress on equipment occurs during set up and not during firing.	Open
34		Operation Training Maintenance	Spilled hydraulic fluid may present a fire hazard. The fluid is very non volatile. However, absorbent materials may hold and wick oil.	In the presence of a source of ignition the fire may be accelerated.	IID	Training and procedures to clear spills	Reduce to IIE		Open
35		Disposal	Toxic	Environmental pollution, mild toxic affect	IIIB	Procedure for disposal use standard mil hydraulic fluid-MIL H 6083D	Reduce to IIID		Open

0834E

PROGRAM Lightweight Towed Howitzer Demonstrator

SYSTEM Howitzer

SUBSYSTEM Fire Control

REVISION 1 DATE 30 January 1987

HAZARD ANALYSIS SUMMARY WORKSHEET

TYPE ANALYSIS Preliminary

COMPLETED BY T. Hillstrom

DATE STARTED 27 January 1986

DATE COMPLETED 12 June 1986

ITEM	SYSTEM SUBSYSTEM UNIT	SYSTEM/EVENT/ OPERATIONAL MODE	HAZARD DESCRIPTION	EFFECT ON SYSTEM OR PERSONNEL	RISK ASSESS-MENT	RECOMMENDED ACTION	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK)	REMARKS	STATUS
1	2	3	4	5	6	7	8	9	10
36		Operation Maintenance	A high pressure oil leak	Possible hydraulic injection injury	IID	Use sound mechanical design principals. Avoid rubber hoses. Provide warning and training material.	Reduce to IIE	Hoses are minimized with manifolds and commutators.	Open
37		Operation Maintenance Training	Nitrogen/oil accumulator explosion due to: 1. Hostile fire 2. Overload, abuse	Possible injury to crew, system damage.	IIC	Shield elements from fire or abuse Provide warnings.	Reduce to IIE		Open
38		Operation	Failure of recoil system due to low oil, seal leakage, internal mechanical failure.	Damage to system possible serious crew injury due to gun hop.	IIC	Provide low oil indication. Provide training and warning instruction	Reduce to IIE		Open
39		Operation Training-Firing	Incorrect ballistic solution.	Death to friendly troops	IB	Fire control system must maintain high accuracy. Provide secure mounting.	ID		Open
40		Maintenance Training	Charging accumulators, with high pressure nitrogen.	Leakage or mechanical failure could cause injury minor to serious.	IIC to IVC	Provide equipment, procedures and training.	Reduce to IID to IVD		Open
41		Maintenance	Mixing oil and oxygen under pressure	Catastrophic explosion, injury, death.	ID	Provide procedures and training.	Reduce to IE		Open

PROGRAM Lightweight Towed Howitzer Demonstrator

SYSTEM Howitzer

SUBSYSTEM Fire Control

REVISION 1 DATE 30 January 1987

HAZARD ANALYSIS SUMMARY WORKSHEET

TYPE ANALYSIS Preliminary

COMPLETED BY T. Hillstrom

DATE STARTED 27 January 1986

DATE COMPLETED 12 June 1986

ITEM	SYSTEM SUBSYSTEM UNIT	SYSTEM/EVENT/ OPERATIONAL MODE	HAZARD DESCRIPTION	EFFECT ON SYSTEM OR PERSONNEL	RISK ASSESS-MENT	RECOMMENDED ACTION	EFFECTS OF RECOMMENDED ACTION (RESIDUAL RISK)	REMARKS	STATUS
1	2	3	4	5	6	7	8	9	10
42	Hydraulic System Controls	Operation Maintenance Training	Shock, vibration or inadvertent activation by soldiers climbing on equipment causes sudden or unexpected movement of hydraulic units.	Possible injury to crew, minor to serious	IB to IVB	Critical valves to have a latch or neutral lock to prevent unexpected function.	Reduce to IE to IVE	Locks are provided.	Open
43	Hydraulic System	Operation Training	The Howitzer may be supported in the air while people work underneath it e.g. to dig a trench for the spade.	A sudden hydraulic failure would cause serious injury.	ID	Provide a mechanical lock for the transport wheels. Provide warnings and training.	Reduce to IE	Locks are provided.	Open

0834E

DESCRIPTION: RELIABILITY AND MAINTAINABILITY PREDICTIONS

STATUS: The latest finished reliability prediction and allocation for the LTHD as of 18 February 1987 is contained in Part A of this section. The report contains:

1. Basic reliability and block diagrams.
2. Reliability prediction worksheet.
3. Mission critical reliability block diagrams.
4. Mission critical reliability prediction and allocation worksheet.

Part B contains unfinished reliability/availability worksheets. The status of each subsystem contained within the reliability prediction is as follows:

1. Cannon - last update was Feb 87
2. Cradle -- Feb 87
3. Trails - Feb 87
4. Gimbal -- Feb 87
5. Platform - Feb 87
6. Wheel system - Mar 87
7. Equilibrators - Feb 87
8. Hydraulic System - Mar 87
9. Loading System - was being updated in Mar 87
10. Spade - Feb 87
11. Fire Control - Feb 87

Consult with Mike Janssen before using any of this reliability prediction data.

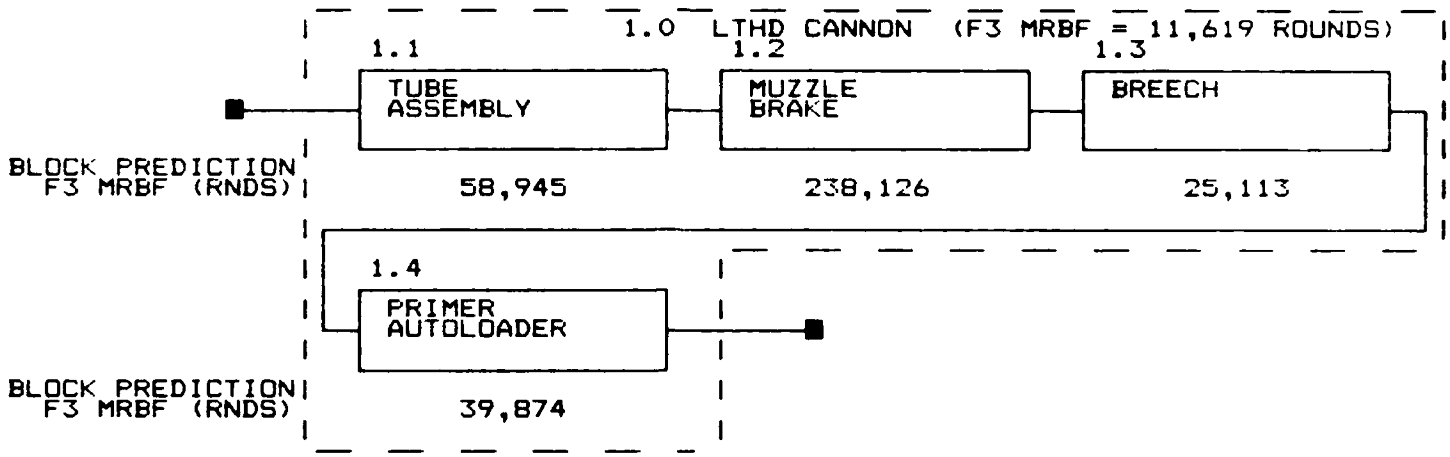
For the maintainability/availability prediction, the subsystems that have finished predictions are: the wheel system, hydraulic system, spade and the fire control. The other subsystems have either an incomplete M/A prediction or a non-valid prediction. Consult with Mike Janssen before using any of this M/A prediction data.

AUTHOR: Mike Janssen

PART A.

TABLE 1 - LTHD SYSTEM RELIABILITY PREDICTION AND ALLOCATION (AS OF 18-FEB-1987)

SUBSYSTEM	MEAN ROUNDS BETWEEN FAILURES (MRBF) (ROUNDS)		
	(F3) BASIC PREDICTION	MISSION CRITICAL (F1) PREDICTION	MISSION CRITICAL (F1) ALLOCATION
1.0 CANNON	11,619	26,245	19,287
2.0 CARRIAGE	980	3,183	2,339
3.0 FIRE CONTROL	708	5,697	4,180
LTHD SYSTEM	397	1,904	1,100 (REQUIREMENT)



RELIABILITY EQUATION

$$F3\ MRBF_{ss} = \frac{1}{\sum_{i=1}^{n} (1/F3\ MRBF_i)}$$

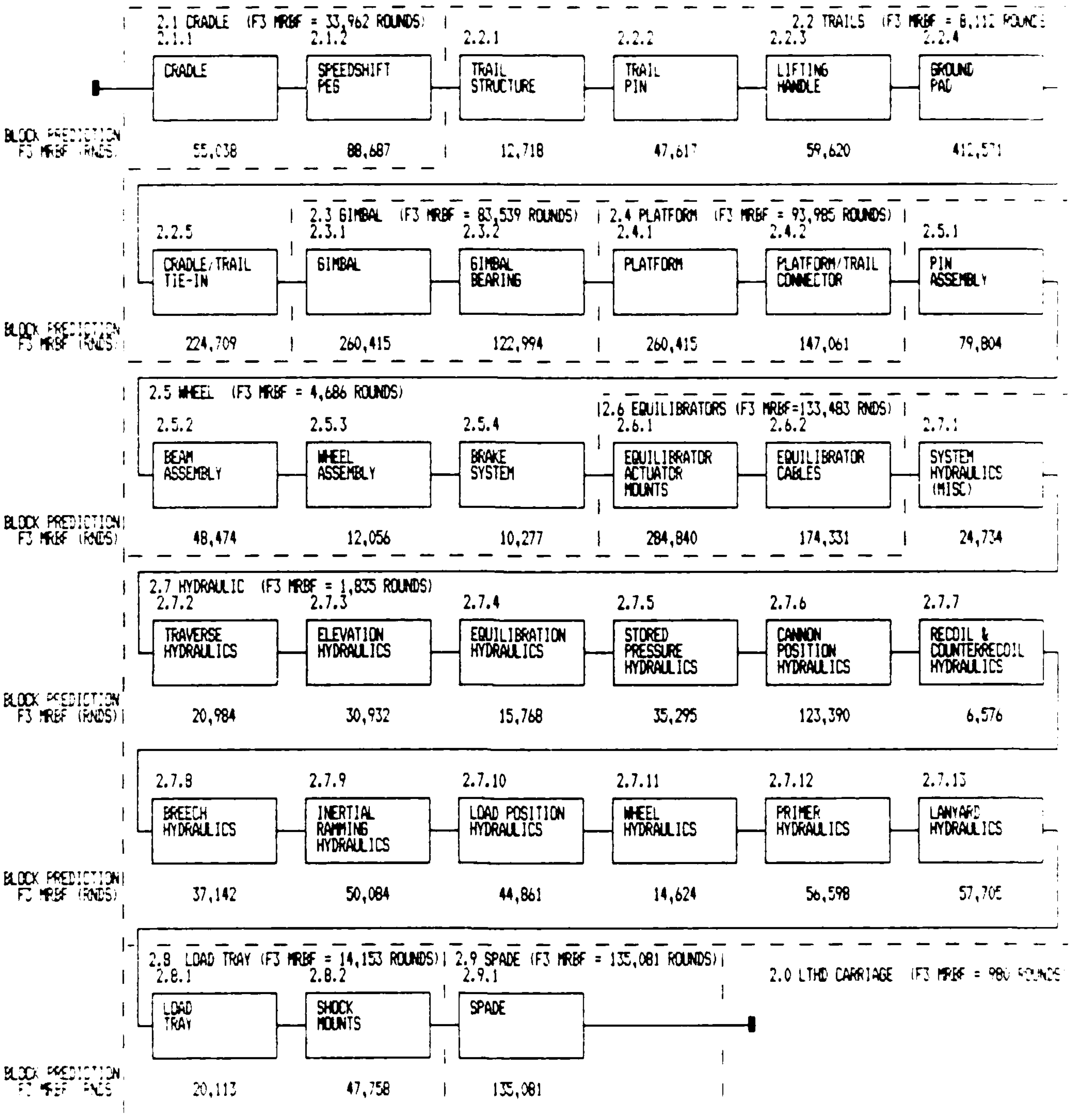
WHERE; $F3\ MRBF_i$ = BLOCK F3 MEAN ROUNDS BETWEEN FAILURES

$F3\ MRBF_{ss}$ = SUBSYSTEM F3 MEAN ROUNDS BETWEEN FAILURES

n = NUMBER OF BLOCKS IN THE SUBSYSTEM

F3 = CORRECTIVE MAINTENANCE (ALL) FAILURES

FIGURE 1 - LTHD CANNON BASIC RELIABILITY BLOCK DIAGRAM
(AS OF 2/18/87)

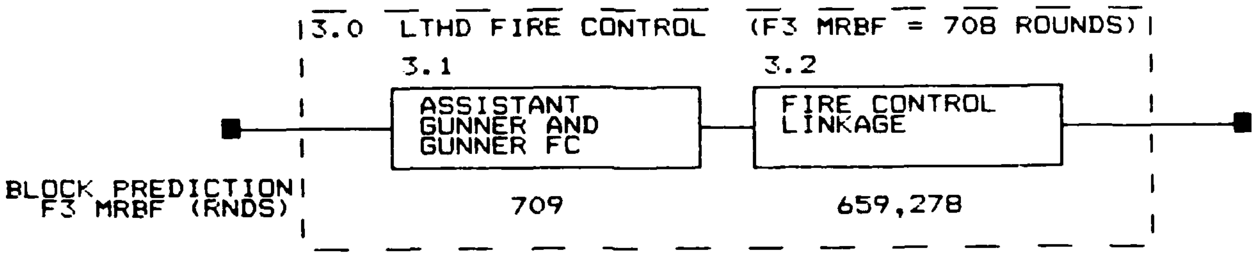


RELIABILITY EQUATION

$$F3\ MRBF_{ss} = \frac{1}{\sum_{i=1}^{n} (1/F3\ MRBF_i)}$$

WHERE;
$F3\ MRBF_i$ = BLOCK F3 MEAN ROUNDS BETWEEN FAILURES
$F3\ MRBF_{ss}$ = SUBSYSTEM F3 MEAN ROUNDS BETWEEN FAILURES
n = NUMBER OF BLOCKS IN THE SUBSYSTEM
F3 = CORRECTIVE MAINTENANCE (ALL) FAILURES

FIGURE 2 - LTHD CARRIAGE BASIC RELIABILITY BLOCK DIAGRAM
(AS OF 2/18/87)



RELIABILITY EQUATION

$$F3\ MRBF_{ss} = \frac{1}{\sum_{i=1}^{n} (1/F3\ MRBF_i)}$$

WHERE; $F3\ MRBF_i$ = BLOCK F3 MEAN ROUNDS BETWEEN FAILURES

$F3\ MRBF_{ss}$ = SUBSYSTEM F3 MEAN ROUNDS BETWEEN FAILURES

n = NUMBER OF BLOCKS IN THE SUBSYSTEM

F3 = CORRECTIVE MAINTENANCE (ALL) FAILURES

FIGURE 3 LTHD FIRE CONTROL BASIC RELIABILITY BLOCK DIAGRAM (AS OF 2/18/87)

BLOCK CODE / PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL F1/F3	MISSION CRITICAL FLR RATE (FLR/ROUND 10X-6)	MISSION CRITICAL BLOCK MRBF (rnds)
LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR				2517.875	397			525.344	[illegible]
1.0	CANNON			86.064	11619			39.103	[illegible]
1.1	TUBE ASSEMBLY			16.965	58945			11.181	89440
1.1.1	TUBE ASSEMBLY			16.965	58945			11.181	89440
5767	TUBE	1	56.779	56.779	10.902	M198 DATA	0.95	10.357	
5781	COLLAR SET	5	2.000	10.000	1.920	ESTIMATE	0.20	0.384	
6016-001	EXTRUSION RAIL	2	1.000	2.000	0.384	ESTIMATE	0.20	0.077	
6022-	KEY	20	0.946	18.920	3.633	M198 DATA	0.10	0.363	
6002-	BOLT	40	0.011	0.440	0.084	CATFAE PRED	N.C.	N.C.	
6003-007	NUT	20	0.011	0.220	0.042	CATFAE PRED	N.C.	N.C.	
1.2	MUZZLE BRAKE			4.199	238126			0.840	1190632
1.2.1	MUZZLE BRAKE			4.199	238126			0.840	1190632
5765	MUZZLE BRAKE	1	18.926	18.926	3.634	M198 DATA	0.20	0.727	
5786	KEY	1	0.946	0.946	0.182	M198 DATA	0.20	0.036	
5787	TRUST COLLAR	1	2.000	2.000	0.384	ESTIMATE	0.20	0.077	
1.3	BREECH			39.820	25113			15.549	64312
1.3.1	BREECH			39.820	25113			15.549	64312
5789	BREECH	1	121.704	121.704	23.367	M109 DATA	0.55	12.852	
5816	BAND (OUTER BREECH)	1	37.850	37.850	7.267	M198 DATA	0.17	1.235	
5788	BAND (INNER BREECH)	1	37.850	37.850	7.267	M198 DATA	0.17	1.235	
6022-005	KEY	2	0.946	1.892	0.363	M198 DATA	0.20	0.073	
----	CLAMP	4	2.000	8.000	1.536	ESTIMATE	0.10	0.154	
----	BOLT	9	0.011	0.099	0.019	CATFAE PRED	N.C.	N.C.	
1.4	PRIMER AUTOLOADER			25.079	39874			10.533	94937
5802	PRIMER AUTOLOADER	1	261.240	261.240	50.158		ARROW PRED+EST	0.21	10.533	
2.0	CARRIAGE			1020.35	980			311.410	[illegible]
2.1	CRADLE			29.445	33962			6.97[illegible]	[illegible]
2.1.1	CRADLE			18.169	55038			4.724	[illegible]
5730	CRADLE	1	94.631	94.631	18.169	M198 DATA	0.26	4.724	
2.1.2	SPEEDSHIFT REL			11.276	88687			[illegible]	[illegible]
[illegible]	BRACKET	1	3.000	3.000	0.576	ESTIMATE	[illegible]	[illegible]	
[illegible]	CRADLE STOP	1	0.500	0.500	0.096	ESTIMATE	[illegible]	[illegible]	
[illegible]	GIMBEL MOUNT	3	0.200	0.600	0.115	ESTIMATE	[illegible]	[illegible]	
[illegible]	GIMBEL SPEEDSHIFT	1	1.00[illegible]	1.00[illegible]	0.192	ESTIMATE	[illegible]	[illegible]	
[illegible]	DISK	1	7.000	7.000	1.344	ESTIMATE	[illegible]	[illegible]	
[illegible]	LOCK HOUSING	1	0.50[illegible]	0.50[illegible]	[illegible]	ESTIMATE	[illegible]	[illegible]	

* [illegible] PER HOUR [illegible] BASED ON GROUND MOBILE ENVIRONMENT ** [illegible]

LTHC SYSTEM RELIABILITY PREDICTION WORKSHEET (AS OF 18 Feb 87)

BLOCK CODE PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5778	LOCK HANDLE	1	14.300	14.300	2.746		AVCO	0.20	0.549	
6013	SPRING	1	2.310	2.310	0.444		AVCO	0.20	0.089	
6002	BOLT	11	0.011	0.121	0.023		CATFAE PRED	N.C.	N.C.	
6003	NUT	8	0.011	0.088	0.017		CATFAE PRED	N.C.	N.C.	
5771	NUT (SPEEDSHIFT PIVOT)	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	
6005	WASHER	8	0.002	0.016	0.003		CATFAE PRED	N.C.	N.C.	
6007	PIN	8	0.374	2.992	0.574		AVCO	0.20	0.115	
6006	BEARING	4	3.790	15.160	2.911		RADC (NPRD-3)	0.20	0.582	
5774,5775	BUSHING (DISK)	2	4.570	9.140	1.755		RADC (NPRD-3)	0.20	0.351	
2.2	TRAILS				123.274	8112			18.207	54923
2.2.1	TRAIL STRUCTURE				78.626	12718			7.837	127593
5841,5897	UPPER TRAIL	2	40.650	81.300	15.610		M198 DATA + EST	0.10	1.561	
5842,5898	LOWER REAR TRAIL	2	20.320	40.640	7.803		M198 DATA + EST	0.10	0.780	
5843,5899	LOWER FRONT TRAIL	2	30.480	60.960	11.704		M198 DATA + EST	0.10	1.170	
5845	FRONT BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5846	WHEEL BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5931	MIDDLE BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5932	REAR BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5933,5934	LATTICE	24	6.770	162.480	31.196		M198 DATA + EST	0.10	3.120	
5834,5835	PIN (TRAIL CLEVIS)	64	0.374	23.936	4.596		AVCO	0.10	0.460	
5844	SPACER	128	0.002	0.256	0.049		ESTIMATE	N.C.	N.C.	
5857,5858	X-RING	64	0.100	6.400	1.229		ESTIMATE	0.10	0.123	
6002-016	BOLT (BULKHEAD)	48	0.011	0.528	0.101		CATFAE PRED	N.C.	N.C.	
6003-007	NUT (BULKHEAD)	48	0.011	0.528	0.101		CATFAE PRED	N.C.	N.C.	
2.2.2	TRAIL PIN				21.001	47617			5.237	190958
6009-003	SCREW	4	0.011	0.044	0.008		CATFAE PRED	0.25	0.002	
6005-010	WASHER	4	0.002	0.008	0.002		CATFAE PRED	0.25	0.000	
6026-001	BEARING PIN	4	14.300	57.200	10.982		AVCO	0.25	2.746	
6006-012	BEARING	4	3.790	15.160	2.911		RADC (NPRD-3)	0.25	0.728	
6024-001	BUSHING (RETAINER)	4	4.570	18.280	3.510		RADC (NPRD-3)	0.25	0.877	
6025-001	RETAINER	4	0.010	0.040	0.008		ESTIMATE	0.25	0.002	
6010-005	SNAP RING	4	0.004	0.016	0.003		ESTIMATE	0.25	0.001	
6006-011	BUSHING (TRAIL BEARING)	4	4.570	18.280	3.510		RADC (NPRD-3)	0.25	0.877	
6003-006	NUT	16	0.011	0.176	0.034		CATFAE PRED	0.05	0.002	
6002-015	BOLT	16	0.011	0.176	0.034		CATFAE PRED	0.05	0.002	
2.2.3	LIFTING HANDLE				16.773	59620			4.035	247808
5891	LIFTING HANDLE	4	1.000	4.000	0.768		ESTIMATE	0.05	0.038	
6004-003	STUD	2	0.051	0.102	0.020		RADC (NPRD-3)	0.05	0.001	
6005-019	WASHER	4	0.002	0.008	0.002		CATFAE PRED	0.05	0.000	
5770	LOCK ARM	2	5.000	10.000	1.920		ESTIMATE	0.25	0.480	
6012-001	PULL PIN	2	14.300	28.600	5.491		AVCO	0.25	1.373	
5762	LOCK PLATE	2	3.000	6.000	1.152		ESTIMATE	0.25	0.288	
6002-[illegible]	BOLT	2	0.011	0.022	0.004		CATFAE PRED	0.25	0.001	
6003	NUT	6	0.011	0.066	0.013		CATFAE PRED	0.25	0.003	
60[illegible]	SPACE CYLINDER	2	1.000	2.000	0.384		ESTIMATE	0.25	0.096	
60[illegible]	BUSHING	8	4.570	36.560	7.020		RADC (NPRD-3)	0.25	1.755	
[illegible]	[illegible]				2.424	4125[illegible]			0.234	[illegible]
5830,58[illegible]	[illegible]	2	3.316	6.632	1.273		RADC (NPRD-3)	0.10	[illegible]	
5856	[illegible]	2	2.776	5.552	1.066		RADC (NPRD-3)	0.10	[illegible]	
60[illegible]	B[illegible]	[illegible]	[illegible]	0.220	0.042		CATFAE PRED	N.C.	N.C.	
60[illegible]	N[illegible]	[illegible]	[illegible]	0.220	0.042		CATFAE PRED	N.C.	N.C.	
[illegible]	[illegible]				[illegible]	[illegible]			[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		ESTIMATE	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		ESTIMATE	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		RADC (NPRD-3)	[illegible]	[illegible]	

[illegible]

BLOCK CODE PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *	(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	[illegible]	[illegible] RATE [illegible]	[illegible]
5864,5865	SUPPORT BAR	3	2.000	6.000	1.152		ESTIMATE	0.20	0.230	
5866	LINK	2	1.000	2.000	0.384		ESTIMATE	0.20	[illegible]	
6002	BOLT	31	0.011	0.341	0.065		CATFAE PRED	N.C.	N.C.	
6003	NUT	31	0.011	0.341	0.065		CATFAE PRED	N.C.	N.C.	
2.3	GIMBAL				11.971	83539			2.978	[illegible]
2.3.1	GIMBAL				3.840	260415			0.960	[illegible]
5810	GIMBAL	1	20.000	20.000	3.840		ESTIMATE	0.25	0.960	
2.3.2	GIMBAL BEARING				8.130	122994			2.018	[illegible]
6007-	PIN (GIMBAL/TRAVERSE)	2	14.300	28.600	5.491		AVCO	0.25	1.373	
5935	SLEEVE	1	4.570	4.570	0.877		RADC (NPRD-3)	0.25	0.219	
5936	SPACER	1	0.002	0.002	0.000		ESTIMATE	0.25	0.000	
5937	COVER	1	0.500	0.500	0.096		ESTIMATE	0.10	0.010	
6002-	BOLT	2	0.011	0.022	0.004		CATFAE PRED	0.25	0.001	
6005-	WASHER	3	0.002	0.006	0.001		CATFAE PRED	0.05	0.000	
6006-	BEARING	2	3.790	7.580	1.455		RADC (NPRD-3)	0.25	0.364	
6010-	SNAP RING	4	0.004	0.016	0.003		ESTIMATE	0.25	0.001	
6030-001	O-RING	1	1.050	1.050	0.202		RADC (NPRD-3)	0.25	0.050	
2.4	PLATFORM				10.640	93985			2.597	385098
2.4.1	PLATFORM				3.840	260415			0.960	1041660
5800	PLATFORM	1	20.000	20.000	3.840		ESTIMATE	0.25	0.960	
2.4.2	PLATFORM/TRAIL CONNECTOR				6.800	147061			1.637	610973
----	HANDLE	2	1.000	2.000	0.384		ESTIMATE	0.10	0.038	
----	BOLT (SPRING LOADED)	2	14.300	28.600	5.491		AVCO + ESTIMATE	0.25	1.373	
6013-001	SPRING	2	2.310	4.620	0.887		AVCO	0.25	0.222	
6010-006	SNAP RING	2	0.004	0.008	0.002		ESTIMATE	0.10	0.000	
6002-029	BOLT	4	0.011	0.044	0.008		CATFAE PRED	0.10	0.001	
6003-	NUT	4	0.011	0.044	0.008		CATFAE PRED	0.10	0.001	
6001-004	ADHESIVE	2	0.050	0.100	0.019		ESTIMATE	0.10	0.002	
2.5	WHEEL SYSTEM				213.406	4686			35.254	28365
2.5.1	PIN ASSEMBLY				12.531	79804			1.405	711789
5730	PIVOT PIN	2	14.300	28.600	5.491		AVCO		0.000	
6005-002	THRUST WASHER	8	0.002	0.016	0.003		CATFAE PRED	0.05	0.000	
6002-001	BOLT (PIVOT)	4	0.011	0.044	0.008		CATFAE PRED	0.05	0.000	
6003-001	NUT (PIVOT)	4	0.011	0.044	0.008		CATFAE PRED	0.05	0.000	
6006-00[illegible]	BUSHING (PIVOT)	8	4.570	36.560	7.020		RADC (NPRD-3)	0.20	1.404	
2.5.2	BEAM ASSEMBLY				20.630	48474			4.152	[illegible]
5794,579[illegible]	LEADING BEAM	2	3.570	7.140	1.371		M198 DATA	0.30	0.411	
5795,579[illegible]	LAGGING BEAM	2	3.570	7.140	1.371		M198 DATA	0.30	0.411	
6007-[illegible]	PIN (SUPPORT)	4	0.374	1.496	0.287		AVCO	0.20	0.057	
5736	CAP (AXLE BEAM END)	8	0.500	4.000	0.768		ESTIMATE	0.05	0.038	
6002-[illegible]	BOLT (AXLE CAP)	16	0.011	0.176	0.034		CATFAE PRED	N.C.	N.C.	
6005-004	WASHER (AXLE CAP)	16	0.002	0.032	0.006		CATFAE PRED	N.C.	N.C.	
6005-006	WASHER (CYLINDER PIVOT)	8	0.002	0.016	0.003		CATFAE PRED	N.C.	N.C.	
[illegible]	BUSHING (CYLINDER PIVOT)	4	4.570	18.280	3.51[illegible]		RADC (NPRD-3)	0.20	[illegible]	
6006-[illegible]	BUSHING (SUPPORT PIVOT)	12	4.570	54.840	10.529		RADC (NPRD-3)	0.20	[illegible]	
[illegible]	CROSS SUPPORT	2	[illegible]	2.0[illegible]	0.384		ESTIMATE	[illegible]	[illegible]	
[illegible]	HANDLE [illegible] SUPPORT	2	3.[illegible]	6.[illegible]	[illegible]		ESTIMATE	[illegible]	[illegible]	
[illegible]	BRACKET	[illegible]	[illegible]	[illegible]	[illegible]		A[illegible]			

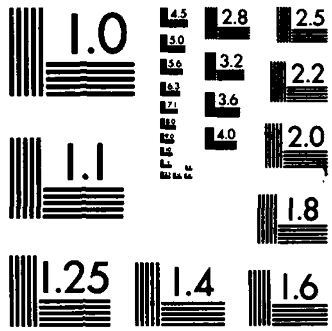
[illegible]

[illegible]	GUIDE (SPRING)	2	[illegible]	[illegible]	[illegible]		ESTIMATE			
[illegible]	BOLT (SUPPORT HANDLE BRKT)	4	[illegible]	[illegible]	[illegible]		CATFAE PRED	N.C.	N.C.	
[illegible]	NUT (SUPPORT HANDLE BRKT)	4	[illegible]	[illegible]	[illegible]		CATFAE PRED	N.C.	N.C.	
[illegible]	BOLT (HANDLE GUIDE)	8	[illegible]	0.088	[illegible]		CATFAE PRED	N.C.	N.C.	
[illegible]	SPRING	2	[illegible]	[illegible]	[illegible]		AVCO	[illegible]	[illegible]	
6033 [illegible]	LOCKWIRE	2	[illegible]	[illegible]	[illegible]		RADC (NPRD-3)	[illegible]		
[illegible]	WHEEL ASSEMBLY				82.944	[illegible]			[illegible]	[illegible]
5738	TIRE	4	31.523	126.092	24.2[illegible]		M198 DATA	[illegible]	[illegible]	
5739	WHEEL	4	1.342	5.368	1.031		M198 DATA	[illegible]	[illegible]	
[illegible]	VALVE STEM AND CAP	4	0.466	1.864	0.358		M198 DATA + EST	[illegible]	[illegible]	
[illegible]	HUB	4	3.354	13.416	2.576		M198 DATA	[illegible]	[illegible]	
574[illegible]	CAP (HUB)	4	1.500	6.000	1.152		ESTIMATE	[illegible]	[illegible]	
6002-003	BOLT (HUB CAP)	32	0.011	0.352	0.068		CATFAE PRED	N.C.	N.C.	
5743	GRASE SEAL	16	3.495	55.920	10.737		RADC (NPRD-3)	[illegible]	[illegible]	
5744	NUT (AXLE BEARING)	8	1.110	8.880	1.705		ESTIMATE	[illegible]	[illegible]	
5745	LOCKWASHER (BEARING)	8	0.002	0.016	0.003		CATFAE PRED	[illegible]	[illegible]	
5746	ROLLER BEARING	8	6.540	52.320	10.046		M198 DATA	[illegible]	2.41[illegible]	
5747	AXLE	4	1.342	5.368	1.031		M198 DATA	[illegible]	0.5[illegible]	
5748	ROTOR (DISC BRAKE)	4	14.256	57.024	10.949		M198 DATA	[illegible]	0.876	
6002-004	BOLT (ROTOR DISC)	24	0.011	0.264	0.051		CATFAE PRED	N.C.	N.C.	
6002-005	BOLT (WHEEL)	32	0.011	0.352	0.068		CATFAE PRED	N.C.	N.C.	
6005-005	WASHER (WHEEL BOLT)	32	0.002	0.064	0.012		CATFAE PRED	N.C.	N.C.	
6019-010	GREASE ZURK	8	10.436	83.488	16.030		RADC (NPRD-3)	N.C.	N.C.	
6019-11	RELIEF VALVE (CAP)	8	1.714	13.712	2.633		RADC (NPRD-3)	N.C.	N.C.	
6007-002	PIN (ROTOR)	4	0.374	1.496	0.287		AVCO	0.05	0.014	
2.5.4	BRAKE SYSTEM				97.302	10277			14.775	67681
5749	BRAKE CALIPER (SERVICE)	4	57.023	228.092	43.794		M198 DATA	0.08	3.504	
6006-002	BUSHING (BRAKE)	16	1.443	23.088	4.433		M198 DATA	0.12	0.532	
5753	PIN (BRAKE)	8	0.374	2.992	0.574		AVCO	0.05	0.029	
5750	PARK BRAKE CALIPER	4	18.112	72.448	13.910		M198 DATA	0.05	0.696	
5827	PIN (PARK BRAKE)	4	0.374	1.496	0.287		AVCO	0.05	0.014	
5824	SHAFT (PARK BRAKE)	2	3.444	6.889	1.323		RADC (NPRD-3)	0.05	0.066	
5825	HEX HEAD (PARK BRAKE)	2	0.011	0.022	0.004		CATFAE PRED	0.05	0.000	
5826	BEARING BLOCK (PARK BRAKE)	4	3.790	15.160	2.911		RADC (NPRD-3)	0.05	0.146	
6002-008	BOLT (BEARING BLOCK)	16	0.011	0.176	0.034		CATFAE PRED	N.C.	N.C.	
5823	ROD END (PARK BRAKE)	4	0.336	1.344	0.258		M198 DATA	0.05	0.013	
5822	ROD (PARK BRAKE)	2	0.671	1.342	0.258		M198 DATA	0.05	0.013	
5819	LEVER (PARK BRAKE)	2	2.012	4.024	0.773		M198 DATA	0.05	0.039	
5715	HYDRAULIC/AIR ACTUATOR	1	50.459	50.459	9.688		NPRD-3+ESTIMATE	0.50	4.844	
5752	RELAY VALVE (W CHECK V)	1	13.416	13.416	2.576		M198 DATA	0.14	0.361	
5715	AIR TANK	1	0.671	0.671	0.129		RADC (NPRD-3)	0.50	0.064	
5757	DRAIN COCK	1	12.075	12.075	2.318		M198 DATA	0.15	0.348	
5759	AIR FILTER	2	3.303	6.606	1.268		RADC (NPRD-3)	0.05	0.063	
5758	FRAME NIPPLE	2	0.466	0.932	0.179		M198 DATA + EST	0.35	0.063	
5756	AIR HOSE ASSEMBLY	2	3.466	6.932	1.331		M198 DATA	0.35	0.466	
5755	GLADHAND	2	1.000	2.000	0.384		ESTIMATE	0.10	0.038	
5754	HOSE SUPPORT BRACKET	1	0.264	0.264	0.051		AVCO	0.10	0.005	
6027	PIPING AND FITTINGS	12	1.765	21.180	4.067		RADC (NPRD-3)	0.35	1.423	
5829	HOSE AND COUPLING	10	1.952	19.520	3.748		RADC (NPRD-3)	0.35	1.312	
6019	ELBOW PIPING	5	0.767	3.835	0.736		M198 DATA	0.35	0.258	
6019-006	NIPPLE	4	0.466	1.864	0.358		M198 DATA + EST	0.35	0.125	
6019-007	UNION	1	1.715	1.715	0.329		ESTIMATE	0.35	0.115	
6019-[illegible]	ADAPTER	6	0.894	5.364	1.030		M198 DATA	0.05	0.051	
6019-[illegible]	TEE	3	0.932	2.796	0.537		M198 DATA + EST	0.35	0.188	
6003-[illegible]	NUT	4	0.011	0.044	0.008		CATFAE PRED	N.C.	N.C.	
6017-[illegible]	X-WASHER	16	0.002	0.032	0.006		CATFAE PRED	N.C.	N.C.	
[illegible]	EQUILIBRATORS				7.492	133483			4.733	[illegible]
[illegible]	EQUILIBRATOR ACTUATOR MOUNT				3.5[illegible]	2848[illegible]			[illegible]	[illegible]
[illegible]	TUBE	[illegible]	[illegible]	[illegible]	[illegible]		ESTIMATE	[illegible]	[illegible]	
[illegible]	TUBE [illegible]	4	[illegible]	[illegible]	[illegible]		ESTIMATE	[illegible]	[illegible]	
[illegible]	CAP	[illegible]	[illegible]	[illegible]	[illegible]		ESTIMATE	[illegible]	[illegible]	

[illegible] SYSTEM RELIABILITY PREDICTION WORKSHEET (AS OF 18-Feb-87)

BLOCK CODE PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF
[illegible]	TRAIL NESTING BUSHING	2	4.570	9.140	1.755		RADC (NPRD-3)	0.50	0.877	
[illegible]	CLAMP SET	3	2.000	6.000	1.152		ESTIMATE	0.25	0.288	
[illegible]	STUD	7	0.051	0.357	0.069		RADC (NPRD-3)	0.25	0.017	
[illegible]	NUT	8	0.011	0.088	0.017		CATFAE PRED	0.25	0.004	
[illegible].6.2	EQUILIBRATOR CABLES				5.736	174331			4.015	[illegible]
5791	CABLE	2	10.400	20.800	3.994		VENDOR DATA	0.70	2.796	
6006-007	BEARING	2	3.790	7.580	1.455		RADC (NPRD-3)	0.70	1.019	
6007-004	PIN	4	0.374	1.496	0.287		AVCO	0.70	0.201	
2.7	HYDRAULIC SYSTEM				544.890	1835			220.[illegible]	[illegible]
2.7.1	SYSTEM HYDRAULICS (MISC)				40.430	24734			6.924	[illegible]
----	MANIFOLD ASSY	4	7.390	29.560	5.676		RADC (NPRD-3)	0.60	3.405	
5906,5907	HAND PUMP	2	50.449	100.898	19.373		RADC (NPRD-3)	0.40	7.749	[illegible]
5903-002	PUMP CONTROL VALVE	2	9.950	19.900	3.821		NPRD-3+ESTIMATE	0.60	2.292	[illegible]
----	QUICK-DISCONNECT CHECK VLV	2	10.436	20.872	4.007		RADC (NPRD-3)	0.50	[illegible]	
5903-003	SAFETY RELIEF VALVE	1	1.714	1.714	0.329		RADC (NPRD-3)	0.50	[illegible]	
----	HOSE AND COUPLING	3	1.952	5.856	1.124		RADC (NPRD-3)	0.35	[illegible]	
----	PIPING AND FITTINGS	18	1.765	31.770	6.100		RADC (NPRD-3)	0.35	[illegible]	[illegible]
2.7.2	TRAVERSE HYDRAULICS				47.656	20984			[illegible]	
5904,5905	CANNON LAY TRAVERSE VALVE	4	9.950	39.800	7.642		NPRD-3+ESTIMATE	0.6[illegible]	[illegible]	[illegible]
5904,5905	HYDRAULIC JOYSTICK	2	21.240	42.480	8.156		RADC (NPRD-3)	0.3[illegible]	[illegible]	[illegible]
5920	TRAVERSE VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	[illegible]	[illegible]	
----	TRAVERSE BEAR LOC	1	23.446	23.446	4.502		NPRD-3 + AVCO	[illegible]	[illegible]	
----	INTENSIFIER (BEAR LOCK)	1	5.500	5.500	1.056		NPRD-3+ESTIMATE	[illegible]	[illegible]	
----	EMERGENCY ZERK???????	1	10.436	10.436	2.004		RADC (NPRD-3)	[illegible]	[illegible]	
5714	TRAVERSE ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	[illegible]	[illegible]	
----	SLIP RING	1	49.879	49.879	9.577		NPRD-3+ESTIMATE	[illegible]		
----	PIPING AND FITTINGS	9	1.765	15.885	3.050		RADC (NPRD-3)	[illegible]		
6007-006	PIN	1	0.374	0.374	0.072		AVCO			
2.7.3	ELEVATION HYDRAULICS				32.329	30932				
5904,5905	CANNON LAY ELEVATION VALVE	4	9.950	39.800	7.642		[illegible]			
5919	ELEVATION VALVE	1	9.950	9.950	1.910		[illegible]			
5716	ELEVATION ACTUATOR	1	50.459	50.459	9.688		[illegible]			
----	SLIP RING	1	49.879	49.879	9.577		[illegible]			
----	PIPING AND FITTINGS	8	1.765	14.120	2.71[illegible]		[illegible]			
6007-009	PIN	1	0.374	0.374	[illegible]		[illegible]			
6006-013	BEARING	1	3.790	3.790	[illegible]		[illegible]			
6005-011	WASHER	2	0.002	0.004	[illegible]					
6017-001	X-WASHER	2	0.002	0.004						
2.7.4	EQUILIBRATION HYDRAULICS				[illegible]					
5893	EQUILIBRATION PRESSURE [illegible]	[illegible]	[illegible]	[illegible]						
5892	EQUILIBRATION VALVE ON [illegible]	[illegible]	[illegible]	[illegible]						
5915	INTENSIFIER (DOUBLE END[illegible]	[illegible]	[illegible]	[illegible]						
5720-002	EQUILIBRATION ACCUM[illegible]	[illegible]								
5712,5713	EQUILIBRATION ACTUATOR	[illegible]	[illegible]							
[illegible]	INTENSIFIER (BEAR [illegible]									
	ELEVATION BEAR [illegible]									
	EMERGENCY ZERK [illegible]									
[illegible]	[illegible]									
	[illegible] AND [illegible]									
	[illegible] AND [illegible]									

AD-A183 996 LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND 2/4
PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87
UNCLASSIFIED FMC-E-3041-VOL-F DAAA21-86-C-0047 F/G 19/6 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5894,5900	PRESSURE GAGE	2	7.180	14.360	2.757		RADC (NPRD-3)	0.05	0.138	
5720-003	RESERVOIR ACCUMULATOR	1	55.045	55.045	10.569		RADC (NPRD-3)	0.30	3.171	
5900-	VALVE (ON/OFF)	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.20	0.382	
----	PILOT OPER CHCK VLV W SEAL	1	16.130	16.130	3.097		NPRD-3+ESTIMATE	0.40	1.239	
----	HYDRAULIC FILTER	1	2.977	2.977	0.572		RADC (NPRD-3)	0.30	0.171	
----	CHECK VALVE (FILTER)	2	8.423	16.846	3.234		RADC (NPRD-3)	0.50	1.617	
----	PIPING AND FITTINGS	7	1.765	12.355	2.372		RADC (NPRD-3)	0.35	0.830	
2.7.6	CANNON POSITION HYDRAULICS				8.104	123390			3.624	275951
5895	CANNON POSITION VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
----	PILOT OPER CHCK VLV W SEAL	2	16.130	32.260	6.194		NPRD-3+ESTIMATE	0.40	2.478	
2.7.7	RECOIL & C'RECOIL HYDRAULICS				152.061	6576			63.405	15772
5710-555	RECOIL CYLINDER	2	152.132	304.264	58.419		M109 DATA	0.45	26.289	
5710-315	C' RECOIL CYLINDER	1	152.132	152.132	29.210		M109 DATA	0.45	13.144	
5710-310	ENERGY STORAGE CYLINDER	1	152.132	152.132	29.210		M109 DATA	0.45	13.144	
5718,5719	C' RECOIL ACCUMULATOR	2	55.045	110.090	21.137		RADC (NPRD-3)	0.30	6.341	
5912	CHECK VALVE	3	8.423	25.269	4.852		RADC (NPRD-3)	0.50	2.426	
5913	RELIEF VALVE	1	1.714	1.714	0.329		RADC (NPRD-3)	0.50	0.165	
5914	PRESSURE REDUCING VALVE	1	1.714	1.714	0.329		RADC (NPRD-3)	0.50	0.165	
5916	CIRCUIT BREAKER	1	10.733	10.733	2.061		NPRD-3 + AVCO	N.C.	N.C.	
5916	ORIFICE	1	7.180	7.180	1.379		RADC (NPRD-3)	N.C.	N.C.	
5947	ROD/PISTON (RECOIL)	2	1.000	2.000	0.384		ESTIMATE	0.45	0.173	
5948	ROD/PISTON (C'RECOIL)	2	2.050	4.100	0.787		NPRD-3+ESTIMATE	0.45	0.354	
5949	ORIFICE ROD	2	2.150	4.300	0.826		NPRD-3+ESTIMATE	0.45	0.372	
5950	GUIDE ROD	2	2.150	4.300	0.826		NPRD-3+ESTIMATE	0.45	0.372	
5951	END CAP	8	1.000	8.000	1.536		ESTIMATE	0.20	0.307	
5952	WASHER (END CAP)	4	0.002	0.008	0.002		CATFAE PRED	0.20	0.000	
5954	COLLAR (END CAP)	4	1.000	4.000	0.768		ESTIMATE	0.20	0.154	
5955	NUT (END CAP)	4	0.011	0.044	0.008		CATFAE PRED	0.05	0.000	
2.7.8	BREECH HYDRAULICS				26.924	37142			13.057	76589
5900-001	BREECH VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5725	BREECH ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
----	ACTUATOR CONTROL VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
----	CHECK VALVE	1	8.423	8.423	1.617		RADC (NPRD-3)	0.50	0.809	
5922	PILOT OPER CTRL FLOW VALVE	2	24.553	49.106	9.428		NPRD-3+ESTIMATE	0.45	4.243	
----	PIPING AND FITTINGS	4	1.765	7.060	1.356		RADC (NPRD-3)	0.35	0.474	
----	HOSE AND COUPLING	2	1.952	3.904	0.750		RADC (NPRD-3)	0.35	0.262	
----	LINK	1	1.000	1.000	0.192		ESTIMATE	0.50	0.096	
5725	PIN	1	0.374	0.374	0.072		AVCO	0.50	0.036	
2.7.9	INERTIAL RAMMING HYDRAULICS				19.967	50084			10.140	98618
5900-002	VALVE (RAM/RETRACT/CREEP)	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5902-	DEINTENSIFIER	1	36.750	36.750	7.056		ESTIMATE	0.55	3.881	
----	AIR FILTER	1	3.303	3.303	0.634		RADC (NPRD-3)	0.05	0.032	
5729	RAMMER POSITION ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
----	PIPING AND FITTINGS	2	1.765	3.530	0.678		RADC (NPRD-3)	0.35	0.237	
2.7.10	LOAD POSITION HYDRAULICS				22.291	44861			10.998	90929
5900-003	VALVE (BATTERY/LOAD)	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5728	LOAD POSITION ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
5921	PILOT OPER CHCK VLV W SEAL	2	16.130	32.260	6.194		NPRD-3+ESTIMATE	0.40	2.478	
5917	BATTERY VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5918	LOAD POSITION VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
----	PIPING AND FITTINGS	2	1.765	3.530	0.678		RADC (NPRD-3)	0.35	0.237	
2.7.11	WHEEL HYDRAULICS				68.380	14624			32.464	30804
5910	WHEEL HYDRAULIC VALVE	8	9.950	79.600	15.283		NPRD-3+ESTIMATE	0.60	9.170	
5721-5722	WHEEL ACTUATOR	4	50.459	201.836	38.753		RADC (NPRD-3)	0.50	19.376	

(*) FAILURE PER MILLION HOURS - BASED ON GROUND MOBILE ENVIRONMENT; (**) 5.2083 ROUNDS PER HOUR CONVERSION FACTOR

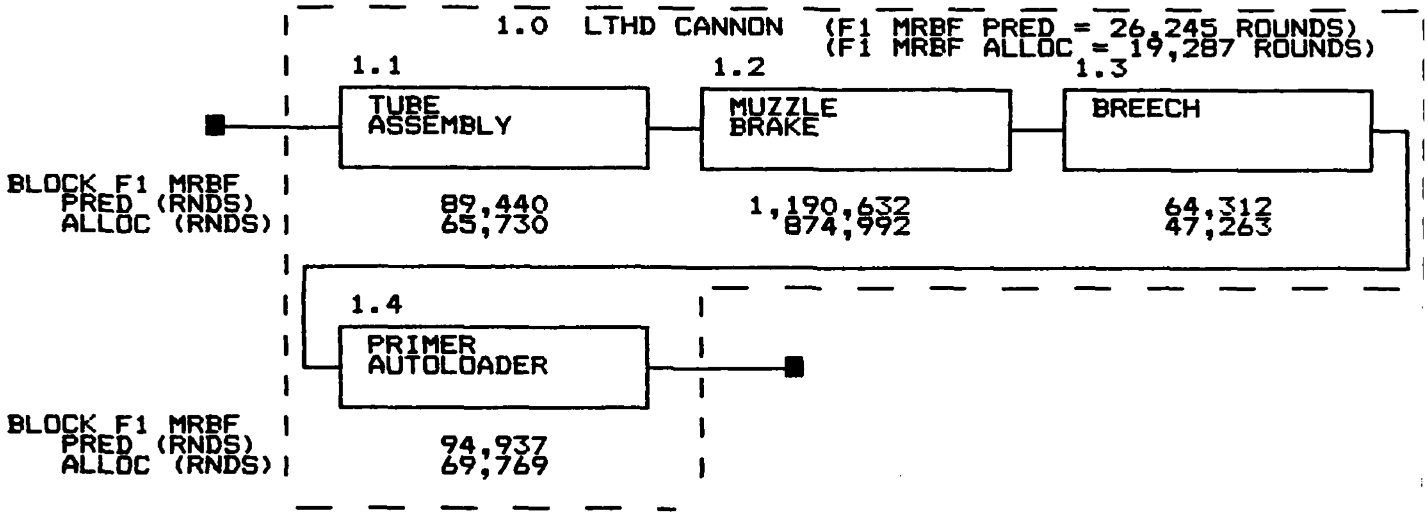
Pg. 12

LTHD SYSTEM RELIABILITY PREDICTION WORKSHEET (AS OF 18-Feb-87)

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
----	LINKAGE (WHEEL ACT VALVE)	4	1.000	4.000	0.768		ESTIMATE	0.50	0.384	
----	BURST PLUG	4	1.000	4.000	0.768		ESTIMATE	0.50	0.384	
5903-001	CIRCUIT BREAKER	2	10.733	21.466	4.121		NPRD-3 + AVCO	N.C.	N.C.	
----	HOSE AND COUPLING	14	1.952	27.328	5.247		RADC (NPRD-3)	0.35	1.836	
----	PIPING AND FITTINGS	8	1.765	14.120	2.711		RADC (NPRD-3)	0.35	0.949	
----	PIN JOINT	8	0.374	2.992	0.574		AVCO	0.50	0.287	
----	RETAINING RING	8	0.100	0.800	0.154		ESTIMATE	0.50	0.077	
2.7.12	PRIMER HYDRAULICS				17.668	56598			8.586	116466
5900-004	PRIMER VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5726	PRIMER ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
5922	PILOT OPER CTRL FLOW VALVE	1	24.553	24.553	4.714		NPRD-3+ESTIMATE	0.45	2.121	
----	PIPING AND FITTINGS	4	1.765	7.060	1.356		RADC (NPRD-3)	0.35	0.474	
2.7.13	LANYARD HYDRAULICS				17.329	57705			8.468	118098
5900-005	LANYARD VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5727	PRIMER ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
5922	PILOT OPER CTRL FLOW VALVE	1	24.553	24.553	4.714		NPRD-3+ESTIMATE	0.45	2.121	
----	PIPING AND FITTINGS	3	1.765	5.295	1.017		RADC (NPRD-3)	0.35	0.356	
2.8	LOAD TRAY				70.658	14153			17.907	55843
2.8.1	LOAD TRAY				49.719	20113			10.037	99635
5867	LOAD TRAY	1	20.284	20.284	3.895		M109 DATA	0.20	0.779	
----	BARS	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	
----	CLEVIS	3	3.800	11.400	2.189		CATFAE PRED	0.20	0.438	
----	ROLLER HOUSING (FIXED)	1	3.000	3.000	0.576		ESTIMATE	0.20	0.115	
----	TIE BAR	2	5.000	10.000	1.920		ESTIMATE	0.20	0.384	
----	TROLLY SUPPORT	4	5.000	20.000	3.840		ESTIMATE	0.20	0.768	
----	ROLLER HOUSING (PIVOTING)	4	3.000	12.000	2.304		ESTIMATE	0.20	0.461	
6002-	BOLT	125	0.011	1.375	0.264		CATFAE PRED	N.C.	N.C.	
6003-	NUT	211	0.011	2.321	0.446		CATFAE PRED	N.C.	N.C.	
6005-	WASHER	546	0.002	1.092	0.210		CATFAE PRED	N.C.	N.C.	
5927	TRACK (REAR)	1	22.312	22.312	4.284		M109 DATA + EST	0.20	0.857	
5928	GUIDE (REAR TRACK)	2	22.312	44.624	8.568		M109 DATA + EST	0.20	1.714	
5926	TRACK (CENTER)	1	22.312	22.312	4.284		M109 DATA + EST	0.20	0.857	
5925	TRACK (FORWARD)	1	22.312	22.312	4.284		M109 DATA + EST	0.20	0.857	
5888	HINGE (BRACKET INNER)	4	3.800	15.200	2.918		ESTIMATE	0.20	0.584	
5889	HINGE (BRACKET OUTER)	4	3.800	15.200	2.918		ESTIMATE	0.20	0.584	
5929,5930, 5940	BAR (TRACK SUPPORT)	3	1.000	3.000	0.576		ESTIMATE	0.20	0.115	
5939	BRACKET(REAR TRACK ROLLER)	4	0.264	1.056	0.203		AVCO	0.20	0.041	
5887	ROLLER	28	0.442	12.376	2.376		NPRD-3 + AVCO	0.40	0.950	
5868	WEARSTRIP	3	1.000	3.000	0.576		ESTIMATE	0.05	0.029	
5869	BACKSTOP (PROJECTILE)	1	2.000	2.000	0.384		ESTIMATE	0.10	0.038	
5870	STRIP	2	1.000	2.000	0.384		ESTIMATE	0.05	0.019	
5871	BRACKET	2	0.264	0.528	0.101		AVCO	0.20	0.020	
6006-015	BUSHING	2	4.570	9.140	1.755		RADC (NPRD-3)	0.20	0.351	
6009-	SCREW	38	0.011	0.418	0.080		CATFAE PRED	N.C.	N.C.	
2.8.2	SHOCK MOUNT				20.939	47758			7.871	127056
5872,5873, 5874	BAR	4	1.000	4.000	0.768		ESTIMATE	0.20	0.154	
5941	PRIMARY SHOCK	2	7.682	15.364	2.950		RADC (NPRD-3)	0.50	1.475	
5875	BRACKET	1	0.264	0.264	0.051		AVCO	0.20	0.010	
5942	SHOCK (MAN)	1	7.682	7.682	1.475		RADC (NPRD-3)	0.50	0.737	
5878	PAD (PROJECTILE STOP)	1	3.316	3.316	0.637		RADC (NPRD-3)	0.20	0.127	
6002-	BOLT	3	0.011	0.033	0.006		CATFAE PRED	0.20	0.001	
6003-	NUT	7	0.011	0.077	0.015		CATFAE PRED	0.20	0.003	
6005-	WASHER	2	0.002	0.004	0.001		CATFAE PRED	0.20	0.000	
5879	MOUNT (PAD)	1	2.776	2.776	0.533		RADC (NPRD-3)	0.20	0.107	
5880	CUSHION	1	3.316	3.316	0.637		RADC (NPRD-3)	0.20	0.127	
5881	BAR (PIN PIVOT) ??????	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	

(*) FAILURE PER MILLION HOURS - BASED ON GROUND MOBILE ENVIRONMENT; (**) 5.2083 ROUNDS PER HOUR CONVERSION FACTOR

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *	(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5877	MOUNT (PROJECTILE STOP)	1	2.776	2.776	0.533	RADC (NPRD-3)	0.50	0.266	
5876	GUIDE (SHOCK MOUNT)	4	11.000	44.000	8.448	M109 DATA + EST	0.30	2.534	
5882	PIN (PROJ STOP PAD)	1	14.300	14.300	2.746	AVCO	0.50	1.373	
6006-014	BUSHING	2	4.570	9.140	1.755	RADC (NPRD-3)	0.50	0.877	
6010-004	SNAP RING	2	0.004	0.008	0.002	ESTIMATE	0.50	0.001	
2.9	SPADE				7.403	135081		2.762	362086
2.9.1	SPADE				7.403	135081		2.762	362086
5820	SPADE	1	37.853	37.853	7.268	M198 DATA	0.38	2.762	
6002-011	BOLT (SPADE/PLATFORM)	64	0.011	0.704	0.135	CATFAE PRED	N.C.	N.C.	
3.0	FIRE CONTROL			1411.46	708			175.83	5687
3.1	ASSISTANT GUNNER & GUNNER			1409.95	709			175.528	5697
----	ELBOW TELESCOPE	1	643.496	643.496	123.552	M198 DATA	N.C.	N.C.	
----	M172 MT, TELE, QUAD	1	132.484	132.484	25.437	M198 DATA	0.18	4.579	REDUNDANT
----	M18 FIRE CONTROL QUADRANT	1	1343.771	1343.771	258.006	M198 DATA	0.23	59.341	REDUNDANT
----	M137 PANORAMIC TELESCOPE	1	3217.480	3217.480	617.760	M198 DATA	0.23	142.085	
----	M171 MT, TELE, QUAD	1	946.318	946.318	181.694	M198 DATA	0.18	32.705	
----	M17 FIRE CONTROL QUADRANT	1	1059.876	1059.876	203.497	M198 DATA	0.23	46.804	REDUNDANT
3.2	FIRE CONTROL LINKAGE			1.52	659278			0.30	3296392
----	TRUNNION TUBE	1	0.500	0.500	0.096	ESTIMATE	0.20	0.019	
----	END CAP	2	0.200	0.400	0.077	ESTIMATE	0.20	0.015	
----	SIDE SUPPORT STRUT	2	1.000	2.000	0.384	ESTIMATE	0.20	0.077	
----	ACTUATOR STRUT	1	1.000	1.000	0.192	ESTIMATE	0.20	0.038	
----	SHORT STRUT	2	1.000	2.000	0.384	ESTIMATE	0.20	0.077	
----	SUPPORT STRUT	2	1.000	2.000	0.384	ESTIMATE	0.20	0.077	



<u>RELIABILITY EQUATION</u>

$$\text{F1 MRBF}_{ss} = \frac{1}{\sum_{i=1}^{n} (1/\text{F1 MRBF}_i)}$$

WHERE; F1 MRBF_i = BLOCK F1 MEAN ROUNDS BETWEEN FAILURES

F1 MRBF_{ss} = SUBSYSTEM F1 MEAN ROUNDS BETWEEN FAILURES

n = NUMBER OF BLOCKS IN THE SUBSYSTEM

F1 = MISSION CRITICAL FAILURES

FIGURE 4 - LTHD CANNON MISSION CRITICAL RELIABILITY BLOCK DIAGRAM
(AS OF 2/18/87)

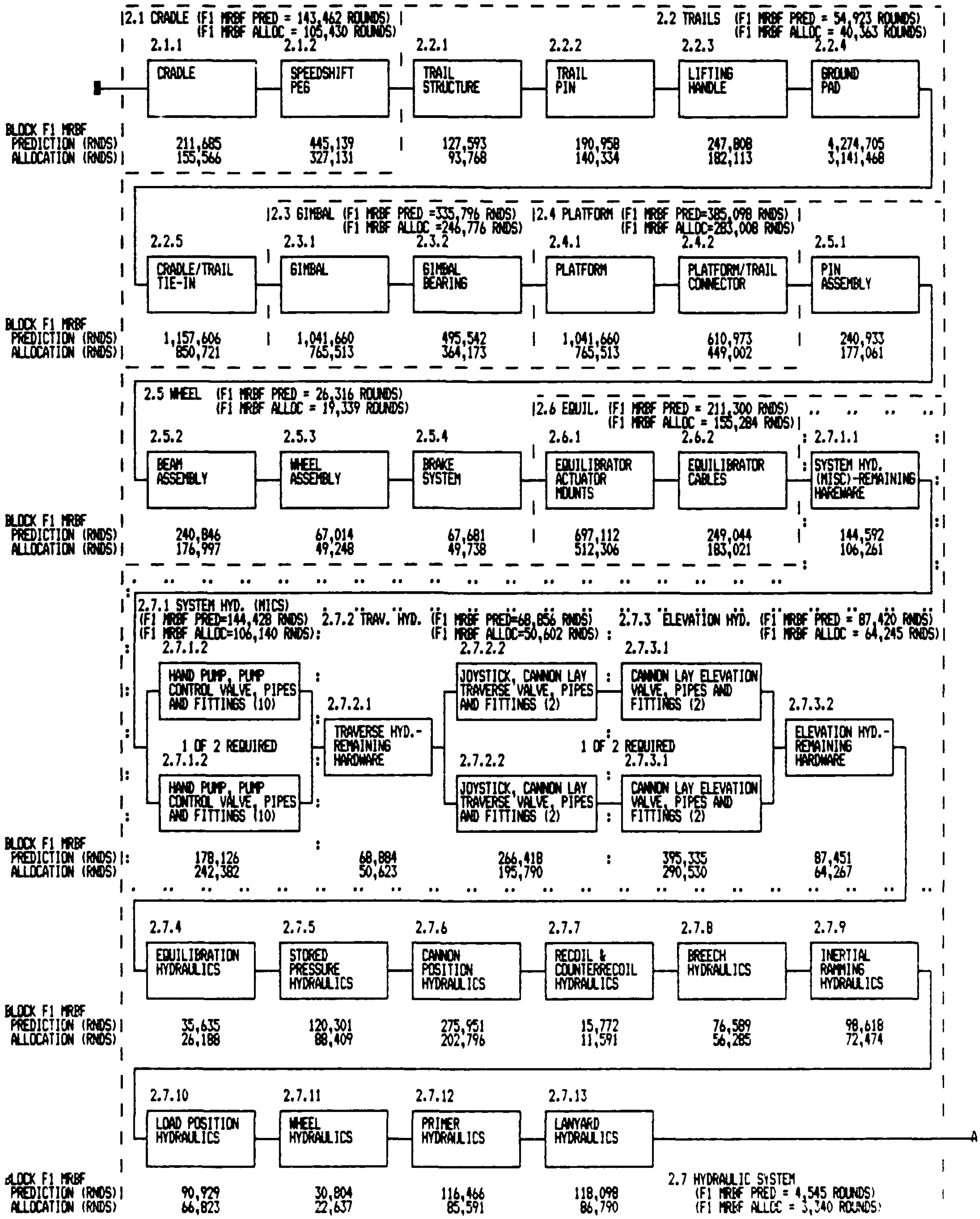
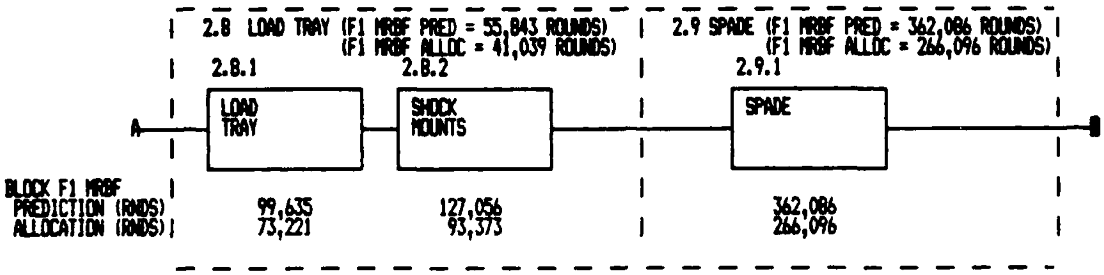


FIGURE 5 – LTHD CARRIAGE MISSION CRITICAL RELIABILITY BLOCK DIAGRAM – 1 OF 2 DIAGRAMS (AS OF 2/18/87)



2.0 LTHD CARRIAGE (F1 MRBF PRED = 3,183 ROUNDS)
(F1 MRBF ALLOC = 2,339 ROUNDS)

RELIABILITY EQUATIONS

$$\text{BLOCK } R = e^{-N/(\text{BLOCK MRBF})}$$

$$R_{2.7.1} = R_{2.7.1.1} \times (R_{2.7.1.2}^{2} - 2R_{2.7.1.2})$$

$$\text{F1 MRBF}_{2.7.1} = \frac{1}{1 - R_{2.7.1}(N)} \int_{0}^{N = 250 \text{ rounds}} R_{2.7.1}(n)\, dn$$

$$R_{2.7.2,2.7.3} = R_{2.7.2.1} \times [(R_{2.7.2.2} \times R_{2.7.3.1})^{2} - 2R_{2.7.2.2} \times R_{2.7.3.1}] \times R_{2.7.3.2}$$

$$\text{F1 MRBF}_{2.7.2,2.7.3} = \frac{1}{1 - R_{2.7.2,2.7.3}(N)} \int_{0}^{N = 250 \text{ rounds}} R_{2.7.2,2.7.3}(n)\, dn$$

$$\lambda = 1/\text{MRBF}$$

$$\lambda_{2.7.2} = \lambda_{2.7.2.1} + [\lambda_{2.7.2.2}/(\lambda_{2.7.2.2} + \lambda_{2.7.3.1})] \times (\lambda_{2.7.2,2.7.3} - \lambda_{2.7.2.1} - \lambda_{2.7.3.2})$$

$$\text{F1 MRBF}_{2.7.2} = 1/\lambda_{2.7.2}$$

$$\lambda_{2.7.3} = \lambda_{2.7.3.2} + [\lambda_{2.7.3.1}/(\lambda_{2.7.2.2} + \lambda_{2.7.3.1})] \times (\lambda_{2.7.2,2.7.3} - \lambda_{2.7.2.1} - \lambda_{2.7.3.2})$$

$$\text{F1 MRBF}_{2.7.3} = 1/\lambda_{2.7.3}$$

$$\text{F1 MRBF}_{ss} = \frac{1}{\sum_{i=1}^{n} (1/\text{F1 MRBF}_{i})}$$

WHERE;

N = 250 ROUNDS FIRED - BASED ON M198 HOWITZER 48-HOUR BATTLEFIELD MISSION (EQUIPMENT MAINTAINED AT THE END OF MISSION)

F1 = MISSION CRITICAL FAILURES

R = RELIABILITY

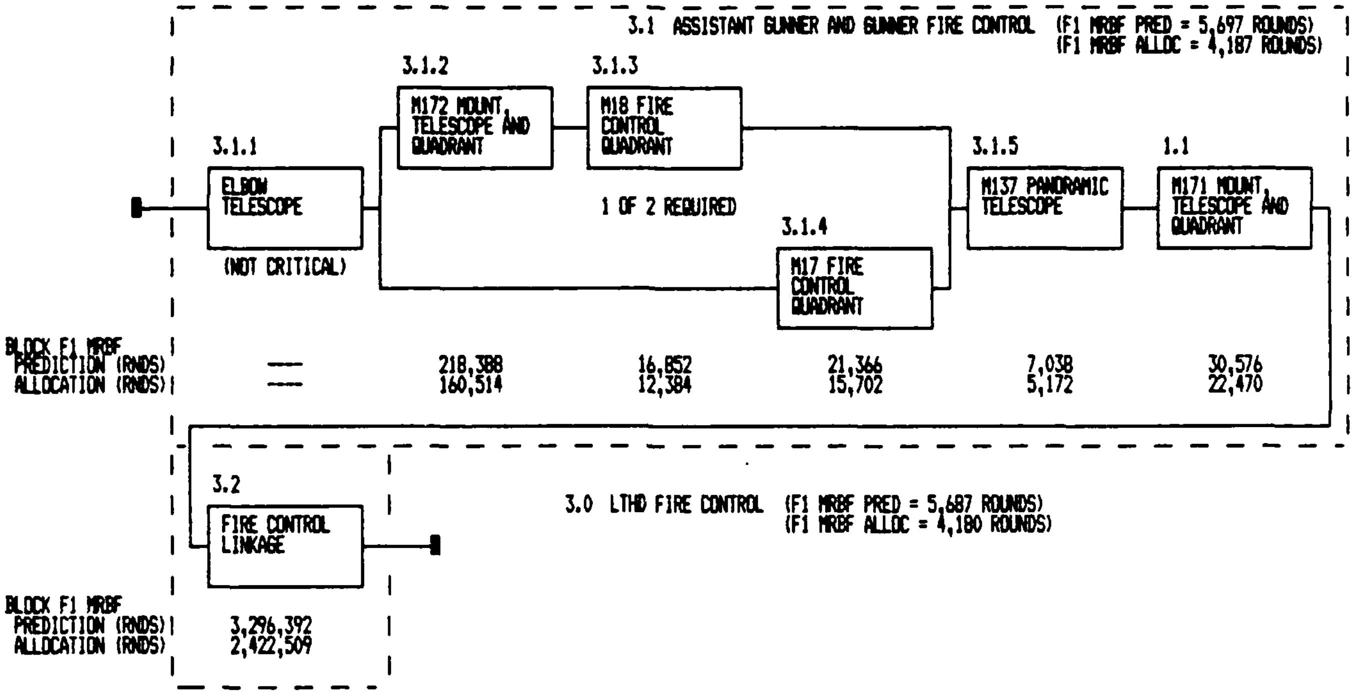
F1 MRBF_{i} = BLOCK F1 MEAN ROUNDS BETWEEN FAILURES

λ = FAILURE RATE (FAILURES PER MILLION ROUNDS)

F1 MRBF_{ss} = SUBSYSTEM F1 MEAN ROUNDS BETWEEN FAILURES

n = NUMBER OF BLOCKS IN THE SUBSYSTEM

FIGURE 5 - LTHD CARRIAGE MISSION CRITICAL RELIABILITY BLOCK DIAGRAM - 2 OF 2 DIAGRAMS (AS OF 2/18/87)



RELIABILITY EQUATIONS

$$\text{BLOCK } R = e^{-N/(\text{BLOCK MRBF})}$$

$$R_{3.1} = (R_{3.1.2} \times R_{3.1.3} + R_{3.1.4} - R_{3.1.2} \times R_{3.1.3} \times R_{3.1.4}) \times R_{3.1.5} \times R_{3.1.6}$$

$$\text{F1 MRBF}_{3.1} = \frac{1}{1 - R_{3.1}(N)} \int_{0}^{N = 250 \text{ rounds}} R_{3.1}(n)\, dn$$

$$\text{F1 MRBF}_{ss} = \frac{1}{\sum_{i=1}^{n} (1/\text{F1 MRBF}_i)}$$

WHERE;

N = 250 ROUNDS FIRED - BASED ON M198 HOWITZER 48-HOUR BATTLEFIELD MISSION (EQUIPMENT MAINTAINED AT THE END OF MISSION)

$\text{F1 MRBF}_{3.1}$ = ASSIST GUNNER & GUNNER FC MEAN ROUNDS BETWEEN FAILURES

F1 = MISSION CRITICAL FAILURES

R = RELIABILITY

F1 MRBF_i = BLOCK F1 MEAN ROUNDS BETWEEN FAILURES

F1 MRBF_{ss} = SUBSYSTEM (FIRE CONTROL) F1 MEAN ROUNDS BETWEEN FAILURES

n = NUMBER OF BLOCKS IN THE SUBSYSTEM

FIGURE 6 - LTHD FIRE CONTROL MISSION CRITICAL RELIABILITY BLOCK DIAGRAM
(AS OF 2/18/87)

 LTHD SYSTEM MISSION CRITICAL (F1) RELIABILITY PREDICTION AND ALLOCATION WORKSHEET (AS OF 18-Feb-87)

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR				528.090	1894		909.091	1100
1.0	CANNON			38.103	26245		51.848	19287
1.1	TUBE ASSEMBLY			11.181	89440		15.214	65730
1.1.1	TUBE ASSEMBLY			11.181	89440		15.214	65730
5767	TUBE	1	0.95	10.357		14.093	14.093	
5781	COLLAR SET	5	0.20	0.384		0.105	0.523	
6016-001	EXTRUSION RAIL	2	0.20	0.077		0.052	0.105	
6022-	KEY	20	0.10	0.363		0.025	0.494	
6002-	BOLT	40	N.C.	N.C.		N.C.	N.C.	
6003-007	NUT	20	N.C.	N.C.		N.C.	N.C.	
1.2	MUZZLE BRAKE			0.840	1190632		1.143	874992
1.2.1	MUZZLE BRAKE			0.840	1190632		1.143	874992
5765	MUZZLE BRAKE	1	0.20	0.727		0.989	0.989	
5786	KEY,	1	0.20	0.036		0.049	0.049	
5787	TRUST COLLAR	1	0.20	0.077		0.105	0.105	
1.3	BREECH			15.549	64312		21.158	47263
1.3.1	BREECH			15.549	64312		21.158	47263
5789	BREECH	1	0.55	12.852		17.488	17.488	
5816	BAND (OUTER BREECH)	1	0.17	1.235		1.681	1.681	
5788	BAND (INNER BREECH)	1	0.17	1.235		1.681	1.681	
6022-005	KEY	2	0.20	0.073		0.049	0.099	
----	CLAMP	4	0.10	0.154		0.052	0.209	
----	BOLT	9	N.C.	N.C.		N.C.	N.C.	
1.4	PRIMER AUTOLOADER			10.533	94937		14.333	69769
5802	PRIMER AUTOLOADER	1	0.21	10.533		14.333	14.333	
2.0	CARRIAGE			314.156	3183		427.483	2339
2.1	CRADLE			6.971	143462		9.485	105430
2.1.1	CRADLE			4.724	211685		6.428	155566
5730	CRADLE	1	0.26	4.724		6.428	6.428	
2.1.2	SPEEDSHIFT PEG			2.246	445139		3.057	327131
5780	BRACKET	1	0.20	0.115		0.157	0.157	
5772	CRADLE STOP	1	0.20	0.019		0.026	0.026	
5777	GIMBEL MOUNT	3	0.20	0.023		0.010	0.031	
5776	GIMBEL SPEEDSHIFT	1	0.20	0.038		0.052	0.052	
5790	DISK	1	0.20	0.269		0.366	0.366	
5773	LOCK HOUSING	1	0.20	0.019		0.026	0.026	
5778	LOCK HANDLE	1	0.20	0.549		0.747	0.747	

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
6013-	SPRING	1	0.20	0.089		0.121	0.121	
6002-	BOLT	11	N.C.	N.C.		N.C.	N.C.	
6003-	NUT	8	N.C.	N.C.		N.C.	N.C.	
5771	NUT (SPEEDSHIFT PIVOT)	2	0.20	0.077		0.052	0.105	
6005-	WASHER	8	N.C.	N.C.		N.C.	N.C.	
6007-	PIN	8	0.20	0.115		0.020	0.156	
6006-	BEARING	4	0.20	0.582		0.198	0.792	
5774,5775	BUSHING (DISK)	2	0.20	0.351		0.239	0.478	
2.2	TRAILS			18.207	54923		24.775	40363
2.2.1	TRAIL STRUCTURE			7.837	127593		10.665	93768
5841,5897	UPPER TRAIL	2	0.10	1.561		1.062	2.124	
5842,5898	LOWER REAR TRAIL	2	0.10	0.780		0.531	1.062	
5843,5899	LOWER FRONT TRAIL	2	0.10	1.170		0.796	1.593	
5845	FRONT BULKHEAD	2	0.10	0.156		0.106	0.212	
5846	WHEEL BULKHEAD	2	0.10	0.156		0.106	0.212	
5931	MIDDLE BULKHEAD	2	0.10	0.156		0.106	0.212	
5932	REAR BULKHEAD	2	0.10	0.156		0.106	0.212	
5933,5934	LATTICE	24	0.10	3.120		0.177	4.245	
5834,5835	PIN (TRAIL CLEVIS)	64	0.10	0.460		0.010	0.625	
5844	SPACER	128	N.C.	N.C.		N.C.	N.C.	
5857,5858	X-RING	64	0.10	0.123		0.003	0.167	
6002-016	BOLT (BULKHEAD)	48	N.C.	N.C.		N.C.	N.C.	
6003-007	NUT (BULKHEAD)	48	N.C.	N.C.		N.C.	N.C.	
2.2.2	TRAIL PIN			5.237	190958		7.126	140334
6009-003	SCREW	4	0.25	0.002		0.001	0.003	
6005-010	WASHER	4	0.25	0.000		0.000	0.001	
6026-001	BEARING PIN	4	0.25	2.746		0.934	3.736	
6006-012	BEARING	4	0.25	0.728		0.248	0.990	
6024-001	BUSHING (RETAINER)	4	0.25	0.877		0.298	1.194	
6025-001	RETAINER	4	0.25	0.002		0.001	0.003	
6010-005	SNAP RING	4	0.25	0.001		0.000	0.001	
6006-011	BUSHING (TRAIL BEARING)	4	0.25	0.877		0.298	1.194	
6003-006	NUT	16	0.05	0.002		0.000	0.002	
6002-015	BOLT	16	0.05	0.002		0.000	0.002	
2.2.3	LIFTING HANDLE			4.035	247808		5.491	182113
5891	LIFTING HANDLE	4	0.05	0.038		0.013	0.052	
6004-003	STUD	2	0.05	0.001		0.001	0.001	
6005-019	WASHER	4	0.05	0.000		0.000	0.000	
5770	LOCK ARM	2	0.25	0.480		0.327	0.653	
6012-001	PULL PIN	2	0.25	1.373		0.934	1.868	
5762	LOCK PLATE	2	0.25	0.288		0.196	0.392	
6002-010	BOLT	2	0.25	0.001		0.001	0.001	
6003-	NUT	6	0.25	0.003		0.001	0.004	
6011-001	SPACE CYLINDER	2	0.25	0.096		0.065	0.131	
6011-016	BUSHING	8	0.25	1.755		0.298	2.388	
2.2.4	GROUND PAD			0.234	4274705		0.318	3141468
5832,5833	GROUND PAD	2	0.10	0.127		0.087	0.173	
5856	SPACER	2	0.10	0.107		0.073	0.145	
6002-017	BOLT	20	N.C.	N.C.		N.C.	N.C.	
6003-008	NUT	20	N.C.	N.C.		N.C.	N.C.	
2.2.5	CRADLE/TRAIL TIE-IN			0.864	1157606		1.175	850721
5855	SLOTTED PLATE	4	0.20	0.461		0.157	0.627	
5854	SHIM	4	0.20	0.015		0.005	0.021	
5863	LUG	4	0.20	0.080		0.027	0.110	
5864,5865	SUPPORT BAR	3	0.20	0.230		0.105	0.314	

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
5866	LINK	2	0.20	0.077		0.052	0.105	
6002-	BOLT	31	N.C.	N.C.		N.C.	N.C.	
6003-	NUT	31	N.C.	N.C.		N.C.	N.C.	
2.3	GIMBAL			2.978	335796		4.052	246776
2.3.1	GIMBAL			0.960	1041660		1.306	765513
5810	GIMBAL	1	0.25	0.960		1.306	1.306	
2.3.2	GIMBAL BEARING			2.018	495542		2.746	364173
6007-	PIN (GIMBAL/TRAVERSE)	2	0.25	1.373		0.934	1.868	
5935	SLEEVE	1	0.25	0.219		0.298	0.298	
5936	SPACER	1	0.25	0.000		0.000	0.000	
5937	COVER	1	0.10	0.010		0.013	0.013	
6002-	BOLT	2	0.25	0.001		0.001	0.001	
6005-	WASHER	3	0.05	0.000		0.000	0.000	
6006-	BEARING	2	0.25	0.364		0.248	0.495	
6010-	SNAP RING	4	0.25	0.001		0.000	0.001	
6030-001	O-RING	1	0.25	0.050		0.069	0.069	
2.4	PLATFORM			2.597	385098		3.533	283008
2.4.1	PLATFORM			0.960	1041660		1.306	765513
5800	PLATFORM	1	0.25	0.960		1.306	1.306	
2.4.2	PLATFORM/TRAIL CONNECTOR			1.637	610973		2.227	449002
----	HANDLE	2	0.10	0.038		0.026	0.052	
----	BOLT (SPRING LOADED)	2	0.25	1.373		0.934	1.868	
6013-001	SPRING	2	0.25	0.222		0.151	0.302	
6010-006	SNAP RING	2	0.10	0.000		0.000	0.000	
6002-029	BOLT	4	0.10	0.001		0.000	0.001	
6003-	NUT	4	0.10	0.001		0.000	0.001	
6001-004	ADHESIVE	2	0.10	0.002		0.001	0.003	
2.5	WHEEL SYSTEM			38.000	26316		51.708	19339
2.5.1	PIN ASSEMBLY			4.151	240933		5.648	177061
5730	PIVOT PIN	2	0.50	2.746		1.868	3.736	
6005-002	THRUST WASHER	8	0.05	0.000		0.000	0.000	
6002-001	BOLT (PIVOT)	4	0.05	0.000		0.000	0.001	
6003-001	NUT (PIVOT)	4	0.05	0.000		0.000	0.001	
6006-001	BUSHING (PIVOT)	8	0.20	1.404		0.239	1.910	
2.5.2	BEAM ASSEMBLY			4.152	240846		5.650	176997
5794,5796	LEADING BEAM	2	0.30	0.411		0.280	0.560	
5795,5797	LAGGING BEAM	2	0.30	0.411		0.280	0.560	
6007-001	PIN (SUPPORT)	4	0.20	0.057		0.020	0.078	
5736	CAP (AXLE BEAM END)	8	0.05	0.038		0.007	0.052	
6002-002	BOLT (AXLE CAP)	16	N.C.	N.C.		N.C.	N.C.	
6005-004	WASHER (AXLE CAP)	16	N.C.	N.C.		N.C.	N.C.	
6005-006	WASHER (CYLINDER PIVOT)	8	N.C.	N.C.		N.C.	N.C.	
6006-003	BUSHING (CYLINDER PIVOT)	4	0.20	0.702		0.239	0.955	
6006-004	BUSHING (SUPPORT PIVOT)	12	0.20	2.106		0.239	2.866	
5803,5804	CROSS SUPPORT	2	0.20	0.077		0.052	0.105	
5809	HANDLE LOCKING (X-SUPPORT)	2	0.20	0.230		0.157	0.314	
5812	BRACKET	2	0.20	0.020		0.014	0.028	
5813	GUIDE (SPRING)	2	0.05	0.010		0.007	0.013	

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
6002-006	BOLT (SUPPORT HANDLE BRKT)	4	N.C.	N.C.		N.C.	N.C.	
6003-005	NUT (SUPPORT HANDLE BRKT)	4	N.C.	N.C.		N.C.	N.C.	
6002-007	BOLT (HANDLE GUIDE)	8	N.C.	N.C.		N.C.	N.C.	
6013-002	SPRING	2	0.10	0.089		0.060	0.121	
6033-001	LOCKWIRE	2	0.10	0.000		0.000	0.000	
2.5.3	WHEEL ASSEMBLY			14.922	67014		20.305	49248
5738	TIRE	4	0.30	7.263		2.471	9.883	
5739	WHEEL	4	0.30	0.309		0.105	0.421	
6020,6021	VALVE STEM AND CAP	4	0.30	0.107		0.037	0.146	
5741	HUB	4	0.62	1.597		0.543	2.173	
5742	CAP (HUB)	4	0.30	0.346		0.118	0.470	
6002-003	BOLT (HUB CAP)	32	N.C.	N.C.		N.C.	N.C.	
5743	GRASE SEAL	16	0.10	1.074		0.091	1.461	
5744	NUT (AXLE BEARING)	8	0.24	0.409		0.070	0.557	
5745	LOCKWASHER (BEARING)	8	0.24	0.001		0.000	0.001	
5746	ROLLER BEARING	8	0.24	2.411		0.410	3.281	
5747	AXLE	4	0.50	0.515		0.175	0.701	
5748	ROTOR (DISC BRAKE)	4	0.08	0.876		0.298	1.192	
6002-004	BOLT (ROTOR DISC)	24	N.C.	N.C.		N.C.	N.C.	
6002-005	BOLT (WHEEL)	32	N.C.	N.C.		N.C.	N.C.	
6005-005	WASHER (WHEEL BOLT)	32	N.C.	N.C.		N.C.	N.C.	
6019-010	GREASE ZURK	8	N.C.	N.C.		N.C.	N.C.	
----	RELIEF VALVE (CAP)	8	N.C.	N.C.		N.C.	N.C.	
6007-002	PIN (ROTOR)	4	0.05	0.014		0.005	0.020	
2.5.4	BRAKE SYSTEM			14.775	67681		20.105	49738
5749	BRAKE CALIPER (SERVICE)	4	0.08	3.504		1.192	4.767	
6006-002	BUSHING (BRAKE)	16	0.12	0.532		0.045	0.724	
5753	PIN (BRAKE)	8	0.05	0.029		0.005	0.039	
5750	PARK BRAKE CALIPER	4	0.05	0.696		0.237	0.946	
5827	PIN (PARK BRAKE)	4	0.05	0.014		0.005	0.020	
5824	SHAFT (PARK BRAKE)	2	0.05	0.066		0.045	0.090	
5825	HEX HEAD (PARK BRAKE)	2	0.05	0.000		0.000	0.000	
5826	BEARING BLOCK (PARK BRAKE)	4	0.05	0.146		0.050	0.198	
6002-008	BOLT (BEARING BLOCK)	16	N.C.	N.C.		N.C.	N.C.	
5823	ROD END (PARK BRAKE)	4	0.05	0.013		0.004	0.018	
5822	ROD (PARK BRAKE)	2	0.05	0.013		0.009	0.018	
5819	LEVER (PARK BRAKE)	2	0.05	0.039		0.026	0.053	
5715	HYDRAULIC/AIR ACTUATOR	1	0.50	4.844		6.592	6.592	
5752	RELAY VALVE (W CHECK V)	1	0.14	0.361		0.491	0.491	
5715	AIR TANK	1	0.50	0.064		0.088	0.088	
5757	DRAIN COCK	1	0.15	0.348		0.473	0.473	
5759	AIR FILTER	2	0.05	0.063		0.043	0.086	
5758	FRAME NIPPLE	2	0.35	0.063		0.043	0.085	
5756	AIR HOSE ASSEMBLY	2	0.35	0.466		0.317	0.634	
5755	GLADHAND	2	0.10	0.038		0.026	0.052	
5754	HOSE SUPPORT BRACKET	1	0.10	0.005		0.007	0.007	
6027-	PIPING AND FITTINGS	12	0.35	1.423		0.161	1.937	
5829	HOSE AND COUPLING	10	0.35	1.312		0.178	1.785	
6019-	ELBOW PIPING	5	0.35	0.258		0.070	0.351	
6019-006	NIPPLE	4	0.35	0.125		0.043	0.170	
6019-007	UNION	1	0.35	0.115		0.157	0.157	
6019-001	ADAPTER	6	0.05	0.051		0.012	0.070	
6019-002	TEE	3	0.35	0.188		0.085	0.256	
6003-002	NUT	4	N.C.	N.C.		N.C.	N.C.	
6017-002	X-WASHER	16	N.C.	N.C.		N.C.	N.C.	
2.6	EQUILIBRATORS			4.733	211300		6.440	155284
2.6.1	EQUILIBRATOR ACTUATOR MOUNTS			1.434	697112		1.952	512306
5763	TUBE	1	0.50	0.048		0.065	0.065	
5779	TUBE (OUTSIDE)	4	0.50	0.192		0.065	0.261	
5760	CAP	2	0.20	0.008		0.005	0.010	
5761	TRAIL NESTING BUSHING	2	0.50	0.877		0.597	1.194	

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
5664	CLAMP SET	3	0.25	0.288		0.131	0.392	
6004-	STUD	7	0.25	0.017		0.003	0.023	
6003-	NUT	8	0.25	0.004		0.001	0.006	
2.6.2	EQUILIBRATOR CABLES			4.015	249044		5.464	183021
5791	CABLE	2	0.70	2.796		1.902	3.804	
6006-007	BEARING	2	0.70	1.019		0.693	1.386	
6007-004	PIN	4	0.70	0.201		0.068	0.274	
2.7	HYDRAULIC SYSTEM			220.002	4545		299.364	3340
2.7.1	SYSTEM HYDRAULICS (MISC)			6.924	144428		9.422	106140
----	MANIFOLD ASSY	4	0.60	3.405		1.158	4.634	
5906,5907	HAND PUMP	2	0.40	7.749	2 REDUNDANT	5.272	10.544	
5903-002	PUMP CONTROL VALVE	2	0.60	2.292	2 REDUNDANT	1.560	3.119	
----	QUICK-DISCONNECT CHECK VLV	2	0.50	2.004		1.363	2.727	
5903-003	SAFETY RELIEF VALVE	1	0.50	0.165		0.224	0.224	
----	HOSE AND COUPLING	3	0.35	0.394		0.178	0.535	
----	PIPING AND FITTINGS	18	0.35	2.135	10 REDUNDAN	0.161	2.905	
2.7.2	TRAVERSE HYDRAULICS			14.523	68856		19.762	50602
5904,5905	CANNON LAY TRAVERSE VALVE	4	0.60	4.585	4 REDUNDANT	1.560	6.239	
5904,5905	HYDRAULIC JOYSTICK	2	0.30	2.447	2 REDUNDANT	1.665	3.330	
5920	TRAVERSE VALVE	1	0.60	1.146		1.560	1.560	
----	TRAVERSE BEAR LOC	1	0.55	2.476		3.369	3.369	
----	INTENSIFIER (BEAR LOCK)	1	0.60	0.634		0.862	0.862	
----	EMERGENCY ZERK???????	1	N.C.	N.C.		N.C.	N.C.	
5714	TRAVERSE ACTUATOR	1	0.50	4.844		6.592	6.592	
----	SLIP RING	1	0.50	4.788		6.516	6.516	
----	PIPING AND FITTINGS	9	0.35	1.067	4 REDUNDANT	0.161	1.453	
6007-006	PIN	1	0.50	0.036		0.049	0.049	
2.7.3	ELEVATION HYDRAULICS			11.439	87420		15.565	64245
5904,5905	CANNON LAY ELEVATION VALVE	4	0.60	4.585	4 REDUNDANT	1.560	6.239	
5919	ELEVATION VALVE	1	0.60	1.146		1.560	1.560	
5716	ELEVATION ACTUATOR	1	0.50	4.844		6.592	6.592	
----	SLIP RING	1	0.50	4.788		6.516	6.516	
----	PIPING AND FITTINGS	8	0.35	0.949	4 REDUNDANT	0.161	1.291	
6007-009	PIN	1	0.50	0.036		0.049	0.049	
6006-013	BEARING	1	0.20	0.146		0.198	0.198	
6005-011	WASHER	2	0.20	0.000		0.000	0.000	
6017-001	X-WASHER	2	0.20	0.000		0.000	0.000	
2.7.4	EQUILIBRATION HYDRAULICS			28.063	35635		38.186	26188
5893	EQUILIBRATION PRESSURE VLV	1	0.60	1.146		1.560	1.560	
5892	EQUILIBRATION VALVE ON/OFF	1	0.60	1.146		1.560	1.560	
5915	INTENSIFIER (DOUBLE-ENDED)	1	0.55	4.720		6.422	6.422	
5720-002	EQUILIBRATION ACCUMULATOR	1	0.30	3.171		4.314	4.314	
5712,5713	EQUILIBRATION ACTUATOR	2	0.50	9.688		6.592	13.183	
----	INTENSIFIER (BEAR LOCK)	1	0.60	0.634		0.862	0.862	
----	ELEVATION BEAR LOC	2	0.55	4.952		3.369	6.738	
----	EMERGENCY ZERK?????????	2	N.C.	N.C.		N.C.	N.C.	
5896	PILOT OPER CHCK VLV W SEAL	1	0.40	1.239		1.686	1.686	
----	PIPING AND FITTINGS	6	0.35	0.712		0.161	0.968	
----	HOSE AND COUPLING	5	0.35	0.656		0.178	0.892	
2.7.5	STORED PRESSURE HYDRAULICS			8.312	120301		11.311	88409
5894,5900	VALVE (PRESSURE GAGE)	2	0.20	0.764		0.520	1.040	
5894,5900	PRESSURE GAGE	2	0.05	0.138		0.094	0.188	

LTHD SYSTEM MISSION CRITICAL (F1) RELIABILITY PREDICTION AND ALLOCATION WORKSHEET (AS OF 18-Feb-87)

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
5720-003	RESERVOIR ACCUMULATOR	1	0.30	3.171		4.314	4.314	
5900-	VALVE (ON/OFF)	1	0.20	0.382		0.520	0.520	
----	PILOT OPER CHCK VLV W SEAL	1	0.40	1.239		1.686	1.686	
----	HYDRAULIC FILTER	1	0.30	0.171		0.233	0.233	
----	CHECK VALVE (FILTER)	2	0.50	1.617		1.100	2.201	
----	PIPING AND FITTINGS	7	0.35	0.830		0.161	1.130	
2.7.6	CANNON POSITION HYDRAULICS			3.624	275951		4.931	202796
5895	CANNON POSITION VALVE	1	0.60	1.146		1.560	1.560	
----	PILOT OPER CHCK VLV W SEAL	2	0.40	2.478		1.686	3.371	
2.7.7	RECOIL & C'RECOIL HYDRAULICS			63.405	15772		86.277	11591
5710-555	RECOIL CYLINDER	2	0.45	26.289		17.886	35.772	
5710-315	C' RECOIL CYLINDER	1	0.45	13.144		17.886	17.886	
5710-310	ENERGY STORAGE CYLINDER	1	0.45	13.144		17.886	17.886	
5718,5719	C' RECOIL ACCUMULATOR	2	0.30	6.341		4.314	8.629	
5912	CHECK VALVE	3	0.50	2.426		1.100	3.301	
5913	RELIEF VALVE	1	0.50	0.165		0.224	0.224	
5914	PRESSURE REDUCING VALVE	1	0.50	0.165		0.224	0.224	
5916	CIRCUIT BREAKER	1	N.C.	N.C.		N.C.	N.C.	
5916	ORIFICE	1	N.C.	N.C.		N.C.	N.C.	
5947	ROD/PISTON (RECOIL)	2	0.45	0.173		0.118	0.235	
5948	ROD/PISTON (C'RECOIL)	2	0.45	0.354		0.241	0.482	
5949	ORIFICE ROD	2	0.45	0.372		0.253	0.506	
5950	GUIDE ROD	2	0.45	0.372		0.253	0.506	
5951	END CAP	8	0.20	0.307		0.052	0.418	
5952	WASHER (END CAP)	4	0.20	0.000		0.000	0.000	
5954	COLLAR (END CAP)	4	0.20	0.154		0.052	0.209	
5955	NUT (END CAP)	4	0.05	0.000		0.000	0.001	
2.7.8	BREECH HYDRAULICS			13.057	76589		17.767	56285
5900-001	BREECH VALVE	1	0.60	1.146		1.560	1.560	
5725	BREECH ACTUATOR	1	0.50	4.844		6.592	6.592	
----	ACTUATOR CONTROL VALVE	1	0.60	1.146		1.560	1.560	
----	CHECK VALVE	1	0.50	0.809		1.100	1.100	
5922	PILOT OPER CTRL FLOW VALVE	2	0.45	4.243		2.887	5.773	
----	PIPING AND FITTINGS	4	0.35	0.474		0.161	0.646	
----	HOSE AND COUPLING	2	0.35	0.262		0.178	0.357	
----	LINK	1	0.50	0.096		0.131	0.131	
5725	PIN	1	0.50	0.036		0.049	0.049	
2.7.9	INERTIAL RAMMING HYDRAULICS			10.140	98618		13.798	72474
5900-002	VALVE (RAM/RETRACT/CREEP)	1	0.60	1.146		1.560	1.560	
5902-	DEINTENSIFIER	1	0.55	3.881		5.281	5.281	
----	AIR FILTER	1	0.05	0.032		0.043	0.043	
5729	RAMMER POSITION ACTUATOR	1	0.50	4.844		6.592	6.592	
----	PIPING AND FITTINGS	2	0.35	0.237		0.161	0.323	
2.7.10	LOAD POSITION HYDRAULICS			10.998	90929		14.965	66823
5900-003	VALVE (BATTERY/LOAD)	1	0.60	1.146		1.560	1.560	
5728	LOAD POSITION ACTUATOR	1	0.50	4.844		6.592	6.592	
5921	PILOT OPER CHCK VLV W SEAL	2	0.40	2.478		1.686	3.371	
5917	BATTERY VALVE	1	0.60	1.146		1.560	1.560	
5918	LOAD POSITION VALVE	1	0.60	1.146		1.560	1.560	
----	PIPING AND FITTINGS	2	0.35	0.237		0.161	0.323	
2.7.11	WHEEL HYDRAULICS			32.464	30804		44.175	22637
5910	WHEEL HYDRAULIC VALVE	8	0.60	9.170		1.560	12.478	
5721-5722	WHEEL ACTUATOR	4	0.50	19.376		6.592	26.366	
----	LINKAGE (WHEEL ACT VALVE)	4	0.50	0.384		0.131	0.523	

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
----	BURST PLUG	4	0.50	0.384		0.131	0.523	
5903-001	CIRCUIT BREAKER	2	N.C.	N.C.		N.C.	N.C.	
----	HOSE AND COUPLING	14	0.35	1.836		0.178	2.499	
----	PIPING AND FITTINGS	8	0.35	0.949		0.161	1.291	
----	PIN JOINT	8	0.50	0.287		0.049	0.391	
----	RETAINING RING	8	0.50	0.077		0.013	0.105	
2.7.12	PRIMER HYDRAULICS			8.586	116466		11.683	85591
5900-004	PRIMER VALVE	1	0.60	1.146		1.560	1.560	
5726	PRIMER ACTUATOR	1	0.50	4.844		6.592	6.592	
5922	PILOT OPER CTRL FLOW VALVE	1	0.45	2.121		2.887	2.887	
----	PIPING AND FITTINGS	4	0.35	0.474		0.161	0.646	
2.7.13	LANYARD HYDRAULICS			8.468	118098		11.522	86790
5900-005	LANYARD VALVE	1	0.60	1.146		1.560	1.560	
5727	PRIMER ACTUATOR	1	0.50	4.844		6.592	6.592	
5922	PILOT OPER CTRL FLOW VALVE	1	0.45	2.121		2.887	2.887	
----	PIPING AND FITTINGS	3	0.35	0.356		0.161	0.484	
2.8	LOAD TRAY			17.907	55843		24.367	41039
2.8.1	LOAD TRAY			10.037	99635		13.657	73221
5867	LOAD TRAY	1	0.20	0.779		1.060	1.060	
----	BARS	2	0.20	0.077		0.052	0.105	
----	CLEVIS	3	0.20	0.438		0.199	0.596	
----	ROLLER HOUSING (FIXED)	1	0.20	0.115		0.157	0.157	
----	TIE BAR	2	0.20	0.384		0.261	0.523	
----	TROLLY SUPPORT	4	0.20	0.768		0.261	1.045	
----	ROLLER HOUSING (PIVOTING)	4	0.20	0.461		0.157	0.627	
6002-	BOLT	125	N.C.	N.C.		N.C.	N.C.	
6003-	NUT	211	N.C.	N.C.		N.C.	N.C.	
6005-	WASHER	546	N.C.	N.C.		N.C.	N.C.	
5927	TRACK (REAR)	1	0.20	0.857		1.166	1.166	
5928	GUIDE (REAR TRACK)	2	0.20	1.714		1.166	2.332	
5926	TRACK (CENTER)	1	0.20	0.857		1.166	1.166	
5925	TRACK (FORWARD)	1	0.20	0.857		1.166	1.166	
5888	HINGE (BRACKET INNER)	4	0.20	0.584		0.199	0.794	
5889	HINGE (BRACKET OUTER)	4	0.20	0.584		0.199	0.794	
5929,5930, 5940	BAR (TRACK SUPPORT)	3	0.20	0.115		0.052	0.157	
5939	BRACKET(REAR TRACK ROLLER)	4	0.20	0.041		0.014	0.055	
5887	ROLLER	28	0.40	0.950		0.046	1.293	
5868	WEARSTRIP	3	0.05	0.029		0.013	0.039	
5869	BACKSTOP (PROJECTILE)	1	0.10	0.038		0.052	0.052	
5870	STRIP	2	0.05	0.019		0.013	0.026	
5871	BRACKET	2	0.20	0.020		0.014	0.028	
6006-015	BUSHING	2	0.20	0.351		0.239	0.478	
6009-	SCREW	38	N.C.	N.C.		N.C.	N.C.	
2.8.2	SHOCK MOUNT			7.871	127056		10.710	93373
5872,5873, 5874	BAR	4	0.20	0.154		0.052	0.209	
5941	PRIMARY SHOCK	2	0.50	1.475		1.004	2.007	
5875	BRACKET	1	0.20	0.010		0.014	0.014	
5942	SHOCK (MAN)	1	0.50	0.737		1.004	1.004	
5878	PAD (PROJECTILE STOP)	1	0.20	0.127		0.173	0.173	
6002-	BOLT	3	0.20	0.001		0.001	0.002	
6003-	NUT	7	0.20	0.003		0.001	0.004	
6005-	WASHER	2	0.20	0.000		0.000	0.000	
5879	MOUNT (PAD)	1	0.20	0.107		0.145	0.145	
5880	CUSHION	1	0.20	0.127		0.173	0.173	
5881	BAR (PIN PIVOT) ??????	2	0.20	0.077		0.052	0.105	
5877	MOUNT (PROJECTILE STOP)	1	0.50	0.266		0.363	0.363	

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)	MISSION CRITICAL (F1) ALLOCATION FAILURE RATE (FLR/ROUND 10X-6) COMP	COMP X QTY	BLOCK MRBF (rounds)
5876	GUIDE (SHOCK MOUNT)	4	0.30	2.534		0.862	3.449	
5882	PIN (PROJ STOP PAD)	1	0.50	1.373		1.868	1.868	
6006-014	BUSHING	2	0.50	0.877		0.597	1.194	
6010-004	SNAP RING	2	0.50	0.001		0.001	0.001	
2.9	SPADE			2.762	362086		3.758	266096
2.9.1	SPADE			2.762	362086		3.758	266096
5820	SPADE	1	0.38	2.762		3.758	3.758	
6002-011	BOLT (SPADE/PLATFORM)	64	N.C.	N.C.		N.C.	N.C.	
3.0	FIRE CONTROL			175.83	5687		239.260	4180
3.1	ASSISTANT GUNNER & GUNNER			175.528	5697		238.847	4187
----	ELBOW TELESCOPE	1	N.C.	N.C.		N.C.	N.C.	
----	M172 MT, TELE, QUAD	1	0.18	4.579	REDUNDANT	6.230	6.230	
----	M18 FIRE CONTROL QUADRANT	1	0.23	59.341	REDUNDANT	80.748	80.748	
----	M137 PANORAMIC TELESCOPE	1	0.23	142.085		193.340	193.340	
----	M171 MT, TELE, QUAD	1	0.18	32.705		44.503	44.503	
----	M17 FIRE CONTROL QUADRANT	1	0.23	46.804	REDUNDANT	63.688	63.688	
3.2	FIRE CONTROL LINKAGE			0.30	3296392		0.413	2422509
----	TRUNNION TUBE	1	0.20	0.019		0.026	0.026	
----	END CAP	2	0.20	0.015		0.010	0.021	
----	SIDE SUPPORT STRUT	2	0.20	0.077		0.052	0.105	
----	ACTUATOR STRUT	1	0.20	0.038		0.052	0.052	
----	SHORT STRUT	2	0.20	0.077		0.052	0.105	
----	SUPPORT STRUT	2	0.20	0.077		0.052	0.105	

PART B. Pg. 26 3/19/87

This reliability prediction worksheet is unfinished, and should be treated as "unfinished". The status on each subsystem reliability predictions is:

1) CANNON - LAST UPDATE WAS FEB 87
2) CRADLE - " " " "
3) TRAILS - " " " "
4) GIMBAL - " " " "
5) PLATFORM - " " " "
6) WHEEL - LAST UPDATE WAS MAR 87
7) EQUL. - LAST UPDATE WAS FEB 87
8) HYD. SYS - LAST UPDATE WAS MAR 87
9) LOAD SYS - Was being updated in MAR 87 - needs rel. pred / for new pa[rt]
10) Spade - LAST UPDATE WAS ~~MAR~~ FEB 87
11) FIRE CONTROL " " " " " "

Consult with me before using any of this reliability prediction data.

Michael S. Jonesen
RAM ENG.

NOT FINISHED

LTHD SYSTEM RELIABILITY PREDICTION WORKSHEET (AS OF 19-Mar-86)

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *	(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR				≈2,530 ERR	≈395 ERR			≈529 ERR	≈1,890 ERR
1.0	CANNON			112.295	8905			38.333	26087
1.1	TUBE ASSEMBLY			18.117	55197			11.411	87635
1.1.1	TUBE ASSEMBLY			18.117	55197			11.411	87635
5767	TUBE (BARREL)	1	56.779	56.779	10.902	M198 DATA	0.95	10.357	
5781-	COLLAR SET	8	2.000	16.000	3.072	ESTIMATE	0.20	0.614	
6016-001	EXTRUSION RAIL	2	1.000	2.000	0.384	ESTIMATE	0.20	0.077	
6022-	KEY	20	0.946	18.920	3.633	M198 DATA	0.10	0.363	
6002-	BOLT	40	0.011	0.440	0.084	CATFAE PRED	N.C.	N.C.	
6003-009	NUT	20	0.011	0.220	0.042	CATFAE PRED	N.C.	N.C.	
1.2	MUZZLE BRAKE			4.199	238126			0.840	1190632
1.2.1	MUZZLE BRAKE			4.199	238126			0.840	1190632
5765,5766	MUZZLE BRAKE	1	18.926	18.926	3.634	M198 DATA	0.20	0.727	
5786	KEY	1	0.946	0.946	0.182	M198 DATA	0.20	0.036	
5787	TRUST COLLAR	1	2.000	2.000	0.384	ESTIMATE	0.20	0.077	
1.3	BREECH			39.820	25113			15.549	64312
1.3.1	BREECH			39.820	25113			15.549	64312
5789	BREECH	1	121.704	121.704	23.367	M109 DATA	0.55	12.852	
5816	BAND (OUTER BREECH)	1	37.850	37.850	7.267	M198 DATA	0.17	1.235	
5788	BAND (INNER BREECH)	1	37.850	37.850	7.267	M198 DATA	0.17	1.235	
6022-005	KEY	2	0.946	1.892	0.363	M198 DATA	0.20	0.073	
....	CLAMP	4	2.000	8.000	1.536	ESTIMATE	0.10	0.154	
....	BOLT	9	0.011	0.099	0.019	CATFAE PRED	N.C.	N.C.	
1.4	PRIMER AUTOLOADER			50.158	19937			10.533	94937
5802	PRIMER AUTOLOADER	1	261.240	261.240	50.158	ARROW PRED+EST	0.21	10.533	
2.0	CARRIAGE			≈1,010 ERR	≈990 ERR			≈315 ERR	≈3,175 ERR
2.1	CRADLE			29.445	33962			6.971	143462
2.1.1	CRADLE			18.169	55038			4.724	211685
5730,5831	CRADLE	1	94.631	94.631	18.169	M198 DATA	0.26	4.724	
2.1.2	SPEEDSHIFT PEG			11.276	88687			2.246	445139
5780	BRACKET	1	3.000	3.000	0.576	ESTIMATE	0.20	0.115	
5772	CRADLE STOP	1	0.500	0.500	0.096	ESTIMATE	0.20	0.019	
5777	GIMBEL MOUNT	3	0.200	0.600	0.115	ESTIMATE	0.20	0.023	
5776	GIMBEL SPEEDSHIFT	1	1.000	1.000	0.192	ESTIMATE	0.20	0.038	
5790	DISK	1	7.000	7.000	1.344	ESTIMATE	0.20	0.269	
5773	LOCK HOUSING	1	0.500	0.500	0.096	ESTIMATE	0.20	0.019	

(*) FAILURE PER MILLION HOURS - BASED ON GROUND MOBILE ENVIRONMENT; (**) 5.2083 ROUNDS PER HOUR CONVERSION FACTOR

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5778	LOCK HANDLE	1	14.300	14.300	2.746		AVCO	0.20	0.549	
6013-	SPRING	1	2.310	2.310	0.444		AVCO	0.20	0.089	
6002-	BOLT	11	0.011	0.121	0.023		CATFAE PRED	N.C.	N.C.	
6003-	NUT	8	0.011	0.088	0.017		CATFAE PRED	N.C.	N.C.	
5771	NUT (SPEEDSHIFT PIVOT)	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	
6005-	WASHER	8	0.002	0.016	0.003		CATFAE PRED	N.C.	N.C.	
6007-	PIN	8	0.374	2.992	0.574		AVCO	0.20	0.115	
6006-	BEARING	4	3.790	15.160	2.911		RADC (NPRD-3)	0.20	0.582	
5774,5775	BUSHING (DISK)	2	4.570	9.140	1.755		RADC (NPRD-3)	0.20	0.351	
2.2	TRAILS				123.249	8114			18.207	54923
2.2.1	TRAIL STRUCTURE				78.626	12718			7.837	127593
5841,5897	UPPER TRAIL	2	40.650	81.300	15.610		M198 DATA + EST	0.10	1.561	
5842,5898	LOWER REAR TRAIL	2	20.320	40.640	7.803		M198 DATA + EST	0.10	0.780	
5843,5899	LOWER FRONT TRAIL	2	30.480	60.960	11.704		M198 DATA + EST	0.10	1.170	
5845	FRONT BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5846	WHEEL BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5931	MIDDLE BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5932	REAR BULKHEAD	2	4.060	8.120	1.559		M198 DATA + EST	0.10	0.156	
5933,5934	LATTICE	24	6.770	162.480	31.196		M198 DATA + EST	0.10	3.120	
5834,5835	PIN (TRAIL CLEVIS)	64	0.374	23.936	4.596		AVCO	0.10	0.460	
5844	SPACER	128	0.002	0.256	0.049		ESTIMATE	N.C.	N.C.	
5857,5858	X-RING	64	0.100	6.400	1.229		ESTIMATE	0.10	0.123	
6002-016	BOLT (BULKHEAD)	48	0.011	0.528	0.101		CATFAE PRED	N.C.	N.C.	
6003-007	NUT (BULKHEAD)	48	0.011	0.528	0.101		CATFAE PRED	N.C.	N.C.	
2.2.2	TRAIL PIN				21.001	47617			5.237	190958
6009-003	SCREW	4	0.011	0.044	0.008		CATFAE PRED	0.25	0.002	
6005-010	WASHER	4	0.002	0.008	0.002		CATFAE PRED	0.25	0.000	
6026-001	BEARING PIN	4	14.300	57.200	10.982		AVCO	0.25	2.746	
6006-012	BEARING	4	3.790	15.160	2.911		RADC (NPRD-3)	0.25	0.728	
6024-001	BUSHING (RETAINER)	4	4.570	18.280	3.510		RADC (NPRD-3)	0.25	0.877	
6025-001	RETAINER	4	0.010	0.040	0.008		ESTIMATE	0.25	0.002	
6010-005	SNAP RING	4	0.004	0.016	0.003		ESTIMATE	0.25	0.001	
6006-011	BUSHING (TRAIL BEARING)	4	4.570	18.280	3.510		RADC (NPRD-3)	0.25	0.877	
6003-006	NUT	16	0.011	0.176	0.034		CATFAE PRED	0.05	0.002	
6002-015	BOLT	16	0.011	0.176	0.034		CATFAE PRED	0.05	0.002	
2.2.3	LIFTING HANDLE				16.773	59620			4.035	247808
5891	LIFTING HANDLE	4	1.000	4.000	0.768		ESTIMATE	0.05	0.038	
6004-003	STUD	2	0.051	0.102	0.020		RADC (NPRD-3)	0.05	0.001	
6005-019	WASHER	4	0.002	0.008	0.002		CATFAE PRED	0.05	0.000	
5770	LOCK ARM	2	5.000	10.000	1.920		ESTIMATE	0.25	0.480	
6012-001	PULL PIN	2	14.300	28.600	5.491		AVCO	0.25	1.373	
5762	LOCK PLATE	2	3.000	6.000	1.152		ESTIMATE	0.25	0.288	
6002-010	BOLT	2	0.011	0.022	0.004		CATFAE PRED	0.25	0.001	
6003-	NUT	6	0.011	0.066	0.013		CATFAE PRED	0.25	0.003	
6011-001	SPACE CYLINDER	2	1.000	2.000	0.384		ESTIMATE	0.25	0.096	
6006-016	BUSHING	8	4.570	36.560	7.020		RADC (NPRD-3)	0.25	1.755	
2.2.4	GROUND PAD				2.398	416931			0.234	4274705
5832,5833	GROUND PAD	2	3.316	6.632	1.273		RADC (NPRD-3)	0.10	0.127	
5856	SPACER	2	2.776	5.552	1.066		RADC (NPRD-3)	0.10	0.107	
6002-017	BOLT	14	0.011	0.154	0.030		CATFAE PRED	N.C.	N.C.	
6003-008	NUT	14	0.011	0.154	0.030		CATFAE PRED	N.C.	N.C.	
2.2.5	CRADLE/TRAIL TIE-IN				4.450	224709			0.864	1157606
5855	SLOTTED PLATE	4	3.000	12.000	2.304		ESTIMATE	0.20	0.461	
5854	SHIM	4	0.100	0.400	0.077		ESTIMATE	0.20	0.015	
5863	LUG	4	0.524	2.096	0.402		RADC (NPRD-3)	0.20	0.080	

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BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *	(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5864,5865	SUPPORT BAR	3	2.000	6.000	1.152		ESTIMATE	0.20	0.230
5866	LINK	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077
6002-	BOLT	31	0.011	0.341	0.065		CATFAE PRED	N.C.	N.C.
6003-	NUT	31	0.011	0.341	0.065		CATFAE PRED	N.C.	N.C.
2.3	GIMBAL				11.971	83539			2.978	335796
2.3.1	GIMBAL				3.840	260415			0.960	1041660
5810	GIMBAL	1	20.000	20.000	3.840		ESTIMATE	0.25	0.960	
2.3.2	GIMBAL BEARING				8.130	122994			2.018	495542
6007-	PIN (GIMBAL/TRAVERSE)	2	14.300	28.600	5.491		AVCO	0.25	1.373	
5935	SLEEVE	1	4.570	4.570	0.877		RADC (NPRD-3)	0.25	0.219	
5936	SPACER	1	0.002	0.002	0.000		ESTIMATE	0.25	0.000	
5937	COVER	1	0.500	0.500	0.096		ESTIMATE	0.10	0.010	
6002-	BOLT	2	0.011	0.022	0.004		CATFAE PRED	0.25	0.001	
6005-	WASHER	3	0.002	0.006	0.001		CATFAE PRED	0.05	0.000	
6006-	BEARING	2	3.790	7.580	1.455		RADC (NPRD-3)	0.25	0.364	
6010-	SNAP RING	4	0.004	0.016	0.003		ESTIMATE	0.25	0.001	
6030-001	O-RING	1	1.050	1.050	0.202		RADC (NPRD-3)	0.25	0.050	
2.4	PLATFORM				10.640	93985			2.597	385098
2.4.1	PLATFORM				3.840	260415			0.960	1041660
5800	PLATFORM	1	20.000	20.000	3.840		ESTIMATE	0.25	0.960	
2.4.2	PLATFORM/TRAIL CONNECTOR				6.800	147061			1.637	610973
----	HANDLE	2	1.000	2.000	0.384		ESTIMATE	0.10	0.038	
----	BOLT (SPRING LOADED)	2	14.300	28.600	5.491		AVCO + ESTIMATE	0.25	1.373	
6013-001	SPRING	2	2.310	4.620	0.887		AVCO	0.25	0.222	
6010-006	SNAP RING	2	0.004	0.008	0.002		ESTIMATE	0.10	0.000	
6002-029	BOLT	4	0.011	0.044	0.008		CATFAE PRED	0.10	0.001	
6003-	NUT	4	0.011	0.044	0.008		CATFAE PRED	0.10	0.001	
6001-004	ADHESIVE	2	0.050	0.100	0.019		ESTIMATE	0.10	0.002	
2.5	WHEEL SYSTEM				208.877	4788			37.452	26701
2.5.1	PIN ASSEMBLY				12.522	79857			4.150	240958
5730	PIVOT PIN	2	14.300	28.600	5.491		AVCO	0.50	2.746	
6005-002	THRUST WASHER	8	0.002	0.016	0.003		CATFAE PRED	0.05	0.000	
6002-001	BOLT (PIVOT)	2	0.011	0.022	0.004		CATFAE PRED	0.05	0.000	
6003-001	NUT (PIVOT)	2	0.011	0.022	0.004		CATFAE PRED	0.05	0.000	
6006-001	BUSHING (PIVOT)	8	4.570	36.560	7.020		RADC (NPRD-3)	0.20	1.404	
2.5.2	BEAM ASSEMBLY				20.626	48484			4.152	240846
5794,5796	LEADING BEAM	2	3.570	7.140	1.371		M198 DATA	0.30	0.411	
5795,5797	LAGGING BEAM	2	3.570	7.140	1.371		M198 DATA	0.30	0.411	
5807	PIN (CROSS SUPPORT)	4	0.374	1.496	0.287		AVCO	0.20	0.057	
5736	CAP (AXLE BEAM END)	8	0.500	4.000	0.768		ESTIMATE	0.05	0.038	
6002-002	BOLT (AXLE CAP)	16	0.011	0.176	0.034		CATFAE PRED	N.C.	N.C.	
6005-004	WASHER (AXLE CAP)	16	0.002	0.032	0.006		CATFAE PRED	N.C.	N.C.	
6005-006	WASHER (CYLINDER PIVOT)	8	0.002	0.016	0.003		CATFAE PRED	N.C.	N.C.	
6006-003	BUSHING (CYLINDER PIVOT)	4	4.570	18.280	3.510		RADC (NPRD-3)	0.20	0.702	
6006-004	BUSHING (SUPPORT PIVOT)	12	4.570	54.840	10.529		RADC (NPRD-3)	0.20	2.106	
5803,5804	CROSS SUPPORT	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	
5809	HANDLE LOCKING (X-SUPPORT)	2	3.000	6.000	1.152		ESTIMATE	0.20	0.230	
5812	BRACKET (CROSS SUPPORT)	2	0.264	0.528	0.101		AVCO	0.20	0.020	

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BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5813	GUIDE (SPRING)	2	0.500	1.000	0.192		ESTIMATE	0.05	0.010	
6002-006	BOLT (SUPPORT HANDLE BRKT)	4	0.011	0.044	0.008		CATFAE PRED	N.C.	N.C.	
6003-005	NUT (SUPPORT HANDLE BRKT)	2	0.011	0.022	0.004		CATFAE PRED	N.C.	N.C.	
6002-007	BOLT (HANDLE GUIDE)	8	0.011	0.088	0.017		CATFAE PRED	N.C.	N.C.	
6013-002	SPRING	2	2.310	4.620	0.887		AVCO	0.10	0.089	
6033	LOCKWIRE	2	0.001	0.002	0.000		RADC (NPRD-3)	0.10	0.000	
2.5.3	WHEEL ASSEMBLY				77.575	12891			14.385	69515
5738	TIRE	4	31.523	126.092	24.210		M198 DATA	0.30	7.263	
5739	WHEEL	4	1.342	5.368	1.031		M198 DATA	0.30	0.309	
6020,6021	VALVE STEM AND CAP	4	0.466	1.864	0.358		M198 DATA + EST	0.30	0.107	
5741	HUB	4	3.354	13.416	2.576		M198 DATA	0.62	1.597	
5742	CAP (HUB)	4	1.500	6.000	1.152		ESTIMATE	0.30	0.346	
6002-003	BOLT (HUB CAP)	32	0.011	0.352	0.068		CATFAE PRED	N.C.	N.C.	
5743	GREASE SEAL	8	3.495	27.960	5.368		RADC (NPRD-3)	0.10	0.537	
5744	NUT (AXLE BEARING)	8	1.110	8.880	1.705		ESTIMATE	0.24	0.409	
5745	LOCKWASHER (BEARING)	8	0.002	0.016	0.003		CATFAE PRED	0.24	0.001	
5746	ROLLER BEARING	8	6.540	52.320	10.046		M198 DATA	0.24	2.411	
5747	AXLE	4	1.342	5.368	1.031		M198 DATA	0.50	0.515	
5748	ROTOR (DISC BRAKE)	4	14.256	57.024	10.949		M198 DATA	0.08	0.876	
6002-004	BOLT (ROTOR DISC)	24	0.011	0.264	0.051		CATFAE PRED	N.C.	N.C.	
6003-044	NUT (WHEEL)	32	0.011	0.352	0.068		CATFAE PRED	N.C.	N.C.	
6005-005	WASHER (WHEEL BOLT)	32	0.002	0.064	0.012		CATFAE PRED	N.C.	N.C.	
6019-010	GREASE ZURK	8	10.436	83.488	16.030		RADC (NPRD-3)	N.C.	N.C.	
6019-11	RELIEF VALVE (CAP)	8	1.714	13.712	2.633		RADC (NPRD-3)	N.C.	N.C.	
6007-002	PIN (ROTOR)	4	0.374	1.496	0.287		AVCO	0.05	0.014	
2.5.4	BRAKE SYSTEM				98.153	10188			14.764	67732
5749	BRAKE CALIPER (SERVICE)	4	57.023	228.092	43.794		M198 DATA	0.08	3.504	
6006-002	BUSHING (BRAKE)	16	1.443	23.088	4.433		M198 DATA	0.12	0.532	
5753	PIN (BRAKE)	8	0.374	2.992	0.574		AVCO	0.05	0.029	
5750	PARK BRAKE CALIPER	4	18.112	72.448	13.910		M198 DATA	0.05	0.696	
5827	PIN (PARK BRAKE)	4	0.374	1.496	0.287		AVCO	0.05	0.014	
5824	SHAFT (PARK BRAKE)	2	3.444	6.889	1.323		RADC (NPRD-3)	0.05	0.066	
5825	HEX HEAD (PARK BRAKE)	2	0.011	0.022	0.004		CATFAE PRED	0.05	0.000	
5826	BEARING BLOCK (PARK BRAKE)	4	3.790	15.160	2.911		RADC (NPRD-3)	0.05	0.146	
6002-008	BOLT (BEARING BLOCK)	16	0.011	0.176	0.034		CATFAE PRED	N.C.	N.C.	
5823	ROD END (PARK BRAKE)	4	0.336	1.344	0.258		M198 DATA	0.05	0.013	
5822	ROD (PARK BRAKE)	2	0.671	1.342	0.258		M198 DATA	0.05	0.013	
5819	LEVER (PARK BRAKE)	2	4.695	9.390	1.803		M198 DATA	0.05	0.090	
5751	HYDRAULIC/AIR ACTUATOR	1	50.459	50.459	9.688		NPRD-3+ESTIMATE	0.50	4.844	
5752	RELAY VALVE (W CHECK V)	1	13.416	13.416	2.576		M198 DATA	0.14	0.361	
5715	AIR TANK	1	0.671	0.671	0.129		RADC (NPRD-3)	0.50	0.064	
5757	DRAIN COCK	1	12.075	12.075	2.318		M198 DATA	0.15	0.348	
5759	AIR FILTER	2	3.303	6.606	1.268		RADC (NPRD-3)	0.05	0.063	
5758	FRAME NIPPLE	2	0.466	0.932	0.179		M198 DATA + EST	0.35	0.063	
5756	AIR HOSE ASSEMBLY	2	3.466	6.932	1.331		M198 DATA	0.35	0.466	
5755	GLADHAND	2	1.000	2.000	0.384		ESTIMATE	0.10	0.038	
5754	HOSE SUPPORT BRACKET	1	0.264	0.264	0.051		AVCO	0.10	0.005	
6027-	PIPING AND FITTINGS	12	1.765	21.180	4.067		RADC (NPRD-3)	0.35	1.423	
6034-	HOSE AND COUPLING	10	1.952	19.520	3.748		RADC (NPRD-3)	0.35	1.312	
6019-	ELBOW PIPING	5	0.767	3.835	0.736		M198 DATA	0.35	0.258	
6019-006	NIPPLE	2	0.466	0.932	0.179		M198 DATA + EST	0.35	0.063	
6019-007	UNION	1	1.715	1.715	0.329		ESTIMATE	0.35	0.115	
6019-001	ADAPTER	6	0.894	5.364	1.030		M198 DATA	0.05	0.051	
6019-002	TEE	3	0.932	2.796	0.537		M198 DATA + EST	0.35	0.188	
6003-002	NUT	4	0.011	0.044	0.008		CATFAE PRED	N.C.	N.C.	
6017-002	X-WASHER	16	0.002	0.032	0.006		CATFAE PRED	N.C.	N.C.	
2.6	EQUILIBRATORS				7.492	133483			4.733	211300
2.6.1	EQUILIBRATOR ACTUATOR MOUNTS				3.511	284840			1.434	697112
5763	TUBE	1	0.500	0.500	0.096		ESTIMATE	0.50	0.048	
5779	TUBE (OUTSIDE)	4	0.500	2.000	0.384		ESTIMATE	0.50	0.192	
5760	CAP	2	0.100	0.200	0.038		ESTIMATE	0.20	0.008	

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5761	TRAIL NESTING BUSHING	2	4.570	9.140	1.755		RADC (NPRD-3)	0.50	0.877	
5664	CLAMP SET	3	2.000	6.000	1.152		ESTIMATE	0.25	0.288	
6004-	STUD	7	0.051	0.357	0.069		RADC (NPRD-3)	0.25	0.017	
6003-	NUT	8	0.011	0.088	0.017		CATFAE PRED	0.25	0.004	
2.6.2	EQUILIBRATOR CABLES				5.736	174331			4.015	249044
5791	CABLE	2	10.400	20.800	3.994		VENDOR DATA	0.70	2.796	
6006-007	BEARING	2	3.790	7.580	1.455		RADC (NPRD-3)	0.70	1.019	
6007-004	PIN	4	0.374	1.496	0.287		AVCO	0.70	0.201	
2.7	HYDRAULIC SYSTEM				514.374	1944			≈218.903	≈4568
2.7.1	SYSTEM HYDRAULICS (MISC)				43.702	22882			6.924	144428
----	MANIFOLD ASSY	4	7.390	29.560	5.676		RADC (NPRD-3)	0.60	3.405	
5906-001	HAND PUMP	2	50.449	100.898	19.373		RADC (NPRD-3)	0.40	7.749	2 REDUNDANT
5906-002	PUMP SELECTOR VALVE	2	9.950	19.900	3.821		NPRD-3+ESTIMATE	0.60	2.292	2 REDUNDANT
5906-003	HYDRAULIC ON/OFF VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
----	QUICK-DISCONNECT CHECK VLV	3	10.436	31.308	6.011		RADC (NPRD-3)	0.50	3.006	
5903-003	SAFETY RELIEF VALVE	1	1.714	1.714	0.329		RADC (NPRD-3)	0.50	0.165	
----	HOSE AND COUPLING	4	1.952	7.808	1.499		RADC (NPRD-3)	0.35	0.525	
----	PIPING AND FITTINGS	15	1.765	26.475	5.083		RADC (NPRD-3)	0.35	1.779	10 REDUNDANT
2.7.2	TRAVERSE HYDRAULICS				29.044	34430			14.523	68856
5904,5905	CANNON LAY TRAVERSE VALVE	4	9.950	39.800	7.642		NPRD-3+ESTIMATE	0.60	4.585	4 REDUNDANT
5920	TRAVERSE VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
----	TRAVERSE BEAR LOC	1	23.446	23.446	4.502		NPRD-3 + AVCO	0.55	2.476	
----	INTENSIFIER (BEAR LOCK)	1	5.500	5.500	1.056		NPRD-3+ESTIMATE	0.60	0.634	
5714	TRAVERSE ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
----	HOSE AND COUPLING	3	1.952	5.856	1.124		RADC (NPRD-3)	0.35	0.394	
----	PIPING AND FITTINGS	9	1.765	15.885	3.050		RADC (NPRD-3)	0.35	1.067	4 REDUNDANT
6007-006	PIN	1	0.374	0.374	0.072		AVCO	0.50	0.036	
2.7.3	ELEVATION HYDRAULICS				23.502	42550			11.439	87420
5904,5905	CANNON LAY ELEVATION VALVE	4	9.950	39.800	7.642		NPRD-3+ESTIMATE	0.60	4.585	4 REDUNDANT
5919	ELEVATION VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5716	ELEVATION ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
----	HOSE AND COUPLING	2	1.952	3.904	0.750		RADC (NPRD-3)	0.35	0.262	
----	PIPING AND FITTINGS	8	1.765	14.120	2.711		RADC (NPRD-3)	0.35	0.949	4 REDUNDANT
6007-009	PIN	1	0.374	0.374	0.072		AVCO	0.50	0.036	
6006-013	BEARING	1	3.790	3.790	0.728		CATFAE PRED	0.20	0.146	
6005-011	WASHER	2	0.002	0.004	0.001		CATFAE PRED	0.20	0.000	
6017-001	X-WASHER	2	0.002	0.004	0.001		CATFAE PRED	0.20	0.000	
2.7.4	EQUILIBRATION HYDRAULICS				59.410	16832			28.063	35635
5893	EQUILIBRATION PRESSURE VLV	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5892	EQUILIBRATION VALVE ON/OFF	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5915	INTENSIFIER (DOUBLE-ENDED)	1	44.692	44.692	8.581		NPRD-3+ESTIMATE	0.55	4.720	
5720-002	EQUILIBRATION ACCUMULATOR	1	55.045	55.045	10.569		RADC (NPRD-3)	0.30	3.171	
5712,5713	EQUILIBRATION ACTUATOR	2	50.459	100.918	19.376		RADC (NPRD-3)	0.50	9.688	
----	ELEVATION BEAR LOC	2	23.446	46.892	9.003		NPRD-3 + AVCO	0.55	4.952	
----	INTENSIFIER (BEAR LOCK)	1	5.500	5.500	1.056		NPRD-3+ESTIMATE	0.60	0.634	
5896	PILOT OPER CHCK VLV W SEAL	1	16.130	16.130	3.097		NPRD-3+ESTIMATE	0.40	1.239	
----	PIPING AND FITTINGS	6	1.765	10.590	2.033		RADC (NPRD-3)	0.35	0.712	
----	HOSE AND COUPLING	5	1.952	9.760	1.874		RADC (NPRD-3)	0.35	0.656	
2.7.5	STORED PRESSURE HYDRAULICS				29.519	33877			9.169	109061
5894,5900	VALVE (PRESSURE GAGE)	2	9.950	19.900	3.821		NPRD-3+ESTIMATE	0.20	0.764	
5894,5900	PRESSURE GAGE	2	7.180	14.360	2.757		RADC (NPRD-3)	0.05	0.138	
5720-003	RESERVOIR ACCUMULATOR	1	55.045	55.045	10.569		RADC (NPRD-3)	0.30	3.171	

(*) FAILURE PER MILLION HOURS - BASED ON GROUND MOBILE ENVIRONMENT; (**) 5.2083 ROUNDS PER HOUR CONVERSION FACTOR

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *	(FLR/ROUND 10X-6)**		BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5978	PILOT OPER CHCK VLV W SEAL	2	16.130	32.260	6.194		NPRD-3+ESTIMATE	0.40	2.478	
5720-005	HYDRAULIC FILTER	1	2.977	2.977	0.572		RADC (NPRD-3)	0.30	0.171	
5710-004	CHECK VALVE (FILTER)	2	8.423	16.846	3.234		RADC (NPRD-3)	0.50	1.617	
----	PIPING AND FITTINGS	7	1.765	12.355	2.372		RADC (NPRD-3)	0.35	0.830	
2.7.6	CANNON POSITION HYDRAULICS				8.104	123390			3.624	275951
5895	CANNON POSITION VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5976,5977	PILOT OPER CHCK VLV W SEAL	2	16.130	32.260	6.194		NPRD-3+ESTIMATE	0.40	2.478	
2.7.7	RECOIL & C'RECOIL HYDRAULICS				150.444	6647			62.596	15975
5710-555	RECOIL CYLINDER	2	152.132	304.264	58.419		M109 DATA	0.45	26.289	
5710-315	C' RECOIL CYLINDER	1	152.132	152.132	29.210		M109 DATA	0.45	13.144	
5710-310	ENERGY STORAGE CYLINDER	1	152.132	152.132	29.210		M109 DATA	0.45	13.144	
5718,5719	C' RECOIL ACCUMULATOR	2	55.045	110.090	21.137		RADC (NPRD-3)	0.30	6.341	
5912,5978	CHECK VALVE	2	8.423	16.846	3.234		RADC (NPRD-3)	0.50	1.617	
5913	RELIEF VALVE	1	1.714	1.714	0.329		RADC (NPRD-3)	0.50	0.165	
5914	PRESSURE REDUCING VALVE	1	1.714	1.714	0.329		RADC (NPRD-3)	0.50	0.165	
5916	CIRCUIT BREAKER	1	10.733	10.733	2.061		NPRD-3 + AVCO	N.C.	N.C.	
5916	ORIFICE	1	7.180	7.180	1.379		RADC (NPRD-3)	N.C.	N.C.	
5947	ROD/PISTON (RECOIL)	2	1.000	2.000	0.384		ESTIMATE	0.45	0.173	
5948	ROD/PISTON (C'RECOIL)	2	2.050	4.100	0.787		NPRD-3+ESTIMATE	0.45	0.354	
5949	ORIFICE ROD	2	2.150	4.300	0.826		NPRD-3+ESTIMATE	0.45	0.372	
5950	GUIDE ROD	2	2.150	4.300	0.826		NPRD-3+ESTIMATE	0.45	0.372	
5951	END CAP	8	1.000	8.000	1.536		ESTIMATE	0.20	0.307	
5952	WASHER (END CAP)	4	0.002	0.008	0.002		CATFAE PRED	0.20	0.000	
5954	COLLAR (END CAP)	4	1.000	4.000	0.768		ESTIMATE	0.20	0.154	
5955	NUT (END CAP)	4	0.011	0.044	0.008		CATFAE PRED	0.05	0.000	
2.7.8	BREECH HYDRAULICS				25.352	39445			12.029	83132
5900-001	BREECH VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5725	BREECH ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
5725-001	CHECK VALVE	1	8.423	8.423	1.617		RADC (NPRD-3)	0.50	0.809	
5922	PILOT OPER CTRL FLOW VALVE	2	24.553	49.106	9.428		NPRD-3+ESTIMATE	0.45	4.243	
----	PIPING AND FITTINGS	5	1.765	8.825	1.694		RADC (NPRD-3)	0.35	0.593	
----	HOSE AND COUPLING	2	1.952	3.904	0.750		RADC (NPRD-3)	0.35	0.262	
----	LINK	1	1.000	1.000	0.192		ESTIMATE	0.50	0.096	
5725	PIN	1	0.374	0.374	0.072		AVCO	0.50	0.036	
2.7.9	INERTIAL RAMMING HYDRAULICS				19.967	50084			10.140	98618
5900-002	VALVE (RAM/RETRACT/CREEP)	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5902	DEINTENSIFIER	1	36.750	36.750	7.056		ESTIMATE	0.55	3.881	
5729-001	AIR FILTER	1	3.303	3.303	0.634		RADC (NPRD-3)	0.05	0.032	
5729	INERTIAL RAMMING ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
----	PIPING AND FITTINGS	2	1.765	3.530	0.678		RADC (NPRD-3)	0.35	0.237	
2.7.10	LOAD POSITION HYDRAULICS				22.291	44861			10.998	90929
5900-003	VALVE (BATTERY/LOAD)	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5728	LOAD POSITION ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
5921,5971	PILOT OPER CHCK VLV W SEAL	2	16.130	32.260	6.194		NPRD-3+ESTIMATE	0.40	2.478	
5917	BATTERY VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5918	LOAD POSITION VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
----	PIPING AND FITTINGS	2	1.765	3.530	0.678		RADC (NPRD-3)	0.35	0.237	
2.7.11	WHEEL HYDRAULICS				68.380	14624			32.464	30804
5910	WHEEL HYDRAULIC VALVE	8	9.950	79.600	15.283		NPRD-3+ESTIMATE	0.60	9.170	
?????	WHEEL ACTUATOR	4	50.459	201.836	38.753		RADC (NPRD-3)	0.50	19.376	
----	LINKAGE (WHEEL ACT VALVE)	4	1.000	4.000	0.768		ESTIMATE	0.50	0.384	
----	BURST PLUG	4	1.000	4.000	0.768		ESTIMATE	0.50	0.384	
5903-001	CIRCUIT BREAKER	2	10.733	21.466	4.121		NPRD-3 + AVCO	N.C.	N.C.	
----	HOSE AND COUPLING	14	1.952	27.328	5.247		RADC (NPRD-3)	0.35	1.836	

(*) FAILURE PER MILLION HOURS - BASED ON GROUND MOBILE ENVIRONMENT; (**) 5.2083 ROUNDS PER HOUR CONVERSION FACTOR

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
----	PIPING AND FITTINGS	8	1.765	14.120	2.711		RADC (NPRD-3)	0.35	0.949	
----	PIN JOINT	8	0.374	2.992	0.574		AVCO	0.50	0.287	
----	RETAINING RING	8	0.100	0.800	0.154		ESTIMATE	0.50	0.077	
2.7.12	PRIMER HYDRAULICS				17.329	57705			8.468	118098
5900-004	PRIMER VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5726	PRIMER ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
5922	PILOT OPER CTRL FLOW VALVE	1	24.553	24.553	4.714		NPRD-3+ESTIMATE	0.45	2.121	
----	PIPING AND FITTINGS	3	1.765	5.295	1.017		RADC (NPRD-3)	0.35	0.356	
2.7.13	LANYARD HYDRAULICS				17.329	57705			8.468	118098
5900-005	LANYARD VALVE	1	9.950	9.950	1.910		NPRD-3+ESTIMATE	0.60	1.146	
5727	PRIMER ACTUATOR	1	50.459	50.459	9.688		RADC (NPRD-3)	0.50	4.844	
5922	PILOT OPER CTRL FLOW VALVE	1	24.553	24.553	4.714		NPRD-3+ESTIMATE	0.45	2.121	
----	PIPING AND FITTINGS	3	1.765	5.295	1.017		RADC (NPRD-3)	0.35	0.356	
2.8	LOAD TRAY				≈100 ERR	≈10,000 ERR			≈20 ~~ERR~~	≈50,000 ERR
2.8.1	LOAD TRAY				ERR	ERR			ERR	ERR
5867	LOAD TRAY	1	20.284	20.284	3.895		M109 DATA	0.20	0.779	
5868	WEARSTRIP	3	1.000	3.000	0.576		ESTIMATE	0.05	0.029	
5869	BASE SPRING (PROJECTILE)	2	?	ERR	ERR		ESTIMATE	0.10	ERR	
5870	STRIP (BACKSTOP)	1	1.000	1.000	0.192		ESTIMATE	0.05	0.010	
5871	BRACKET (BACKSTOP)	2	0.264	0.528	0.101		AVCO	0.20	0.020	
5881	RETAINER PLATE	4	?	ERR	ERR		AVCO	0.20	ERR	
5783	ROD	2	?	ERR	ERR		AVCO	0.20	ERR	
5768	FORWARD PLATE	2	?	ERR	ERR		AVCO	0.20	ERR	
5773	AFT PLATE	2	?	ERR	ERR		AVCO	0.20	ERR	
5814	FORWARD STRUT	2	?	ERR	ERR		AVCO	0.20	ERR	
5815	REAR STRUT	2	?	ERR	ERR		AVCO	0.20	ERR	
5737	BLOCK (CLEVIS)	2	?	ERR	ERR		AVCO	0.20	ERR	
5817	PIVOT PIN	2	?	ERR	ERR		AVCO	0.20	ERR	
5883	HOUSING	4	?	ERR	ERR		AVCO	0.20	ERR	
5885	SUPPORT	4	?	ERR	ERR		AVCO	0.20	ERR	
5884	PAD (BEARING)	4	?	ERR	ERR		AVCO	0.20	ERR	
5778	SLEEVE	4	?	ERR	ERR		AVCO	0.20	ERR	
5887	ROLLER	16	?	ERR	ERR		AVCO	0.20	ERR	
5818	SUPPORT	4	?	ERR	ERR		AVCO	0.20	ERR	
5833	TOP PLATE	2	?	ERR	ERR		AVCO	0.20	ERR	
5962	ROLLER	16	?	ERR	ERR		AVCO	0.20	ERR	
5837	PAD (BEARING)	4	?	ERR	ERR		AVCO	0.20	ERR	
5840	FRAME	2	?	ERR	ERR		AVCO	0.20	ERR	
5861	PIVOT PIN	2	?	ERR	ERR		AVCO	0.20	ERR	
5886	PIN (HEADED)	1	?	ERR	ERR		AVCO	0.20	ERR	
5890	WASHER (BUMPER)	2	?	ERR	ERR		AVCO	0.20	ERR	
5981	SPACER	2	?	ERR	ERR		AVCO	0.20	ERR	
6002-	BOLT, SCREW	221	0.011	2.431	0.467		CATFAE PRED	0.20	0.093	
6003-	NUT	183	0.011	2.013	0.386		CATFAE PRED	N.C.	N.C.	
6005-	WASHER	262	0.002	0.524	0.101		CATFAE PRED	N.C.	N.C.	
6006-	BUSHING	5	4.570	22.850	4.387		RADC (NPRD-3)	0.50	2.194	
6006-	BEARING	8	3.790	30.320	5.821		RADC (NPRD-3)	0.70	4.075	
2.8.2	TRACK				ERR	ERR			ERR	ERR
5929,5930, 5940	BAR (TRACK SUPPORT)	3	1.000	3.000	0.576		ESTIMATE	0.20	0.115	
5939	BRACKET (ROLLER MOUNT)	4	0.264	1.056	0.203		AVCO	0.20	0.041	
5908	SPACER	1	?	ERR	ERR		AVCO	0.20	ERR	
5798	BUTTON (GUIDE)	4	?	ERR	ERR		AVCO	0.20	ERR	
5924	SUPPORT (FORWARD TRACK)	1	?	ERR	ERR		AVCO	0.20	ERR	
5925,5926	TRACK (FORWARD, CENTER)	3	22.312	66.936	12.852		M109 DATA + EST	0.20	2.570	
5888,5889	HINGE (BRACKET INNER)	8	3.800	30.400	5.837		ESTIMATE	0.20	1.167	
5928,5938	GUIDE (REAR TRACK)	2	22.312	44.624	8.568		M109 DATA + EST	0.20	1.714	
5731,5734	TIE BAR	7	1.000	7.000	1.344		ESTIMATE	0.20	0.269	

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BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	BASIC (F3) RELIABILITY PREDICTION FAILURE RATE (FLR/HOUR 10X-6) *		(FLR/ROUND 10X-6)**	BLOCK MRBF (rnds)	DATA SOURCE	MISSION CRITICAL (F1) PRED F1/F3	FLR RATE (FLR/ROUND 10X-6)	BLOCK MRBF (rounds)
5927	TRACK (REAR)	2	22.312	44.624	8.568		M109 DATA + EST	0.20	1.714	
5735	PLATE	8	?	ERR	ERR		AVCO	0.20	ERR	
5784	STIFFENER	4	?	ERR	ERR		AVCO	0.20	ERR	
6007-012	PIVOT PIN	4	14.300	57.200	10.982		AVCO	0.50	5.491	
6002-	BOLT	68	0.011	0.748	0.144		CATFAE PRED	0.20	0.029	
6003-	NUT	96	0.011	1.056	0.203		CATFAE PRED	N.C.	N.C.	
6005-	WASHER	150	0.002	0.300	0.058		CATFAE PRED	N.C.	N.C.	
6006-	BUSHING	12	4.570	54.840	10.529		RADC (NPRD-3)	0.50	5.265	
2.8.3	SHOCK MOUNT				ERR	ERR			ERR	ERR
5941	SHOCK ABSORBER (FRONT)	2	?	ERR	ERR		RADC (NPRD-3)	0.50	ERR	
5982	BAR (STOP)	1	?	ERR	ERR		RADC (NPRD-3)	0.50	ERR	
5942	SHOCK (MAIN)	2	?	ERR	ERR		RADC (NPRD-3)	0.50	ERR	
5872,5873, 5874	SHOCK MOUNT	4	1.000	4.000	0.768		ESTIMATE	0.20	0.154	
5875	BRACKET	1	0.264	0.264	0.051		AVCO	0.20	0.010	
5876,5836	GUIDE (SHOCK MOUNT)	4	11.000	44.000	8.448		M109 DATA + EST	0.30	2.534	
5877	MOUNT (PROJECTILE STOP)	1	2.776	2.776	0.533		RADC (NPRD-3)	0.50	0.266	
5878	PAD (PROJECTILE STOP)	1	3.316	3.316	0.637		RADC (NPRD-3)	0.50	0.318	
5880	CUSHION	1	3.316	3.316	0.637		RADC (NPRD-3)	0.20	0.127	
5879	MOUNT (PAD)	1	2.776	2.776	0.533		RADC (NPRD-3)	0.20	0.107	
5882	PIN (PROJ STOP PAD)	1	14.300	14.300	2.746		AVCO	0.50	1.373	
5983	GUIDE (SHOCK PLUNGER)	2	?	ERR	ERR		RADC (NPRD-3)	0.50	ERR	
5984	SPACER	16	?	ERR	ERR		RADC (NPRD-3)	0.50	ERR	
5991	BLOCK (STRIKER)	1	?	ERR	ERR		RADC (NPRD-3)	0.50	ERR	
5992	ROD	2	?	ERR	ERR		RADC (NPRD-3)	0.50	ERR	
6002-	BOLT, SCREW	44	0.011	0.484	0.093		CATFAE PRED	0.20	0.019	
6003-	NUT	30	0.011	0.330	0.063		CATFAE PRED	N.C.	N.C.	
6005-	WASHER	88	0.002	0.176	0.034		CATFAE PRED	N.C.	N.C.	
6006-	SLEEVE	26	?	ERR	ERR		RADC (NPRD-3)	0.70	ERR	
2.9	SPADE				7.403	135081			2.762	362086
2.9.1	SPADE				7.403	135081			2.762	362086
5820,5821	SPADE	1	37.853	37.853	7.268		M198 DATA	0.38	2.762	
6002-011	BOLT (SPADE/PLATFORM)	64	0.011	0.704	0.135		CATFAE PRED	N.C.	N.C.	
3.0	FIRE CONTROL				1411.46	708			175.83	5687
3.1	ASSISTANT GUNNER & GUNNER				1409.947	709			175.528	5697
----	ELBOW TELESCOPE	1	643.496	643.496	123.552		M198 DATA	N.C.	N.C.	
----	M172 MT, TELE, QUAD	1	132.484	132.484	25.437		M198 DATA	0.18	4.579	REDUNDANT
----	M18 FIRE CONTROL QUADRANT	1	1343.771	1343.771	258.006		M198 DATA	0.23	59.341	REDUNDANT
----	M17 FIRE CONTROL QUADRANT	1	1059.876	1059.876	203.497		M198 DATA	0.23	46.804	REDUNDANT
----	M137 PANORAMIC TELESCOPE	1	3217.480	3217.480	617.760		M198 DATA	0.23	142.085	
----	M171 MT, TELE, QUAD	1	946.318	946.318	181.694		M198 DATA	0.18	32.705	
3.2	FIRE CONTROL LINKAGE				1.517	659278			0.303	3296392
----	TRUNNION TUBE	1	0.500	0.500	0.096		ESTIMATE	0.20	0.019	
----	END CAP	2	0.200	0.400	0.077		ESTIMATE	0.20	0.015	
----	SIDE SUPPORT STRUT	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	
----	ACTUATOR STRUT	1	1.000	1.000	0.192		ESTIMATE	0.20	0.038	
----	SHORT STRUT	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	
----	SUPPORT STRUT	2	1.000	2.000	0.384		ESTIMATE	0.20	0.077	

PART B. 3/19/87

This Maintainability / Availability (M/A) prediction worksheet is unfinished, and should be Treated as "unfinished". The subsystems that have finished M/A predictions are: 1) the Wheel System 2) the Hydraulic System, 3) the Spade, and 4) the Fire Control (3.1). The other subsystems have either an incomplete M/A prediction or a non-valid M/A prediction. Consult with me before using any of this M/A prediction data.

Michael L. Janssen
RAM ENG.

NOT FINISHED

LTHD SYSTEM MAINTAINABILITY PREDICTION WORKSHEET (AS OF 17-Mar-86)

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	FAILURE RATE (FLR/HR 10X-6) ORG SPPRT	FAILURE RATE (FLR/HR 10X-6) DIRECT SPPRT	AVE MAINTENANCE TASK TIMES (minutes) LC	IS	DS	EX	RE	AL	CH	MEAN TIME TO REPAIR COMB (hrs)	ORG SPPRT (hrs)	DIR SPPRT (hrs)	INHERENT AVAIL-ABILITY
LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR			ERR	ERR								ERR	ERR	ERR	ERR
1.0	CANNON		227.291	356.816								2.10	0.81	2.92	0.998775
1.1	TUBE ASSEMBLY		28.112	65.587								6.40	1.59	8.47	0.999396
1.1.1	TUBE ASSEMBLY		28.112	65.587								6.40	1.59	8.47	0.999396
5767	TUBE (BARREL)	1	9.652	47.127								9.98	3.93	11.22	
5781-	COLLAR SET	8	8.000	8.000	10	10	10	10	10	10	10	1.17	0.47	1.87	
6016-001	EXTRUSION RAIL	2	1.000	1.000	7	7	7	0	7	7	7	0.70	0.28	1.12	
6022-	KEY	20	9.460	9.460	6	6	6	6	6	6	6	0.70	0.28	1.12	
6002-	BOLT	40													
6003-009	NUT	20													
1.2	MUZZLE BRAKE		6.763	15.109								0.83	0.47	1.00	0.999982
1.2.1	MUZZLE BRAKE		6.763	15.109								0.83	0.47	1.00	0.999982
5765,5766	MUZZLE BRAKE	1	5.489	13.437								0.85	0.50	0.99	
5786	KEY	1	0.274	0.672								0.85	0.50	0.99	
5787	TRUST COLLAR	1	1.000	1.000	7	7	7	0	7	7	7	0.70	0.28	1.12	
1.3	BREECH		61.796	145.500								2.19	1.71	2.40	0.999546
1.3.1	BREECH		61.796	145.500								2.19	1.71	2.40	0.999546
5789	BREECH	1	35.294	86.410								2.94	2.50	3.12	
5816	BAND (OUTER BREECH)	1	10.977	26.874								1.02	0.61	1.19	
5788	BAND (INNER BREECH)	1	10.977	26.874								1.02	0.61	1.19	
6022-005	KEY	2	0.549	1.343								0.85	0.50	0.99	
----	CLAMP	4	4.000	4.000	12	12	12	60	12	12	12	2.20	0.88	3.52	
----	BOLT	9													
1.4	PRIMER AUTOLOADER		130.620	130.620								0.58	0.23	0.93	0.999848
5802	PRIMER AUTOLOADER	1	130.620	130.620	5	5	5	5	5	5	5	0.58	0.23	0.93	
2.0	CARRIAGE		ERR	ERR								ERR	ERR	ERR	ERR
2.1	CRADLE		36.821	116.312								6.15	1.31	7.68	0.999058
2.1.1	CRADLE		7.570	87.061								9.12	4.28	9.54	0.999139
5730,5831	CRADLE	1	7.570	87.061								9.12	4.28	9.54	
2.1.2	SPEEDSHIFT PEG		29.251	29.251								1.34	0.54	2.14	0.99992[illegible]
5780	BRACKET	1	1.500	1.500	5	5	5	5	5	5	5	0.58	0.23	0.93	
5772	CRADLE STOP	1	0.250	0.250	10	10	10	10	10	10	10	1.17	0.47	1.87	
5777	GIMBEL MOUNT	3	0.300	0.300	7	7	7	0	7	7	7	0.70	0.28	1.12	
5776	GIMBEL SPEEDSHIFT	1	0.500	0.500	6	6	6	6	6	6	6	0.70	0.28	1.12	
5790	DISK	1	3.500	3.500	12	12	12	60	12	12	12	2.20	0.88	3.52	
5773	LOCK HOUSING	1	0.250	0.250	13	13	13	0	13	13	13	1.30	0.52	2.08	

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BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	FAILURE RATE (FLR/HR 10X-6) ORG SPPRT	DIRECT SPPRT	AVE MAINTENANCE TASK TIMES (minutes) LC	IS	DS	EX	RE	AL	CH	MEAN TIME TO REPAIR COMB (hrs)	ORG SPPRT (hrs)	DIR SPPRT (hrs)	INHERENT AVAIL-ABILITY
5778	LOCK HANDLE	1	7.150	7.150	13	13	13	0	13	13	13	1.30	0.52	2.08	
6013-	SPRING	1	1.155	1.155	13	13	13	0	13	13	13	1.30	0.52	2.08	
6002-	BOLT	11													
6003-	NUT	8													
5771	NUT (SPEEDSHIFT PIVOT)	2	1.000	1.000	13	13	13	0	13	13	13	1.30	0.52	2.08	
6005-	WASHER	8													
6007-	PIN	8	1.496	1.496	13	13	13	0	13	13	13	1.30	0.52	2.08	
6006-	BEARING	4	7.580	7.580	13	13	13	0	13	13	13	1.30	0.52	2.08	
5774,5775	BUSHING (DISK)	2	4.570	4.570	13	13	13	0	13	13	13	1.30	0.52	2.08	
2.2	TRAILS		304.365	304.365								0.77	0.44	1.09	0.999508
2.2.1	TRAIL STRUCTURE		188.930	188.930								0.73	0.42	1.04	0.999702
5841,5897	UPPER TRAIL	2	40.650	40.650	5	5	5	5	5	5	5	0.58	0.23	0.93	
5842,5898	LOWER REAR TRAIL	2	20.320	20.320	10	10	10	10	10	10	10	1.17	0.47	1.87	
5843,5899	LOWER FRONT TRAIL	2	30.480	30.480	7	7	7	0	7	7	7	0.70	0.28	1.12	
5845	FRONT BULKHEAD	2	4.060	4.060	6	6	6	6	6	6	6	0.70	0.28	1.12	
5846	WHEEL BULKHEAD	2	4.060	4.060	12	12	12	60	12	12	12	2.20	0.88	3.52	
5931	MIDDLE BULKHEAD	2	4.060	4.060	13	13	13	0	13	13	13	1.30	0.52	2.08	
5932	REAR BULKHEAD	2	4.060	4.060	13	13	13	0	13	13	13	1.30	0.52	2.08	
5933,5934	LATTICE	24	81.240	81.240	13	13	13	0	13	13	13	1.30	0.52	2.08	
5834,5835	PIN (TRAIL CLEVIS)	64													
5844	SPACER	128													
5857,5858	X-RING	64													
6002-016	BOLT (BULKHEAD)	48													
6003-007	NUT (BULKHEAD)	48													
2.2.2	TRAIL PIN		54.460	54.460								0.74	0.42	1.05	0.999919
6009-003	SCREW	4													
6005-010	WASHER	4													
6026-001	BEARING PIN	4	28.600	28.600	7	7	7	0	7	7	7	0.70	0.28	1.12	
6006-012	BEARING	4	7.580	7.580	6	6	6	6	6	6	6	0.70	0.28	1.12	
6024-001	BUSHING (RETAINER)	4	9.140	9.140	12	12	12	60	12	12	12.	2.20	0.88	3.52	
6025-001	RETAINER	4													
6010-005	SNAP RING	4													
6006-011	BUSHING (TRAIL BEARING)	4	9.140	9.140	13	13	13	0	13	13	13	1.30	0.52	2.08	
6003-006	NUT	16													
6002-015	BOLT	16													
2.2.3	LIFTING HANDLE		43.635	43.635								1.05	0.60	1.49	0.999909
5891	LIFTING HANDLE	4	2.000	2.000	5	5	5	5	5	5	5	0.58	0.23	0.93	
6004-003	STUD	2	0.051	0.051	10	10	10	10	10	10	10	1.17	0.47	1.87	
6005-019	WASHER	4	0.004	0.004	7	7	7	0	7	7	7	0.70	0.28	1.12	
5770	LOCK ARM	2	5.000	5.000	6	6	6	6	6	6	6	0.70	0.28	1.12	
6012-001	PULL PIN	2	14.300	14.300	12	12	12	60	12	12	12	2.20	0.88	3.52	
5762	LOCK PLATE	2	3.000	3.000	13	13	13	0	13	13	13	1.30	0.52	2.08	
6002-010	BOLT	2													
6003-	NUT	6													
6011-001	SPACE CYLINDER	2	1.000	1.000	13	13	13	0	13	13	13	1.30	0.52	2.08	
6006-016	BUSHING	8	18.280	18.280	13	13	13	0	13	13	13	1.30	0.52	2.08	
2.2.4	GROUND PAD		6.092	6.092								0.59	0.34	0.85	0.999993
5832,5833	GROUND PAD	2	3.316	3.316	5	5	5	5	5	5	5	0.58	0.23	0.93	
5856	SPACER	2	2.776	2.776	10	10	10	10	10	10	10	1.17	0.47	1.87	
6002-017	BOLT	14													
6003-008	NUT	14													
2.2.5	CRADLE/TRAIL TIE-IN		11.248	11.248								0.55	0.31	0.78	0.999987
5855	SLOTTED PLATE	4	6.000	6.000	5	5	5	5	5	5	5	0.58	0.23	0.93	
5854	SHIM	4	0.200	0.200	10	10	10	10	10	10	10	1.17	0.47	1.87	
5863	LUG	4	1.048	1.048	7	7	7	0	7	7	7	0.70	0.28	1.12	

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5864,5865	SUPPORT BAR	3	3.000	3.000	6	6	6	6	6	6	6	0.70	0.28	1.12	
5866	LINK	2	1.000	1.000	12	12	12	60	12	12	12	2.20	0.88	3.52	
6002-	BOLT	31													
6003-	NUT	31													
2.3	GIMBAL		31.161	31.161								0.51	0.29	0.73	0.999968
2.3.1	GIMBAL		10.000	10.000								0.41	0.23	0.58	0.999992
5810	GIMBAL	1	10.000	10.000	5	5	5	5	5	5	5	0.58	0.23	0.93	
2.3.2	GIMBAL BEARING		21.161	21.161								0.56	0.32	0.79	0.999976
6007-	PIN (GIMBAL/TRAVERSE)	2	14.300	14.300	5	5	5	5	5	5	5	0.58	0.23	0.93	
5935	SLEEVE	1	2.285	2.285	10	10	10	10	10	10	10	1.17	0.47	1.87	
5936	SPACER	1													
5937	COVER	1	0.250	0.250	6	6	6	6	6	6	6	0.70	0.28	1.12	
6002-	BOLT	2													
6005-	WASHER	3	0.003	0.003	13	13	13	0	13	13	13	1.30	0.52	2.08	
6006-	BEARING	2	3.790	3.790	13	13	13	0	13	13	13	1.30	0.52	2.08	
6010-	SNAP RING	4	0.008	0.008	13	13	13	0	13	13	13	1.30	0.52	2.08	
6030-001	O-RING	1	0.525	0.525	13	13	13	0	13	13	13	1.30	0.52	2.08	
2.4	PLATFORM		27.610	27.610								0.63	0.36	0.90	0.999965
2.4.1	PLATFORM		10.000	10.000								0.41	0.23	0.58	0.999992
5800	PLATFORM	1	10.000	10.000	5	5	5	5	5	5	5	0.58	0.23	0.93	
2.4.2	PLATFORM/TRAIL CONNECTOR		17.610	17.610								0.75	0.43	1.07	0.999973
----	HANDLE	2	1.000	1.000	5	5	5	5	5	5	5	0.58	0.23	0.93	
----	BOLT (SPRING LOADED)	2	14.300	14.300	10	10	10	10	10	10	10	1.17	0.47	1.87	
6013-001	SPRING	2	2.310	2.310	7	7	7	0	7	7	7	0.70	0.28	1.12	
6010-006	SNAP RING	2													
6002-029	BOLT	4													
6003-	NUT	4													
6001-004	ADHESIVE	2													
2.5	WHEEL SYSTEM		447.000	639.130								1.27	0.46	1.84	0.998618
2.5.1	PIN ASSEMBLY		48.870	16.290								0.28	0.24	0.41	0.999982
5730	PIVOT PIN	2	21.450	7.150	5	5		5		2		0.28	0.16	0.65	
6005-002	THRUST WASHER	8													
6002-001	BOLT (PIVOT)	2													
6003-001	NUT (PIVOT)	2													
6006-001	BUSHING (PIVOT)	8	27.420	9.140	5	15	4	1	4	2		0.52	0.30	1.18	
2.5.2	BEAM ASSEMBLY		66.750	40.294								0.74	0.15	1.72	0.999920
5794,5796	LEADING BEAM	2	0.357	6.783	5		128	5	128		10	4.60	1.19	4.78	
5795,5797	LAGGING BEAM	2	0.357	6.783	5		128	5	128		10	4.60	1.19	4.78	
5807	PIN (CROSS SUPPORT)	4	1.122	0.374	5	5		1				0.18	0.10	0.42	
5736	CAP (AXLE BEAM END)	8	3.000	1.000	5	5		2				0.20	0.11	0.46	
6002-002	BOLT (AXLE CAP)	16													
6005-004	WASHER (AXLE CAP)	16													
6005-006	WASHER (CYLINDER PIVOT)	8													
6006-003	BUSHING (CYLINDER PIVOT)	4	13.710	4.570	5	10		3		5		0.38	0.22	0.88	
6006-004	BUSHING (SUPPORT PIVOT)	12	41.130	13.710	5	5		3				0.22	0.12	0.50	
5803,5804	CROSS SUPPORT	2	1.000	1.000	5			14		5		0.40	0.16	0.64	
5809	HANDLE LOCKING (X-SUPPORT)	2	3.000	3.000	5	5		2				0.20	0.08	0.32	
5812	BRACKET (CROSS SUPPORT)	2	0.264	0.264	5	5		2				0.20	0.08	0.32	

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5813	GUIDE (SPRING)	2	0.500	0.500	5	5		7			2	0.32	0.13	0.51	
6002-006	BOLT (SUPPORT HANDLE BRKT)	4													
6003-005	NUT (SUPPORT HANDLE BRKT)	2													
6002-007	BOLT (HANDLE GUIDE)	8													
6013-002	SPRING	2	2.310	2.310	5	5		2			2	0.23	0.09	0.37	
6033	LOCKWIRE	2													
2.5.3	WHEEL ASSEMBLY		234.880	168.108								1.11	0.49	1.97	0.999553
5738	TIRE	4	100.874	25.218	1	2	11	20	2	5	5	0.77	0.48	1.92	
5739	WHEEL	4	4.294	1.074	1	2	11	20	2	5	5	0.77	0.48	1.92	
6020,6021	VALVE STEM AND CAP	4	1.491	0.373	1	2	11	20	2	5	5	0.77	0.48	1.92	
5741	HUB	4	0.671	12.745								5.73	3.53	5.85	
5742	CAP (HUB)	4	1.800	4.200	5	5	10	22	2			0.73	0.24	0.95	
6002-003	BOLT (HUB CAP)	32													
5743	GREASE SEAL	8	8.388	19.572	5	5	10	22	2			0.73	0.24	0.95	
5744	NUT (AXLE BEARING)	8	4.440	4.440	5	12	10	24	2			0.88	0.35	1.41	
5745	LOCKWASHER (BEARING)	8													
5746	ROLLER BEARING	8	15.696	36.624								2.27	1.56	2.57	
5747	AXLE	4	1.610	3.758								2.27	1.56	2.57	
5748	ROTOR (DISC BRAKE)	4	17.107	39.917	1	2	11	30	2	5	5	0.93	0.30	1.20	
6002-004	BOLT (ROTOR DISC)	24													
6003-044	NUT (WHEEL)	32													
6005-005	WASHER (WHEEL BOLT)	32													
6019-010	GREASE ZURK	8	66.790	16.698	5	5		15			5	0.50	0.31	1.25	
6019-11	RELIEF VALVE (CAP)	8	10.970	2.742	5	5		15			5	0.50	0.31	1.25	
6007-002	PIN (ROTOR)	4	0.748	0.748	5	5	23	10	15	5	5	1.13	0.45	1.81	
2.5.4	BRAKE SYSTEM		96.501	414.437								1.64	0.74	1.85	0.999162
5749	BRAKE CALIPER (SERVICE)	4	22.809	205.283								2.31	1.37	2.41	
6006-002	BUSHING (BRAKE)	16	6.926	16.162	5	10	11	10	11			0.78	0.25	1.01	
5753	PIN (BRAKE)	8	0.898	2.094	5	10	11	10	11			0.78	0.25	1.01	
5750	PARK BRAKE CALIPER	4	28.979	43.469								1.19	0.82	1.44	
5827	PIN (PARK BRAKE)	4	0.598	0.898								1.19	0.82	1.44	
5824	SHAFT (PARK BRAKE)	2	3.444	3.444	5	5		6				0.27	0.11	0.43	
5825	HEX HEAD (PARK BRAKE)	2													
5826	BEARING BLOCK (PARK BRAKE)	4	7.580	7.580	5	5	5	5	5			0.42	0.17	0.67	
6002-008	BOLT (BEARING BLOCK)	16													
5823	ROD END (PARK BRAKE)	4	0.672	0.672	5	5		6		5		0.35	0.14	0.56	
5822	ROD (PARK BRAKE)	2	0.671	0.671	5	5		4		5		0.32	0.13	0.51	
5819	LEVER (PARK BRAKE)	2	4.695	4.695								0.57	0.41	0.72	
5751	HYDRAULIC/AIR ACTUATOR	1	5.046	45.413	10	20		14	20		5	1.15	0.31	1.24	
5752	RELAY VALVE (W CHECK V)	1	1.342	12.074	10	30		24	20		5	1.48	0.40	1.60	
5715	AIR TANK	1	0.067	0.604	10	20		34	20		5	1.48	0.40	1.60	
5757	DRAIN COCK	1	1.207	10.868								1.15	0.68	1.20	
5759	AIR FILTER	2	0.661	5.945	10	12		5	5		5	0.62	0.17	0.67	
5758	FRAME NIPPLE	2	0.093	0.839								1.15	0.68	1.20	
5756	AIR HOSE ASSEMBLY	2	3.466	3.466								0.61	0.46	0.75	
5755	GLADHAND	2	1.600	0.400								0.52	0.46	0.75	
5754	HOSE SUPPORT BRACKET	1	0.211	0.053	5	5			2			0.20	0.13	0.50	
6027-	PIPING AND FITTINGS	12	2.118	19.062								1.76	1.04	1.84	
6034-	HOSE AND COUPLING	10	1.952	17.568								1.48	0.88	1.55	
6019-	ELBOW PIPING	5	0.383	3.452								1.67	0.99	1.74	
6019-006	NIPPLE	2	0.093	0.839								1.15	0.68	1.20	
6019-007	UNION	1	0.172	1.544								1.15	0.68	1.20	
6019-001	ADAPTER	6	0.536	4.828								1.67	0.99	1.75	
6019-002	TEE	3	0.280	2.516								0.57	0.34	0.60	
6003-002	NUT	4													
6017-002	X-WASHER	16													
2.6	EQUILIBRATORS		19.487	19.487								1.17	0.47	1.87	0.999954
2.6.1	EQUILIBRATOR ACTUATOR MOUNTS		9.099	9.099								1.17	0.47	1.87	0.999979
5763	TUBE	1	0.250	0.250	10	10	10	10	10	10	10	1.17	0.47	1.87	
5779	TUBE (OUTSIDE)	4	1.000	1.000	10	10	10	10	10	10	10	1.17	0.47	1.87	
5760	CAP	2	0.100	0.100	10	10	10	10	10	10	10	1.17	0.47	1.87	

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5761	TRAIL NESTING BUSHING	2	4.570	4.570	10	10	10	10	10	10	10	1.17	0.47	1.87	
5664	CLAMP SET	3	3.000	3.000	10	10	10	10	10	10	10	1.17	0.47	1.87	
6004-	STUD	7	0.179	0.179	10	10	10	10	10	10	10	1.17	0.47	1.87	
6003-	NUT	8													
2.6.2	EQUILIBRATOR CABLES		14.938	14.938								1.17	0.47	1.87	C.999965
5791	CABLE	2	10.400	10.400	10	10	10	10	10	10	10	1.17	0.47	1.87	
6006-007	BEARING	2	3.790	3.790	10	10	10	10	10	10	10	1.17	0.47	1.87	
6007-004	PIN	4	0.748	0.748	10	10	10	10	10	10	10	1.17	0.47	1.87	
2.7	HYDRAULIC SYSTEM		303.706	2374.447								2.97	0.72	3.25	0.992118
2.7.1	SYSTEM HYDRAULICS (MISC)		22.761	204.852								1.90	0.51	2.06	0.999567
----	MANIFOLD ASSY	4	2.956	26.604	5	5	197	40	227	1	5	8.00	2.16	8.65	
5906-001	HAND PUMP	2	10.090	90.808		5		24	15		5	0.82	0.22	0.88	
5906-002	PUMP SELECTOR VALVE	2	1.990	17.910	5	5	30	44	60		5	2.48	0.67	2.68	
5906-003	HYDRAULIC ON/OFF VALVE	1	0.995	8.955	5	5	30	34	60		5	2.32	0.63	2.50	
----	QUICK-DISCONNECT CHECK VLV	3	3.131	28.177			10	5	20			0.58	0.16	0.63	
5903-003	SAFETY RELIEF VALVE	1	0.171	1.543	5	5		1	15		5	0.52	0.14	0.56	
----	HOSE AND COUPLING	4	0.781	7.027		5	7	10	15	2		0.65	0.18	0.70	
----	PIPING AND FITTINGS	15	2.648	23.828		5	7	10	15	2		0.65	0.18	0.70	
2.7.2	TRAVERSE HYDRAULICS		15.370	135.900								1.67	0.45	1.81	0.999747
5904,5905	CANNON LAY TRAVERSE VALVE	4	3.980	35.820	5	49	30	44	60		5	3.22	0.87	3.48	
5920	TRAVERSE VALVE	1	0.995	8.955	5	49		29	15			1.63	0.44	1.77	
----	TRAVERSE BEAR LOC	1	2.345	21.101		30	14	17	15		5	1.35	0.36	1.46	
----	INTENSIFIER (BEAR LOCK)	1	0.550	4.950		30		17	15		5	1.12	0.30	1.21	
5714	TRAVERSE ACTUATOR	1	5.046	45.413		30		17	15		5	1.12	0.30	1.21	
----	HOSE AND COUPLING	3	0.586	5.270		5	7	10	15	2		0.65	0.18	0.70	
----	PIPING AND FITTINGS	9	1.589	14.297		5	7	10	15	2		0.65	0.18	0.70	
6007-006	PIN	1	0.281	0.094		5		6				0.18	0.10	0.42	
2.7.3	ELEVATION HYDRAULICS		14.946	107.451								1.74	0.41	1.93	0.999787
5904,5905	CANNON LAY ELEVATION VALVE	4	3.980	35.820	5	49	30	44	60		5	3.22	0.87	3.48	
5919	ELEVATION VALVE	1	0.995	8.955	5	49		29	15			1.63	0.44	1.77	
5716	ELEVATION ACTUATOR	1	5.046	45.413		30		17	15	5		1.12	0.30	1.21	
----	HOSE AND COUPLING	2	0.390	3.514		5	7	10	15	2		0.65	0.18	0.70	
----	PIPING AND FITTINGS	8	1.412	12.708		5	7	10	15	2		0.65	0.18	0.70	
6007-009	PIN	1	0.281	0.094		5		6				0.18	0.10	0.42	
6006-013	BEARING	1	2.843	0.948		5		6				0.18	0.10	0.42	
6005-011	WASHER	2													
6017-001	X-WASHER	2													
2.7.4	EQUILIBRATION HYDRAULICS		30.943	278.484								1.68	0.45	1.81	0.999481
5893	EQUILIBRATION PRESSURE VLV	1	0.995	8.955	5	5		44	15		5	1.23	0.33	1.33	
5892	EQUILIBRATION VALVE ON/OFF	1	0.995	8.955	5	5		34	15		5	1.07	0.29	1.15	
5915	INTENSIFIER (DOUBLE-ENDED)	1	4.469	40.223	5	5		44	15		5	1.23	0.33	1.33	
5720-002	EQUILIBRATION ACCUMULATOR	1	5.505	49.541	5	67	20	66	30			3.13	0.85	3.39	
5712,5713	EQUILIBRATION ACTUATOR	2	10.092	90.826	5	20		40	15	10	5	1.58	0.43	1.71	
----	ELEVATION BEAR LOC	2	4.689	42.203		30		17	15		5	1.12	0.30	1.21	
----	INTENSIFIER (BEAR LOCK)	1	0.550	4.950		30		17	15		5	1.12	0.30	1.21	
5896	PILOT OPER CHCK VLV W SEAL	1	1.613	14.517	5	68	15	19	30			2.28	0.62	2.47	
----	PIPING AND FITTINGS	6	1.059	9.531		5	7	10	15	2		0.65	0.18	0.70	
----	HOSE AND COUPLING	5	0.976	8.784		5	7	10	15	2		0.65	0.18	0.70	
2.7.5	STORED PRESSURE HYDRAULICS		17.309	136.434								1.95	0.48	2.14	0.9997[illegible]
5894,5900	VALVE (PRESSURE GAGE)	2	1.990	17.910	5	5		34	15		5	1.07	0.29	1.15	
5894,5900	PRESSURE GAGE	2	1.436	12.924	5		34	5	17		5	1.10	0.30	1.19	
5720-003	RESERVOIR ACCUMULATOR	1	5.505	49.541	5	67	20	66	30			3.13	0.85	3.39	

(*) FAILURE PER MILLION HOURS - BASED ON GROUND MOBILE ENVIRONMENT; (**) 5.2083 ROUNDS PER HOUR CONVERSION FAC[illegible]

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	FAILURE RATE (FLR/HR 10X-6) ORG SPPRT	DIRECT SPPRT	AVE MAINTENANCE TASK TIMES (minutes) LC	IS	DS	EX	RE	AL	CH	MEAN TIME TO REPAIR COMB (hrs)	ORG SPPRT (hrs)	DIR SPPRT (hrs)	INHERENT AVAIL-ABILITY
5978	PILOT OPER CHCK VLV W SEAL	2	3.226	29.034	5	40	30	5	60			2.33	0.63	2.52	
5720-005	HYDRAULIC FILTER	1	2.233	0.744		2		10				0.20	0.11	0.46	
5710-004	CHECK VALVE (FILTER)	2	1.685	15.161		5		5	15			0.42	0.11	0.45	
----	PIPING AND FITTINGS	7	1.236	11.120		5	7	10	15	2		0.65	0.18	0.70	
2.7.6	CANNON POSITION HYDRAULICS		4.221	37.989								0.74	0.20	0.80	0.999969
5895	CANNON POSITION VALVE	1	0.995	8.955	5	5		44	15		5	1.23	0.33	1.33	
5976,5977	PILOT OPER CHCK VLV W SEAL	2	3.226	29.034	5	5		10	15			0.58	0.16	0.63	
2.7.7	RECOIL & C'RECOIL HYDRAULICS		89.994	693.511								6.71	1.59	7.37	0.99[illegible]771
5710-555	RECOIL CYLINDER	2	30.426	273.838	5	5	197	40	227	1	5	8.00	2.16	8.65	
5710-315	C' RECOIL CYLINDER	1	15.213	136.919	5	5	197	40	227	1	5	8.00	2.16	8.65	
5710-310	ENERGY STORAGE CYLINDER	1	15.213	136.919	5	5	197	40	227	1	5	8.00	2.16	8.65	
5718,5719	C' RECOIL ACCUMULATOR	2	11.009	99.081	5	5	30	15	60		5	2.00	0.54	2.16	
5912,5978	CHECK VALVE	2	1.685	15.161	5	5	30	5	60		5	1.83	0.50	1.98	
5913	RELIEF VALVE	1	0.171	1.543	5	5		5	15		5	0.58	0.16	0.63	
5914	PRESSURE REDUCING VALVE	1	0.171	1.543	5	5	30	5	30		5	1.33	0.36	1.44	
5916	CIRCUIT BREAKER	1	8.050	2.683		5		5				0.17	0.10	0.38	
5916	ORIFICE	1	5.385	1.795		5		5				0.17	0.10	0.38	
5947	ROD/PISTON (RECOIL)	2	0.200	1.800	5	5	197	40	227	1	5	8.00	2.16	8.65	
5948	ROD/PISTON (C'RECOIL)	2	0.410	3.690	5	5	197	40	227	1	5	8.00	2.16	8.65	
5949	ORIFICE ROD	2	0.430	3.870	5	5	8	240	20			4.63	1.25	5.01	
5950	GUIDE ROD	2	0.430	3.870	5	5	8	240	20			4.63	1.25	5.01	
5951	END CAP	8	0.800	7.200		5	98	30	127			4.33	1.17	4.68	
5952	WASHER (END CAP)	4													
5954	COLLAR (END CAP)	4	0.400	3.600		5	8	60	37			1.83	0.50	1.98	
5955	NUT (END CAP)	4													
2.7.8	BREECH HYDRAULICS		14.097	117.944								1.05	0.27	1.14	0.999862
5900-001	BREECH VALVE	1	0.995	8.955		10		44	15		5	1.23	0.33	1.33	
5725	BREECH ACTUATOR	1	5.046	45.413	5	51		7	15	10	5	1.55	0.42	1.68	
5725-001	CHECK VALVE	1	0.842	7.581	5	51		7	15	10	5	1.55	0.42	1.68	
5922	PILOT OPER CTRL FLOW VALVE	2	4.911	44.195	5	2		10	15			0.53	0.14	0.58	
----	PIPING AND FITTINGS	5	0.882	7.943		5	7	10	15	2		0.65	0.18	0.70	
----	HOSE AND COUPLING	2	0.390	3.514		5	7	10	15	2		0.65	0.18	0.70	
----	LINK	1	0.750	0.250		5		11				0.27	0.15	0.61	
5725	PIN	1	0.281	0.094		5		6				0.18	0.10	0.42	
2.7.9	INERTIAL RAMMING HYDRAULICS		12.546	91.446								1.47	0.35	1.62	0.999847
5900-002	VALVE (RAM/RETRACT/CREEP)	1	0.995	8.955		10		44	15		5	1.23	0.33	1.33	
5902	DEINTENSIFIER	1	3.675	33.075	5	5	30	10	60		5	1.92	0.52	2.07	
5729-001	AIR FILTER	1	2.477	0.826				10				0.17	0.10	0.38	
5729	INERTIAL RAMMING ACTUATOR	1	5.046	45.413	5	10		30	30		5	1.33	0.36	1.44	
----	PIPING AND FITTINGS	2	0.353	3.177		5	7	10	15	2		0.65	0.18	0.70	
2.7.10	LOAD POSITION HYDRAULICS		11.610	104.489								1.25	0.34	1.36	0.99985[illegible]
5900-003	VALVE (BATTERY/LOAD)	1	0.995	8.955		10		44	15		5	1.23	0.33	1.33	
5728	LOAD POSITION ACTUATOR	1	5.046	45.413	5	10		60	30		5	1.83	0.50	1.98	
5921,5971	PILOT OPER CHCK VLV W SEAL	2	3.226	29.034	5	5		20	15			0.75	0.20	0.81	
5917	BATTERY VALVE	1	0.995	8.955	5	5		18	15			0.72	0.19	0.77	
5918	LOAD POSITION VALVE	1	0.995	8.955	5	5		18	15			0.72	0.19	0.77	
----	PIPING AND FITTINGS	2	0.353	3.177		5	7	10	15	2		0.65	0.18	0.70	
2.7.11	WHEEL HYDRAULICS		51.857	303.485								0.81	0.19	0.91	0.999713
5910	WHEEL HYDRAULIC VALVE	8	7.960	71.640	5	5		44	15			1.15	0.31	1.24	
?????	WHEEL ACTUATOR	4	20.184	181.652	5	5		12	15		5	0.70	0.19	0.76	
----	LINKAGE (WHEEL ACT VALVE)	4	3.000	1.000		5		15			5	0.42	0.24	0.95	
----	BURST PLUG	4	3.000	1.000				5				0.08	0.05	0.19	
5903-001	CIRCUIT BREAKER	2	2.147	19.319		56		15	15			1.43	0.39	1.55	
----	HOSE AND COUPLING	14	2.733	24.595		5	7	10	15	2		0.65	0.18	0.70	

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14.42

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	FAILURE RATE (FLR/HR 10X-6) ORG SPPRT	DIRECT SPPRT	AVE MAINTENANCE TASK TIMES (minutes) LC	IS	DS	EX	RE	AL	CH	MEAN TIME TO REPAIR COMB (hrs)	ORG SPPRT (hrs)	DIR SPPRT (hrs)	INHERENT AVAIL-ABILITY
----	PIPING AND FITTINGS	8	10.590	3.530		5		6				0.18	0.10	0.42	
----	PIN JOINT	8	2.244	0.748		5		6				0.18	0.10	0.42	
----	RETAINING RING	8													
2.7.12	PRIMER HYDRAULICS		9.026	81.231								1.19	0.32	1.28	0.999893
5900-004	PRIMER VALVE	1	0.995	8.955		10		44	15		5	1.23	0.33	1.33	
5726	PRIMER ACTUATOR	1	5.046	45.413	5	51		7	15	10	5	1.55	0.42	1.68	
5922	PILOT OPER CTRL FLOW VALVE	1	2.455	22.098	5	2		10	15			0.53	0.14	0.58	
----	PIPING AND FITTINGS	3	0.529	4.766		5	7	10	15	2		0.65	0.18	0.70	
2.7.13	LANYARD HYDRAULICS		9.026	81.231								1.19	0.32	1.28	0.999893
5900-005	LANYARD VALVE	1	0.995	8.955		10		44	15		5	1.23	0.33	1.33	
5727	PRIMER ACTUATOR	1	5.046	45.413	5	51		7	15	10	5	1.55	0.42	1.68	
5922	PILOT OPER CTRL FLOW VALVE	1	2.455	22.098	5	2		10	15			0.53	0.14	0.58	
----	PIPING AND FITTINGS	3	0.529	4.766		5	7	10	15	2		0.65	0.18	0.70	
2.8	LOAD TRAY		ERR	ERR								ERR	ERR	ERR	ERR
2.8.1	LOAD TRAY		ERR	ERR								ERR	ERR	ERR	ERR
5867	LOAD TRAY	1	10.142	10.142	10	10	10	10	10	10	10	1.17	0.47	1.87	
5868	WEARSTRIP	3	1.500	1.500	10	10	10	10	10	10	10	1.17	0.47	1.87	
5869	BASE SPRING (PROJECTILE)	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5870	STRIP (BACKSTOP)	1	0.500	0.500	10	10	10	10	10	10	10	1.17	0.47	1.87	
5871	BRACKET (BACKSTOP)	2	0.264	0.264	10	10	10	10	10	10	10	1.17	0.47	1.87	
5881	RETAINER PLATE	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5783	ROD	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5768	FORWARD PLATE	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5773	AFT PLATE	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5814	FORWARD STRUT	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5815	REAR STRUT	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5737	BLOCK (CLEVIS)	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5817	PIVOT PIN	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5883	HOUSING	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5885	SUPPORT	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5884	PAD (BEARING)	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5778	SLEEVE	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5887	ROLLER	16	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5818	SUPPORT	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5833	TOP PLATE	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5962	ROLLER	16	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5837	PAD (BEARING)	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5840	FRAME	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5861	PIVOT PIN	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5886	PIN (HEADED)	1	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5890	WASHER (BUMPER)	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5981	SPACER	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
6002-	BOLT, SCREW	221													
6003-	NUT	183													
6005-	WASHER	262													
6006-	BUSHING	5	11.425	11.425	10	10	10	10	10	10	10	1.17	0.47	1.87	
6006-	BEARING	8	15.160	15.160	10	10	10	10	10	10	10	1.17	0.47	1.87	
2.8.2	TRACK		ERR	ERR								ERR	ERR	ERR	ERR
5929,5930, 5940	BAR (TRACK SUPPORT)	3	1.500	1.500	10	10	10	10	10	10	10	1.17	0.47	1.87	
5939	BRACKET (ROLLER MOUNT)	4	0.528	0.528	10	10	10	10	10	10	10	1.17	0.47	1.87	
5908	SPACER	1	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5798	BUTTON (GUIDE)	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5924	SUPPORT (FORWARD TRACK)	1	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5925,5926	TRACK (FORWARD, CENTER)	3	33.468	33.468	10	10	10	10	10	10	10	1.17	0.47	1.87	
5888,5889	HINGE (BRACKET INNER)	8	15.200	15.200	10	10	10	10	10	10	10	1.17	0.47	1.87	
5928,5938	GUIDE (REAR TRACK)	2	22.312	22.312	10	10	10	10	10	10	10	1.17	0.47	1.87	
5731,5734	TIE BAR	7	3.500	3.500	10	10	10	10	10	10	10	1.17	0.47	1.87	

(*) FAILURE PER MILLION HOURS - BASED ON GROUND MOBILE ENVIRONMENT; (**) 5.2083 ROUNDS PER HOUR CONVERSION FACTOR

BLOCK CODE/ PART NUMBER	NOMENCLATURE	QTY	FAILURE RATE (FLR/HR 10X-6) ORG SPPRT	DIRECT SPPRT	AVE MAINTENANCE TASK TIMES (minutes) LC	IS	DS	EX	RE	AL	CH	MEAN TIME TO REPAIR COMB (hrs)	ORG SPPRT (hrs)	DIR SPPRT (hrs)	INHERENT AVAIL-ABILITY
5927	TRACK (REAR)	2	22.312	22.312	10	10	10	10	10	10	10	1.17	0.47	1.87	
5735	PLATE	8	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5784	STIFFENER	4	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
6007-012	PIVOT PIN	4	28.600	28.600	10	10	10	10	10	10	10	1.17	0.47	1.87	
6002-	BOLT	68													
6003-	NUT	96													
6005-	WASHER	150													
6006-	BUSHING	12	27.420	27.420	10	10	10	10	10	10	10	1.17	0.47	1.87	
2.8.3	SHOCK MOUNT		ERR	ERR								ERR	ERR	ERR	ERR
5941	SHOCK ABSORBER (FRONT)	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5982	BAR (STOP)	1	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5942	SHOCK (MAIN)	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5872,5873, 5874	SHOCK MOUNT	4	2.000	2.000	10	10	10	10	10	10	10	1.17	0.47	1.87	
5875	BRACKET	1	0.132	0.132	10	10	10	10	10	10	10	1.17	0.47	1.87	
5876,5836	GUIDE (SHOCK MOUNT)	4	22.000	22.000	10	10	10	10	10	10	10	1.17	0.47	1.87	
5877	MOUNT (PROJECTILE STOP)	1	1.388	1.388	10	10	10	10	10	10	10	1.17	0.47	1.87	
5878	PAD (PROJECTILE STOP)	1	1.658	1.658	10	10	10	10	10	10	10	1.17	0.47	1.87	
5880	CUSHION	1	1.658	1.658	10	10	10	10	10	10	10	1.17	0.47	1.87	
5879	MOUNT (PAD)	1	1.388	1.388	10	10	10	10	10	10	10	1.17	0.47	1.87	
5882	PIN (PROJ STOP PAD)	1	7.150	7.150	10	10	10	10	10	10	10	1.17	0.47	1.87	
5983	GUIDE (SHOCK PLUNGER)	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5984	SPACER	16	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5991	BLOCK (STRIKER)	1	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
5992	ROD	2	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
6002-	BOLT, SCREW	44													
6003-	NUT	30													
6005-	WASHER	88													
6006-	SLEEVE	26	ERR	ERR	10	10	10	10	10	10	10	1.17	ERR	ERR	
2.9	SPADE		3.028	34.825								1.68	0.79	1.76	0.999935
2.9.1	SPADE		3.028	34.825								1.68	0.79	1.76	0.999935
5820,5821	SPADE	1	3.028	34.825								1.68	0.79	1.76	
6002-011	BOLT (SPADE/PLATFORM)	64													
3.0	FIRE CONTROL		885.16	6466.16								1.86	0.47	2.06	0.986-8[illegible]
3.1	ASSISTANT GUNNER & GUNNER		881.211	6462.214								1.87	0.46	2.06	0.986-8[illegible]
----	ELBOW TELESCOPE	1	77.220	566.276								0.59	0.15	0.65	
----	M172 MT, TELE, QUAD	1	15.898	116.586								4.83	1.20	5.33	
----	M18 FIRE CONTROL QUADRANT	1	161.253	1182.518								1.95	0.48	2.15	
----	M17 FIRE CONTROL QUADRANT	1	127.185	932.691								1.66	0.41	1.83	
----	M137 PANORAMIC TELESCOPE	1	386.098	2831.382								1.81	0.45	1.99	
----	M171 MT, TELE, QUAD	1	113.558	832.760								2.63	0.65	2.90	
3.2	FIRE CONTROL LINKAGE		3.950	3.950								1.17	1.17	1.17	0.9999[illegible]
----	TRUNNION TUBE	1	0.250	0.250	10	10	10	10	10	10	10	1.17			
----	END CAP	2	0.200	0.200	10	10	10	10	10	10	10	1.17			
----	SIDE SUPPORT STRUT	2	1.000	1.000	10	10	10	10	10	10	10	1.17			
----	ACTUATOR STRUT	1	0.500	0.500	10	10	10	10	10	10	10	1.17			
----	SHORT STRUT	2	1.000	1.000	10	10	10	10	10	10	10	1.17			
----	SUPPORT STRUT	2	1.000	1.000	10	10	10	10	10	10	10	1.17			

DESCRIPTION: TRADE STUDIES

STATUS:

The Dolly vs. Fixed Wheel tradeoff is complete. Fixed wheels were selected over the separable dolly.

The Fire Control tradeoff is complete. A non-M198 direct fire scope was chosen over an M198 direct fire scope with azimuth [illegible] limits as well as a configuration which would add 50 lbs weight, increase the overall system length and provide poor access to the load tray.

The Loading Out of Battery vs. Loading In Battery tradeoff is complete. Loading 3 feet out of battery was selected over [illegible] at all other barrel positions.

AUTHOR: Dolly vs. Fixed Wheels - Dave Boudreau, Paul Anderson
Fire Control - Bart Anderson, Scott Dacko
Loading Out of Battery/In Battery - Dave Warwick,
Bart Anderson

5710-775

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TRADE STUDY [illegible]

[illegible] DOLLY [illegible] FIXED WHEELS (IN TRAILS)

[illegible]

ATTRIBUTES / ALTERNATIVES	WT	DOLLY	SC	WT SC	2 WHEEL (IN TRAILS)	SC	WT SC	4 WHEEL (IN TRAILS)	SC	WT SC
[illegible]	8									
[illegible]	8									
[illegible]	10	[illegible]	3	30	LESS WT THAN [illegible]	10	100	WT ≥ [illegible]	6	[illegible]
[illegible]	6	[illegible] REMOVED [illegible]	2	[illegible]	NEEDS A TRAILER JACK - [illegible] TONGUE WEIGHT ANGLE OF DEPARTURE [illegible]	5	[illegible]	[illegible]	10	[illegible]
[illegible]	10	E[illegible]	10	100	NOT AS STABLE	1	10	EXCEEDS [illegible]	3	30
[illegible]	9		10	90		7	63		8	72
[illegible]	9	[illegible] RETRIEVED, [illegible] POSITION - DIFF	4	36		8	72		10	[illegible]
[illegible]	9	[illegible]	[illegible]	[illegible]	[illegible]	5	45	[illegible]	5	45
[illegible]	8	DOES NOT HELP STABILITY [illegible] NOT ATTACHED	1	8	INCREASES WT IN TRAILS	5	40	INCREASES WT IN TRAILS [illegible]	6	48
[illegible]	7	[illegible] DOLLY [illegible]	5	[illegible]	TRAILS HELP PROTECT WHEELS (SHELL FRAGMENTS)	[illegible]	12	TRAILS HELP [illegible] WHEELS	7	49
[illegible]	7		[illegible]			[illegible]			[illegible]	
[illegible]	1		[illegible]			[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	6		[illegible]	[illegible]		[illegible]	48		[illegible]	[illegible]
[illegible]	4	[illegible] DOLLY [illegible]	1	[illegible]	HEAVY TORQUE WT	[illegible]	[illegible]		10	40
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	½ [illegible]	[illegible]	[illegible]	[illegible] ALL[illegible]	8	40
				[illegible]			[illegible]			121

FMC

TRADE MADE AT FIRE CONTROL

SEQUENCE OF EVENTS AND RATIONALE

- EMPLOY M198 FIRE CONTROL AND COMPLY WITH HUMAN FACTORS REQUIREMENTS REQUIRED BY STATEMENT OF WORK

COMPLICATIONS

- M138 DIRECT FIRE SCOPE MUST BE RAISED 4.5" TO SEE OVER PLATFORM
  - (DROPPING PLATFORM TOP 4.5" WOULD RAISE WEIGHT BY OVER 50 LBM)
- RAISING FC TRUNNION 4.5" NECESSITATES ADDITION OF 50 LBM PLATFORM FOR BOTH GUNNER AND ASSISTANT GUNNER
- M138 DIRECT FIRE SCOPE EYE PIECE IS 90° TUBE ℄
  - MOVES FC 12" BEYOND LOAD TRAY ENTRANCE FOR 400 MIL TRAV L
  - ACCESS TO LOAD TRAY REQUIRES REACHING UNDER FC TRUNNION SHAFT
  - INCREASES OVERALL LENGTH 12"

LTHD 69
15 JANUARY 1987
BA
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FMC

TRADE MADE AT FIRE CONTROL (CONTINUED)

SITUATION ANALYSIS

- IF A DIRECT FIRE SCOPE WITH A 4.5" PERISCOPE AND REAR EYE PIECE WERE USED
  - ACCESS TO LOAD TRAY WOULD BE SATISFACTORY
  - HUMAN FACTORS FOR ASSISTANT GUNNER WOULD BE SATISFACTORY
  - 50 LBM WEIGHT PENALTY WOULD BE AVOIDED
- IF AN M138 DIRECT FIRE SCOPE WERE USED
  - DIRECT FIRE BELOW 7° WOULD NOT BE POSSIBLE
  - TRAV. L BEYOND 175 MILS WOULD EXCEED HF LIMITS FOR AG

DECISION

TRADE

50 LBM WEIGHT/PENALTY POOR ACCESS TO LOAD TRAY INCREASED OVERALL LENGTH	FOR →	NON M198 DIRECT FIRE SCOPE OR M198 DF SCOPE W/AZ & QE LIMITS

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FINAL REPORT

LOADING OUT OF BATTERY vs. LOADING IN BATTERY

TRADE OFF STUDY

PREPARED BY : Dave Warwick DATE : 86-9-26

ACCEPTED BY : BART ANDERSON DATE : 29 Sep 86

[redacted]

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PROBLEM DESCRIPTION

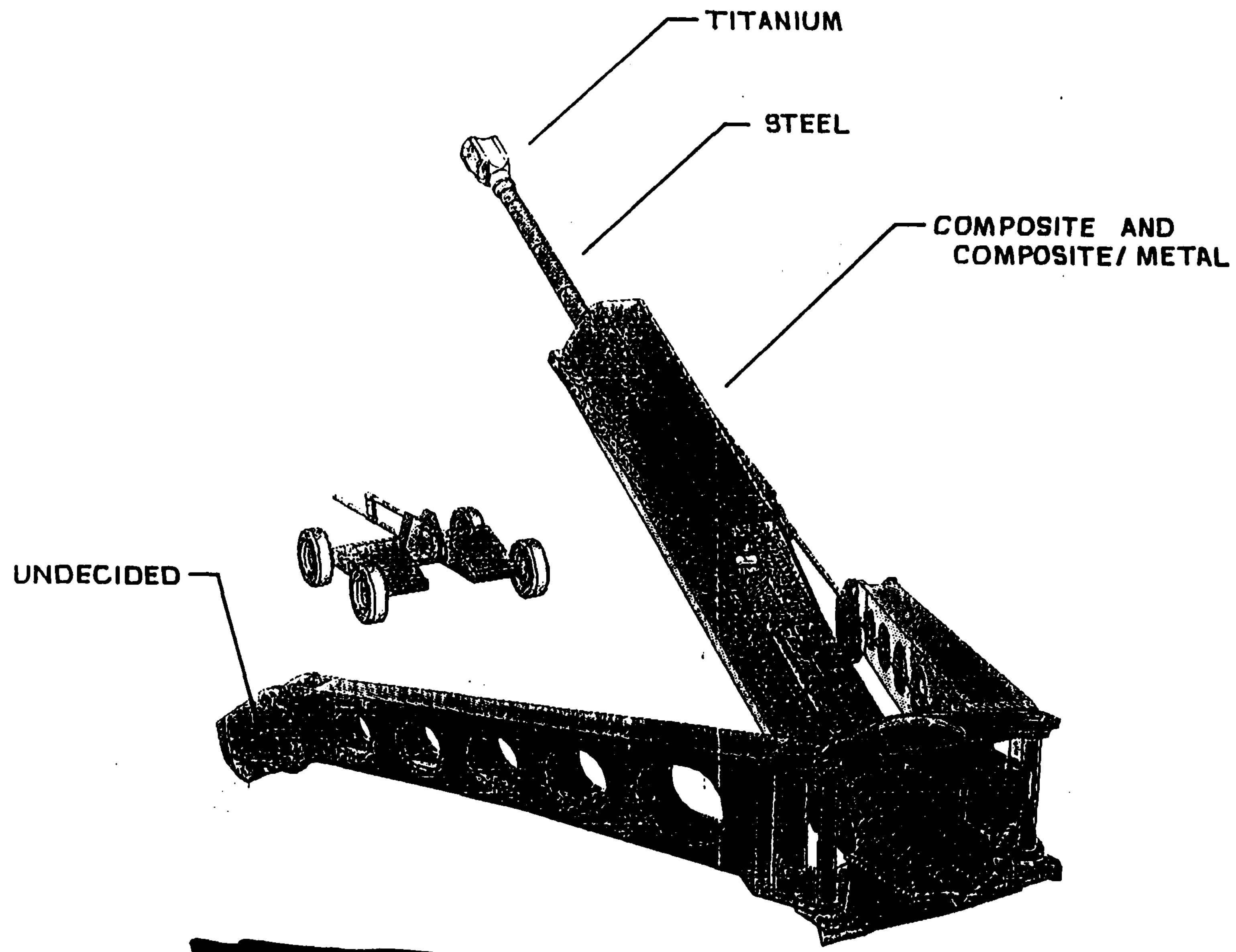
The desired result of the Lightweight Towed Howitzer program is to provide a weapon which has the same capabilities as the present howitzer, the M198, but which is more versatile due to its lighter weight.

In the M198, the recoiling mass recoils back from the trunnion center line. The recoiling mass of the Lightweight Towed Howitzer Demonstrator (LTHD) is forward of the trunnion center line and recoils back toward but not past that center line. On the M198, the trails extend rearward to prevent the recoil forces from tipping the howitzer backward where as, on the LTHD they extend forward to prevent the weight of the howitzer from tipping it forward. The trunnion center line of the LTHD is only 18 inches above the ground. All of these changes were made in order to provide a stable howitzer which is 7,000 lbs. lighter than the present M198 (the M198 weighs 16,000 lbs.).

When the recoiling mass of the LTHD is in battery, the breech opening is about 9 feet (along the center line of the barrel) forward from the center line of the trunnions. When the cannon is elevated to 45 deg. (the maximum elevation for loading) the breech opening is about 7.5 feet above the ground. In this position, it is not possible to load the howitzer without mechanical assistance nor is it possible for the artillery crew, who are stationed behind the howitzer, to accurately determine the position and condition of the bag charge. Mispositioned or damaged charges are serious problems and must be detected and corrected before the firing sequence continues. The customer is comfortable with power ramming of projectiles but is quite uneasy with mechanical handling of the bag charges.

If the LTHD could be loaded in its fully recoiled position, some of the hydraulics could be eliminated and an artillery crewman could load and position the bag charge by hand. This change in the configuration would reduce weight and complexity and would give the artillery crew the capability of visually checking the condition and position of the charge before firing.

 [redacted]



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FMC LTIID - SYSTEM CONCEPT

Pg!

Discussion of Results

From an examination of the present configuration of the LTHD, it is not possible to load at full recoil (see figure 1). Since the trunnion center line is so low, the breech opening is very close to the gimbal when the recoiling mass is fully recoiled. The breech block hinges up but does not move far enough out of the way to allow clear access to the chamber for loading.

If the recoiling mass is positioned about 2 feet forward from full recoil, the cannon could be loaded (see figure 2). A power rammer will still be required but can be incorporated into the load tray eliminating the rammer positioning mechanism. At 2 feet from full recoil, the chamber is close enough to the artillery crew that the charge could be manually positioned and visually inspected prior to closing the breech.

One of the original design requirements was that the howitzer be capable of handling misfires and cookoffs in a controlled and predictable fashion. Since it is dimensionally possible to load in this recoiled position, a numeric analysis was conducted to determine if the howitzer could withstand a misfire when it was fully recoiled and remain upright and intact. For this analysis, chamber pressures were used to determine a rearward force on the howitzer structure (worst case ammunition combination is M203A1 & XM795 which produced a maximum chamber pressure of 56,000 psi). The assumptions used in this analysis were as follows:

- recoiling mass is fully recoiled and resting against the slide
- structure is perfectly rigid; no structural deformation occurs
- no sliding; howitzer is fixed to the ground and only allowed to pivot about its rear most point of contact with the ground
- torque component from rifling not considered

Based on these assumptions , at 26 ms. after start of chamber pressurization the ends of the trails will have raised just over 30 inches off the ground (see graph, figure 3). Based on this analysis, it appears that the howitzer will not overturn as a result of a misfire at the fully recoiled position. All of the energy of firing will be transmitted directly to the slide. A maximum calculated force of 2.1 million lbs. occurs 6 ms. after start of chamber pressurization. This force is over 26

 [redacted]

Goals and Benefits

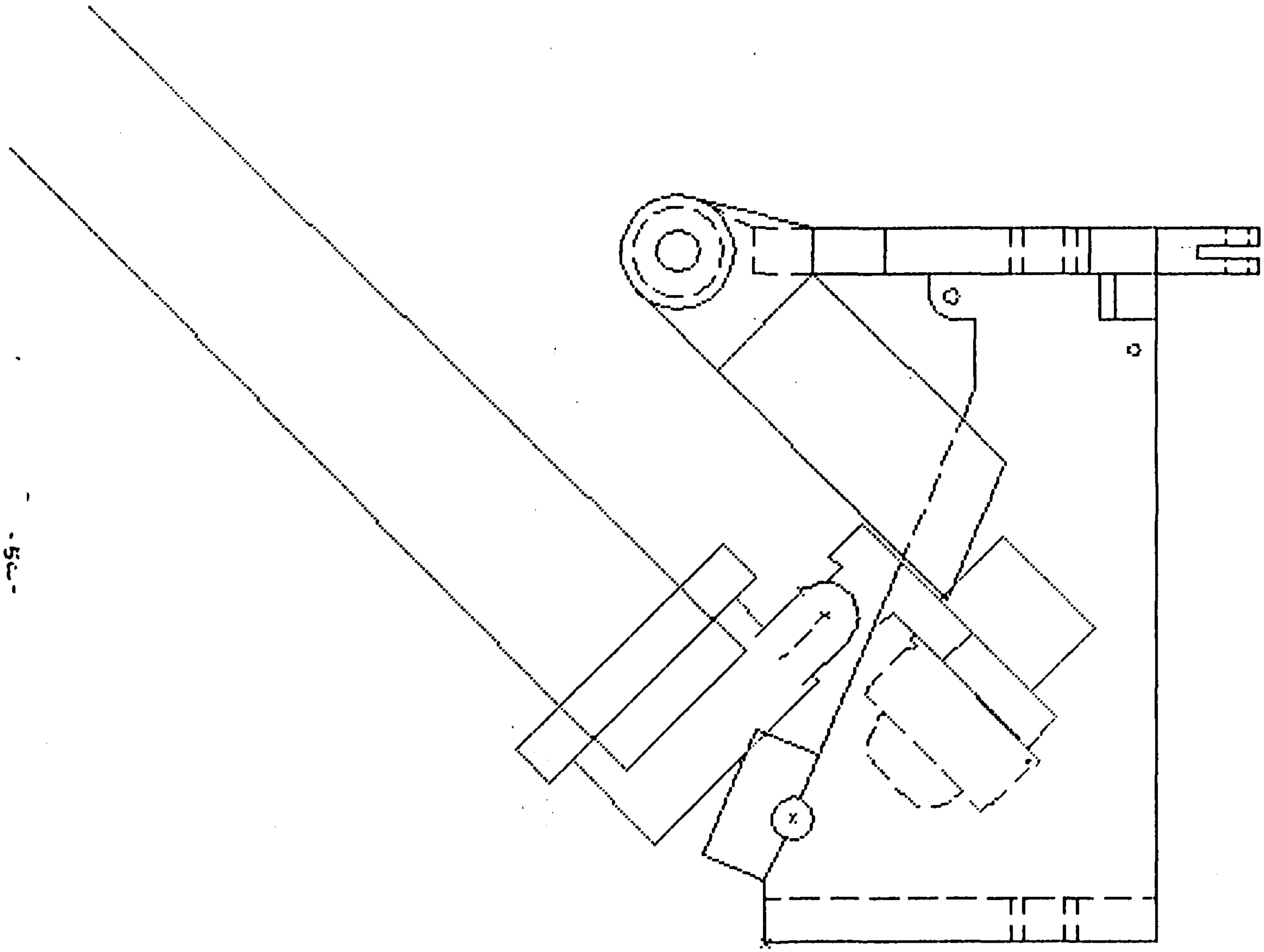
1. Overall system capabilities
   - -load & fire all types of 155 mm. ammunition used by or under development for the M198 howitzer
   - -load at elevations up to 45 degrees
   - -fire at a rate of 4 rounds per minute

2. Chamber close to artillery crew
   - -manual loading especially of bag charges
   - -visual inspection of potential problems
   - -correction of problems

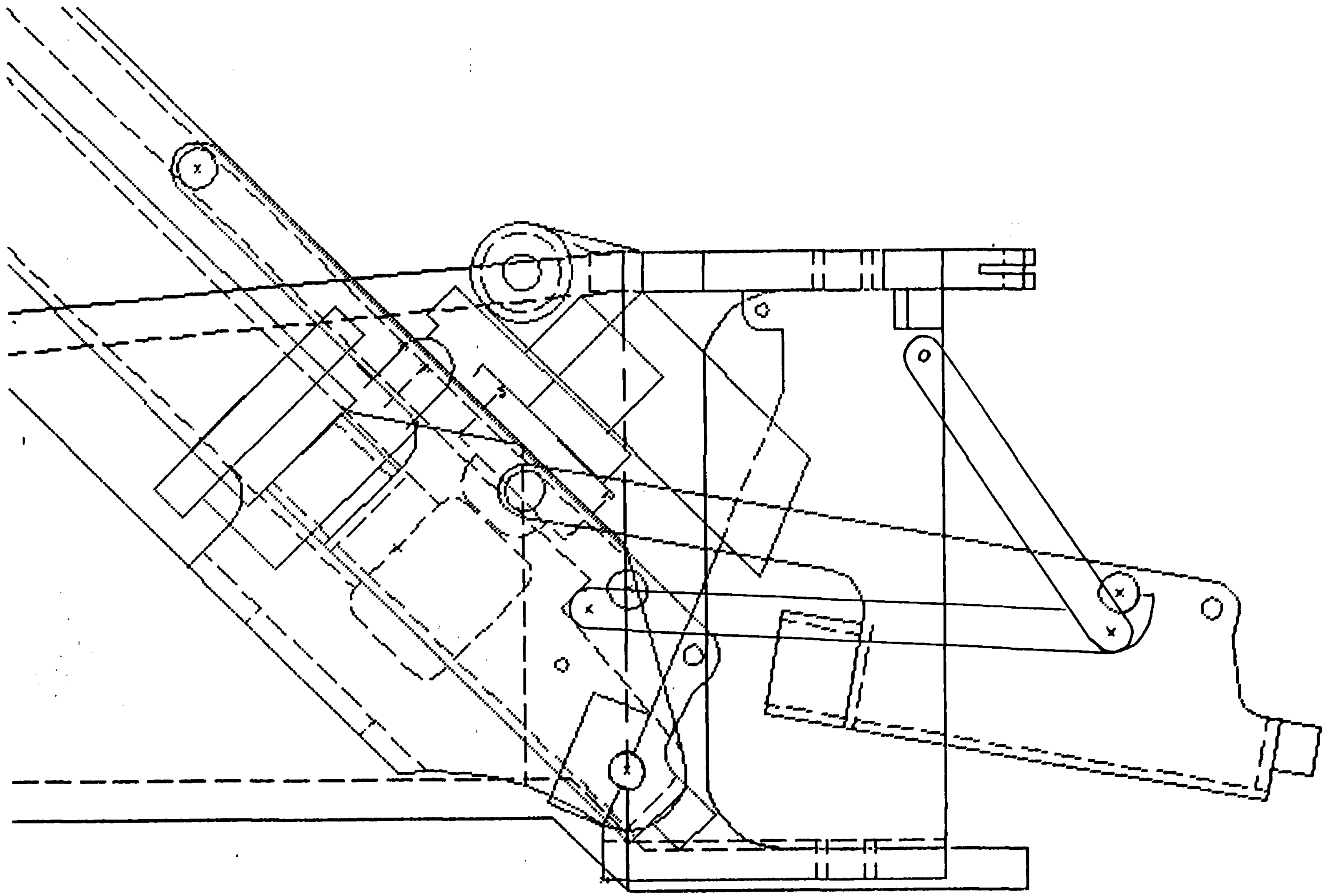
3. Elimination of hydraulics
   - -simplify system
   - -reduce weight
   - -reduce / eliminate need for energy recovery

4. Eliminate auto primer feeder
   - -reduce weight
   - -reduce complexity / increase reliability

 [redacted]



[redacted] 45 DEG. EL. FULL RECOIL
-FIGURE 1-



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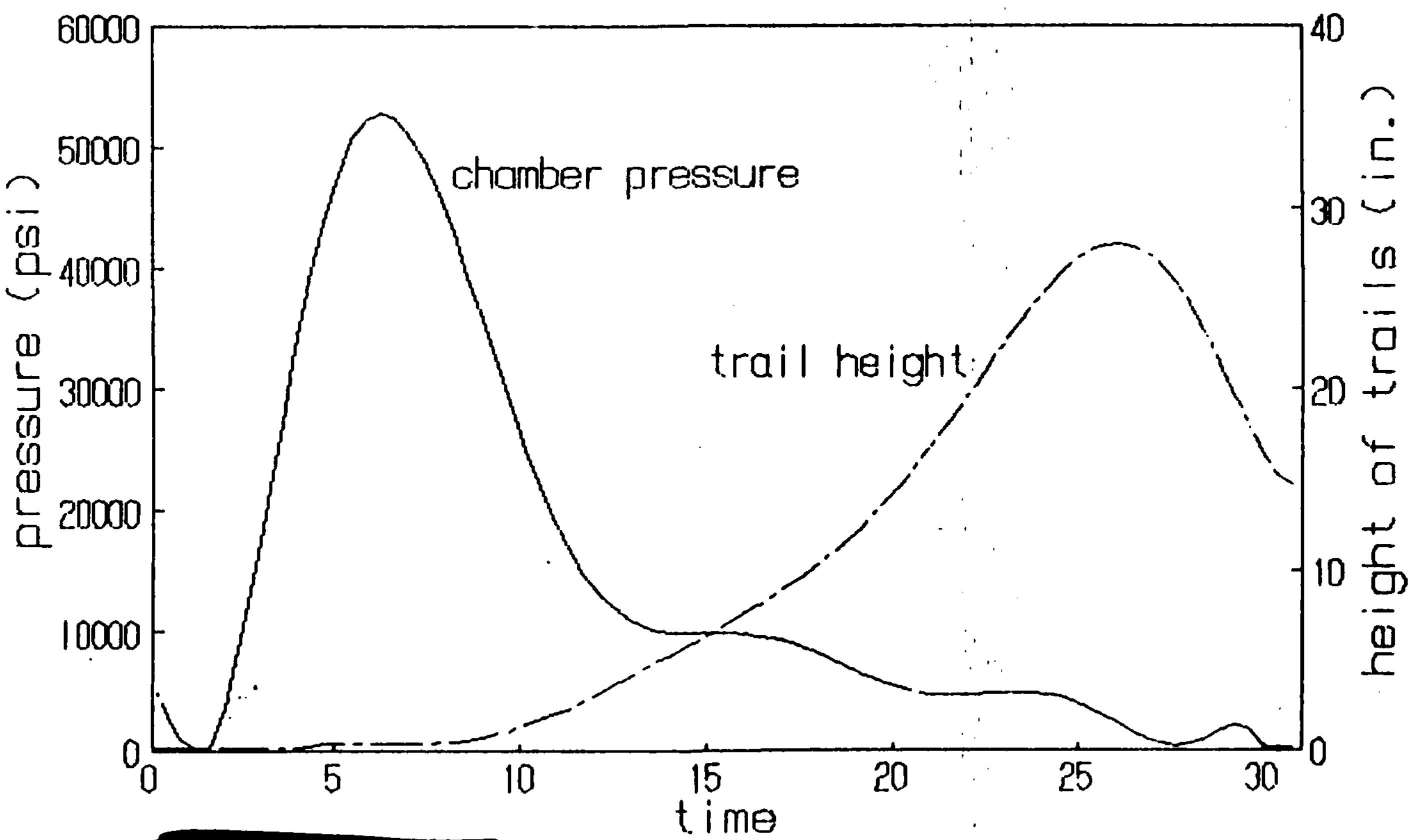
45 DEG. EL. 2FT. FROM FULL RECOIL
FIGURE 2-

LTHD LOAD OUT OF BATTERY

chamber pressure & trail lift

vs. time (ms.)



[redacted]

times the maximum force that the slide is presently designed to accommodate and will cause some kind of structural damage to the slide. A shear stress of well over 100,000 psi. will be experienced in the interrupted threads between the cannon and yoke and over 167,000 psi. between the breech block and breech ring. This would require the use of a material with a tensile strength of at least 175,000 psi. for the yoke / cannon interface and 300,000 psi tensile strength material for the breech block / breech ring interface. Another possible failure area is the "spade" which sticks into the ground below the gimbal. The spade is designed to prevent any horizontal movement of the howitzer. The spade itself is not likely to "plow" much dirt but will probably tear loose from the base structure. If the spade does separate from the howitzer structure, the entire howitzer will be relatively free to move backwards. This is particularly dangerous since the artillery crew will be standing behind the howitzer during firing.

As a result of the extremely high forces present, some kind of catastrophic failure will occur in the event of a misfire. This failure will more than likely render the Howitzer unusable and may endanger the lives of some of the artillery crew as well.

Table I lists various considerations of the two loading concepts considered with a measure of technical/developmental risk and customer acceptability assigned. Critical items are ones which must be satisfied in the design or the howitzer will not be able to perform its function safely.

Low scores in the OPERATIONS section of the Load Out of Battery (LOB) concept are because of the additional design effort that will be needed to obtain the the required performance. The low scores on the Load In Battery (LIB) concept are the result of the customers dissatisfaction with mechanical handling of bag charges and poor visibility of the chamber when the oscillating mass is in battery.

In the SAFETY section, the low scores associated with the LOB concept are due to the possibility that of one of these failures might occur without sufficient recoiling space to safely dissipate the energy of firing. A missfire, for the purposes of this discussion, shall be defined as any unplanned ignition of the charge which is the result of some action of the crew or some mechanical interference. An example of this would be the lanyard snagging on something while the recoiling mass is moving back into battery. A cookoff shall be defined as the unplanned ignition of the

SUMMARY OF TRADEOFF STUDY ON LOADING THE LTMD AT FULL RECOIL

ATTRIBUTES / ALTERNATIVES-->	OVER ALL IMPORTANCE TO SYSTEM	LOAD OUT OF BATTERY: COMMENTS	DEVELOP. RISK	CUSTOMER ACCEPT.	WEIGHTED SCORE	LOAD IN BATTERY: COMMENTS	DEVELOP. RISK	CUSTOMER ACCEPT.	WEIGHTED SCORE
OPERATIONS:									
LOADING/RAMMING OF PROJ.	10	CRITICAL	5	8	65	CRITICAL	9	8	85
LOADING/RAMMING OF CHARGE	10	CRITICAL	9	8	85	CRITICAL	9	5	70
VISIBILITY OF OPERATIONS	9	V. IMPORTANT		8	72	V. IMPORTANT		4	36
RATE OF FIRE:									
MAX <= 800 MILLS	8	DESIGN REQUIREMENT	3	5	32	DESIGN REQUIREMENT	8	7	60
MAX > 800 MILLS	8	DESIGN REQUIREMENT	3	5	32	DESIGN REQUIREMENT	8	7	60
SAFETY:									
MECHANICAL SAFETY	10	CRITICAL		2	20	CRITICAL		8	80
MISFIRE OPERATION	10	MISFIRE OR COOKOFF WILL INCAPASITATE HOWITZER AND ENDANGER ARTILLERY CREW.		2	20	CRITICAL		8	80
COOKOFFS	10			2	20	CRITICAL		8	80
HUMAN FACTORS:									
EASE OF OPERATION	5	NECESSARY FOR EFF. OPERATION	3	6	22.5	NECESSARY FOR EFF. OPERATION	6	8	35
COST:									
END SYSTEM COST	5		4	5	22.5		6	5	27.5
TRAINING:									
ARTILLERY PERSONNEL	4	SOME EXTRA TRAINING REQ'D. IN LIGHT OF THE HIGHER HAZARDS POSSIBLE WITH MISFIRE OR COOKOFF SITUATIONS.	6	4	20	NO MORE TRAINING THAN IS NOW REQUIRED FOR THE M198.	7	5	24
FIRING STABILITY	8	IMPORTANT	8	7	60	IMPORTANT	8	7	60
WEIGHT (TOT. SYS. < 9000 lbs.)	8	DESIGN REQUIREMENT	7	8	60	DESIGN REQUIREMENT	9	8	68
RELIABILITY	7			5	35			6	42
MAINTAINABILITY	6			5	30			6	36

[redacted]

SCORE..... 596

SCORE..... 844

charge as a result of the charge getting too hot in the chamber. (This type of ignition would probably not develop the maximum chamber pressure attainable by normal firing.) The potential for a cookoff depends on the amount of time that the charge is in the chamber and the chamber temperature during that time interval. Data enabling the calculation of a safe time interval prior to high cookoff risk has not been made available, so the precise risk of experiencing a cookoff is not known.

In the HUMAN FACTORS section, the low score was assigned to the LOB concept because of the anticipated difficulty of designing the system to meet the necessary human factors requirements. In the LOB concept, a man would be required to lean through the gimbal with a bag charge and position it in the chamber by hand. Since human interfacing is required with the howitzer and ammunition in the LIB concept, a higher score was assigned.

As illustrated by the total weighted scores in table I, the concept of loading the howitzer out of battery raises some serious safety and cost questions.

SUMMARY

The load out of battery concept will require considerable additional design time to develop. Aspects such as energy recovery and constant recoiling length have not been designed into any previous recoil/counterrecoil system resulting in a greater developmental risk. The reliability of such a recoil/counterrecoil system will likely be degraded by the increased complexity. The cost of development, prototype, and production will increase in proportion to the increase in complexity. Lastly, once the functional design is complete, it probably will be unacceptable with regards to survivability of a misfire and personnel safety. Thus, it is the conclusion of this study that the load out of battery concept should not be pursued in the design of the Lightweight Towed Howitzer Demonstrator.

 [redacted]

APPENDIX

FIRING REACTION FORCE CALCULATIONS

 [redacted]

CALCULATE OVERTURNING TORQUE:

ASSUMPTIONS –

* OSCILLATING MASS FULLY RECOILED AND IS IN SOLID CONTACT WITH THE SLIDE
* STRUCTURE IS PERFECTLY RIGID; NO STRUCTURAL DEFORMATION OCCURS.
* OVERALL STRUCTURE IS RIGIDLY FIXED TO THE GROUND AND IS ALLOWED TO PIVOT ABOUT ITS REAR MOST POINT OF CONTACT ON THE GROUND.

FORMULAS USED:

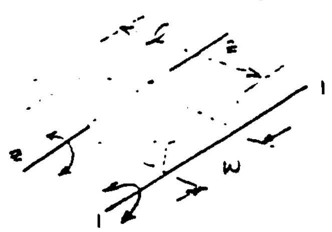
$$F = P \cdot A$$

F = FORCE
P = CHAMBER PRESSURE
A = AREA

$$\tau = F a$$

τ = TORQUE
a = MOMENT ARM

$$I_H = \frac{m(w^2 + \ell^2)}{12} + m d^2$$



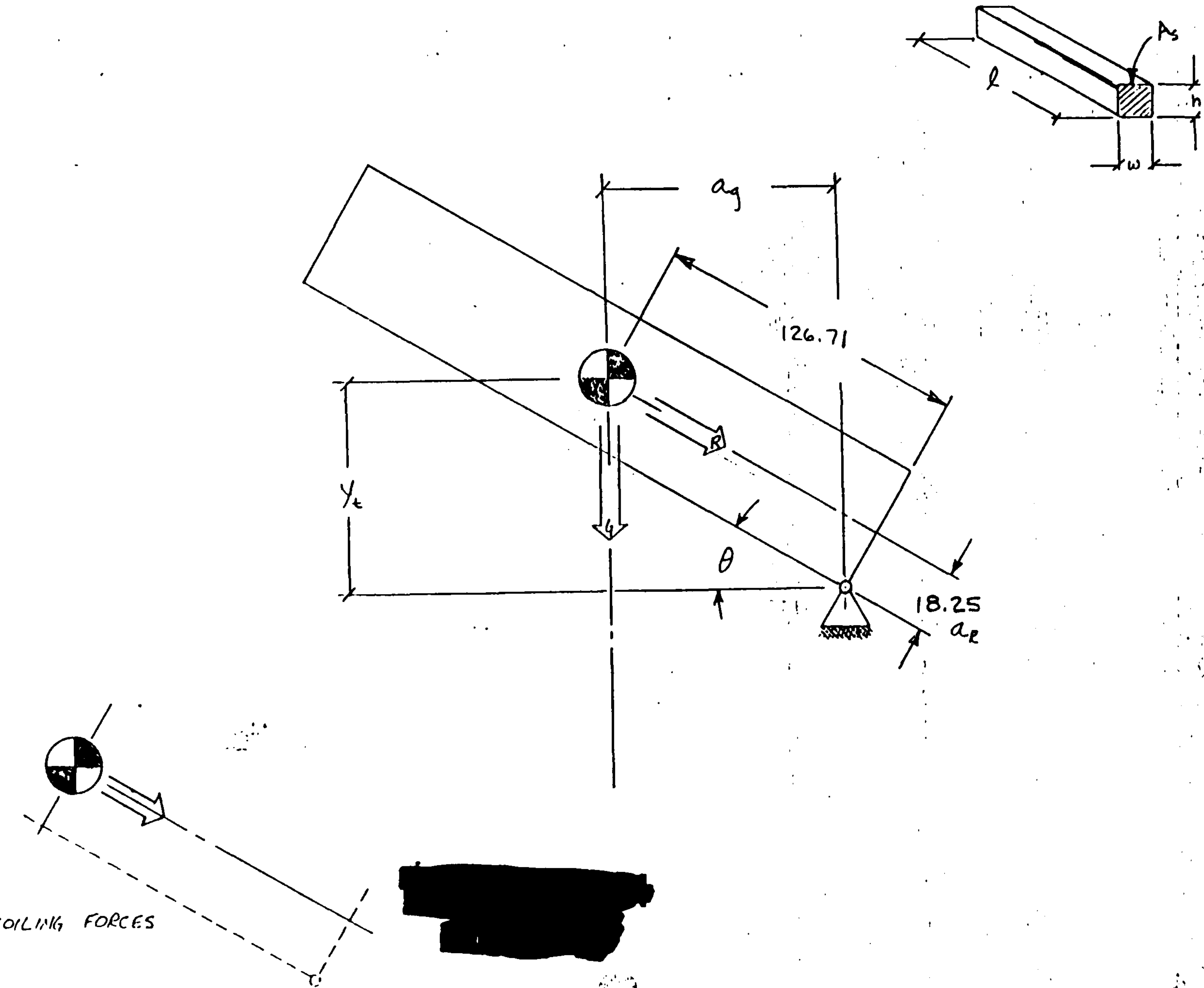
d = DIST FROM C.G. AXIS TO AXIS OF ROT.
m = MASS OF ENTIRE SYSTEM
W = WIDTH OF HOWITZER
ℓ = LENGTH OF HOWITZER

$$\alpha = \tau / I$$

$$\theta = \theta_0 + \omega_0 t + \tfrac{1}{2}\alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

α = ANGULAR ACCELERATION
ω = ANGULAR VELOCITY
θ = ANGULAR POSITION
} IN UNITS OF RADIANS



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RECOILING FORCES

CONCLUSIONS:

OUTBOARD ENDS OF THE TRAILS WILL RISE SLIGHTLY JUST 30" INTO THE AIR. AS STATED IN THE ASSUMPTIONS, THIS ASSUMES THAT THE HOWITZER ASSY ITSELF DOES NOT MOVE AND THAT NOTHING BREAKS. IN REALITY, I AM CONVINCED THAT SOMETHING WILL FAIL. FURTHER ANALYSIS NEEDS TO BE CONDUCTED TO DETERMINE THE EXACT NATURE AND EXTENT OF THIS FAILURE.

POSSIBLE FAILURE POINTS:

- SLIDE
- SPADE ASSY
- THREAD INTERFACE BETWEEN YOKE AND CANNON
- GIMBAL BEARINGS

[redacted]

LTHD - OVERTURNING FORCES WHEN FIRED AT FULL RECOIL AT 0 DEG. ELEVATION

CONSTANTS:

HOWITZER WIDTH	96.0 IN
HOWITZER HEIGHT	78.0 IN
HOWITZER LENGTH	330.0 IN
TOTAL SYST. WEIGTH	8000.0 LB
SYST. MASS	20.72 LB SEC 2/IN
ROT. C/L FROM C.G.	128.02 IN
GRAV. ACCEL.	386.1 IN/SEC 2
CHAMBER AREA	38.5 IN 2
MOMENT OF INERTIA	543534 IN LB SEC 2
TIME INTERVAL	0.001 SEC
RECOIL MOM. ARM	18.25 IN

a	b	c	d	e	f	g	h	i	j
	CHAMBER		FORCES		OVERTURNING	ANGULAR	ANGULAR	ANGULAR	LIFT AT
TIME	PRESSURE	RECOIL	GRAV.MOMENT	GRAV.(RESIST)	TORQUE	ACCEL.	POSITION	VELOCITY	ENDS OF
(SEC)	(PSI)	(LBS)	ARM (IN)	(IN LBS)	(IN LBS)	(RAD/SEC 2)	(RAD)	(RAD/SEC)	TRAILS(IN)
0.000	0	0	128.02	1024140.20	0	0	0	0	0
0.001	2055	79085.67	128.02	1024140.20	419173.25	7.71E-01	3.86E-07	7.71E-04	0.000127
0.002	6441	247878.73	128.02	1024140.20	3499646.61	6.44E+00	4.38E-06	7.21E-03	0.001571
0.003	16222	624295.72	128.02	1024140.20	10369256.72	1.91E+01	2.11E-05	2.63E-02	0.008543
0.004	32696	1258289.54	128.02	1024140.20	21939643.89	4.04E+01	6.76E-05	6.67E-02	0.030849
0.005	49729	1913796.20	128.02	1024140.19	33902640.42	6.24E+01	1.65E-04	1.29E-01	0.085442
0.006	56014	2155671.34	128.02	1024140.18	38316861.84	7.05E+01	3.30E-04	2.00E-01	0.194246
0.007	51025	1963672.12	128.02	1024140.14	34812876.11	6.40E+01	5.61E-04	2.64E-01	0.379460
0.008	42151	1622160.58	128.02	1024140.04	28580290.57	5.26E+01	8.51E-04	3.16E-01	0.660329
0.009	33929	1305740.94	128.02	1024139.83	22805632.33	4.20E+01	1.19E-03	3.58E-01	1.052452
0.010	25241	971387.52	128.02	1024139.47	16703682.71	3.07E+01	1.56E-03	3.89E-01	1.567823
0.011	19072	733976.57	128.02	1024138.95	12370933.54	2.28E+01	1.96E-03	4.12E-01	2.215267
0.012	14982	576574.93	128.02	1024138.23	9498354.23	1.75E+01	2.38E-03	4.29E-01	3.001425
0.013	12137	467086.50	128.02	1024137.29	7500191.30	1.38E+01	2.82E-03	4.43E-01	3.931455
0.014	10077	387808.41	128.02	1024136.13	6053367.30	1.11E+01	3.27E-03	4.54E-01	5.009472
0.015	9448	363601.65	128.02	1024134.73	5611595.39	1.03E+01	3.73E-03	4.64E-01	6.239018
0.016	8819	339394.89	128.02	1024133.09	3311636.68	6.09E+00	4.19E-03	4.70E-01	7.622801
0.017	8190	315188.14	128.02	1024131.19	3002397.26	5.52E+00	4.67E-03	4.76E-01	9.162739
0.018	7561	290981.38	128.02	1024129.05	2693158.09	4.95E+00	5.14E-03	4.81E-01	10.860559
0.019	6932	266774.62	128.02	1024126.64	2383919.17	4.39E+00	5.63E-03	4.85E-01	12.717804
0.020	6303	242567.87	128.02	1024123.98	2074680.52	3.82E+00	6.12E-03	4.89E-01	14.735826
0.021	5674	218361.11	128.02	1024121.05	1765442.13	3.25E+00	6.61E-03	4.92E-01	16.915792
0.022	5045	194154.35	128.01	1024117.85	1456204.01	2.68E+00	7.10E-03	4.95E-01	19.258679
0.023	4416	169947.60	128.01	1024114.39	1146966.16	2.11E+00	7.60E-03	4.97E-01	21.765278
0.024	3787	145740.84	128.01	1024110.65	837728.57	1.54E+00	8.09E-03	4.99E-01	24.436192
0.025	3158	121534.08	128.01	1024106.65	528491.25	9.72E-01	8.59E-03	5.00E-01	27.271834
0.026	2529	97327.33	128.01	1024102.39	219254.20	4.03E-01	9.09E-03	5.00E-01	30.272432
0.027	1900	73120.57	128.01	1024097.86	-89982.59	-1.66E-01	9.59E-03	5.00E-01	27.106839
0.028	1271	48913.81	128.01	1024093.08	-399219.13	-7.34E-01	1.01E-02	4.99E-01	23.776399
0.029	642	24707.06	128.01	1024088.04	-708455.41	-1.30E+00	1.06E-02	4.98E-01	20.281448
0.030	13	500.30	128.01	1024082.76	-1017691.45	-1.[illegible]0	1.11E-02	4.96E-01	16.622511

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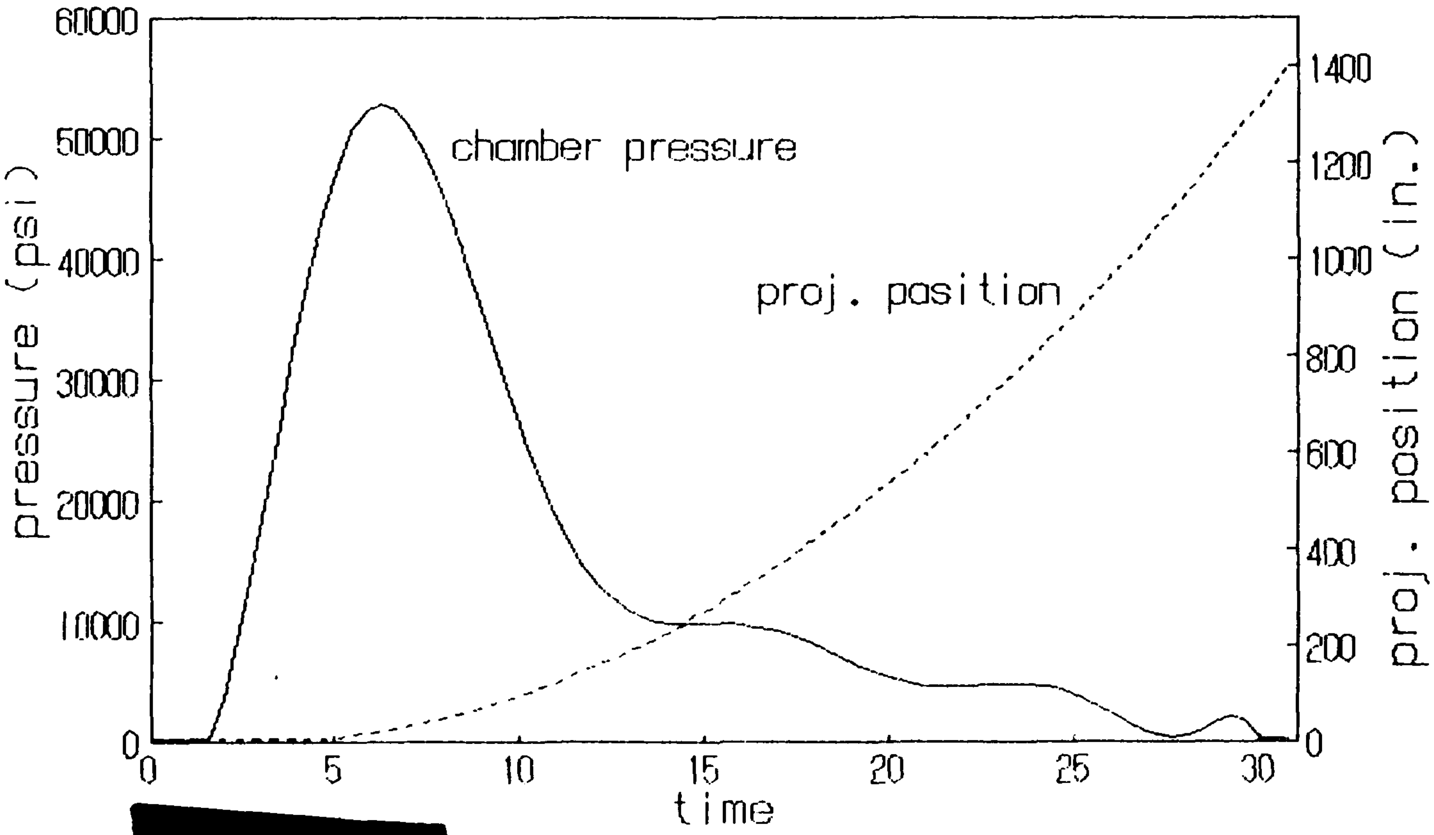
(A4)

LTHD LOAD OUT OF BATTERY

chamber pressure & projectile pos.
vs. time (ms.)



[redacted]

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(A5)

F/150

DESCRIPTION: MATERIAL AND JOINT TEST PLAN

STATUS: The Material and Joint Test Plan is current as of 13 February 1987.

AUTHOR: Ellen Brady, Deborah Fellows, Dave Flippo and Mike Lemoine

FMC Corporation

Northern Ordnance Division
4800 East River Road
Minneapolis Minnesota 55421
(612) 571 9201 Telex 29 0432

FMC

12 February 1987

Commander
Armament Research Development & Engineering Center
U.S. Army Armament, Munitions, & Chemical Command
Dover, New Jersey 07801-5001

Attention: Rob Nitzsche
SMCAR-FSA-F

Subject: Contract DAAA21-86-C-0047
Lightweight Towed Howitzer Demonstrator (LTHD)
Test Plans (CDRL A006)

Enclosure: (1) Test Plans (Revised based on 7 January comments)

Enclosure (1) is submitted with changes in accordance with the requirements of the subject contract. Composite material process specifications, Appendix A of the Test Plan, are submitted to answer questions about the material.

If you have any questions, please contact me at (612) 572-6333.

FMC CORPORATION
Northern Ordnance Division

D P Peterson

D. P. Peterson
Contracts Administration Manager

Enclosures

cc/5169F

E-2853
13 February 1987
(Supercedes Test Plan dated 5 Dec. 86)

155mm LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR
Test Plan IAW CDRL A006 and Section C
Paragraph C2C2 of SOW

Prepared for:
Commander, U.S. Army
Armament, Munitions and Chemical Command
Dover, New Jersey 07801

Prepared Under Contract:
DAAAK21-86-C-0047

Prepared by:
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5089F

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TABLE OF CONTENTS

Boeing Material Specification 8-256F has been supplied by Hexcel, the material supplier, as the material qualification specification.

1.0 FOREWORD

1.0.1 Tests Planned During Phase II

The tests listed in figure 1 (LTHD Test Schedule) will be conducted during Phase II to provide material test samples which are representative of those materials and joints utilized in the FMC LTHD design. The composite material chosen for the design is Hexcel's W3X282-42-F593 Graphite/Epoxy Prepreg. The low/ high temperature/ high humidity tests will be performed by FMC and will qualify the Hexcel material. If the test data does not meet Hexcel published data, then FMC data will be used as design allowables. The room temperature test will be performed by both FMC and the vendor chosen to build parts of the demonstrator. Conducting this test will provide a check of the vendor's process and fabrication procedures by comparison of the vendor's data with FMC's data. Additional test samples will be fabricated and provided to the government for test and evaluation upon request.

1.0.2 Quality Control Planned During Phase II

The quality control plan outlined in section 5.0 will be exercised for the purpose of preventing production of defective test panels and verifying that only quality test panels be used in FMC LTHD Phase II Composite Testing. The material specification to be followed is that recommended by the material supplier, Hexcel: Boeing Material Specification 8-256F, Appendix A. Cured test panel quality will be controlled by using only quality raw materials, insuring that all process specifications are followed, and final checking of test panel integrity. Raw materials will be acceptable for use if they have been certified by the vendor, pass all FMC QC inspection tests, and have been properly stored. Test panels will be acceptable if they have been fabricated per process specification and pass all FMC QC inspection tests. Test specimens will be acceptable if they have not been damaged by machining and meet all the dimensional and conditioning requirements specified in the Phase II composite test plan.

In addition to assuring the quality of the Phase II test panels, implementing this quality control plan will provide a check of the quality control procedures planned for the FMC Lightweight Towed Howitzer Demonstrator.

LTHD TEST SCHEDULE

		JAN	FEB	MAR	APR
1101	Graphite Epoxy Low/High Temp/High Humidity Tensile Test		←——	——→	
1102	Graphite Epoxy Low/High Temp/High Humidity Shear Test		←——	——→	
1103	Graphite Epoxy Low/High Temp/High Humidity Compression Test		←——	——→	
1110	Adhesive Low/High Temp/High Humidity Double Lap Shear and Flexural Shear Strength Tests		←——	→	
1111	Adhesive Low/High Temp/High Humidity T-Peel Test		←——	→	
1120	Trunnion Lug Test		←——	→	
1130	Graphite Epoxy Chemical Resistance Test		←——	→	
1140	Titanium Weld Test		←——	→	
1150	Aluminum Silicon Carbide Weld Test		←——	→	
1160	Graphite Epoxy Room Temp Tensile Test		←——	→	
1201	Cradle Trunnion Structural Joint Test		←——	→	

FIGURE 1

2.0 MATERIAL QUALIFICATION TESTS

2.0.1 LOW/HIGH TEMPERATURE/HIGH HUMIDITY TENSILE TEST

2.0.1.1 PURPOSE. This test is to verify the mechanical properties of W3X282-42-F593 composite material when this material is subjected to extreme environmental conditions.

2.0.1.2 TEST SPECIMENS. Forty specimens will be tested, twenty each for high and low temperature tests. Of each set of twenty specimens, ten will be tested for properties in the warp direction (0 degrees) and ten for properties in the fill direction (90 degrees). Each specimen will consist of 8 plies of prepreg with a [0] layup. Total specimen thickness will be .072 inches. Specimens will measure 1.000 ± .010 inch wide by a minimum of 10.0 inches total length with endtabs bonded on each side of each end. Additional specimen details will conform to section 7 and figure 1 of ASTM D 3039.

2.0.1.3 TEST EQUIPMENT. The equipment required to perform this test consists of:

1) A tensile test machine with grips capable of securing the test specimens described in section 2.0.1.2 above. It shall also be capable of applying a constant crosshead movement of .050 inches per minute. A load indicator, accurate to within ± 1% of the maximum indicated test load, must be included as part of the test machine and the machine must be capable of continuously recording the load, longitudinal strain, and transverse strain.
2) A liquid nitrogen chamber capable of -65 ± 10F minimum.
3) A constant temperature water bath or equivalent capable of 200 ± 10F minimum.
4) An extensometer that is compatible with the test machine described in #1 above.

2.0.1.4 TEST PROCEDURES, LOW TEMPERATURE.

1) Measure the width and thickness of the twenty specimens in several places and record the minimum value of each on the data sheet. (See included sample data sheet)
2) Place the test specimens in the liquid nitrogen chamber and allow them to reach -65 ± 10F throughout. (Minimum time 12 hours)
3) Set the tensile test machine to provide a

constant cross head speed of .050 inch/min

4) Install a specimen in the grips and attach the extensometer on the specimen.
5) Apply the load and plot the load vs longitudinal strain on figure 1 of the data sheet. Plot the longitudinal and transverse strains on figure 2 of the data sheet.
6) Record the maximum load carried by the specimen on the data sheet.
7) Record the extension at or as near as possible to the moment of rupture.
8) Calculate and record to three significant figures:
   1. Tensile strength
   2. Elastic modulus
   3. Poisson's ratio
9) Repeat steps 4 through 8 for the remaining specimens.
10) Calculate and record to three significant figures for each property listed in step 8:
   1. Average value
   2. Standard deviation
   3. Coefficient of variation

2.0.1.5 TEST PROCEDURES, HIGH TEMPERATURE/HIGH HUMIDITY

1) Measure the width and thickness of the twenty remaining specimens in several places and record the dimensions that yield the minimum cross sectional area of each specimen on the data sheet.
2) Condition these specimens per BMS 8-256F, section 5.3.3 with the exception of a 200 ± 10F immersion instead of the 160 ± 10F immersion.
3) Repeat steps 3 thru 10 from section 2.0.1.4

2.0.1.6 ACCEPTANCE CRITERIA. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be acceptable if there is a 99% probability of falling within one standard deviation of the mean. In the event that one data point lies outside of this range, that point will be deleted from the data set and another specimen will be tested and inserted into the data set. If any specimen fails due to non-test related conditions or obvious manufacturing problems, that specimen shall be discarded and another will be tested and inserted into the data set.

2.0.1.7 CRITICAL TEST CONDITIONS.

1) The temperatures of the nitrogen chamber and the water bath will be −65 ± 10F and 200 ± 10F, respectively.

2.0.1.8 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
COMPOSITE TESTING
TEST 1101

LOW/HIGH TEMPERATURE/HIGH HUMIDITY TENSILE TEST
DATA SHEET 1

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ____
VOLUME % REINFORCEMENT ____%
SPECIMEN TEMPERATURE: ____ DEG F
CROSSHEAD SPEED: .050 IN/MIN
SPECIMEN TYPE (WARP OR FILL): ______
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%
CONDITIONING: ______________________________

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPECIMEN NO.	W (IN)	X	T (IN)	=	A (SQ IN)
1	________		________		________
2	________		________		________
3	________		________		________
4	________		________		________
5	________		________		________

CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 3039 FOR FORMULAS):

	AVE		STD DEV		COV
1) TENSILE STRENGTH	________	PSI	______	PSI	____
2) ELASTIC MODULUS	________	PSI	______	PSI	____
3) POISSON'S RATIO	________		______		____
4) EXT @ RUPTURE	________	IN	______	IN	____

LTHD
COMPOSITE TESTING
TEST 1101

LOW/HIGH TEMPERATURE/HIGH HUMIDITY TENSILE TEST
DATA SHEET 1

LOAD AND STRAIN DATA:

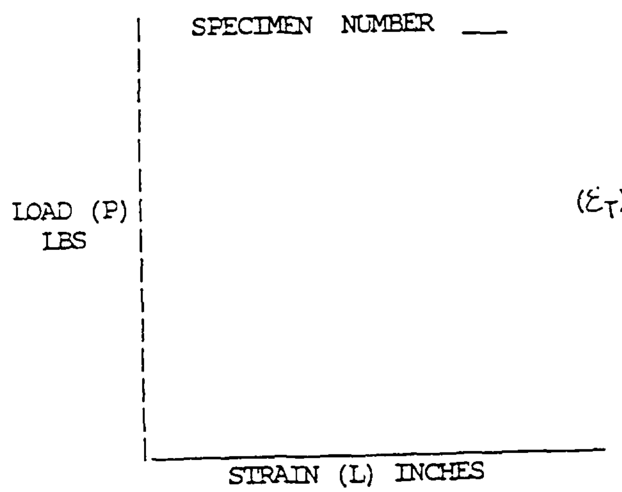


FIGURE 1.

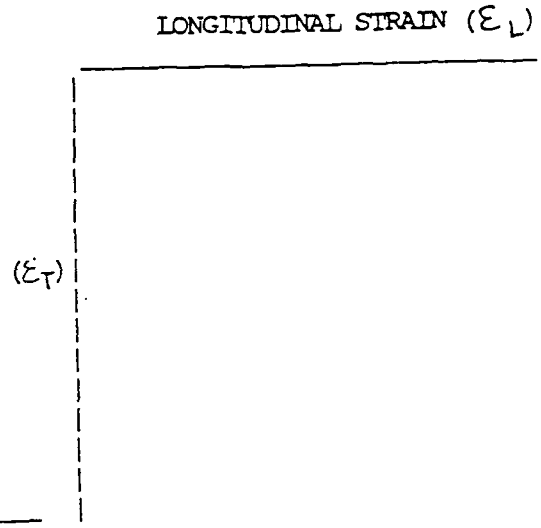


FIGURE 2.

MAXIMUM LOAD CARRIED	_____	LB
EXTENSION AT RUPTURE	_____	IN
TENSILE STRENGTH	_____	PSI
SLOPE OF LINEAR PORTION OF FIG. 1	_____	
MEASURING INSTRUMENT GAGE LENGTH	_____	IN
SLOPE OF LINEAR PORTION OF FIG. 2 (POISSON'S RATIO, u)	_____	

ELASTIC MODULUS (E) $E = (\Delta P/\Delta L)(L/A)$ PSI

E =

E =

COMMENTS:

2.0.2 LOW/HIGH TEMPERATURE/HIGH HUMIDITY SHEAR TEST

2.0.2.1 PURPOSE. This test is to verify the mechanical properties of W3X282-42-F593 composite material when this material is subjected to extreme environmental conditions.

2.0.2.2 TEST SPECIMENS. Twenty specimens will be tested, ten each for high and low temperature tests. Each specimen will consist of 8 plies of prepreg with a [$\pm$ 45] layup symmetric about the midplane. The total specimen thickness will be .072 inches and they will be 1.000 $\pm$ .010 inches wide by a minimum of 10.0 inches total length with endtabs bonded on each side of each end. Additional specimen details will conform to section 7 and figure 1 of ASTM D 3039.

2.0.2.3 TEST EQUIPMENT. The equipment required to perform this test consists of:

1) A tensile test machine with grips capable of securing the specimens described in section 2.0.2.2. It shall also be capable of applying a constant crosshead movement of .050 inches per minute. A load indicator, accurate to within $\pm$ 1% of the maximum indicated test load, must be included as part of the test machine and the machine must be capable of plotting load vs. longitudinal and transverse strain.
2) A liquid nitrogen chamber capable of -65 $\pm$ 10F minimum.
3) A constant temperature water bath or equivalent capable of 200 $\pm$ 10F minimum.
4) A biaxial extensometer that is compatible with the test machine described in #1 above.

2.0.2.4 TEST PROCEDURES, LOW TEMPERATURES.

1) Measure the width, thickness,and length of the ten specimens in several places and record the minimum value of each on the data sheet. (See included sample data sheet)
2) Place the test specimens in the liquid nitrogen chamber and allow them to reach -65 $\pm$ 10F throughout. (Minimum time 12 hours)
3) Set the test machine to provide a constant cross head speed of .050 inch/min
4) Install a specimen in the grips and attach the extensometer so a reading of longitudinal and transverse strain is obtained.

5) Apply the load and continuously record the load longitudinal strain and transverse strain.
6) Record the maximum load carried by the specimen on the data sheet and plot the two strains on the graph on the data sheet.
7) Record each strain at or as near as possible to the moment of rupture.
8) Calculate and record to three significant figures:
   1. Shear strength
   2. Shear modulus
9) Repeat steps 4 through 8 for the remaining specimens.
10) Calculate and record to three significant figures for each property listed in step 9:
   1. Average value
   2. Standard deviation
   3. Coefficient of variation

2.0.2.5 TEST PROCEDURES, HIGH TEMPERATURE/HIGH HUMIDITY

1) Measure the width and thickness of the ten remaining specimens in several places and record the dimensions that yield the minimum cross sectional area of each specimen on the data sheet.
2) Condition these specimens per BMS 8-256F, section 5.3.3 with the exception of a 200 ± 10F immersion instead of the 160 ± 10F immersion.
3) Repeat steps 3 thru 10 from section 2.0.3.4

2.0.2.6 ACCEPTANCE CRITERIA. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be acceptable if there is a 99% probability of falling within one standard deviation of the mean. In the event that one data point lies outside of this range, that point will be deleted from the data set and another specimen will be tested and inserted into the data set. If any specimen fails due to non-test related conditions or obvious manufacturing problems, that specimen shall be discarded and another will be tested and inserted into the data set.

2.0.2.7 CRITICAL TEST CONDITIONS.

1) The temperatures of the nitrogen chamber and the water bath will be -65 ± 10F and 200 ± 10F, respectively.

2.0.2.8 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
COMPOSITE TESTING
TEST 1102

LOW/HIGH TEMPERATURE/HIGH HUMIDITY SHEAR TEST
DATA SHEET 2

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ____
VOLUME % REINFORCEMENT: ____%
SPECIMEN TEMPERATURE: ____ DEG F
CROSSHEAD SPEED: .050 IN/MIN
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%
CONDITIONING: ______________________________

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPECIMEN NO.	W (IN)	X	T (IN)	=	A (SQ IN)
1	____		____		____
2	____		____		____
3	____		____		____
4	____		____		____
5	____		____		____

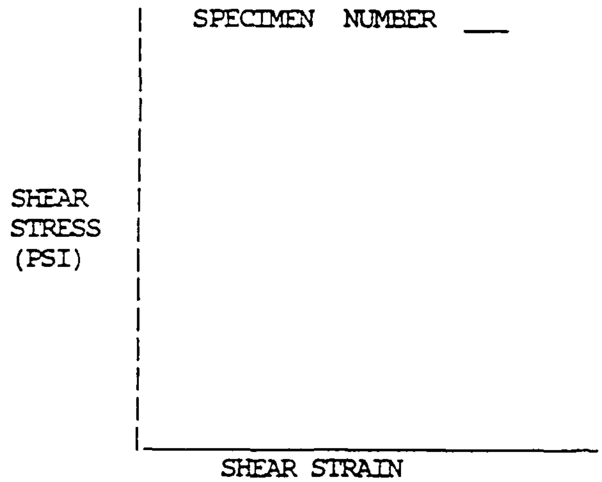
CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 3518 FOR FORMULAS):

	AVE		STD DEV		COV
1) SHEAR STRENGTH	____	PSI	____	PSI	____
2) SHEAR MODULUS	____	PSI	____	PSI	____
3) LONG. STRAIN @ RUP	____	IN	____	IN	____
4) TRAN. STRAIN @ RUP	____	IN	____	IN	____

LTHD
COMPOSITE TESTING
TEST 1102

LOW/HIGH TEMPERATURE/HIGH HUMIDITY SHEAR TEST
DATA SHEET 2

LOAD AND STRAIN DATA:



SHEAR STRAIN IS DEFINED AS LONGITUDINAL STRAIN (ε_L) AT ANY GIVEN LOAD MINUS TRANSVERSE STRAIN (ε_T) AT THAT SAME LOAD.

FIGURE 1.

MAXIMUM LOAD CARRIED (P)	_____	LBS
LONGITUDINAL STRAIN @ RUPTURE ( )	_____	IN
TRANSVERSE STRAIN @ RUPTURE ( )	_____	IN
SHEAR STRENGTH (S=P/2WT)	_____	PSI
SLOPE OF LINEAR PORTION OF FIG. 1 (SHEAR MODULUS, PSI)	_____	PSI

COMMENTS:

2.0.3 LOW/HIGH TEMPERATURE/HIGH HUMIDITY COMPRESSION TEST

2.0.3.1 PURPOSE. This test is to verify the mechanical properties of W3X282-42-F593 composite material when this material is subjected to environmental extremes.

2.0.3.2 TEST SPECIMENS. Eighty specimens will be tested, twenty each for strength and stiffness tests at both high and low temperatures. Of each set of twenty specimens, ten will be tested for properties in the warp direction (0 degrees) and ten for properties in the fill direction (90 degrees). Each strength specimen will consist of 6 plies of prepreg with a [0] layup. Total specimen thickness will be 0.054 inches before endtabs are added. Specimens will measure .500 ± .001 inch wide by a minimum of 2.200 inches long and will have .500 inch by 1.000 inch endtabs on each side of each end. These tabs will be made from 6 plies of 7781 glass fabric and will be bound to the specimen with BM-CA40H adhesive. The stiffness specimens (40 total) will be identical to the strength specimens except they will not have endtabs.

2.0.3.3 TEST EQUIPMENT. The equipment required to perform this test consists of:

1) A compressive test machine with grips capable of securing the test specimens described in section 2.0.3.2 above. It shall be capable of applying a constant crosshead movement of .050 inches per minute and it shall be equipped with a load indicator accurate to within ±1% of the maximum indicated test load. The machine must be capable of continuously recording load, longitudinal strain, and transverse strain.
2) A liquid nitrogen chamber capable of -65 ± 10F minimum.
3) A constant temperature water bath or equivalent capable of 200 ± 10F minimum.
4) Strain gages compatible with the test machine described in #1 above.

2.0.3.4 TEST PROCEDURES, LOW TEMPERATURES.

1) Measure the width, thickness,and length of twenty strength and twenty stiffness specimens in several places and record the dimensions that yield the minimum cross sectional area for each specimen on the data sheet.
2) Place the test specimens in the liquid nitrogen chamber and allow them to reach -65 ± 10F throughout. (Minimum time 1 hour)

3) Set the test machine to provide a constant cross head speed of .050 inch/min
4) Install a strength specimen in the machine.
5) Apply the load and record the load that causes the specimen to fracture.
6) Repeat steps 4 and 5 for the remaining strength specimens.
7) Calculate the compression strength of each specimen and the average compression strength of the specimens and record on the data sheet.
8) Attach strain gages to the stiffness specimens such that the gages are located in the middle of the gage portion of the sample. One gage shall be mounted to measure longitudinal strain and the other gage shall be mounted on the opposite side of the sample in such a way that it will measure transverse strain.
9) Connect the strain gages to the test machine and apply the load.
10) Continuously record the applied load, the longitudinal strain, and the transverse strain.
11) Plot the longitudinal strain vs the load on figure 1 of the data sheet.
12) Plot the longitudinal strain vs the transverse strain on figure 2 of the data sheet.
13) Calculate and record to three significant figures:
    1. Compressive strength
    2. Poisson's ratio
    3. Modulus of elasticity
14) Repeat steps 8 through 13 for the remaining specimens.
15) Calculate and record to three significant figures for each property listed in step 14:
    1. Average value
    2. Standard deviation
    3. Coefficient of variation

2.0.3.5 TEST PROCEDURES, HIGH TEMPERATURE/HIGH HUMIDITY

1) Measure the width and thickness of the remaining specimens in several places and record the dimensions that yield the minimum cross sectional area of each on the data sheet.
2) Condition these specimens per BMS 8-256F, section 5.3.3 with the exception of a 200 $\pm$ 10F immersion instead of the 160 $\pm$ 10F immersion.
3) Repeat steps 3 thru 15 from section 2.0.3.4

2.0.3.6 ACCEPTANCE CRITERIA. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be acceptable if there is a 99% probability of falling within one standard deviation of the mean. In the event that one data point lies outside of this range, that point will be deleted from the data set and another specimen will be tested and inserted into the data set. If any specimen fails due to non-test related conditions or obvious manufacturing problems, that specimen shall be discarded and another will be tested and inserted into the data set.

2.0.3.7 CRITICAL TEST CONDITIONS.

1) The temperatures of the nitrogen chamber and the water bath will be -65 ± 10F and 200 ± 10F, respectively.

2.0.3.8 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
COMPOSITE TESTING
TEST 1103

LOW/HIGH TEMPERATURE/HIGH HUMIDITY COMPRESSION TEST
DATA SHEET 3

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ____
VOLUME % REINFORCEMENT: ____%
SPECIMEN TEMPERATURE: ____ DEG F
CROSSHEAD SPEED: .050 IN/MIN
SPECIMEN TYPE (WARP OR FILL,
STIFFNESS OR STRENGTH): ____________
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%
CONDITIONING: ____________

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPEC NO.	W (IN)	X	T (IN)	=	A (SQ IN)	L (IN)
1	______		______		______	____
2	______		______		______	____
3	______		______		______	____
4	______		______		______	____
5	______		______		______	____

CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 695 FOR FORMULAS):

	AVE		STD DEV		COV
1) COMPRESSIVE STRENGTH	______	PSI	______	PSI	____
2) POISSON'S RATIO	______		______		____
3) MODULUS OF ELASTCITY	______	PSI	______	PSI	____

LTHD
COMPOSITE TESTING
TEST 1103

LOW/HIGH TEMPERATURE/HIGH HUMIDITY COMPRESSION TEST
DATA SHEET 3

LOAD AND STRAIN DATA:

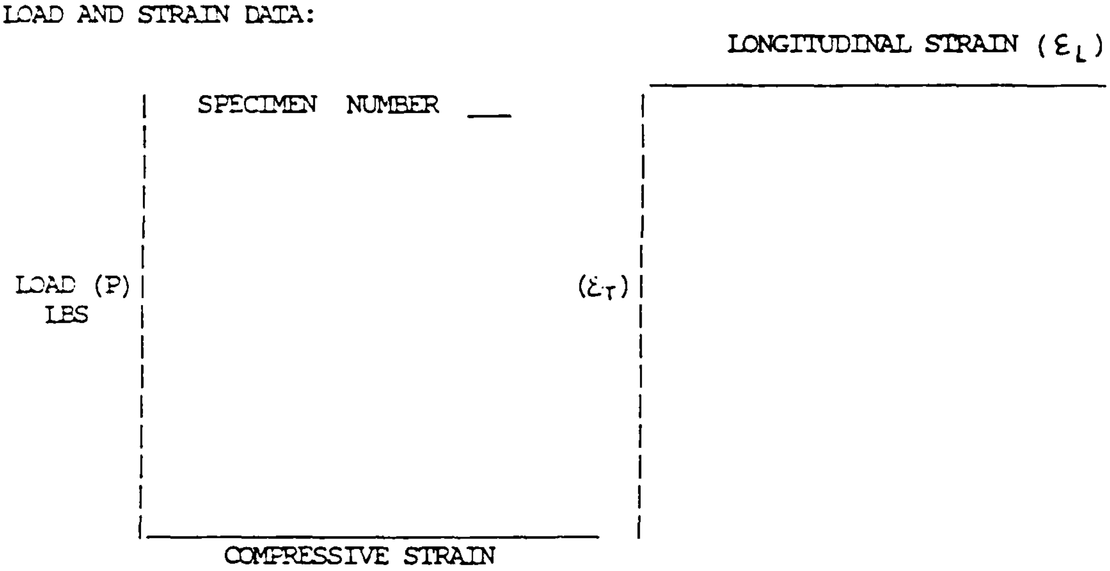


FIGURE 1. FIGURE 2.

MAXIMUM LOAD CARRIED (P) _____ LB

COMPRESSIVE STRENGTH (P/A) _____ PSI

MODULUS OF ELASTICITY (SLOPE OF FIG. 1) _____

POISSON'S RATIO (SLOPE OF FIG. 2) _____

COMMENTS:

2.0.4 LOW/HIGH TEMPERATURE/HIGH HUMIDITY ADHESIVE TEST (DOUBLE LAP SHEAR STRENGTH AND FLEXURAL STRENGTH METHODS)

2.0.4.1 PURPOSE. This test is to verify the shear strength of FM 300M adhesive when applied to two different substrates, and when subjected to extreme environmental conditions. The two substrates to be tested are:

1) W3X282-42-F593 graphite/epoxy composite
2) HRH 10-1/8-6 honeycomb

2.0.4.2 TEST SPECIMENS. Forty specimens will be tested, ten each for high and low temperature tests on each bonding system. The specimens for the first substrate type shall be made by making four panels of the bonding system and then cutting five specimens from each of these panels. The panels will consist of two 8-layer sheets of W3X282-42-F593 fabric with a [0/0/+45/90/90/-45/0/0] layup sandwiched around the substrate. Panels will measure 7.000 ± .125" wide by 9.304 ± .125" long and they will be made per figure 2 of ASTM D 3528 where L=.40 +.01 -.05. The specimens will be 1.000 ± .010" wide and a spacer the thickness of T2 shall be used as shown in figure 1 of ASTM D 3528. T2 shall be .162". Additional panel/specimen details and manufacturing details shall conform to sections 5 and 6 of ASTM D 3528. The honeycomb specimens shall be made by making ten panels 12" wide by 16" long. These panels shall include two 8 ply skins of the W3X282-42-F593 fabric laminate described above sandwiched around a 2.000" thick HRH 10-1/8-6 honeycomb. The specimens will be cut from these panels in 5" widths and 14" lengths. Additional specimen details and manufacturing details shall conform to ASTM C 393.

2.0.4.3 TEST EQUIPMENT. The equipment required to perform this test consists of:

1) A tensile test machine with grips capable of securing the test specimens described in section 2.0.4.2 above. It shall also be capable of applying a constant crosshead movement of .050" per minute. A load indicator, accurate to within ± 1% of the maximum indicated test load, must be included as part of the test machine and the machine must be capable of continuously recording the load, longitudinal strain, and transverse strain.

2) A liquid nitrogen chamber capable of -65 ± 10F minimum.
3) A constant temperature water bath or equivalent capable of 200 ± 10F minimum.
4) A test chamber capable of maintaining thermal stability of the specimen during the test.
5) Four steel bars 2.000" in diameter and 3.000" long. These bars must be circular within .020" and they must be straight to within .015".
6) Flexural test load fittings compatible with the test machine described in #1 above. See figure 1 of ASTM C 393 for typical fittings.

2.0.4.4 TEST PROCEDURES, LOW TEMPERATURE.

1) Using ten specimens of the W3X282-42-F593 substrate (specimens must betaken from each panel) measure the width and length of the overlap within ± .010 inch and calculate the shear area. Record this data on the test data sheet.
2) Place the specimens in the liquid nitrogen chamber and allow them to reach -65 ± 10F throughout. (12 hours)
3) Set the tensile test machine to provide a constant cross head speed of .050 inch/min
4) Install a specimen in the grips so the final 1.25 inch of each end is used for gripping. Remove all slack from the linkage.
5) Apply the load at a rate of .050 inch/minute.
6) Record on the data sheet the maximum load carried by the specimen.
7) Calculate and record to three significant figures the adhesive shear stress at failure.
8) Repeat steps 4 through 7 for the remaining specimens.
9) Calculate and record to three significant figures for the adhesive shear stress:
   1. Average value
   2. Standard deviation
   3. Coefficient of variation
10) Remove the grips used for the pull test and set-up the machine for the flexure test of the honeycomb substrate specimens. (See figure 1 of ASTM C 393).
11) Set the crosshead speed at such a rate that the maximum load will occur between 3 and 6 minutes.
12) Measure the length and width of the adhesive bond on the ten honeycomb specimens and record

on the data sheet.

13) Place the specimens in the liquid nitrogen chamber and allow them to reach a constant -65 ± 10F temperature throughout. (Minimum time 12 hours)
14) Provide a means of instrumenting and continuously monitoring the flexure at the midpoint. Deflection measurements shall be accurate to within ±.001"
15) Place a specimen in the machine using either the midspan load or the two-point load method. (See ASTM C 393).
16) Apply the load and record the load at which the adhesive bond fails. This should be evidenced by the deflection increasing with no additional load or by a disproportionate increase in deflection with an increase in load.
17) Calculate the adhesive shear stress and record on the data sheet.
18) Repeat steps 15 thru 17 for the remaining honeycomb specimens.
19) Calculate the average, standard deviation, and coefficient of variation of the adhesive shear strength and record on the data sheet.

2.0.4.5 TEST PROCEDURES, HIGH TEMPERATURE/HIGH HUMIDITY

1) Reinstall the pulling grips in the machine.
2) Using ten specimens of the W3X282-42-F593 substrate (specimens must be taken from each panel) measure the width and length of the overlap within ±.010 inch and calculate the shear area. Record this data on the test data sheet.
3) Condition these specimens per BMS 8-256F, section 5.3.3 with the exception of a 200 ± 10F immersion instead of the 160 ± 10F immersion.
4) Repeat steps 3 thru 9 from section 2.0.4.4.
5) Repeat steps 10 thru 12 from section 2.0.4.4
6) Condition these specimens per BMS 8-256F, section 5.3.3 with the exception of a 200 ± 10F immersion instead of the 160 ± 10F immersion.
7) Repeat steps 14 thru 19 from section 2.0.4.4

2.0.4.6 ACCEPTANCE CRITERIA. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be acceptable if there is a 99% probability of falling within one standard deviation of the mean. In the event that one data point lies outside of this range, that point will be deleted from the data set and another specimen will be tested and inserted into the data set. If any specimen fails due to non-test related conditions or obvious manufacturing problems, that specimen shall be discarded and another will be tested and inserted into the data set.

2.0.4.7 CRITICAL TEST CONDITIONS.

1) The temperatures of the nitrogen chamber and the water bath will be -65 ± 10F and 200 ± 10F, respectively.

2.0.4.8 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
COMPOSITE TESTING
TEST 1110

LOW/HIGH TEMPERATURE/HIGH HUMIDITY ADHESIVE TEST (DOUBLE LAP SHEAR STRENGTH AND FLEXURAL SHEAR STRENGTH METHODS)
DATA SHEET 4

DATE:
TEST PERSONNEL:
ADHESIVE NAME: FM 300M MFG NAME AND CODE NO. ____________
ADHESIVE DATA:
BATCH/LOT NUMBER ____________
SURFACE PREPARATION: ____________
MIXING DIRECTIONS: ____________
APPLICATION DIRECTIONS: ____________
ASSEMBLY CONDITIONS: ____________
CURING CONDITIONS: ____________
ADDITIONAL INFORMATION: ____________
____

ADHEREND DATA:
MATERIAL: ____________
MATERIAL THICKNESS: ____________
TEST TEMPERATURE: ____ DEG F
CROSSHEAD SPEED: ____ IN/MIN

TEST DATA

SPECIMEN NO. PANEL/ITEM	W(IN) INITIAL/ FINAL	X L(IN) INITIAL/ FINAL	= A (SQ IN) INITIAL/ FINAL		FINAL LOAD (LBS) P
/	____	____	____	____	____
/	____	____	____	____	____
/	____	____	____	____	____
/	____	____	____	____	____
/	____	____	____	____	____

SPECIMEN NO. PANEL/ITEM	ADHESIVE SHEAR STRESS (PSI) P/2A (FINAL)	FAILURE MODE (ADHESION, COHESION, OR BASE MATERIAL)
/	____	____
/	____	____
/	____	____
/	____	____
/	____	____

LOW/HIGH TEMPERATURE/HIGH HUMIDITY ADHESIVE TEST (DOUBLE LAP SHEAR STRENGTH AND FLEXURAL SHEAR STRENGTH METHODS)
DATA SHEET 4

CALCULATE THE AVERAGE, STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE ADHESIVE SHEAR STRENGTH (SEE ASTM D 3039 FOR FORMULAS):

	AVE	STD DEV	COV
ADHESIVE SHEAR STRENGTH	_________ PSI	_______ PSI	_____

2.0.5 LOW/HIGH TEMPERATURE/HIGH HUMIDITY T-PEEL ADHESIVE TEST

2.0.5.1 PURPOSE.This test is to verify the peel resistance of FM 300M adhesive when applied to a steel substrate, and when subjected to extreme environmental conditions.

2.0.5.2 TEST SPECIMENS. Twenty specimens will be tested, ten each for high and low temperature tests. Four panels of five specimens each shall be made by the following procedure. Lay five surface-prepared 1" by 12" pieces of steel (.015"-.020" thick) side by side on a caul plate. Place a 5" by 9" piece of film adhesive on the five specimens, leaving 3" at the end of each specimen free of adhesive. Add a scrim cloth on top of the adhesive. Prepare another five pieces of steel the same way except for the addition of the scrim cloth. Sandwich the two half-panels together and clamp to give a 1" by 9" by .005" thick bond line. Repeat this procedure for the other three panels. After curing the panels, snap the 1" wide specimens apart and clean off the edges. Lightly clamp a specimen in a vice and bend the non-bonded 3" ends apart, perpendicular to the bond line as shown in figure 1 of ASTM D 1876. Repeat this last step for the other specimens.

2.0.5.3 TEST EQUIPMENT. The equipment required to perform this test consists of:

1) A tensile test machine with grips capable of securing the test specimens described in section 2.0.5.2 above and capable of printing a chart of inches of separation vs. applied load
2) A liquid nitrogen chamber capable of -65 ± 10F minimum.
3) A constant temperature water bath or equivalent capable of 200 ± 10F minimum.
4) A test chamber capable of maintaining thermal stability of the specimen during the test.

2.0.5.4 TEST PROCEDURES, LOW TEMPERATURE.

1) Measure the width of ten specimens at several places and record the average width within .001 inch on the data sheet.
2) Place the specimens in the liquid nitrogen chamber and allow them to reach -65 ± 10F throughout. (12 hours minimum)
3) Set the tensile test machine to provide a constant cross head speed of .050 inch/min.
4) Clamp a TEE specimen in the test grips and

apply the load while charting the head movement vs. applied load.

5) Determine the peel resistance over at least a five inch length of the bond line after the initial peak.
6) Calculate the peeling strength in pounds/inch of specimen width.
7) Repeat steps 2 through 6 for the remaining specimens.
8) Calculate the average, standard deviation, and coefficient of variation of the peeling load.

2.0.5.5 TEST PROCEDURES, HIGH TEMPERATURE/HIGH HUMIDITY

1) Measure the width of ten specimens at several places and record the average width within .001 inch on the data sheet.
2) Condition these specimens per BMS 8-256F, section 5.3.3 with the exception of a 200 ± 10F immersion instead of the 160 ± 10F immersion.
3) Repeat steps 4 thru 8 from section 2.0.5.4

2.0.5.6 ACCEPTANCE CRITERIA. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be acceptable if there is a 99% probability of falling within one standard deviation of the mean. In the event that one data point lies outside of this range, that point will be deleted from the data set and another specimen will be tested and inserted into the data set. If any specimen fails due to non-test related conditions or obvious manufacturing problems, that specimen shall be discarded and another will be tested and inserted into the data set.

2.0.5.7 CRITICAL TEST CONDITIONS.

1) The temperatures of the nitrogen chamber and the water bath will be -65 ± 10F and 200 ± 10F, respectively.

2.0.5.8 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
COMPOSITE TESTING
TEST 1111

LOW/HIGH TEMPERATURE/HIGH HUMIDITY T-PEEL ADHESIVE TEST
DATA SHEET 5

DATE:
TEST PERSONNEL:
ADHESIVE NAME: FM 300M MFG NAME AND CODE NO. ____________________
ADHESIVE DATA:
BATCH/LOT NUMBER ____________________
SURFACE PREPARATION: ____________________
MIXING DIRECTIONS: ____________________
APPLICATION DIRECTIONS: ____________________
ASSEMBLY CONDITIONS: ____________________
CURING CONDITIONS: ____________________
ADDITIONAL INFORMATION: ____________________
____

ADHEREND DATA:
MATERIAL: ____________________
MATERIAL THICKNESS: ____________________
TEST TEMPERATURE: ____ DEG F
CROSSHEAD SPEED: ____ IN/MIN

TEST DATA

SPECIMEN NO. PANEL/ITEM	SPECIMEN WIDTH W (IN)	ADHESIVE THICKNESS	LOAD REQ'D TO PEEL 5 IN. P (LBS)	PEEL STRENGTH P/W	FAILURE MODE (ADHESION, COHESION, OR BASE MAT'L)
/					
/					
/					
/					
/					
/					
/					
/					
/					
/					

CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE ADHESIVE PEEL STRENGTH (SEE ASTM D 3039 FOR FORMULAS):

	AVE		STD DEV		COV
ADHESIVE PEEL STRENGTH	________	LB/IN	________	LB/IN	_____

2.0.6 TRUNNION LUG TESTS

2.0.6.1 PURPOSE. These tests are to verify the sizing of the cradle trunnion lug when exposed to simulated firing loads (compression test) and simulated towing loads (tensile test). The trunnion lug will be tested because it is the most critical of the composite joints.

2.0.6.2 TEST SPECIMEN. Two tensile specimens and two compression specimens will be tested. The specimen geometries will be per Figure 2.1. The specimen layups will match the layup of the current trunnion design.

2.0.6.3 TEST EQUIPMENT. The equipment required to perform these tests consists of:

1) A tensile test machine with fixtures and grips capable of securing the test specimens described in section 2.0.6.2 above. It shall also be capable of applying a constant crosshead movement of .050"/min. A load indicator, accurate to within ± 1% of the maximum indicated test load, must be included as part of the test machine and the machine must be capable of continuously recording the load.
2) A compressive test machine with fixtures and grips capable of securing the test specimens described in section 2.0.6.2 above. It shall be capable of applying a constant crosshead movement of .050"/min and it shall be equipped with a load indicator accurate to within ± 1% of the maximum indicated test load. The machine must be capable of continuously recording load.

2.0.6.4 TENSILE TEST PROCEDURE.

1) Calculate the tensile area of the bearing specimens and record this on the data sheet.
2) Install a specimen in the machine.
3) Set the crosshead speed of the test machine to .050"/min and apply the load.
4) Apply the load and record the load that causes the specimen to fail.
5) Remove the load and remove the specimen.
6) Repeat steps 2 through 5 for the second specimen.
7) Calculate the tensile strength of each specimen and the average tensile strength. Record on the data sheet.

2.0.6.5 COMPRESSION TEST PROCEDURE

1) Calculate the bearing area of the compression specimens and record this on the data sheet.
2) Install a specimen in the machine.
3) Set the test machine to provide a constant crosshead speed of .050"/min.
4) Apply the load and record the load that causes the specimen to fail.
5) Remove the load and remove the specimen.
6) Repeat steps 2 through 5 for the second specimen.
7) Calculate the compression strength of each specimen and the average compression strength. Record on the data sheet.

2.0.6.6 ACCEPTANCE CRITERIA. These tests will be acceptable if there is reasonable agreement between the two data points of each test.

2.0.6.7 CRITICAL TEST CONDITIONS.

1) The size of the specimens will be per Figure 2.1.

2.0.6.8 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
COMPOSITE TESTING
TEST 1120

TRUNNION LUG TEST DATA SHEET 6
TENSILE TEST

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ________
VOLUME % REINFORCEMENT: ________%
CROSSHEAD SPEED: ________ IN/MIN
TEST TEMPERATURE: ________F
TEST HUMIDITY: ________%

SPECIMEN NO.	BEARING AREA (SQ IN)	TENSILE STRENGTH (PSI)
___	________	________
___	________	________

AVERAGE TENSILE STRENGTH: ________ PSI

COMMENTS:

LTHD
COMPOSITE TESTING
TEST 1120

TRUNNION LUG TEST DATA SHEET 6
COMPRESSION TEST

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

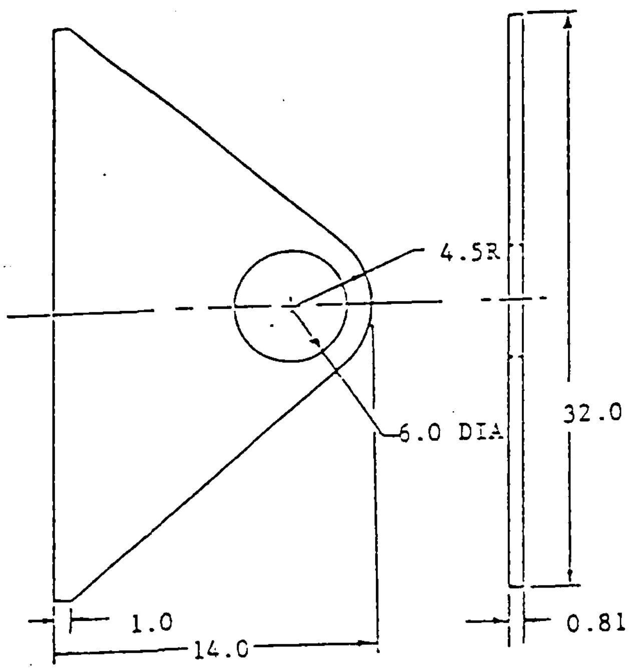
VOID CONTENT OF MATERIAL: ________
VOLUME % REINFORCEMENT: ________ %
CROSSHEAD SPEED: ________ IN/MIN
TEST TEMPERATURE: ________ F
TEST HUMIDITY: ________ %

SPECIMEN NO.	BEARING AREA (SQ IN)	COMPRESSION STRENGTH (PSI)
___	________	________
___	________	________

AVERAGE COMPRESSION STRENGTH: ________ PSI

COMMENTS:

COMPRESSION SPECIMEN



TENSILE SPECIMEN

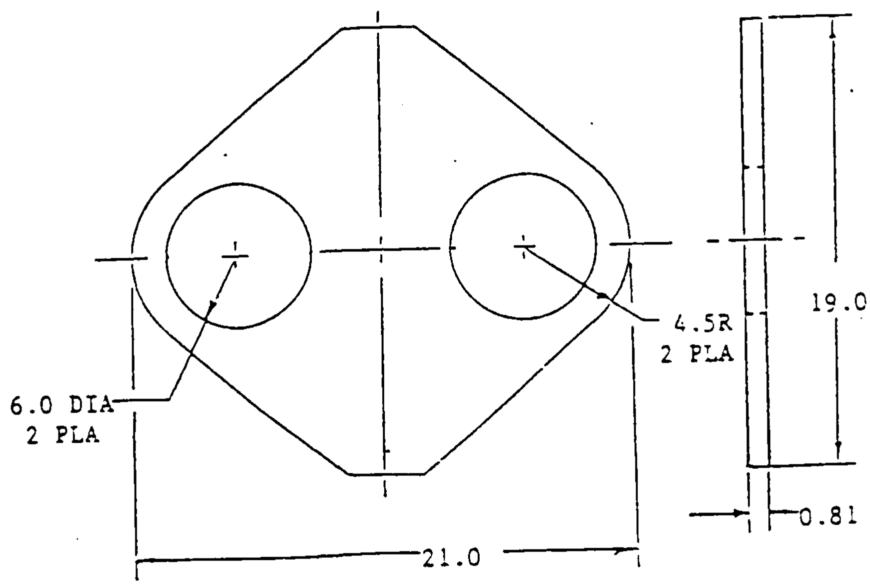


FIGURE 2.1

2.0.7 CHEMICAL RESISTANCE TEST

2.0.7.1 PURPOSE. This test is to assess the affects of hydraulic fluid and ethylene glycol solutions on the material properties of W3X282-42-F593 composite material.

2.0.7.2 TEST SPECIMENS. Twenty specimens will be tested, ten each for tensile and shear tests at high temperature. The ten tensile specimens will consist of 8 plies of prepreg with a [0/0/+45/90/90/-45/0/0] layup. Total specimen thickness will be .072 inches. Specimens will measure 1.000 ± .010 inches wide by a minimum of 10.0 inches total length with endtabs bonded on each side of each end. Additional specimen details will conform to section 7 and figure 1 of ASTM D 3039. The ten shear specimens will be identical to the tensile specimens except their layup will be [± 45], symmetric about the mid-plane.

2.0.7.3 TEST EQUIPMENT. The equipment required to perform this test consists of:

1) A tensile test machine with grips capable of securing the specimens described in section 2.0.7.2. This machine shall be capable of providing a direct record of applied load, longitudinal strain, and transverse strain. The machine shall also be capable of providing a constant crosshead speed of .050 inches/minute.
2) A 200 ± 10F bath of a 50 % solution of ethylene glycol
3) A 200 ± 10F bath of MIL-F-17111 hydraulic fluid
4) A biaxial extensometer that is compatible with the test machine described in #1 above.

2.0.7.4 TEST PROCEDURES.

1) Place the tensile specimens in the ethylene glycol solution and allow them to soak for 48 hours.
2) Remove the specimens from the ethylene glycol, wipe off the excess solution, and place the specimens in the hydraulic fluid bath for 48 hours.
3) Set the test machine to provide a constant crosshead movement of .050 inches/minute.
4) Remove the specimens from the hydraulic fluid bath and wipe off excess fluid.
5) Measure the width and thickness of the specimens in several places and record the dimensions that yield the minimum tensile area.

6) Install a specimen in the grips and connect the extensometer to provide a constant readout of load, longitudinal strain, and transverse strain.
7) Apply the load and plot the data onto figures 1 and 2 of the data sheet.
8) Record the maximum load carried and the extension at or as near as possible to the moment of rupture.
9) Calculate and record to three significant figures:
    1. Tensile strength
    2. Elastic modulus
    3. Poisson's ratio
10) Repeat steps 6 thru 9 for the remaining specimens
11) Calculate and record to three significant figures for each property listed in step 9:
    1) Average value
    2) Standard deviation
    3) Coefficient of variation
12) Repeat steps 1 thru 6 for the shear specimens.
13) Apply the load and plot the data onto figure 3 of the data sheet.
14) Repeat steps 8 thru 9.
15) Repeat steps 12 thru 14 for the remaining specimens.
16) Repeat step 11 for the shear specimens.

2.0.7.5 ACCEPTANCE CRITERIA. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be acceptable if there is a 99% probability of falling within one standard deviation of the mean. In the event that one data point lies outside of this range, that point will be deleted from the data set and another specimen will be tested and inserted into the data set. If any specimen fails due to non-test related conditions or obvious manufacturing problems, that specimen shall be discarded and another will be tested and inserted into the data set.

2.0.7.6 CRITICAL TEST CONDITIONS.

1) The temperatures of the fluid baths in section 2.0.7.3, items 2 and 3, will be 200 ± 10F.

2.0.7.7 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
COMPOSITE TESTING
TEST 1130

CHEMICAL RESISTANCE TEST DATA SHEET 7

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ____
VOLUME % REINFORCEMENT ____%
SPECIMEN TEMPERATURE: ____ DEG F
CROSSHEAD SPEED: .050 IN/MIN
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%
CONDITIONING: ____________________

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPECIMEN NO.	W (IN)	X	T (IN)	=	A (SQ IN)
1	______		______		______
2	______		______		______
3	______		______		______
4	______		______		______
5	______		______		______

CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 3039 FOR FORMULAS):

	AVE		STD DEV		COV
1) TENSILE STRENGTH	______	PSI	______	PSI	____
2) ELASTIC MODULUS	______	PSI	______	PSI	____
3) POISSON'S RATIO	______		______		____

LTHD
COMPOSITE TESTING
TEST 1130

CHEMICAL RESISTANCE TEST DATA SHEET 7

LOAD AND STRAIN DATA:

SPECIMEN NUMBER ___

LOAD (P) LBS

STRAIN (L) INCHES/INCH

FIGURE 1.

LONGITUDINAL STRAIN (ε_L)

(ε_T)

FIGURE 2.

MAXIMUM LOAD CARRIED ____

TENSILE STRENGTH ____

SLOPE OF LINEAR PORTION OF FIG. 1 ____

MEASURING INSTRUMENT GAGE LENGTH ____

SLOPE OF LINEAR PORTION OF FIG. 2
(POISSON'S RATIO, u) ____

ELASTIC MODULUS (E) $E = (\Delta P/\Delta L)(L/A)$ PSI

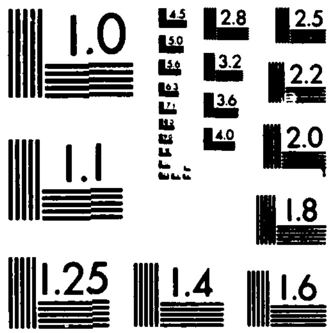
E =

E =

COMMENTS:

AD-A183 996 LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN NORTHERN ORDNANCE DIV R RATHE ET AL APR 87 3/4

UNCLASSIFIED FMC-E-3041-VOL-F DAAA21-86-C-0047 F/G 19/6 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LTHD
COMPOSITE TESTING
TEST 1130

CHEMICAL RESISTANCE TEST DATA SHEET 7

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ____
VOLUME % REINFORCEMENT: ____%
SPECIMEN TEMPERATURE: ____ DEG F
CROSSHEAD SPEED: .050 IN/MIN
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%
CONDITIONING: ____________________

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPECIMEN NO.	W (IN)	X	T (IN)	=	A (SQ IN)
1	____		____		____
2	____		____		____
3	____		____		____
4	____		____		____
5	____		____		____

CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 3518 FOR FORMULAS):

	AVE	STD DEV	COV
1) SHEAR STRENGTH	____ PSI	____ PSI	____
2) SHEAR MODULUS	____ PSI	____ PSI	____

LTHD
COMPOSITE TESTING
TEST 1130

CHEMICAL RESISTANCE TEST DATA SHEET 7

LOAD AND STRAIN DATA:

SPECIMEN NUMBER ___

SHEAR STRESS (PSI)

SHEAR STRAIN

SHEAR STRAIN IS DEFINED AS LONGITUDINAL STRAIN (ε_L) AT ANY GIVEN LOAD MINUS TRANSVERSE STRAIN (ε_T) AT THAT SAME LOAD.

FIGURE 3.

MAXIMUM LOAD CARRIED (P) _____ LBS

SHEAR STRENGTH (S=P/2WT) _____ PSI

SLOPE OF LINEAR PORTION OF FIG. 1 (SHEAR MODULUS, PSI) _____ PSI

COMMENTS:

2.1 WELD JOINT TESTS

2.1.1 TITANIUM WELD TEST

2.1.1.1 PURPOSE. This test is to verify the mechanical properties of Titanium weld joints. Tensile strength tests, radiographic inspections, and macro-etching inspections will be conducted.

2.1.1.2 TEST SPECIMENS. Ten plate specimens will be tested for each test. These specimens will be machined from a welded panel made by butt-welding two .125" plates per MIL-STD-1595. This base panel shall be 18" wide (9" per plate) by 36" long.

2.1.1.2.1 TENSILE SPECIMENS. The tensile specimens shall conform to figure 6. of ASTM E 8-84 with dimensions for a standard 1.5" wide plate specimen. Specimens shall be machined such that the weld joint is centered in the "G" dimension.

2.1.1.2.2 RADIOGRAPHIC SPECIMENS. The radiographic specimens shall be prepared from the cutouts of the tensile panels.

2.1.1.2.3 MACROINSPECTION SPECIMENS. The specimens used for macroinspection shall be prepared from the cutouts of the tensile panels. These specimens will be cut and ground across the weld and then etched with etchant composition 187 per ASTM E 407-70.

2.1.1.3 TEST EQUIPMENT. The equipment required to perform these tests consists of:

1) A tensile test machine with grips capable of securing the specimens described in section 2.1.1.2.1 above. This machine must be capable of a constant crosshead motion of .050 inch per minute and it must be capable of continuously recording applied load, axial strain, and transverse strain.
2) A biaxial extensometer that is compatible with the tensile test machine.
3) Etchants as required for macroscopic examination of the weld joints and as described in ASTM E 407-70.
4) An X-RAY facility capable of radiographic inspection of Titanium weld joints.

2.1.1.4 TEST PROCEDURES, TENSILE TEST.

1) Measure the width and thickness of the tensile specimens in several places and record the dimensions that yield the minimum cross sectional area of each specimen on the data sheet.
2) Secure a specimen in the grips and set the crosshead speed to .050 inch/minute.
3) Attach the extensometer to the specimen and set the tensile test machine to continuously record load, axial strain, and transverse strain.
4) Apply the load and record the information on data sheet 8.
5) Calculate the tensile strength and record it on the data sheet.
6) Repeat steps 2 thru 5 for the remaining specimens.
7) Calculate and record to three significant figures:
    1. Average tensile strength of weld joint
    2. Standard deviation of weld joint strength
    3. Coefficient of variation of weld joint strength

2.1.1.5 TEST PROCEDURES, MACROSCOPIC INSPECTION.

1) Cut the specimen perpendicular to and .500" each side of the weld and grind the cut surface smooth.
2) Etch the specimen with etchant, composition 187, from ASTM E 407.
3) Examine the weld grain structure microscopically
4) Repeat steps 1 thru 3 for ten total specimens.

2.1.1.6 TEST PROCEDURES, RADIOGRAPHIC INSPECTION.

1) Radiographic inspection shall be performed in accordance with ASTM E 94 using quality level 2-2T.
2) Quality shall be per ASTM E 142.

2.1.1.7 ACCEPTANCE CRITERIA.

1) Finished welds may have a light wheat or straw colored heat tint. Darker heat tints are not acceptable.
2) No crack type defects shall be allowed.
3) Lack of penetration and lack of fusion are not acceptable.
4) Tungsten inclusions shall be counted as porosity.
5) Porosity in excess of that listed in Table XIII shall not be allowed.

2.1.1.9 CRITICAL TEST CONDITIONS.

1) Direction of the central beam of radiation shall be perpendicular to the surface of the film.
2) Safety measures shall be followed in accordance with the National Committee on Radiation Protection and Measurement.

2.1.1.10 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

Pg. 45

LTHD
TITANIUM TESTING
TEST 1140

TITANIUM WELD JOINT TEST
DATA SHEET 8

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION: ______________________________

____

____

FRACTURE LOCATION: AT WELD JOINT ____ NOT AT WELD JOINT ____
WELD DEFECTS EVIDENT ______________________________

____

CROSSHEAD SPEED: .050 IN/MIN
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPECIMEN NO.	W (IN)	X	T (IN)	=	A (SQ IN)
1	______		______		______
2	______		______		______
3	______		______		______
4	______		______		______
5	______		______		______

CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 3039 FOR FORMULAS):

	AVE	STD DEV	COV
1) TENSILE STRENGTH	______ PSI	______ PSI	____
2) ELASTIC MODULUS	______ PSI	______ PSI	____
3) POISSON'S RATIO	______	______	____
4) EXT @ RUPTURE	______ IN	______ IN	____

LTHD
TITANIUM TESTING
TEST 1140

TITANIUM WELD JOINT TEST
DATA SHEET 8

LOAD AND STRAIN DATA:

SPECIMEN NUMBER ___

LOAD (P) LBS

STRAIN (L) INCHES/INCH

FIGURE 1.

LONGITUDINAL STRAIN (ε_L)

(ε_T)

FIGURE 2.

MAXIMUM LOAD CARRIED	_____	LB
EXTENSION AT RUPTURE	_____	IN
TENSILE STRENGTH	_____	PSI
SLOPE OF LINEAR PORTION OF FIG. 1	_____	
MEASURING INSTRUMENT GAGE LENGTH	_____	IN
SLOPE OF LINEAR PORTION OF FIG. 2 (POISSON'S RATIO, u)	_____	

ELASTIC MODULUS (E) $E = (\Delta P/\Delta L)(L/A)$ PSI

E =

E =

COMMENTS:

2.1.2 ALUMINUM SILICON CARBIDE WELD TEST

2.1.2.1 PURPOSE. This test is to verify the mechanical properties of Aluminum Silicon carbide weld joints. Tensile strength tests, radiographic inspections, and macroetching inspections will be conducted.

2.1.2.2 TEST SPECIMENS. Ten plate specimens will be tested for each test. These specimens will be machined from a welded panel made by butt-welding two .125" plates per MIL-STD-1595. This base panel shall be 18" wide (9" per plate) by 36" long.

2.1.2.2.1 TENSILE SPECIMENS. The tensile specimens shall conform to figure 6. of ASTM E 8-84 with dimensions for a standard 1.5" wide plate specimen. Specimens shall be machined such that the weld joint is centered in the "G" dimension.

2.1.2.2.2 RADIOGRAPHIC SPECIMENS. The radiographic specimens shall be prepared from the cutouts of the tensile panels.

2.1.2.2.3 MACROINSPECTION SPECIMENS. The specimens used for macroinspection shall be prepared from the cutouts of the tensile panels. These specimens will be cut and ground across the weld and then etched with etchant composition 2 per ASTM E 407-70.

2.1.2.3 TEST EQUIPMENT. The equipment required to perform these tests consists of:

1) A tensile test machine with grips capable of securing the specimens described in section 2.1.2.2.1 above. This machine must be capable of a constant crosshead motion of .050 inch per minute and it must be capable of continuously recording applied load, axial strain, and transverse strain.
2) A biaxial extensometer that is compatible with the tensile test machine.
3) Etchants as required for macroscopic examination of the weld joints and as described in ASTM E 407-70.
4) An X-RAY facility capable of radiographic inspection of aluminum silicon carbide weld joints.

2.1.2.4 TEST PROCEDURES, TENSILE TEST.

1) Measure the width and thickness of the tensile specimens in several places and record the dimensions that yield the minimum cross sectional area of each specimen on the data sheet.
2) Secure a specimen in the grips and set the crosshead speed to .050 inch/minute.
3) Attach the extensometer to the specimen and set the tensile test machine to continuously record load, axial strain, and transverse strain.
4) Apply the load and record the information on data sheet 9.
5) Calculate the tensile strength and record it on the data sheet.
6) Repeat steps 2 thru 5 for the remaining specimens.
7) Calculate and record to three significant figures:
   1. Average tensile strength of weld joint
   2. Standard deviation of weld joint strength
   3. Coefficient of variation of weld joint strength

2.1.2.5 TEST PROCEDURES, MACROSCOPIC INSPECTION.

1) Cut the specimen perpendicular to and .500" each side of the weld and grind the cut surface smooth.
2) Etch the specimen with etchant composition 2 from ASTM E 407.
3) Examine the weld grain structure microscopically
4) Repeat steps 1 thru 3 for five total specimens.

2.1.2.6 TEST PROCEDURES, RADIOGRAPHIC INSPECTION.

1) Radiographic inspection shall be performed in accordance with ASTM E 94 using quality level 2-2T.
2) Quality shall be per ASTM E 142.

2.1.1.7 ACCEPTANCE CRITERIA.

1) Finished welds may have a light wheat or straw colored heat tint. Darker heat tints are not acceptable.
2) No crack type defects shall be allowed.
3) Lack of penetration and lack of fusion are not acceptable.
4) Tungsten inclusions shall be counted as porosity.
5) Porosity in excess of that listed in Table XIII shall not be allowed.

2.1.1.9 CRITICAL TEST CONDITIONS.

1) Direction of the central beam of radiation shall be perpendicular to the surface of the film.
2) Safety measures shall be followed in accordance with the National Committee on Radiation Protection and Measurement.

2.1.2.9 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

LTHD
AlSiC TESTING
TEST 1150

ALUMINUM SILICON CARBIDE WELD JOINT TEST
DATA SHEET 9

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:____

FRACTURE LOCATION: AT WELD JOINT ____ NOT AT WELD JOINT ____
WELD DEFECTS EVIDENT ____

CROSSHEAD SPEED: .050 IN/MIN
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPECIMEN NO.	W (IN)	X	T (IN)	=	A (SQ IN)
1	______		______		______
2	______		______		______
3	______		______		______
4	______		______		______
5	______		______		______

CALCULATE THE AVERAGE, STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 3039 FOR FORMULAS):

	AVE	STD DEV	COV
1) TENSILE STRENGTH	______ PSI	______ PSI	____
2) ELASTIC MODULUS	______ PSI	______ PSI	____
3) POISSON'S RATIO	______	______	____
4) EXT @ RUPTURE	______ IN	______ IN	____

LTHD
AlSiC TESTING
TEST 1150

ALUMINUM SILICON CARBIDE WELD JOINT TEST
DATA SHEET 9

LOAD AND STRAIN DATA:

LONGITUDINAL STRAIN ($\mathcal{E}_L$)

SPECIMEN NUMBER ___

LOAD (P) LBS

($\mathcal{E}_T$)

STRAIN (L) INCHES/INCH

FIGURE 1.

FIGURE 2.

MAXIMUM LOAD CARRIED	_____	LB
EXTENSION AT RUPTURE	_____	IN
TENSILE STRENGTH	_____	PSI
SLOPE OF LINEAR PORTION OF FIG. 1	_____	
MEASURING INSTRUMENT GAGE LENGTH	_____	IN
SLOPE OF LINEAR PORTION OF FIG. 2 (POISSON'S RATIO, u)	_____	

ELASTIC MODULUS (E) $E = (\Delta P/\Delta L)(L/A)$ PSI

E =

E =

COMMENTS:

TABLE XIII. Maximum allowable porosity.

Porosity	Porosity size, area, or amount	
	Base metal thickness 1/	
	≤ 0.063 2/	> 0.063 3/
Any pore	0.6 t	0.4 t or 0.18 inch 4/
Pores of > 0.3 t	8 pores	NA
Pores of > 0.2 t or >0.12 inch 4/	NA	12 pores
Total porosity area	0.10 t inch^2	0.10 inch^2
Cluster porosity area in any 1/2 inch of weld length	0.04 t inch^2	0.025 t inch^2
Aligned porosity area 5/	0.02 t inch^2	0.015 t inch^2

1/ Where the members of the test weld differ in thickness, t is the thickness of the thicker member.

2/ These values apply to a 4 inch weld length. For groove welds in tube, the values shall be adjusted in proportion to the tube circumference.

3/ These values apply to a 6 inch weld length. For groove welds in tube, the values shall be adjusted in proportion to the tube circumference.

4/ The applicable maximum is the lesser of the two values.

5/ Aligned porosity is defined as a group of more than 3 pores within 1/2 inch of weld length, and which may be intersected by a straight line.

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3.0 VENDOR PROCESS QUALIFICATION TEST

3.0.1 ROOM TEMPERATURE TENSILE TEST

3.0.1.1 PURPOSE. This test is to verify the vendor's processing of W3X282-42-F593 composite material.

3.0.1.2 TEST SPECIMENS. Ten specimens will be tested. Each specimen will consist of 8 plies of prepreg with a [0] layup. Total specimen thickness will be .072 inches. Specimens will measure 1.000 ± .010 inch wide by a minimum of 10.0 inches total length with endtabs bonded on each side of each end. Additional specimen details will conform to section 7 and figure 1 of ASTM D 3039.

3.0.1.3 TEST EQUIPMENT. The equipment required to perform this test consists of:

1) A tensile test machine with grips capable of securing the test specimens described in section 3.0.1.2 above. It shall also be capable of applying a constant crosshead movement of .050 inches per minute. A load indicator, accurate to within ± 1% of the maximum indicated test load, must be included as part of the test machine and the machine must be capable of continuously recording the load, longitudinal strain, and transverse strain.
2) An extensometer that is compatible with the test machine described in #1 above.

3.0.1.4 TEST PROCEDURE.

1) Measure the width and thickness of the ten specimens in several places and record the minimum value of each on the data sheet. (See included sample data sheet)
2) Set the tensile test machine to provide a constant cross head speed of .050 inch/min
3) Install a specimen in the grips and attach the extensometer on the specimen.
4) Apply the load and plot the load vs longitudinal strain on figure 1 of the data sheet. Plot the longitudinal and transverse strains on figure 2 of the data sheet.
5) Record the maximum load carried by the specimen on the data sheet.
6) Record the extension at or as near as possible to the moment of rupture.
7) Calculate and record to three significant figures:

1. Tensile strength
2. Elastic modulus
3. Poisson's ratio

8) Repeat steps 3 thru 7 for the remaining specimens
9) Calculate and record to three significant figures for each property listed in step 7:
   1. Average value
   2. Standard deviation
   3. Coefficient of variation

3.0.1.5 ACCEPTANCE CRITERIA. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be acceptable if there is a 99% probability of falling within one standard deviation of the mean. In the event that one data point lies outside of this range, that point will be deleted from the data set and another specimen will be tested and inserted into the data set. If any specimen fails due to non-test related conditions or obvious manufacturing problems, that specimen shall be discarded and another will be tested and inserted into the data set.

3.0.1.6 CRITICAL TEST CONDITIONS.

1) The test specimen geometry shall be consistent with that described in section 3.0.1.2.

3.0.1.7 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after test completion.

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LTHD
COMPOSITE TESTING
TEST 1160

ROOM TEMPERATURE TENSILE TEST
DATA SHEET 10

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ____
VOLUME % REINFORCEMENT ____%
CROSSHEAD SPEED: .050 IN/MIN
TEST TEMPERATURE: ____ DEG F
TEST HUMIDITY: ____%

SPECIMEN GAGE DIMENSIONS (MINIMUM VALUES)

SPECIMEN NO.	W (IN)	X	T (IN)	=	A (SQ IN)
1	____		____		____
2	____		____		____
3	____		____		____
4	____		____		____
5	____		____		____

CALCULATE THE AVERAGE , STANDARD DEVIATION, AND COEFFICIENT OF VARIATION OF THE FOLLOWING (SEE ASTM D 3039 FOR FORMULAS):

	AVE		STD DEV		COV
1) TENSILE STRENGTH	____	PSI	____	PSI	____
2) ELASTIC MODULUS	____	PSI	____	PSI	____
3) POISSON'S RATIO	____		____		____
4) EXT @ RUPTURE	____	IN	____	IN	____

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LTHD
COMPOSITE TESTING
TEST 1160

ROOM TEMPERATURE TENSILE TEST
DATA SHEET 10

LOAD AND STRAIN DATA:

LONGITUDINAL STRAIN (ε_L)

SPECIMEN NUMBER ___

LOAD (P) LBS

(ε_T)

STRAIN (L) INCHES

FIGURE 1. FIGURE 2.

MAXIMUM LOAD CARRIED	_____	LB
EXTENSION AT RUPTURE	_____	IN
TENSILE STRENGTH	_____	PSI
SLOPE OF LINEAR PORTION OF FIG. 1	_____	
MEASURING INSTRUMENT GAGE LENGTH	_____	IN
SLOPE OF LINEAR PORTION OF FIG. 2 (POISSON'S RATIO, u)	_____	

ELASTIC MODULUS (E) $E = (\Delta P/\Delta L)(L/A)$ PSI

E =

E =

COMMENTS:

4.0 CRADLE TRUNNION STRUCTURAL JOINT TEST

4.0.1 PURPOSE. The purpose of the trunnion joint structural load test is to verify the integrity of the cradle trunnion joint under simulated firing loads.

4.0.2 OBJECTIVE. Using a composite mockup of the cradle trunnion joint section, impart simulated firing loads of up to one and one-half the expected calculated maximum impulse load. This shall be accomplished through the use of a hydraulic ram actuated for a duration of up to 300 ms.

4.0.3 EQUIPMENT/FIXTURES. The following test equipment and/or fixturing shall be utilized during this test:

1. Simulated Cradle Trunnion Joint Mockup
2. 5000 PSI Hydraulic Power Supply
3. Hydraulic Ram Cylinder (6")
4. Mockup Interface Fixture (Plate)
5. Mockup Interface Fixture (Trunnion Device)
6. Pressure Transducers
7. Digital Chart Recorder
8. 36" Drill Base
9. Electronic Solenoid Valve Assembly
10. Various Hydraulic Hoses and Gages

4.0.4 TEST CONDITIONS. The testing will be performed in an environment at FMC/NOD of 68F-75F ambient temperature and relative humidity of 50% ± 20%.

4.0.5 TEST PROCEDURES.

1. Secure the 36" drill base to the test platform.
2. Mount the cradle trunnion joint mockup, utilizing the mockup interface fixture plate, to the drill base as shown in Fig. 4.1.
3. Install the mockup interface fixture (trunnion device) into the cradle trunnion joint mockup, per Fig. 4.1.

4. Install and adjust the alignment of the hydraulic ram cylinder and connect system hoses, per Fig. 4.1.

5. Connect and calibrate pressure transducers and associated instrumentation.

6. Verify all hydraulic and electrical instrumentation setups, per Fig. 4.1.

7. Apply reduced hydraulic pressure to the hydraulic ram cylinder and bleed hydraulic system of air.

8. Adjust system pressure for 600 PSI applied to the hydraulic ram cylinder.

9. Actuate the hydraulic ram and record instrumentation data.

10. Inspect cradle trunnion joint mockup. Inspect for signs of deformation, laminate separation, cracking or laminate compression.

11. If inspection results are satisfactory, increase hydraulic system pressure to 1500 PSI.

12. Repeat steps 9 and 10 for two cycles.

13. Increase system pressure to 2500 PSI. Note: This will impart a simulated load of 70,600 PSI.

14. Repeat step 9 for 50 cycles, and inspect I.A.W. step 10 every 5 cycles.

15. Increase system pressure to 3600 PSI. Note: This will impart a simulated load of 101,800 PSI.

16. Perform steps 9 and 10 for 10 cycles.

17. At completion of this test, thoroughly inspect the cradle trunnion joint for signs of deformation.

18. Remove the mockup interface fixture (trunnion device) and perform inspection of the trunnion bore. Record all dimensions.

19. Disconnect and disassemble test setup.

4.0.6 ACCEPTANCE CRITERIA. At the completion of this test, the cradle trunnion joint mockup shall show no signs of stress, deformation, cracking, laminate separation, or compression.

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4.0.7 CRITICAL TEST CONDITIONS.

1) The test setup of the cradle trunnion joint mockup will be per Fig. 4.1.

4.0.8 TEST SCHEDULE. Results from these tests will be provided to the customer no later than 30 days after the test completion

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LTHD
COMPOSITE TESTING
TEST 1201

CRADLE TRUNNION STRUCTURAL JOINT TEST DATA SHEET 11

DATE:
TEST PERSONNEL:
MATERIAL DESCRIPTION:

VOID CONTENT OF MATERIAL: ________
VOLUME % REINFORCEMENT: ________%
TEST TEMPERATURE: ________F
TEST HUMIDITY: ________%

PRESSURE READING (PSI)	INSPECTION COMMENTS
________	________________________________
	________________________________
	________________________________
	________________________________
	________________________________
________	________________________________
	________________________________
	________________________________
	________________________________
	________________________________
________	________________________________
	________________________________
	________________________________
	________________________________
	________________________________
________	________________________________
	________________________________
	________________________________
	________________________________
	________________________________

COMMENTS:

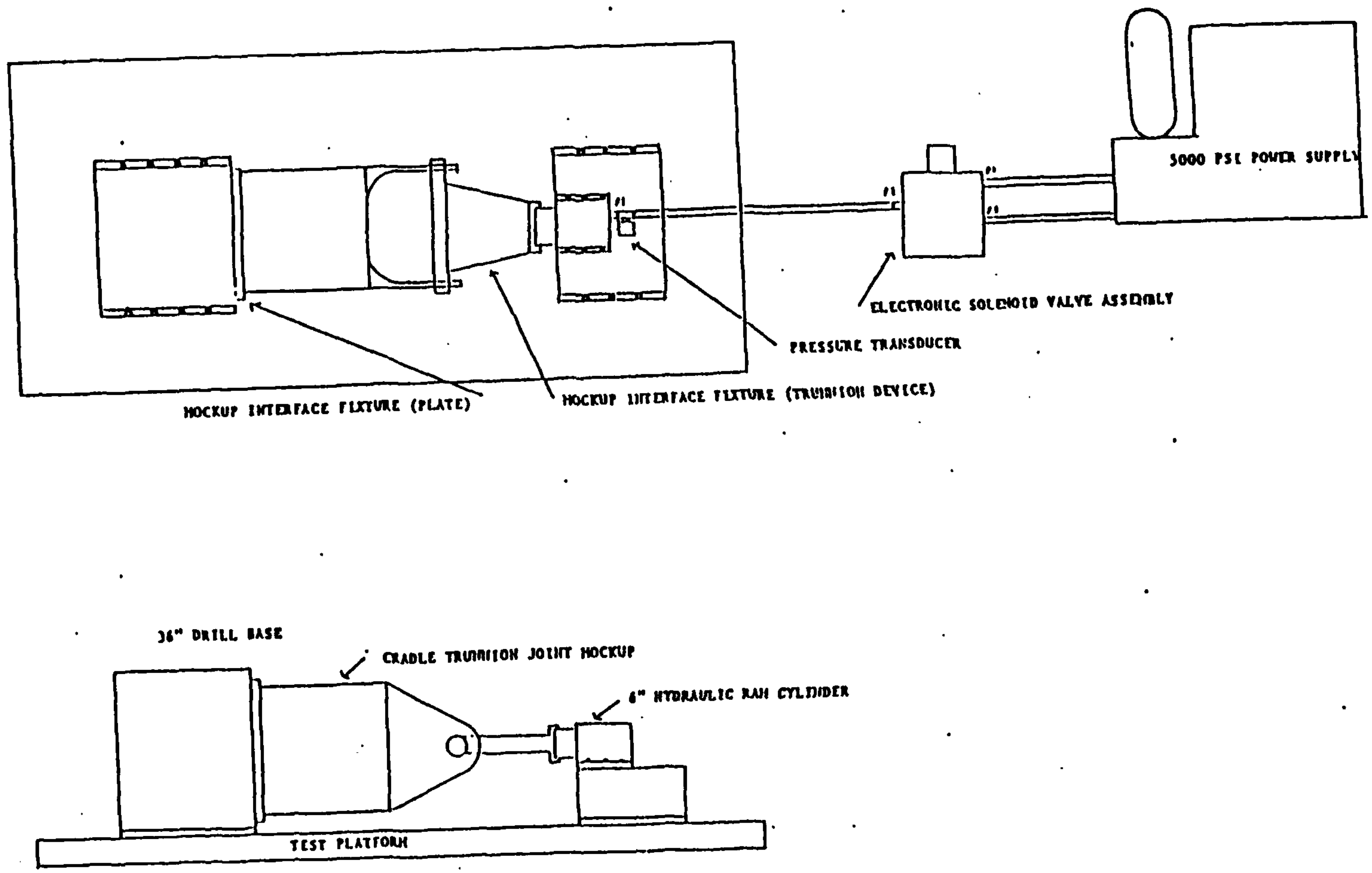

FIGURE 4.1

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5.0 QUALITY CONTROL

This plan covers the quality control of prepreg, adhesive, and core materials and their processing into test panels.

5.0.1 QUALITY CONTROL INSPECTION OF PREPREG MATERIALS

5.0.1.1 PURPOSE. Quality control inspection and testing of incoming prepreg will be performed to verify the quality of these materials and provide complete documentation for future traceability. Acceptance critera will be based on manufacturer's material specifications. If the prepreg is certified by the supplier, passes all FMC inspection tests based on the manufacturer's material specification, and is stored properly, it will be considered acceptable for use in fabricating test panels. (Gel Time and Differential Scanning Calorimetry will be used to screen out any prepreg that may not be processable per process specification.)

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QUALITY CONTROL INSPECTION OF PREPREG MATERIALS

DATA SHEET 1

DATE:

QC PERSONNEL:

MATERIAL DESCRIPTION: ____________________

____

PRODUCT NAME: ____________________
PRODUCT FORM: ____________________
BATCH/LOT NUMBER: ____________________
QUANTITY: ____________________
DATE OF MANUFACTURE: ____________________
EXPIRATION DATE: ____________________
SHIP DATE: ____________________
RECEIVING DATE: ____________________
STORAGE REQUIREMENTS: ____________________
  ACTUAL STORAGE RECORD: ____________________
  ACTUAL OUT-TIME: ____________________
MSDS RECEIVED? ____________________
  SPECIAL PRECAUTIONS: ____________________

VENDOR CERTS: ____________________
  CERTIFICATION OF RESIN: ____________________
  CERTIFICATION OF REINFORCEMENT: ____________________
  PREPREG PROPERTIES: ____________________

DEFECT RECORD? ____________________

____

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LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF PREPREG MATERIALS

DATA SHEET 1

FMC INSPECTION

VISUAL CHECKS: ____________________
PACKAGING: ____________________
PREPREG QUALITY: ____________________
NOTE ANY DEFECTS: ____________________

NOTE TRACK AND DRAPE CHARACTERISTICS:

MEASURE WIDTH OF PREPREG: __________
____
____
AVE. __________

GEL TIME AT 350F PER ASTM D 3532

SPECIMEN NO.	T (MINUTES)
1	
2	
3	
AVERAGE	

DIFFERENTIAL SCANNING CALORIMETRY (DSC) TEST METHOD:
RUN TWO SAMPLES
SAMPLE: 10-15 mg.
ATMOSPHERE: NITROGEN, 20 cc/min FLOW RATE
SCAN: 40-300C
HEAT-UP RATE: 5C/min

ATTACH DSC THERMOGRAM

5.0.2 QUALITY CONTROL INSPECTION OF ADHESIVES

5.0.2.1 PURPOSE. Quality control inspection and testing of incoming adhesives will be performed to verify the quality of these materials and provide complete documentation for future traceability. Acceptance critera will be based on manufacturer's material specifications. If the adhesive is certified by the supplier, passes all FMC inspection tests based on the manufacturer's material specification, and is stored properly, it will be considered acceptable for use in fabricating test panels.

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LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF ADHESIVES

DATA SHEET 2

DATE:

QC PERSONNEL:

MATERIAL DESCRIPTION: ______________________________
____

PRODUCT NAME: ______________________________
PRODUCT FORM: ______________________________
BATCH/LOT NUMBER: ______________________________
LOT NUMBER: ______________________________
QUANTITY: ______________________________
DATE OF MANUFACTURE: ______________________________
EXPIRATION DATE: ______________________________
SHIP DATE: ______________________________
RECEIVING DATE: ______________________________
STORAGE REQUIREMENTS: ______________________________
ACTUAL STORAGE RECORD: ______________________________
ACTUAL OUT-TIME: ______________________________
MSDS RECEIVED? ______________________________
SPECIAL PRECAUTIONS: ______________________________

VENDOR CERTS: ______________________________
CERTIFICATION OF ADHESIVE: ______________________________
ADHESIVE PROPERTIES REPORTED: ______________________________
PREPREG PROPERTIES: ______________________________

FMC INSPECTION

VISUAL CHECKS: ______________________________
PACKAGING: ______________________________
ADHESIVE QUALITY: ______________________________
NOTE ANY DEFECTS: ______________________________
____
____

5.0.3 QUALITY CONTROL INSPECTION OF CORE MATERIALS

5.0.3.1 PURPOSE. Quality control inspection and testing of incoming core materials will be performed to verify the quality of these materials and provide complete documentation for future traceability. Acceptance critera will be based on manufacturer's material specifications. If the core material is certified by the supplier, passes all FMC inspection tests based on the manufacturer's material specification, and is stored properly, it will be considered acceptable for use in fabricating test panels.

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LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF CORE MATERIALS

DATA SHEET 3

DATE:

QC PERSONNEL:

MATERIAL DESCRIPTION: ____________________
____

PRODUCT NAME: ____________________
PRODUCT FORM: ____________________
BATCH/LOT NUMBER: ____________________
LOT NUMBER: ____________________
QUANTITY: ____________________
DATE OF MANUFACTURE: ____________________
EXPIRATION DATE: ____________________
SHIP DATE: ____________________
RECEIVING DATE: ____________________
STORAGE REQUIREMENTS: ____________________
ACTUAL STORAGE RECORD: ____________________
ACTUAL OUT-TIME: ____________________
MSDS RECEIVED? ____________________
SPECIAL PRECAUTIONS: ____________________

VENDOR CERTS: ____________________
CERTIFICATION OF MATERIALS: ____________________
REPAIR RECORD: ____________________
PRODUCT PROPERTIES REPORTED: ____________________

FMC INSPECTION

VISUAL CHECKS: ____________________
PACKAGING: ____________________
CORE MATERIALS QUALITY: ____________________
NOTE ANY DEFECTS: ____________________
____
____

MEASURE DIMENSIONS: LENGTH__________ WIDTH________ THICKNESS_______

5.0.4 QUALITY CONTROL OF TEST PANEL LAY-UP

5.0.4.1 PURPOSE. Quality control's objective is to insure that all manufacturer's process specifications are followed. In-process monitoring and complete documentation of the actual lay-up performed will be required to insure part quality and provide a record for future reference. The lay-up will be acceptable if all raw materials used passed quality control inspection, have been properly stored, and have been laid-up according to the manufacturer's process specification.

LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF TEST PANEL LAY-UP

DATA SHEET 4

DATE:
QC PERSONNEL:

DESCRIPTION OF TEST PANEL TO BE FABRICATED: ______________________________
____

RAW MATERIALS USED IN FABRICATING TEST PANELS:	IS RAW MATERIAL QUALITY ACCEPTABLE?
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________

TOOLING AND BAGGING MATERIALS:	DO ALL MATERIALS MEET PROCESS SPECIFICATIONS?
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________

RECORD OUT-TIME OF RAW MATERIALS (IF APPLICABLE)

OUT OF STORAGE AT ______________________________
USABLE AT ______________________________
PUT BACK IN STORAGE AT ______________________________

LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF TEST PANEL LAY-UP

DATA SHEET 4

RECORD DATE AND TIME: LAY-UP STARTS ______________________
RECORD HISTORY OF LAY-UP (IF LONGER THAN 1 DAY) ______________

RECORD TEMPERATURE AND HUMIDITY OF LAY-UP AREA:
TEMPERATURE ____________ HUMIDITY ______________

LAY-UP PROCEDURE	IS PROCESS SPECIFICATION BEING FOLLOWED?

RECORD ANY DEFECTS:

RECORD CORRECTIVE ACTION:

LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF TEST PANEL LAY-UP

DATA SHEET 4

FINAL CHECK

HAS PROCESS SPECIFICATION BEEN MET? ______________________
LAY-UP ACCEPTABLE? ______________________
THERMOCOUPLERS IN PLACE? ______________________
BAGGING ACCEPTABLE? ______________________
VACUUM PRESSURE, IF APPLICABLE? ______________________
COMMENTS:

5.0.5 QUALITY CONTROL OF TEST PANEL CURING

5.0.5.1 PURPOSE. Quality control's objective is to insure that all manufacturer's process specifications are followed. Constant in-process monitoring and complete documentation of the actual cure cycle performed will be required to insure part quality and provide a record for future reference. Inspection of cured test panels will be performed to check for defects. If there is any reason to suspect that the composite has not been completely cured, Differential Scanning Calorimetry will be performed. The cured test panels will be acceptable if all manufacturer's cure process specifications were followed and test panels pass all FMC QC inspection tests, based on manufacturer's cured material specifications.

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LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF TEST PANEL CURING

DATA SHEET 5

DATE:
QC PERSONNEL:

DESCRIPTION OF TEST PANEL TO BE FABRICATED: ______________________________
____

DOES LAY-UP MEET PROCESS SPECIFICATION? ______________________________

RECORD DATE AND TIME CURE STARTS: ______________________________

PROCESS SPECIFICATION CURE PROCEDURE	MONITOR CURE PROCEDURE

RECORD ANY DEVIATIONS FROM PROCESS SPECIFICATION:

RECORD ANY CORRECTIVE ACTIONS:

SAVE ALL PRESSURE AND THERMOCOUPLE RECORDINGS

LTHD
QUALITY CONTROL

QUALITY CONTROL INSPECTION OF TEST PANEL CURING

DATA SHEET 5

FMC INSPECTION OF CURED TEST PANEL

WAS PROCESS SPECIFICATION MET? ______________________________

VISUAL CHECK
NOTE ANY DEFECTS?

MEASURE FINAL DIMENSIONS:

ADDITIONAL NDE TESTING: LOW-ENERGY RADIOGRAPHY OF TEST PANELS WILL BE PERFORMED TO CHECK FOR LARGE VOIDS, DELAMINATION, DENSITY VARIATIONS, AND INCLUSIONS. ULTRASONIC C-SCAN MAY BE PERFORMED ON SELECTED PANELS.

DESTRUCTIVE TESTING:

FIBER VOLUME __________________(PER ASTM D 3171)
RESIN SOLIDS __________________(PER ASTM D 2584)
SPECIFIC GRAVITY _______________(PER ASTM D 792)
VOID CONTENT __________________(PER ASTM D 2734)

DSC MAY BE RUN ON SELECTED PANELS
DSC TEST METHOD:
RUN TWO SAMPLES
SAMPLE: 10-15 mg.
ATMOSPHERE: NITROGEN, 20 cc/min FLOW RATE
SCAN: 40-300C
HEAT-UP RATE: 5C/min

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APPENDIX A.

"Boeing Material Specification 8-256F"

The following specification will be used to establish acceptance criteria for test materials and to outline procedures for test panel processing.

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1\. SCOPE

a. This specification establishes requirements for non self-adhesive, controlled flow, 350F (177C) cure, epoxy resin-impregnated BMS 9-8 Type I graphite fiber unidirectional tapes and woven fabrics.

b. This specification requires qualified products.

2\. CLASSIFICATION

Preimpregnated materials shall be of the following Types, Classes and Grades or Styles.

2.1 TYPES

Type shall specify prepreg nominal resin content.

Type I - nominal resin content, 44 percent by weight

Type II - nominal resin content, 38 percent by weight

Type III - obsolete

Type IV - nominal resin content, 40 percent by weight

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2.2 CLASSES

Class shall specify graphite prepreg form.

Class 1 - Unidirectional prepreg tape
Class 2 - Woven fabric prepreg

2.3 CLASS 1 - GRADES

Grade shall specify nominal areal weight of unidirectional graphite tape in gm/m².

Grade 95
Grade 145
Grade 190

2.4 CLASS 2 - STYLES

Style shall specify weave style of BMS 9-8 graphite fabric

Style

3K-70-PW plain weave, nonporous

3\. REFERENCES

Except where a specific issue is indicated, the issue of the following references in effect on the date of invitation for bid shall form a part of this specification to the extent indicated herein.

a. ANSI B46.1 Surface Texture, Surface Roughness, Waviness and Lay

b. ASTM D695 Compressive Properties of Rigid Plastics

c. ASTM E4 Load Verification of Testing Machines

BY [illegible]	CUSTOMER APPVL	CONTROLLED FLOW EPOXY PREIMPREGNATED GRAPHITE TAPES AND WOVEN FABRICS - 350F (177C CURE)	BMS 8-256F
CK'D [illegible]	Q. C.	BOEING MATERIAL SPECIFICATION	PAGE 1 OF 30
ENG. [illegible]	MAT'L [illegible]		

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DUBLIN QA DEPT

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3. (Continued)

d. BMS 9-8 Graphite Reinforcements, Yarn and Fabric

e. BMS 15-3 Release Sheet Materials - Non-Contamination

f. BSS 7273 G_{IC} Interlaminar Toughness, Fiber-Reinforced Composites

g. BSS 7305 High Performance Liquid Chromatography Reverse Phase Method

h. D6-51846 Advanced Composite Preimpregnated Material Suppliers Process Control Document Requirements and a Checklist for Technology Audits

i. MIL-HDBK-53-1 Guide for Attribute Lot Sampling Inspection

j. MIL-STD-401 Sandwich Constructions and Core Materials; General Test Methods

4. DEFINITIONS

a. Bleeder - Porous material used to absorb excess resin from prepreg during cure.

b. Breather - A loosely woven or matted material that serves as a continuous vacuum path over a part but is not in contact with the resin.

c. Controlled Flow - A characteristic of a resin system with elevated viscosity during cure.

d. Fabric Prepreg Batch - Prepreg containing fabric meeting the requirements of BMS 9-8 with traceability to the individual fabric batches and impregnated with one batch of resin in one continuous operation.

e. Fuzz Balls - These occur when individual filaments are abraded or broken during the manufacture of the impregnated material. These broken filaments and/or abraded particles collect as loose filament bundles or balls which are occasionally incorporated into the impregnated material.

f. Handling Life - The out-of-refrigeration time over which the material maintains its handleability, i.e., capable of demonstrating properties in Sections 5.2.1 and 5.2.2

g. Prepreg Lot - Prepreg from one batch submitted for acceptance at one time.

h. Puckers - Areas on prepreg material where the material has locally blistered from the separator film or release paper.

i. Resin Batch - Resin mixed in one mixer in one operation or blended together in one homogeneous mix with traceability to individual component lots.

j. Storage Life - The time in storage at 10F or below, while contained in a moisture barrier of continuous polyethylene 6 mil or thicker, over which the material maintains its handling life as well as all other requirements of this specification.

k. Surface Resin Starvation - Incomplete resin filling of the tool side part surface.

m. Tape Prepreg Batch - Prepreg containing unidirectional reinforcement meeting the requirements of BMS 9-8 with traceability to individual yarn lots and impregnated with one batch of resin in one continuous operation.

n. Worked - Processing operation which closes interstices in fabric.

5. MATERIAL REQUIREMENTS

5.1 COMPOSITION

The graphite fiber unidirectional tape or woven fabric shall be impregnated with a thermosetting epoxy resin formulated, catalyzed, and "B" staged in such a manner as to yield preimpregnated reinforcement exhibiting controlled-flow characteristics that meet the requirements of this specification.

5.2 PREPREG PROPERTIES

5.2.1 PHYSICAL PROPERTIES

The prepreg shall conform to the requirements of Table I when tested in accordance with the designated method.

5.2.2 CHEMICAL PROPERTIES

The prepreg resin shall conform to the requirements of Table II when tested in accordance with the designated methods.

5.2.3 INTERLAMINAR POROSITY

The prepreg, when fabricated into panels and examined as specified in Section 8.1.5, shall not exhibit any internal porosity in excess of standards specified in Table IV.

5.2.4 DEFECT LIMITATIONS AND AND DIMENSIONAL REQUIREMENTS - CLASS 1 (TAPES)

a. The preimpregnated material shall be uniform in quality and condition, and shall not exhibit characteristics detrimental to handling, layup, or structural properties.

b. The material shall be free from crimped or misaligned fibers, cured resin particles, foreign material, twists, unwetted fibers, dry or boardy areas, and puckers.

c. Location of yarn splices shall be clearly indicated on the prepreg or release film.

d. All graphite yarns shall be collimated and parallel to the centerline of the prepreg.

e. The length of open spaces between fibers shall not exceed 10 inches. The width of open spaces between fibers shall not exceed 0.030 inches. One open space 0.010 to 0.030 inches wide and not exceeding 10 inches long is acceptable in each 10 sq. ft. of prepreg. Open spaces less than 0.010 inches wide and not exceeding 10 inches long are acceptable.

f. Tolerance on the width of the material is ± 0.050 inch.

g. Fibers must be flush with the edge of the separator.

h. The orientation of the yarn within the prepreg shall not deviate from a straight line by more than 0.032 inch in 1 foot of length.

i. Fuzz balls which do not cause a sudden discernable change in the prepreg thickness shall be acceptable, provided the overall thickness change is no more than 100 percent of the nominal thickness for grade 95 material, and no more than 50 percent of the nominal thickness for all other grades. In determining if there is any apparent fiber distortion caused by a fuzz ball, it shall not be necessary to remove the fuzz ball from the prepreg.

j. The edge of the prepreg tape shall not deviate from a straight line by more than 0.025 inch per foot of length.

5.2.5 DEFECT LIMITATION AND DIMENSIONAL REQUIREMENTS - CLASS 2 (FABRICS)

a. The preimpregnated material shall be uniform in quality and condition and shall not exhibit characteristics detrimental to handling, layup, or structural properties.

b. Visible indications of impurities, dry areas, areas of nonuniformity, incomplete impregnation, cured resin, hard spots, or localized color differences in the impregnated fabric supplied shall be marked by tags as nonconforming areas (see Section 5.2.6).

c. Impregnated fabric shall be free from curled or folded selvages that overlap nonselvage areas, wrinkles, or resin-rich areas.

d. Selvage width on each side of the fabric shall not exceed 1.5 inches.

e. The warp and fill yarns shall be perpendicular to each other and shall be parallel to the warp and fill direction of the impregnated cloth within 2 inches over the full cloth width exclusive of selvage and within 1 inch in any 21 inches of cloth width or length.

f. Width of the material shall be within ± 1 inch. Width shall not include selvages.

5.2.6 NONCONFORMING MATERIAL (TAPES AND FABRICS)

a. Areas of unacceptable material (not conforming) to *Sections 5.2.4 or 5.2.5* shall be identified on the prepreg roll edge by markers at both the beginning and the end of the defective area. For areas of non-weaving defects encompassing more than 3 ft. along the material's length, additional markers shall be placed at intervals of 2 ft. (maximum) between the beginning and ending markers. Use a single marker for single point defects. For weaving defects, only those defects exceeding the fabric quality requirements of BMS 9-8 shall be marked except each crease, cut, tear, smash, fabric splice and weave separation. Markers may be any color distinguishable from the impregnated material. Material containing unacceptable areas (not conforming in accordance with 5.2.6) *shall not be counted* toward the amount purchased.

b. Prepreg material may be cut to remove defects, but 90 percent of supplied prepreg shall be in lengths of not less than 50 feet and the remaining 10 percent shall be in lengths not less than 15 feet.

c. The type, location, and length of each defect (marked to show the outside roll end) or cut shall be itemized on a defect log for each roll.

d. Material shall have a roll maximum defect weight limit of 15 percent.

5.2.7 STORAGE STABILITY AND OUT OF REFRIGERATION TIME REQUIREMENTS

All materials shall be capable of meeting the qualification requirements of this specification after the following exposures:

a. Storage Life: 180 days from date of shipment, stored at 10F or below in a sealed moisture proof container.

b. Handling Life: 240 hours at room temperature (80F maximum).

5.3 LAMINATE/SANDWICH PROPERTIES

5.3.1 IMPACT PROPERTIES AND CRACK GROWTH RESISTANCE

a. Cured laminate sections shall have the minimum mechanical properties shown in Table III when tested in accordance with Section 8.2.3.

b. Cured laminates shall have minimum G_{IC} values as shown in Table III when tested in accordance with BSS 7273.

5.3.2 PHYSICAL PROPERTIES

Laminates, when fabricated from preimpregnated materials as described in Section 8.3, shall meet the requirements of Table IV, Laminate/Sandwich Physical Properties.

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5.3.3 MECHANICAL PROPERTIES

a. Laminate and sandwich panels, when fabricated from preimpregnated materials as described in Section 8.3, shall meet requirements of Tables V, VI, VIII, and IX when tested dry.

b. In addition to the above, laminate specimens immersed in 160F water for 14 days prior to test shall meet the requirements specified in Table VII.

c. In addition to the above, sandwich specimens exposed 24 hours at 160F and 95-100 percent RH prior to test shall meet the requirements of Tables VIII and IX.

6. QUALIFICATION

a. Direct all requests for qualification to a Materiel Department of The Boeing Company.

b. Qualification shall be based upon the manufacture and successful test of three batches of the material. The three batches shall contain at least two different resin batches and at least two different lots of the reinforcement. For Class 2, the two different lots of reinforcement apply to the fill direction only.

c. Suppliers seeking qualification to this specification shall submit to an audit of their product manufacturing operations, raw material traceability, process records, test procedures, and quality assurance records. If deemed necessary by the supplier, The Boeing Company will enter into a nondisclosure agreement with the supplier, to protect the proprietary rights of both. The Boeing Company reserves the right to reaudit any or all follow-on production orders subsequent to qualification.

d. When requested by The Boeing Company, Materiel Department, the supplier shall provide qualification material, quantities to be determined at the time of qualification. Additionally, the supplier shall submit two copies of test data including individual specimen values, showing that the material meets all the requirements of the specification, for the Type, Class, and Grade/Style submitted. The test facility (supplier or test laboratory) used in determination of the data shall be identified.

e. Materials submitted for qualification shall be tested against the requirements of this specification both "as-received" and after exposure to the maximum storage/work life periods and shall also be evaluated for manufacturing suitability.

f. After review of supplier data and completion of Boeing tests, the supplier will be advised of qualification status. Qualified products will be listed in the Boeing Material Qualified Products List, showing the supplier's product designation.

g. Qualification of additional grades or styles requires one batch of material to be submitted for test to The Boeing Company.

h. The supplier shall have on file a Boeing-approved Process Control Document containing baseline chemical, in-process test information, and manufacturing procedures. No change in approved product formulation, critical raw materials or suppliers, basic methods of manufacture, testing, or geographic location shall be made without notification and prior approval by Boeing in writing. Requalification and a revised supplier designation may be required.

i. Any or all of the qualification tests may be repeated at any time by the purchaser and the material must pass the qualification requirements.

j. Process Control Documents shall be in accordance with D6-51846.

7. QUALITY CONTROL

7.1 <u>SUPPLIER QUALITY CONTROL</u>

a. Test every roll of material to verify compliance with the designated requirements of Table I Prepreg Physical Properties, except test only the first and last rolls of each prepreg batch for Volatile Content and Flow.

7.1 (Continued)

b. Test each prepreg batch to the requirements of Table II, Chemical Properties. If the supplier cannot perform the tests of Table II, then the tests must be conducted by a Boeing-approval laboratory. Test one roll of the prepreg batch for Infrared Analysis. Test the first and last rolls of the prepreg batch for LC analysis. Chemical properties data shall be submitted to the purchaser with each material shipment.

c. The laminate and sandwich physical and mechanical properties required by Tables IV, V, VI, VII, VIII, and IX for tape and fabric prepreg shall be tested as follows for each prepreg batch.

NO. OF POUNDS IN BATCH		
CLASS 1	CLASS 2	TEST FREQUENCY FOR BATCHES SHIPPED
1-250	1-300	Test 1 roll
251-500	301-750	Test 2 rolls
500+	751+	Test 2 rolls plus 1 roll for each additional 500 lbs. or part thereof

d. Suppliers shall furnish actual test data comprised of the average and individual values showing conformance with the above requirements for each prepreg batch and shall identify such data with the specification revision letter in effect, the rolls of material used in determining the data, and the test facility that generated the data. Should the material fail to comply with the above requirements, one retest of the failed property is allowed. The second failure to comply shall be cause for material rejection. All data shall accompany the material shipment.

e. The supplier shall submit the roll defect log(s) in accordance with Section 5.2.6.c with each shipment and attach a copy to the roll container.

f. The supplier shall maintain, for a period of 5 years, all records pertaining to raw material receiving inspection and certification, in-process records, and product testing in accordance with the approved Manufacturing and Quality Assurance Plan. Such records shall be available for inspection by authorized representatives of The Boeing Company.

7.2 PURCHASER QUALITY CONTROL

a. Check the packaging, marking, and supplier's test data to verify conformance to the appropriate sections of this specification.

b. Test each prepreg lot within the shipment to verify conformance with the designated requirements of Table I and Sections 5.3.2 and 5.3.3 (as appropriate for each Grade/Style). The minimum number of rolls to be tested for each prepreg lot shall be as follows:

No. of Rolls in Lot	No. of Rolls to Test
1 - 10	1
11 - 30	2
31 - 60	3
61 - 90	4
90 +	1 additional roll for each additional 40 rolls

c. The acceptance tests in Sections 5.3.2 and 5.3.3 may be performed on a skip-lot basis for each vendor and class in accordance with a suitably documented plan having an AQL of at least 10 percent. MIL-HDBK-53-1 and MIL-HDBK-53-2 are suitable guides to preparing a skip-lot plan.

d. The acceptance tests in Section 5.3.2 and 5.3.3 are not required if the purchaser has an implemented chemical characterization capability and performs the tests of Section 5.2.2 on each prepreg lot to the requirements of Table II.

e. Quality Control may perform any additional tests of this specification deemed necessary to ensure continuing uniform quality in production shipments.

f. All test data and records must be kept on file and readily available for review.

8. MATERIAL TEST METHODS

The test methods described below or Boeing-approved equivalent test methods shall be used.

8.1 PHYSICAL PROPERTIES TESTS

Except as otherwise noted in the test method, test three samples equally spaced across the width of the prepreg for each physical property.

8.1.1 RESIN CONTENT/GRAPHITE AREAL WEIGHT - UNCURED PREPREG

a. Cut three samples, each 10 cm x 10 cm minimum and, for Class 2, at least 2.5 cm from the edge of the prepreg. Cut the samples so that the edges are parallel and perpendicular to the carbon fiber. Weigh to the nearest milligram (W_1). Determine area (A) of each sample to the nearest square millimeter.

b. Extract the three separate samples in separate beakers containing 50 ml minimum of warm (approximately 100F) concentrated nitric acid. Extract fiber for 15 minutes minimum, stirring occasionally. (Option: Follow Suppliers' recommended procedure if approved by Boeing).

c. Separate the fibers by filtering or decant the acid.

********* CAUTION *********	Discard filtered acid and water before filtering acetone. Do not allow any of the acetone to mix with the acid.

NOTE: Caution must be taken not to lose any fiber.

d. Repeat steps b and c two times, then follow by rinsing the fibers with water and then rinse with Acetone.

e. Dry the fibers at 220 ± 10F for 30 minutes. Allow to cool to room temperature in a desiccator.

f. Weigh fibers to the nearest milligram (W_2).

g. Calculate Resin Content Percent = $\frac{W_1 - W_2}{W_1} \times 100$

h. Calculate Graphite Areal Weight = $\frac{W_2}{A}$

i. Report average and individual areal weight and resin content. The average value must meet the requirements of Table I.

8.1.2 VOLATILE CONTENT

a. Place a piece of prepreg, 2 x 2 inches minimum, in a tared (W_1) aluminum pan and weigh the sample and pan to the nearest milligram (W_2).

b. Place the sample in an air circulating oven at 325 ± 10F for 20 ± 5 minutes.

c. Remove the sample, cool to room temperature in a desiccator, and weigh to the nearest milligram (dried sample + pan) (W_3).

d. Calculate Volatile Content Percent = $\frac{W_2 - W_3}{W_2 - W_1} \times 100$, percent

e. Report average of three tests.

8.1.3 FLOW

a. Cut four pieces of graphite prepreg, each 4 inches square; two pieces of perforated Teflon separator, 6 inches square; and six pieces of 1581 or 181 style glass bleeder fabric. Weigh the prepreg to the nearest milligram (W_1).

NOTE: Use a perforated Teflon or equivalent release film with 0.045 inch hole diameter and 2.22 percent open area (24 holes/in.^{2}).

b. Lay up the specimen starting with three plies glass cloth followed by one ply Teflon separator, then four plies of prepreg (0 degree, 90 degree, 90 degree, 0 degree), then one ply of Teflon separator and three plies of glass cloth.

8.1.3 (Continued)

c. Heat the layup in a press at 350 ± 10F, 100 ± 5 psi for 15 ± 10 minutes. Remove the release and bleeder plies and flash and weigh the cured specimen (W_2).

d. Calculate: Flow = $\frac{W_1 - W_2}{W_1}$ X 100, percent

8.1.4 PLY THICKNESS - CURED LAMINATE

a. Measure the cured laminates prepared for mechanical testing using a single 1/4-inch-diameter flat-face anvil micrometer. Do not measure thickness across the laminate edge area where edge bleeding or edge damming will affect laminate thickness.

b. The reported ply thickness shall be the average of at least 10 determinations uniformly distributed over the laminate surface and divided by the number of plies in the laminate.

8.1.5 INTERLAMINAR POROSITY

a. Do not use release films when fabricating panels.

b. Fabricate a tape or fabric (as appropriate) test panel as shown in Figure 1a and stabilize core as shown in Figure 1b.

c. As a minimum, cross-section panel along the line marked AA in Figure 1a. Examine visually, polish 1 linear inch of exposed edge in the 3 ply area which appears to have the highest porosity with 2-micron diamond polish, and examine under 50X magnification for internal porosity. Calculate the internal porosity based upon the worst 1 linear inch of polished cross section.

8.1.6 ENVIRONMENTAL RESISTANCE TEST METHOD

a. Cut twelve 3 x 1-inch specimens from a four-ply (0/90) fabric test panel and clean with acetone.

b. Immerse two specimens briefly in each fluid listed in Table IV and dry with clean gauze. Weigh each specimen and record the weight to the nearest 0.1 mg (W_1).

c. Submerge the specimens in each of the test fluids for 14 days. Remove the specimens, dry with clean gauze, weigh, and record weights to the nearest 0.1 mg (W_2).

d. Calculate the percent weight increase using the following equation:

Percent Weight Increase = $\frac{W_2 - W_1}{W_1}$ x 100

8.2 MECHANICAL PROPERTIES TESTS

a. Use the test methods described below.

b. Except as otherwise noted in the test method, test five specimens for each laminate property and four specimens for each sandwich property.

c. Tensile and compression specimens may be fabricated from the same panel.

d. Perform all mechanical property testing using test machines complying with ASTM E4.

e. Laminate and sandwich test panels are to be fabricated in accordance with Section 8.3.

f. Specimens shall be machined to ± 1 degree of the fiber test direction.

g. Specimens tested at room temperature shall be conditioned and tested at 75 ± 10F.

8.2 (Continued)

h. Hold test specimens at test temperature of -75 ± 10F, 160 ± 10F, or 200 ± 10F prior to initiating test load according to the following table:

TEST	TIME AT TEST TEMPERATURE (MINUTES)
All dry tests except impact	10 ± 3
Flatwise tension and impact	30 + 5 - 0
All wet tests	2 ± 1

i. Wet conditioning is as described in Section 5.3.1. Specimens shall be tested within 6 hours of removal from exposure, and shall be protected against moisture loss during the interim period.

8.2.1 TENSILE TESTS

a. Prepare tensile specimens in accordance with Figures 2 and 3.

b. Test in a universal test machine at a load rate of 0.05 inch per minute.

c. Measure strain with an extensometer or a strain gauge.

d. Ultimate tensile strength, psi = $F_t = \frac{P}{A} = \frac{P}{bt}$

where:

P = ultimate tensile load, lb

A = specimen nominal cross-sectional area, square inches (nominal thickness) x (measured width)

b = width, measured to nearest 0.001 inch

t = nominal thickness calculated from nominal thickness/ply (see Table IV A) x number of plies

e. Modulus of Elasticity, psi - See Figure 4

The modulus of elasticity is obtained from the slope of the load-deflection curve divided by the area.

$E_t = \frac{gP}{AY}$

where:

g = gage length of the extensometer

P/Y = initial straight-line portion of the load-deflection curve, lb/in.

A = specimen nominal cross-sectional area, square inches (nominal thickness) x (measured width)

f. Tensile Strain Ultimate, micro in./in. - See Figure 4

The strain to failure is obtained from the stress-strain or load-deflection curves.

g. Test values shall meet the requirements listed in Tables V or VI.

6.2.2 COMPRESSIVE STRENGTH AND MODULUS

a. Ultimate compressive stress can be obtained using a specimen as shown in Figure 5a. Test in accordance with ASTM D695.

b. Compressive modulus testing requires a separate specimen, shown in Figure 5b. Test this coupon to approximately 1/3 failure load of the above, again using the ASTM D695 compression fixture. Use an appropriate compressometer to measure strain.

c. Calculate compressive stress and modulus as follows:

Compressive Strength, Ultimate, psi

$$F_c = \frac{P}{A} = \frac{P}{bt}$$

Compressive Modulus of Elasticity, psi

$$E_c = \frac{gP}{AY}$$

Compressive Ultimate Strain, micro in./in.

$$c = \frac{\text{Average } F_c}{\text{Average } E_c}$$

where:

g = gage length of the extensometer

P = ultimate compressive load, lb

A = specimen nominal cross-sectional area, square inches (nominal thickness x actual width)

b = width, measured to nearest 0.001 inch

t = nominal thickness, calculated from nominal thickness/ply (see Table IV A)

P/Y = apparent load per unit deflection (lb/in.) based on the slope of a straight line best fit of the load deflection curve (see Figure 4) which ignores those portions of the load deflection wave affected by machine deflection or compressometer slippage.

6.2.3 THROUGH-PENETRATION IMPACT PROPERTIES TESTING

a. For Class 1 material, prepare three 6 by 6-inch laminate sections of 12 plies aligned in a quasi-isotropic lay-up of $(+45/90/-45/0/+45/90)_s$.

b. For Class 2 material, prepare three 6 x 6-inch laminate sections of 12 plies aligned in a $(0/90, \pm 45)_{3S}$ orientation.

c. Grip specimen in a fixture equivalent to Figure 6. Specimen shall have a free area of 5 x 5 inches. Fastener bolt shall be tightened until no vibration is detected after coin tap at specimen center.

d. Perform a through-penetration impact test on an Effects Technology, Incorporated Model 8000 Instrumented Impact Tester or equivalent. The following conditions shall be used:

Indenter: 1/2-inch steel hemispherical tip with 3/8-inch shank

Velocity: 4 $\pm$ 0.1 feet/second

Energy: Greater than 25 foot-pounds available

8.2.3 (Continued)

e. Data capture shall be on an oscilloscope or computer-based system with sufficient resolution to define clearly the incipient damage load and the fiber fracture load.

f. Calculate impact mechanical properties as shown in the example in Figure 7. Divide P_F and P_I by nominal thickness (t_n) to normalize.

g. Each specimen shall be tested only one time.

8.2.4 G_{IC} INTERLAMINAR TOUGHNESS TEST

Test cured laminates in accordance with the methods described in BSS 7273.

8.2.5 LONG BEAM FLEXURE - 0-90 LAYUP

a. Cut test specimens from the test panel described in Figure 8a.

Specimen dimensions are 3 ± 0.03 inches x 24 inches, with core ribbon direction parallel to the 24 inch dimension. Test 5 specimens bag side up at each test condition.

b. Test Set-up (see Figure 8c)

(1) Use two-point loading with a 22-inch support span and a 4-inch load span, employing 1-inch wide steel blocks with a rubber pad (1 x 3 x 1/8 inch) of Shore "A" durometer of 60 on the load blocks or reaction points. Use of the rubber pads is optional. Deflection (Y) is measured at the center of the span. Test bagside up. Except for the above the test procedure shall be in accordance with MIL-STD-401.

(2) Report the ultimate load (P) and the P/Y value. P/Y is the slope of the tangent drawn to the initial portion of the load-deflection curve (see Figure 4).

8.2.6 LONG BEAM FLEXURE - QUASI ISOTROPIC LAYUP

a. Cut test specimens from the panel described in Figure 8b. Specimen dimensions are 3 ± 0.03 inches x 24 inches, with the core ribbon direction parallel to the 24 inch dimension. Test five specimens bag side up at each test condition.

b. Test Set-up (see Figure 8c)

(1) Use two-point loading with a 22-inch support span and a 4-inch load span, employing 1-inch wide steel blocks with a rubber pad (1 x 3 x 1/8 inch) of Shore "A" durometer of 60 on the load blocks or reaction points. Use of the rubber pad is optional. Deflection (Y) is measured at the center of the span. Test bagside up. Except for the above the test procedure shall be in accordance with MIL-STD-401.

(2) Report the ultimate load (P) and the P/Y value. P/Y is the slope of the tangent drawn to the initial portion of the load-deflection curve (see Figure 4).

8.2.7 FLATWISE TENSILE

a. Specimen

Machine flatwise tensile test specimens 2.0 x 2.0 inches square to 0-degree tape fiber or fabric warp direction from panel shown in Figure 8a.

b. Procedure

Test in accordance with MIL-STD-401.

Report the ultimate strength in pounds per square inch.

8.3 TEST PANEL PREPARATION

****
C A U T I O N   Protective gloves should be worn while handling materials qualified to this specification.
****

a. For all layups, carefully align graphite fibers within ± 1 degree of the required fiber direction. For fabrics, align warp yarns in layup.

b. Manually sweep every ply to consolidate part before curing.

c. Use vacuum bagging procedure shown in Figure 9.

d. Leak check each vacuum bag layup prior to cure. Draw 22 inches vacuum minimum in the bag. Close off the vacuum line and measure the leakage rate using a gage on the assembly. The vacuum under each bag must not fall more than 5 inches in 5 minutes.

e. Cure specimen test panels in an autoclave using the Figure 10 cure cycle.

8.4 CHEMICAL CHARACTERIZATION TESTS

8.4.1 INFRARED SPECTROSCOPY

a. Calibrate IR instrument in accordance with manufacturer's specification.

b. Sample Preparation

Extract a sample of prepreg with reagent grade acetone at room temperature. Make sure all the resin is extracted by manipulating the fibers with a probe. Place a few drops of this solution on a salt block. Allow the acetone to evaporate. The resin film should be of such thickness as to give transmittance of 10 to 30 percent with the strongest absorbing peak.

c. Report

The spectrum should be compared manually or computer aided with the standard spectrum, on file, to detect contaminants or gross change in formulation. (The standard to be furnished to supplier by Boeing.)

8.4.2 LIQUID CHROMATOGRAPHY

a. Perform column calibration in accordance with BSS 7305.

b. Sample Preparation

Extract a sample of prepreg with 90:10 $CH_3CN:H_2O$ solvent. Sample concentration should be 3 mg of prepreg/1 ml of 90:10 $CH_3CN:H_2O$ solvent. Resin dissolution is ensured by shaking for 10 minutes. The solution is filtered through a 0.5 micron millipore FH filter or equivalent.

c. Instrument Parameters

Column: micro-Bondapak C18 Waters 1/ or equivalent.

Mobile Phase: Gradient Program 2/

Item	Concentration
0	60% CH_3CN
14	100% CH_3CN 3/
18	100% CH_3CN
20	60% CH_3CN 3/
24	60% CH_3CN

Flow Rate: 1.5 ml/min

Injection Volume: 10 microliters 4/

Detection: UV 230nm

Attenuation: 0.2 AUFS

Chart Speed: 1 cm/minute (0.5 inch/minutes)

8.4.2 (Continued)

1/ Minimum column plate count requirement N(DEP) 3500 using 5 sigma method. Column calibration should be performed each day an analysis is conducted. (column calibration procedure, see item a).

2/ Water purity from Milli-Q-System or equivalent is recommended. Acetonitrile purity of HPLC grade is recommended.

3/ Gradient to be linear.

4/ Other injection volumes may be used if the sample concentration is proportionally adjusted.

d. Report

(1) The chromatogram should be compared manually or computer aided with a standard chromatogram to detect contaminants or gross change in formulation. (The standard to be furnished to supplier by Boeing.)

(2) Peak area ratios (average of two replicates) as required for each supplier (see QPL).

9. *MATERIAL IDENTIFICATION*

Place the following information on a label on the inside the core of each roll of prepreg.

a. Batch number, roll number, roll length

b. BMS 8-256, current revision letter, Type, Class, Grade/Style

c. Quantity and width

d. Manufacturer and material designation

e. Date of impregnation

f. Fiber identification (BMS 9-8 Class, Grade) and manufacturer's designation

10. PACKAGING AND MARKING

10.1 CARRIER

a. All graphite prepreg shall be interleaved with noncontaminating carrier material.

b. If the carrier or interleaf material has a release coating, the coating shall be fully cured and nontransferring. The carrier width shall be not less than the prepreg including selvages. The carrier material shall contain a nontransferring or non-inhibiting color and be easily removable from the prepreg at ambient temperatures by manufacturing personnel after normal handling during fabrication.

c. For Class 2 prepregs, the carrier material shall have a diamond-embossed pattern, and shall be placed on the warp surface of the prepreg with the long dimension of the diamond pattern parallel to the fabric warp direction.

10.2 ROLL SIZE

For Class 1 and Class 2, individual rolls shall be between 20 and 70 pounds of net conforming material weight. Only one roll of each batch may be below minimum weight.

10.3 CORE CONFIGURATION

a. Rolls of prepreg shall be supported by a core that is not deformed by the material weight. The core itself should be supported at all times within the shipping container during shipping and storage in such a way that the material will not be damaged from its own weight.

10.3 (Continued)

b. Core inside diameter shall be 10 inches minimum for Class 1 prepregs, and 3 inches minimum for Class 2 prepreg.

c. Core length shall be 2 to 6 inches longer than the carrier width for Class 2 materials.

d. Cores shall be longer than the release paper, by 2 ± 1 inches on either side, for Class 1 materials.

10.4 COLOR CODE R

Each prepreg roll shall be color coded either by colored carrier or by color marking of the roll core end or center. The color code is as follows: R

Grade/Style	Carrier/Roll Core Color
95	Purple
145	Orange
190	White
3K-70-PW	Purple

10.5 PACKAGING

a. Packaging shall be accomplished in such a manner as to assure delivery of material capable of meeting the requirements of this specification.

b. Seal each roll in an airtight, noncontaminating bag, 0.006 inch minimum thickness. Dessicant shall be placed in bags prior to sealing. R

c. Rolls of material which have been stored at lower than room temperature shall not be exposed to ambient atmospheric conditions unless contained in a sealed moisture proof bag. Sealed bags shall not be opened until the contents have attained ambient temperature and no moisture is visible on the surface of the bags.

10.6 MARKING

a. Each container of prepreg shall be permanently and legibly marked to give the information in Section 9.

b. Letter on each container, in letters at least 3/4 inch high (or use equivalent statement): R

"SHIP AND STORE AT 10F OR BELOW"

"DO NOT STAND ON END" (for containers carrying class 2 materials only)

c. Each container shall have the date of shipment and the purchase order number printed on the package.

TABLE I

PREPREG PHYSICAL PROPERTIES

PROPERTY	REQUIREMENT TYPE I	TYPE II	TYPE IV	TEST METHOD
Resin Content, percent by wt. 1/ 2/	44 ± 2	38 ± 2	40 ± 2	8.1.1
Volatiles Content, percent by wt. 1/	QPL	QPL	QPL	8.1.2
Flow, percent wt. 1/	QPL	QPL	QPL	8.1.3
Areal Weight Graphite Only 1/	gm/m²			8.1.1
Grade 95	95 ± 5			
Grade 145	145 ± 5			
Grade 190	190 ± 5			
Style 3K-70-PW	193 ± 8			

1/ Required for supplier and purchaser quality control testing.

2/ Supplier QC Testing:

For Grade 95 tape, any roll of any prepreg lot may be within +/- 3 percent of nominal.

For all other Grades and Styles, 20 percent or one roll of any prepreg lot may be within +/- 3 percent of nominal.

Purchaser QC Testing:

For all Grades and Styles all sampled rolls (in accordance with 7.2.b) of any prepreg lot may be within +/- 3 percent of nominal.

TABLE II

PREPREG CHEMICAL PROPERTIES

PROPERTY	REQUIREMENT	TEST METHOD
Uncured Resin Chemical Structure	Report Infrared Scan	8.4.1
Resin Component Analysis	see QPL	8.4.2

TABLE III

IMPACT MECHANICAL PROPERTIES MINIMUM AVERAGE REQUIREMENTS

CLASS	TYPE	TEMPERATURE (F)	INCIPIENT DAMAGE LOAD (P_I)/in	FIBER FRACTURE LOAD (P_F)/in	G_{IC} (LB-IN.)
1	II	-75	2500	3950	NR
		RT	2700	4600	0.5
		200	2900	5200	NR
2	I	-75	4000	5000	NR
		RT	4000	5000	1.0
		200	4000	5000	NR
2	IV	-75	4000	5000	NR
		RT	4000	5000	1.0
		200	4000	5000	NR

TABLE IV

LAMINATE/SANDWICH PHYSICAL PROPERTIES (ALL CLASSES)

PROPERTY	GRADE/STYLE	REQUIREMENTS TYPE I	TYPE II	TYPE IV	TEST METHOD
Ply Thickness, mils 1/	95	NR	3.5-4.5	NR	8.1.4
	145	NR	5.5-6.7	NR	
	190	NR	7.3-8.7	NR	
	3K-70-PW	8.4-10.0	NR	7.7-9.3	
Interlaminar Porosity	All Grades and Styles	ALL TYPES 0.1 percent			8.1.5
Environmental Resistance, percent weight increase, maximum	ALL	ALL TYPES			8.1.6
Fluid	Exposure Temp.				
Isopropanol (Technical), TT-I-735	RT	0.5			
Methyl ethyl ketone, TT-M-261	RT	1.5			
JP-4 Jet Fuel, MIL-T-5624	RT	0.5			
Deicing fluid, MIL-A-8243	RT	0.5			
Hydraulic fluid 2/	RT	0.5			
Hydraulic fluid 2/	160F	1.3			

1/ Required for supplier and purchaser quality control testing.

2/ Monsanto low-density aviation hydraulic test fluid.

TABLE IV A

LAMINATE NOMINAL PER-PLY THICKNESS

GRADE/STYLE	NOMINAL THICKNESS, INCH		
	TYPE I	TYPE II	TYPE IV
95	NR	0.0040	NR
145	NR	0.0061	NR
190	NR	0.0080	NR
3K-70-PW	0.0092	NR	0.0085

TABLE V

LAMINATE MECHANICAL PROPERTIES (CLASS 1 - TAPES)

TEST	TEST TEMP.	REQUIREMENTS FOR TYPE II		TEST METHOD
		MIN. AVERAGE OR RANGE	MIN. INDIVIDUAL OR RANGE	
Tensile Strength Ultimate, ksi 0 degrees	-75F	160	140	8.2.1
	RT 1/	180	160	
	200F	180	160	
Tensile Modulus, msi 0 degrees	-75F	17.0-20.0	16.0-21.0	8.2.1
	RT 1/	17.0-20.0	16.0-21.0	
	200F	17.0-20.0	16.0-21.0	
Tensile Strain Ultimate, μ-in./in 0 degrees	-75F	9,000	7,000	8.2.1
	RT 1/	9,500	7,500	
	200F	9,000	7,000	
Compression Strength Ultimate, ksi 0 degrees	-75F	170	150	8.2.2
	RT	160	140	
	160F	150	130	
	200F	140	120	
Compression Modulus, msi 0 degrees	-75F	15.5 - 18.5	14.5 - 19.5	8.2.2
	RT	15.0 - 18.0	14.0 - 19.0	
	160F	15.0 - 18.0	14.0 - 19.0	
	200F	15.0 - 18.0	14.0 - 19.0	

1/ Required for supplier and purchaser quality control testing. Dry test only.

TABLE VI

LAMINATE MECHANICAL PROPERTIES (CLASS 2 - FABRICS)

TEST	TEST TEMP.	CLASS 2, STYLE 3K-70-PW MIN. AVERAGE OR RANGE TYPE I	MIN. AVERAGE OR RANGE TYPE IV	MIN. INDIVIDUAL OR RANGE TYPE I	MIN. INDIVIDUAL OR RANGE TYPE IV	TEST METHOD
Tensile Strength Ultimate, ksi Warp and Fill	-75F	55	60	50	55	8.2.1
	RT 1/	65	70	60	65	
	200F	60	65	50	55	
Tensile Modulus, msi Warp and Fill	-75F	7.0-9.5	7.6-10.3	6.0-10.5	6.5-11.4	8.2.1
	RT 1/	7.0-9.5	7.6-10.3	6.0-10.5	6.5-11.4	
	200F	7.0-9.5	7.6-10.3	6.0-10.5	6.5-11.4	
Tensile Strain Ultimate, μ-in./in. Warp and Fill	-75F	6,000	6,000	NR	NR	8.2.1
	RT 1/	7,000	7,000	NR	NR	
	200F	6,700	6,700	NR	NR	
Compression Strength Ultimate, ksi Warp and Fill	-75F	70	75	60	65	8.2.2
	RT	70	75	60	65	
	160F	60	65	50	55	
	200F	55	60	45	50	
Compression Modulus, msi Warp and Fill	-75F	6.5-9.0	7.0-9.7	5.5-10.0	6.0-10.8	8.2.2
	RT	6.0-8.5	6.5-9.2	5.0-9.5	5.4-10.3	
	160F	6.0-8.5	6.5-9.2	5.0-9.5	5.4-10.3	
	200F	6.0-8.5	6.5-9.2	5.0-9.5	5.4-10.3	

1/ Required for supplier and purchaser quality control. Dry test in fill direction only.

TABLE VII

LAMINATE WET MECHANICAL PROPERTIES (ALL CLASSES)

CLASS	TEST	TEST TEMP.	CLASS 2 TYPE I MIN AVG	CLASS 2 TYPE I MIN IND	CLASS 2 TYPE IV MIN AVG	CLASS 2 TYPE IV MIN IND	CLASS 1 TYPE II MIN AVG	CLASS 1 TYPE II MIN	TEST METHOD
1	Compression Strength, ksi 0 degrees	RT	NR	NR	NR	NR	160	140	8.2.2
		160F	NR	NR	NR	NR	120	90	
		200F 1/	NR	NR	NR	NR	100	70	
2	Compression Strength, ksi Warp and Fill	RT	65	50	70	55	NR	NR	8.2.2
		160F	55	40	60	45	NR	NR	
		200F 2/	45	35	50	40	NR	NR	

1/ Either 200F wet long beam flexure ultimate and P/Y, or 200F wet compression strength ultimate is required for supplier and purchaser quality control. The test selected is at the option of both the supplier and the purchaser. Test Class 2 in the fill direction only.

2/ Either 200F wet Quasi-Isotropic long beam flexure ultimate and P/Y, or 200F wet compression strength ultimate is required for supplier and purchaser quality control. The test selected is at the option of both the supplier and the purchaser. Test Class 2 in the fill direction only.

TABLE VIII

MECHANICAL PROPERTY REQUIREMENTS FOR SANDWICH TEST PANELS (CLASS 1 - TAPES)

PROPERTY	TYPE II MINIMUM AVERAGE REQUIREMENT	TEST METHOD
Long Beam Flexure 0-90 Layup Ultimate, lb		8.2.5
-75F	200	
RT	200	
200F	180	
200 wet 1/	170	
P/Y, lb/in.		8.2.5
-75F	235	
RT	235	
200F	220	
200 wet 1/	220	
Flatwise Tensile, Psi		8.2.7
-75F	450	
RT	450	
200F	400	

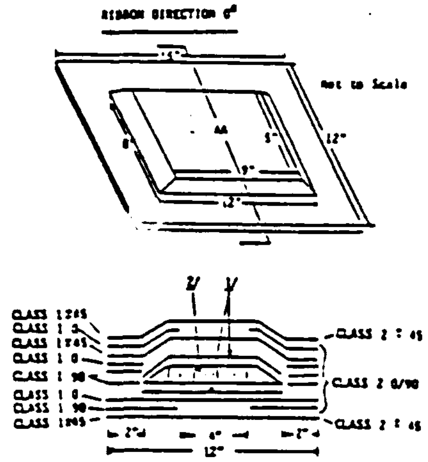
1/ Either 200F wet long beam flexure ultimate and P/Y, or 200F wet compression strength ultimate (see Table VII) are required for supplier and purchaser quality control. The test selected is at the option of both the supplier and the purchaser.

TABLE IX

MECHANICAL PROPERTY REQUIREMENTS FOR SANDWICH TEST PANELS (CLASS 2 - FABRICS)

PROPERTY	TYPES I & IV, STYLE 3K-70-PW MINIMUM AVERAGE REQUIREMENT	MINIMUM INDIVIDUAL REQUIREMENT	TEST METHOD
Long Beam Flexure 0-90 Layup Ultimate, lb			8.2.5
-75F	250	NR	
RT	210	NR	
200F	190	NR	
200F wet	150	NR	
P/Y, lb/in.			
-75F	220	NR	
RT	200	NR	
200F	200	NR	
200F wet	160	NR	
Quasi-Isotropic Long Beam Flexure Bagside Ultimate, lb			8.2.6
RT	210	180	
200F wet 1/	140	130	
P/Y, lb/in.			
RT	150	NR	
200F wet 1/	125	NR	
Flatwise Tensile, Psi			8.2.7
-75F	550	NR	
RT	600	NR	
200F	550	NR	

1/ Either 200F wet Quasi-Isotropic long beam flexure ultimate and P/Y, or 200F wet compression strength ultimate (see Table VII) is required for supplier and purchaser quality control. The test selected is at the option of both the supplier and the purchaser. Test in fill direction only.



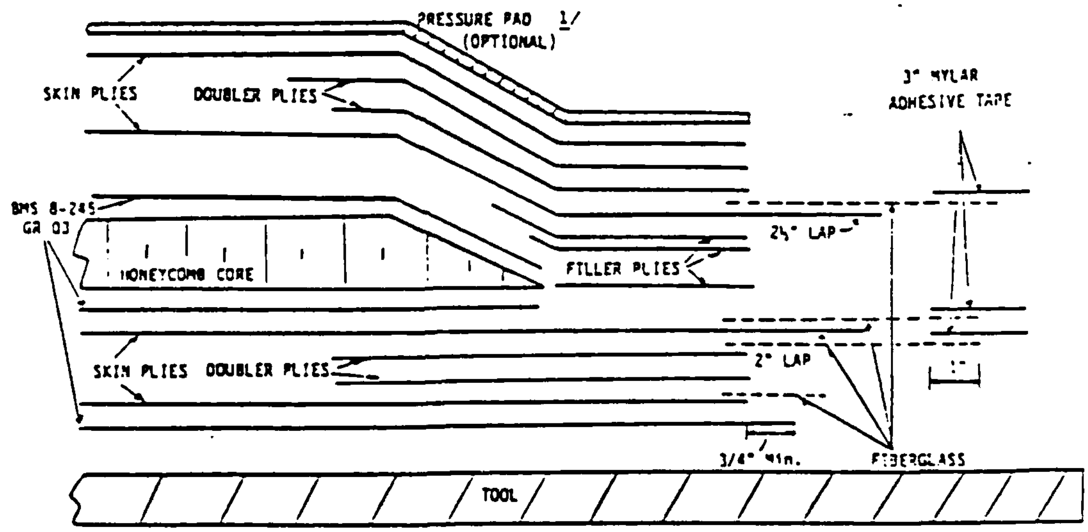
1/ Use one ply of BMS 8-245 Grade 03 on each face of the core.

2/ BMS 8-124 Class IV, Type V, Grade 3.

3/ Tied down as shown in Figure 1b.

INTERLAMINAR POROSITY TEST PANEL

Figure 1a



NOTE: A vacuum path must exist by contact between fiberglass tie-down, bleeder, and vacuum source line.

HONEYCOMB STABILIZATION METHOD

Figure 1b

1/ Overlap rubber pad at least 1/2 inch beyond core chamfer.

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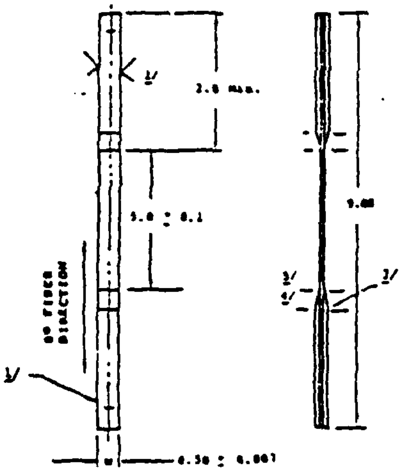


FLAGNOTES

1/ ALIGNMENT HOLES ARE OPTIONAL. IF HOLES ARE USED, HOLES SHALL BE WITHIN 0.005 INCH OF SPECIMEN CENTERLINE.

2/ 32 EDGE FINISH IN ACCORDANCE WITH ANSI B46.1. EDGES SHALL BE MACHINED AND TESTED PARALLEL TO THE FIBER DIRECTION.

3/ TAPER MAY BE ACHIEVED BY (a) STAGGERING EACH PLY BY 0.10 INCH OR (b) MACHINING TO THE SAME RELATIVE ANGLE OBTAINED WITH STAGGERING.

4/ EDGES OF OPPOSING BONDED TABS SHALL MATCH WITHIN 0.020 INCHES.

5/ BALANCE ORIENTATION TO PREVENT DAMAGE.

General Notes:

1. All dimensions are in inches. Dimensions shown without tolerances are nominal.

2. Edge flat and parallel within 0.005 inch.

3. a. Use precured fiberglass tabs constructed in a balanced orientation (0/90) of 5 plies of Style 181 (1581 and 7581 optional) prepreg in accordance with note 3.b.

   b. Use 250F curing fiberglass tabs and adhesives for -65F, RT and 160F specimens. Use 350F curing fiberglass tabs and adhesive for 270F specimens.

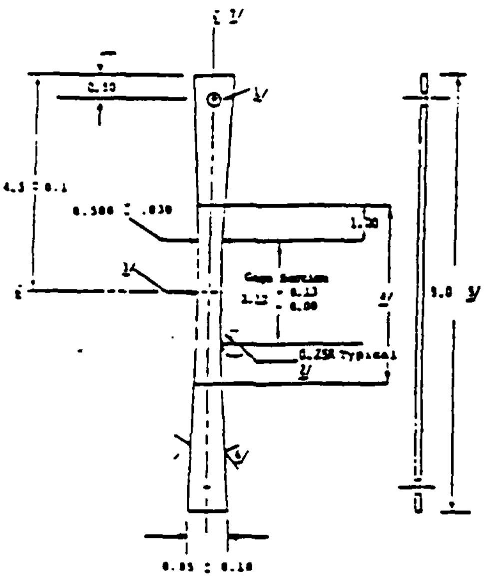
   c. Bonding surface preparation - Use BMS 15-3 Class 3 impregnated peel ply and/or hand sand with 100 grit in *0 degree* direction. Solvent wipe sanded surface prior to bonding.

LAMINATE PLY REQUIREMENTS

GRADE	ORIENTATION	NO. OF PLIES
95	0 Degree	12
145	0 Degree	8
190	0 Degree	6

TENSILE TEST SPECIMENS FOR UNIDIRECTIONAL TAPE (CLASS 1)

Figure 2



FLAGNOTES:

1/ ALIGNMENT HOLES ARE OPTIONAL. IF HOLES ARE USED, HOLES SHALL BE WITHIN 0.005 INCH OF SPECIMEN CENTERLINE.

2/ TRANSITION FROM CENTER SECTION TO TAPERED SECTION SHALL BE SMOOTHLY JOINED IN THE AREA OF 1/4 RAD.

3/ THE WIDTH INWARD FROM THE ENDS OF THE GAGE SECTION SHALL BE REDUCED GRADUALLY AND EQUALLY BY 0.003-0.005 INCHES AT THE CENTER TO PREVENT ABRUPT CHANGES IN DIMENSION.

4/ MINIMUM LENGTH OF UNGRIPPED SECTION. RESULTS OBTAINED FROM SPECIMENS WHICH FAIL ENTIRELY OUTSIDE OF GAGE SECTION MAY BE DISREGARDED.

5/ SPECIMEN LENGTH MAY EXCEED 9 INCHES, HOWEVER THE TAPER MUST BE HELD CONSTANT. ANY EXTENSION OF LENGTH BEYOND 9 INCHES MAY HAVE PARALLEL SIDES.

6/ 125 EDGE FLATNESS IS REQUIRED IN ACCORDANCE WITH ANSI B46.1.

7/ THE SPECIMEN SHALL BE SYMMETRICAL ABOUT THE VERTICAL CENTERLINE AND ABOUT THE CENTER IN THE GAGE SECTION WITHIN 0.002 INCH.

General Notes:

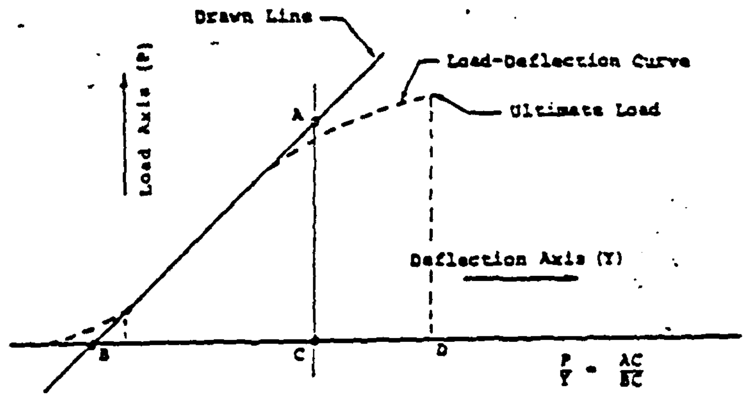
All dimensions in inches.

LAMINATE PLY THICKNESS

STYLE	ORIENTATION	NO. OF PLIES
3K-70-PW	Warp and Fill	12

TENSILE TEST SPECIMEN FOR WOVEN FABRIC (CLASS 2)

Figure 3

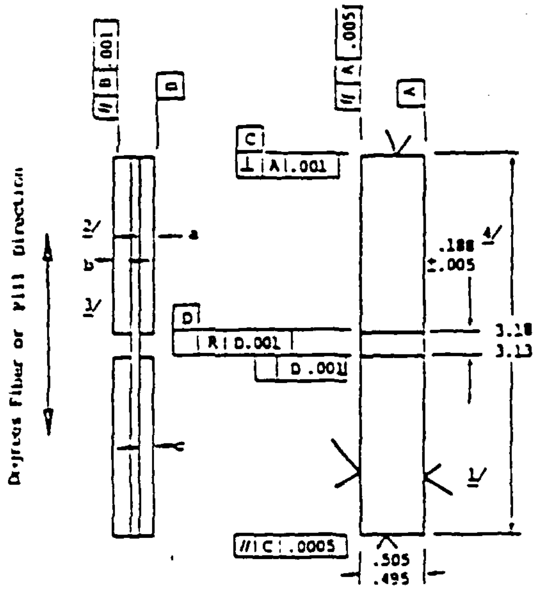


Ultimate Strain = $\frac{BD}{g}$ (where g is the gage length)

NOTE: Measure deflection from zero load to at least 3/4 of expected ultimate load.

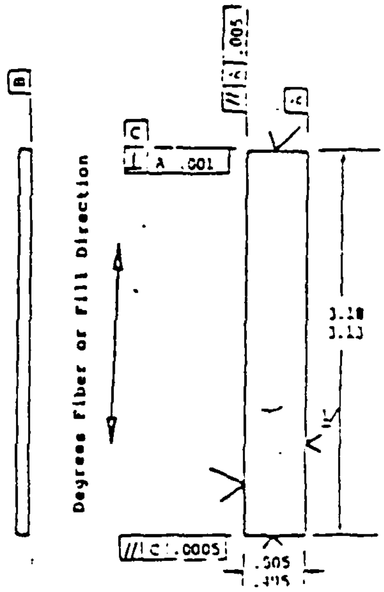
LOAD-DEFLECTION CURVE

Figure 4



COMPRESSION ULTIMATE STRENGTH SPECIMEN

Figure 5a



COMPRESSION MODULUS SPECIMEN

Figure 5b

General Notes:

1. Laminate ply requirements same as for tensile test specimens (Figures 2 and 3).
2. Test in accordance with ASTM D695 in compression fixture using appropriate compressometer.
3. Prepare the specimen prior to bonding the tabs by removing previously applied BMS 15-1, Class 1 impregnated peel ply, by handsanding the bonding area of the test panel with 150 grit sandpaper, sandblasting or sanding the tab to remove all surface gloss, and cleaning thoroughly with acetone or MEK. For tab bonding, 250F curing adhesive (such as BMS 5-80 and BMS 5-101) may be used for tests at 160F and below. BMS 8-245 shall be used for 270F tests and may be used for the lower temperatures.

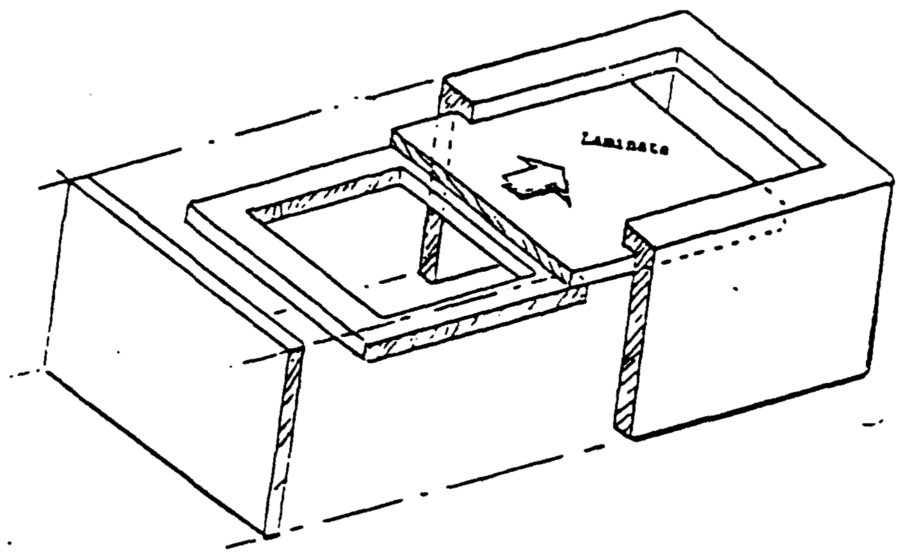
Flagnotes:

1/ 32 edge finish is required in accordance with ANSI B46.1. Edges shall be machined and tested parallel to the fiber direction.

2/ Support tab material shall be typically the same as that being tested. The fiber direction of the tabs shall have the same orientation as that found in the specimen.

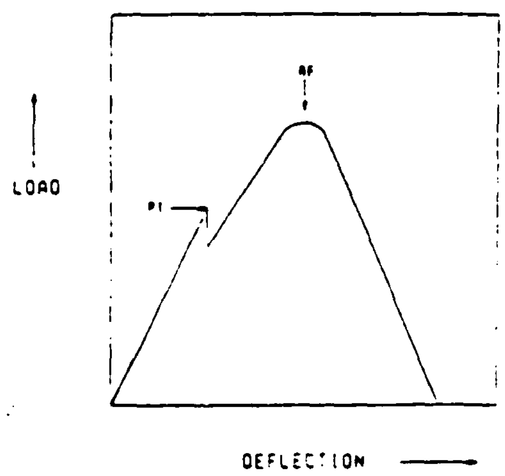
3/ a must equal b to within 0.010 inch and c must equal a to within 0.002 inch.

4/ Edges of opposite side bonded tabs shall match within 0.005 inches.



IMPACT TEST FIXTURE

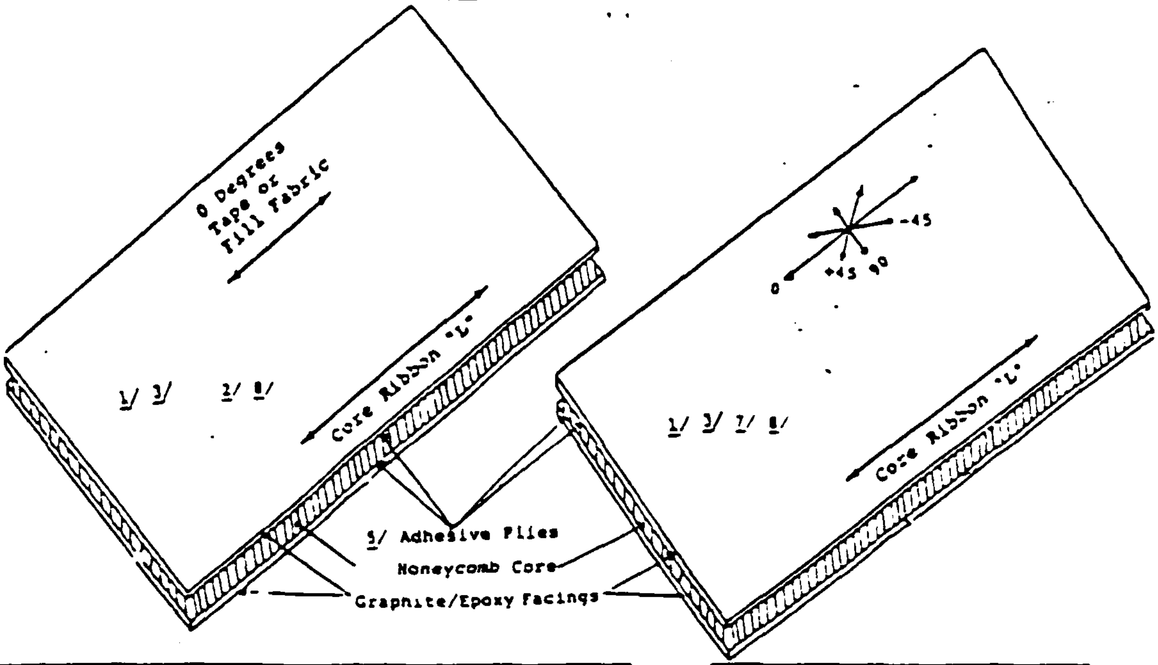
Figure 6



P_I = incipient damage load (matrix fracture)
P_F = fiber fracture load

IMPACT PROPERTY DATA ANALYSIS

Figure 7



CLASS	GRADE/STYLE	NO. OF FACE PLIES AND ORIENTATION LONG BEAM FLEXURE AND FLATWISE TENSION 4/
1	95	(0°/90°/90°/0°)
1	145	(0°/90°/0°)
1	190	(0°/90°)
2	3K-70-PW	2 fill plies

SANDWICH TEST PANEL - 0-90 LAYUP

Figure 8a

BMS 8-256 CLASS	GRADE/ STYLE	NO. OF PLIES AND ORIENTATION 6/
2	3K-70-PW	(±45)/(0/90)

SANDWICH TEST PANEL
QUASI-ISOTROPIC

Figure 8b

1/ Panel dimensions shall be such as to allow machining of the number and kinds of test coupons specified in Sections 8.2.5, 8.2.6 and 8.2.7.

2/ Honeycomb core, BMS 8-124 Class IV, Type V, Grade 8.0, 0.50 ± 0.006 inch thick.

3/ Use of peel ply for flatwise tensile specimens is optional. Do not use peel ply on long beam flexure specimens.

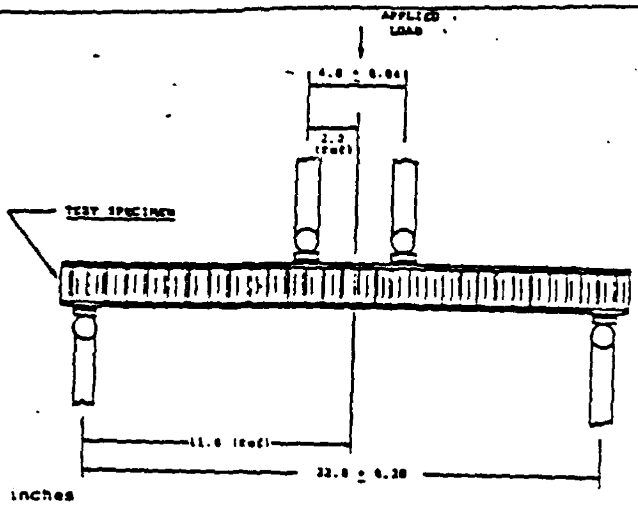
4/ 0 degree ply next to tool.

5/ One ply BMS 8-245 Grade 03.

6/ First ply called out is toolside ply.

7/ Honeycomb core BMS 8-124 Class IV Type V, Grade 3.0, 0.50 ± 0.006 inch thick.

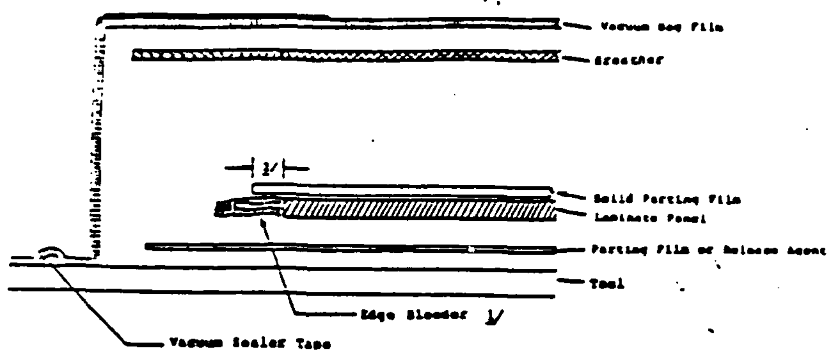
8/ All layups shall be symmetrical about the core centerline.



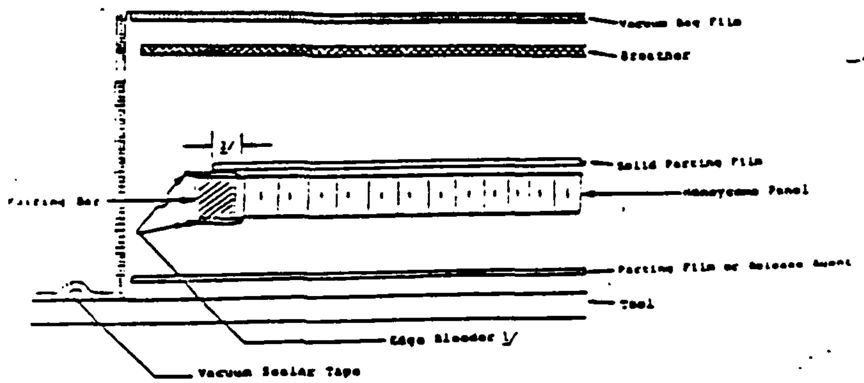
All dimensions in inches

LONG BEAM FLEXURE TEST

FIGURE 8c



Laminate Panel



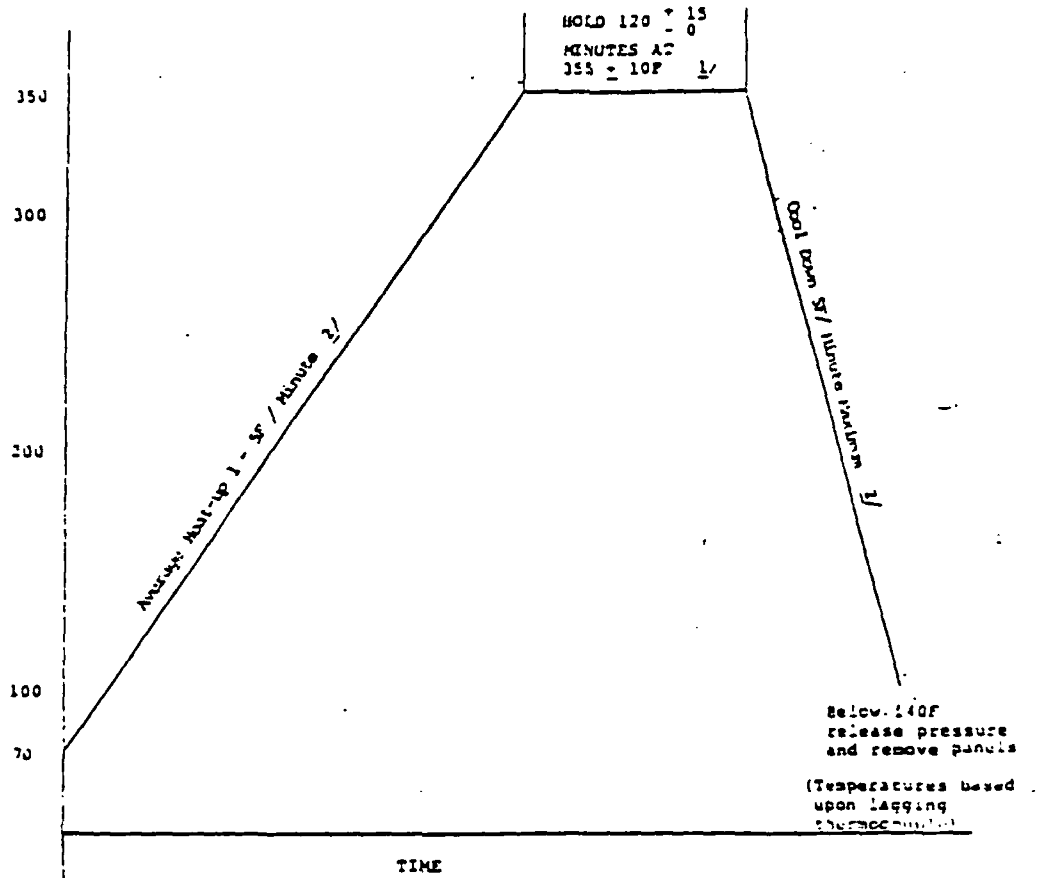
Sandwich Panel

1/ Use a 1-inch minimum width edge bleeder with connection to vacuum source.

2/ Parting film must overlap the edge bleeder a minimum of 1/2 inch.

TYPICAL VACUUM BAG ASSEMBLIES FOR LAMINATE AND SANDWICH PANELS

Figure 9



- Apply 22 inches Hg vacuum minimum to vacuum bag.
- Apply 45 ± 5 psig pressure to autoclave. Vent vacuum bag to atmosphere when pressure reaches 20.
- Pressure under the vacuum bag on each assembly must remain at 0 +5/-0 psig throughout the cure cycle

1/ Time at cure is based on lagging thermocouple.

2/ Measured over 15-minute intervals.

CURE CYCLE

Figure 10

MATERIAL CLASSIFICATION	SUPPLIER PRODUCT DESIGNATION	SUPPLIER	QUALIFYING DIVISION	DATE
Class 2 Type I 3K-70-PW	W3T-282-42-F593-1 W3G-282-42-F593-1	Hexcel Corp. Livermore Plant 10 Trevarno Rd. Livermore, California 94550 Percent Volatiles / Percent Flow 6.0 max. / 4.5 max. 6.0 max. / 4.5 max. Liquid Chromatogram Ratios 1/ R_1 TBD, R_2 TBD, R_3 TBD, R_4 TBD	BCAC	7/2/80
Class 2 Type IV 3K-70-PW	W3T-282-42-F593-18 W3G-282-42-F593-18	Percent Volatiles / Percent Flow 6.0 max. / 4.5 max. 6.0 max. / 4.5 max. Liquid Chromatogram Ratios 1/ R_1 TBD, R_2 TBD, R_3 TBD, R_4 TBD	BMAC	7/15/85
Class 1 Type II Grade 190	T6T190-12-F593-12	Percent Volatiles / Percent Flow 4.0 Max / 19.0 ± 6.0	BMAC	11/30/84

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MATERIAL CLASSIFICATION	SUPPLIER PRODUCT DESIGNATION	SUPPLIER	QUALIFYING DIVISION	DATE
		Fiberite Corporation 501 W. Third Street Winona, Minnesota 55987	BCAC	1/22/81
Class 2 Type I		Percent Volatiles / Percent Flow		
3K-70-PW	HMF-322/81C HMF-322D/81C	2.0 max. 5.0 max. 2.0 max. 5.0 max.		
		Liquid Chromatogram Ratios 1/ R_1 0.275-0.580 R_2 0.052-0.111		
		1/ Definition of ratios and baseline are as agreed to by Boeing and the supplier.		

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F/160

DESCRIPTION: STRUCTURAL TEST PLAN

STATUS: A preliminary structural test plan to test the major LTHD components was developed and is current as of 13 March 1987. Revisions to the first draft have been started by Dave Langerud and are also included in this section.

About 8 potential testing firms have been identified as having the needed facilities. This list was being narrowed down as of 13 March 1987.

AUTHOR: Mike Lemoine, Dave Langerud

NON-COMPOSITE STRUCTURAL TESTING

1.0 STRUCTURAL TESTING

1.1 PURPOSE. This test is intended to verify, through static load tests, the structural integrity of the main components of the Lightweight Towed Howitzer. Components tested shall be the cradle, gimbal, trails, and platform structures. These components shall be tested as an assembled unit under load conditions expected during various firing scenarios.

1.2 TEST EQUIPMENT. The equipment required to perform this test consists of the following:

1) A test facility capable of simultaneously applying an 80,000 lb direct static load and a 42,500 ft-lb torque load.
2) Stress coat paint. (Can we stress coat composite?)
3) Biaxial strain gages.
4) Strain gage monitoring equipment.
5) Connecting hardware for the major components.
6) A means of elevating and training the cradle and gimbal in the platform.
7) Load plates to attach to the cradle at the front and rear manifolds. All applied loads shall be input thru these load plates.
8) A means of simulating the 3900 lb weight of the recoiling components.
9) A backing plate for the spade.

1.3 TEST PROCEDURES.

1) Assemble the howitzer components.
2) Attach the load plates to the cradle at the manifolds.
3) Apply stress coat to areas expected to be highly stressed.
4) Apply the recoiling component load.
5) Position the cradle to 0 degrees elevation and 0 degrees train.
6) Apply a 20,000 lb direct load to the front face of the forward load plate while simultaneously applying a 5,000 ft-lb torque to both the front and rear load plates.
7) Remove the load after 10 seconds and examine the stress coat. Place strain gages accordingly.
8) Take strain measurements while applying the full 80,000 lb direct load to the front load plate and 21,500 ft-lb torque load to each load plate. Apply the load for ten seconds.
9) Remove strain gages and clean off stress coat.
10) Position the cradle to 0 degrees elevation and 22.5 degrees train.
11) Repeat steps 6 through 9.
12) Position the cradle to 72 degrees elevation and 22.5

1.3 TEST PROCEDURES (CONTINUED)

degrees train.

13) Repeat steps 6 through 9.
14) Position the cradle to 72 degrees elevation and 0 degrees train.
15) Repeat steps 6 through 9.
16) Disassemble.

1.4 ACCEPTANCE CRITERIA. The individual components shall show no signs of yielding, cracking, or any other type of permanent deformation. Strain gage readings shall be below ______ psi for Titanium components, below ______ psi for the trail (Aluminum Silicon Carbide composite), and below ______ psi for the cradle (W3X282-42-F593 Graphite Epoxy composite). Welds in areas suspected of overstress shall be radiographed or inspected otherwise to insure soundness.

1.5 CRITICAL TEST CONDITIONS. Pin connections shall be made using the production assembly hardware if possible. Undersized pins or pins of any weaker material than that specified shall not be permitted when substitutions are required. Threaded connections shall use grade 8 capscrews and all capscrews in critical load areas shall be replaced at test completion. The direct static load shall be applied in each case such that it is parallel to the longitudinal axis of the cradle within ___

1.6 TEST SCHEDULE. The individule components will be fabricated by August 14, 1987. Testing can begin on September 1, 1987 and it must be completed by September 18, 1987. A test report shall be submitted no later the 30 days after the conclusion of testing.

Tom — Our test guys need some help — can you assist in filling in some of the blanks etc?
Steve

1.0 STRUCTURAL TESTING

1.1 PURPOSE. This test is intended to verify, through static load tests, the structural integrity of the main components of the Lightweight Towed Howitzer. Components tested shall be the cradle, gimbal, trails, and platform structures. These components shall be tested as an assembled unit under load conditions expected during various firing scenarios.

SPADE

1.2 TEST EQUIPMENT. The equipment required to perform this test consists of the following:

1) A test facility capable of simultaneously applying an 80,000 lb direct static load and a 42,500 ft-lb torque load. / Trade name like Kleenex
2) Stress coat paint. (Can we stress coat composites?)
3) Biaxial strain gages.
4) Strain gage monitoring equipment.
5) Connecting hardware for the major components.
6) A means of elevating and training the cradle and gimbal in the platform. ← TRAVERSE
7) Load plates to attach to the cradle at the front and rear manifolds. All applied loads shall be input thru these load plates.
8) A means of simulating the (3900) lb weight of the recoiling components. ? 6200
9) A backing plate for the spade. ? Battery or Load

Links may be Required Traverse ~ 2 Links QE 2 Links

1.3 TEST PROCEDURES.

1) Assemble the howitzer components.
2) Attach the load plates to the cradle at the manifolds.
3) Apply stress coat to areas expected to be highly stressed.
4) Apply the recoiling component load.
5) Position the cradle to 0 degrees elevation and 0 degrees train. ← TRAVERSE
6) Apply a 20,000 lb direct load to the front face of the forward load plate while simultaneously applying a 5,000 ft-lb torque to both the front and rear load plates.
7) Remove the load after 10 seconds and examine the stress coat. Place strain gages accordingly.
8) Take strain measurements while applying the full 80,000 lb direct load to the front load plate and 21,500 ft-lb torque load to each load plate. Apply the load for ten seconds.
9) Remove strain gages and clean off stress coat.
10) Position the cradle to 0 degrees elevation and 22.5 degrees train. ← TRAVERSE
11) Repeat steps 6 through 9.
12) Position the cradle to 72 degrees elevation and 22.5

Cyl. loads
Stress coat load stress coat unload
Only extensional strains crack
Get compressive stresses as they unload

→ incremental load 25, 50, 75, 100%

Dwgs shall be provided showing location of gauges

1.3 TEST PROCEDURES (CONTINUED)

degrees train. ← TRAVERSE

13) Repeat steps 6 through 9.
14) Position the cradle to 72 degrees elevation and 0 degrees train. ← TRAVERSE
15) Repeat steps 6 through 9.
16) Disassemble.

1.4 ACCEPTANCE CRITERIA. The individual components shall show no signs of yielding, cracking, or any other type of permanent deformation. Strain gage readings shall be below ______ psi for Titanium components, below ______ psi for the trails (Aluminum Silicon Carbide composite), and below ______ psi for the cradle (W3X232-42-F593 Graphite Epoxy composite). Welds in areas suspected of overstress shall be radiographed or inspected otherwise to insure soundness.

1.5 CRITICAL TEST CONDITIONS. Pin connections shall be made using the production assembly hardware if possible. Undersized pins or pins of any weaker material than that specified shall not be permitted when substitutions are required. Threaded connections shall use grade 8 capscrews and all capscrews in critical load areas shall be replaced at test completion. The direct static load shall be applied in each case such that it is parallel to the longitudinal axis of the cradle within ___

1.6 TEST SCHEDULE. The individule components will be fabricated by August 14, 1987. Testing can begin on September 1, 1987 and it must be completed by September 18, 1987. A test report shall be submitted no later the 30 days after the conclusion of testing.

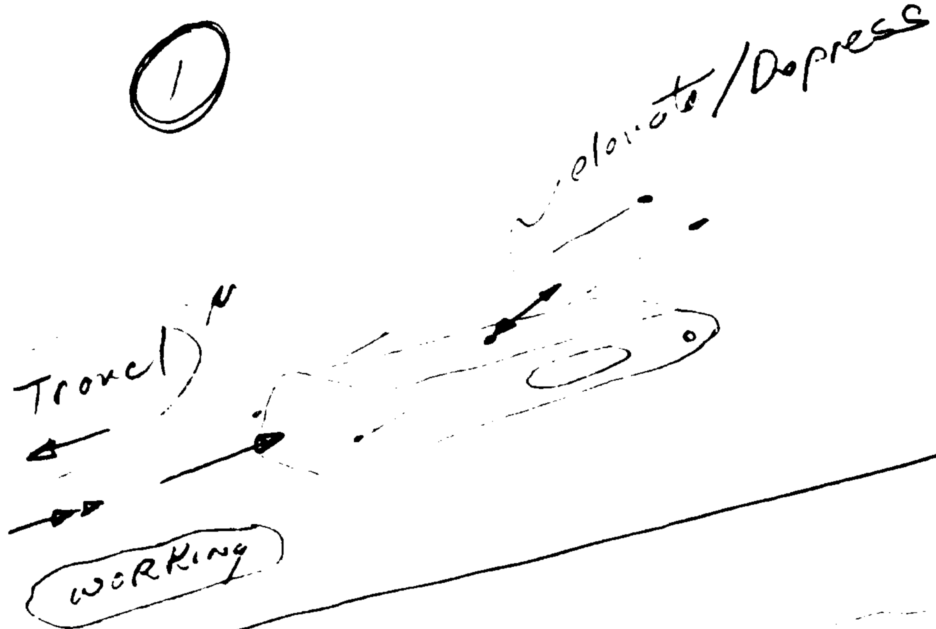
1.0 STRUCTURAL TESTING

1.1 PURPOSE. This Test Program is intended to verify, through static Load Tests, the Structural Integrity of the main components of the lightweight Towed Howitzer. Components tested shall be Cradle, Gimbal, Trails Platform and Spade Structures.

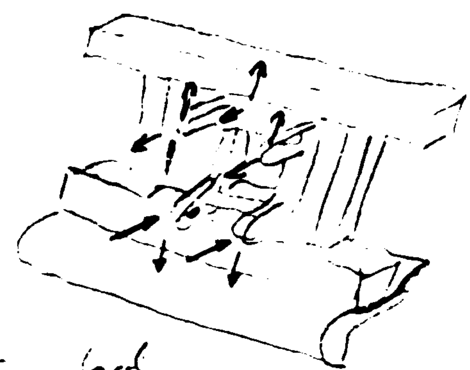
The Spade Platform and Gimbal Shall be Tested as an Assembled unit. The cradle and Trails Shall Be Tested Separately.

These components shall Be Tested under Load conditions expected during various firing scenarios and Towing.

(1)



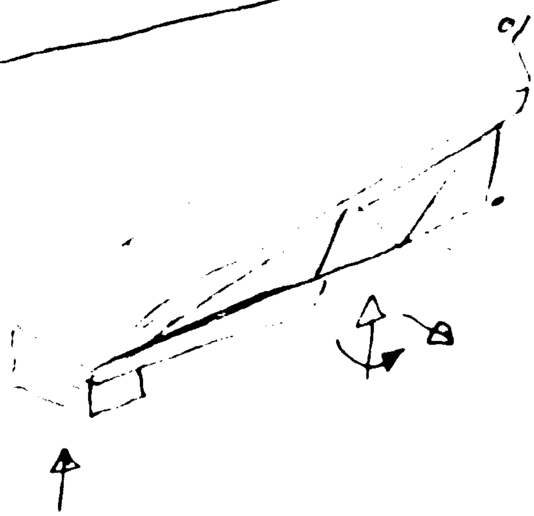
(2)



Working
0 & 22½ Traverse
0 & 72 QE
Support @ spade &
Trail connections

Travel
Support @ Gimbal
Apply loads @ Trail connections

(3)



Travel
working

1.2 CRADLE TEST LOAD CONDITIONS

1) 90,000 LB THrust Load and 26,000 Ft-LB Torque independently and Simultaneously

2) A means of Simulating The 3900 LB weight of The Recoiling Components and Supporting The Cradle via The EQuilobration Cables.

3) Application of 20,000 LB force excerted by The elevation Depression Cylinder

4) 9000 LB Tensile load expected During Towing

5) 30,000 LB Load and 20,000 LB Load Applied at The wheel Bulk Head Connections

6) Spead SHift

1.3 Spade, Platform and Gimbal Test load Conditions

Gimbal to be oriented @ ϕ Deg Traverse and 22 1/2 Deg Traverse

2-9-87
OSL

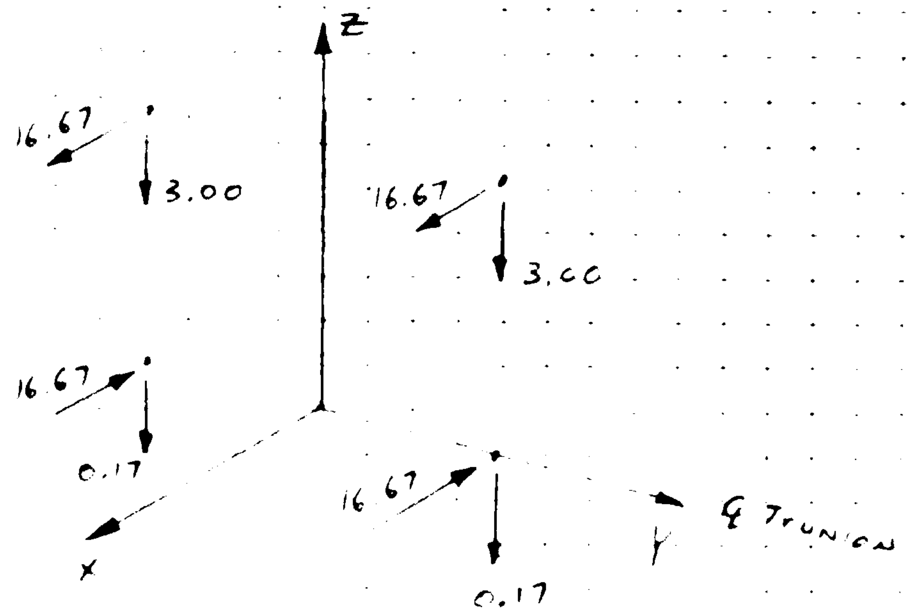
GIMBAL LOADS

CHARGE = 8S ; Recoil Force = 75 Kip
Rifleing Torque = 26,000 ft lb = 312 IN-KIP

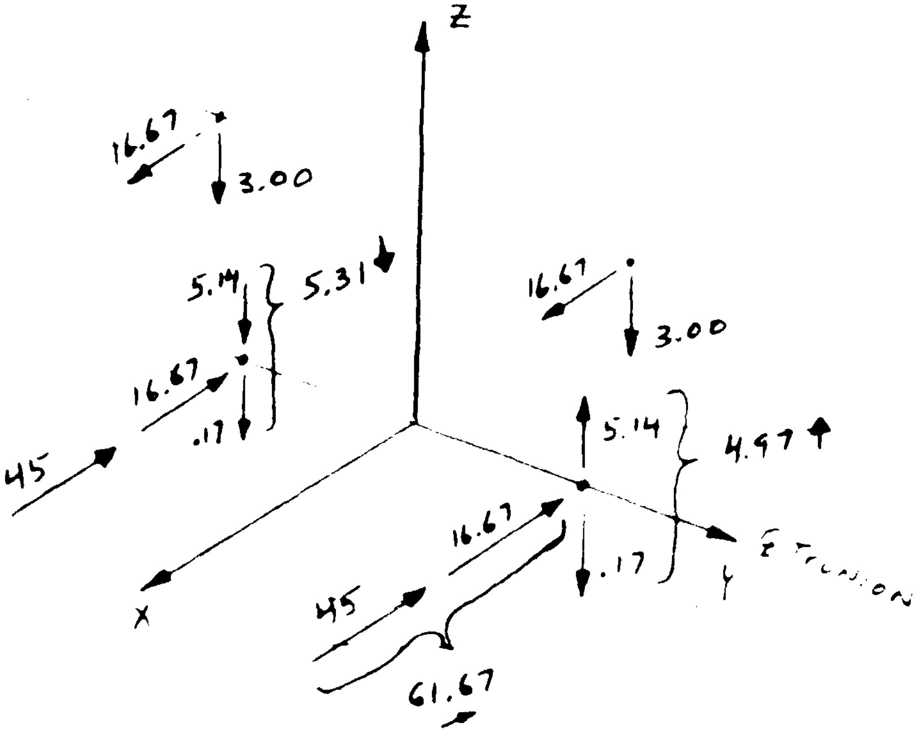
Per Feb 23 Letter from J. Ries & L. Libhardt

Recoil = 75 × 1.2 = 90 Kip
TORQUE = 312 × .65 = 202.8 in Kip
} Static Loads

1. Ø° QE Static @ Battery



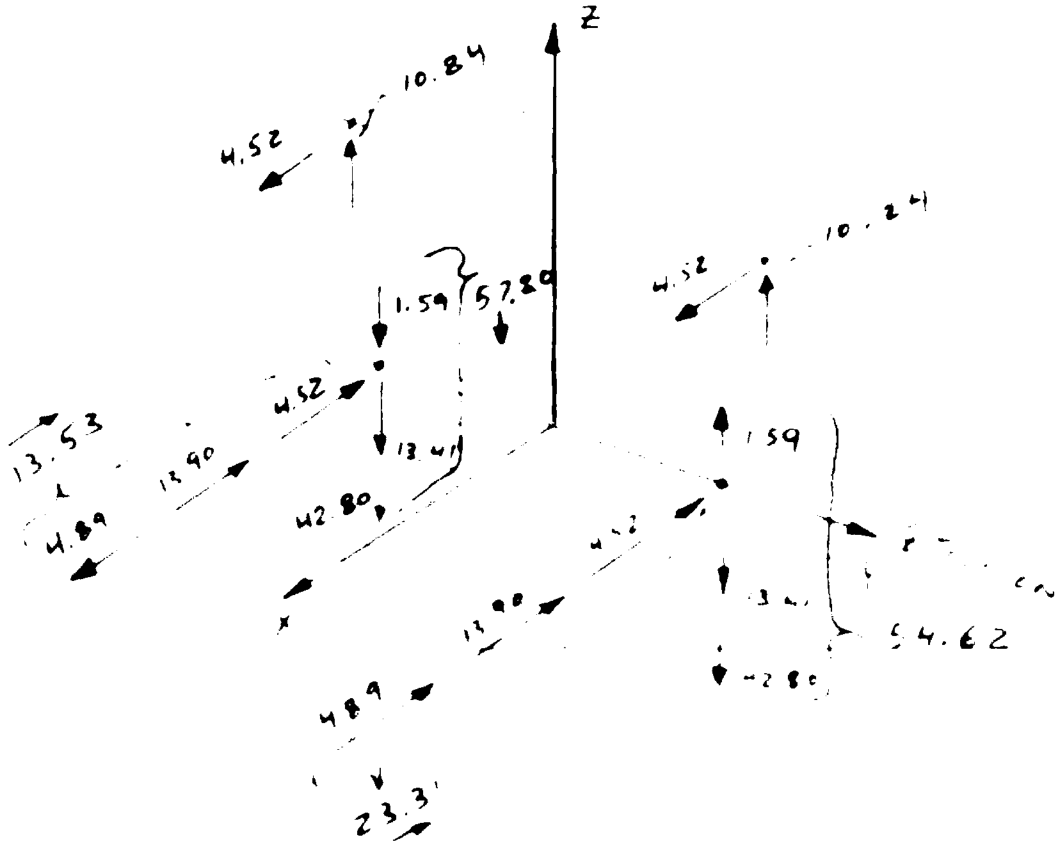
2. ϕ° QE Dead wt + Recoil + Torque



$$\frac{202.8}{39.44} = 5.14$$

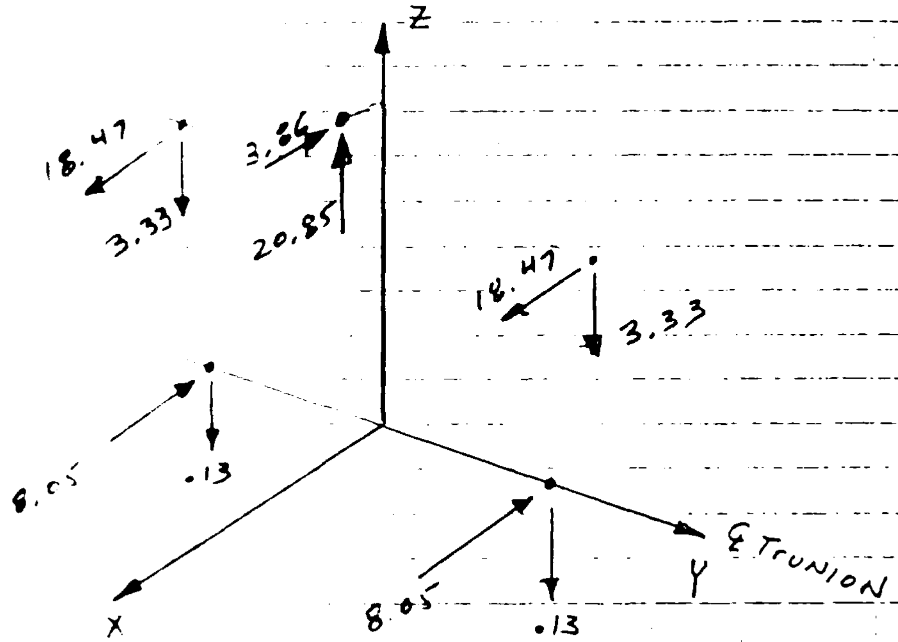
2-9-87
DSL

3. 72° QE Dead Wt + Recoil + Torque



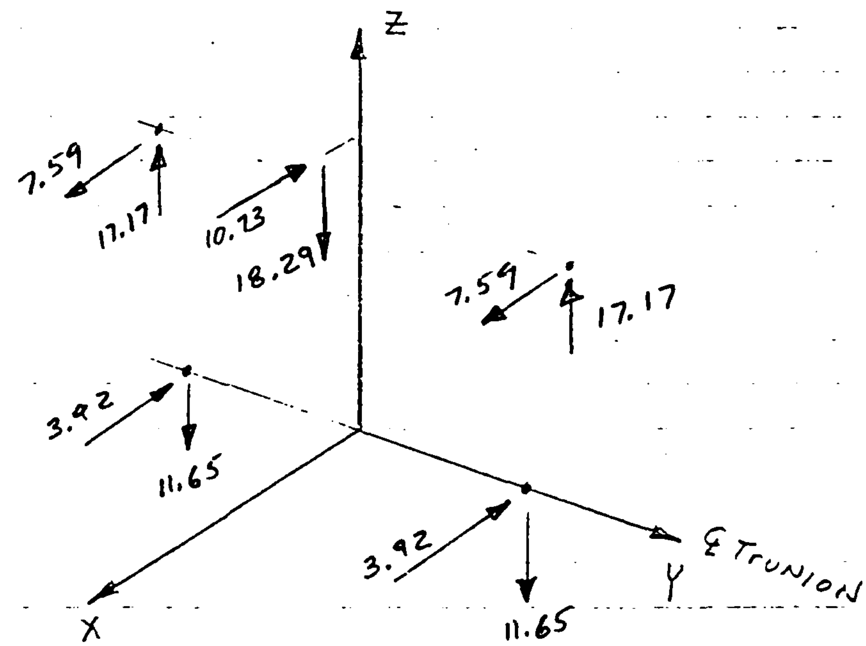
2-9-87 [illegible] 13
DSL

4 0° QE @ LOAD & Depress



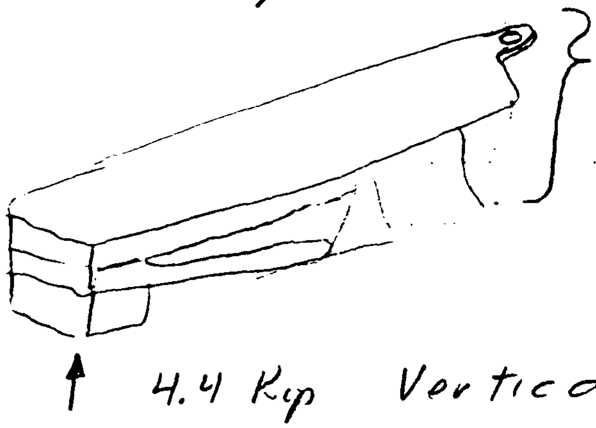
2-9-87
DSL

5) 72° QE @ LOAD, DEPRESS



1.4 Trail Test load Conditions

1) Working Static



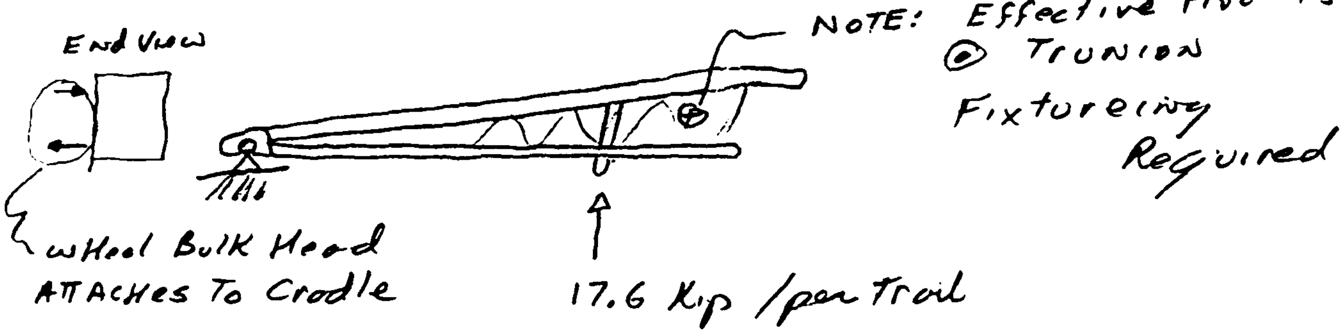
Boundry conditions To simulate working supports

↑ 4.4 Kip Vertical

2) Working Speed Shift

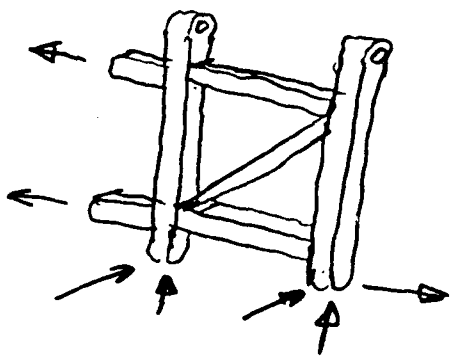
500 LBS

3) Trovel - 4½ G's Vertical

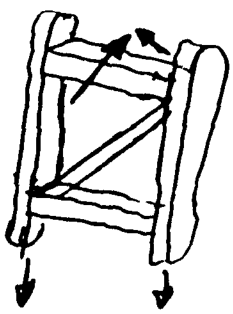


4) Trovel Bump & Skid
Some Boundry condition as (3)

Loads Applied To wheel Bulk Head



5) wheel Actuator forces



F/170

DESCRIPTION: QUALITY ASSURANCE PROGRAM PLAN

STATUS: The Quality Assurance Program Plan was written 30 September 1986 and is current at least to 27 October 1986. A review of the report is needed to determine what changes are required to bring it completely up-to-date.

AUTHOR: Lyman Malberg

E-2691
30 September, 1986

155 MM LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR QUALITY ASSURANCE PROGRAM PLAN

Prepared for:
Commander, U.S. Army
Armament, Munitions and Chemical Command
Dover, New Jersey 07801

Prepared Under Contract:
DAAAK21-86-C-0047

Prepared by:
Lyman L. Malberg
LTHD Project Quality Engineer
FMC Corporation, Northern Ordnance Division
Minneapolis, Minnesota 55421

Approved by:

Robert Rathe
LTHD Program Manager
FMC Corporation, Northern Ordnance Division
Minneapolis, Minnesota 55421

Table of Contents

Section 1
Introduction

This Quality Assurance Program Plan (QAPP) description provides the necessary information concerning quality functions that will be in effect for the Lightweight Towed Howitzer Demonstrator Program at Northern Ordnance Division of FMC Corporation. The information is specifically applicable to the Demonstrator and related hardware for this program.

Section 2
Scope

2.1 Applicability

The FMC Quality Assurance (QA) system applies to all supplies and services manufactured for Phase III of the Lightweight Towed Howitzer Demonstrator (LHTD) project.

2.2 Intent

The QA Program Plan will be in accordance with all aspects of the Statement of Work (SOW) in the contract. This program plan utilizes MIL-Q 9858 and AMCR 700 6 as guidelines.

2.3 Summary

The LTHD quality program is designed to provide adequate quality procedures and controls throughout design, development, fabrication, processing, assembly, inspection, test, maintenance, packaging, shipping, and storage.

Additionally, the quality program has been designed to complement the unique considerations of single-piece fabrication. This plan recognizes the need for research, when necessary, to develop inspection techniques and instrumentation compatible with advanced manufacturing methods and design requirements.

This program provides for the prevention and ready detection of discrepancies, and for timely and positive corrective action. The program also includes effective control of purchased materials and subcontracted work.

All LTHD supplies and services under the contract, whether manufactured or performed within the FMC plant or at any other source, are controlled to ensure conformance to contract and QA requirements.

2.4 Relation to Other Contract Requirements

Any procedure or document executed in the implementation of the QA Program plan is in addition to, and not in derogation of, other contract requirements. If any inconsistency exists between the contract schedule or its general provisions and this document, the contract schedule and its general provisions shall take precedence.

Section 3
Applicable Documents

[illegible] Specifications (Military)

* indicates specification applies as a guide [illegible]

MIL Q 9858A, Quality Program Requirements*

MIL I 45208A, Inspection System Requirements*

MIL STD 45662, Calibration System Requirements

AMCR [illegible] [illegible] AMC Quality Assurance System*

[illegible] Specifications (FMC)

E 900, Calibration Procedures Manual

Applicable portions of E 899, Quality Work Instructions [illegible] referenced in this document [illegible] any other [illegible] [illegible] process)

Section 4
Quality Program Management

4.[illegible] Organization

4.[illegible] LTHD Program Organization

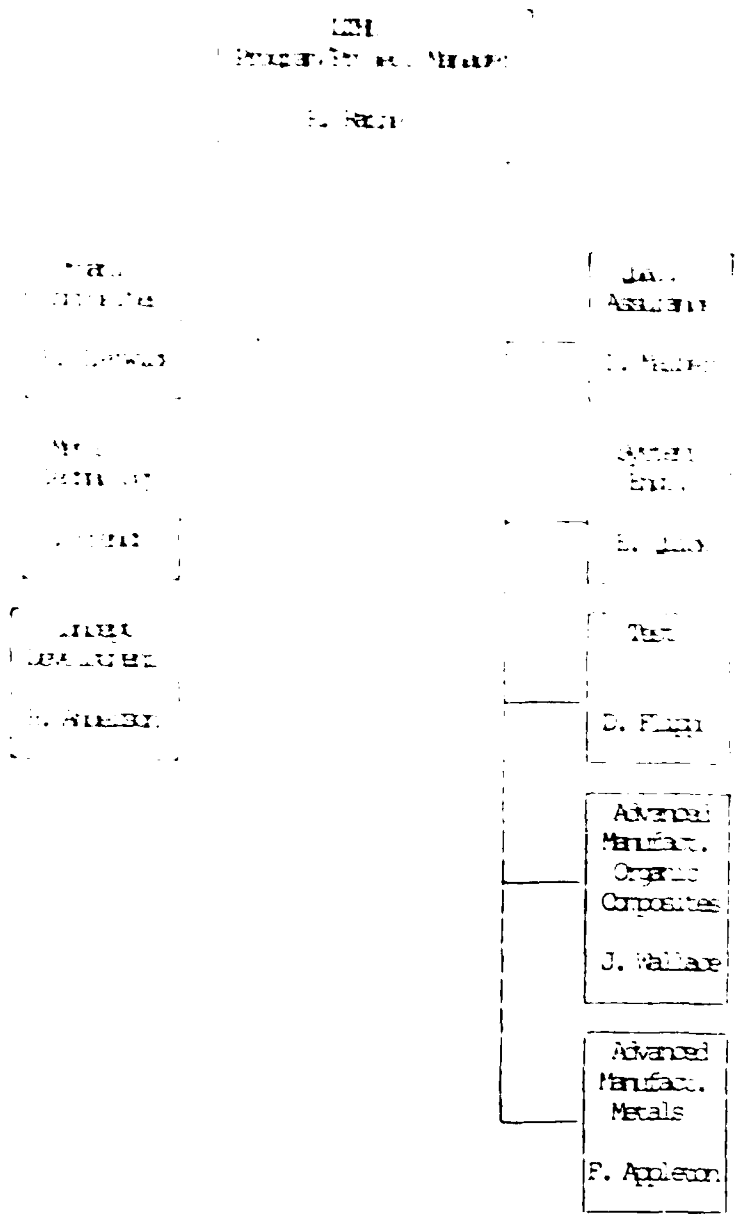
The organization for the LTHD Program is detailed in Figure [illegible]. As illustrated, the LTHD QA Engineer reports to the program manager. The QA Engineer has primary responsibility for providing a system of quality control which ensures compliance with contractual requirements. Recognizing that effective quality control requires appropriate designs and effective manufacturing processes, as well as inspection, the FMC LTHD program is structured to provide quality responsibility within each coordinating department.

4.[illegible] QA Department

The QA Engineer reports to the QA Department Manager as shown in figure 2. The QA Engineer will have access to the facilities, equipment, and manpower of the QA Department.

4.[illegible] Duties and Responsibilities

In addition to the specific quality assurance duties, the Quality Engineer will monitor all other departments to ensure compliance with their respective QA responsibilities, as defined in this plan.



Test
Advanced
Manufact.
Organic
Composites
J. Wallace
Advanced
Manufact.
Metals
F. Appleton

[illegible]

[illegible] Department Manager

[illegible]

[illegible] MRB Supervisor	[illegible] Supervisor	Procure- ment Supervisor	[illegible] Manager	[illegible] Manager	[illegible]
E. [illegible]	[illegible]	R. [illegible]	L. [illegible]	[illegible]	
MRB Data Entry Statistical Reporting Elec. Process Review Metallurgical Process Review Special Projects	[illegible] Training Final Insp.-[illegible]	Procurement Review Receiving Insp. Coordination Source Develop- ment Supplier Documenta- tion Control MRB (Receiving Insp)	NDT Metallurgical Inspection	Mech/Elec Ins [illegible] Machine & [illegible] Tech. Support	[illegible]

[illegible]

[illegible]
[illegible]
Engineering, Advanced Manufacturing with [illegible]
Systems Engineering

METAL MATRIX MATERIALS
Primary Responsibility: Metals Technology
Secondary Responsibility: Quality Assurance, Advanced Manufacturing with Metals, Test, Systems Engineering

YORK AEROSPACE AND MAROTTA SCIENTIFIC SUBCONTRACTS
Primary Responsibility: Metals Technology/Concept Development
Secondary Responsibility: Quality Assurance, Advanced Manufacturing with Metals, Test, Systems Engineering

ALL OTHER MATERIALS/COMPONENTS/PURCHASES/SUBCONTRACTS
Primary Responsibility: Quality Assurance
Secondary Responsibility: Concept Development, System Engineering, Test, Advanced Manufacturing with Metals

c. Maintenance of records to clearly identify procedures and processes utilized in the performance of the contract.
Primary Responsibility: Quality Assurance
Secondary Responsibility: All supporting departments

d. Identification of specific problems and deficiencies; control and review of the corrections in conjunction with Engineering to ensure designs and procedures have been properly modified.
Primary Responsibility: Quality Assurance
Secondary Responsibility: System Engineering, Test

... Configuration Control

a. Design engineering will develop a procedure for documenting and controlling drawing changes. QA will monitor this process once released for manufacture or upon release of a purchase order.

b. New drawings will be prepared as level 2 in accordance with Northern Ordnance Drafting Practices standard as tailored by DI-E-10396. Drawings will be reviewed for technical accuracy and design integrity by the Engineering checker before final approval by the project engineer. The Engineering Standards section will review these drawings for conformance to the level 2 requirements of DOD-D-1000 and the tailoring requirements of DI-E-10396. Drawings prepared by subcontractors will be subject to the same review and control procedures. Drawings will be prepared using ARRADCOM formats, drawing numbers and FSCM's.

Northern Ordnance will control the documentation of new items by following the order of precedence described in MIL-STD-143 and reviewing the DODISS to determine the existence of items suitable of application in the LTHD. Specification Control drawings will be prepared only when no suitable item can be determined to exist.

c. Part numbers received from AMCCOM will be assigned by the project engineer. He will maintain accountability records of such assignment.

d. Drawings will be released for fabrication or procurement by the project engineer. Changes to drawings will be authorized by the project engineer. He will provide distribution and maint... control of any related paperwork.

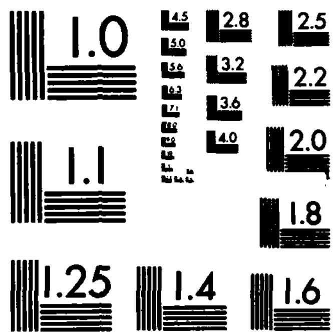
The engineer will specify drawing changes by marking ... the master drawing. The marked up print will be ... the designers and the Project Engineer (or his ...) will become the authorization for fabrication ... changes.

The master drawing will be changed as ind... print, revision level raised, and a des... will be entered in the revision block. ... drawing will be compared with the ... satisfactory the checker will ... will submit for the project eng... engineer will indicate his app... block. The project engine... suitable files in the ... delivery.

AD-A183 996 LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN NORTHERN ORDNANCE DIV R RATHE ET AL APR 87

4/4

UNCLASSIFIED FMC-E-3041-VOL-F DAAA21-86-C-0047 F/G 19/6 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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4.2.3 Calibration

Calibration procedures are all maintained in the Northern Ordnance Calibration Manual, E-900. This document details the format utilized for calibration of all items used in the final acceptance of a component or assembly. This manual is maintained by QA, to further monitor the program, ensuring all procedures are in compliance with the necessary standards. Additional calibration procedures will be initiated and maintained when necessary to accommodate developments in instrumentation.

4.2.4 Purchasing Control

QA or the "primary" responsible department identified in 4.2.1 performs the function of ensuring that products supplied in the performance of the contract meet all specifications necessary to comply with quality and performance requirements. To attain this goal, the following functions will be adhered to:

a. Only those suppliers approved by QA will furnish products used in Phase III of LTHD. Suppliers of raw material or key components (as described in 4.2.2.b) may be initially selected by the cognizant engineer based on ability of the supplier to meet design requirements. In such cases, the cognizant engineer is responsible for surveying and approving the supplier after consulting with QA for quality requirements.

b. All quality and technical certifications required of suppliers with specific products will be identified by the QA department.

c. Procedures for the acceptance of the product will be determined by the "primary" responsible department identified in 4.2.1 after consultation with QA.

d. Maintenance of records concerning the ability of suppliers to meet specified requirements will be completed by QA. This will include initiation of corrective action when necessary.

4.2.5 Manufacturing Control

The following items will comprise manufacturing control in the QA Program

a. Inspection will be performed on all incoming material used in the LTHD. The procedures and plans for inspection will be designed and directed by the "primary" responsible department indicated in 4.2.1, as thought appropriate. All inspection plans, processes, and procedures developed by other departments will be reviewed by QA prior to use.

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b. Design Engineering will specify those requirements necessary to perform at stated capabilities. Inspection operations will then be designated throughout the fabrication, assembly, test, and shipping processes to ensure compliance as thought necessary by QA. Detailed records will be maintained indicating the extent and date of inspection, sample size, accepted and rejected quantities, and inspector. Such records may include, but are not limited to, process sheets, test reports, log books, and inspection plans.

c. Unusual difficulties, questionable conditions and nonconforming material will be identified and segregated from other material. During development and manufacture of the product, Design Engineering and Quality Assurance will evaluate proper disposition of discrepant material. Use of nonconforming or repaired material shall require Government approval.

d. QA will develop procedures for maintaining quality during handling, storage, and delivery all material provided for the LTHD. This will include, for example, such activities as verifying materials with special storage requirements are properly stocked and shelf life items are properly identified.

e. Laboratory testing shall be accomplished by Northern Ordnance Division of FMC Corporation or it's supplier. This testing shall have written laboratory procedure containing information necessary to control the various test principles and quality of the end item.

4.2.6 <u>Inspection Equipment Lists</u>

A Quality Assurance Equipment list will be developed and maintained current by QA with appropriate input from Design Engineering. This list will be indexed by hardware drawing number and will identify equipment required for acceptance inspection.

4.2.7 <u>Statistical Process Control</u>

Where deemed appropriate and useful by QA, statistical process control data will be collected and analyzed by QA for the purpose of determining process capability, process trend analysis, producibility information, and correlation studies. QA will identify characteristics to target for use of statistical process control and document statistical procedures and methodology when used.

QA will coordinate with Advanced Manufacturing departments to develop and monitor process trend charts where deemed appropriate for the demonstrator system.

Pg. 14

4.2.8 Corrective Action

QA will have primary responsibility for corrective action for all purchased and FMC manufactured material and services. QA will interface with other departments as required to determine exact causes and verify timely corrective action is complete and effective.

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Section 5

Product Assurance Testing

5.1 A separate document entitled "Preliminary 155 MM Lightweight Towed Howitzer Demonstrator Product Assurance Test Program Plan" has been prepared. See FMC/NOD Engineering Specification E-2690.

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Section 6
Coordinated Government/Contractor Actions

6.1 Government Inspection

Government inspection at subcontractor or vendor facilities, when identified that inspection of items on vendor or subcontractor premises by the Government is required, arrangements will be made to ascertain this with the vendor or subcontractor by initial identification of this action on the purchase order.

6.2 Government Property

Government property will be received, inspected, documented, maintained, modified, handled, stored, and returned to the Government in accordance with FMC Specification E-899, Quality Work Instructions.

Pg. 1

F/180

DESCRIPTION: PRODUCT ASSURANCE TEST PLAN

STATUS: The Product Assurance Test Plan is current as of 4 March 1987 and reflects the current configuration. A review of the plan prior to the completion of Phase II and during testing would be useful to incorporate necessary revisions.

AUTHOR: Floyd Manson, Dave Flippo, Ellen Brady, Deborah Fellows

NEW

Pg. 2

E-2690
XX APRIL 1987
As of 4 Mar 87

155MM LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR
PRODUCT ASSURANCE TEST PROGRAM PLAN

Prepared for:
Commander, U.S. Army
Armament, Munitions and Chemical Command
Dover, New Jersey 07801

Prepared Under Contract:
DAAAK21-86-C-0047
(Section C para C.2.C.2.e of SOW)

Prepared By:
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Systems RM&A Engineer
FMC Corporation, Northern Ordnance Division
Minneapolis, Minnesota 55421

Contributing Authors:
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Minneapolis, Minnesota 55421

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FMC Corporation, Northern Ordnance Division
Minneapolis, Minnesota 55421

Deborah M. Fellows
Engineer, Advanced Technology FMC Corporation,
Northern Ordnance Division
Minneapolis, Minnesota 55421

Approved by:

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Errol A. Quick
LTHD Project Systems Engineer
FMC Corporation, Northern Ordnance Division
Minneapolis, Minnesota 55421

____
Robert Rathe
LTHD Program Manager
FMC Corporation, Northern Ordnance Division
Minneapolis, Minnesota 55421

FOREWORD

This Product Assurance Test Plan was prepared for the Commander, U.S. Army Armament, Munitions and Chemical Command in compliance with the provisions of Contract DAAAK21-86-C-0047 for Phase II of the Lightweight Towed Howitzer Demonstrator. This plan will meet the requirements identified in paragraph C.2.C.2.e of the Scope of Work. It should also be noted, that this plan is a stand alone plan which is referrenced in Section 5 of the Quality Assurance Program Plan required by the Contract Data Requirements List, Sequence number A023.

It is intended that this plan provides the test and evaluation requirements for the Lightweight Towed Howitzer Demonstrator. This plan will be updated upon comments and funding from the procuring activity or upon the identification of new performance requirements or new technology advances.

This document supercedes all previously distributed Product Assurance Test Program Plans.

Table of Contents

Part 1
INTRODUCTION

Part 2
TEST PROGRAM CONTROL

Table of Contents Continued

Table of Contents Continued

Table of Contents Continued

Table of Contents Continued

155 MM LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PRODUCT ASSURANCE TEST PROGRAM PLAN

PART 1

INTRODUCTION

1.0 SCOPE

1.1 Purpose

This document provides the general plan for assuring the compliance of the Lightweight Towed Howitzer Demonstrator (LTHD) to the quality, operational and reliability performance requirements of the 155 MM Lightweight Towed Howitzer Demonstrator Contract, DAAK21-86-C-0047, and the LTHD Preliminery Design Specification, E-2733.

1.2 Applicability

The provisions of this product assurance test plan are applicability to the demonstration model of the Lightweight Towed Howitzer designed and developed by the Northern Ordnance Division of the FMC Corporation.

1.3 Implementation

This product assurance test plan will be implemented by FMC Northern Ordnance LTHD Program/Project organization. A project test engineer and a project QA Engineer reporting directly to the program manager, will be assigned to implement the entire scope of this plan.

2.0 REFERENCE DOCUMENTS

The following documents of reference form an integral part of this plan to the extent specified herewithin.

2.1 Military Documents

MIL-STD-1944 Polymor Matrix Composites

2.2 LTHD Program Document

E-2691	LTHD Quality Assurance Program Plan
E-2853	155mm LTHD Test Plan dated 13 February 1987
FMC/NOD	LTHD Phase II RAM Approach, 3 September, 1986

2.3 Contractor Documents

E-899C	Quality Work Instructions
E-1099A	Quality Assurance Program

2.4 Trade Association Documents

ASTM - E - 8-84	
ASTM - E -94	
ASTM - E -142	
ASTM - E - 238	Pin-Type Bearing of Metallic Methods
ASTM - C -393	
ASTM - D - 695	Compressive Properties of Rigid Plastics
ASTM - D - 790	Flexible Properties of Unreinforced Forced and Reinforced Plastics and Electrical Insulating Materials
ASTM - D - 792	Specific Gravity and Density of Plastics by Displacement
ASTM - E - 793	Heats of Fusion and Crystallization by Differential Scanning Colormetry (DSC)

ASTM - D - 897	Tensile Properties of Adhesives Bonds
ASTM - D - 1876	Peel Resistance of Adhesives
ASTM - D - 2563	Recommended Practices for Classifying Visual Defects In Glass - Reinforced Plastics Laminates and Parts
ASTM - D - 2584	Ignition Loss of Cured Reinforced Resins
ASTM - D - 2734	Void Content of Reinforced Plastics
ASTM - D - 3039	Tensile Properties of Fiber-Resin Composites
ASTM - D - 3171	Fiber Content of Rosin-Matrix Composites by Matrix Digestion
ASTM - D - 3355	Test Method for Fiber Content of unidirectional, Fiber Composites by Electrical Resistivity
ASTM - D - 3410	Compressive Properties of Unidirectional or Crossply Fiber-Resin Composites
ASTM - D - 3418	Transition Temperatures of Polymers by Thermal Analysis
ASTM - D - 3518	Practice For In-Plane Shear Stress-Strain Response of Unidirectional Reinforced Plastics
ASTM - D - 3528	Strength Properties of Double Lap Shear Adhesive Joints by Tension Loading
ASTM - W - 3532	Gel Time of Carbon Fiber-Epoxy Prereg
ASTM - D - 4065	Determining and Reporting Dynamic Mechanical Properties of Plastics

2.5 Other Documents

Boeing Material Specification 8 - 256F

3.0 DEFINITIONS

This section provides - standardized interpretation of terms and acronyms used within this document.

3.1 Definition of Terms

The definition of terms included in MIL-STD-1098, MIL-STD-721C, and other reference documents listed in Section 2.0 shall apply.

3.2 Definition of Acronyms

AG	Assistant Gunner
ASTM	American Society for Testing and Materials
DSC	Differential Scannings Calorimetry
IWP	Individual Work Packages
LTHD	Lightweight Towed Howitzer Demonstrator
MM	Millimeter
PSCS	Project Status and Control System
PSI	Pounds Per Square Inch
QA	Quality Assurance
WPBPS	Work Package Budget Planning Sheet

155MM LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PRODUCT ASSURANCE TEST PROGRAM PLAN

PART 2
TEST PROGRAM CONTROL

1.0 TEST PLAN MANAGEMENT

The LTHD Test Program shall be managed by both the project quality assurance engineer and the project test engineer. Their dual responsibilities shall include the tracking of task accomplishments and test program reviews.

1.1 Tracking Task Accomplishments

A combination of the Individual Work Package (IWP), Figure 1.1 and the Work Package Budget Planning Sheet (WPBPS), Figure 1.2, provide effective tools for tracking task accomplishments and expenditures. The IWP is approved by the project quality assurance manager. The work performance sheets are approved by program management. Area managers ensure that work being performed correlates with work authorized.

1.1.1 Individual Work Package. The IWP will provide a detailed breakdown and brief description of the hierarchy of tasks and subtasks to be accomplished during the program.

1.1.2 Work Package Budget Planning Sheet. The work package budget planning sheet defines internal milestones (objective indicators) for task or subtask efforts, establishes start and end dates for the work effort, and lays out the monthly budget for accomplishing the task or subtask. Not every subtask defined in the IWP will have an individual budget planning sheet. These forms will be used only at the task hierarchy level deemed necessary for accurate budgetary control.

1.2.2 **Test Program Status Reporting.** Regular, current and disciplined information on test development and accomplishment progress permits management interaction with the planned activities for the next period and enforces a management chain of accountability, responsibility, and communications within the project. A progress report, in FMC Northern Ordnance format, will be delivered to the customer on a scheduled basis. This progress report will address all work performed during the reporting period, any problem areas, and their solution. Photographs close-up and illustrations will be added when appropriate to enhance the clarification of performed work. An outline of projected work that will be completed during the next reporting period will also be addressed. Last of all, a section of the Progress Report will be used to address the overall status of the test program.

Figure 2.1

Individual Work Package

Figure 2.2

Work Package Budget Planning Sheet

2.0 TEST PLANNING AND IMPLEMENTATION

Verification that the LTHD conforms to system requirements will be performed at several different levels of testing within the development program. Test requirements, Part 3, of this document, defines the testing approach and design/performance issues to be addressed by analysis, composites testing, component/subsystem testing, and integrated system testing. A detailed LTHD Test Plan (E - 2853) has been provided to the customer describing the step-by-step conduct of the testing effort. No later than 30 days after each test event, a test report will be completed and provided the customer summarizing significant test findings.

2.1 Low-Risk Hardware Items

Low-risk hardware items will be qualified to meet conformance requirements through analytical examinations. One valid form of analytical verification is the comparison of the item in question with similar existing equipment, which has either passed qualification tests or has demonstrated reliability performance in actual usage. Many purchased items will be qualified by the manufacturer prior to their being received by FMC Northern Ordnance.

Low-risk is defined as a condition where risk is identifiable and would have minor effect or consequence on program objectives, but the probability of occurrence is sufficiently low as to cause no concern. No special program emphasis is required other than normal design group monitoring and control.

2.2 Medium and High-Risk Hardware Items

Medium and high-risk hardware items will be tested to verify hydraulic, functional, and performance requirements. Hydrostatic tests are intended to verify the ability of items to withstand the effects of operating pressures. Functional test will begin at the assembly of moving parts and continue through the subunit/subsystem level.

Medium-risk is defined as a condition where risk is identifiable and its occurrence would affect program objectives, cost, or schedule. Probability of occurrence is high enough to require close control of all contributing factors and establishment of risk milestones and an acceptable fallback position. This level of risk would be handled as an action.

High risk is a condition where there is a high probability of occurrence and the consequence would have a significant impact on the program. This condition could be acceptable for pure research or technology demonstration.

2.3 Composite Material Testing

Composite material testing will be conducted by the contractor and/or subcontractor to verify the integrity of the design and manufacture of composite material.

2.4 Integrated System Testing

Integrated system testing will be conducted to verify system performance capability and the integrated compatibility of subsystems.

2.5 Structural Testing

Structural testing of major components such as the trails, slide and rails, and gimbal will be conducted to verify the integrity of design and manufacturing.

2.6 System Testing

System testing will be conducted to verify performance capability of the LTHD.

3.0 QUALITY CONTROL

The Quality Assurance Program Plan (E - 2691) provides the necessary information concerning quality functions that will be in effect for the Lightweight Towed Howitzer Demonstrator Program at Northern Ordnance Division of FMC Corporation.

3.1 Quality Control During Phase II

Section 5.0 pf the of the Lightweight Towed Howitzer Demonstrator Test Plan (E - 2853) dated 13 February 1987 provides the quatilty control plan which will be exercised during the Phase II composite testing.

155MM LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PRODUCT ASSURANCE TEST PROGRAM PLAN

PART 3
TEST REQUIREMENTS

1.0 GENERAL

General requirements for LTHD testing in order to verify compliance of design, conformance, and to qualify materials are defined and described in this part of the LTHD Product Assurance Test Program Plan.

1.1 General Procedure

Test shall be conducted as per the detailed requirements specified in the continuing section of this document and the LTHD Test Plan (E - 2853) dated 13 February 1987.

1.1.1 Problem Report. Upon failure or non-verification of any test element, a Problem Report shall be initiated and processed. See Figure 3.1.

Figure 3.1

Example, Test Problem Report

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2.0 COMPOSITE MATERIAL TESTING

2.1 Low/High Temperature/High Humidity Material Testing - Tests 1101, 1102, and 1103

2.1.1 Purpose. The purpose of this testing is to verify the mechanical properties of graphite/epoxy composite materials under extreme environmental conditions; hot, wet and sub-zero.

2.1.2 Test Equipment/Apparatus. The following test equipment and/or apparatuses shall be utilized.

1. Low Temperature Sub-Zero: A liquid nitrogen chamber.
2. High Temperature/High Humidity: A constant temperature water bath along with heat lamps in order to maintain the test condition temperature during transfer of samples from bath to testing machines.
3. Tensile Strength Test Machine.
4. Compressive Strength Test Machine.
5. Shear Strength Test Machine.

2.1.3 Test Samples. Details on the test specimens for the tensile, shear and compression tests are listed in paragraphs 2.0.1.2, 2.0.2.2 and 2.0.3.2 of the LTHD Test Plan dated 13 February 1987.

2.1.4 Test Conditions. Test conditions shall be as follows:

1. Low Temperature. The tensile strength test samples shall be cycled down to a temperature of -65±10F throughout (minimum of 12 hours.)
2. High Temperature/High Humidity. The tensile compressive, and shear test samples shall be submerged in water at a constant temperature of 200±10F.

2.1.5 Test Procedure. The test procedure is as follows:

1. Low Temperature. With the specimen set-up in the tensile strength test machine and contained inside the cold temperature chamber, the tensile, shear and compression tests shall be conducted as outlined in the test plan.

2. High Temperature/High Humidity. Using heat lamps to maintain test condition temperature, conduct tensile, compression, and shear tests as outlined in the test plan.

2.1.6 Test Report. The test report shall denote actual and calculated test results of tensile strength, compressive strength, shear modulus, elastic modulus, and poisson's ratios. These measurements shall be in the axial and transverse fiber directions. Resulting values shall be used for LTHD design allowables and reliability data input.

2.1.7 Test Report Distribution. The original copy of each test report shall be maintained by project design engineering. A copy of each test report shall be forwarded to the customer no later than 30 days after test completion. Copies will also be distributed to the following:

1. Advanced Technology Engineering
2. LTHD Project Test Engineering
3. LTHD System Engineering
4. LTHD Project RAM Engineering
5. LTHD Project QA Engineering

2.2 Low/High Temperature/High Humidity Adhesive Test (Double Lap Shear Strength and Flexural Strength Methods) - Test 1110

2.2.1 Purpose. This test vertifies the shear strength of FM 300M adhesive when applied to two different substrates when it is subject to extreme environmental conditions.

2.2.2 Test Materials. The materials to be tested are as follows:

1. FM 300M with W3X282-42-F593 graphite/epoxy composite.
2. HRH 10-1/8-6 honeycomb.

2.2.3 Test Equipment/Apparatus. The test equipment shall consist of, but not limited to the following:

1. Tensile test apparatus with compatible flexural test load fittings.

2. Water tank large enough to hold specimen and maintain a constant water temperature of 200 +10F.

3. A liquid nitrogen chamber.

2.2.4 Test Conditions. The water tank shall be filled with water and heated to a constant temperature of 200}+10F. The specimens shall be sumberged in the 200}F water for 12 hours. The specimens will be placed into the liquid nitrogen chamber and allowed to reach -65 +10F throughtout (12 hours).

2.2.5 Test Procedure. See paragraphs 2.0.4.4 and 2.0.4.5 for test procedures (Test Plan dated 13 February 1987).

2.2.6 Test Report. The test report shall denote the actual results of the adhesive tests of each specimen. Resulting values shall be used for LTHD design allowables and reliability data input.

2.2.7 Test Report Distribution. The original copy of each test report shall be maintained by project design engineering. Results of the tests will be provided to the customer no later than 30 days after test completion. Copies will also be distributed to the following:

1. Advanced Technology Engineering

2. LTHD Project Test Engineering
3. LTHD Project QA Engineering
4. LTHD Project System Engineering
5. LTHD Project RAM Engineering

2.3 Low/High Temperature/High Humidity T-Peel Adhesive Test Test - 1111

2.3.1 Purpose. This test covers the determination of the peel resistance of FM 300M adhesive when applied to a steel substrate and then subjected to extreme environmental conditions. The adhesive systems tested shall be the same as those tested in the previous test, subsection 2.2.

2.3.2 Test Equipment/Apparatus

1. T-Peel Tensile Test Apparatus per ASTM-D-1876.

2. Liquid nitrogen chamber and a constant temperature water bath or equivalent capable of 200 +10F minimum.

2.3.3 Samples and Procedure. Twenty specimens will be tested. See paragraphs 2.0.5.4 and 2.0.5.5 of the test plan dated 13 February 1987.

2.3.4 Test Report. Results of the test will be provided to the customer no later than 30 days after test completion.

2.4 Trunnion Lug Test - Test 1120

2.4.1. Purpose. The purpose of this testing is to verify the sizing of the cradle trunnion lug when exposed to simulated firing loads (compression test) and simulated towing loads (tensile test).

2.4.2 Test Equipment. A tensile and compression test machine with fixtures and grips capable of securing the test specimens.

2.4.3 Test Samples. Two tensile and two compression specimens will be tested. The specimens will match the layup of the current trunnion design.

2.4.4 Test Procedure. The test procedures for the tensile and compression tests are listed in paragraphs 2.0.6.4 and 2.0.6.5 of the test plan.

2.4.5 Test Evaluation and Report. A comparison of the test results data with the analytical predictions shall be conducted. Results of the tests will be provided to the customer no later than 30 days after test completion. Copies will also be distributed to the following:

1. Advanced Technology Engineering
2. LTHD Project Design Engineering
3. LTHD Project QA Engineering
4. LTHD Project RAM Engineering
5. LTHD Project Test Engineering

2.5 Chemical Resistance Testing - Test 1130

2.5.1 Purpose. To assess the effects of hydraulic oil and ethylene glycol solution on graphite/epoxy material properties of laminates used in the LTHD.

2.5.2 Test Equipment. Constant temperature hydraulic oil and ethylene glycol baths.

2.5.3 Test Samples. Ten tensile specimens and ten adhesive shear specimens will be tested.

2.5.4 Test Procedures. Specimens shall be immersed in ethylene glycol 50% solution at 200}F for 48 hours and then in hydraulic oil per MIL-F-17111 at 200}+10F for 48 hours. Detailed test procedures are listed in paragraph 2.0.7.4 of the test plan.

2.5.5 Test Evaluation and Report. Test results shall be compared with the test results of non-exposed samples which were previously tested. Effects on strength and modulus shall be documented. The effects on the design shall be determined and documented.

2.5.6 Test Report Distribution. Results of the tests will be provided the customer no later than 30 days after test completion of the test. A copy of the test report shall be distributed to the following:

1. Advanced Technology Engineering
2. LTHD Project Test Engineering
3. LTHD Project QA Engineering
4. LTHD Project System Engineering
5. LTHD Project RAM Engineering

2.6 Titanium Weld Test - Test 1140

2.6.1 Purpose. To verify the mechnical properties of Titanium weld joints. Tensile strength tests, radiographic inspections and macro-etching inspections will be conducted.

2.6.2 Test Equipment. The test equipment shall consist of, but not be limited to the following:

1. Tensile test machine
2. A biaxial extensometer which is compatible with the tensile test machine.
3. Etchants as required for macroscopic examination of the weld joints in accordance with ASTM - E -407-70.
4. X-ray facility capable of radiographic inspection.

2.6.3 Test Samples. Ten plate specimens will be tested.

2.6.4 Test Procedure. Details on test procedures are listed in paragraphs 2.1.1.4, 2.1.1.5, and 2.1.1.6 of the test plan.

2.6.5 Test Evaluation. Acceptance criteria is as described in paragraph 2.1.1.7 of the test plan dated 13 February 1987.

2.6.6 Test Report Distribution. Results of the tests will be provided the customer no later than 30 days after test completion. Copies of the test report will be distributed as indicated in paragraph 2.5.7 above.

2.7 Aluminum Silicon Carbide Weld Test - Test 1150

2.7.1 Purpose. To verify the mechnical properties of Aluminum Silicon Carbide weld joints. Tensile strength tests, radiographic inspections and macro-etching inspections will be conducted.

2.7.2 Test Equipment. The test equipment required for these tests is as listed in paragraph 2.6.2 above.

2.7.3 Test Samples. Ten plate specimens will be tested for each test. Specimens will be machined from a welded panel made by butt-welding two .125 inch plates per MIL-STD-1595.

2.7.4 Test Procedure. Details on test procedures are listed in paragraphs 2.1.2.4, 2.1.2.5, and 2.1.2.6 of the test plan.

2.7.5 Test Evaluation. Acceptance criteria is as described in paragraph 2.1.2.7 of the test plan dated 13 February 1987.

2.7.6 Test Report Distribution. Results of the tests will be provided the customer no later than 30 days after test completion. Copies of the test report will be distributed as indicated in paragraph 2.5.7 above.

2.8 Vendor Process Qualification Test - Test 1160

2.8.1 Purpose. To verify the vendor's processing of W3X383-42-F593 composite material.

2.8.2 Test Equipment. The test equipment shall consist of, but not be limited to the following:

1. Tensile test machine
2. A load indicator.
3. An extenspmeter that is compatible with the tensile test machine.

2.8.3 Test Samples. Ten plate specimens will be tested. Details of specimen sizes and layup are cutlined in paragraph 3.0.1.2 of the test plan.

2.8.4 Test Procedure. Tensile strength, elastic modulus and Poisson"s ratio will be determined.

2.8.5 Test Evaluation. A statistical analysis will be performed on the test results to establish a standard deviation and mean. The results will be accepted if there is a 99% probability of falling within one standard deviation of the mean.

2.8.6 Test Report Distribution. Results of the tests will be provided the customer no later than 30 days after test completion. Copies of the test report will be distributed as indicated in paragraph 2.5.7 above.

3.0 COMPONENT INSPECTION

Component inspection shall be accomplished by the Quality Assurance Department under the direction of the LTHD project QA engineer with assistance from the LTHD project test engineer. Piece parts shall be inspected upon receipt or manufacture for acceptance per drawing specifications. If any component is found to be out of drawing tolerance, it will be documented on a problem report (see Figure 3.1) and corrected in the best method to ensure a reliable component at the next level of assembly.

4.0 INTEGRATED SYSTEM TESTING

4.1 Subunit Hydrostatic Testing

Subunit hydrostatic testing shall confirm system hydraulic component integrity. Testing will verify that component design, manufacturing process, and sublevel assembly techniques have been performed per system requirements. Cause for rejection shall include: wall/vessel rupture, component distortion, significant internal leakage above design calculations, or any exterior leakage. In addition, any unspecified abnormality experienced during testing as determined by the Test Engineer may be grounds for rejection.

Each hydraulically controlled subunit shall be hydrostatically tested at one and one half times the nominal operating pressure for period not less than 10 minutes per hydraulic cavity. Those cavities normally pressurized at return or head pressure shall be tested at 50 PSI +/- 5 PSI for not less than 10 minutes.

The following assemblies shall be subjected to hydrostatic testing:

4.1.1 Gunner's Manifold Assembly

4.1.2 Assistant Gunner's Manifold Assembly

4.1.3 Cannoneer's Manifold Assembly

4.1.4 Traverse Cylinder Assembly

4.1.5 Front Slide Manifold Assembly

4.1.6 Elevation Cylinder Assembly

4.1.7 Recoil Assembly

4.1.8 Mid-Slide Manifold Assembly

4.1.9 Equilibrator Cylinder Assembly

4.1.10 Counter-Recoil Cylinder Assembly

4.2 Subunit Hydraulic Functional Testing

Subunit hydraulic functional testing shall confirm system hydraulic component operation prior to next level of assembly. Testing will verify component design, manufacturing process, and sublevel assembly techniques have been performed per system requirements. Cause for rejection shall include, internal pistons, valves, or linkages which bind, score, or actuate erratically. Leakage during actuation will not be acceptable. In addition, any unspecified abnormality in operation that is encountered during testing by the Test Engineer shall be grounds for rejection.

The following subunits shall be subjected to hydraulic functional testing:

4.2.1 Elevation Cylinder Assembly

4.2.2 Gunner's Manifold Assembly

4.2.3 Assistant Gunner's Manifold Assembly

4.2.4 Cannoneer's Manifold Assembly

4.2.5 Front Slide Manifold Assembly

4.2.6 Mid-Slide Manifold Assembly

4.2.7 Counter Recoil Cylinder Assembly

4.2.8 Traverse Cylinder Assembly

4.2.9 Equilibrator Cylinder Assembly

4.3 Recoil Cylinder Flow Test

To be determined.

5.0 STRUCTURAL TESTING

5.1 Cradle Trunnion Structural Joint Test - Test 1201

5.1.1 Purpose. The purpose of this test is to determine the integrity of the cradle trunnion joint section during imparted simulated firing loads of up to one and one-half the expected calculated maximum impluse load. The actual strength of the composite LTHD trunnion joint shall be measured.

5.1.2 Test Equipment/Apparatus. Test equipment shall consist of, but not limited to, the following:

1. Simulated cradle trunnion joint mock-up.
2. Hydraulic ram cylinder.
3. Mock-up interface fixture (plate and trunnion devices).
4. 5000 PSI hydraulic power supply.
5. 36 inch drill base.

5.1.3 Test Procedure. The sample shall be loaded through the pivot points with the identical bushings and hardware as designed for the LTHD. Details of the procedures to be followed are listed in paragraph 4.0.5 of the test plan.

5.1.4 Test Evaluation and Report. Test data results shall be documented and compared with calculated joint strength data. The actual test data and the evaluation results shall be documented in a written report. A use-as-is determination will be considered. Recommendations to improve the joint design or additional testing may also be considered.

5.1.5 Test Report Distribution. The original copy of each test report shall be maintained by project design engineering. Results of the test will be provided to the customer no later than 30 days after test completion. Copies of the test report shall be distributed to the following:

1. Advanced Technology Engineering
2. LTHD Project Test Engineering

3. LTHD Project QA Engineering
4. LTHD Project System Engineering
5. LTHD project RAM Engineering

5.2 Trails Structure Testing

To be determined.

5.3 Cradle Structure Testing

To be determined.

5.4 Gimbal Structure Testing

To be determined.

5.5 Platform Structure Testing

To be determined.

6.0 SYSTEMS TESTING

System level testing shall confirm the operational performance of LTHD. Each system operational component shall be exercised to verify that it will operate per design requirements and limits. Preliminary system testing will be performed at FMC/NOD prior to Demonstrator Testing. This testing will be Non-destructive in nature and performed to verify the functional capabilities of LTHD. Causes for rejection may include: Component failure, system leakage, operating out of design limits, failure to meet operating velocities, personnel or equipment safety hazard, or any unspecified abnormality as determined by the Test Engineer conducting to test.

6.1 System Alignment Test

6.1.1 Traverse Positions.

Verify that the Howitzer traverse system positions the cradle assembly. Verify and record the maximum operating limits in azimuth.

6.2.2 Traverse Plane.

Verify system traverse plane with the howitzer leveled, using a Gunner's Quadrant. Operate the traverse system through it's operational limits, and record readings of the Gunner's Quadrant for the specified positions:

CRADLE POSITION	QUADRANT READING
0 DEGREES	______ MIN.
+5 DEGREES	______ MIN.
+10 DEGREES	______ MIN.
+15 DEGREES	______ MIN.
+20 DEGREES	______ MIN.
+25 DEGREES	______ MIN.
+27 DEGREES	______ MIN.
-27 DEGREES	______ MIN.
-25 DEGREES	______ MIN.
-20 DEGREES	______ MIN.
-15 DEGREES	______ MIN.
-10 DEGREES	______ MIN.
- 5 DEGREES	______ MIN.

6.1.3 Elevation Position. Verify that the howitzer elevation system positions the slide assembly. Verify and record the maximum operating limits of the elevation system.

6.1.4 Slew In Elevation Travel. Verify elevation slew at the specified positions. Using a plumb line and telescope verify and record the slew in elevation travel from maximum depression to no less than 45° elevation.

AZIMUTH POSITION	SLEW RATE
0 DEGREES	________MIN.
+10 DEGREES	________MIN.
+25 DEGREES	________MIN.
-25 DEGREES	________MIN.
-10 DEGREES	________MIN.

6.2 Cradle Assembly Operational Test

6.2.1 Load Tray. Verify that the cradle assembly load tray operates smoothly in the cradle without binding or restriction.

Verify that the load tray properly positions in the cradle for projectile ramming.

Verify Projectile seating distances for various types of simulated 155MM ammunition.

Verify load tray velocities at the following elevations for projectile loading. Record and compare the load tray velocities with those calculated.

ELEVATION POSITION	TRAY VELOCITY
Max. Depression	________IPS
0 Deg. Elevation	________IPS
15 Deg. Elevation	________IPS
45 Deg. Elevation	________IPS
60 Deg. Elevation	________IPS
72 Deg. Elevation	________IPS

6.2.2 Primer Autoloader. Verify the operation of the primer autoloader is functional. Verify that all safety aspects of the primer autoloader are operational. Perform simulated misfire conditions and verify primer extraction.

6.2.3 Howitzer Emplacement Test. Verify that the LTHD Howitzer can be emplaced by a crew of four personnel. Verify that all mechanisms are operational at the completion of emplacement. Verify that this procedure can be accomplished in four minutes or less. Document any and all equipment and personnel safety considerations.

6.2.4 Howitzer Speed Shifting Test. Verify that the LTHD Howitzer can be speed shifted by a crew of four personnel. Verify that all mechanisms remain functional for shift requirements. Verify that this procedure can be accomplished in four minutes or less. Document any and all equipment and personnel safety considerations.

6.2.5 Howitzer Displacement Test. Verify that the LTHD Howitzer can be displaced by a crew of four personnel. Verify that all mechanisms are functional at the completion of displacement. Verify that this procedure can be accomplished in four minutes or less. Document any and all equipment and personnel safety considerations.

6.2.6 Towing Stability Test Verify through rough terrain or simulated rough terrain environment that LTHD can withstand the shock, loading, and stress without structural or component damage. Verify that all aspects of system operation are functional at the completion of this procedure.

6.2.7 Load Displacement Test Verify load displacing characteristics of LTHD at various cannon positions. Verify load displacement with the cannon positioned in battery, at load position, and out of battery. Record and determine center of gravity for all positions.

6.3 System Proof Firing Test

Verify that LTHD can withstand the structural effects of proof firing conditions. Verify that all system components remain operational during and after completion of each firing exercise. Instrument and record all data pertaining to pressures, structural deviations, recoil/counterrecoil velocities, muzzle overpressures, and load displacements.

END
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