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Technical Report No. LWL-CR-09F70

LAUNCHER IMPROVEMENT FOR ILLUMINATION SYSTEM FLARE, SURFACE: PARACHUTE XM183

FINAL REPORT

By

Daniel J. Herkes

Engineering Mechanics Division
IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

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U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

AD-757731

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ABSTRACT

The objective of this nine-month program was to improve the present feasibility model launcher for mass production. In addition, design features such as flare package retention and positive locking were to be investigated. To assure system reliability, a method of verifying these objectives was required.

During the course of this program, a development approach and test plan was generated and approved for engineering activities. A verification test fixture was designed and constructed to simulate impact type loading on a launcher. Experimental and production type launcher systems can be subjected to peak recoil conditions of 1600 lb for 5 msec through three firing elevations.

The Land Warfare Laboratory prototype model was studied and redesigned to accommodate the objectives of reduction in manufacturing cost, ease of assembly, stability and simple emplacement under adverse conditions during a tactical assignment. Fifteen development launchers were fabricated and tested for design verification. Incorporated into the basic concept were features such as positive framework-to-base locking in four positions, improved structural supporting, flare package assembly retention, and an improved method of anchoring.

Following an engineering analysis of these pilot design improvements, 175 launcher systems were manufactured and delivered.

FOREWORD

This is the Final Report for IITRI Project No. J6249, entitled, "Launcher Improvement for Illumination System Flare, Surface: Parachute XM183," which was performed under Contract No. DAAD05-71-C-0315 for the U. S. Army Land Warfare Laboratory. This project was initiated on 28 April 1971 and was successfully concluded on 28 January 1972 with the manufacture of 175 launcher systems, experimentally verified, that possess the necessary characteristics to meet the contractually specified performance goals. The success of this project is due in a large part to the guidance of Messrs. Paul Frosell and Howard Carroll, Technical Program Monitors, U. S. Army Land Warfare Laboratory.

Major contributors to the technical work reported herein are:

K. Norikane, Design Engineer, responsible for the technical direction, the design of the verification test fixture, improvement of the launcher design, and fabrication coordination.

A. P. Meyers, Research Engineer, responsible for the system analysis and design guidance throughout the program.

J. Schnieder of Dudek and Bock Spring Manufacturing Co., whose manufacturing experience greatly contributed to fabricating design and areas of cost reduction.

TABLE OF CONTENTS

	Page
ABSTRACT	ii
FOREWORD	iii
TABLE OF CONTENTS	iv
LIST OF FIGURES	v
TABLES	v
1. INTRODUCTION	1
1.1 Launcher Description	1
1.2 Contract Objectives	1
2. PROGRAM REVIEW	2
2.1 Engineering Study and System Design	2
2.2 Verification Test Fixture	4
2.3 Launcher Construction and Delivery	4
3. TEST PLAN AND ANALYSIS	4
3.1 Preliminary Investigation	4
3.2 Test System Description	6
4. PRODUCTION SYSTEM DESIGN	10
4.1 Launcher Base	10
4.2 Framework	11
4.3 Anchoring	11
5. VERIFICATION TEST PLAN	14
5.1 Test Plan A	14
5.2 Test Plan B	17
6. CONCLUSIONS	17

LIST OF FIGURES

Figure No.		Page
1.	Program Planning Chart	3
2.	Pendulum Test Fixture for Improved Illumination Flare Launcher: Parachute XM183	5
3.	Time-Force Curves	7
4.	Model of Pendulum Text Fixture	9
5.	Schemata of Top and Side Views of the Launcher in a Firing Position	12
6.	Launcher in a Transportation Position	13
7.	Launcher Firing Order	15

TABLES

I.	Sequential Data for Five Launchers Tested for Strength and Stability	16

1. INTRODUCTION

An improved production launcher design for the Illumination System Flare, Surface, Parachute XM183 was undertaken. This unit is a lightweight, self-contained system, which provides illumination for night surveillance operations.

The system operates on the mortar principle, sequentially expelling 12 fin-stabilized parachute flare rounds. The launching tubes are arranged in three rows of four tubes each, presenting four separate vertical and three horizontal bore centerline impulse positions. A prototype launcher, utilizing an aluminum scissor-leg design, did not provide the proper transmission of recoil energy from firing impulses to the ground. At the U. S. Army Land Warfare Laboratory (USALWL), wire-formed launchers were designed and limited testing proved this engineering concept to be effective in maintaining the necessary launch stability.

1.1 Launcher Description

The launcher system is a lightweight framework basically constructed of mild steel wire-formed rods intimately attached by resistance welding. The framework is attached to a die-stamped aluminum baseplate in such a manner as to pivot the flare package through a choice of three firing elevations for a particular tactical mission. After the system is unfolded, it is staked to the ground for stability, and a firing elevation is selected. The forward position locking struts are then mechanically interlocked with the lower or horizontal rods with wire-formed anchoring stakes. Two angle formed stakes are inserted through the baseplate and into the ground to resist shifting from the firing impulses. All flexible couplings, such as the supporting legs, are mechanically joined by wire-formed loops. The launcher framework with base and stakes, minus the flare package assembly, weighs approximately 2.2 lb.

1.2 Contract Objectives

The wire-formed launcher system must be rugged, simple, easy to operate, and reliable. It must remain erect, anchored to the ground, and not be seriously deformed during the firing cycle. Further, the system must be designed so that it can be erected with ease in darkness under possibly adverse conditions.

The overall objectives of this program, namely, to design, fabricate, and test a low-cost, mass-produced system featuring reliable operation while retaining the basic engineering concepts, have been met. The launcher design has been tested and its operational feasibility proved. Also, a verification plan has been generated for substantiating the design objectives and a method of evaluating production launcher systems for Government acceptance.

Specific objectives which have guided the course of the program are:

Improve the USALWL feasibility model for mass production.

Investigate the feasibility of substituting a wire-formed stake for the rear angle iron stake.

Incorporate into the launcher design a method of retaining the projectile package assembly for ease of assembly and field operations.

Design pivot rods and positioning struts for reliable operation and fastening and evolve methods for low-cost production.

Design a fixture for inert testing of launchers under peak recoil conditions having impact type loading of 1600 lb for 5 msec.

2. PROGRAM REVIEW

Engineering activities were initiated on 28 April 1971, and in compliance with the contract, an engineering plan was submitted for review and approval. A Preliminary Design and Visualization Plan (Fig. 1) was generated during the first two weeks of this project and is an agenda of events required to accomplish the program goals within the 36 week time frame.

Also, in compliance with contractual requirements, a test plan (Section 3) was submitted containing IITRI's design philosophy of launcher testing, a description of a test fixture, and a plan for testing.

The Dudek and Bock Spring Manufacturing Company was subcontracted for manufacturing of components. Their proximity to IITRI and a fully equipped inspection department with testing equipment for all phases of wire-form manufacture combined to make them a good choice.

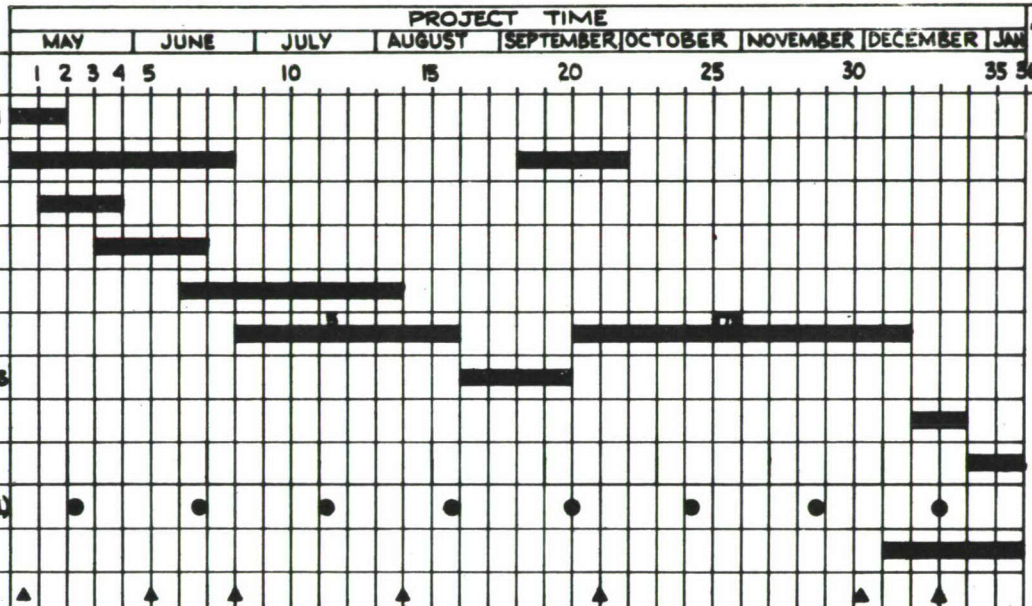
2.1 Engineering Study System Design

The launcher design was divided into two phases. The first or preliminary phase included the following tasks:

Obtain background history and technical data from the Program Monitor.

Perform dynamic analysis of launcher system.

Redesign pivot rods and positioning struts, redesign rear stakes, and devise projectile package retention device.



	TASK	STAFF TIME IN MAN-WEEKS/TASK: SENIOR ENG.	ENG.	ASSOC. ENG.	ASST. ENG.	TECH.	SHOP	TOTAL
I	PRELIMINARY DESIGN & VISUAL. PLAN	.2	3.0	1.0				4.2
II	LAUNCHER DESIGN & STUDIES	.2	4.0	3.0				7.2
III	TEST PLAN FORMULATION	.2	1.0	1.0				2.2
IV	DESIGN OF TEST FIXTURE	.1	2.0	1.5				3.6
V	TEST FIXTURE FABRICATION					2.5	4.2	6.7
VI	LAUNCHER FABRICATION	DUDEK & BOCK - MFG. SUBCONT'R						
VII	TEST OF 5 PRELIMINARY LAUNCHERS	.1	.8			.8		2.6
VIII	ACCEPTANCE TEST (10 OF 175)		1.0			1.0		2.0
IX	DELIVER LAUNCHERS		.2					.2
X	MONTHLY REPORTS (TECH & FINANC'L)	.1	1.0					1.1
XI	FINAL REPORT	.2	1.5					1.7
XII	CONFERENCES		1.0					1.0
LEVEL OF EFFORT (IITRI STAFF)		1.1	15.5	6.5		4.3	4.2	31.1

WORK LOAD BY PERIOD IN MAN-WEEKS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	TOTAL
SENIOR ENGINEER	.2	.2	.2	.1	.1														.1													.1	.1				1.1
ENGINEER	2.	2.	1.	1.	1.	1.	1.	1.				.2			.2	.2			1.	1.					.2				2			.5	.5	.5	.5	.5	15.5
ASSOCIATE ENGINEER	1.	1.	.5	.5	.5	.5	.5												.5	.5	.5	.5															6.5
ASSISTANT ENGINEER																																					
TECHNICIAN											1.	.5	.5	.5			.2	.2	.2	.2													.5	.5			4.3
SHOP							1.	1.	1.	1.	.2																										4.2
TOTALS	.32	.32	1.7	1.6	1.6	1.5	2.5	2.	1.	1.	1.2	.7	.5	.5	.2	.2	.2	.2	1.8	1.7	.5	.5			.2				.2			.6	1.1	1.	.5	.5	31.1

FIG. 1 PROGRAM PLANNING CHART

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Confer with Dudek and Bock (manufacturing subcontractors) and make changes based on the mass manufacturability of launcher components. The criteria for production design changes are: adaptability of component parts to automatic wire-forming machines, assembly of components, economics of components, and assembly procedures.

Detail components for fabrication of initial five test launchers.

The final design phase included the incorporation of all engineering changes after the initial testing, the preparation of drawings, and item specifications.

2.2 Verification Test Fixture

A test fixture (Fig. 2) was designed, fabricated, and assembled to simulate actual launching conditions. The fixture was designed to impart the specified force of 1600 lb for 5 msec at any of the 12 launcher tube stations.

2.3 Launcher Construction Delivery

Five preliminary design launchers were fabricated and assembled by Dudek and Bock and design improvements were verified. Testing was conducted in accordance with the test plan discussed in Section 3. High speed (Fastex) photographs were made to determine launcher stability under dynamic conditions.

Following engineering evaluation and minor redesign, 175 launchers were released for production and acceptance testing was performed on 10 launchers selected at random. The five preliminary design launchers and 175 final design launchers were delivered to Aberdeen Proving Ground.

3. TEST PLAN AND ANALYSIS

The test plan was created to provide the Government with a test device capable of subjecting launchers to an impulse of 8 lb-sec to determine acceptable production standards. A brief study of launcher dynamics and a study of the application of a mechanical dynamic force to a launcher were conducted for the design of the test system shown in Fig. 2. This system was employed by IITRI to test both the preliminary design and the final launchers. The test system determines both the structural integrity of the launchers and, with the use of high-speed movies, dynamic stability.

3.1 Preliminary Investigation

The internal ballistics of the flare system was analyzed to determine the actual momentum imparted to the launcher. The momentum imparted to the launcher when the flare ejects is given by:

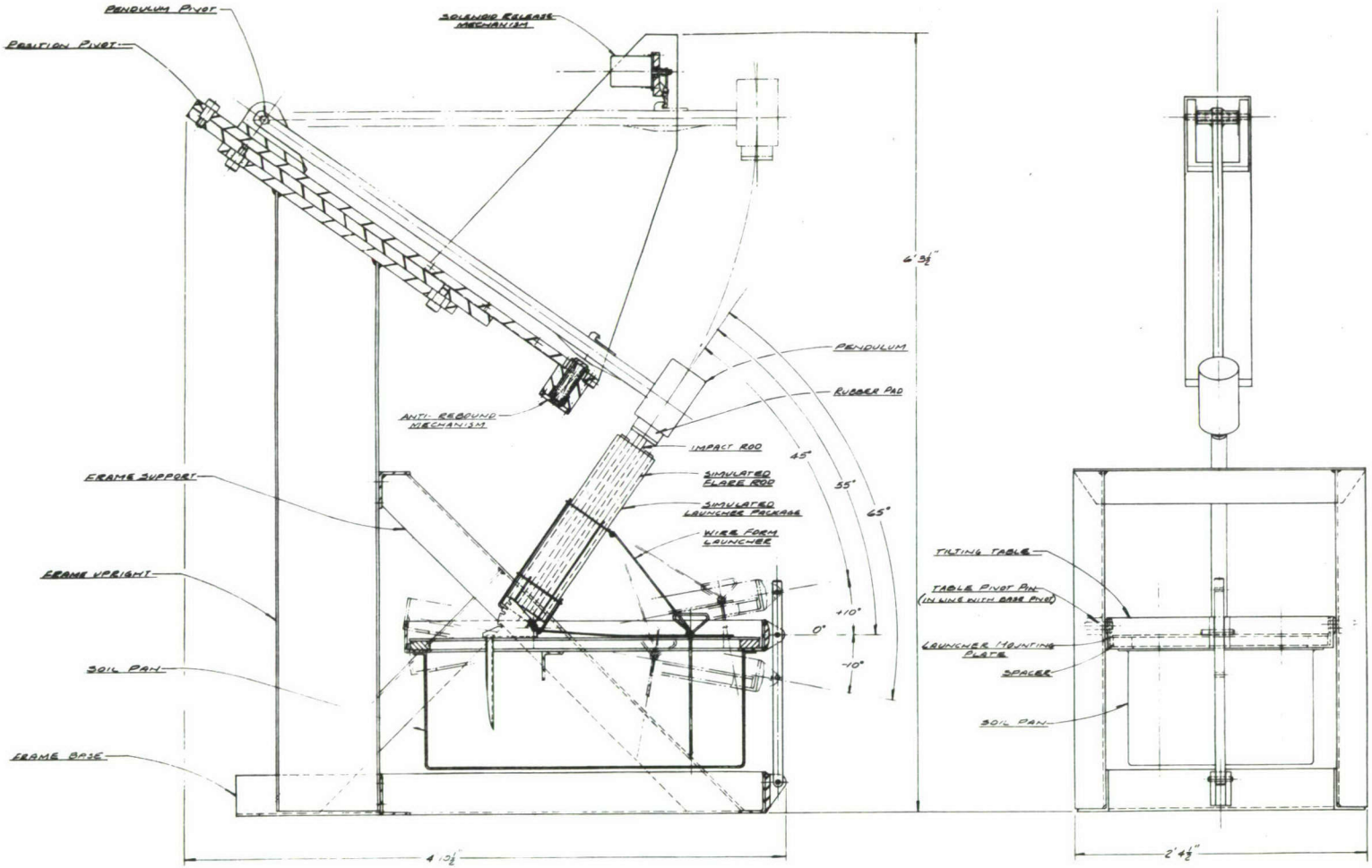


FIG. 2 PENDULUM TEST FIXTURE FOR IMPROVED ILLUMINATION FLARE LAUNCHER: PARACHUTE XM185

SCALE: 1/4 LITAI PROJ # 16269

$$Q = mpVp + mgVg$$

or

$$Q = \frac{WpVp}{g} + \frac{WgVg}{g}$$

where,

Wp = flare weight, 0.4 lb
Wg = propellant weight, 0.01625 lb (0.26 oz)
Vp = flare muzzle velocity, 354 fps
Vg = average gas exit velocity, 4700 fps

Evaluating:

$$Q = \frac{(0.4)(354)}{32.2} + \frac{(0.01625)(4700)}{32.3}$$

$$Q = 4.8 + 2.37 = 7.17 \text{ lb-sec}$$

The specifications for the test system, the application of a 1600-lb force for 5 msec, or an impulse of 8.0 lb-sec, is fulfilled by the calculated impulse of 7.17 lb-sec.

Fig. 3 illustrates four types of force-time curves; constant force, ballistic, pendulum perfect-spring, and pendulum rubber-faced. The specified constant force versus time (1600 lb for 5 msec) will provide an impulse of 8.0 lb-sec. The mechanical application of this type of loading, however, would be virtually impossible to achieve, prohibitive in cost, and not representative of the impulse from a ballistic system as shown in Fig. 3. The pendulum type of impulse is more nearly representative of the ballistic curve. The chosen type of impulse (i.e., a pendulum with a rubber face) is a compromise of the ballistic and pendulum systems. The inherent hysteresis of rubber reduces the peak force and increases the return time of the stored force as shown in Fig. 3.

3.2 Test System Description

The criteria for the pendulum test fixture shown in Fig. 2 are:

Testing of production launchers.

Launcher positions.

Launcher firing positions.

Reproducible impulse.

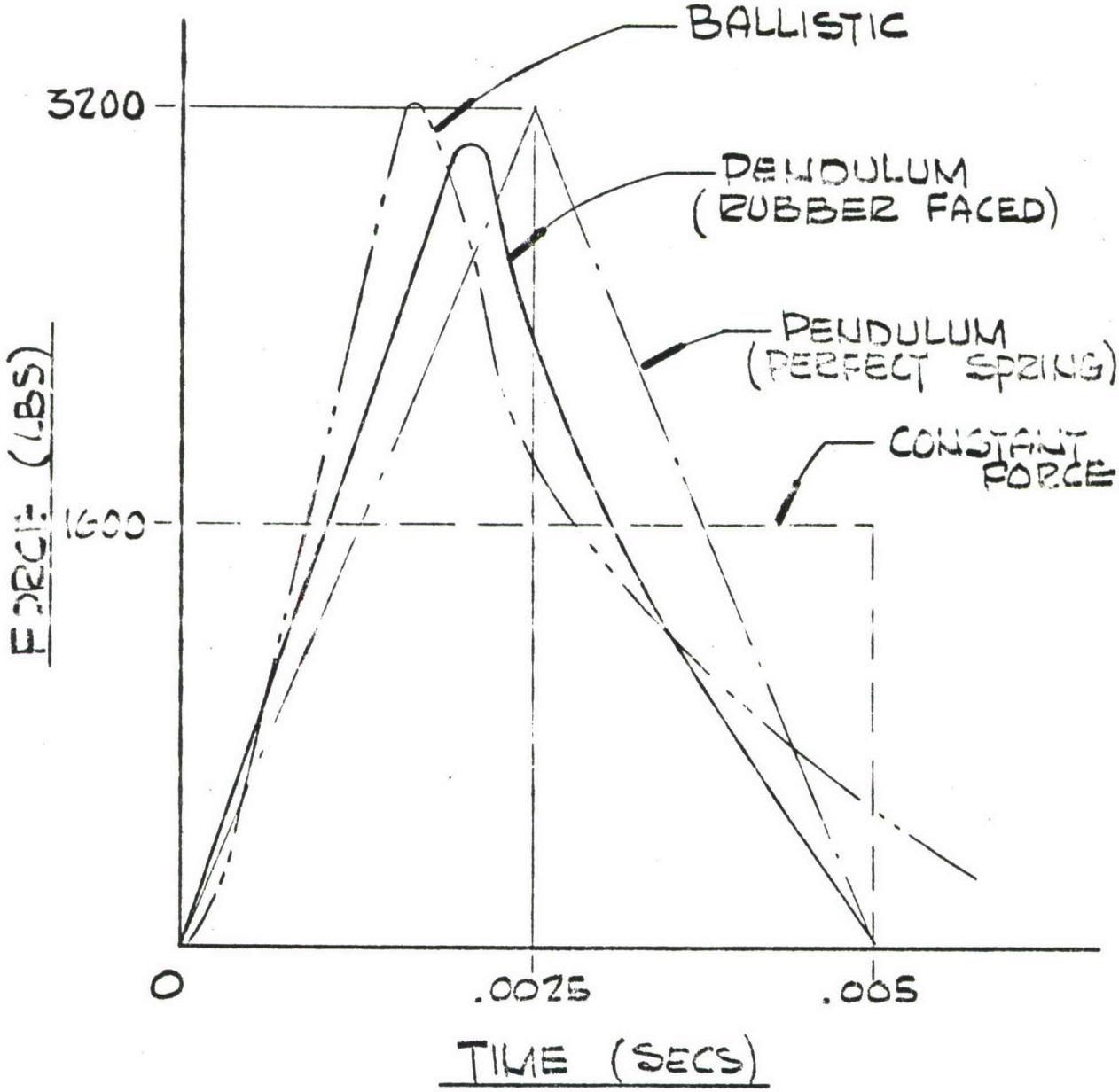


FIG. 3 VARIOUS FORCE-TIME CURVES FOR CONSTANT IMPULSE

One of the goals of the program was the development of a testing device that could be utilized in the testing of production launchers. The simplicity of the pendulum test fixture makes it readily applicable to this aim. It was also used by IITRI to obtain data of the launcher system.

The launcher has three positions from which flares are launched. These are 65, 55, and 45 deg, quadrant elevation (QE) from the ground. The launcher has 12 launching tubes or 12 different firing positions. As the flares are fired from the launcher, the center of gravity of the launcher changes. The combination of the launcher position, the number of flares in the launcher, and the firing position induces a different reaction in the launcher due to a uniform momentum input.

The pendulum test fixture (Fig. 4) accommodates the three launcher elevation positions, the 12 firing positions, and exerts a reproducible impulse to the launcher system. The test fixture consists of three main assemblies to accomplish this, i.e., the frame, tilting table, and pendulum mechanism.

The frame is fabricated of steel structural members, mostly angle iron, which provide a base for the system, a pivot for the tilting table, and an inclined mounting for the pendulum mechanism. The frame can be easily disassembled for shipment.

The tilting table has an angle iron welded frame that can be positioned 0 deg horizontally, +10, or -10 deg. The horizontal position maintains the system in the 55 deg launcher position, the +10 deg corresponds to the 45 deg launcher position. The table pivot point is in line with the launcher base pivot in order to maintain the launcher package in the same position regardless of launching QE. A mounting plate which positions the launcher by use of the rear and front stakes is attached to the tilting table. Also mounted to the tilting table is a bottom pan which can be filled with various soils so that the launcher system can be tested in conditions of actual field use.

The pendulum mechanism is mounted to the frame at an inclined plane of 55 deg from the vertical. This is in a plane normal to the launcher package and was selected so that a change of impacting row position will not vary the drop height of the pendulum. The pendulum mechanism is moved 1-3/8 in. in the inclined plane in either direction from the position shown to impact on any of the three rows of launcher positions. For changing of the left-right firing position the pendulum mechanism is pivoted about the top pivot pin. The pendulum is seared in the drop position and is actuated by a pull solenoid. The energizing of the solenoid also initiates the test recording instruments. Rebounding impacts of the pendulum on the launcher are prevented by a spring-loaded plunger that is released after the pendulum impacts the launcher package.

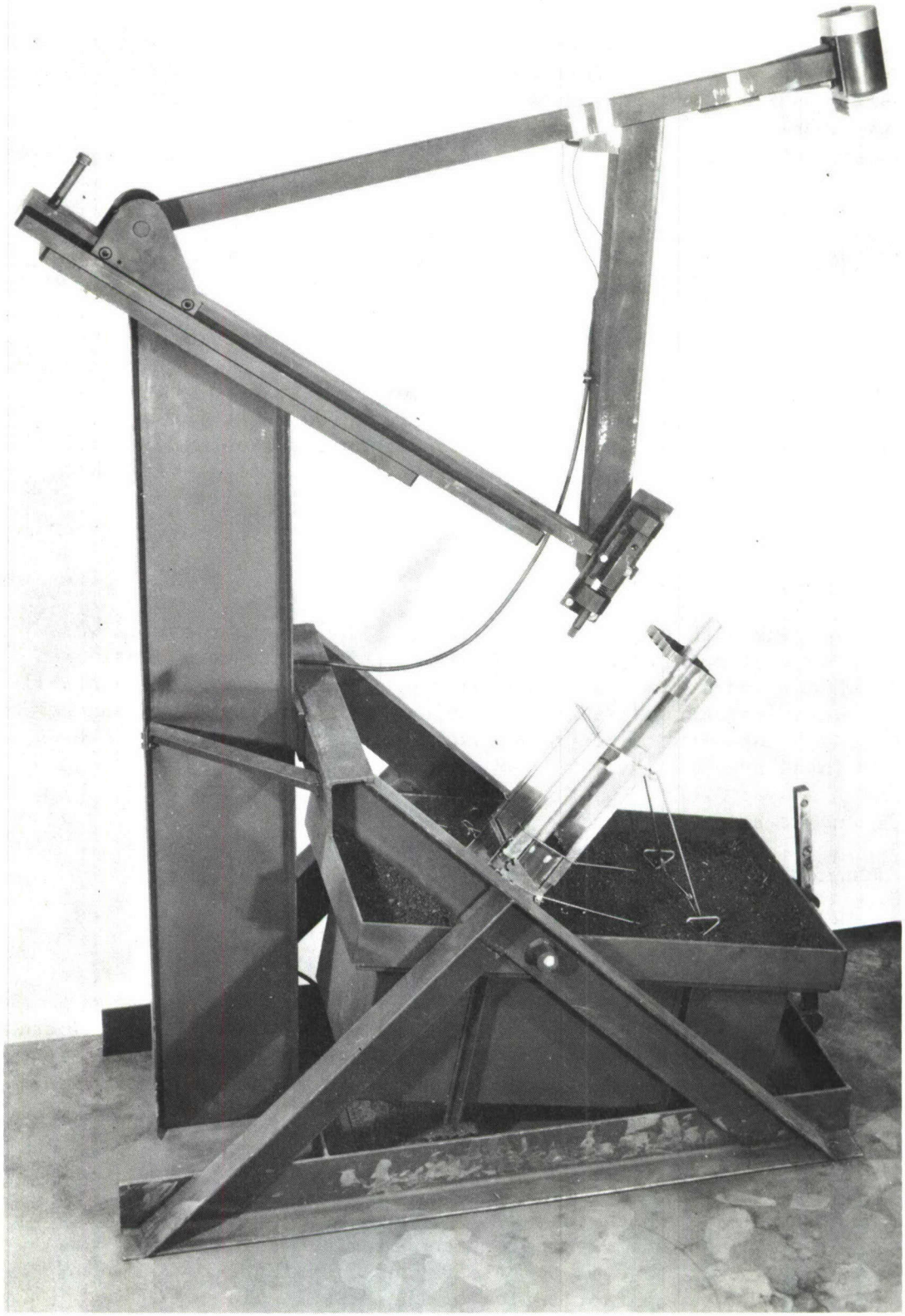


Fig. 4 MODEL OF PENDULUM TEST FIXTURE

The pendulum weight is adjustable so that a range of momentum can be delivered to the launchers without the necessity of varying the drop position. Add-on weights to the pendulum are calibrated to achieve the following momentums:

80% = 6.4 lb-sec
100% = 8.0 lb-sec
125% = 10.0 lb-sec
150% = 12.0 lb-sec
200% = 16.0 lb-sec

The force-time histories of each of the above momentums were recorded.

Rods, simulating the weight and center of gravity of the flares are inserted into the launcher package. An impact rod, that extends 1 in. above the simulated flare package, is inserted into the launcher chamber. Any combinations of firing positions, weight, and center of gravity that represents the number of firings, can be simulated by the distribution of these rods.

4. PRODUCTION SYSTEM DESIGN

In keeping with the stated objectives, the launcher system was analyzed from several points of view. Design improvements were considered in areas in which production cost, ease of emplacement and/or firing stability would directly affect the launcher mission. For clarity, the launcher system is divided into four major functional elements which interface with each other. These are:

Launcher Base

Framework

Anchoring

Flare Assembly

The first three elements and improvements instituted by IITRI are discussed in detail. The Flare Assembly was not part of the study but is included here to elucidate operational procedures in respect to the overall system.

4.1 Launcher Base

The base, about which the system is assembled, erected and fired, is of one-piece construction, fabricated from aluminum sheet stock. The operating function of the base is to receive and distribute recoil transmissions to the ground. The fabrication of the base is die struck and formed to provide the anchoring and elevating operations. The USALWL

prototype base, made of 0.090 aluminum 6061-T6 sheet stock, offered a 30 sq. in. projected ground support with provisions for two angle stake openings. IITRI increased the base area approximately 3 sq. in., thereby relocating the stake openings for easier implementation. One advantage of the relocation of the openings rearward from the pivot bar, is that full depth penetration of the rear stake is no longer required. The base material and thickness was not changed. An aluminum 2024 alloy was considered early in the study but was rejected because of its poor bending qualities. The increase base surface projection also makes possible the incorporation of a fourth locking position to secure the framework and base in the transporting mode.

The front support pivot rod contained within the base assembly interlocks the framework and supporting rods to the base. The original design required wire-forming, threading, and a nut for component retention. This concept was replaced by a straight rod with two roll-formed grooves, for use with two speed nuts, which reducesboth assembly time and costs.

Fig. 5 is an engineering drawing of the top and side views of the launcher in a firing position; Fig. 6 is a photograph of the launcher, without the flare assembly and stakes, in a transportation position.

4.2 Framework

The launcher framework is of wire-formed construction and retains the flare assembly. The framework becomes an integral member of the base assembly through the front support pivot rod and may be repositioned for operation by latching the rear position support rod into the sidewall notches of the base. The USALWL model did not possess a positive locking arrangement for any given elevation during a firing cycle. A wire-formed, over-the-center, lock was designed to correct this condition. The locks are integrally positioned by the front and rear support rods and can be manipulated in darkness by an operator wearing heavy gloves.

A retainer clip was designed into the framework for the purpose of locking the flare package securely in assembly. The clip, a cold drawn 18-gage steel strip, is spot welded to the frame and contributes to structural rigidity as a tension member.

The upper frame wire form and the lower frame wire were redesigned for ease of fabrication and assembly. The supporting strut was redesigned as a two-piece construction and the wire diameter was changed from 1/8 in. to 3/16 in. for increased structural rigidity and strength.

All framework components are 1010 steel and 1/8 in. diameter, with the exception of the front and rear support rods which are 3/16 in. diameter and 1045 steel alloy.

4.3 Anchoring

When securing the launcher system to ground, it becomes apparent that wire-formed anchors cannot be substituted for the rear angle stakes.

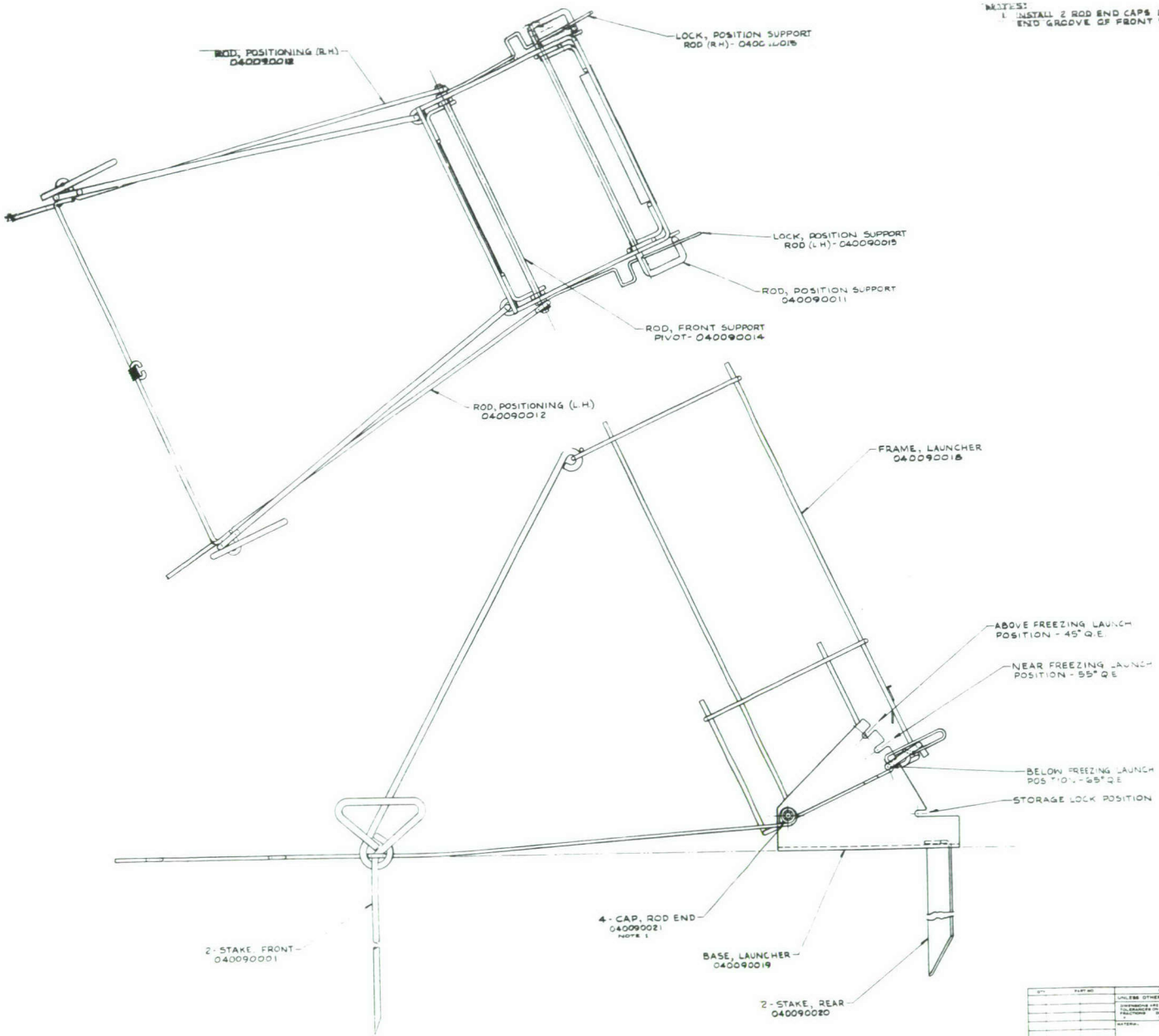
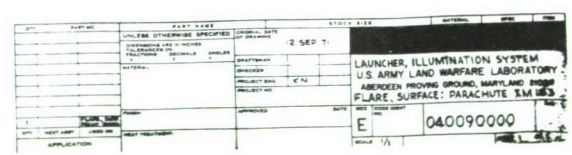


FIG. 5 SCHEMATIC OF TOP AND SIDE VIEWS OF THE LAUNCHER IN A FIRING POSITION.



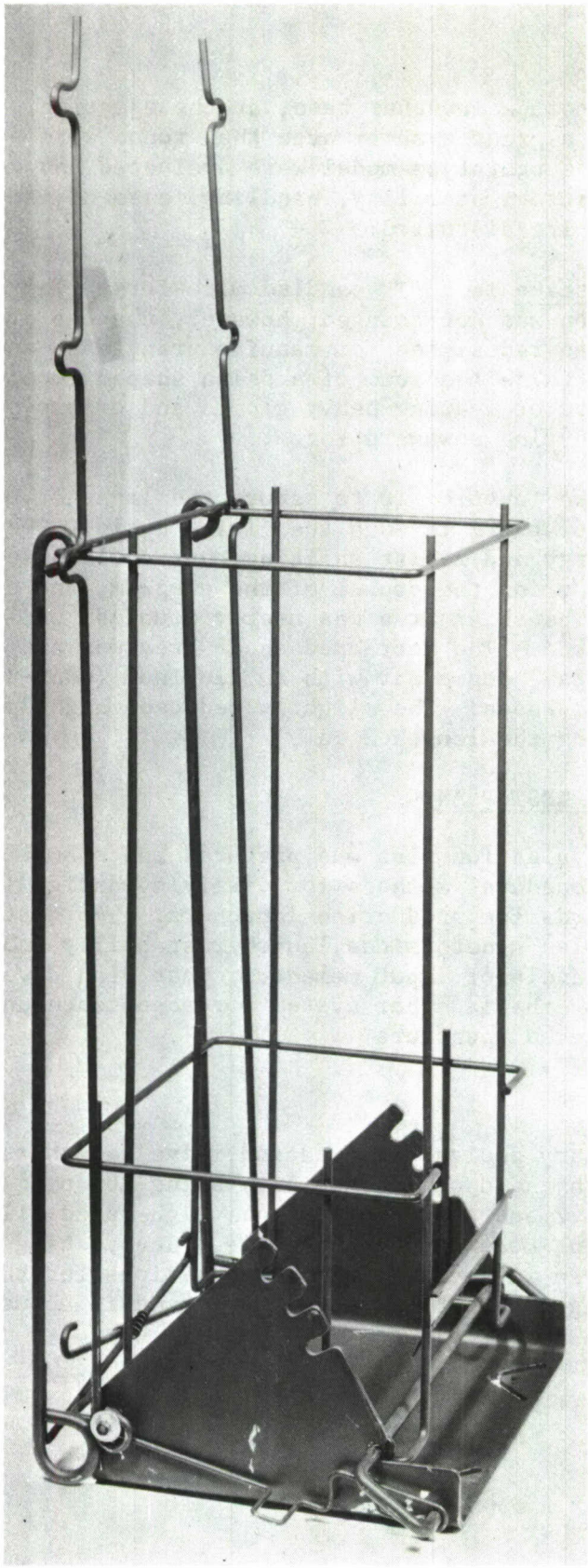


Fig. 6 LAUNCHER IN A TRANSPORTATION POSITION

The momentum imparted to the launcher base, at the ejection of the flare, requires stakes having a greater shear area than round wire stock provides. The ground stakes of the prototype model were evaluated and several design changes were made to improve stability, handling, ease of manufacture and cost reduction. These are discussed.

The forward stake is a "T" handled wire-form. The length, diameter and material designation was not changed; however, the cap or handling projection of the stake was redesigned for manufacturing ease and cost reduction. The design improvement takes the form of a delta shaped loop which can be manipulated by the operator wearing heavy gloves and offers sufficient surface projection for exerting downward force.

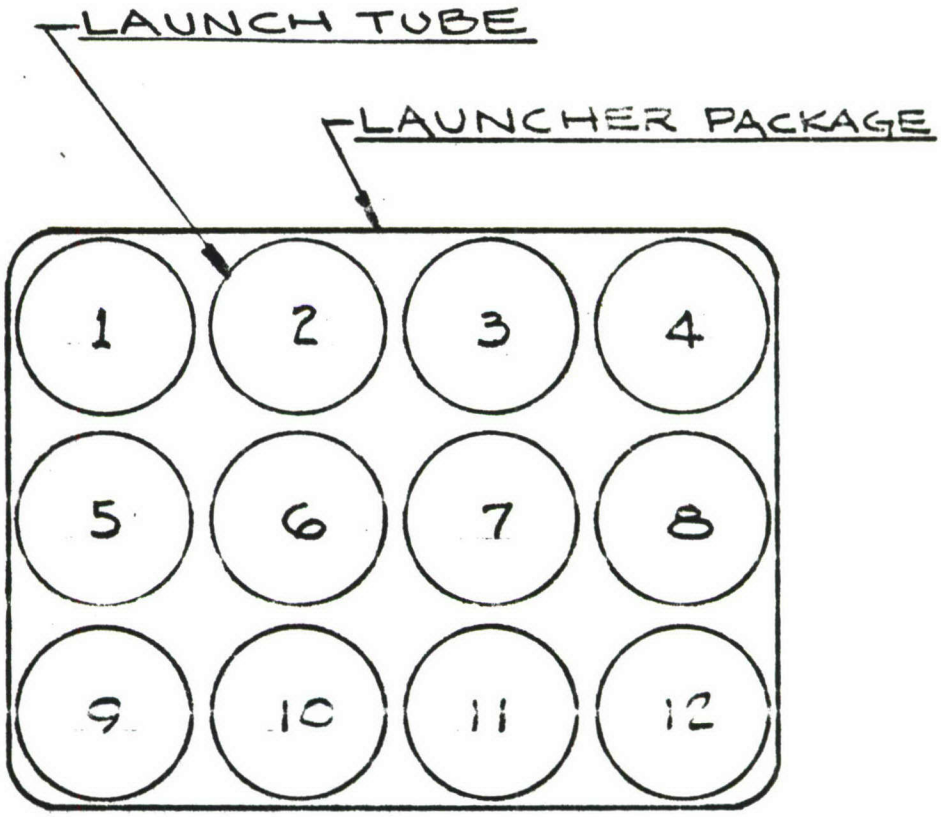
The rear stake function is to secure the launcher base to ground and maintain a stable platform through the firing cycle. The stake must receive the recoil energy and resist shifting that could affect stability and target accuracy. During the course of the program, the existing angle iron was redesigned. The shear area was nearly doubled, while the weight and length were decreased. The increased shear area was accomplished by substituting for the steel angle bar with an aluminum (6061-T6) die form with a like section thickness. The slightly reduced weight of the new design resulted from decreasing the length 2 in.

5. VERIFICATION TEST PLAN

A test and evaluation plan was prepared and submitted early in the program, containing procedural methods for verifying design improvements and acceptance test standards for production launchers. Two test procedures were developed: Test Plan A determines launcher stability and structural integrity at various levels of input momentum; Test Plan B verifies the structural integrity of the launcher system for acceptance and should be performed on the completed launchers.

5.1 Test Plan A

For preliminary design verification, five launchers were tested for structural strength and dynamic stability using the pendulum test fixture described in Section 3.2 and shown in Fig. 4. High-speed films were taken beginning at 100 percent momentum input levels. The testing sequence for these launchers is given in Table I. Impact positions for the tests were conducted in the firing order that would be followed in actual operation (see Fig. 7).



FIRING ORDER: 1, 2, 7, 8, 12, 11, 3, 4, 6, 5, 9, 10

FIG. 7 LAUNCHER FIRING ORDER

Table I

SEQUENTIAL DATA FOR FIVE LAUNCHERS
TESTED FOR STRENGTH AND STABILITY

Test Series	Input Momentum (percent)	Elevation (deg)	Impact in Normal Firing Order
1	80	65	12
2	100	65	12
3	125	65	12
4	150	65	12
5	200	65	1
6	100	55	12
7	100	45	12
8	125	55	12
9	125	45	12
10	150	55	12
11	150	45	12

During this test series, structural damage and latch failures developed for the first five tests beginning at the 100 through the 200 percent levels. Slight bending of support rods, which developed accumulatively over a period of 12 impacts, constituted the structural damage. This condition was corrected by increasing the strut diameter to 3/16 in. The rear support pin was released when retaining lock failures occurred. This condition prevailed only when the top row of launcher positions was impacted. Lock releasing was resolved by redesigning the wire-form to operate in a reversed direction. When the tests were resumed using the redesigned components, no failures, latch releases, or framework distortions occurred and the launcher system demonstrated good stability throughout the entire three firing elevation positions.

Ten final design launchers were tested at the 125 percent momentum level and at 65 deg elevation. The 65 deg position was selected because the maximum force experienced by the launcher occurs at this angle. During these tests, the launchers again demonstrated excellent stability. Failures occurred during early tests when impacting caused the pivot rod retaining nuts to fall off. This deficiency was corrected by replacing the nuts with an arched spring lock which is simply pressed onto the pivot rod and into a groove. This fastener prevents vibration-induced loosening and eliminates the need for secondary fasteners.

5.2 Test Plan B

For Government acceptance, these tests should be performed, using the aforementioned test fixture, to validate quality assurance of mass-produced launchers. The test procedure is given below.

Input Momentum (percent)	Elevation (deg)	Impact	Impact Position
125	65	6	6
125	65	6	7

6. CONCLUSIONS

Within the scope of this contract and time frame, a mass-production type, wire-form launcher design was developed, tested and evaluated. In keeping with the specifications of this program, the improved launcher system retains the basic engineering concepts, while demonstrating a dynamically stable platform which meets all prerequisites for reliability.

The verification test fixture designed for simulating expulsion setback has proved capable for its intended use and is an able tool for its second function, namely, as a method for acceptance qualification. The test fixture can easily qualify launcher operations under wide range soil conditions in respect to various elevation positions.

Limited firing tests conducted at USALWL indicate that, with slight modification, the wire-form launcher should perform satisfactorily as a part of the XM183 system.

Director of Defense, Research & Engineering Department of Defense WASH DC 20310	1
Director Defense Advanced Research Projects Agency WASH DC 20310	3
HQDA (DARD-DDC) WASH DC 20310	4
HQDA (DARD-ARZ-C) WASH DC 20310	1
HQDA (DAFD-ZB) WASH DC 20310	1
HQDA (DAMO-PLW) WASH DC 20310	1
HQDA (DAMO-IAM) WASH DC 20310	1
Commander US Army Materiel Command ATTN: AMCDL WASH DC 20315	1
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Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

Engineering Mechanics Division
IIT Research Institute
10 West 35th Street, Chicago, Ill. 60616

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

Launcher Improvement for Illumination System Flare, Surface: Parachute XM183

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final Report

5. AUTHOR(S) *(First name, middle initial, last name)*

Daniel J. Herkes

6. REPORT DATE

December 1972

7a. TOTAL NO. OF PAGES

7b. NO. OF REFS

8a. CONTRACT OR GRANT NO.

DAAD05-71-C-0315

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Approved for public release: distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

U. S. Army Land Warfare Laboratory
Aberdeen Proving Ground, MD 21005

13. ABSTRACT

The objective of this nine-month program was to improve the present feasibility model launcher for mass production. In addition, design features such as flare package retention and positive locking were to be investigated. To assure system reliability, a method of verifying these objectives was required.

During the course of this program, a development approach and test plan was generated and approved for engineering activities. A verification test fixture was designed and constructed to simulate impact type loading on a launcher. Experimental and production type launcher systems can be subjected to peak recoil conditions of 1600 lb for 5 msec through three firing elevations.

The Land Warfare Laboratory prototype model was studied and redesigned to accommodate the objectives of reduction in manufacturing cost, ease of assembly, stability and simple emplacement under adverse conditions during a tactical assignment. Fifteen development launchers were fabricated and tested for design verification. Incorporated into the basic concept were features such as positive framework-to-base locking in four positions, improved structural supporting, flare package assembly retention, and an improved method of anchoring.

Following an engineering analysis of these pilot design improvements, 175 launcher systems were manufactured and delivered.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Launcher						
Illumination						
Wire-Form						
Lighweight						
Test Fixture						

Unclassified

Security Classification