MHSMP-69-11

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Mason & Hanger-Silas Mason Co., Inc.

ENGINEERS AND CONTRACTORS
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Pantex Plant

SANDIA LABORATORIES

4-INCH SAMPLE RECOVERY CANISTERS

TEST MODEL D SERIES

P. L. Goode - Testing
G. W. Neff - Reporting

For

Sandia Laboratories
Albuquerque, New Mexico

September 1969 to May 1970
Purchase Order No. 94-4639 and 94-4683

ATOMIC ENERGY COMMISSION · UNITED STATES OF AMERICA

DEVELOPMENT DIVISION

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ACKNOWLEDGEMENT

The work described in this report was supervised by Phillip L. Goode*.

Glenn W. Neff compiled the tables, charts, and figures and edited the report.

*Present address: *Amarillo Gear Works, Amarillo, Texas*

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ABSTRACT

Six tests were conducted on 4-Inch Test Model D Closures to develop an improved closure for the redesigned Sandia Recovery Canister (SRC). The first three closures tested used variations of the high explosive (HE) design used on the previous Model B (Second) Series[1] (P64283). The last three units tested used variations of the HE design used in the Midi Mist Event SRC.

[1] *4-Inch Sample Recovery Canister, Model B (Second) Series, P. L. Goode, Mason & Hanger-Silas Mason Co., Inc., Pantex Plant, Development Division, February-July 1969*

DISCUSSION

General

Pantex fabricated the hardware for this test series on Purchase Order 94-4639. These units were then assembled and tested on Purchase Order 94-4683. During the test series, mechanical strength requirements were revised downward by Sandia. The last two units, lower mechanical strength, of this test series were, therefore, annealed in an attempt to minimize internal shrapnel generation and fracture of the closure section. Concurrent sleeve testing at Sandia, indicated that a liner was still necessary. Table I denotes the heat treatment requirements and conditions of the components used in the closure fabrication. The data shown for TMD4-005 and 006 are the annealed values; their original conditions were the same as those values recorded for TMD4-001 through 004.

HE Assembly

The HE, du Pont Detasheet EL-506C, was applied in an annulus to the unit with adhesive transfer tape (3M Co., #465 in 10-inch wide rolls). Three EL-506C variations were used; C-1 (.042" thick), C-2 (.084" thick), and C-4 (.166" thick).

To minimize stretching of the HE, it was first placed on the transfer tape, then cut slightly larger than required. The prepared HE was then weighed and the weight recorded. One end of the HE sheet was attached to the closure unit. The rest was allowed to hang free while the assembly was rotated and the HE was guided around the assembly by hand . The excess HE was then trimmed to create a closed joint. If the HE was stretched during application, it would partially recover (later) and leave a gap. The HE trimmings and transfer tape paper backing were weighed and substracted from the first weights to arrive at the assembled HE weight. Each additional layer was added in the same manner, staggering the longitudinal joints approximately 45°. The process was continued until the desired HE configuration was achieved.

Assembly of the modified Midi-Mist HE design (M-3) caused minor difficulty when placing each layer of HE over a cylindrical surface abutting a conical surface. The flexibility of C-1 detasheet allowed each layer to be wrapped around these dissimilar surfaces. The outer two layers on each assembly had to have small pie-shaped wedges cut out. This allowed placement over the cylindrical surface without forming a ridge in the HE assembly.

Design

The sleeve assemblies consisted of two C 4142 seamless alloy steel tubes, shrunk fit together with a diametrical interference fit of .000 to .005-inch. The forward flange had a diametrical interference fit of .006 to .008-inch and was not pinned. This feature allowed the closure unit to separate from the forward flange during testing. The ring spacer was eliminated and instead a step was machined as an integral part of the outer sleeve (Fig. 1). The step was eliminated from the last two units (Fig. 2). This made an additional 1½-inch length available for closure. The inner sleeve was pinned to the outer sleeve with six hardened steel pins. All units had 1010-1020 seamless steel liners shrunk inside of the inner sleeve. An interference fit of .001 to .002-inch on the diameters was used. Details of each unit are given in Table II and shown in Figs. 3 through 8.

Testing Procedures

Fig. 9 shows a typical test setup. Each closure was tested similarly, except units TMD4-001 and 004 which were evacuated. Tests 001 and 004 used a Plexiglas vacuum seal on the extension pipe to allow camera coverage of the closure I.D. A McLeod gage was used to moniter the vacuum prior to firing.

All closures were placed on cradles with their center lines two feet off the ground. Plywood boxes, (4 ft. x 4 ft. x 7 ft. long) were placed around the first four tests and filled with washed sand (4 yd^3) for tamping.

Radial cover expansion data is shown in Fig. 10. The expansion rates for TMD4-001 and 004 were expected, i.e., 004 expanded slower than 001 due to the reduced HE charge. Both 001 and 004 covers were heat treated to give an ultimate tensile strength of approximately 100 kpsi. After 240 μsec, the 004 cover probably broke up. The resulting shrapnel may have completed the last four pin switch circuits. The dual growth rate curve for TMD4-002 (ultimate tensile 170 kpsi) was not expected and was probably due to erroneous signals at 1¼ inches, 1½ inches and 2 inches. These errors may have been caused by breakage of the Plexiglas pin switch (piezo electric gages) holder.

The charge to mass ratio[2] (c/m) is plotted with reference to axial position in Fig. 11. This figure shows the variation in c/m used for the six tests. This is not a non-true dimensionless ratio, but may be converted to a valid ratio by using a factor of 0.008. As herein used C/M is the number of C-1 layers present divided by the steel thickness in inches. The axial position is referenced to the innerface of the forward flange as zero inches. These closures were tested in the sequence of 001, 004, 002, 003, 005, 006.

[2]*Charge to mass c/m ratio as denoted by John Dresser, Org. 9133, Sandia Corporation, Albuquerque, New Mexico*

TMD4-001 was overdriven with the liner separating into two parts at a distance five inches from the start of the taper. Therefore, the HE charge for TMD4-004 was reduced considerably resulting in an underdriven closure. TMD4-002 was a compromise between the previous two tests (001 and 004) yet it also resulted in an overdriven closure. The liner of test 002 separated at 5.75 inches from the forward flange.

A closure review meeting was held at Sandia, Albuquerque, resulting in the decision to eliminate the stress riser, now an unnecessary part of the closure units, and to use a modified HE charge of the Midi Mist type for the TMD4 units. The last three tests (003, 005, and 006) of the series used variations of the Midi Mist design, (M3) HE design. Fig. 11 shows the c/m ratios used for those shots. TMD4-003 was the first unit to use the M3 design and resulted in an excellent closure with the full length of the liner retained in the closure unit. Note that the space formerly occupied by the stress riser was utilized for additional length of closure and that the maximum amount of HE was placed over the minimum wall thickness.

Fig. 11 shows plots of percent area closed (% AC) versus axial distance, same reference. Of the first four tests which had the same heat treatments, TMD4-003 had the smallest slope (% AC/Axial length) and the best closure.

RESULTS

General

The first three closures tested gave a fair but overdriven closure (TMD4-001). The second, a slightly underdriven closure (TMD4-004), and the third, a fair but overdriven closure (TMD4-002). The foam inserts (mock experiment package) were apparently damaged by hot gasses estimated at approximately 300 psi. It is desirable, but not essential, to eliminate the gas damage. TMD4-001 and 002 formed jets of particulate matter upon closure which should be eliminated to properly protect the experiments in the experimental section of the SRC.

The second three closures tested gave excellent closures (TMD4-003, 005 and 006). They all used variations of the M3 HE design. All resulted in shrapnel-free, jetless closures with little or no gas damage to the foam insert. The M3 design places the maximum amount of HE over the minimum wall thickness whereas previous HE designs had placed the maximum HE thickness over non-minimum wall thickness areas, see Fig. 3 and 5 for a comparison of the HE design used on TMD4-001 and 003.

Table III lists the instrumentation data acquired for the test series. Instrumentation used included initial wall motion switches, radial cover expansion switches, closure cable, dynamic and passive pressure gages. All data were recorded on tape (Honeywell magnetic tape recorder, Model 7620) in addition to oscilliscopes and/or rasters.

<u>Specific Tests</u> (See photographs, Figs. 12 through 28, and drawings of closure cross-sections, Figs. 29 through 34.)

<u>TMD4-001</u>

Fairly good closure was achieved, but it was overdriven, similar to TMB4-017[3]. The liner was fairly solidly closed, but forward end was lost, shrouded or

[3] *See report of tests performed on Sandia Corporation Purchase Order 94-4577 dated February-July 1969.*

shreaded (3½ inches retained). Unit separated at the stress riser. The forward end of the gage filler assembly was shattered and blackened. Considerable damage was done to the unshielded 300 psi gage, probably due to high temperature material. There was evidence of "jetting" upon closure with particulate matter near the center line of the unit damaging the gage filler assembly. The unit apparently experienced an in ernal pressure of approximately 300 psi. No large shrapnel was generated.

TMD4-004

This closure was underdriven, leaving an aperature of approximately ¼ inch remaining at the center; maximum area closed off was 99 percent. All of the liner was retained. The liner did not separate into two parts. The forward flange was separated from the unit. as planned.

The gage filler assembly consisting of an aluminum passive pressure gage was coated with a light layer of black dust. There were no other indications of gas, shrapnel, or particulate matter damage. There was no evidence of jetting, which should occur only when the liner completely closes. The passive pressure gage gave no indications of having compressed, therefore, the internal pressure was not more than 410 psi.

TMD4-002

A fairly good overdriven closure was attained. The liner remained fairly solidly contained; but forward end of the liner was lost (4½ inches retained). This unit did not separate at the stress riser. The forward flange was separated from the unit. The foam filler was exposed to gas, shrapnel, and jetting damage.

TMD4-003

Good closure was produced, but the inner sleeve had longitudinal splits. The liner was fully retained and was solidly closed for 5/8 inch. The forward flange was separated from the unit. The filler was not exposed to gas, shrapnel, or jetting damage. A filament wound cover was used, but it appeared to influence the closure quality very little.

TMD4-005

The best closure resulted, however, the inner sleeve again had longitudinal splits. The liner was fully retained and was solidly closed for 2 inches. A fault 3/4-inch wide by 2½-inch long by approximately 1/64-inch deep was percent in the closure section near the centerline.

TMD4-006

The closure was good and splitting was virtually eliminated, but a very thin band was left open about ¼-inch wide by 1/16-inch near the center of the liner. The liner was fully retained and the foam filler was not damaged other than being blackened.

Table I

Heat Treatment Requirements and Conditions

TMD4 Unit No.	Component[1] No.	Material Seamless Steel Tubing	Requirement: Tensile Yield[9] and/or UTS[2] kpsi	Requirement: Hardness, BHN[3] or Rockwell	Actual Condition: Tensile Yield[9] and/or UTS[2] kpsi	Actual Condition: Hardness, BHN[3] or Rockwell	Method of Certification: Hardness Ring	Method of Certification: Standard[4] Tensile Test
	101	4140	105-120	20-24C	111	19.3C	x	x
	201	4140	-	200 or less	-	87B	x	-
	301	4142	-	200 or less	-	91B	x	-
001	401	MT-1015	35 Tensile Yield	100 or less	34 Tensile Yield	54B	x	x
	102	4140	105-120	20-24C	114	20.0	x	x
	202	4140	-	200 or less	-	86B	x	-
	302	4142[5]	-	200 or less	-	85B	x	-
002	402	MT-1015	35 Tensile Yield	100 or less	34 Tensile Yield	54B	x	x
	103	4140	105-120	20-24C	110	19.4C	x	x
	203	4140	-	200 or less	-	86B	x	-
	303	4142[5]	-	200 or less	-	88B	x	-
003	403	MT-1015	35 Tensile Yield	100 or less	34 Tensile Yield	54B	x	x
	104	4140	105-120	20-24C	109	19.9C	x	x
	204	4140	-	200 or less	-	88B	x	-
	304	4142	-	200 or less	-	92B	x	-
004	404	MT-1015	35 Tensile Yield	100 or less	34 Tensile Yield	54B	x	x
	105	4140	-	94B or less	-	84B	x[7]	x[8]
	205	4140	-	94B or less	-	84B	x[7]	-
	305	4142[6]	-	94B or less	-	-	-	-
005	405	MT-1015	35 Tensile Yield	100 or less	37 Tensile Yield	59B	x	x
	106	4140	-	94B or less	-	-	x	x
	206	4140	-	94B or less				-
	306	4142[10]	-	94B or less				-
006	406	MT-1015	35 Tensile Yield	100 or less	37 Tensile Yield[11]	59B	x	x

[1] *1xx = inner sleeve, 2xx = outer sleeve, 3xx = HE cover, 4xx = liner*

[2] *UTS - Ultimate Tensile Strength, based on original cross section area*

[3] *BHN - Brinell Hardness Number*

[4] *Standard Tensile Test per Federal Test Method Standard No. 151A, Method 211.1, Type R3 Specimen*

[5] *This cover was not used on final assembly, cover for FM4-008 was used instead*

[6] *This cover was not used on final assembly, cover for FM4-009 was used instead after it had been fully annealed*

[7] *Hardness ring values were taken from the original hardness rings which were also re-heat treated*

[8] *Standard Tensile Test per Federal Test Method Standard No. 151A, Method 211.1, Type 4R Specimen*

[9] *Defined as minimum flow stress, post yield*

[10] *This cover was not used on final assembly, cover from FM4-010 was fully annealed and substituted*

[11] *Liners for Units 005 and 006 were made from the same piece of material, so one test respresents both*

Table II

HE and Sleeve Assembly of TMD4-001 Through 006

TMD4 Unit No.	Type[1] Assy.	Taper Length (in)	Taper Dist.[2] Front (in)	Stress Riser "V" (in)	Stress Riser Dist.[2] Front (in)	HE Fabrication Cover Type	LWG Loc.	HE Layers C-1	HE Layers C-2	HE[1] Designation	Main Chg.[3] (lbs)	Test Configurations Tampers Type	Liner Origin	Liner OD (in)	Liner Length (in)	Ref.[4] Figs.	Shot Date
001	P72246-D	6	6	x	4.438	Steel[5]	Std.[6]	14	1	P64283-F	2.38	Machined[7] Lead	Std.[8]	4.5	6.5	13 thru 15	9/25/69
002	P72246-D	6	6	x	4.438	Steel[9]	Std.[6]	14	1	P64283-G	2.00	Machined[10]	Std.[8]	4.5	6.5	16 17 18	11/13/69
003	P72246-D	6	6	Omitted	-	Steel[11] and Fiberglass	Std.[6]	6	-	P83624-B	1.49	Laminated inner No outer	Std.[8]	4.5	10.5	19 thru 22	12/18/69
004	P72246-D	6	6	x	4.438	Steel[5]	Std.[6]	13	-	P64283-C	1.38	Machined[7]	Std.[8]	4.5	6.5	23,24	10/15/69
005	P72246-E	6	7.5	Omitted	-	Steel[9]	Std.[6]	6	-	P83624-C	1.77	Laminated Inner No Outer	Non-[12] Std.	4.5	12.0	25,26	2/27/70
006	P72246-E	6	7.5	Omitted	-	Steel[9]	Std.[6]	5	-	P83624-C	1.62	Laminated Inner No Outer	Non-[12] Std.	4.5	12.0	27,28	4/2/70

[1] *Drawing number*
[2] *See Fig. 1*
[3] *Without LWG or HE transition (add approximately .25 lbs)*
[4] *Preshot and Post-shot photo's*
[5] *Steel cover, 9" OD x 7/16" wall per P72250A*
[6] ***Folded over** design see Figs. 3 through 8*
[7] *Outer tamper per P64279D, inner tamper, per P64278D*
[8] *10.500" in from the front of the forward flange of the closure unit*
[9] *Steel cover, 9" OD x 7/16" wall per P64209*
[10] *Outer tamper per P64279D had its ID machined to accommodate new OD of HE buildup due to 1/16" Neoprene sheet under part of the HE charge. Inner tamper per P64278E*
[11] *Steel cover, 9" OD x 7/16" wall wrapped with 1/2" wall thickness fiberglass per P72251*
[12] *12.000" in from the front of the forward flange of the closure unit*

Table III

Instrumentation Data

TMD4 Unit No.	Switches: Initial Wall Motion (μsec) Gage 1	Gage 2	Gage 3	Gage 4	Switches: Cover Expansion Radial Array	Switches: Closure Cable (μsec)	Pressure Gages: Active, Shielded Gage 1	Active, Shielded Gage 2	Active, Unshielded Gage 1	Active, Unshielded Gage 2	Pressure Gages: Passive	Fastax Framing Cameras: Frame Time (μsec)	No. 1 Coverage	Frame Time (μsec)	No. 2 Coverage	Frame Time (μsec)	No. 3 Coverage	Miscellaneous: Vacuum (μ)	Extension pipe	Foam Conditions
001	-	-	-	-	Fig. 10	-	280[1] psi	310[2]	825[3]	-	-	250	Overall	250	Closeup	167	Bore	≤1000	Closed end Plastic Disk	Gas damage, no large Shrapnel, evidence of gas/particulate matter jetting
002	50[9]	55[10]	65[11]	75[12]	Fig. 10	149	-	-	-	-	≥450[13] psi	250	Overall	250	Closeup	-	-	Ambient	Open end	Gas damage, shrapnel damage, and jetting damage
003	-	-	-	-	-	-	-[15]	-	-	-	-	267	Overall	267	Closeup and bore	-	-	≥5000[14]	Closed end plastic disk	No gas damage, no shrapnel, no jetting complete closure
004	DNT[4]	DNT[5]	DNT[6]	-	Fig. 10	DNT[7]	-	-	-	-	≤410[8] psi	303	Overall	250	Closeup	-	-	Ambient	Open end	Light gas damage, no shrapnel, no jetting but incomplete closure
005			-	-			-	-	-	-	-	250	Overall	167	Closeup and bore	-	-	Ambient	Open end	No gas damage, no shrapnel, no jetting complete closure
006	-	-	-	-	-	-	-	-	-	-	-	250	Overall	250	Closeup and bore	789	Cover[16] Expansion	Ambient	Open end	No gas damage, no shrapnel, no jetting complete closure

[1] *Schaevitz-Bytrex Model HFH Pressure Transducer, max. 300 psi, shielded (half-bridge).*

[2] *Schaevitz-Bytrex Model HFH Pressure Transducer, max. 200 psi, shielded*

[3] *Schaevitz-Bytrex Model HFH Pressure Transducer, max. 300 psi, unshielded, gage overdrive due to shrapnel.*

[4] *Did not trigger, located at the notch (4-7/16" from face of forward flange).*

[5] *Did not trigger, located at the start of the taper (6" from face of forward flange).*

[6] *Did not trigger, located at maximum HE cross section (8-5/8" from face of forward flange).*

[7] *Did not trigger, unit was slightly underdriven (ID = 1/4" end closure).*

[8] *Honeycomb gage wasn't crushed, therefore the pressure it saw was equal to or less than its 410 psi calibration pressure.*

[9] *Located aft the notch. Scope records inconclusive. Tape data is listed.*

[10] *Located aft of the notch 1½". Scope record inconclusive. Tape data is listed.*

[11] *Located aft of the notch 3". Scope records inconclusive. Tape data is listed.*

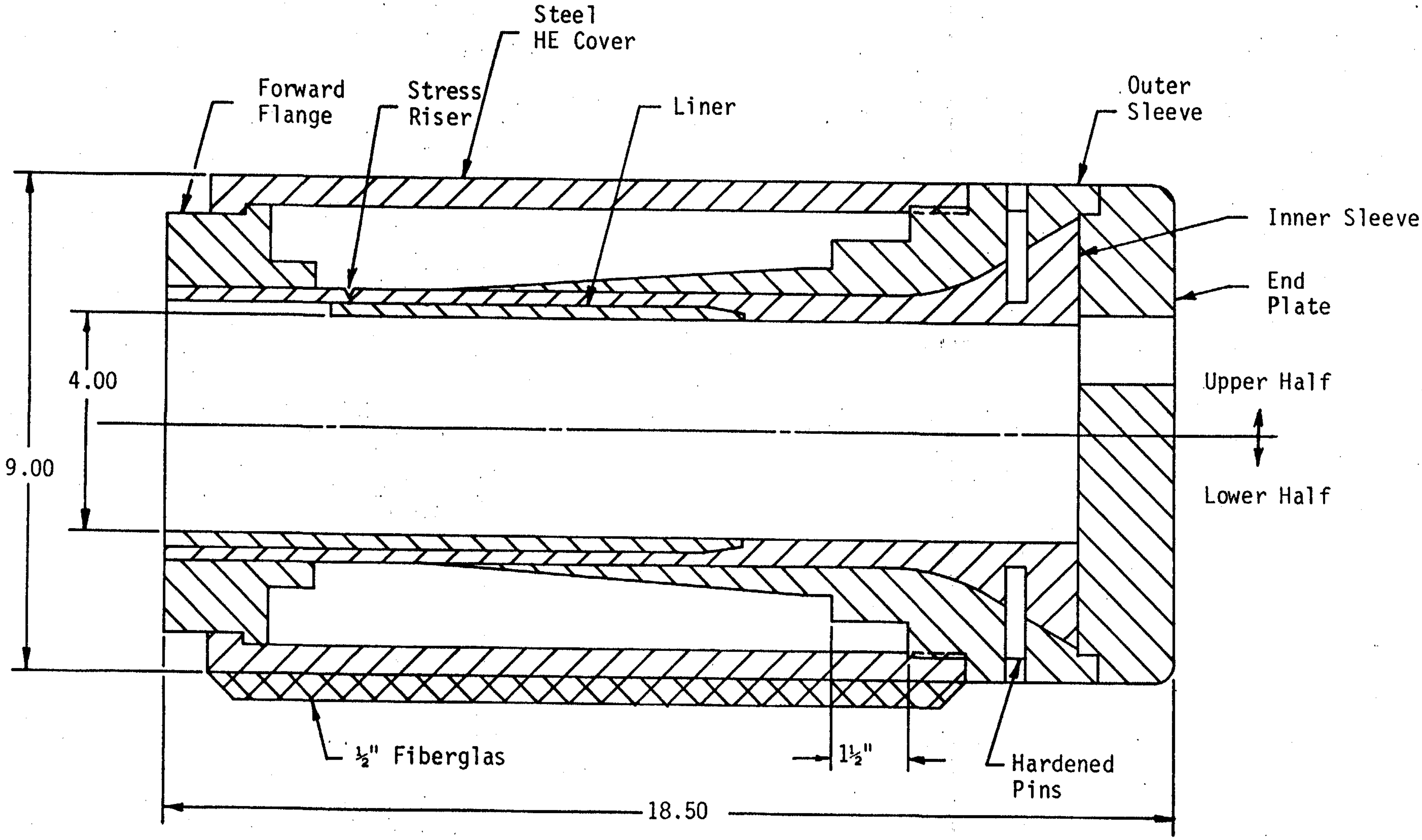
[12] *Located aft of the notch 4½". Scope records inconclusive. Tape data is listed*

[13] *Honeycomb gage was crushed, therefore the pressure it saw could have been greater than its 450 psi calibration pressure, but the gage saw heavy shrapnel damage which probably crushed the gage instead of a pressure pulse.*

[14] *Vacuum gasket inadvertently not used on end of unit, Ducseal used but a leak was present.*

[15] *Micro-systems Model 0178 Pressure Transducer, max. 500 psi, shielded, inconclusive data.*

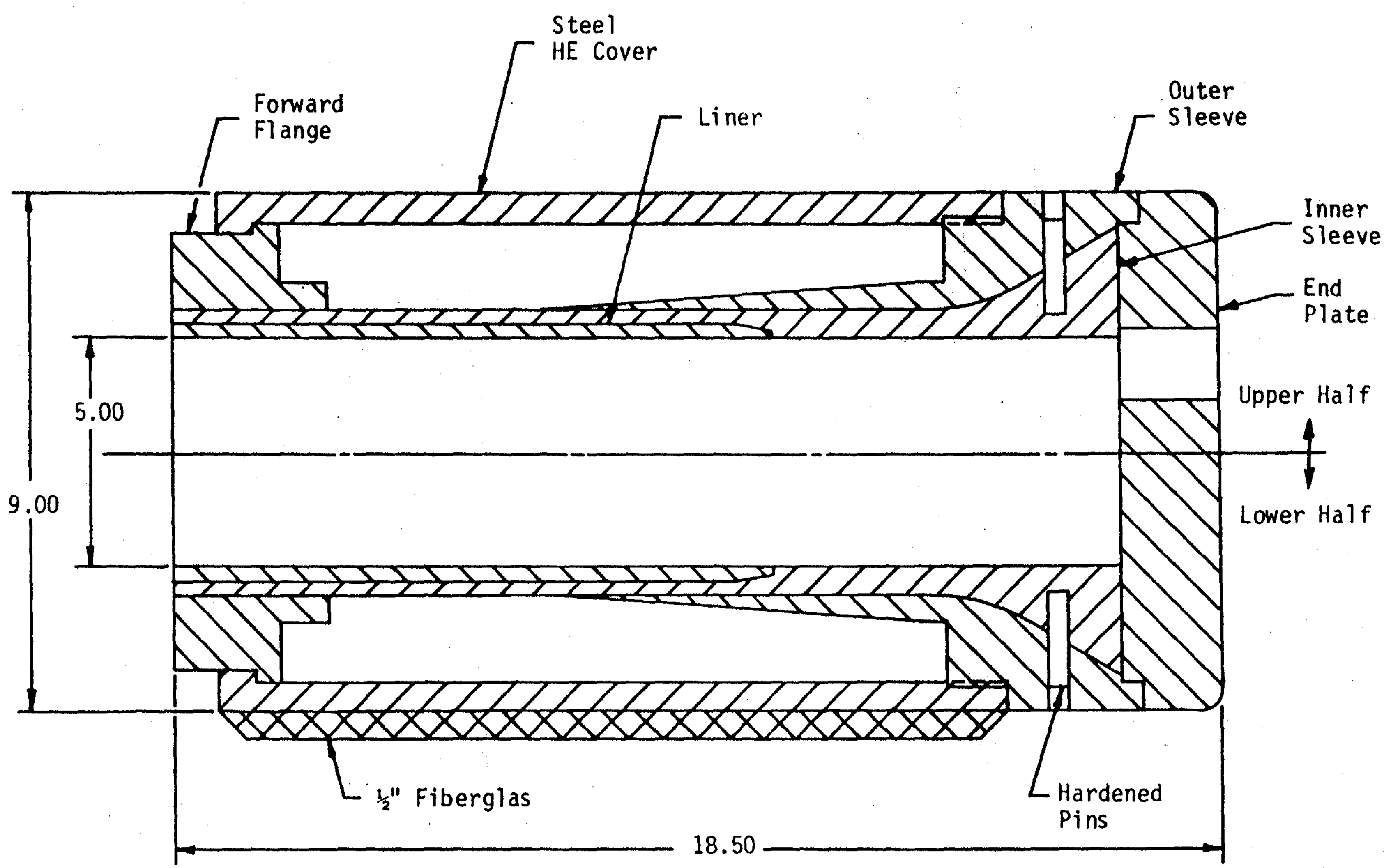
[16] *Cordin Model 116 Framing Camera coverage rather than Fastex.*



<u>Upper Half:</u> Test Model D-4 Design Used For TMD4-005

<u>Lower Half:</u> Test Model D-4 Design Used For TMD4-006

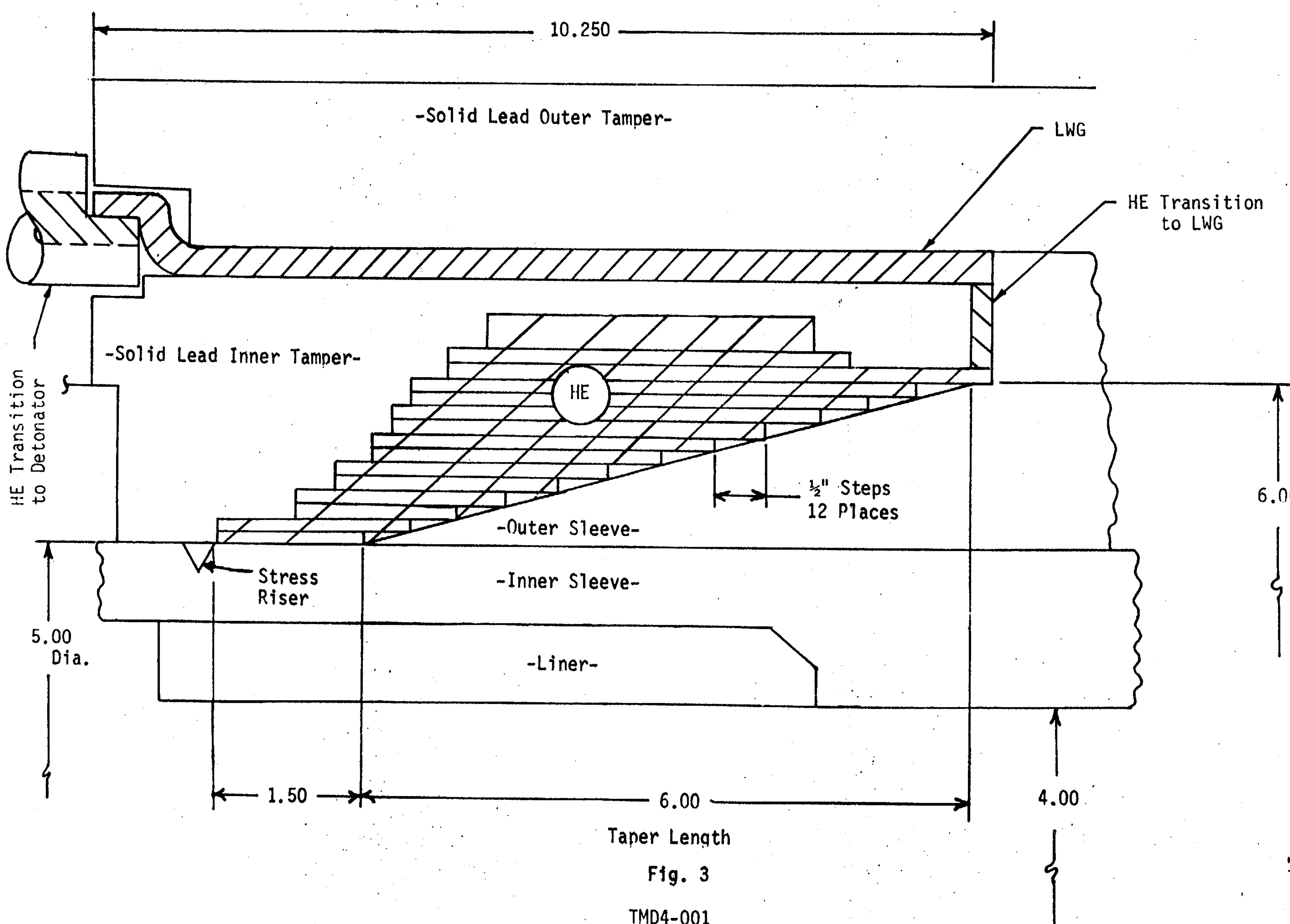
Fig. 1



Upper Half: Test Model D-4 Design Used for TMD4-005

Lower Half: Test Model D-4 Design Used for TMD4-006

Fig. 2



Taper Length

Fig. 3

TMD4-001
HE Design: P64283-F

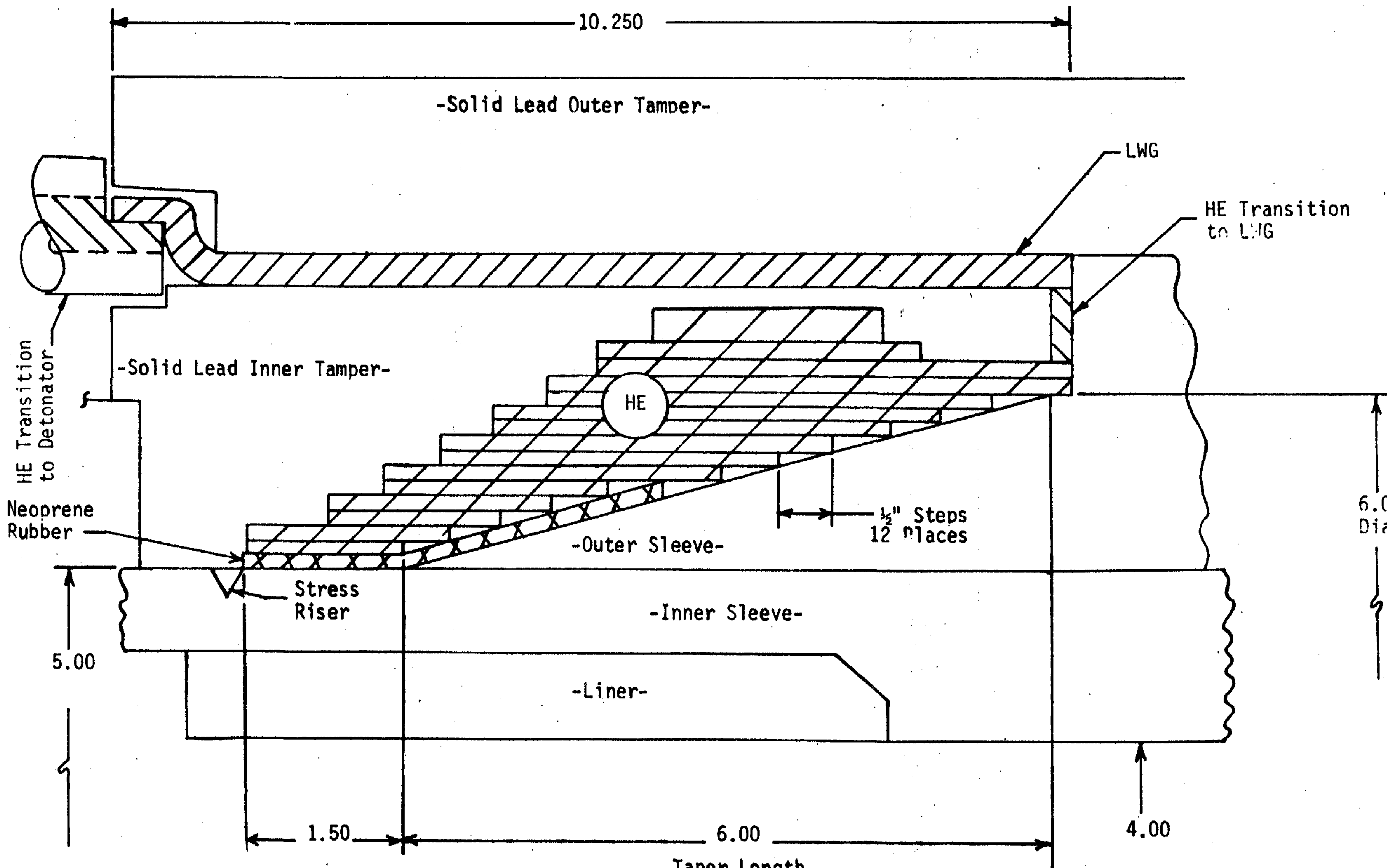


Fig. 4

TMD4-002
HE Design: P64283-G

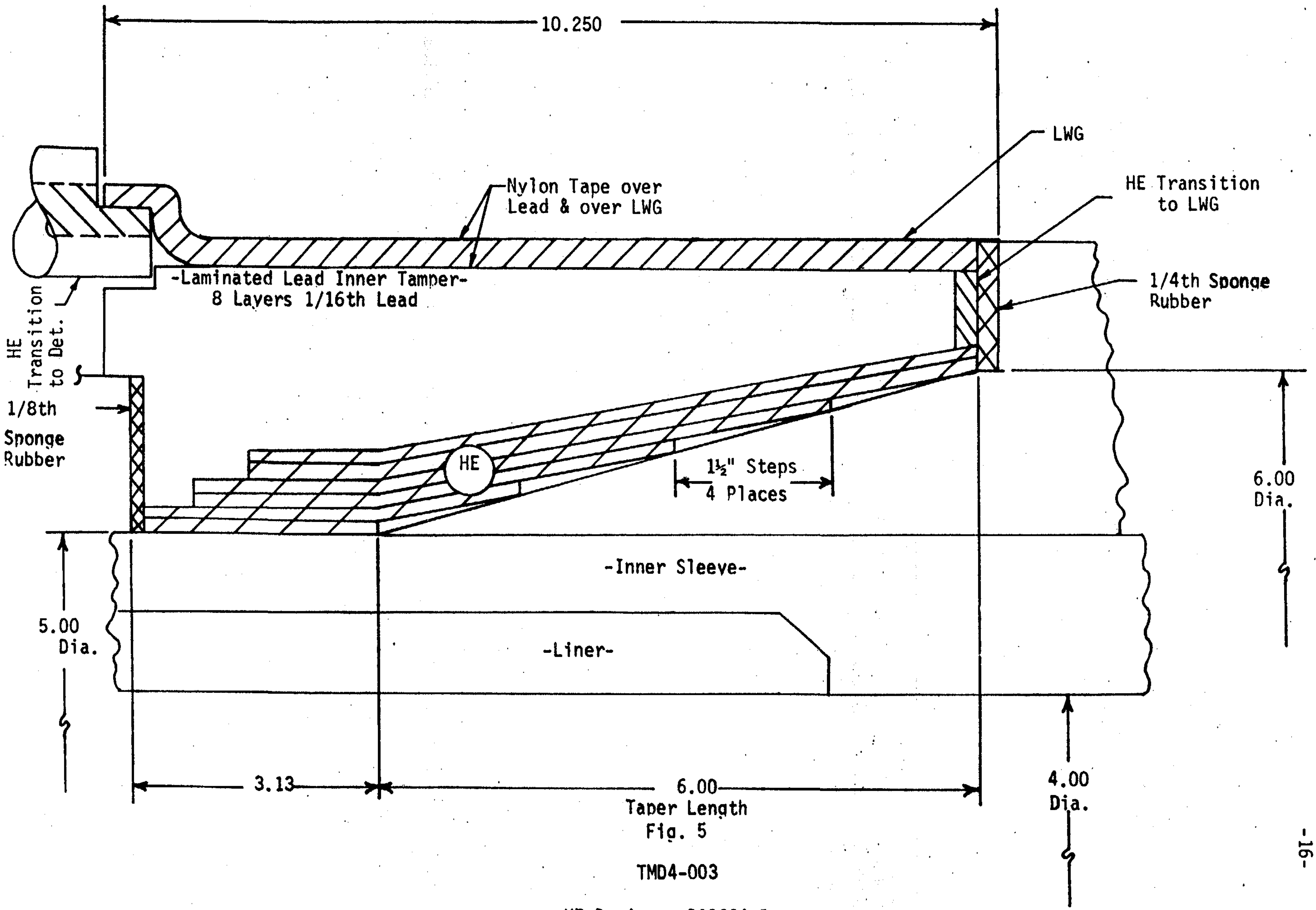


Fig. 5

TMD4-003

HE Design: P83624-B

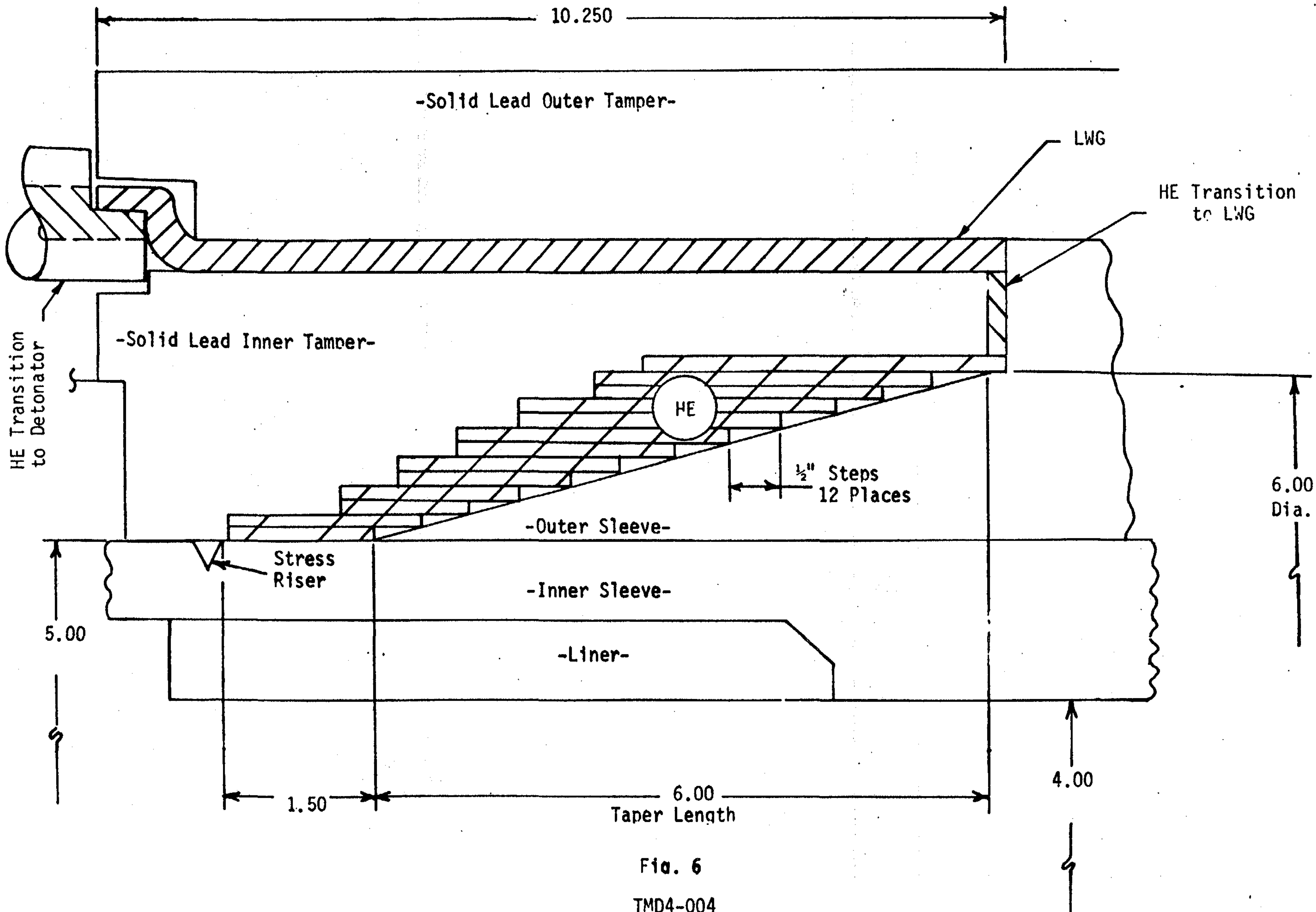


Fig. 6

TMD4-004
HE Design: P64283-C

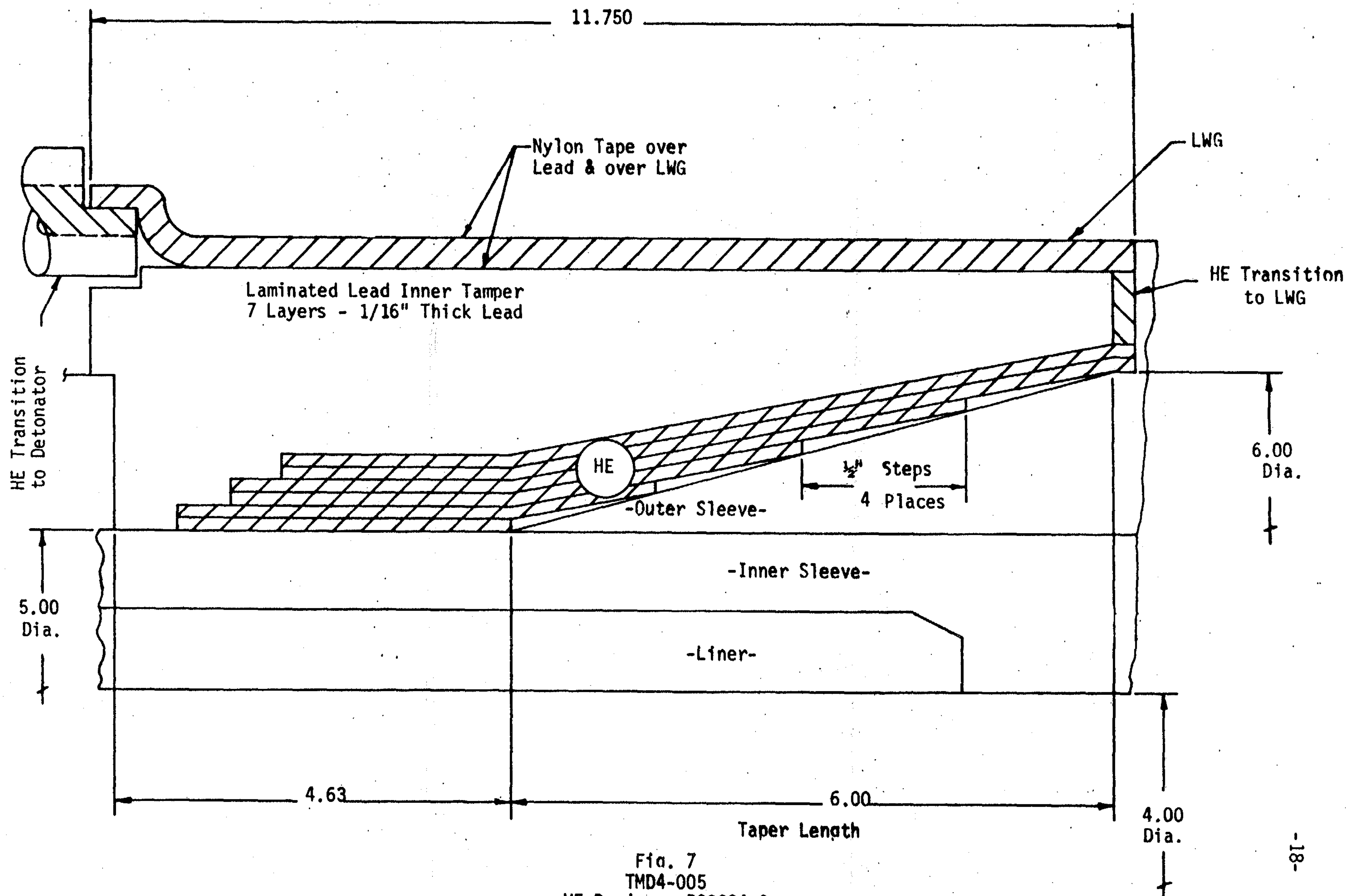


Fig. 7
TMD4-005
HE Design: P83624-C

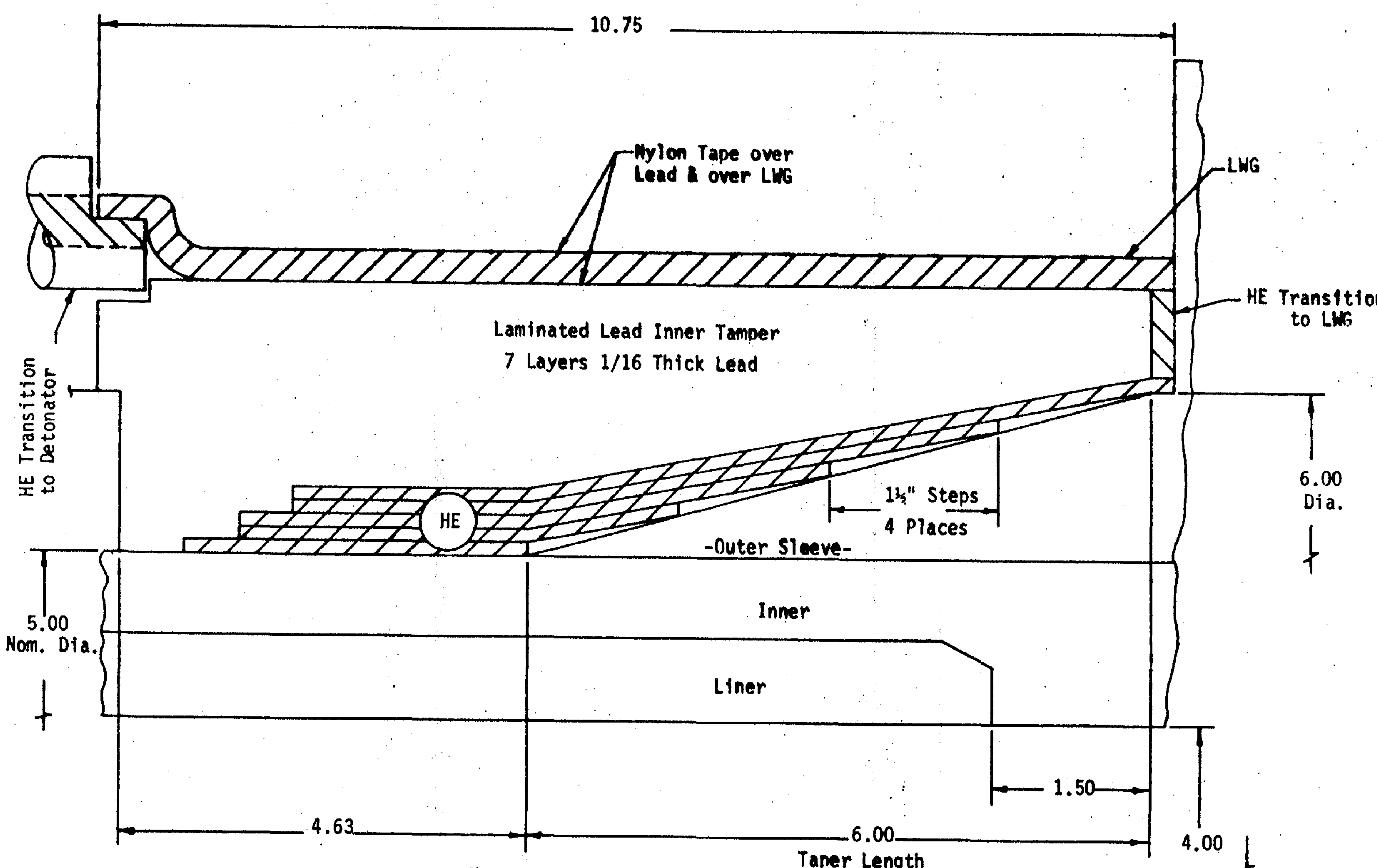
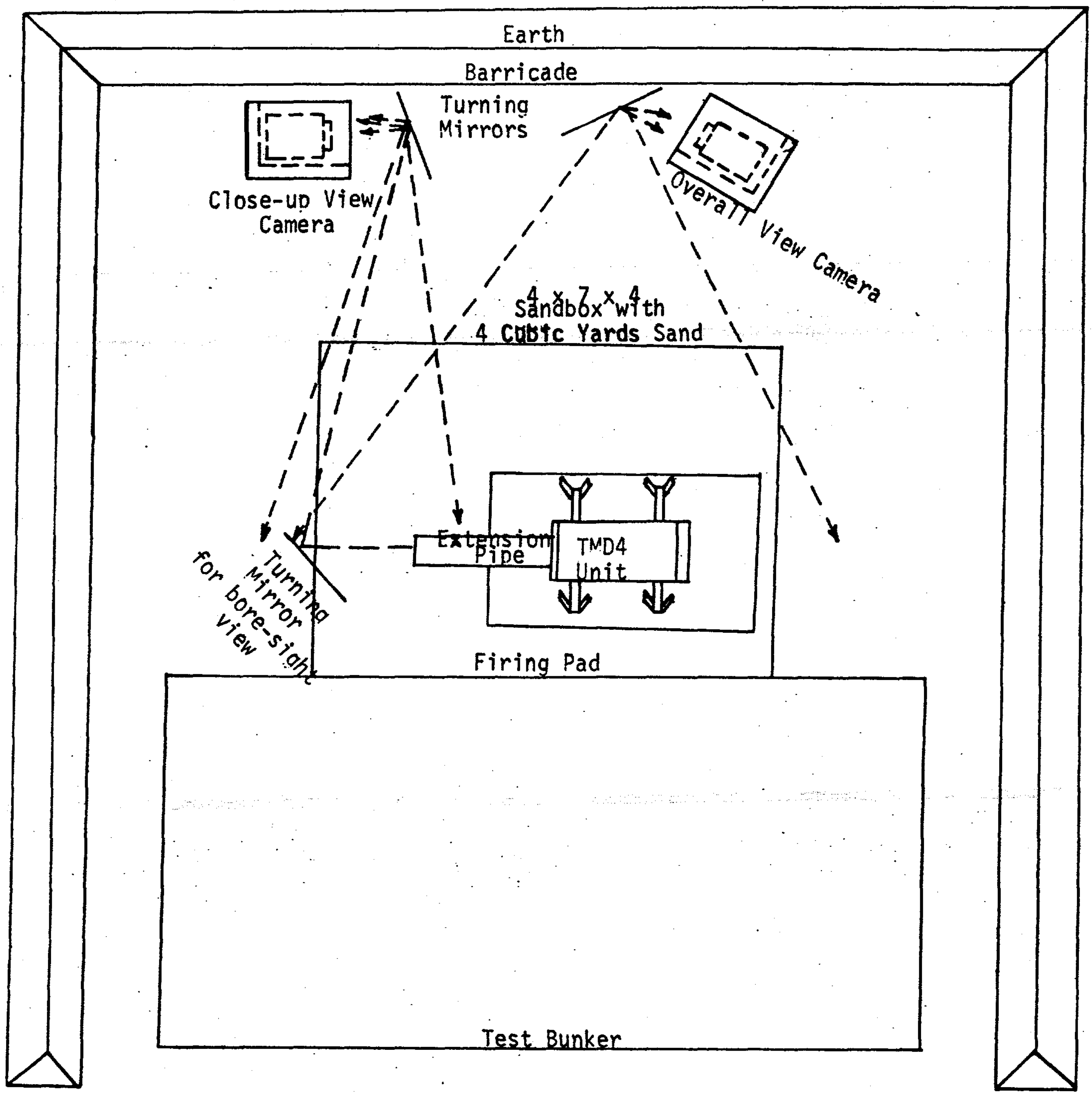


Fig. 8

TMD4-005
HE Design P83624-C



Plan View of Test Set Up

Fig. 9

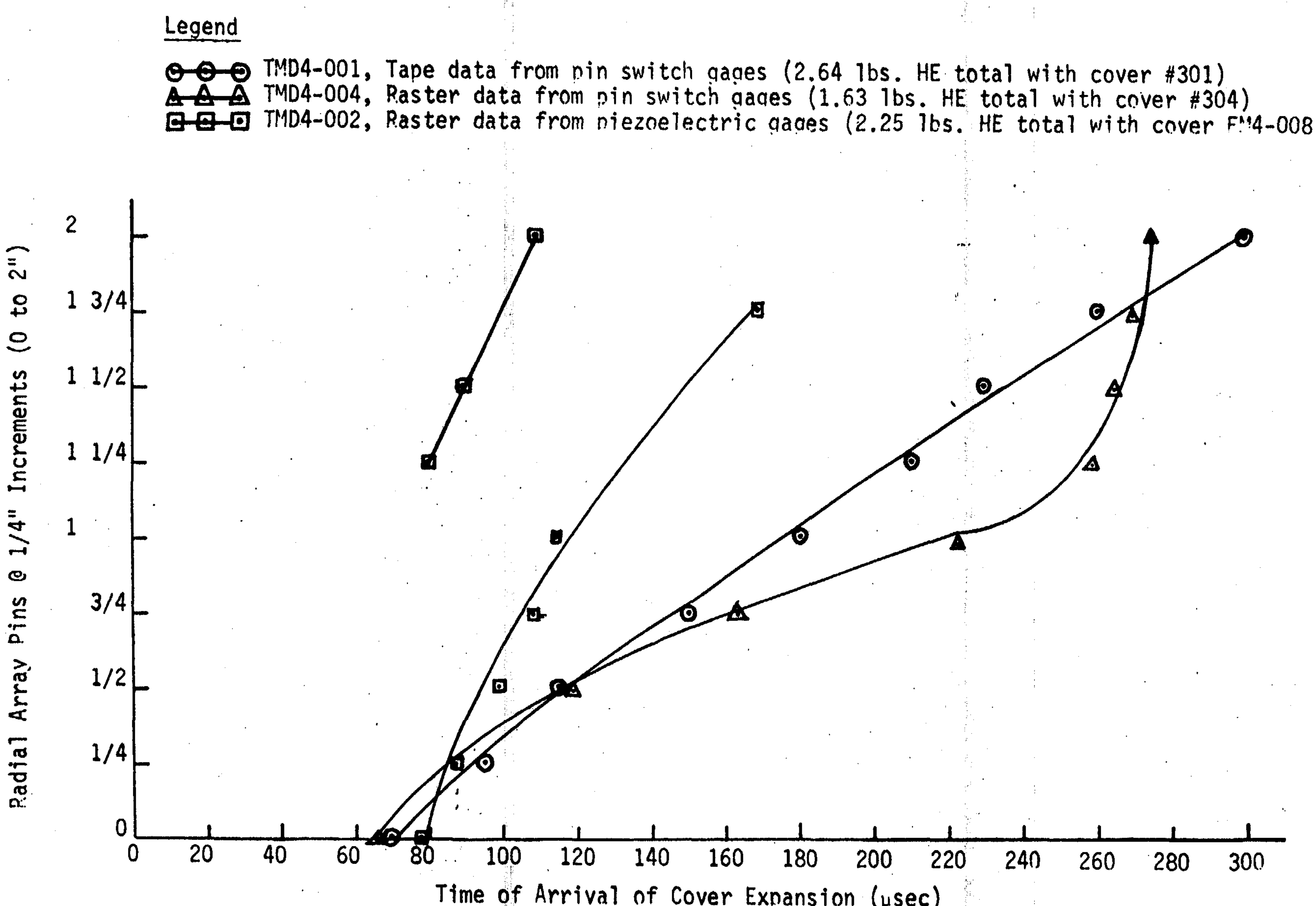
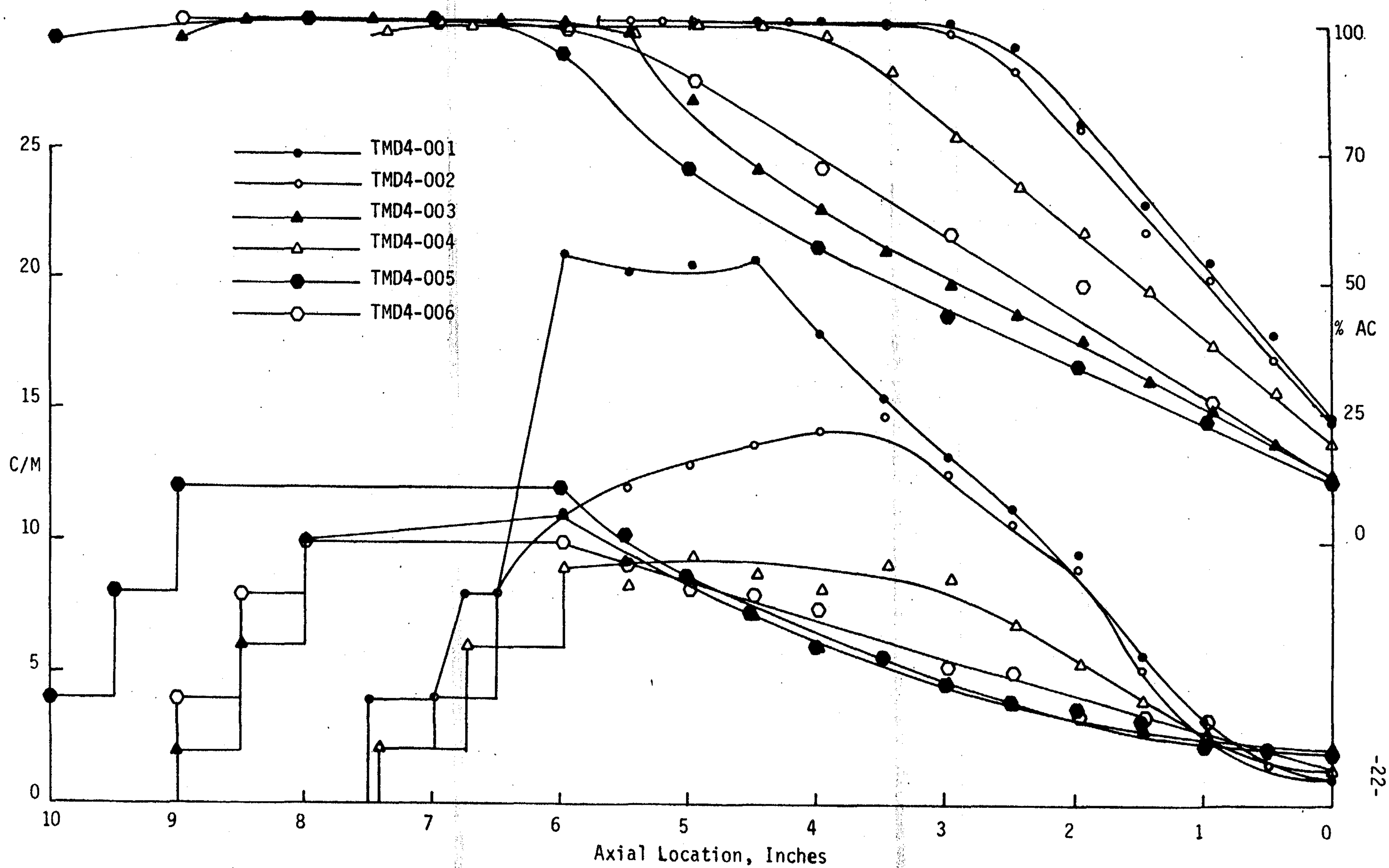


Fig. 10

Radial Cover Growth Rate in Sand

Fig. 11


TMD4-001
TMD4-002
TMD4-003
TMD4-004
TMD4-005
TMD4-006
C/M
25
20
15
10
5
0
% AC
100
70
50
25
0
10
9
8
7
6
5
4
3
2
1
0
Axial Location, Inches

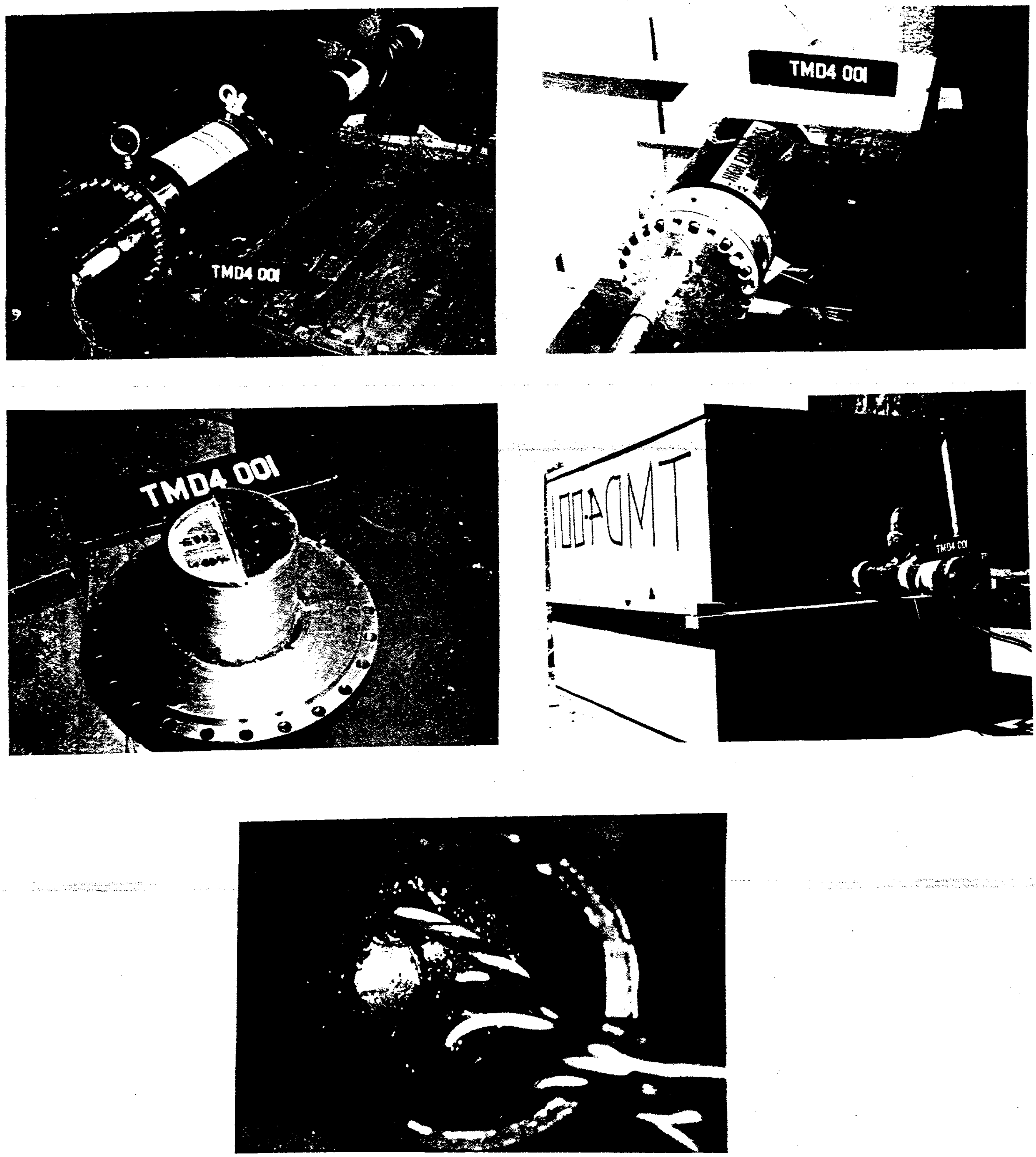


Fig. 12

TMD4-001 Preshot

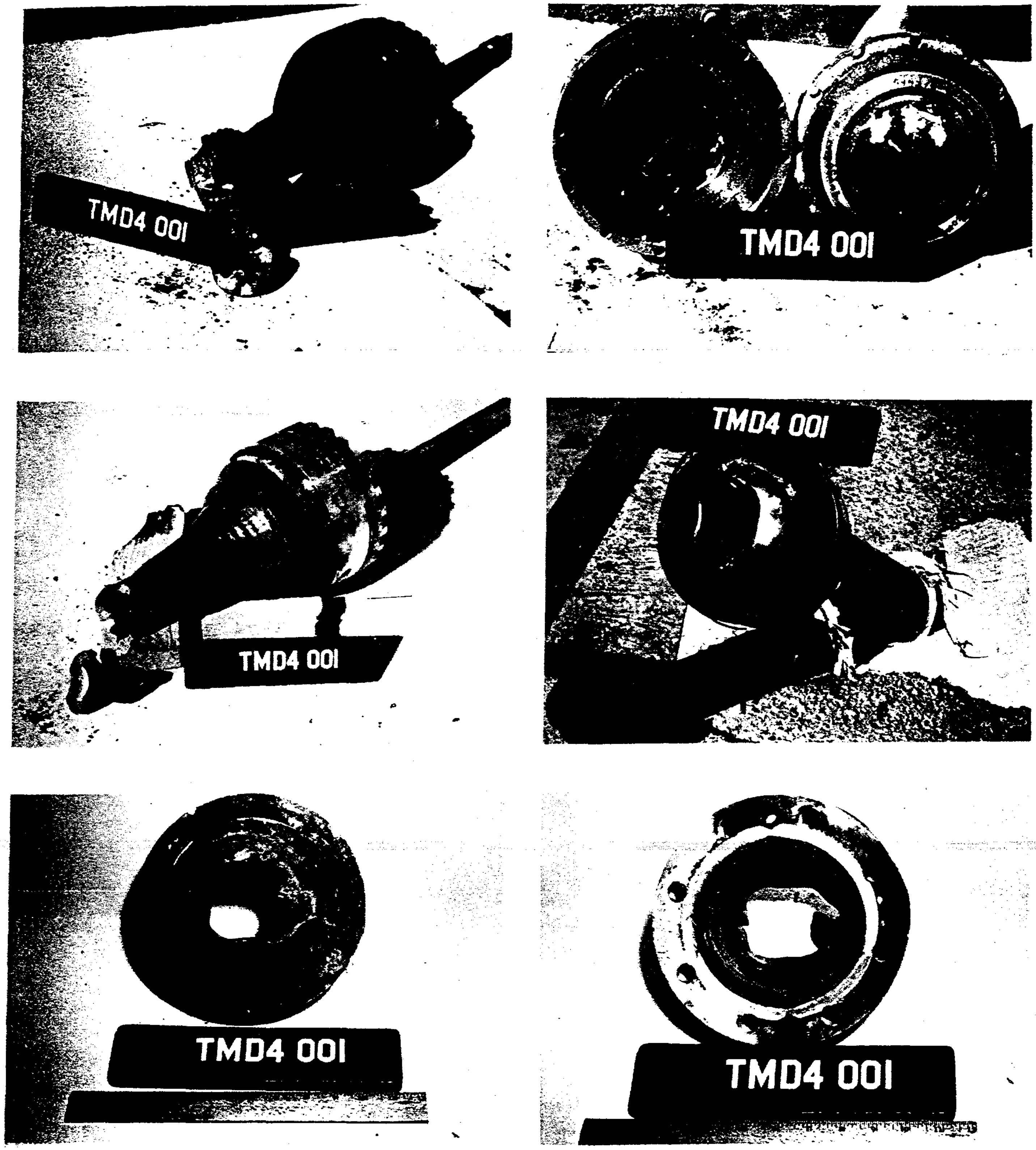


Fig. 13

TMD4-001 Postshot

Fig. 14

TMD4-001 Postshot

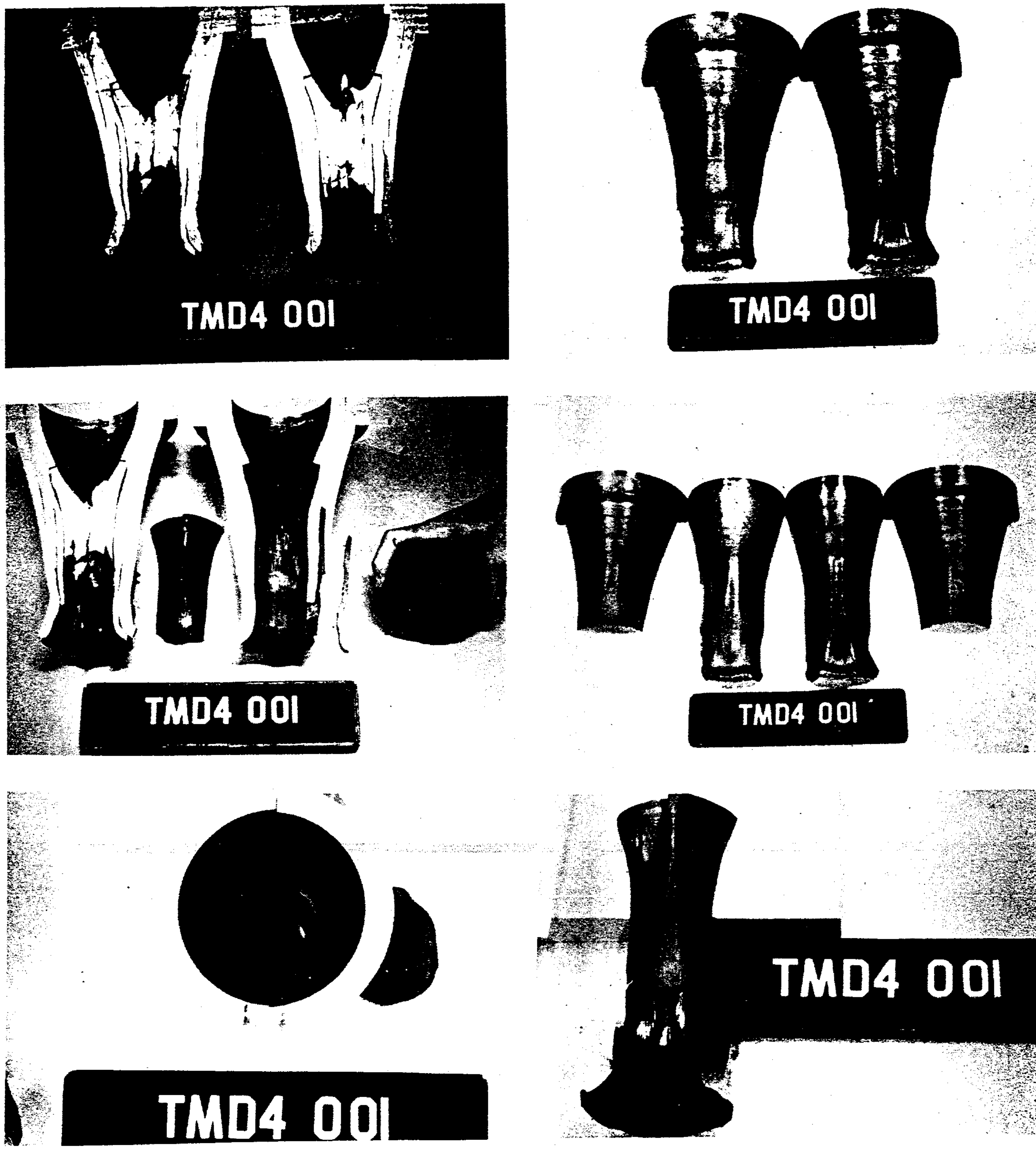
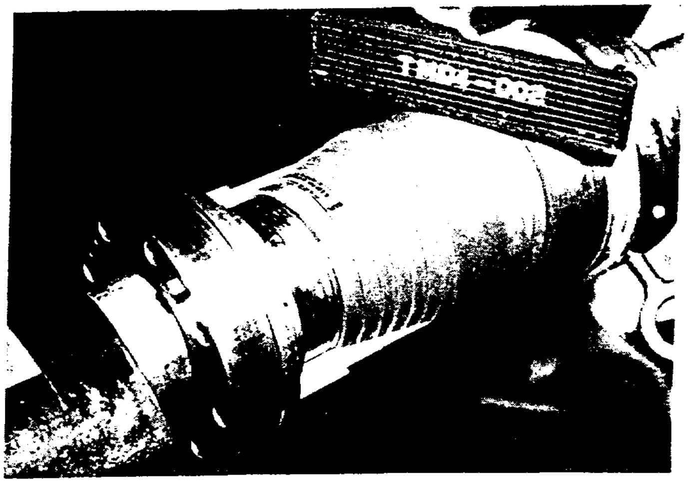
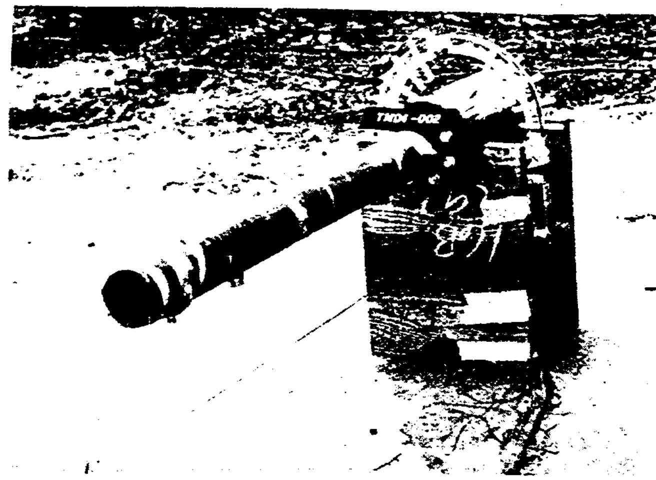


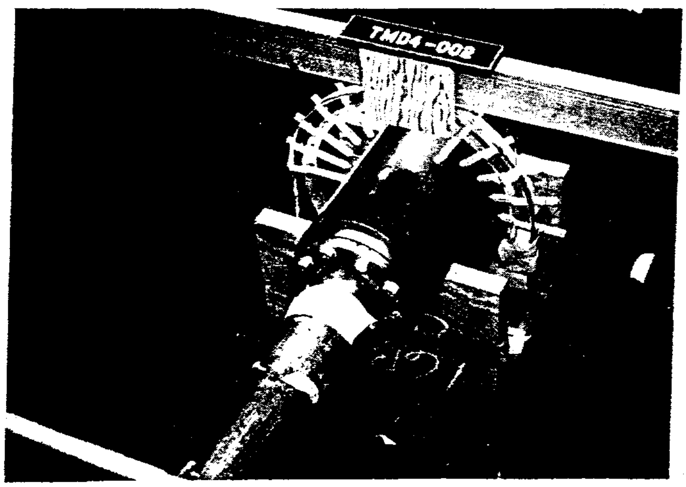
Fig. 15
TMD4-001 Postshot



HE Buildup

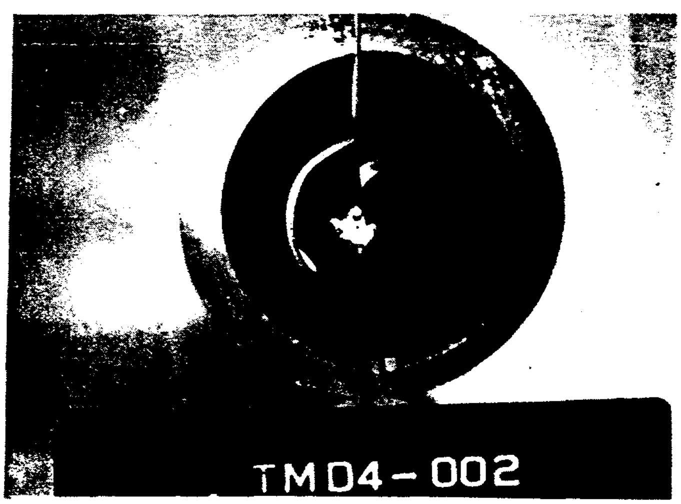


Preshot



Preshot

Postshot



Postshot

Postshot

Fig. 17

TMD4-002

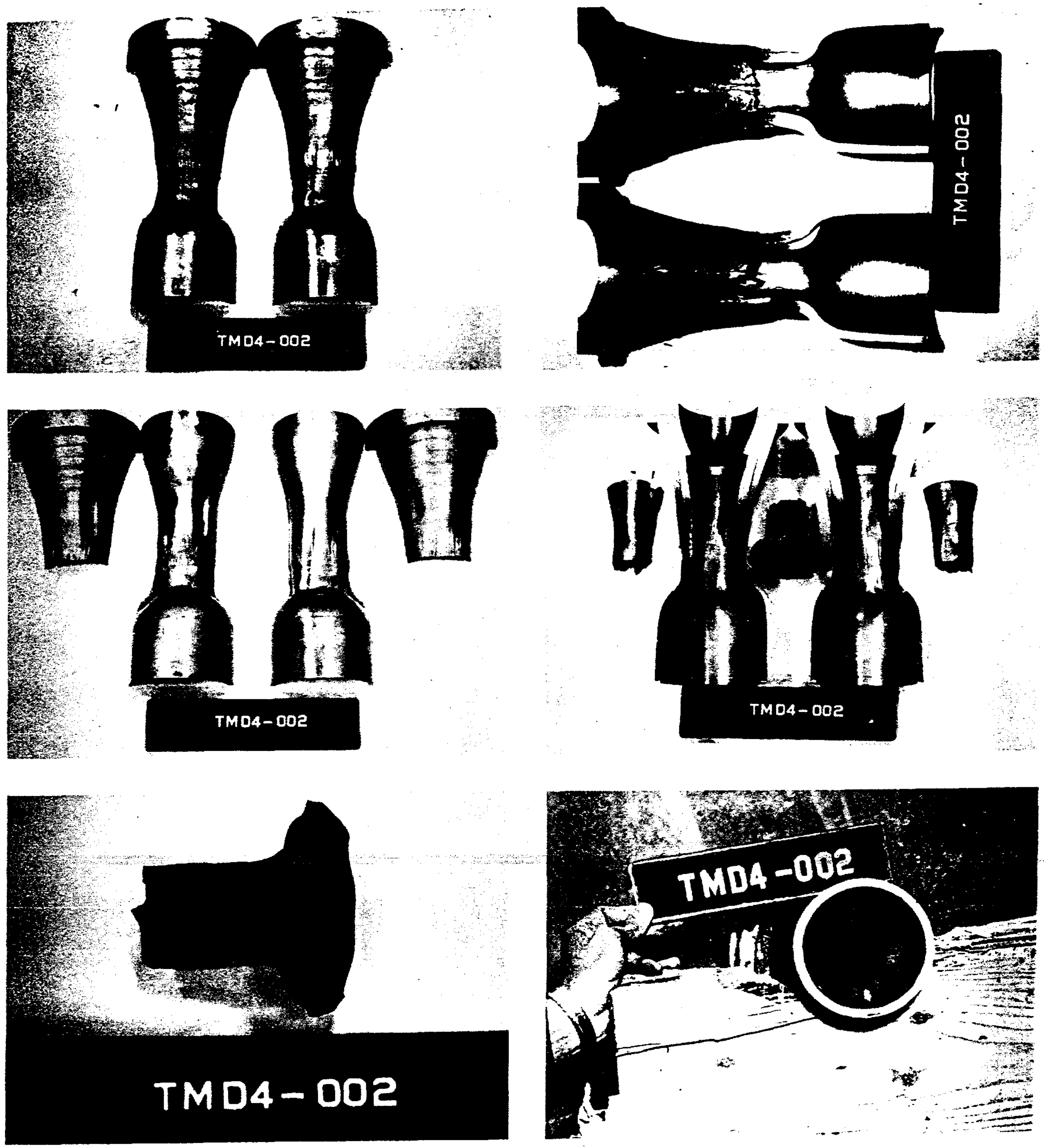
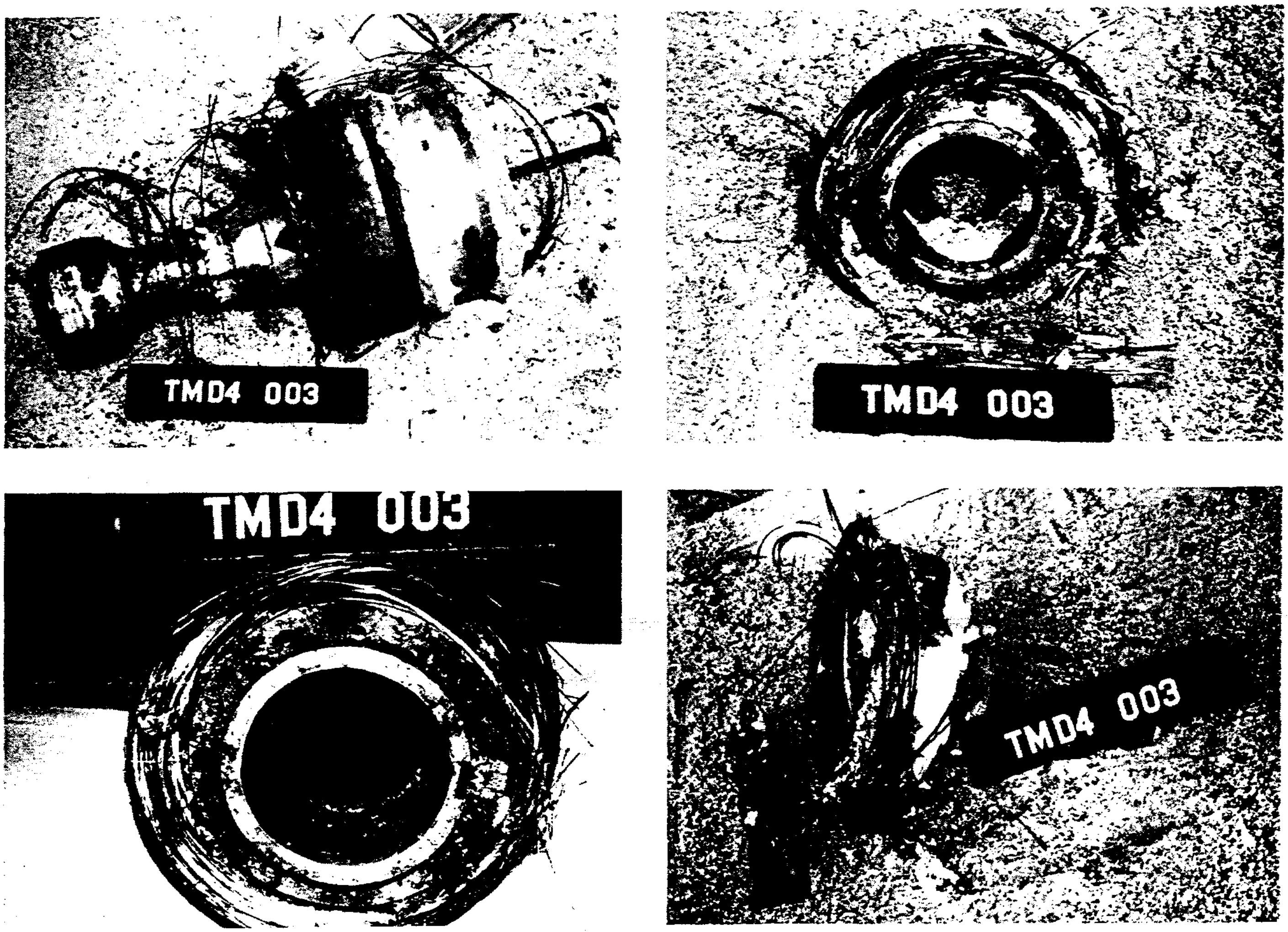


Fig. 18

TMD4-002 Postshot

TMD4-003 Preshot



TMD4-003 Post Shot

Fig. 19

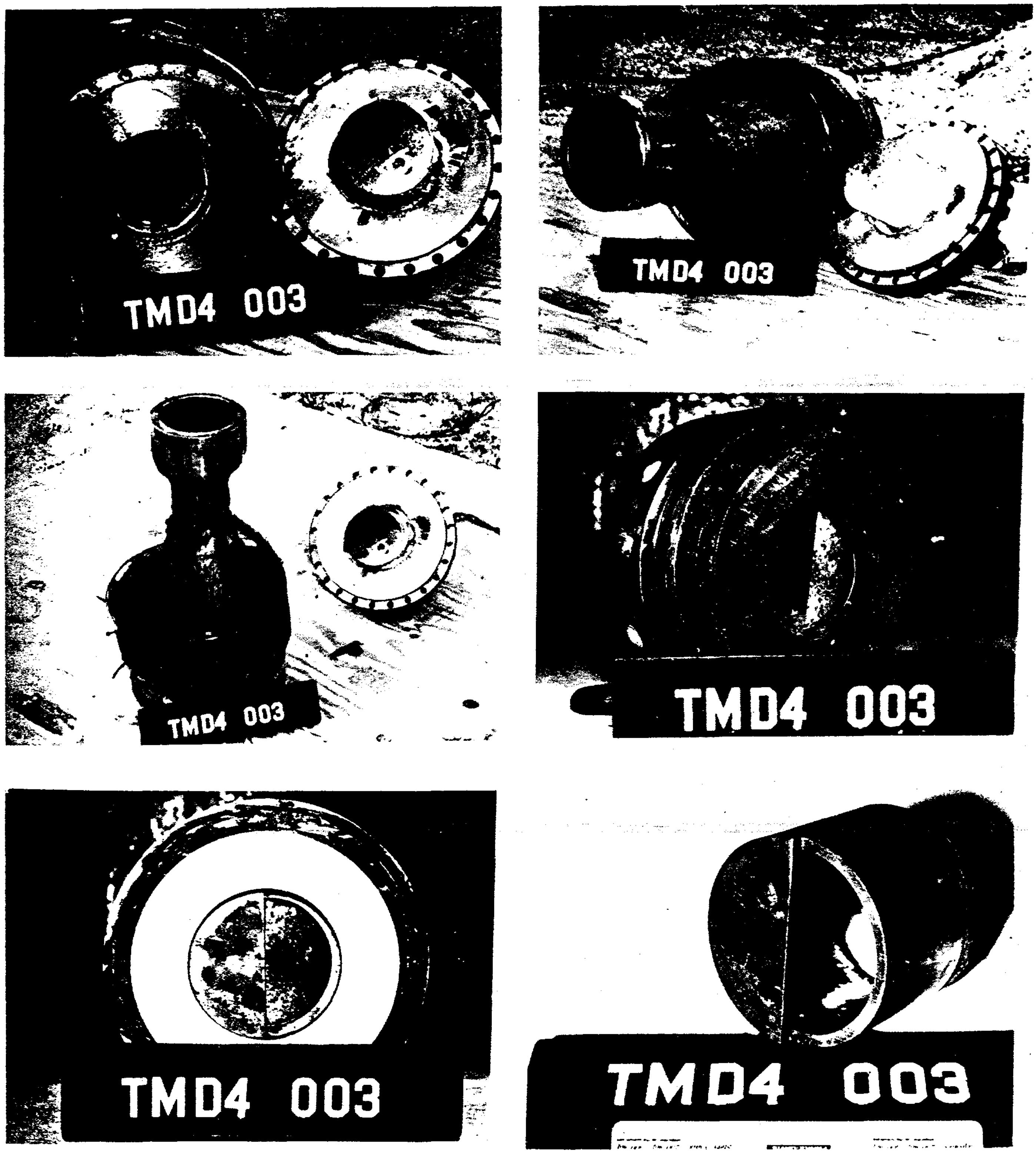


Fig. 20

TMD4-003 Post Shot

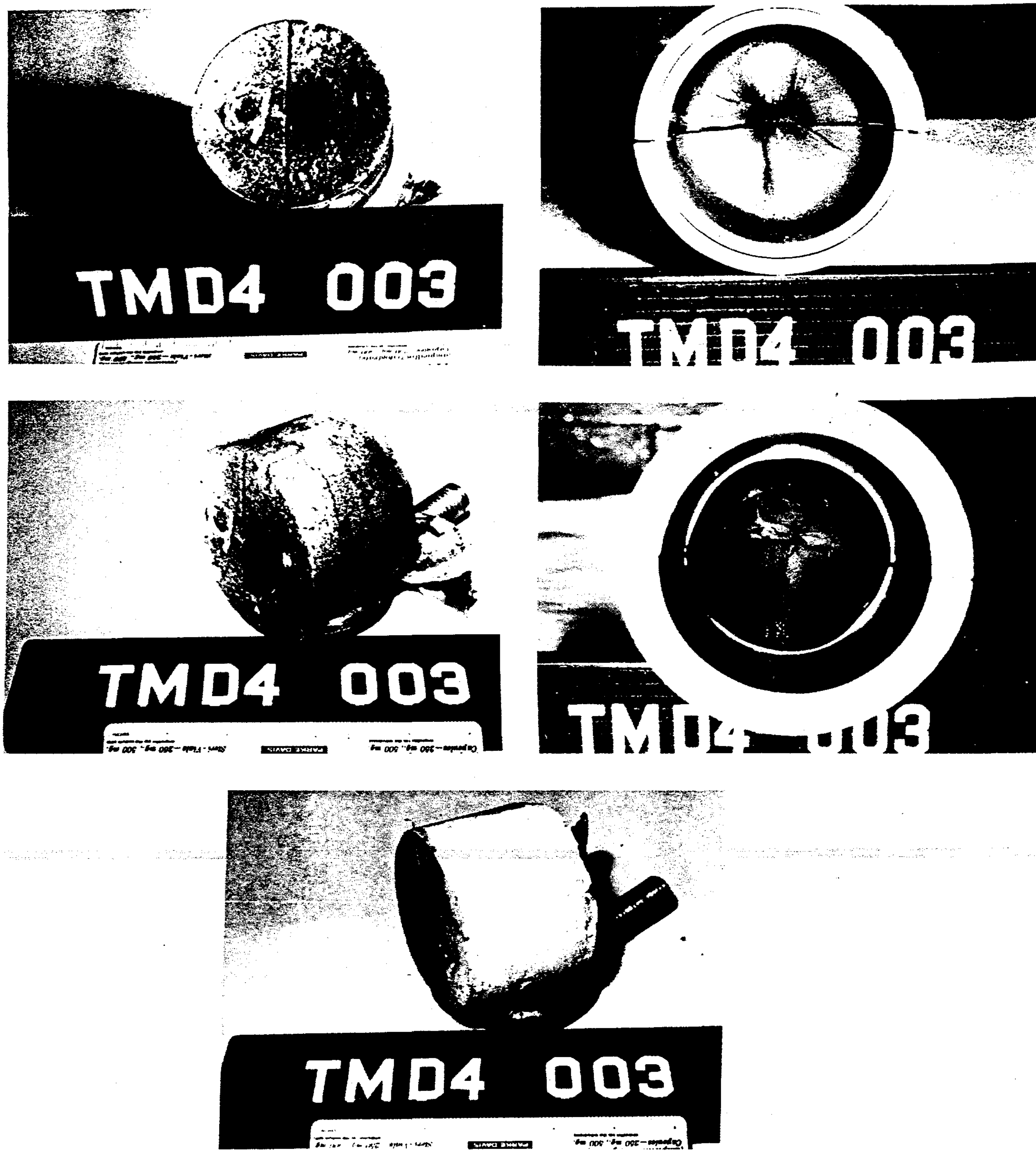
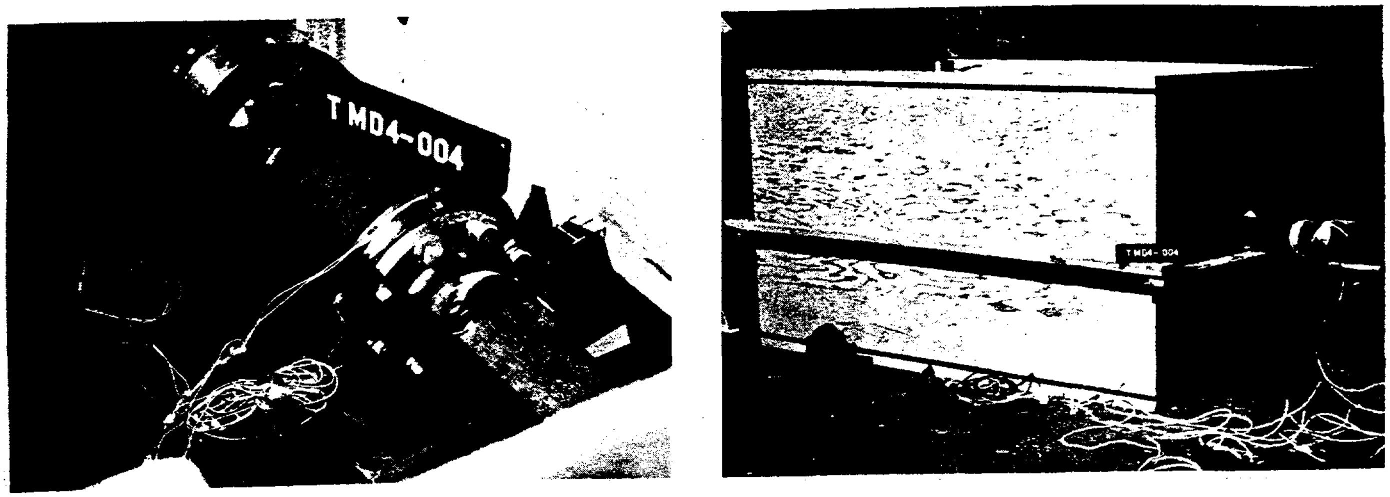


Fig. 21
TMD4-003 Postshot

Fig. 22

TMD4-003 Postshot



TMD4-004 Preshot

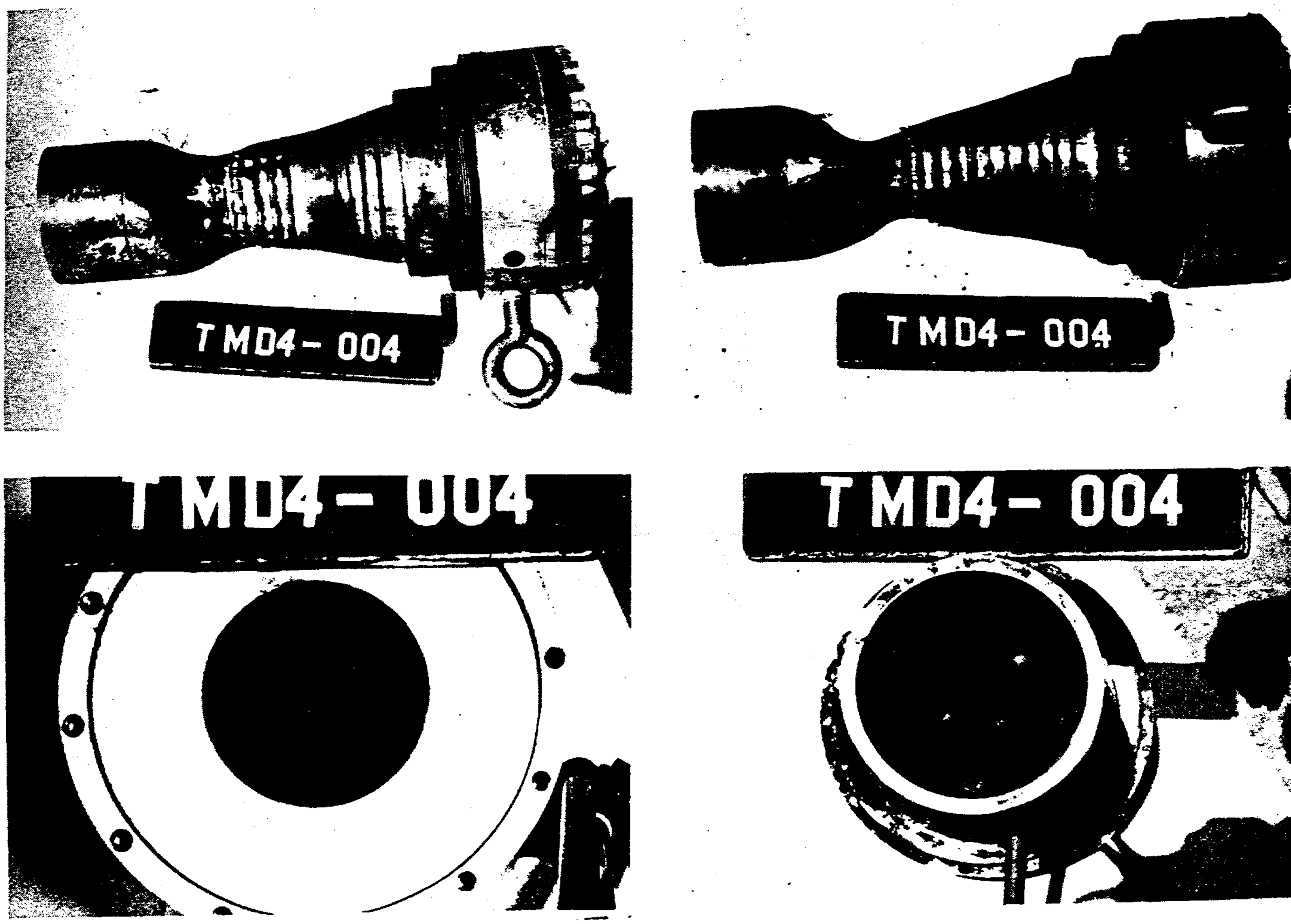


Fig. 23

TMD4-004 Postshot

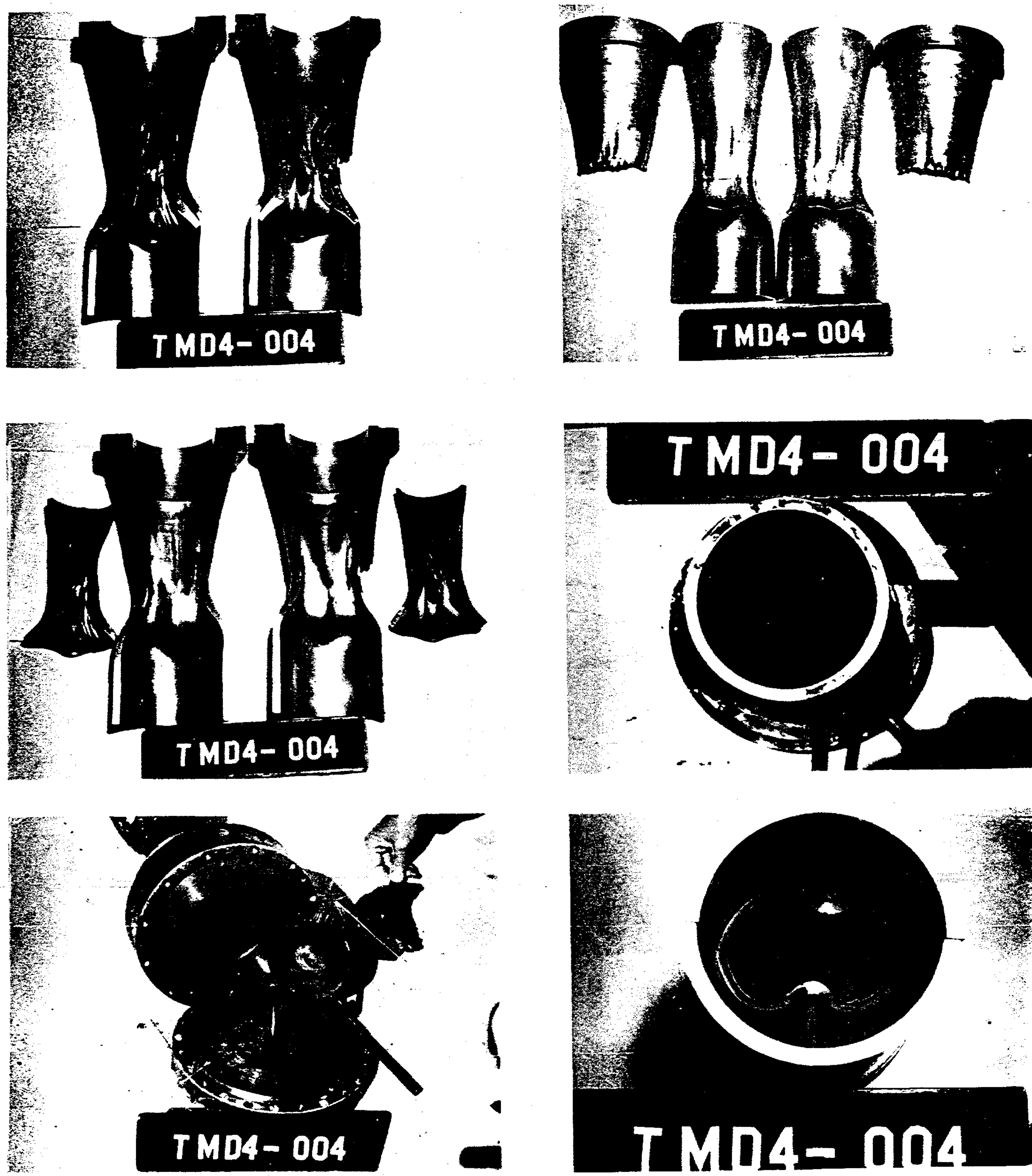
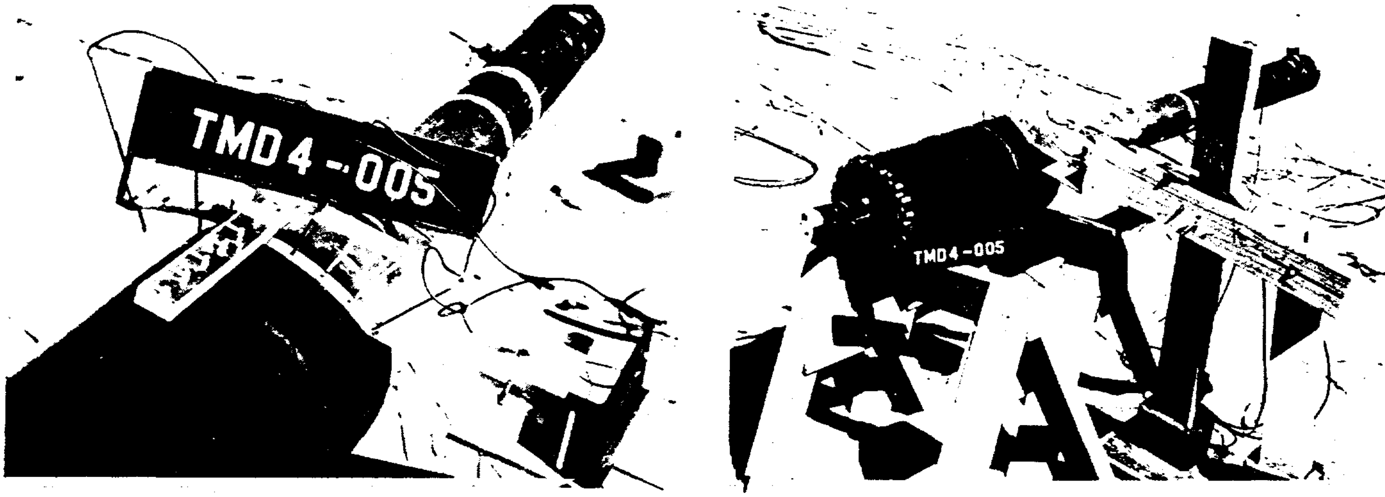


Fig. 24

TMD4-004 Postshot



TMD4-005 Preshot

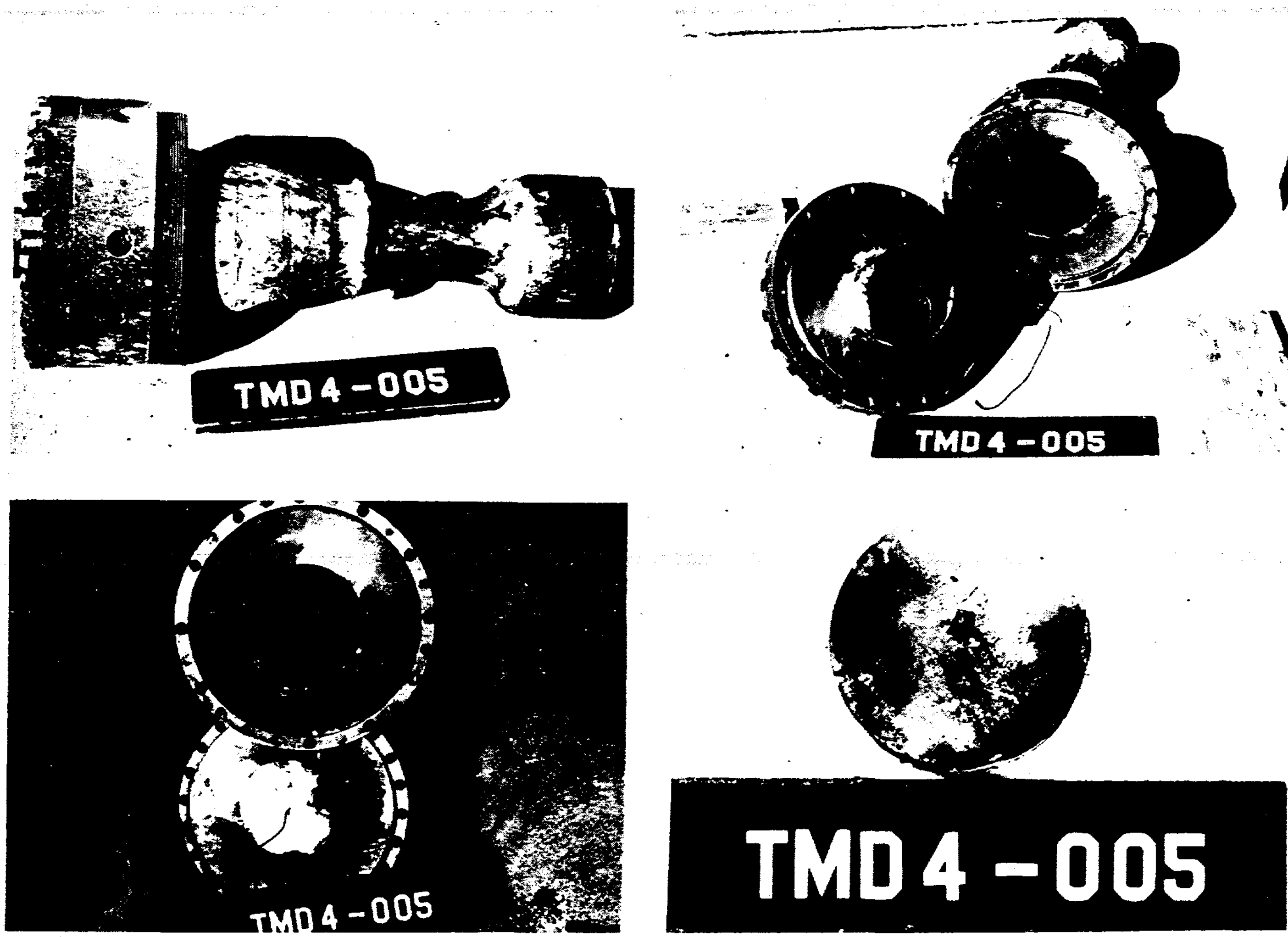


Fig. 25
TMD4-005 Postshot

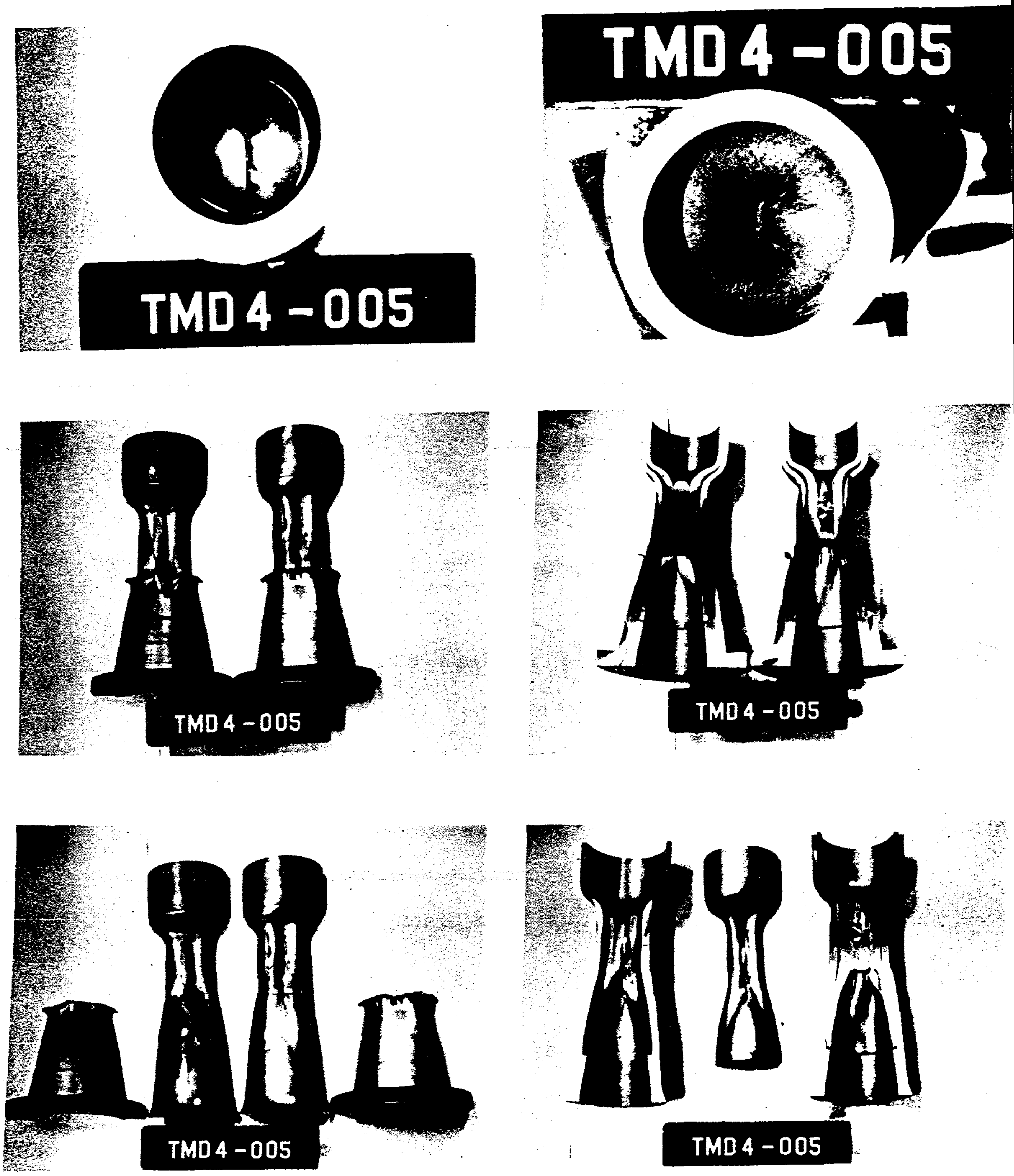
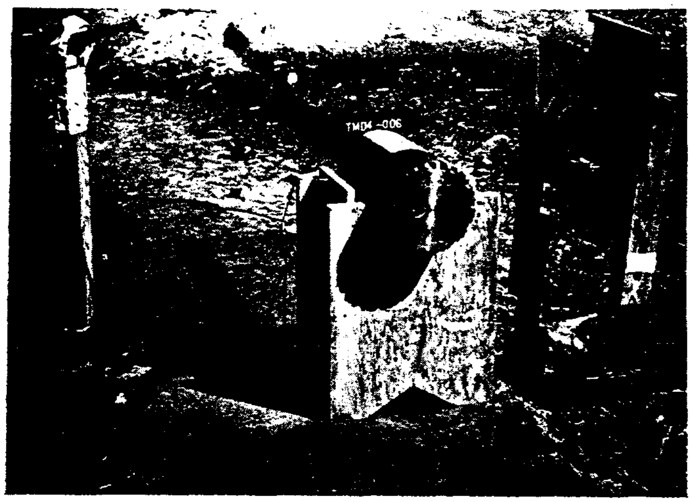


Fig. 26
TMD4-005 Post Shot



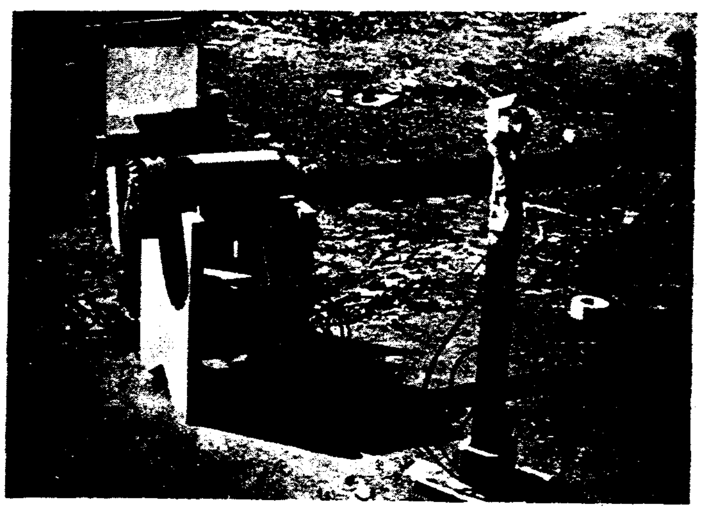


Fig. 27

TMD4-006 Preshot

Fig. 28

TMD4-006 Postshot

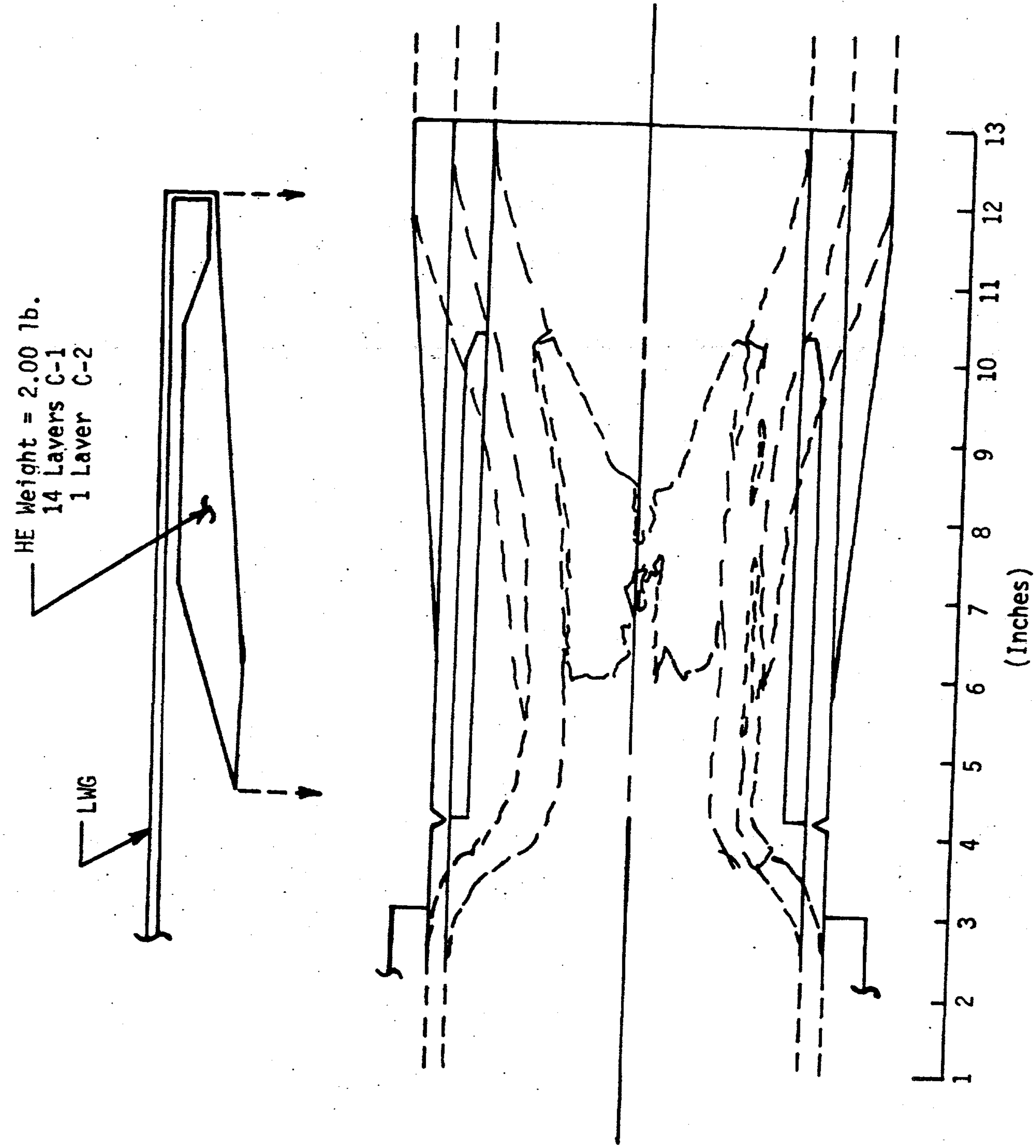


Fig. 29
TMD4-002

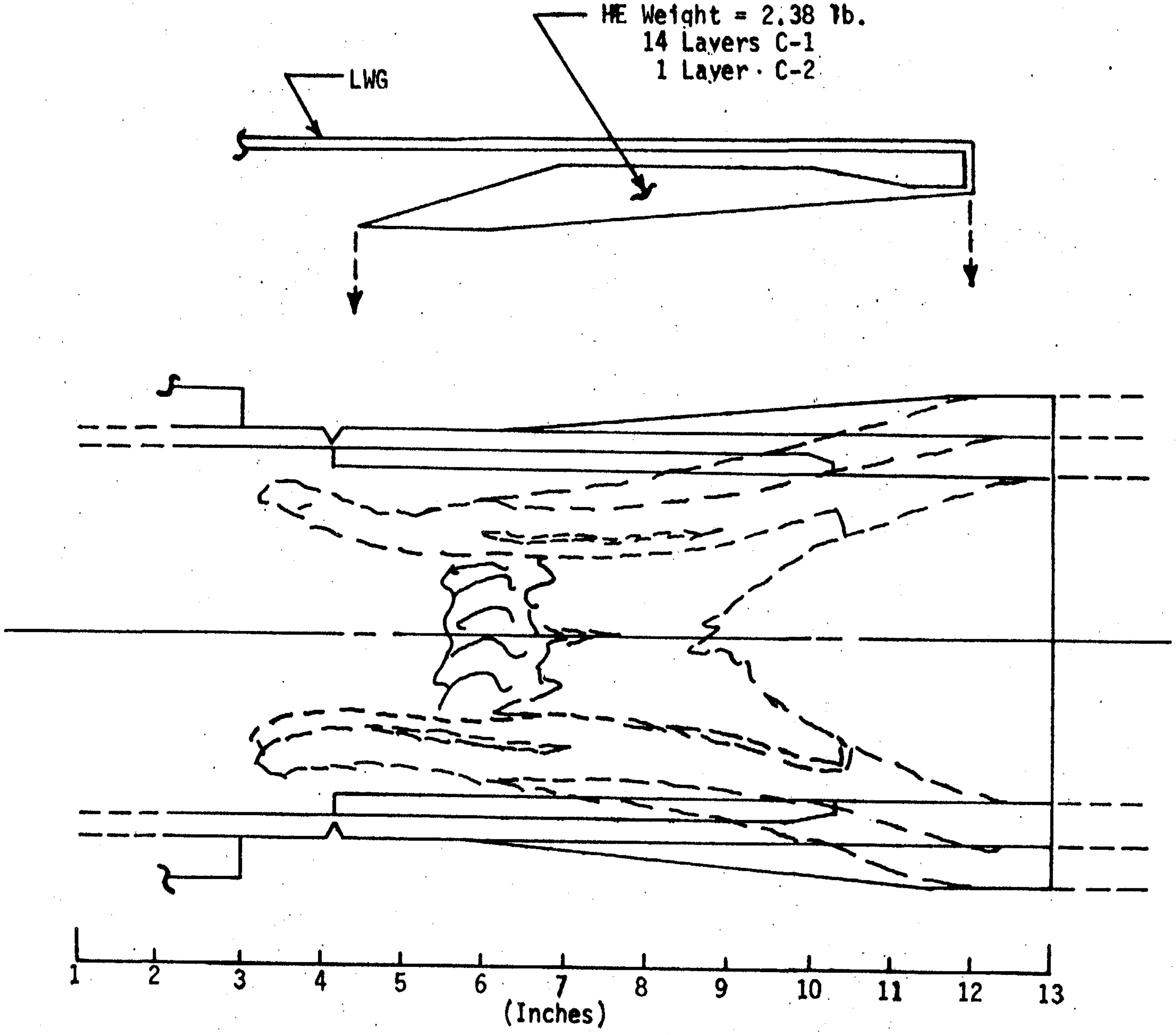


Fig. 30

TMD4-001

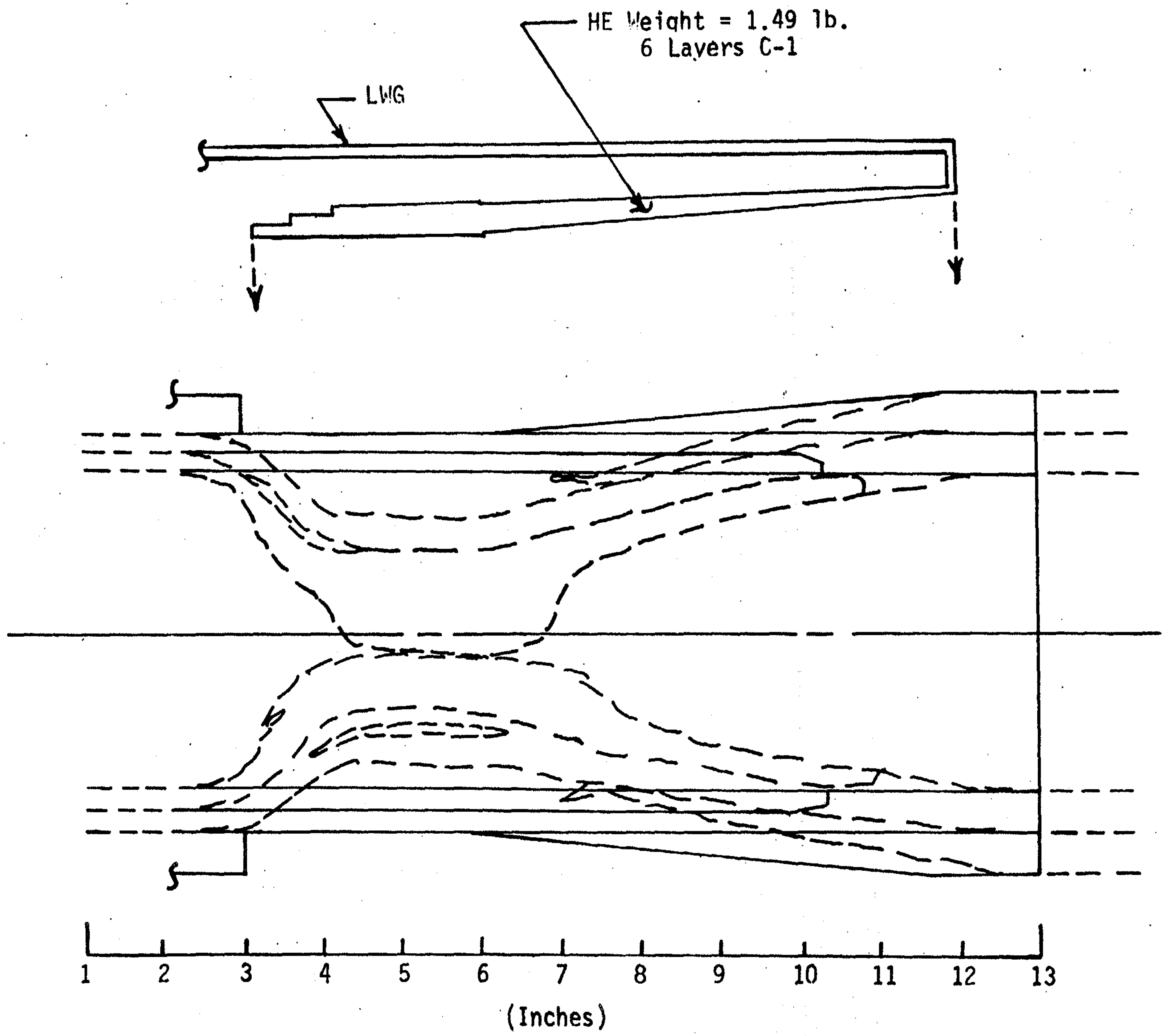


Fig. 31
TMD4-003

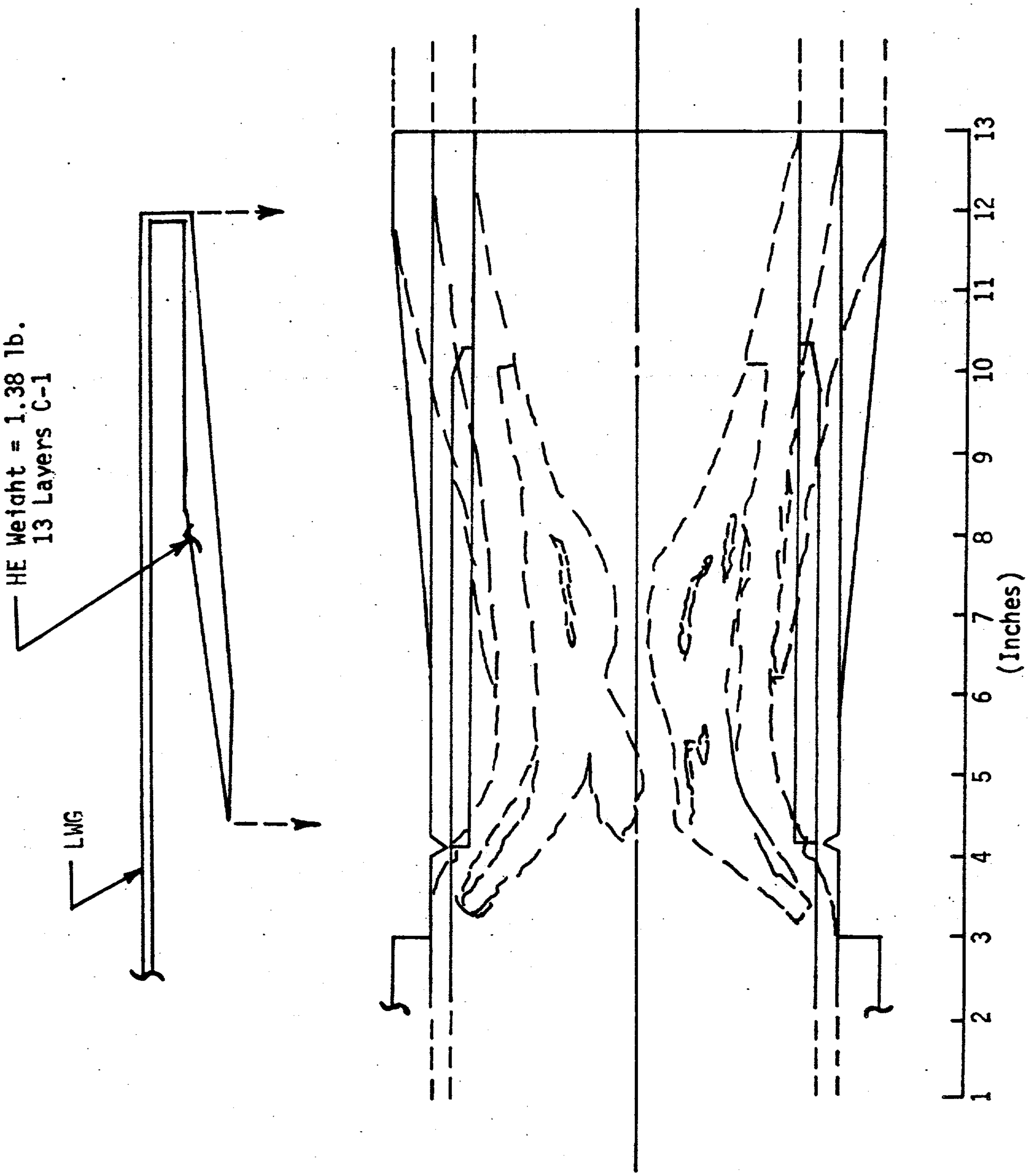


Fig. 32

TMD4-004

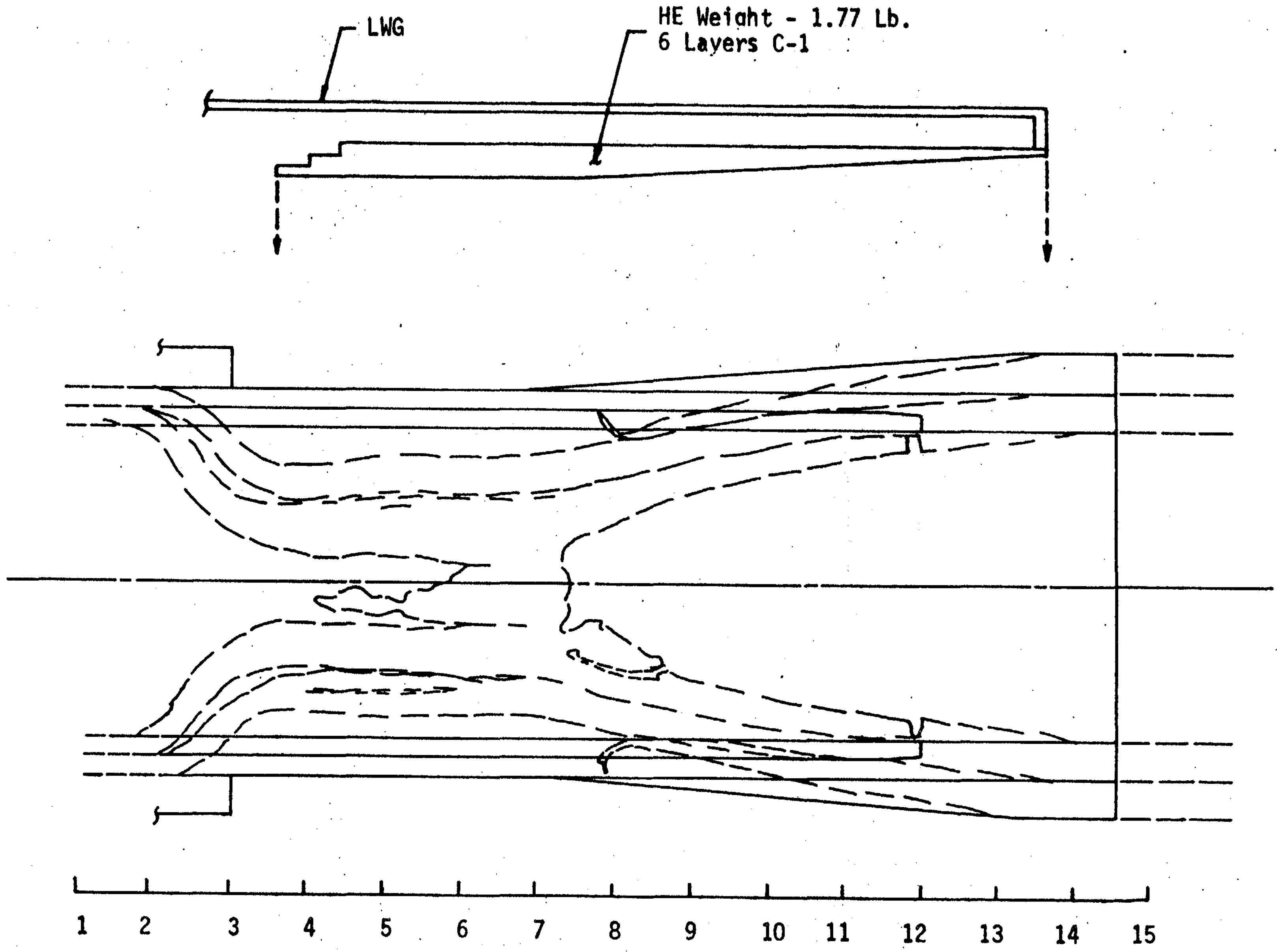


Fig. 33

TMD4-005

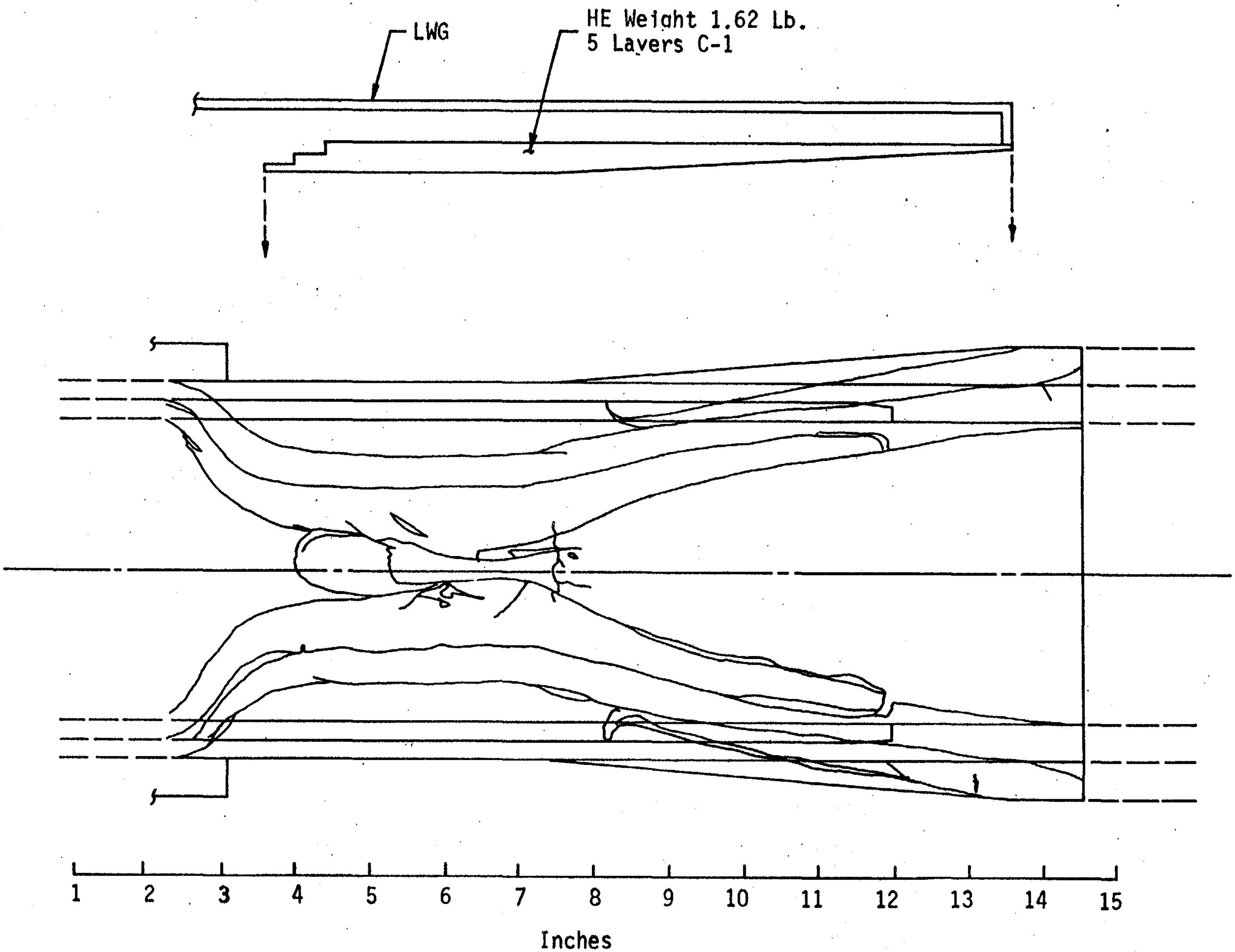


Fig. 34

TMD4-006

Appendix A

Cost Summary

Purchase Order 94-4639 - Fabrication of TMD4-001 through 006, Pantex Engineering Order 24-3-11-00-601

Purchase Order 94-4683 - Testing of TMD4-001 through 006, Pantex Engineering Order 24-3-11-00-619

Purchase Order	Authorized Funds	Amount Spent
94-4639	$18,500.00	$17,789.24
94-4683	$21,000.00	$21,372.97

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