

DTIC FILE COPY

2

AD

AD-E402 080

AD-A228 932

Contractor Report ARFSD-CR-90014

VOLCANO XM89 TRAINING CANISTER

T. P. Herbert
Honeywell, Inc.
Defense Systems Group, Code 08638
5640 Smetana Drive
Minnetonka, NM 55343

N. Cutillo
Project Engineer
ARDEC

DTIC
ELECTE
NOV 15 1990
S B D

June 1990



US ARMY
ARMAMENT MUNITIONS
& CHEMICAL COMMAND
ARMAMENT RDE CENTER

**U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND
ENGINEERING CENTER**

Fire Support Armaments Center

Picatinny Arsenal, New Jersey

Approved for public release; distribution unlimited.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

The citation in this report of the names of commercial firms or commercially available products or services does not constitute official endorsement by or approval of the U.S. Government.

Destroy this report when no longer needed by any method that will prevent disclosure of contents or reconstruction of the document. Do not return to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		Approved for public release; distribution unlimited.			
4. PERFORMING ORGANIZATION REPORT NUMBER(S)		5. MONITORING ORGANIZATION REPORT NUMBER(S) Contractor Report ARFSD-CR-90014			
6a. NAME OF PERFORMING ORGANIZATION Honeywell Inc.	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION ARDEC-FSAC Mines and Demolition Div. (SMCAR-FSM-S)			
6c. ADDRESS (City, State, and ZIP Code) Defense Systems Group, Code 08638 5640 Smetana Drive, Minnetonka, MN 55343		7b. ADDRESS (City, State, and ZIP Code) Picatinny Arsenal, NJ 07806-5000			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION ARDEC, 1MD STINFO BR	8b. OFFICE SYMBOL (If applicable) SMCAR-IMI-I	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAK10-83-C-0059			
8c. ADDRESS (City, State, and ZIP Code) Picatinny Arsenal, NJ 07806-5000		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) VOLCANO XM89 Training Canister					
12. PERSONAL AUTHOR(S) N. Cutillo, ARDEC Project Engineer, T.P. Herbert, Honeywell Technical Director					
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM <u>5/89</u> TO <u>6/90</u>	14. DATE OF REPORT (Year, Month, Day) 5 June 1990	15. PAGE COUNT 52		
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)			
FIELD	GROUP	SUB-GROUP	VOLCANO XM89 Training Canister		
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
This report covers the development phase of the VOLCANO XM89 Training Canister and includes a system technical description and discussions of each engineering task as well as ILS activities. Hardware development sections include requirements and specifications, a general design history, and design details.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL I Haznedari		22b. TELEPHONE (Include Area Code) AV680-3316	22c. OFFICE SYMBOL SMCAR-IMI-I		

**XM89 TRAINING CANISTER
FINAL REPORT, A197**

TABLE OF CONTENTS

1.0	Introduction	4
2.0	XM89 Training Canister Design	4
2.1	General Description and Requirements	4
2.2	Design History	7
2.3	Major Component Design	9
3.0	Test and Evaluation	19
3.1	General	19
3.2	Objectives	19
3.3	Engineering Tests	19
3.4	Conclusions	23
4.0	Reliability	26
4.1	Failure Analysis	26
4.2	Reliability Program Support	26
5.0	Safety	26
5.1	Preliminary Hazard Analysis	29
5.2	Safety Assessment Report	29
6.0	Human Factors	29
6.1	Human Factors Test	29
6.2	HEDAD-O	30
7.0	Production	31
7.1	Production Design Support	31
7.2	Production Build	31
7.3	Tooling	32
7.4	Producibility Highlites	34
7.5	Future Product Enhancements	35
8.0	Quality	36
8.1	Quality Development Support	36
8.2	Quality Production Support	39
9.0	Integrated Logistics Support	41
9.1	LSA Program	41
9.2	Technical Manual	43
9.2.1	Technical Manual Development Schedule	49
9.2.2	Technical Manual Data Develop. & Organization	49
10.0	Distribution List	52

LIST OF FIGURES

1 - 1	XM89 Training Canister Development Schedule
2 - 1	XM89 Training Canister Assembly
2 - 2	Breech and Connector Assembly
2 - 3	Breech Assembly
2 - 4	Cable Assembly
2 - 5	Heavywall Tube
2 - 6	Switch Knob
2 - 7	Switch Plate
2 - 8	Tube Cover Plate
3 - 1	Integrated Test Schedule
3 - 2	Prototype Test Outline
3 - 3	Qualification Test Outline
7 - 1	Final Assembly Fixture
8 - 1	Assembly Inspection Procedure
8 - 2	XM89 Training Canister Tester
9 - 1	XM89 Training Canister Repair Analysis

LIST OF TABLES

2 - 1	XM89 Training Canister Concept Trade-off
3 - 1	XM89 Training Canister Requirement Verification
4 - 1	Failure Analysis Summary
5 - 1	Hazard Analysis Worksheets
8 - 1	Waiver and Deviation Summary



Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

1.0 INTRODUCTION

This XM89 training canister final report is submitted in fulfillment of CDRL No. A197 of contract DAAK10-83-C-0059 and describes the development phase of the VOLCANO XM89 training canister. Figure 1-1 shows the development schedule for the XM89 training canister.

2.0 XM89 TRAINING CANISTER DESIGN

2.1 General Description and Requirements

The XM89 training canister (figure 2-1) is a reusable, totally inert canister with a primary function to aid in the training of personnel of the operation and maintenance of the VOLCANO mine dispensing system. The XM89 training canister is a no-maintenance item with a total life expectancy equal to or exceeding 50 training cycles. The major components of the XM89 training canister are the breech, Heavywall tube, end cap, switch mounting plate, rotary four position switch, connector, resistor and fuse. The XM89 training canister is physically comparable to the M87 and M88 canisters and is capable of inducing faults into the VOLCANO system via the four position rotary switch. The XM89 training canister was designed with four switch positions to simulate the following:

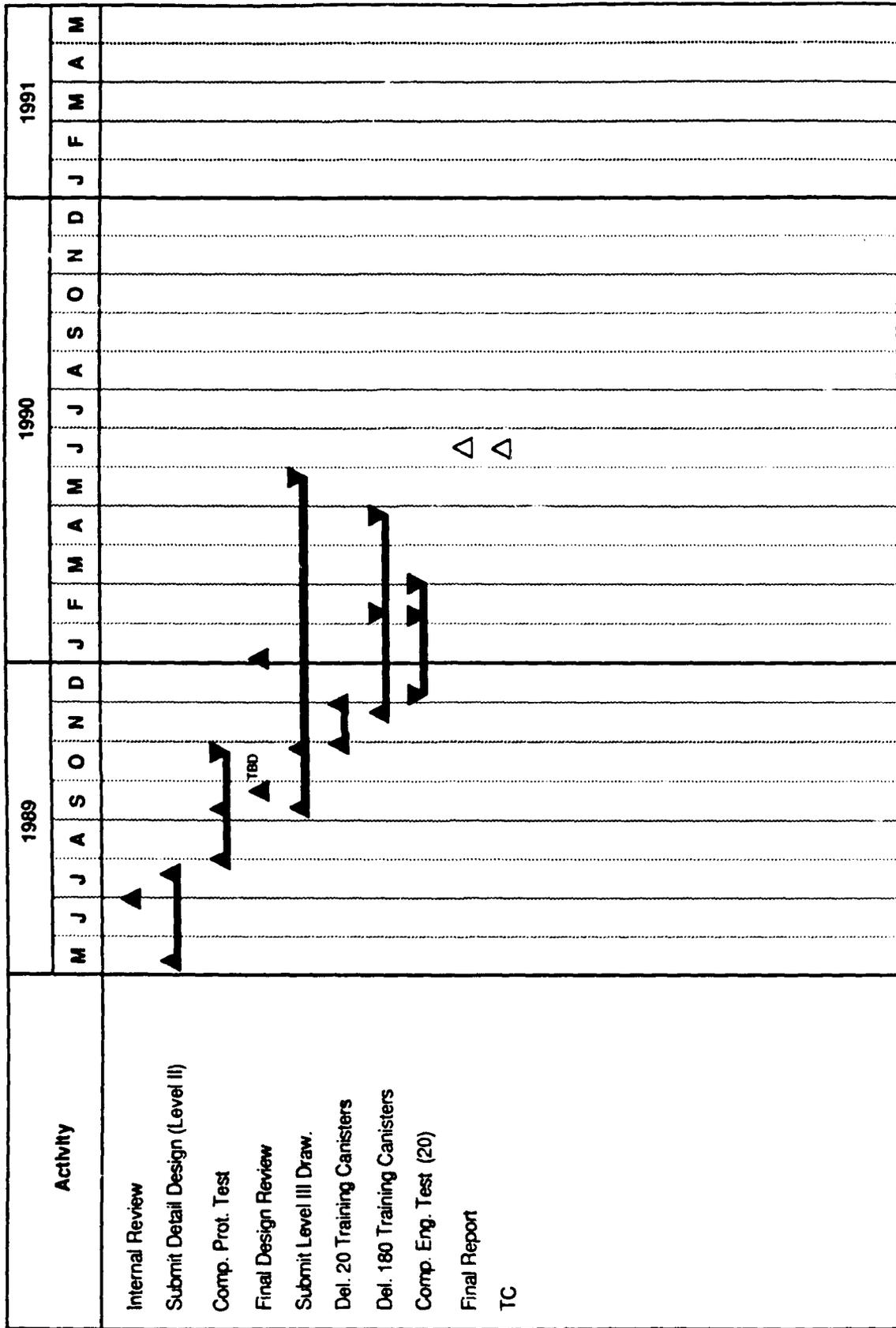
- 1.) Position 1 simulates a functional canister.
- 2.) Position 2 simulates an error code 4, shorted electric primer.
- 3.) Position 3 simulates an error code 8, rack electronics failure.
- 4.) Position 4 simulates an error code 9, open electric primer.

The XM89 training canister is distinguishable from the M87 and M88 canisters by its color (blue with no color bands indicating a totally inert munition).

The general requirements of the contract for the XM89 training canister are provided below:

- 1.) The XM89 training canister shall conform to the overall dimensional envelope of the M87 canister.
- 2.) The weight of the XM89 training canister shall be 30 ± 1 lbs.
- 3.) The center of gravity shall be midway ± 0.5 inch along the longitudinal axis of the canister.
- 4.) The XM89 training canister shall have markings distinguishing it from the M87 and M88 canisters.

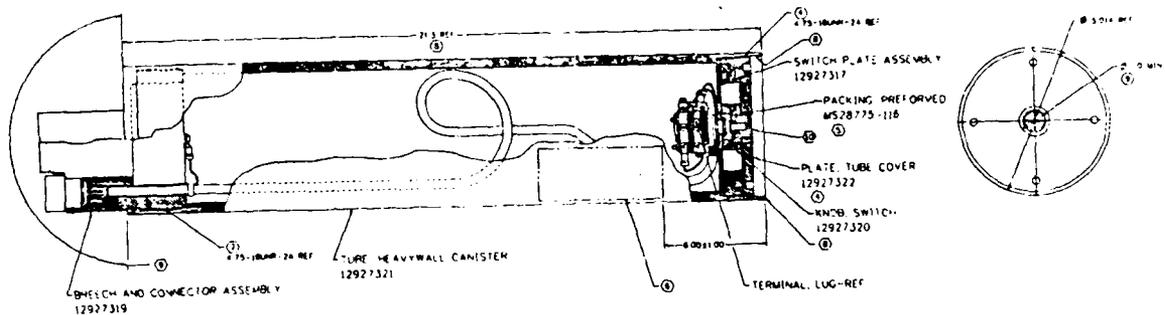
**MASTER PROGRAM SCHEDULE
TRAINING CANISTER
REVISED**



▲▲ - WEEKS APC
▼ - CHANGES

ECS H19 037A 00
6-19-90

Figure 1-1: XM89 Training Canister Development Schedule



- 5.) The XM89 training canister shall contain no explosives.
- 6.) The launcher rack interface shall be consistent with the M87 canister.
- 7.) The XM89 training canister shall provide a primer substitute to allow normal M139 system self test and firing capabilities.
- 8.) The pull switch of the M87 canister shall be simulated with a switch capable of simulating either an open or closed pull switch.
- 9.) The XM89 training canister shall incorporate a four position switch to allow the canister to simulate; a.) a functional canister, b.) an error code 4, shorted canister, c.) an error code 8, rack electronics failure, or d.) an error code 9, open canister electric primer.
- 10.) The XM89 training canister shall be packaged in the same manner as the M87 canister.
- 11.) The XM89 training canister shall be designed for a useful life of 20 years or up to 50 missions.
- 12.) The XM89 training canister shall remain operational following the test environments described in section 3.0.

2.2 Design History

A design specification was prepared which detailed the requirements, design and producibility goals, and development schedule. The general requirements are discussed in section 2.1. The major design and producibility goals were:

- 1.) Minimize Unit Production Cost (UPC) and Life Cycle Costs (LCC).
- 2.) Minimize maintenance.
- 3.) Minimize piece part count.
- 4.) Simplify assembly
- 5.) Utilize existing hardware designs

A "brainstorming" session was performed with representatives from design, production, quality, test and logistics. The desired output was a number of XM89 training canister concepts which would meet the requirements and goals. A summary of several of the concepts is discussed with advantages and disadvantages of each. Table 2-1 shows the concept trade-offs.

The first concept was to modify the existing canister by removing the explosive components and ballast fill the canister tube.

Another concept was to injection mold the entire XM89 training canister. The selector switch, cable and connector would be molded into the plastic.

A third concept investigated was to sand cast, permanent mold cast or lost foam cast the entire configuration except for the selector switch and connector.

The final and accepted concept was to utilize a modified breech housing, a thick walled canister tube and new tube closure method. A major concern of the final concept was the method to attach the breech and the closure cap to the tube.

Three attachment methods were investigated including using threaded fasteners, welding the components together or threading the components. To minimize the piece parts while allowing for easy assembly, the threaded components method was selected. The detail design of the final concept is discussed in the following sections.

Table 2-1: XM89 Training Canister Concept Trade-off

Concept	Advantages	Disadvantages
Modify existing canister	Existing piece parts Familiarity of assembly Proven strength Proven durability (slug canisters)	High part count Expensive piece parts (precision machining) Thin wall tube susceptible to dents and damage High inspection time
Injection Mold entire assembly	Minimize final machining No secondary finish Plastic is virtually indestructible	High non-recurring costs (mold fabrication) Process applicable to medium to large quantities Weight requirement could not be met without additional ballast
Sand cast entire assembly	Minimize initial machining Durable material Process applicable to low to medium quantities	Final machining required to meet weight requirement Unproven breech strength around lug area Requires additional metal finish
Modified breech with heavy wall tube	Proven breech strength Proven durability (slugs) Part familiarity Small part count Easy assembly	Redesigned tube and closure Requires additional metal finish Breech attachment method

2.3 Major Component Design

2.3.1 Breech and Connector Assembly

The Breech and Connector Assembly (figure 2-2) consists of the XM89 training canister breech and the cable assembly. The subassemblies are discussed independently in the following sections. The cable assembly is fed throughout the .750 inch hole of the breech until the connector is completely inserted into the breech housing. A spring pin is used to stake the connector in place while silicone hybrid RTV is back filled into the .750 inch hole. The ground lug is terminated into the threaded ground hole in the back of the breech. Electrical continuity testing is performed at this level to ensure that neither the resistor nor the fuse leads have made contact with the breech housing.

2.3.1.1 XM89 Training Canister Breech Housing

The breech housing (figure 2-3) is fabricated from the same raw impact extrusion as the M87 and M88 canisters currently in production. Features of the XM89 training canister breech different from the M87 and M88 canisters are; a.) no slider housing assembly, pressure cartridge or pull switch is used on the XM89 training canister, b.) the heavy wall tube is threaded onto the breech instead of the roll crimps and rivets used in the M87 and M88 canisters, c.) the dimensioning has been modified to simplify the machining processes due to the removal of the M87 canister components and related features.

The machining of the breech is required to detail the interface features, add the holes for the cable assembly, add a threaded hole for the grounding lug and thread the housing for the tube attachment. The protective finish of the breech is chromated which allows the latching mechanism of the launcher rack to penetrate and make electrical contact for the simulation of the error code 4.

2.3.1.2 Cable Assembly

The cable assembly (figure 2-4) consists of the canister connector, the resistor simulating the electric primer, the fuse simulating the coil assemblies, and the wires to interface with the breech ground hole and the four position selector switch.

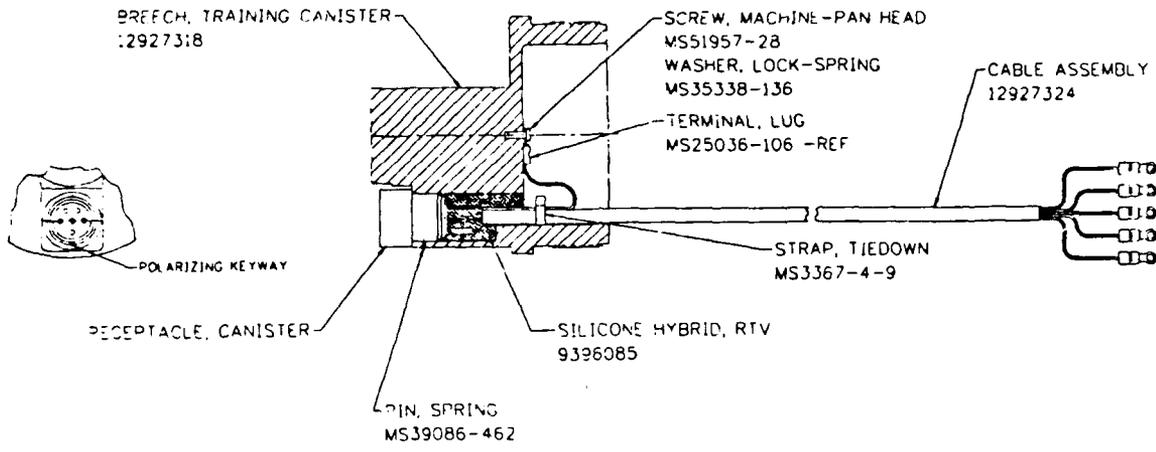


Figure 2-2: Breech and Connector Assembly

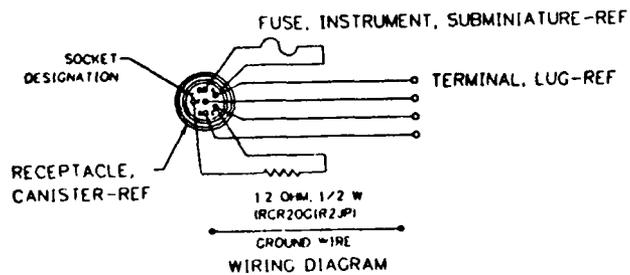
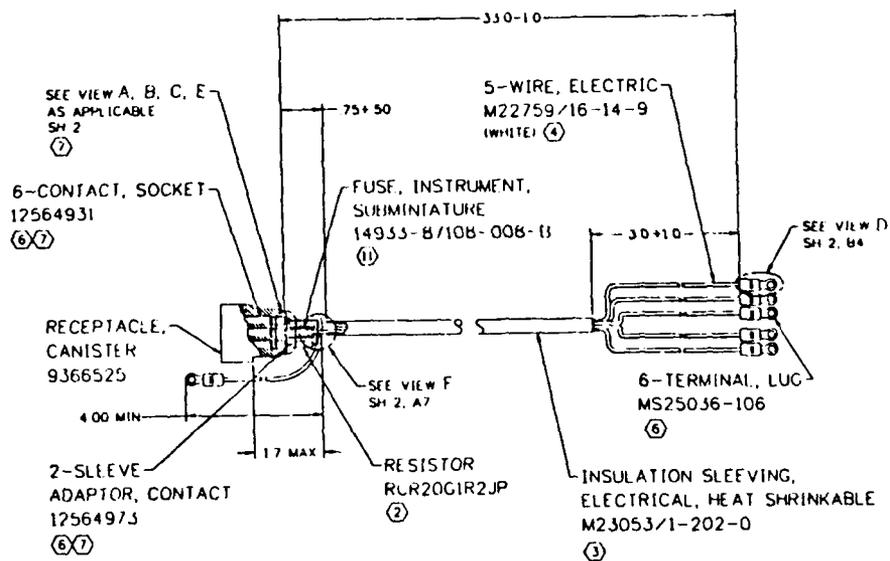


Figure 2-4: Cable Assembly

The canister connector is a six pin receptacle, and is common to the M87 and M88 canisters. The resistor (p/n RCR20G1R2JP) is a 1.2 Ω , 1/2 W device which simulates the electric primer of the M87 and M88 canisters. The nominal resistance of the electric primer is 1.3 Ω . The resistor will permit normal operation of the M139 dispenser including self test and firing.

The purpose of the subminiature fuse is to create a short circuit across the launcher rack capacitor resulting in a change to the launcher rack capacitor charging time constant. This induces an error code 8 (rack capacitor charging failure) when the XM89 training canister switch is rotated to switch position 3. The resistance of the fuse must be less than 1.5 Ω before the capacitor charging time constant is affected to a point where the XM89 training canister will no longer fail the self test and produce an error code 8. The fuse has been submitted to a durability test and was demonstrated to survive twice the life of the device.

The reason for using a fuse and not a hardwire short circuit was to protect the driver circuit card assembly (CCA) of the dispenser control unit (DCU). In the event the XM89 training canister selector switch is rotated from position 1 to position 3 following successful completion of the system self test and before final arming of the system, a 40 V signal would be applied directly across a 24.7 Ω , 7 W resistor on the driver CCA. The fuse will burn open prior to any damage to the 24.7 Ω , 7 W resistor. The fuse is protected with insulation sleeving to prevent inadvertent grounding to the breech housing.

The cable assembly interfaces the connector assembly with the selector switch. The cable assembly utilizes crimped terminal lugs to eliminate any soldering. The wire are covered with a insulation sleeving to protect the wires and aid in assembly.

2.3.2 Heavywall Tube Assembly

The heavy wall tube assembly is shown in figure 2-5. The primary purpose of the tube is to simulate the weight of the 6 mine assemblies and the thin wall tube of the M87 and M88 canisters. The heavy wall tube is fabricated from standard 5.0 inch outside diameter carbon steel tubing with a wall thickness of .312 inch. Each end of the tube is threaded to attach the breech and the closure assembly. The threads are the same on each end of the tube to simplify the machining and allow the operator to assembly in either orientation. Each end of the tube is dimensioned independently of each other to allow for the standard tolerances. The tube protective finish is a manganese phosphate which provides good corrosion resistance and eliminates the requirement for a paint primer.

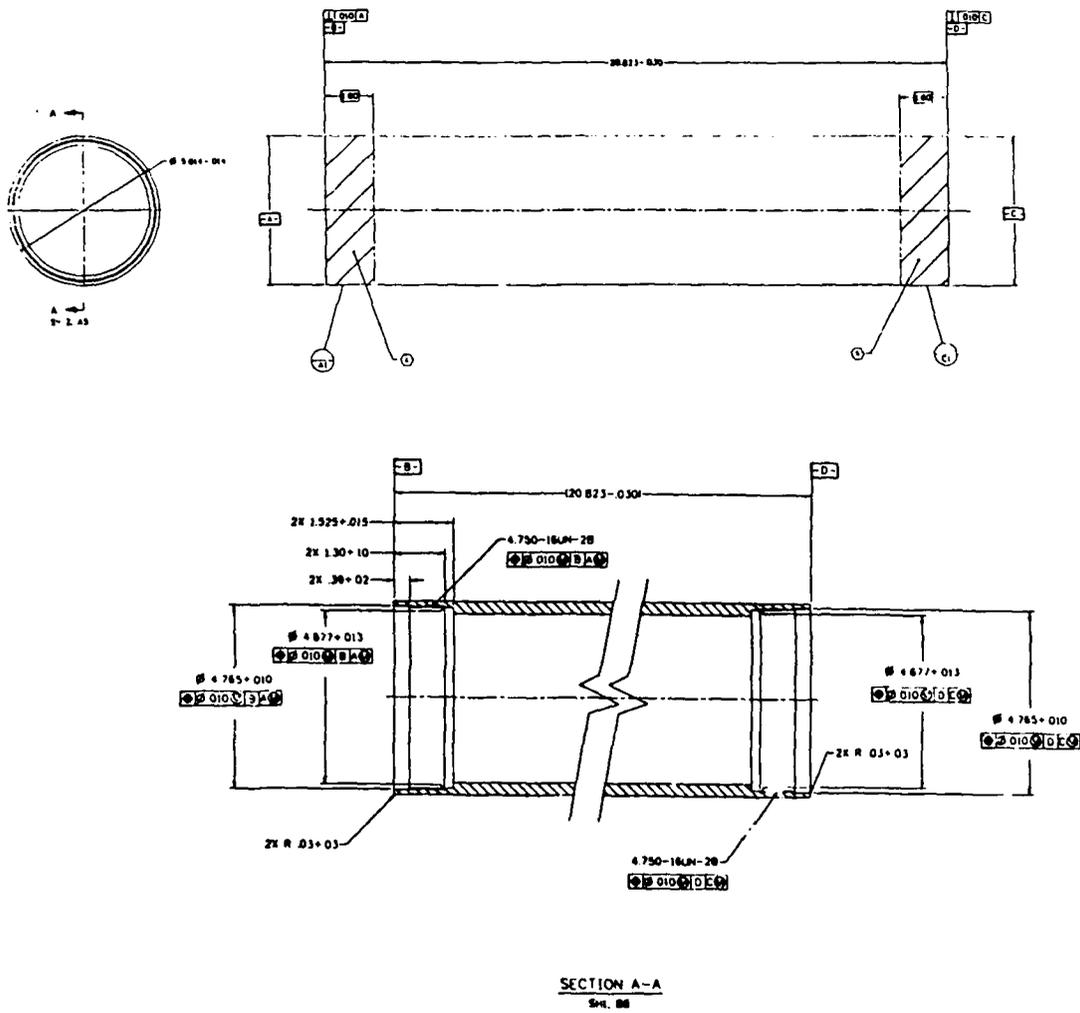


Figure 2-5: Heavywall Tube

2.3.3 Tube Closure

The tube closure contains the selector switch, the switch knob, the switch plate and the tube cover plate. As shown in figure 2-1, the switch is mounted to the switch plate. The switch shaft utilizes an o-ring to seal the opening between the switch and the switch plate. The switch knob is assembled over the shaft of the switch. The tube cover plate is threaded to the Heavywall tube to seal and secure the assembly.

2.3.3.1 Selector Switch

The selector switch is a military specified device, and was designed for four positions to simulate the following:

- 1.) Position 1 simulates a functional canister.
- 2.) Position 2 simulates an error code 4, shorted electric primer.
- 3.) Position 3 simulates an error code 8, rack electronics failure.
- 4.) Position 4 simulates an error code 9, open electric primer.

The switch design utilizes two decks to accommodate the two independent circuits (primer firing circuit and rack capacitor charging circuit). The switch was designed for a maximum of 5 amps for 10,000 electrical cycles.

2.3.3.2 Switch Knob

The switch knob (figure 2-6) is used to interface with the trainer by using a standard flat blade screwdriver. The switch knob uses a cross pattern to prevent trainees from visually identifying whether a failure has been set.

2.3.3.3 Switch Plate

The switch plate (figure 2-7) is an aluminum sheet used to secure the switch. The cable assembly is also secured to the plate for protection against the vibration environments.

2.3.3.4 Tube Cover Plate

The tube cover plate (figure 2-8) is used to secure the switch plate assembly and the switch knob to the tube assembly. The tube cover plate is threaded to the heavy wall tube and torqued to 70±10 ft-lbs. A permanent metal adhesive is used to secure the plate to the tube.

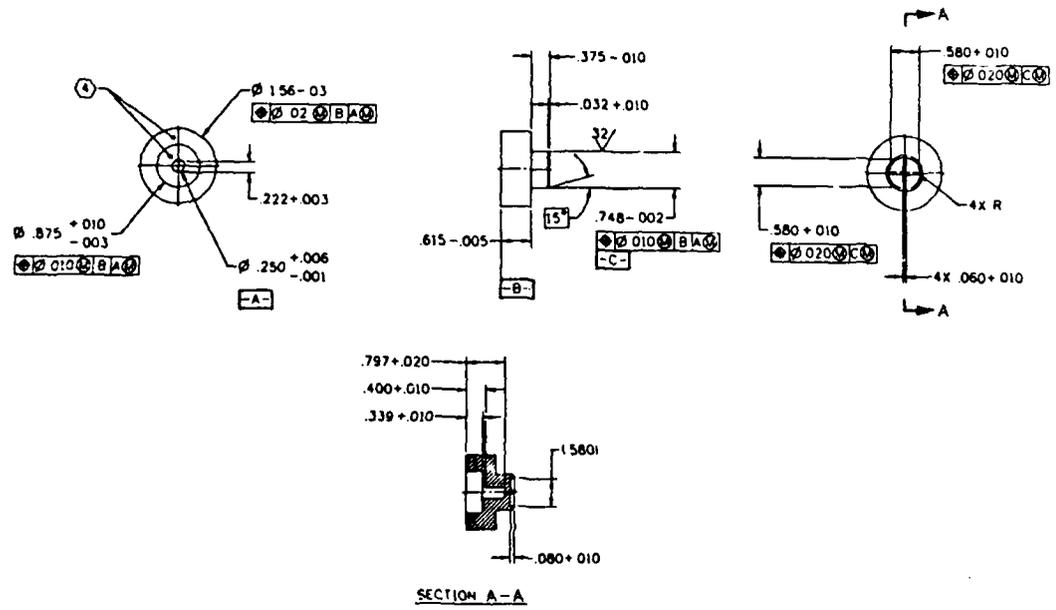


Figure 2-6: Switch Knob

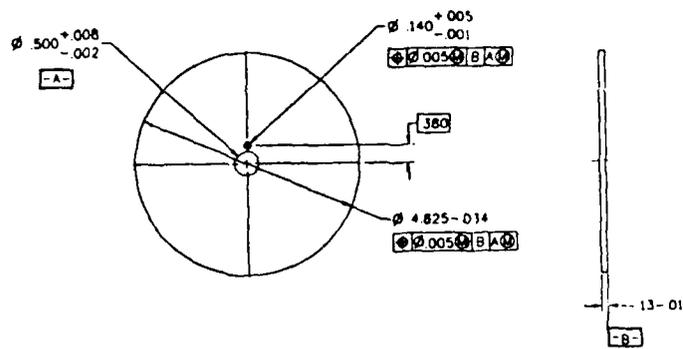


Figure 2-7: Switch Plate

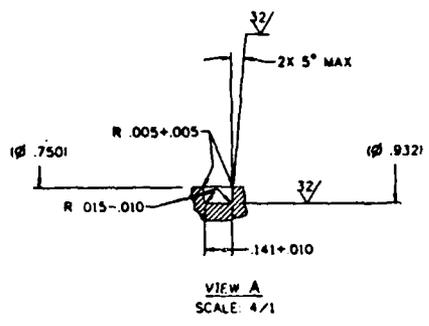
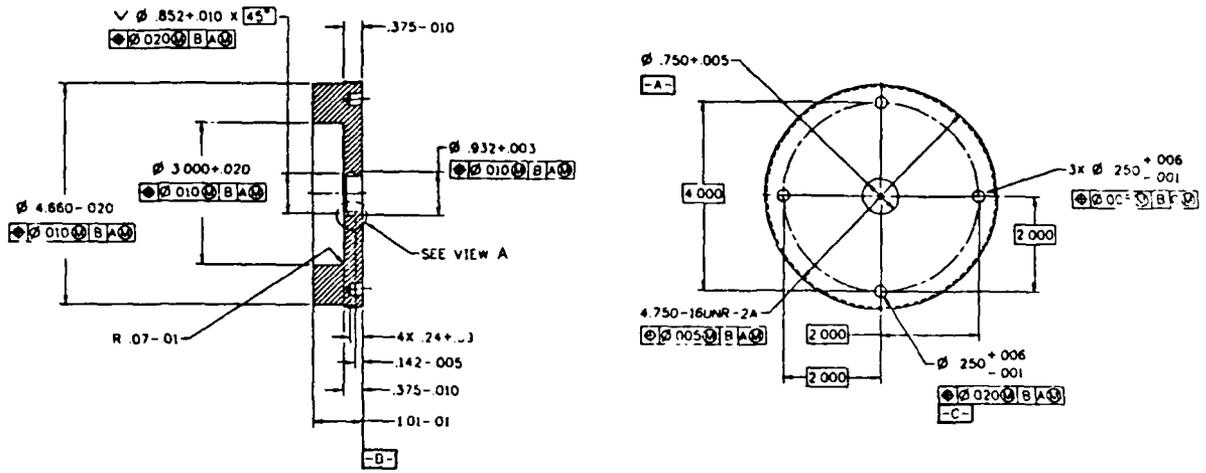


Figure 2-8: Tube Cover Plate

3.0 TEST AND EVALUATION

3.1 General

The VOLCANO XM89 training canister test program consisted of a prototype engineering (laboratory) test and an engineering qualification (laboratory) test. Based on a 30 Nov 89 TIWG¹ held at HQ, TECOM--APG, no TT/UT activity was required for type classification standard of the XM89 training canister.

An integrated test plan (reference ES 30330-139) for the XM89 training canister development program was prepared and submitted in accordance with DI-T-1904 and Contract Data Requirement List (CDRL) A150. An engineering qualification test plan (reference ES 30330-141) was prepared and submitted in accordance with DI-T-3702A and CDRL A151. Two engineering test reports--prototype and qualification (reference OEXM 37,929D and OEXM 37,941D) were prepared and submitted in accordance with DI-T-1906 and CDRL A152. The integrated test schedule for development of the XM89 training canister is presented in Figure 3-1.

3.2 Objectives

Perform engineering tests on the XM89 training canister to evaluate the safety, reliability and performance of the design during and after exposure to specified environments.

3.3 Engineering Tests

The engineering test program for the XM89 training canister consisted of a prototype test and a qualification test.

3.3.1 Prototype XM89 training canister Test

A preliminary engineering test was performed in the Honeywell Hopkins Environmental Laboratory with prototype XM89 training canisters in accordance with test plan ES 30330-14J.

¹Also refer to AMSAA's Abbreviated Independent Evaluation Plan (AIEP) for the XM89 Training Canister, November 1989.

Revision B. The results of the tests are documented in test report OEXM 37,929D. An outline of the test is presented in Figure 3-2.

Five XM89 training canister assemblies of a prototype design were subjected to a limited sequential environmental test which included M548A1 tactical vibration, mechanical shock (ground equipment), secured cargo vibration, extreme temperature storage/operation and water immersion.

During a portion of tactical vibration and mechanical shock tests the XM89 training canisters were monitored for electrical discontinuities. No discontinuities or functional deficiencies² were noted during the tests.

At the conclusion of testing, two of the canisters were subjected to a fifty repetition DCU firing sequence to verify the integrity of the 1.2 ohm, 0.5 watt resistor (RCR20G1R2JP) and the switch. No degradation of the resistor or the switch was noted after fifty firings.

Upon completion of the water immersion test, two of the four units tested exhibited gross leakage through the canister connector³. This leakage was attributed to poor workmanship during rework of the canisters⁴. The three canisters which were not reworked demonstrated seal integrity.

3.3.2 Engineering Qualification Test

In order to qualify the design of the XM89 training canister in the absence of a formal TT/UT, an engineering qualification test was performed by Honeywell. The test plan (ES 30330-141, Revision B) reflects a joint agreement between ARDEC, AMSAA, TECOM, CSTA and Honeywell⁵. The results of the test are documented in OEXM 37,941D. Personnel from CSTA/APG were present during the majority of the test to observe the test methods and results.

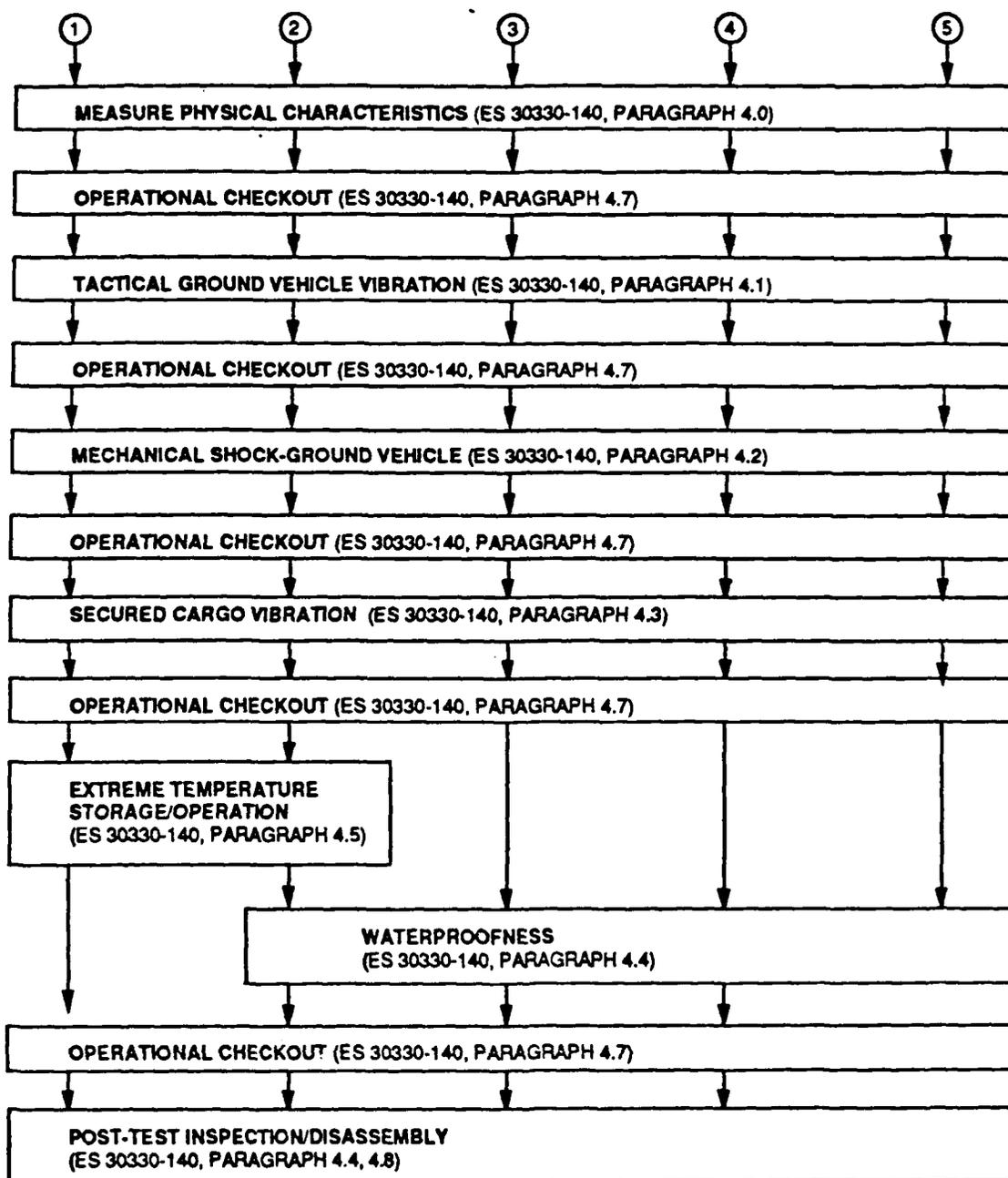
²Of the five canisters tested only two were capable of producing an error code 8 in switch position three. Due to limited hardware availability, the subminiature fuse (DESC 87108-008-B) necessary to produce an error code 8 was presented in only two of the test canisters. The remaining three canisters contained a 10 kohm resistor in place of the fuse.

³The leakage did not affect the function of the training canister in any of the four switch positions.

⁴These two canisters were disassembled prior to testing to install subminiature fuses. Consequently, the connector assembly was not repotted and water was able to penetrate the canister through the connector potting.

⁵Reference 30 Nov 89 TWIG held at APG HQ.

VOLCANO Prototype Training Canister Test Sequence - 5 Canisters



ECS.D19.032.BS
6-6-00

Figure 3-2: Prototype Test Outline

Twenty XM89 training canisters (P/N 12927323) were subjected to the sequential environmental test outlined in Figure 3-3. The test represented a life cycle of transportation, operation and storage under a combination of the most extreme environments. All canisters were exposed to 3000 miles of secured cargo, common carrier vibration and 352 miles (44 missions) of tactical M548A1 vibration⁶. Individual groups of four canisters were then exposed to mechanical shock, loose cargo, temperature and humidity, blowing rain and extreme temperature storage/operation environments. During and after each environment the canisters were functionally tested with a Dispenser Control Unit (P/N 9366432), a Launcher Rack (P/N 9378653) and a Launcher Rack Cable (P/N 9385014). At the conclusion of the test, eleven of the canisters were disassembled and inspected for damage.

No XM89 training canister functional deficiencies were noted during or after the test environments. Post-test inspection of the twenty canisters and ten canister shipping containers⁷ (P/N 9392425) revealed only one anomaly--one of the three bolts which secure the switch (MS25002-2) elements on canister S/N 18 unthreaded during M548A1 tactical vibration. This canister remained functional throughout the remaining tests and the two remaining bolts held the switch elements together. No other structural degradation was identified from the other test specimens. No evidence of water intrusion was detected on the units exposed to temperature and humidity or blowing rain environments.

3.4 Conclusions

Based on the results of the engineering qualification test the XM89 training canister demonstrated a 20 year life reliability under the most extreme operating environments. The 20 year life reliability was demonstrated at a confidence level of 98%(zero failures) based on the Barlow-Gupta reliability methodology. The XM89 training canister demonstrated full compatibility with the M139 Mine Dispenser, and met the requirements shown in table 3-1.

⁶The tactical vibration environment specified for the training canister was an "overtest" for the following reasons. First, the spectrum used for the vibration test was derived at APG for the M548 vehicle. The VOLCANO system was designed for the M548A1 vehicle, which features an improved suspension system. Second, the the M548 vibration data was measured at the bed of the vehicle. Consequently, to input this data to the face of the launcher rack ignores the significant high frequency damping effect of the VOLCANO mounting hardware.

⁷Canister shipping containers were used to perform training canister secured cargo vibration.

TRAINING CANISTER ENGINEERING TEST SEQUENCE

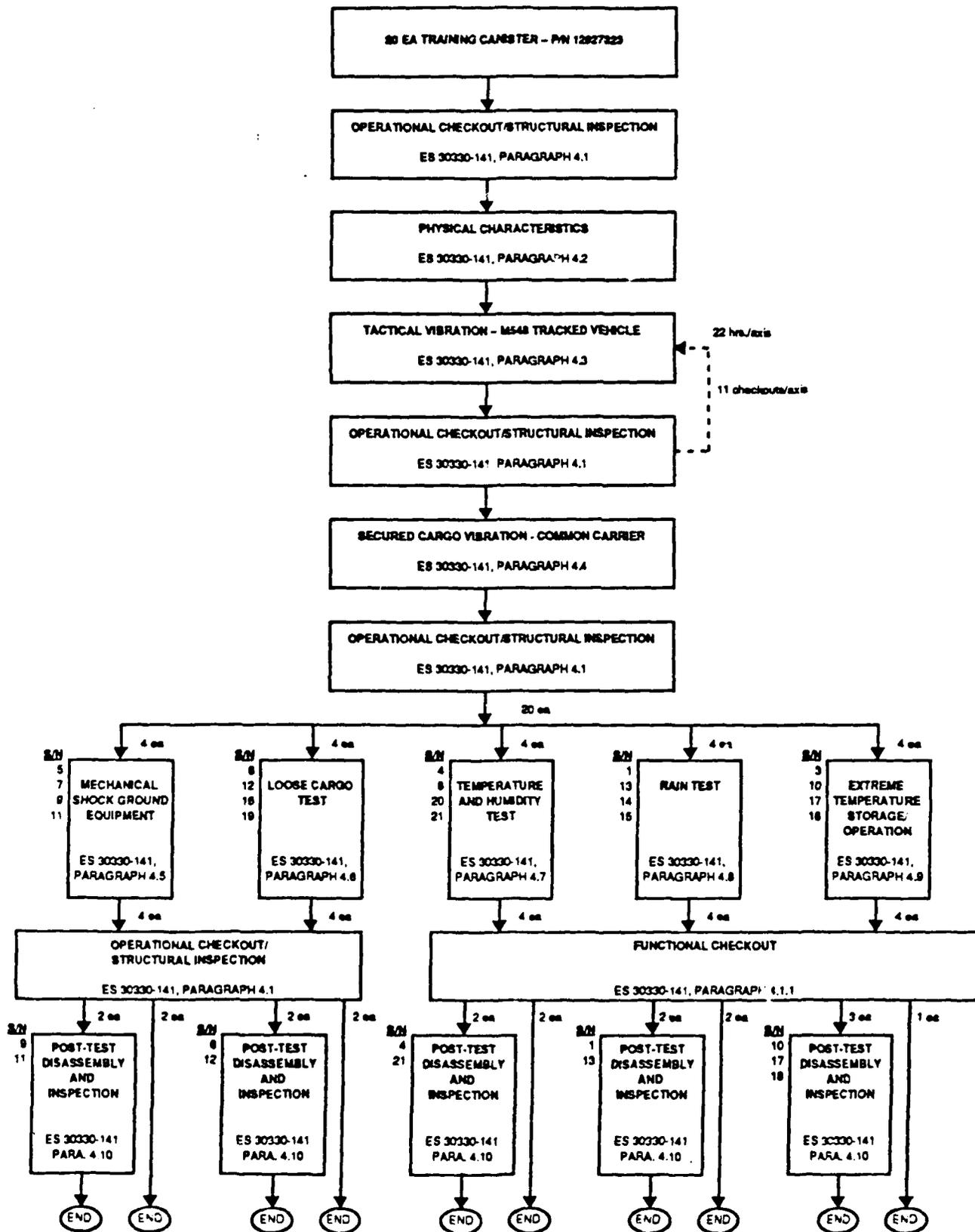


Figure 3-3: Qualification Test Outline

ECS G19.103.KA
3/23/90

Table 3-1: Requirement Verification

Item	Requirement	Test Results
Dimensions	Equal to M87 and M88 Length = 24.13 - 0.09 in. Diameter = 5.014 - 0.014 in.	Length = 24.09 in. Diameter = 5.01 in.
Weight	30±1 lbs.	Average = 30.2 lbs.
C of G	Midway 10.41±0.50 in.	C of G = 10.47
Markings	Distinguishable from M87 and M88 canisters	XM89 is blue with no additional markings
Explosives	Totally inert	Totally inert
Rack Interface	Equal to M87 and M88	Verified with 25 XM89 canisters
Primer Substitute	Normal M139 operation	1.2 ohm resistor used and verified on 25 canisters
Pull switch	Simulate open or closed pull switch.	Four position switch simulates the pull switch
Rotary switch	Simulate functional canister and induces 3 error codes	Fully tested and described in test report OEXM 39615D
Packaging	Same as M87 and M88	Fully tested and described in test report OEXM 39615D
Useful life	20 years or up to 50 missions	Demonstrated 20 year reliability with no failures at 98% confidence
Test environments	Described in section 3.1	Fully tested and described in test report OEXM 39615D

4.0 RELIABILITY

The reliability program tasks included all failure analysis and program support activities throughout the development of the XM89 training canister. The results of each task are described below.

4.1 Failure Analysis

All hardware and MANPRINT type failures that occurred during the functional tests, quality acceptance tests, prototype tests and engineering tests were reported using a formal Failure and Action Report. Table 4-1 details the failure analyses performed and the corrective actions implemented.

4.2 Reliability Program Support Activities

The reliability engineer was an integral part of the XM89 training canister concept development, design down select, and final development. Included in the final development support was the control of parts selection. The part selection guidelines were in accordance with paragraph C.3.2.6.11 of the contract specifying military parts for all non-specific XM89 training canister parts. As previously discussed in section 2.0, no non-standard parts are included in the XM89 training canister assembly.

5.0 SAFETY

The objectives of the safety program were:

- 1.) Safety consistent with the statement of work requirements in a timely, cost effective manner.
- 2.) Identification and evaluation of safety hazards.
- 3.) Minimize redesign efforts for safety by early identification of hazards and eliminating or controlling them on a timely basis.
- 4.) Control of revisions and modification to ensure they do not degrade the inherent safety of the system.

A preliminary hazard analysis and a safety assessment were prepared for the XM89 training canisters. The results are presented in the following sections.

Table 4-1: Failure Analysis Summary

Failure Analysis and Corrective Action

Failure Category ¹	F&A No.	Date of Failure	Part Name	Part Number	Failure Analysis	Corrective Action
ED	89-08-004	8/28/89	Switch, rotary	MS25002-2	The mechanical stop screw's effective length was shortened by the gnd. terminal lug. The shortened length allowed the movable wiper to be turned onto the wrong series of terminals.	The ground wire terminal lug was moved from the switch body to one of the switch deck assembly bolts. Refer to F&A # 89-09-001 for the latest change to the gnd. wire terminal lug.
	89-08-005	8/30/89	Switch, rotary	MS25002-2	Same as above.	Same of above.
	89-08-006	8/29/89	10 Kohm resistor	RCR07G103 JP	The 10 Kohm resistor didn't change the RC time constant of the L.R. capacitors enough to allow the DCU software to recognize an error code 8.	The resistor was replaced by a 1/2 A slow blow fuse. The fuse changes the RC time constant and protects the DCU Driver CCA from being damaged due to human error.
PD	89-09-001	9/14/89	Switch Plate Assy.	12927317	The method for grounding switch terminal 13 to the breech was dependent on the mechanical connection between the switch plate and the canister's tube.	Change the length of the ground wire and terminal switch terminal 13 on the breech instead of the switch body.
	89-08-001	8/21/89	Breech	12927318	Canisters couldn't be inserted into the L.R. because the breech design didn't allow for proper mating with the L.R. bolt retainer.	The breech was re-designed -- removed the hole intended to accept the bolt retainer and replaced it w/ a shelf to accommodate both the bolt retainer and arming latch lever.
	89-08-003	8/22/89	Breech	12927318	Canisters couldn't be latched into the L.R. because the breech design caused training canister connector to L.R. connector interference.	The breech was re-designed -- the height of the feature machined to accommodate the connector was changed to match the M87 tactical canister's dimension.
U	89-08-002	8/22/89	Socket, contact	12564931	Varying resistance across the 1.2 ohm resistor -- the exact cause wasn't determined.	None at this time -- a different F&A approach will be used to determine the cause of failure should this failure mode be encountered during the engineering test.

¹ See section 3.0 of this report for failure category abbreviation definitions.

5.1 Preliminary Hazard Analysis

The Preliminary Hazard Analysis (PHA) was prepared in accordance with data item description DI-SAFT-80101 and submitted as CDRL No. A165. The analysis considered safety hazards of the XM89 training canister. The results of the analysis revealed that the XM89 training canister has no likely category I or II safety concerns for either its manufacture or use. The only potential hazards associated with it are hazardous mechanical and electrical features and interface hazards. The analysis identified nine hazards of which two were critical, six were marginal and one was negligible. All identified hazards were determined to be at an acceptable level with no likely category I or II hazards. The hazard analysis worksheets are provided in table 5-1.

5.2 Safety Assessment Report

The Safety Assessment Report (SAR) was prepared in accordance with data item description DI-SAFT-80102 and submitted as CDRL No. A166. Because of its simple design and small piece part count, the VOLCANO XM89 training canister will present few safety hazards to the manufacturer or user. A summation of the hazards identified is provided in section 5.1.

6.0 HUMAN FACTORS

The human factors engineer participated in all design and program reviews. The human factors design criteria was developed in accordance with MIL-STD-1472C. Formal human engineering testing and a human engineering design approach document for the operator were performed and are detailed in the following sections.

6.1 Human Engineering Test

The Human Engineering Test Report was submitted as CDRL No. A193. The test demonstrated the following results:

The XM89 training canister's switch can be set to the desired error code position in day or night lighting conditions, with bare hands or wet cold mittens, on both air and ground VOLCANO system configurations.

HONEYWELL

PRELIMINARY HAZARD ANALYSIS

PROGRAM: VOLCANO
 SYSTEM: Training Canister
 SUBSYSTEM:

POTENTIAL HAZARDS CHECKLIST: HAZ ELECTRICAL FEATURES
 HAZ THERMAL FEATURES
 HAZARDOUS EMISSIONS
 HAZARDOUS CHEMICALS
 HAZARDOUS MECH FEATURES
 HAZ LIGHT EMISSION
 HIGH PRESSURE FLUIDS
 INTERFACE HAZARDS

DATE: 7 July 1989
 CONTRACT NUMBER: DAAK10-83-C-0059
 PREPARED BY: M. A. Peterson

REVISION: I

ASSEMBLY, COMPONENT OR MATERIAL	LIFE PHASE	HAZARD DESCRIPTION	EFFECT	CAT.	LEVEL	PLANNED OR RECOMMENDED SAFETY ACTION	REMARKS AND STATUS
---------------------------------	------------	--------------------	--------	------	-------	--------------------------------------	--------------------

Tube Assy.	1,2,4	Sharp edges on metal parts	Possible injury to personnel during assembly of the canister or during handling	III	D	The edges will be rounded per MIL-STD-1472C, paragraph 5.13.5.4.	The rounded edges will be on the level II drawings due the 10 weeks after contract award.
Breach Assy.	1,2,4	Sharp edges on metal parts	Possible injury to personnel during assembly of the canister or during handling.	III	D	The edges will be rounded per MIL-STD-1472C, paragraph 5.13.5.4.	The rounded edges will be on the level II drawings due the 10 weeks after contract award.
Connector Assy.	1	Miswire of a connector pin (only one miswire at a time was considered, i.e. single point failures only).	Some miswires produce no functional change to the training canister. Other miswires create a situation where switch positions 1 thru 4 produce different error codes than per the training canister design.	IV	D	The connector assemblies will be 100% inspected for miswires using a test box before the assemblies are assembled within the canister assy. This action will greatly reduce the possibility of miswires reaching the field but won't eliminate the hazard altogether since 100% inspection isn't 100% effective.	The test box will be built before the 180 deliverable canisters are manufactured.

- LIFE PHASES:
 1. MANUFACTURE
 2. TRANSPORTATION
 3. STORAGE
 4. INSTALLATION
 5. OPERATION
- HAZARD CHARACTERISTICS
 * HAZARD SEVERITY PER MIL-STD-882B, PARA. 4.5.1; I - CATASTROPHIC; II - CRITICAL; III - MARGINAL; IV - NEGLIGIBLE
 ** HAZARD PROBABILITY PER MIL-STD-882B, PARA. 4.5.2; A - FREQUENT; B - PROBABLE; C - OCCASIONAL; D - REMOTE; E - IMPROBABLE; TBD - TO BE DETERMINED PENDING ANALYSIS/TESTING

Table 5-1: Hazard Analysis Worksheets(sheet 1 of 6)

PRELIMINARY HAZARD ANALYSIS

HONEYWELL

PROGRAM: VOLCANO
 SYSTEM: Training Canister
 SUBSYSTEM:

POTENTIAL HAZARDS CHECKLIST

<input type="checkbox"/> EXPLOSIVES	<input type="checkbox"/> HAZ ELECTRICAL FEATURES
<input type="checkbox"/> FUEL	<input type="checkbox"/> HAZ THERMAL FEATURES
<input type="checkbox"/> HAZARDOUS CHEMICALS	<input type="checkbox"/> HAZ ACOUSTIC EMISSIONS
<input checked="" type="checkbox"/> HAZARDOUS MECH FEATURES	<input type="checkbox"/> HAZ ACOUSTIC FEATURES
<input type="checkbox"/> HIGH PRESSURE FLUIDS	<input checked="" type="checkbox"/> HAZ LIGHT EMISSION
	<input checked="" type="checkbox"/> INTERFACE HAZARDS

DATE: 7 July 1989
 CONTRACT NUMBER: DAAK10-83-C-0059
 PREPARED BY: M. A. Peterson

REVISION 1

ASSEMBLY, COMPONENT OR MATERIAL	LIFE PHASE	HAZARD DESCRIPTION	EFFECT	CAT.	LEVEL	PLANNED OR RECOMMENDED SAFETY ACTION	REMARKS AND STATUS
---------------------------------	------------	--------------------	--------	------	-------	--------------------------------------	--------------------

Canister Assy.	2, 4	Incorrect handling	Possible injury to personnel from the canister being dropped on the individual or the unit being thrust into an individual, etc.(canister weighs 30 lbs.)	III	C	Technical manuals will include procedures to instruct the operators on how the canister should be handled. This action will minimize the number of hazard occurrences but the hazard will not be eliminated.	These procedures will be incorporated in the draft change to the manuals due 16 weeks after contract award.
----------------	------	--------------------	---	-----	---	--	---

Canister Assy.	4	Incorrect loading of the training canister into the launcher rack.	Possible pinched fingers between the canister and the rack.	III	C	Technical manuals will include procedures to instruct the operators on how the canisters should be loaded into the racks. This action will minimize the number of hazard occurrences but the hazard will not be eliminated.	These procedures will be incorporated in the draft change to the manuals due 16 weeks after contract award.
----------------	---	--	---	-----	---	---	---

- LIFE PHASES:
1. MANUFACTURE
 2. TRANSPORTATION
 3. STORAGE
 4. INSTALLATION
 5. OPERATION
- HAZARD CHARACTERISTICS
- * HAZARD SEVERITY PER MIL-STD-882B, PARA. 4.5.1; I - CATASTROPHIC, II - CRITICAL; III - MARGINAL; IV - NEGLIGIBLE
 - ** HAZARD PROBABILITY PER MIL-STD-882B, PARA. 4.5.2; A - FREQUENT; B - PROBABLE; C - OCCASIONAL; D - REMOTE; E - IMPROBABLE; TBD - TO BE DETERMINED PENDING ANALYSIS/TESTING

Table 5-1: Hazard Analysis Worksheets(sheet 3 of 6)

HONEYWELL

PRELIMINARY HAZARD ANALYSIS

PROGRAM: VOLCANO
 SYSTEM: Training Canister
 SUBSYSTEM:

POTENTIAL HAZARDS CHECKLIST: HAZ ELECTRICAL FEATURES
 HAZ THERMAL FEATURES
 HAZARDOUS EMISSIONS
 HAZARDOUS CHEMICALS
 HAZARDOUS MECH FEATURES
 HAZ LIGHT EMISSION
 HIGH PRESSURE FLUIDS
 INTERFACE HAZARDS

DATE: 7 July 1989
 CONTRACT NUMBER: DAAK10-83-C-0059
 PREPARED BY: M. A. Peterson

REVISION 1

ASSEMBLY, COMPONENT OR MATERIAL	LIFE PHASE	HAZARD DESCRIPTION	EFFECT	CAT.	LEVEL	PLANNED OR RECOMMENDED SAFETY ACTION	REMARKS AND STATUS
Canister Assy.	5	The trainer moves the switch to position 3 (error code 4 - shorted primer) after the trainees have completed the VOLCANO system Built In Test (BIT).	Possible damage to the Driver CCA's in the DCU if this hazard is still present when the DCU sends a fire pulse to that canister during the training mission.	III	D	The technical manuals will include a procedure on how and when the training canister's switch position should be set. Also, NET of AMCCOM will be informed to include a section in their training which instructs the trainers not to change the switch position after the trainees have completed the VOLCANO system BIT. The DCU Driver CCA's had current limiting resistors added in order to protect the CCA's from damage due to shorted primers.	The training canister operating procedures will be incorporated in the draft change to the manuals due 16 weeks after contract award. ECO 88E5132 added the current limiting resistors to the Driver CCA's.

LIFE PHASES:
 1. MANUFACTURE
 2. TRANSPORTATION
 3. STORAGE
 4. INSTALLATION
 5. OPERATION

HAZARD CHARACTERISTICS
 * HAZARD SEVERITY PER MIL-STD-882B, PARA. 4.5.1; I - CATASTROPHIC; II - CRITICAL; III - MARGINAL; IV - NEGLIGIBLE
 ** HAZARD PROBABILITY PER MIL-STD-882B, PARA. 4.5.2; A - FREQUENT; B - PROBABLE; C - OCCASIONAL; D - REMOTE; E - IMPROBABLE; TBD - TO BE DETERMINED PENDING ANALYSIS/TESTING

Table 5-1: Hazard Analysis Worksheets(sheet 4 of 6)

HONEYWELL PRELIMINARY HAZARD ANALYSIS

PROGRAM: VOLCANO
 SYSTEM: Training Canister
 SUBSYSTEM:

POTENTIAL HAZARDS CHECKLIST X HAZ. ELECTRICAL FEATURES
 - EXPLOSIVES
 - FUEL
 - HAZARDOUS CHEMICALS
 - HAZARDOUS MECH FEATURES
 - HIGH PRESSURE FLUIDS

HAZ. THERMAL FEATURES
 HAZARDOUS EMISSIONS
 HAZ. ACOUSTIC FEATURES
 HAZ. LIGHT EMISSION
 INTERFACE HAZARDS

DATE 7 July 1989 REVISION 1
 CONTRACT NUMBER:
 DAAK10-83-C-0059
 PREPARED BY: M. A. Peterson

ASSEMBLY, COMPONENT OR MATERIAL	LIFE PHASE	HAZARD DESCRIPTION	EFFECT	CAT.	LEVEL	PLANNED OR RECOMMENDED SAFETY ACTION	REMARKS AND STATUS
---------------------------------	------------	--------------------	--------	------	-------	--------------------------------------	--------------------

Canister Assy.	5	The trainer moves the switch to position 4 (error code 8 -- shorted capacitor) after the trainees have completed the VOLCANO system Built In Test (BIT).	Possible damage to the rack electronics from approx. 65 watts being pumped through a 24.7 ohm resistor.	II	D	The short created between the rack's self destruct (SD) setting capacitors (when the switch is set in position 4) will be replaced with a 10 Kohm resistor. This resistor will act as a current limiting resistor for the rack's 24.7 ohm resistor and reduce the potential 65 watts being pumped through it down to approx. 0.16 watts. The 10 Kohm resistor will still produce an error code 8 because it will change the RC time constant for the charging of the rack's SD setting capacitors.	This change is currently in process.
----------------	---	--	---	----	---	--	--------------------------------------

32

- LIFE PHASES:
 1. MANUFACTURE
 2. TRANSPORTATION
 3. STORAGE
 4. INSTALLATION
 5. OPERATION

- HAZARD CHARACTERISTICS
 * HAZARD SEVERITY PER MIL-STD-882B, PARA. 4.5.1; I - CATASTROPHIC; II - CRITICAL; III - MARGINAL; IV - NEGLIGIBLE
 ** HAZARD PROBABILITY PER MIL-STD-882B, PARA. 4.5.2; A - FREQUENT; B - PROBABLE; C - OCCASIONAL; D - REMOTE; E - IMPROBABLE; TBD - TO BE DETERMINED PENDING ANALYSIS/TESTING

Table 5-1: Hazard Analysis Worksheets(sheet 5 of 6)

PRELIMINARY HAZARD ANALYSIS

HONEYWELL

PROGRAM: VOLCANO
 SYSTEM: Training Canister
 SUBSYSTEM:

POTENTIAL HAZARDS CHECKLIST
 - EXPLOSIVES
 - FUEL
 - HAZARDOUS CHEMICALS
 - HAZARDOUS MECH FEATURES
 - HIGH PRESSURE FLUIDS
 - HAZ ELECTRICAL FEATURES
 - HAZ THERMAL FEATURES
 - HAZARDOUS EMISSIONS
 - HAZ ACOUSTIC FEATURES
 - HAZ LIGHT EMISSION
 - INTERFACE HAZARDS

DATE: 7 July 1989
 CONTRACT NUMBER: DAAK10-83-C-0059
 PREPARED BY: M. A. Peterson

REVISION: 1

ASSEMBLY, COMPONENT OR MATERIAL	LIFE PHASE	HAZARD DESCRIPTION	EFFECT	CAT. LEVEL	PLANNED OR RECOMMENDED SAFETY ACTION	REMARKS AND STATUS
---------------------------------	------------	--------------------	--------	------------	--------------------------------------	--------------------

Canister Assy.	5	Loose parts coming off the canister from vibration or shock.	Potential damage to the helicopter.	* **		The canister is designed with the existing breach, a steel tube, and an end cap which is threaded into the tube. The only moving part is the rotary four position switch. The breach is secured to the tube with locking sealant (e.g. Lock-Tite) and the end cap to the tube with thread sealant and the frictional forces of the large threaded joint area. The canister will be subjected to a series of vibration and mechanical shock tests during Honeywell's engineering tests. These tests shall prove that the canister is designed to eliminate the stated hazard.
						The engineering tests begin 29 weeks after contract award. See the Integrated Test Plan, CDRL A150.

33

- LIFE PHASES:
 1. MANUFACTURE
 2. TRANSPORTATION
 3. STORAGE
 4. INSTALLATION
 5. OPERATION

- HAZARD CHARACTERISTICS
 HAZARD SEVERITY PER MIL-STD-882B, PARA. 4.5.1: I - CATASTROPHIC; II - CRITICAL; III - MARGINAL; IV - NEGLIGIBLE
 HAZARD PROBABILITY PER MIL-STD-882B, PARA. 4.5.2: A - FREQUENT; B - PROBABLE; C - OCCASIONAL; D - REMOTE; E - IMPROBABLE; TBD - TO BE DETERMINED PENDING ANALYSIS/TESTING

Table 5-1: Hazard Analysis Worksheets(sheet 6 of 6)

HONEYWELL

PRELIMINARY HAZARD ANALYSIS

PROGRAM: VOLCANO

SYSTEM: Training Canister

SUBSYSTEM:

POTENTIAL HAZARDS CHECKLIST

- HAZ ELECTRICAL FEATURES
- HAZ THERMAL FEATURES
- HAZARDOUS EMISSIONS
- HAZ ACOUSTIC FEATURES
- HAZARDOUS CHEMICALS
- HAZ LIGHT EMISSION
- X HAZARDOUS MECH FEATURES
- HIGH PRESSURE FLUIDS
- INTERFACE HAZARDS

DATE 7 July 1989

CONTRACT NUMBER: DAAK10-83-C-0059

REVISION 1

PREPARED BY: M. A. Peterson

ASSEMBLY, COMPONENT OR MATERIAL	LIFE PHASE	HAZARD DESCRIPTION	EFFECT	CAT.	LEVEL	PLANNED OR RECOMMENDED SAFETY ACTION	REMARKS AND STATUS
---------------------------------	------------	--------------------	--------	------	-------	--------------------------------------	--------------------

Canister Assy.	5	Loose parts coming off the canister from vibration or shock.	Potential damage to the ground vehicle.	III	D	The canister is designed with the existing breech, a steel tube, and an end cap which is threaded into the tube. The only moving part is the rotary four position switch. The breech is secured to the tube with locking sealant (e.g. Lock-Tite) and the end cap to the tube with thread sealant and the frictional forces of the large threaded joint area. The canister will be subjected to a series of vibration and mechanical shock tests during Honeywell's engineering tests. These tests shall prove that the canister is designed to eliminate the stated hazard.	The engineering tests begin 29 weeks after contract award. See the Integrated Test Plan, CDRL A150.
----------------	---	--	---	-----	---	--	---

3 4

- LIFE PHASES:
1. MANUFACTURE
 2. TRANSPORTATION
 3. STORAGE
 4. INSTALLATION
 5. OPERATION

- HAZARD CHARACTERISTICS
- * HAZARD SEVERITY PER MIL-STD-882B, PARA. 4.5.1; I - CATASTROPHIC; II - CRITICAL; III - MARGINAL; IV - NEGLIGIBLE
 - ** HAZARD PROBABILITY PER MIL-STD-882B, PARA. 4.5.2; A - FREQUENT; B - PROBABLE; C - OCCASIONAL; D - REMOTE; E - IMPROBABLE; TBD - TO BE DETERMINED PENDING ANALYSIS/TESTING

The XM89 training canister's switch can be set to the desired error code position with individuals possessing the entire range of hand sizes found among Army trainers, i.e., a 5th percentile woman, a 50th percentile woman, a 50th percentile man, and a 95th percentile man.

Training mission equipment is minimal. All that is required to induce errors into the VOLCANO system during a training mission (besides the XM89 training canisters) is one trainer, one flat blade screwdriver and one flashlight for night missions.

Errors can be induced efficiently (four canisters in less than fifteen seconds), safely (no safety hazards were observed at any time during the test), and accurately (0.98 reliability at a 90% confidence level).

6.2 Human Engineering Design Approach Document-Operator(HEDAD-O)

The HEDAD-O was prepared in accordance with data item description DI-H-7056, and submitted in accordance with CDRL No. A192. The conclusions of the analysis is discussed below.

The operator interface tasks of handling and installing the XM89 training canister into the M139 VOLCANO Mine Dispenser Base can be effectively accomplished using normal skills, dexterity, and strength because the XM89 has the same weight, envelope and end cap lip as the type classified M87 tactical mine canister.

The current rotary switch operator interface has evolved through a design process which considered and met the MIL-H-46855 human engineering requirements and applicable MIL-STD-1472C design criteria.

Based on human engineering analyses outlined in the HEDAD-O, the XM89 training canister's operator interfaces have been identified and adequate consideration was given to control these interfaces so that a type classified XM89 will fulfill the US Army's training needs for the M139 VOLCANO mine dispensing system.

7.0 PRODUCTION

7.1 Production Design Support

The design of the XM89 training canister involved a multi-disciplinary approach. The production engineer assisted the design engineering team in identifying & documenting the final product requirements. This approach involved numerous "brain storming" sessions to help identify various approaches to meet those requirements.

Priorities for the production engineer were to; a.) keep the piece part count to an absolute minimum, b.) keep the assembly process and piece part manufacturing as simple as possible (small learning curve), and c.) incorporate multiple functions within the piece parts. These priorities were combined with those of the program design engineer to identify overall goals of the product design. After various approaches were identified, meetings were held with vendors and their engineers to discuss difficulties or advantages in the different approaches. The vendors provided piece part producibility inputs, as well as additional approaches to meet the requirements.

7.2 Production Build

The production build of the XM89 was separated into two builds: An initial build of 25 units, which were identified as "engineering models", and a build of 200 units of which 180 were deliverable to ARDEC.

All piece parts were manufactured in one build with the exception of the breech. The material costs were minimized by procuring parts in one lot or setup. The piece parts were kept simple to minimize changes except for the breech housing which was made in house. The breech housing is the cost and schedule driver of the entire assembly and was made in lots of 25 and 200, so it was beneficial to incorporate any desired machining, producibility and inspection changes learned (by producing the 25) into the manufacture of the 200 units.

7.2.1 Engineering Model Build

Production assembly processes were developed on a computer aided process planning system prior to the build of the 25 engineering models. All assemblies were built by assembly operators with

the production, design, and quality engineers present. This approach provided insight to assembly problem areas, tooling needs, and minimizing the assembly personnel learning curve minimization. During this build, the process plans were further refined to provide additional work instructions or clarifications as required. The TDP utilized during this build was in a "development mode", which allows the engineers to document and make any necessary changes on the floor without stopping the build to wait for formal change orders. This process allowed the incorporation and documentation of the changes to the hardware being built on the assembly drawings. Assembly and inspection personnel comments/changes were also addressed and incorporated into the inspection processes and TDP.

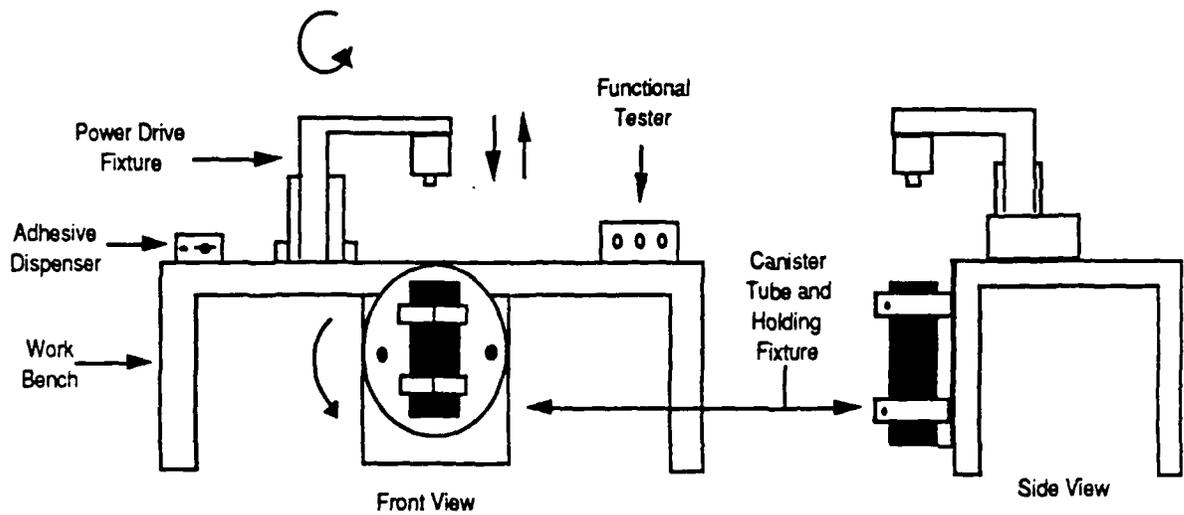
7.2.2 Deliverable Hardware Build

The production of 200 units was initiated approximately six weeks after completion of the 25 engineering model build. This schedule was set to allow completion of engineering testing of the 25 units. Successful engineering testing was a prerequisite to final assembly of the 200 units due to their permanent, non-repairable condition after final adhesive cure. The production process plans used for the engineering build were updated to reflect process changes and drawing improvements. Permanent socket adapters/tooling for the end cap assembly were made to support the 200 unit build. As in the engineering model build, an engine lathe was utilized to hold and rotate the heavy wall canister tube. With this approach, the operator must lift and load the tube as well as clamp, reload, and re-clamp the assembly. This multiple handling could be eliminated with a fixed assembly station as in Figure 7-1.

The 200 production build required little production engineering support. During the 25 engineering model build, the breech surface was difficult to mask off for final painting. For the 200 build, a launcher rack was used as tooling. The launcher rack provided the proper masking, as well as a holding fixture.

7.3 Tooling

To simplify the assembly process, several tools were developed and are discussed in this section. Tooling developed during the build of the 25 units included a breech to 1/2" square drive socket adapter, and a deep reach, 4" on center spanner, 1/2" square drive socket adapter for the cover plate. Both socket adapters were made to allow for hand operation during initial part assembly, and a 1/2" drive, "click" style torque wrench for final tightening. The switch knob piece part features necessitated a vendor die cast mold. The raw breech housing impact extrusion utilizes a



- Load canister tube in the horizontal position at waist height
- Rotate canister tube 90° to assemble breech
- Rotate canister tube 180° to assemble switch & cover plate
- Rotate canister tube 90° to assemble final test and to remove completed assembly

Figure 7-1: XM89 Final Assembly Fixture

permanent die cast set. This raw impact extrusion is common with that used on the M87 and M88 canisters, which are in production.

For final assembly, an engine lathe was utilized to hold and rotate the heavy wall canister tube for assembly. A future production approach would be to load the tube vertically into a "lazy suzan" style holding fixture (Figure 7-1) that can rotate 180° in the vertical plane. This approach would minimize handling the approximate 25 pound canister tube, allowing the operator to sit or stand for assembly, and allow for a single-axis, vertical assembly direction of the individual piece parts. Production quantities would also dictate use of torque-sensing, auto shut-off air driven nut runners for final spin of the breech assembly and cover plate down into a stationary canister tube.

7.4 Producibility Highlights

With ease of manufacture and assembly as a goal, the product was found to be very producible, both in piece part manufacture and in assembly. The following is a list of some of the producibility highlights of the piece parts:

- 1.) Heavywall Canister Tube
 - Standard 5" O.D. mechanical steel tubing
 - Each end is machined identical (reversible) yet dimensionally independent
 - Single machine, one set up processing
 - Manganese Phosphate finish eliminates paint primer, providing good corrosion resistance
- 2.) Switch Plate
 - Standard aluminum sheet stock
 - May be stamped to net shape in volume production (simple machined part, approximately 5 machined dimensions)
 - Allows for standard 1/2" diameter switch mounting
- 3.) Tube Cover Plate
 - Standard aluminum plate stock, or extruded stock
 - Single machine, one set up processing
- 4.) Switch Knob
 - Standard aluminum die casting
 - Net shape process
 - Allows for standard "D" shape switch shaft mating

5.) Breech

- Aluminum impact extrusion
- Majority of features provided net shape via the impact extrusion process
- Currently permanently tooled for production
- Common raw material piece part with production tactical canisters
- Two machine, two set up processing (lathe & horizontal machining centers)

6.) Miscellaneous Hardware

- All military or federal standard/specification type parts except connector
- Connector common with canisters currently in production

7.) Switch Plate Assembly

- Simple assembly, easy to automate
- Allows desired random switch knob location
- Single axis assembly

8.) Tube Cover Plate and Switch Plate Assembly

- Provides sealing both at switch knob & at tube
- Captures switch knob in place
- Secures switch plate against tube
- Retains o-ring
- Single axis assembly

9.) Breech to Tube Assembly

- Single axis assembly to either end of tube
- Adhesive provides both environmental sealing as well as permanent assembly

10.) Painting/Finishing

- Standard 1" diameter masking dot required
- Fast dry/cure enamel top coating
- Standard 1/2" stencil characters

7.5 Future Product Enhancements

The following is a list of areas/items which could be addressed to possibly make this product more producible:

- Change of breech, cover plate, and canister tube threads from 16 per inch to 12 or 8 per inch. This would permit faster machining of piece parts and expedite assembly spin down.

- Change method of switch termination, allow push in & lock to eliminate crimping of terminal lugs and subsequent torquing of terminal screws.
- Change wire from 14 AWG to 18 or 20 AWG. More flexibility for ease of termination; less raw material used.
- Change cable assembly insulation sleeving to a lighter wall thickness and/or also change heating process to expedite shrink time.
- Eliminate ground screw on breech; replace with a drive rivet; simplifies machining and assembly.
- Automate the metering and push out of adhesive during application in final assembly. This would give uniform consistency and minimize variability during manual application.
- Develop a holding fixture, as in Figure 7-1, for final assembly to eliminate excessive handling and manual torquing.
- Develop a paint line in which the assembly can hang and rotate to be painted and cured. The hanging fixture would also provide proper masking.
- Change switch from a "MS" part to a common commercial, less expensive piece part.

8.0 QUALITY

8.1 Quality Development Support

Quality Engineering supported the development stages of the program by reviewing the TDP, preparing Quality plans, fabrication specification and inspection procedures, maintaining the "development mode" drawings and submitting necessary waivers and deviations.

8.1.1 Review Drawing Package

The Quality Engineer reviewed and approved the level II piece part drawings before they were released. The Quality Engineer also reviewed and approved the level II assembly

drawings before the build of the 25 engineering models began. All changes to released drawings were approved by the quality engineer prior to the 200 unit build.

8.1.2 Quality Program Plans

The Quality Assurance Program Plans for the XM89 training canister (CDRL A169) and the M548A1 mounting hardware (CDRL A111) were combined into one Quality Plan due to the commonality. The plan described Honeywell's Divisional Quality System as well as program specific information (e.g. class 1 inspection procedures) defined at that time.

8.1.3 Piece Part Inspection

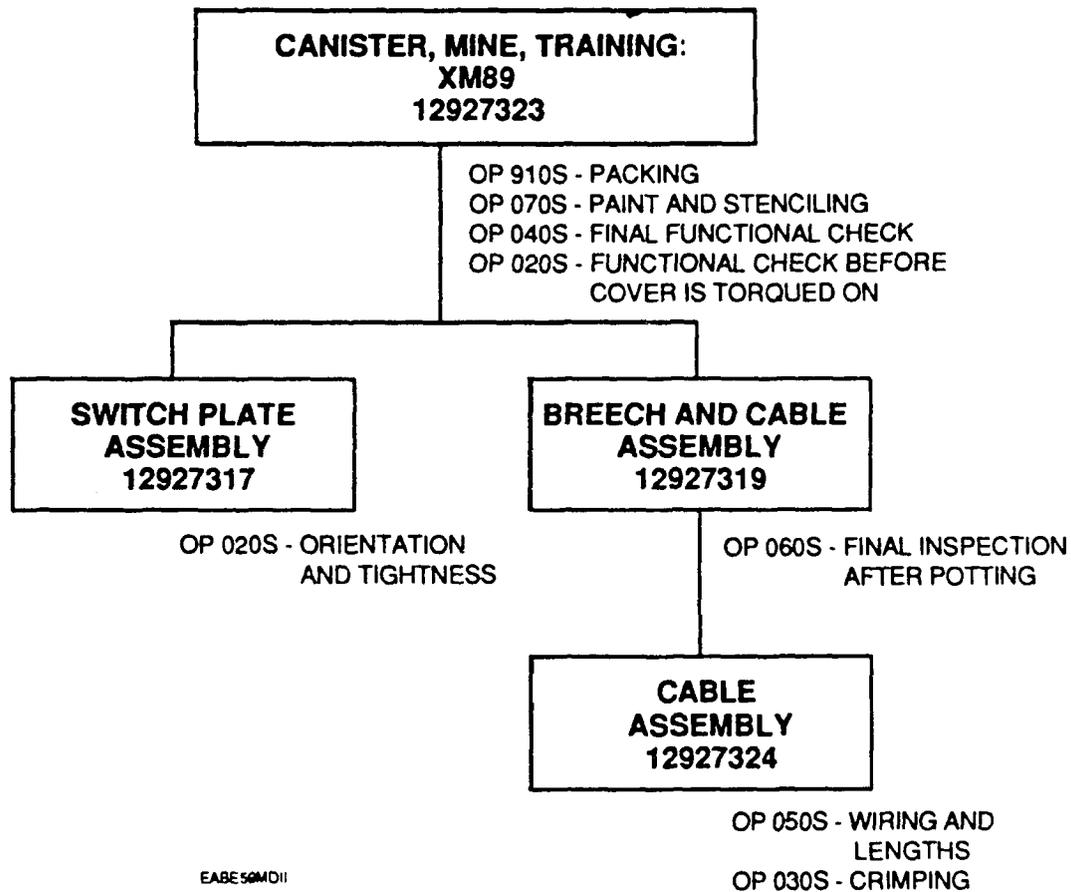
Classification of Characteristics (C of C's) were created for the approved TDP, and were provided to the vendors in order to define quality requirements. Inspection procedures based on the C of C's were created to detail the required Honeywell inspections.

8.1.4 Assembly Floor Documentation

The 25 XM89 training canisters were built in a 'development mode' documentation procedure. The 'development mode' procedure was developed for initial engineering builds to document in real time all piece part and process changes on to working master drawings. The master drawing were kept under the Quality Engineers control and recorded the as-built configuration of the hardware. One ECO was processed following the build incorporating the changes identified.

8.1.5 Assembly Inspection

For the build of the 25 engineering models, preliminary inspection procedures were created to verify the drawing requirements. The inspection procedures were updated to the ECO processed following the build (An overview of the assembly inspection procedures created can be found in figure 8-1).



XM89 Assembly Inspection Procedures

Figure 8-1: XM89 Training Canister Assembly Inspection Procedure

8.1.6 Waivers and Deviations

During the build of the 25 models the Quality Engineer processed only two waivers and one deviation (Copies of the waivers and deviation, as well as a complete status of the corrective actions can be found in table 8-1).

8.1.7 Military Fabrication Specification (CDRL No. A161)

Submittal #1	July 19, 1989	(Preliminary)
Submittal #2	October 31, 1989	
Submittal #3	May 8, 1990	

The preliminary fabrication specification (Submittal #1) was derived from MIL-C-70660(AR), Military Specification for Canister Assembly, M88 Loading, Assembling and Packing. The preliminary specification was updated to reflect the Level III drawing package submitted to ARDEC for review. Submittal #3 incorporated; 1) customer comments on the first two submittals, which included implementing the "Zero AQL" format, 2) recommendations from the prototype and production builds, and 3) recommendations from the engineering tests.

8.2 Quality Production Support

Quality Engineering supported the production stages of the program by reviewing and approving the level III TDP, updating the inspection procedures and defining the required test equipment.

8.2.1 Technical Data Package Review

After the build of the 25 engineering models was complete, the XM89 level II TDP was updated from the "development mode" master drawings. The TDP was also updated to level III format including producibility enhancements and overall adherence to Honeywell TDP Guidelines.

Table 8-1: Waiver and Deviation Summary

Waivers

Number: 0059-W-0003
 Part Number: 9366525
 Part Name: Connector Receptacle
 Quantity: 225
 Description: Defect: ECP 0240-E-0020R1 Not Approved
 Disposition: Use-As-Is
 Cause: ECP not approved. This ECP only changes P/N from a 28 million Honeywell P/N to the ARDEC P/N. This ECP changed nothing in part configuration.

Number: 0059-W-0004
 Part Number: 12927318
 Part Name: Breech. Training Canister
 Quantity: 26
 Description: Defect: R .06 + .06 u/s to .007
 Disposition: Use-As-Is
 Cause: Characteristic not programmed into machine
 Proposed CA: Add characteristic to machining program.
 Status: Complete. Next lot of breech housings received had this radius correctly machined.

Deviations

Number: 0059-D-0001
 Part Number: 12927324
 Part Name: Cable Assembly
 Quantity: 180 max
 Description: 1.) Defect: Commercial fuses (P/N 230.500) will be used for the first 22 training canisters instead of the DESC P/N 87108-008-B fuse.
 Disposition: Use-As-Is
 Cause: Excessive lead time
 Proposed C/A: DESC fuses were used for deliverable build.
 Status: Complete.
 2.) Defect: Commercial resistors (P/N RCR20G1R2J) will be used instead of the military resistors (P/N RCR20G1R2JP).
 Disposition: Use-As-Is
 Cause: Military resistor was placed on DESC suspension.
 Proposed C/A: NA. DESC will release resistor from suspension following investigation.
 Status: The resistor has been taken off DESC suspension.

8.2.2 Inspection Procedures Update

The Quality Engineer updated the receiving inspection and assembly inspection procedures before the 200 XM89 build to incorporate the TDP changes described above in section 8.2.1.

8.2.3 Production Floor Support

Quality Engineering was closely involved in the production build of the 200 XM89 training canisters to ensure the inspection procedures were complete. Proper training was given to the inspectors on the operation of the XM89 training canister electrical tester which is described in section 8.2.4.

8.2.4 Test Equipment

After the build and inspection of the 25 engineering models was completed, an automatic tester for the canister's electrical functioning was fabricated for the production build. Quality and Production Engineering combined efforts in designing a custom test cable (shown in figure 8-2) which would utilize a PC-based data acquisition test station. Each canister is electrically functioned in a minute, with a variables data printout. The manual continuity test took on average 15 minutes per canister.

9.0 INTEGRATED LOGISTICS SUPPORT

Integrated Logistics Support (ILS) efforts for the XM89 training canister began during the design phase of the canister and continued throughout the development of the technical manual change pages. Logistics consideration became a major factor in the selection of the slotted selector switch. The development of the XM89 training canister demonstrated the advantages of ILS input early in the development process.

9.1 LSA Program

The XM89 training canister ILS program analyzed the XM89 training canister for operational and maintenance considerations. The first consideration was the determination of a repairable versus a throw-away device. Factors in this consideration were:

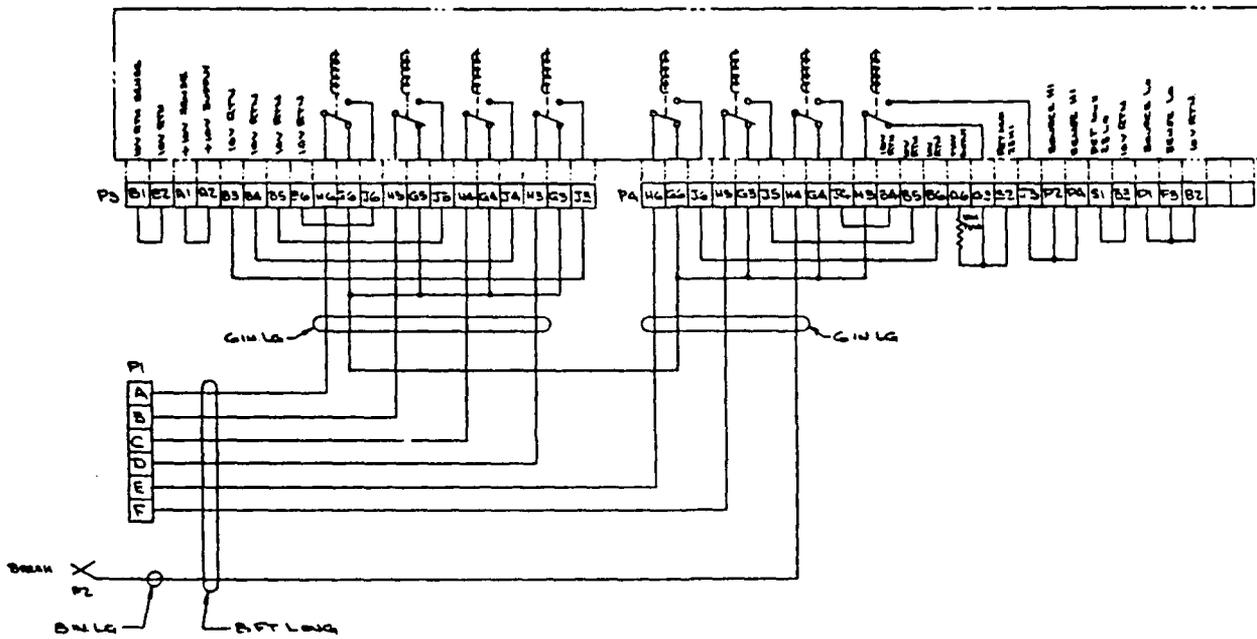


Figure 8-2: XM89 Training Canister Tester

- 1) Reliability of components used in the XM89 training canister.
- 2) Production methods of assembling the XM89 training canister.
- 3) XM89 training canister Unit Production Cost (UPC).

Based on the component failure rates, the only internal component under consideration for replacement was the selector switch. The 40 mission requirement and the low UPC of the XM89 training canister, combined with the high reliability of the switch drove the decision to recommend a throw-away canister.

A summary of the Repair/Throw-away Analysis is as follows:

Use: 2 Missions per year at 1.33 hours per mission

Life Expectancy: Comparison of 10 years and 20 years

Training scenario uses 1 connector mating and 2 switch operations per mission

MTBF of critical subassemblies:

- 1) Rotary Switch MS25002/2, Requirements: 10,000 cycles mechanical, 10,000 cycles electrical

MTBF= 21.9×10^6 hrs/failure

- 2) Connector (PN: 9366535) with MIL-C-39029/5 contacts, Requirements: 500 mating cycles without failure

MTBF= 2.2×10^6 hrs/failure

Cost per Unit: \$450 @ production quantities of 1000 units

CONCLUSION: Figure 9-1 shows the plot of the unit cost against the MTBF of either the switch or connector subassemblies which indicate a non-repairable device with a significant margin.

9.2 Technical Manuals

The technical manual task consisted of developing change pages for the existing VOLCANO technical manuals (TM 9-1095-208-10 and TM 9-1095-208-23&P) covering peculiar XM89 training

canister information. The XM89 training canister change pages were to be included as part of change 1 to both manuals.

9.2.1 Technical Manual Development Schedule

The technical manual change pages were prepared in accordance with the development schedule proposed during the Technical Manual Guidance Conference held at Picatinny Arsenal, NJ on 20-21 June 1989. Due to the anticipated small number of pages impacted, an agreement was made at this conference to conduct manuscript reviews by mail and to conduct validation of material in conjunction with the human factors testing.

9.2.2 Technical Manual Data Development and Organization

The technical manual data was developed from Logistic Support Analysis data. Since the XM89 training canister was determined to be non-repairable, maintenance tasks were required to inspect and verify for serviceability. The level at which condemnation would occur became a minor issue. Although troubleshooting procedures were developed for determining faulty canisters at the crew level, a final continuity check at unit level maintenance would be the most effective method of accurately condemning a faulty canister.

XM89 training canister descriptive data was placed in a new chapter of the Operator's Manual. This chapter was intended to provide detailed descriptive information, theory of operation, and training methods and scenarios to effectively utilize the canister. A chart was developed to act as a guide for loading XM89 and M88 canisters for training missions and a layout of launcher racks to assist in locating canisters with error codes for both the trainers who set codes into the system and for the trainees, who, during troubleshooting practice, will locate the "faulty" canisters. During training scenario troubleshooting practice, the trainee uses the VOLCANO troubleshooting charts to troubleshoot errors entered by the trainer and will use the XM89 training canister troubleshooting charts when the trainee or trainer has determined that a XM89 training canister has potentially failed.

Operating and maintenance procedures developed during the XM89 training canister change page development consisted of troubleshooting for faulty XM89 training canisters and training scenarios. The training scenarios were not performed but were reviewed for completeness and accuracy. The troubleshooting procedures were validated hands-on in conjunction with the human factors testing on 9 January 1990 at HOPG.

VOLCANO TRAINING CANISTER REPAIR ANALYSIS (based on 2 missions/year)

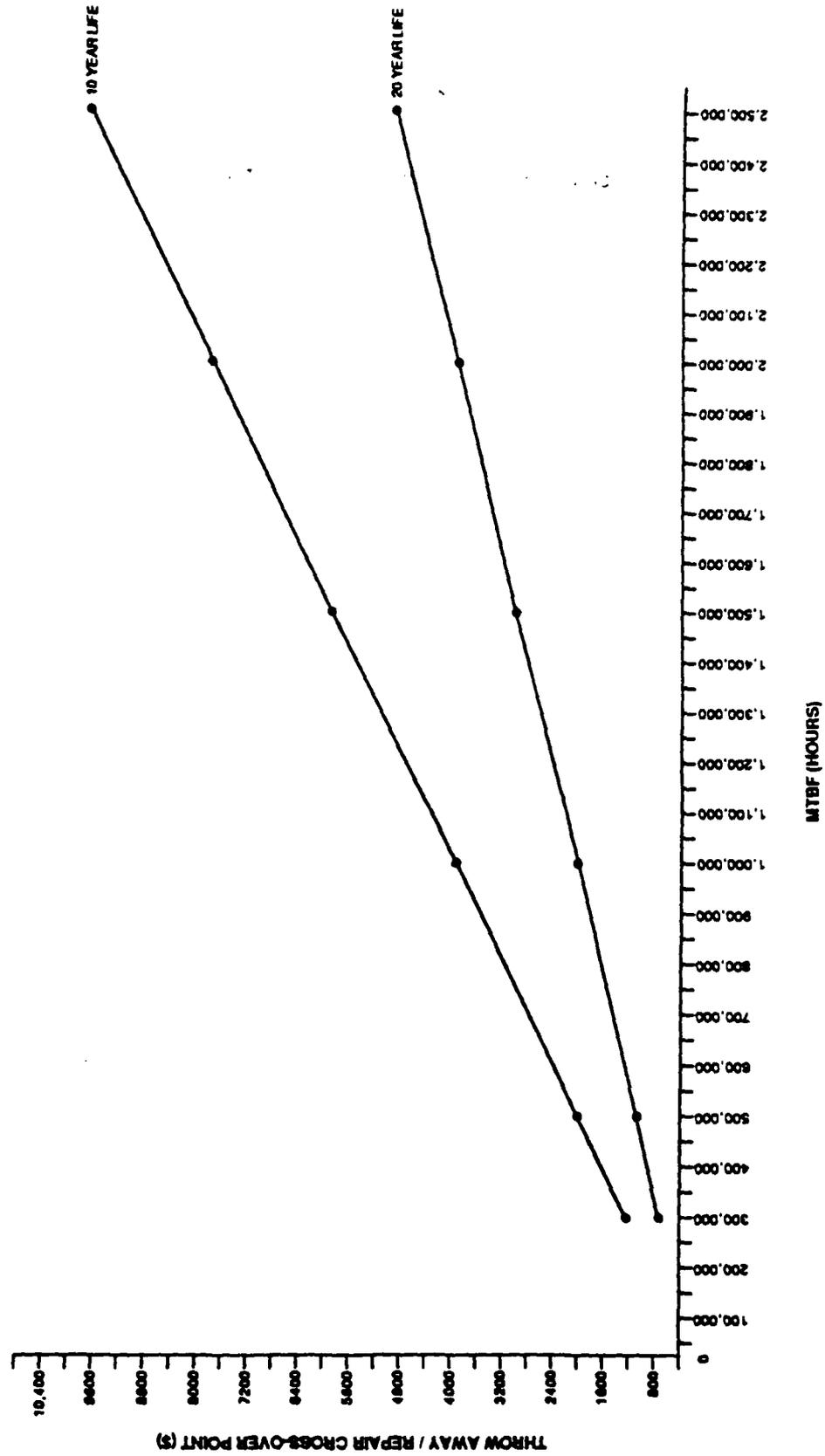


Figure 9-1: XM89 Training Canister Repair Analysis

9.2.3 Technical Manual Change Page Delivery

The XM89 training canister change pages were delivered on 26 February 1990 as a complete, fully contained change 1 to the Operator Manual and the Unit, Aviation Unit, and Direct Support Maintenance Manual. In conclusion, this technical manual change page task was completed within the bounds of the program schedule, as discussed at the Technical Manual Guidance Conference, with minimal problems. This effort was successful due to a demonstrated good working relationship between Honeywell and AMCCOM Logistics and Publications groups.

MANDATORY DISTRIBUTION LIST

Commander
U.S. Army Armament
Research, Development and Engineering Center (ARDEC)
Picatinny Arsenal, NJ 07806-5000

attn: SMCAR-FSM-M (D) (1/0 copy)
SMCAR-FSC-ATA (D) (1/0 copy)
SMCAR-SF (D) (1/0 copy)
SMCAR-FSM-F (D) (1/0 copy)
SMCAR-AEP (D) (1/0 copy)
SMCAR-FSD-ATA (D) (1/0 copy)
SMCAR-MSI (D) (1/0 copy)
AMSMC-QAT-M (D) (1/0 copy)
AMSMC-QAT-I (D) (1/0 copy)
AMSMC-LSA (D) (1/0 copy)
AMSMC-PCW-B (D) (1/0 copy)
AMSMC-MAY-TA (D) (1/0 copy)
AMSMC-TM (D) (1/0 copy)
AMSMC-DSM-AC (D) (1/0 copy)
AMSMC-GC (D) (1/0 copy)
AMSMC-CAD-V (D) (1/0 copy)
SLCHE-AR (D) (1/0 copy)
AMCFM-MCD-P (D) (1/0 copy)

Commander
U.S. Army Armament, Munitions and Chemical Command
Rock Island, IL 61299-6000

attn: AMSMC-QAD (R) (1/0 copy)
AMSMC-MMP-I (R) (1/0 copy)
AMSMC-CAR-C (R) (1/0 copy)

DPRO - Honeywell

attn: Mr. D. Oldre MN12-6254 (1/0 copy)
Mr. C. Scott MN29-3691 (1/0 copy)

Commander
U.S. Army Armament, Munitions and Chemical Command
ATTN: AMSMC-GCL(D)
Picatinny Arsenal, NJ 07806-5000

Administrator
Defense Technical Information Center
ATTN: Accessions Division (12)
Cameron Station
Alexandria, VA 22304-6145

Director
U.S. Army Materiel Systems Analysis Activity
ATTN: AMXSY-MP
Aberdeen Proving Ground, MD 21005-5066

Commander
Chemical Research, Development and Engineering Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-MSI
Aberdeen Proving Ground, MD 21010-5423

Commander
Chemical Research, Development and Engineering Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-RSP-A
Aberdeen Proving Ground, MD 21010-5423

Director
Ballistic Research Laboratory
ATTN: AMXBR-OD-ST
Aberdeen Proving Ground, MD 21005-5066

Chief
Benet Weapons Laboratory, CCAC
Armament Research, Development and Engineering Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-CCB-TL
Watervliet, NY 12189-5000

Commander
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-ESP-L
Rock Island, IL 61299-6000

Director
U.S. Army TRADOC Systems Analysis Activity
ATTN: ATAA-SL
White Sands Missile Range, NM 88002