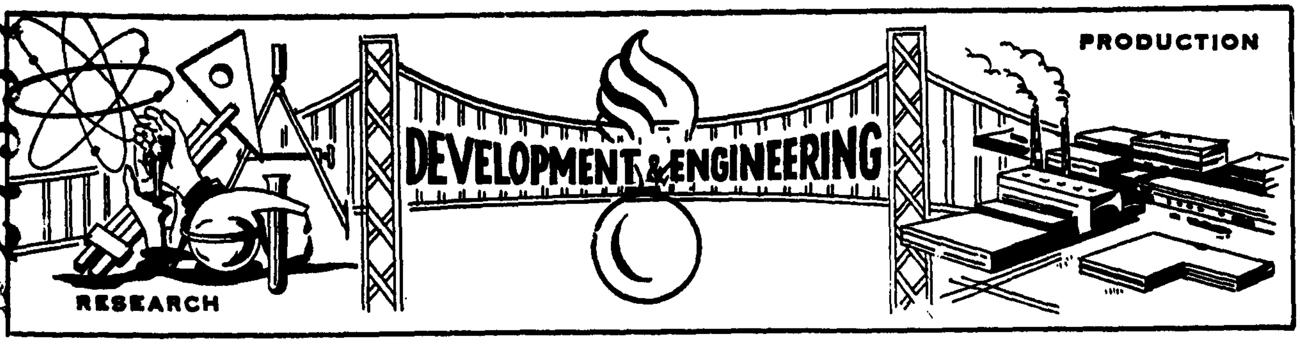


TECHNICAL REPORT
DC-TR: 5-61

PRODUCTION ENGINEERING
OF
METAL AND OTHER INERT PARTS
FOR
M30 ROCKET MOTOR
FOR
NIKE HERCULES MISSILE

(FINAL ENGINEERING REPORT)

BY
HAROLD MANNHEIMER

COPY NO. 29 OF 35 DECEMBER 1961

AMMUNITION GROUP
PICATINNY ARSENAL, DOVER, NEW JERSEY

TECHNICAL REPORT

PRODUCTION ENGINEERING OF METAL AND OTHER INERT PARTS FOR M30 ROCKET MOTOR FOR NIKE HERCULES MISSILE

(FINAL ENGINEERING REPORT)

BY

HAROLD MANNHEIMER

Project No: PA-11-3D1

OCMS Code No: 4120.12.0601.700

Report No: DC-TR: 5-61

SUBMITTED BY: F. V. Youngblood
F. YOUNGBLOOD
Chief, Rocket &
Guided Missile Section

REVIEWED BY: H. D. Rutkovsky
H. D. RUTKOVSKY
Chief, Ammunition
Engineering Branch

APPROVED BY: S. Fleischnick
S. FLEISCHNICK
Chief, Ammunition
Production & Maint
Engineering Division

TABLE OF CONTENTS

SECTION I

INTRODUCTION

The M30 Rocket Motor is the sustainer motor for the Nike Hercules Missile. The principal components of the motor are the case, the gas generator, the blast tube, and the nozzle. The motor is initiated in flight by electric squibs after the booster rockets have burned out and have been jettisoned. The electrically initiated black powder in the squibs initiates potassium nitrate pellets, contained in a styrofoam cup, which in turn initiate the case-bonded polysulfide perchlorate propellant grain of the gas generator. The gas generator effluent ignites the main propellant grain--also a composition of case-bonded polysulfide perchlorate with a star perforation.

The engineering services to be provided under the Scope of Work were:

1. Provide improved production processes and techniques for mass production.

2. Minimize or eliminate the use of strategic materials.

3. Reduce manufacturing cost.

4. Broaden supply base.

5. Substitute standard items for non-standard items where possible.

6. Assure ease of loading, assembly and inspection.

7. Provide technical information for field use as required.

The specific tasks were unrelated and therefore handled separately. These tasks included:

1. A study to determine whether the time required for holding the hydrostatic test pressure on the motor case can be reduced without detriment.

2. A study to find suitable alternate materials for internally insulating the blast tube and adapter at reduced cost.

3. A liner removal study to determine which, if any, of the motor metal parts can be economically reconditioned after static firings.

4. An accelerated corrosion study to determine which parts are susceptible to corrosion, the effects of such corrosion and applicable measures for inhibiting corrosion.

5. A temperature gradient program to determine the time that the loaded rocket motor can be exposed to extreme temperatures and not fall below the firing or storage temperature limits.

SECTION II

SUMMARY

The Scope of Work, as originally issued (May 1958) by the Army Rocket and Guided Missile Agency (ARGMA), encompassed a complete production engineering study on the motor metal parts, a pilot lot, and a description of manufacture in addition to the studies outlined in Section I. However, the funding authorization was not sufficient to cover the entire program included in the Scope of Work. Additional funding was anticipated (sufficient to permit conducting the program) and the bulk of the phases to be contracted out were held in abeyance pending receipt of the additional funding, although the preparatory processing for competitive bidding on the production engineering study was completed. Meanwhile, several phases were initiated which could be performed by Picatinny Arsenal and did not require a "knowledge contract". At a later date, ARGMA advised that because of the cut-back in the Nike Hercules program, additional funding for the production engineering study would not be authorized. At this time, a revised Scope of Work (dated7 April 1959) was submitted by ARGMA to Picatinny Arsenal. The revised Scope of Work excluded the tasks which would have required an extensive metal parts production engineering "knowledge contract" and permitted concentration of effort on the tasks listed in Section I.

Briefly, the tasks accomplished were:

a. Hydrostatic Pressure Test Study -- The hydrostatic test requirements for the motor case were thought to be somewhat excessive. An analytical study was conducted which resulted in recommendations that certain test requirements be reduced.

b. Alternate Insulation Study -- The blast tube and adapter insulation was a single source, expensive item. Other likely materials were selected and tested. A less expensive, alternate material was recommended.

c. Liner Removal Study -- Some of the metal parts can be reclaimed after static firing if the liner which bonds the propellant to the metal parts can be removed safely and economically. Tests disclosed a non-toxic solvent which would remove or loosen the liner material at ambient temperature.

d. Corrosion Study -- Motor metal parts were subjected to a corrosive atmosphere to determine areas susceptible to corrosion. Several corrosion inhibiting coatings were tested and evaluated on the basis of effectiveness and practicability for in-plant and field use.

e. Temperature Gradient Study -- Tests were conducted on a loaded motor in a low temperature environments to determine the rate of temperature change in the grain and the time that the rocket motor can be exposed to extreme temperatures without falling below the specified firing or storage temperature limits.

SECTION III

CONCLUSIONS

Since this report encompasses five different areas, the conclusions are presented in Section V (Study).

SECTION IV

RECOMMENDATIONS

The applicable recommendations are included with each study.

SECTION V

STUDY

A. Hydrostatic Test Pressure Study

Missile Purchase Description MPD-5008A requires that after completion of fabrication, the blast tube and case metal parts assemblies be subjected to an internal hydrostatic pressure of 900 psi for a period of five minutes without leakage or permanent distortion in excess of drawing dimensions.

The sidewalls of the motor case and blast tube were considered to be critical areas as well as being representative of the possible trouble points of the unit, with the exception of threads. Therefore, sidewalls are the only areas considered in this study.

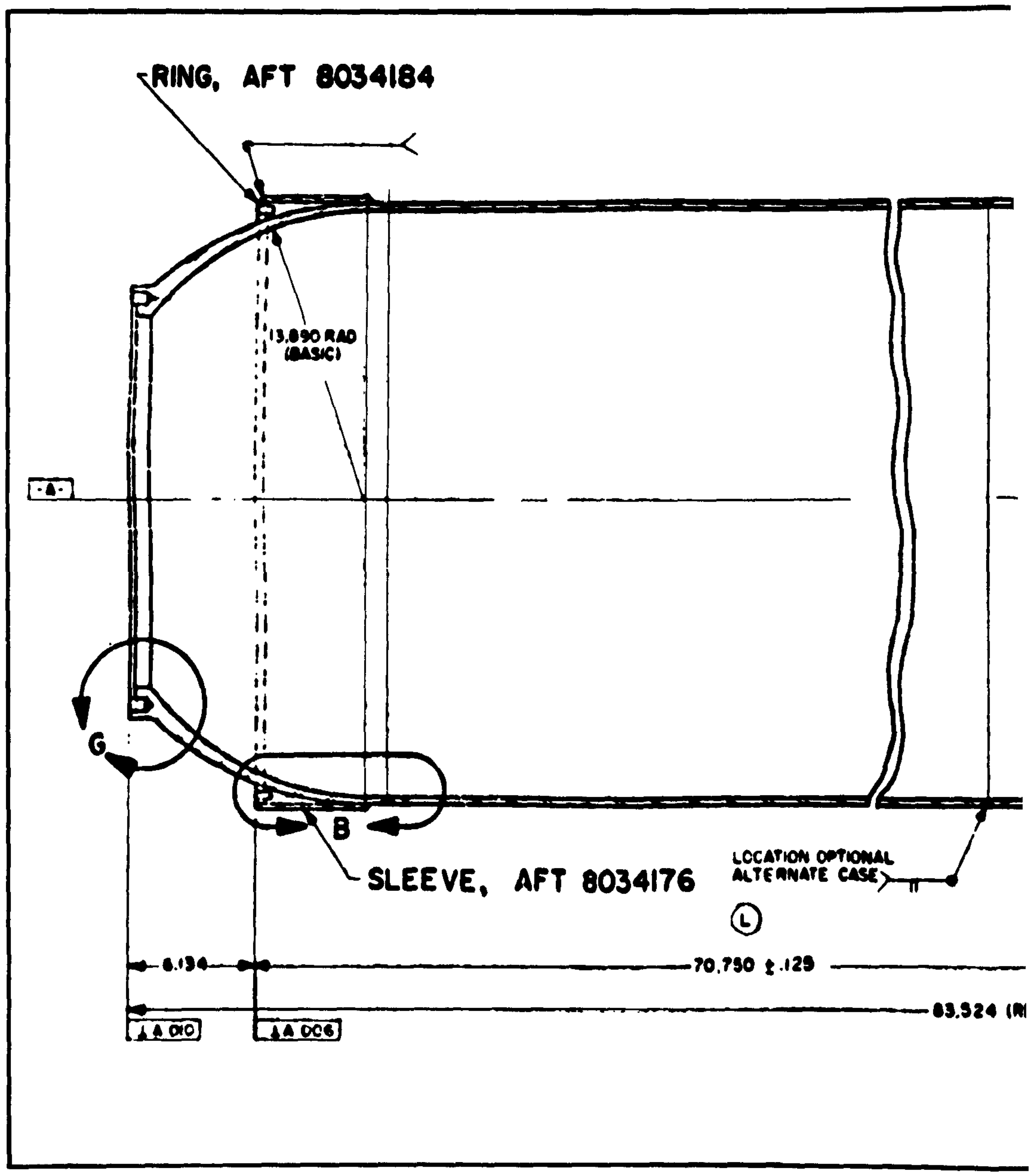
Acceptance specifications for the M30 Rocket Motor require that those components subjected to hydrostatic pressure testing be dimensionally inspected following the pressure test for conformance to drawing dimensions. Thus, all pressure testing is considered to be performed below the specified lower yield point. Yielding, if it should occur, would be noted immediately... either by a decrease in pressure or by an increase in the volume of water pumped into the unit under test, depending on the test procedure. Further evidence of yielding would be detected during the subsequent dimensional inspection. With an extremely rapid loading rate the phenomenon of delayed yield might be experienced if the yield strength were below the specified minimum; this delay is usually well under one second. Such a situation might be encountered in cyclic testing, but need not be considered here.

It should be noted that the various authorities in the fields of pressure vessel fabrication and materials testing limit their hydrostatic test requirements to 10 or 15 seconds to insure pressure stability. A longer time is required for volumetric testing in which a stipulated amount of permanent expansion is permitted.

Since the blast tube has a substantial strength safety factor, neither the operational pressure nor the test pressure approach the minimum yield strength of the tube side wall (Appendix A). Therefore, the only type of failure anticipated would be caused by a substantial defect, which undoubtedly would become apparent well before the five-minute requirement has been met.

Although the motor case is hydrostatically tested to a pressure relatively close to the minimum yield point of the sidewall, with little allowance for an imperfect longitudinal weld, the average operating pressure (assuming maximum pre-firing temperature) is approximately half that required to cause yielding. While, in certain instances, work hardening might conceivably occur near the yield point, hydrostatic test is not generally considered a valid method for increasing strength.

Hydrostatic testing is not completely non-destructive, even when conducted at pressures well below these conducive to yielding, since minor flaws such as those originating in embrittlement adjacent to welds


RING, AFT 8034184
13.890 RAD
(BASIC)
A
G
B
SLEEVE, AFT 8034176
LOCATION OPTIONAL
ALTERNATE CASE
L
6.134
70.750 ±.125
83.524
⊥ A .010
⊥ A .006

1

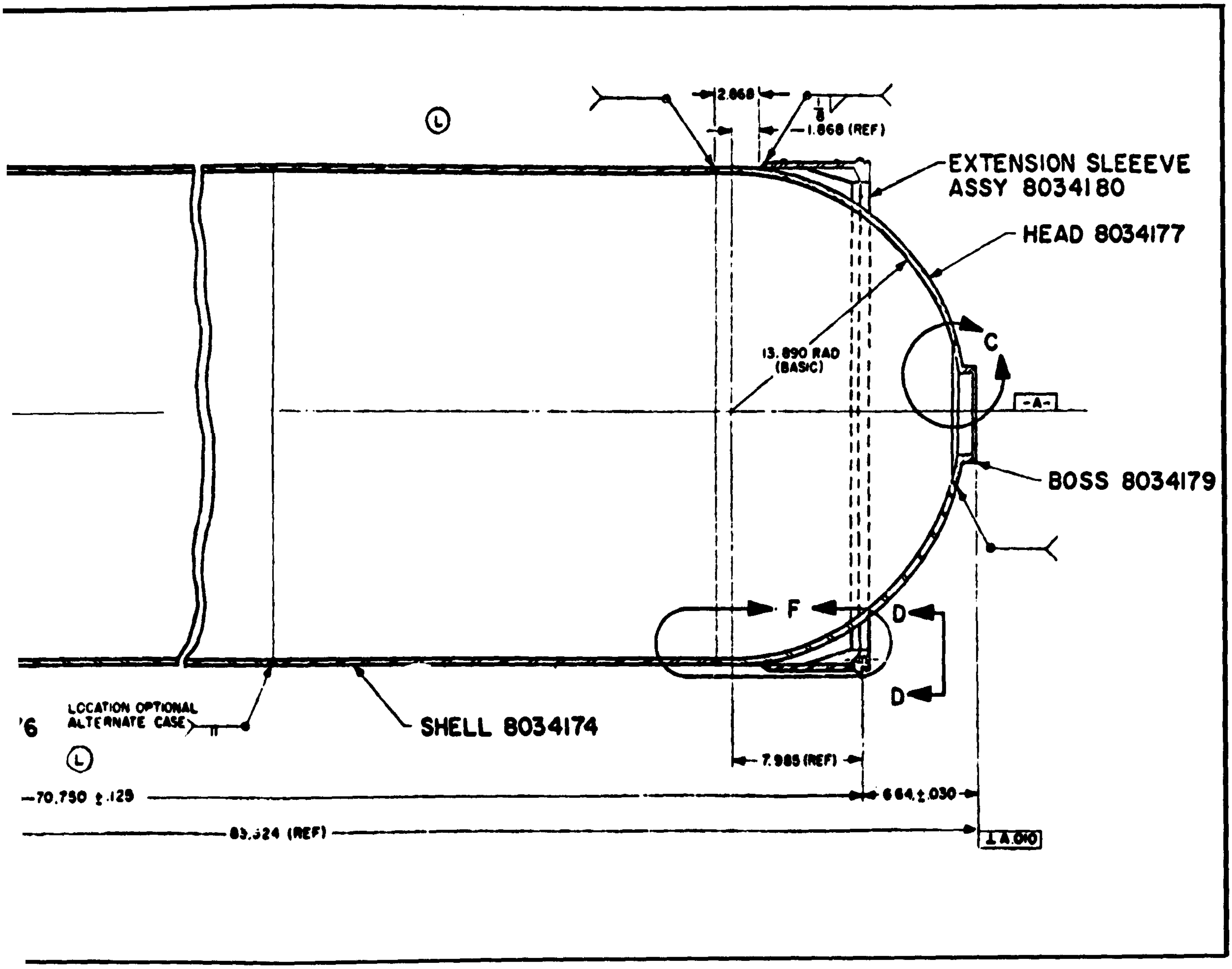


Figure 1. Rocket Motor Case

2

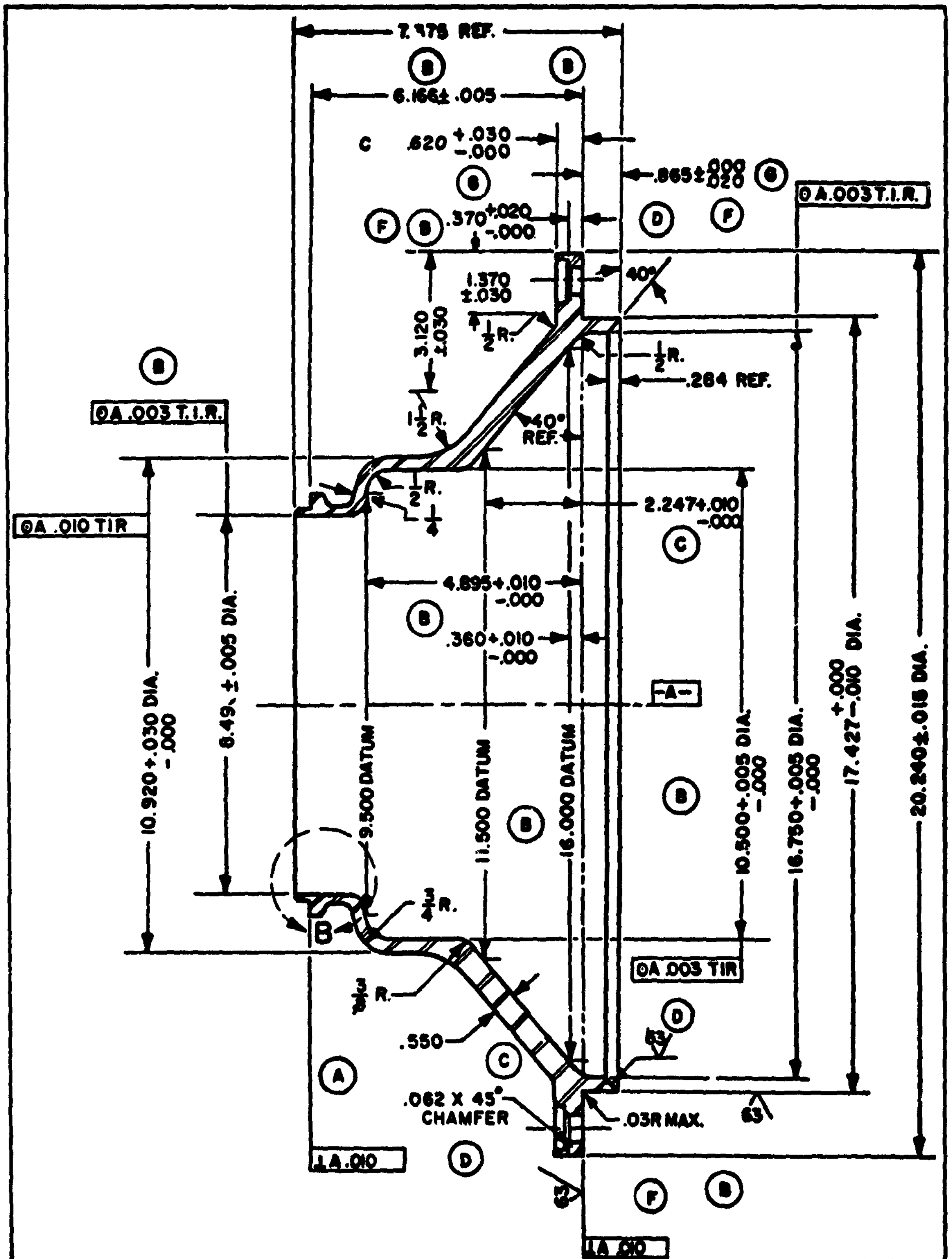


Figure 2. Adapter

and not detected by X-Ray or hydrostatic test, might become sufficiently progressive under hydrostatic test pressure to cause subsequent operational failure of the tested piece.

It is concluded that a long (five-minute) period for holding hydrostatic test pressure will produce no beneficial results, and that it might actually be detrimental to the motors tested.

Recommendation:

As a result of the study, these recommendations were made:

1. The five-minute time requirement for hydrostatic test be reduced to that time required for the hydrostatic pressure to stabilize at 900 psi. The actual time requirement would vary with the test installation and apparatus, operator and inspector; however, 10 seconds would be ample in most cases.

2. Care be taken not to overstress the motor case assembly by substantially exceeding the 900 psi requirement.

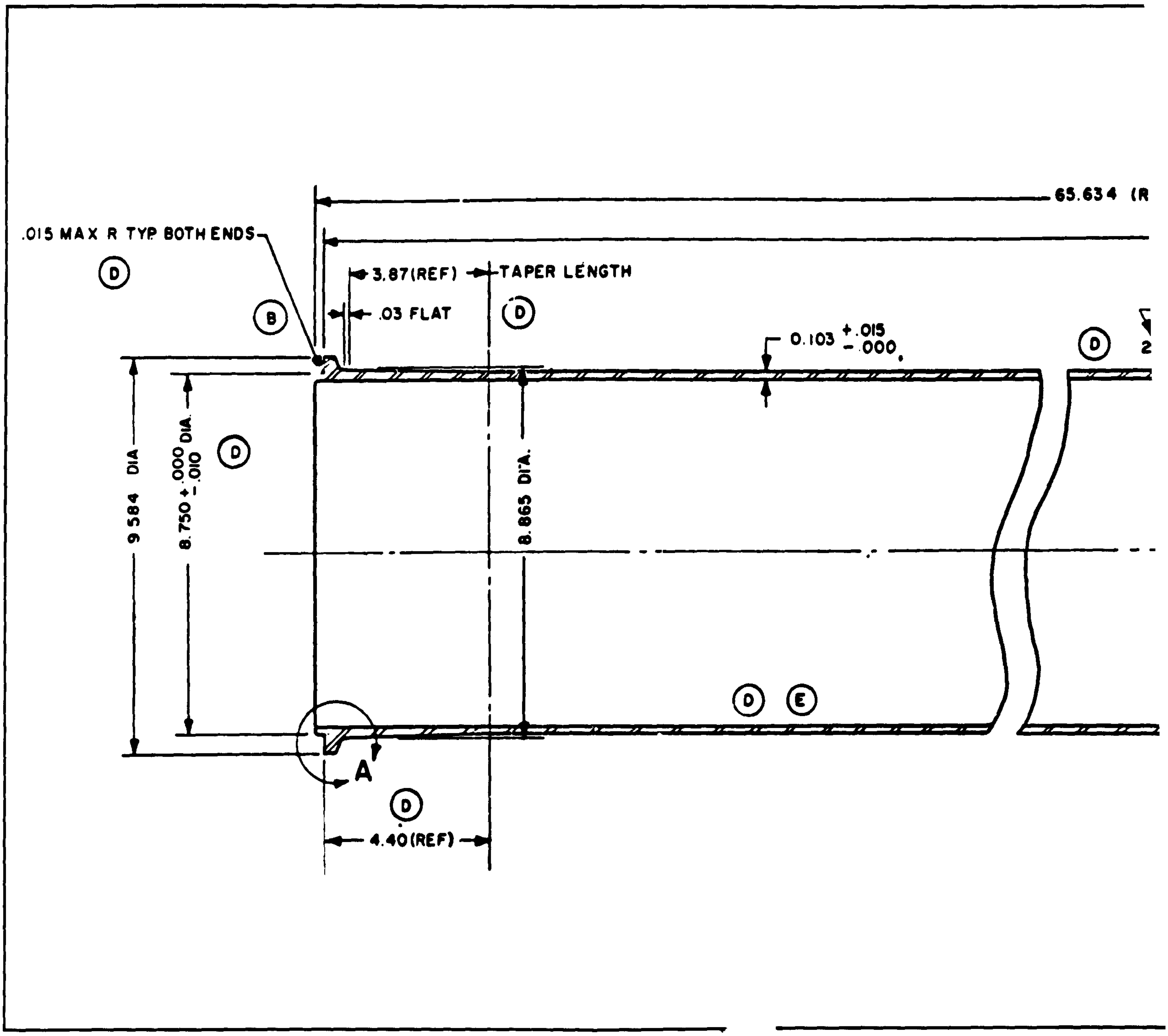
3. ARGMA consider the use of supplementary, acceptance tests for determining functional reliability; e.g., flaw detection by eddy current or ultrasonics.

B. Alternate Insulation Materials Study

Blast tube and adapter insulation used in the M30 Rocket Motor is a single source, proprietory item, and is considered to be relatively expensive. And, while the material meets the erosion and heat insulation requirements under operating conditions, it is quite sensitive to humidity. This sensitivity requires storage of insulation units in hermetically sealed packages before installation in the metal assembly and sealing of the assembly and the use of desiccant after installation. Therefore, an investigation for selecting an alternate material to broaden the supply base and decrease the cost of fabricated insulation units was undertaken.

The investigation was begun with a study of the properties, fabrication techniques, and cost of the insulation units now being used (Rocketon, supplied by the Haveg Corporation, Wilmington, Delaware) and of the adequacy of other materials for meeting the program requirements. Little information was available on commercial materials, including those supplied by the Haveg Corporation, when subjected to environments approximating the firing conditions of the M30 Rocket Motor. Therefore, a study was initiated to select likely materials and subject them to screening tests prior to a recommendation to ARGMA for the full-scale testing of the most promising of the screened materials.

The use of a small-scale rocket motor was considered the best approach to minimize the expense of testing samples selected for screening. Several test facilities were investigated, and the Research Institute of Temple University was selected to perform the tests since a small rocket motor was available which could be operated over a satisfactory range of temperature, gas velocity, pressure, and firing time. While the test motor operated on a liquid propellant (oxygen-water-alcohol) system which created an atmosphere varying somewhat from that created by the solid propellant used in the M30 Rocket Motor, the design and fabrication of equipment for burning solid propellant for the required time would have



65.634 (R
.015 MAX R TYP BOTH ENDS
D
3.87(REF)
TAPER LENGTH
B
.03 FLAT
D
0.103 +.015 -.000
D
9.584 DIA
8.750 +.000 -.010 DIA.
D
8.865 DIA.
D
E
A
D
4.40(REF)

1

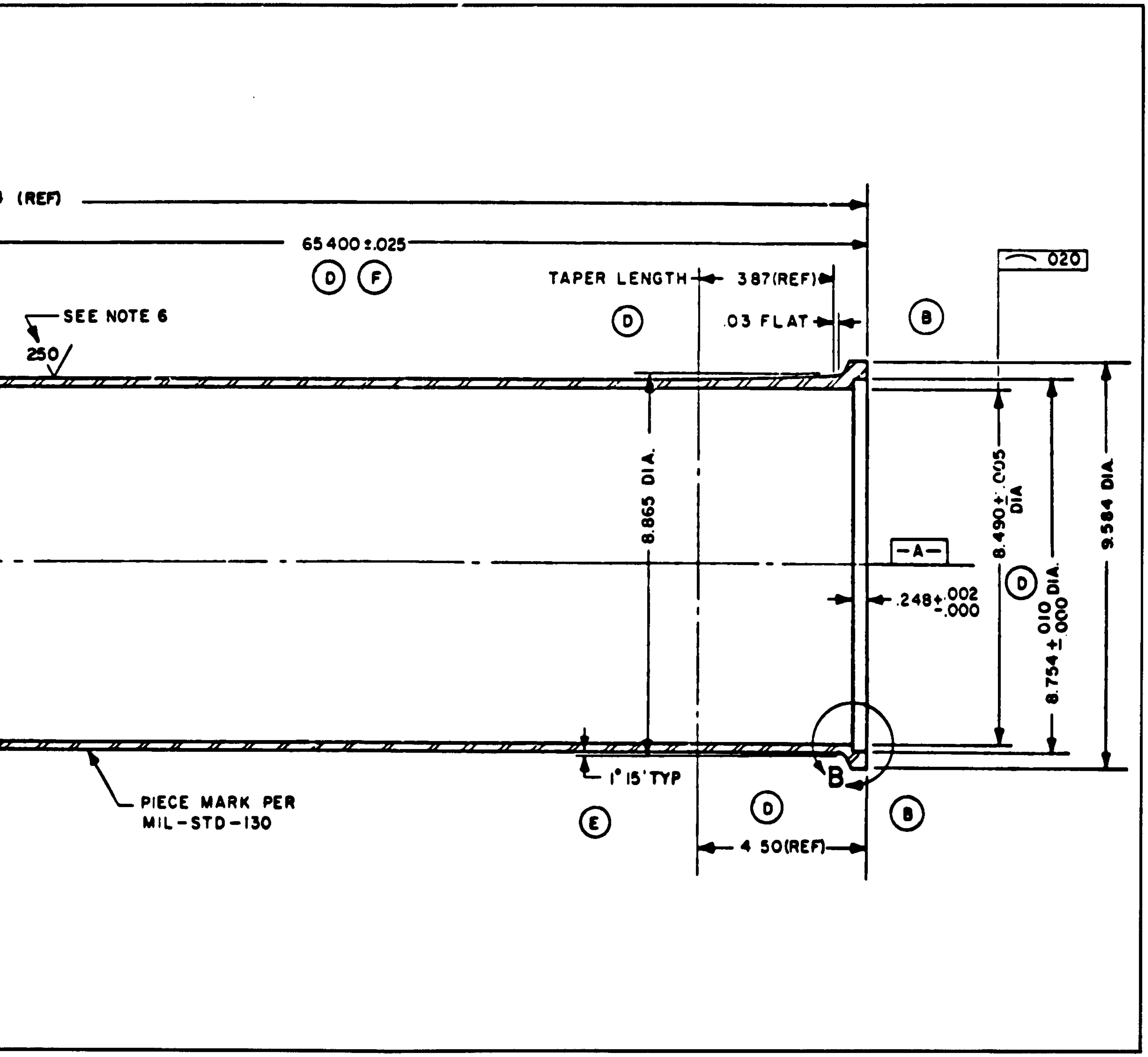
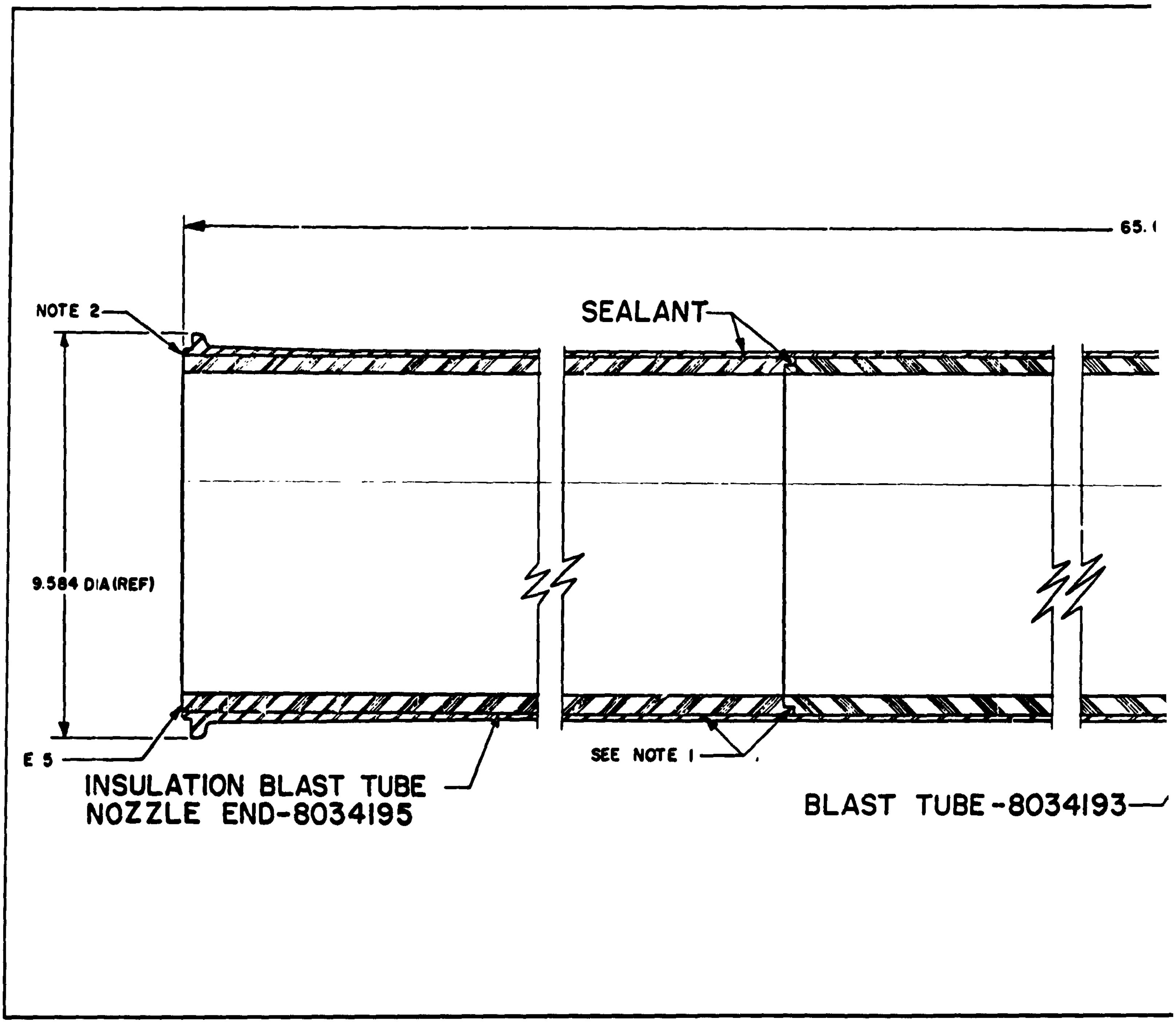


Figure 3. Blast Tube

2



65.(
NOTE 2
SEALANT
9.584 DIA (REF)
E 5
SEE NOTE 1
INSULATION BLAST TUBE
NOZZLE END-8034195
BLAST TUBE-8034193

1

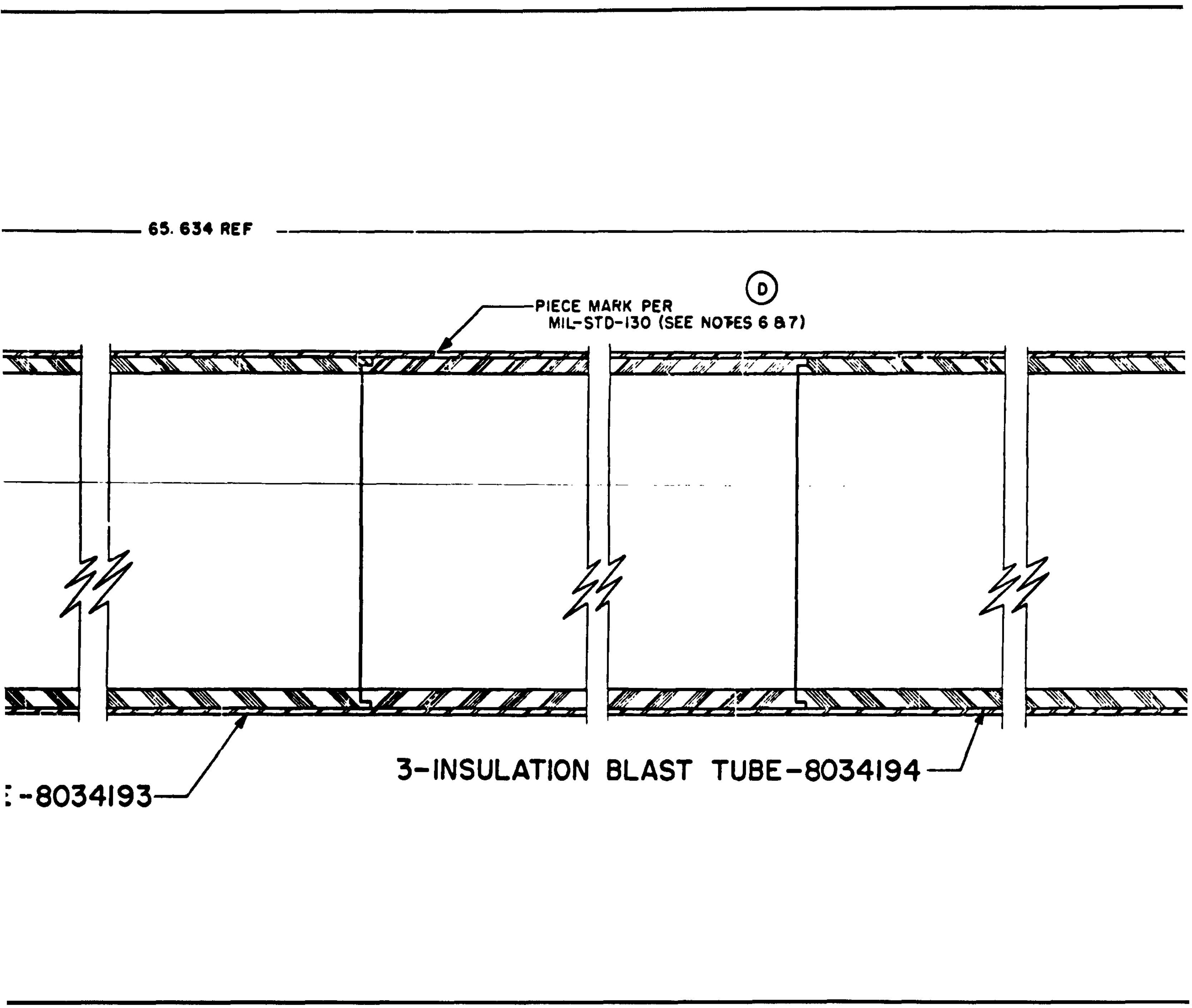


Figure 4. Blast Tube with

2

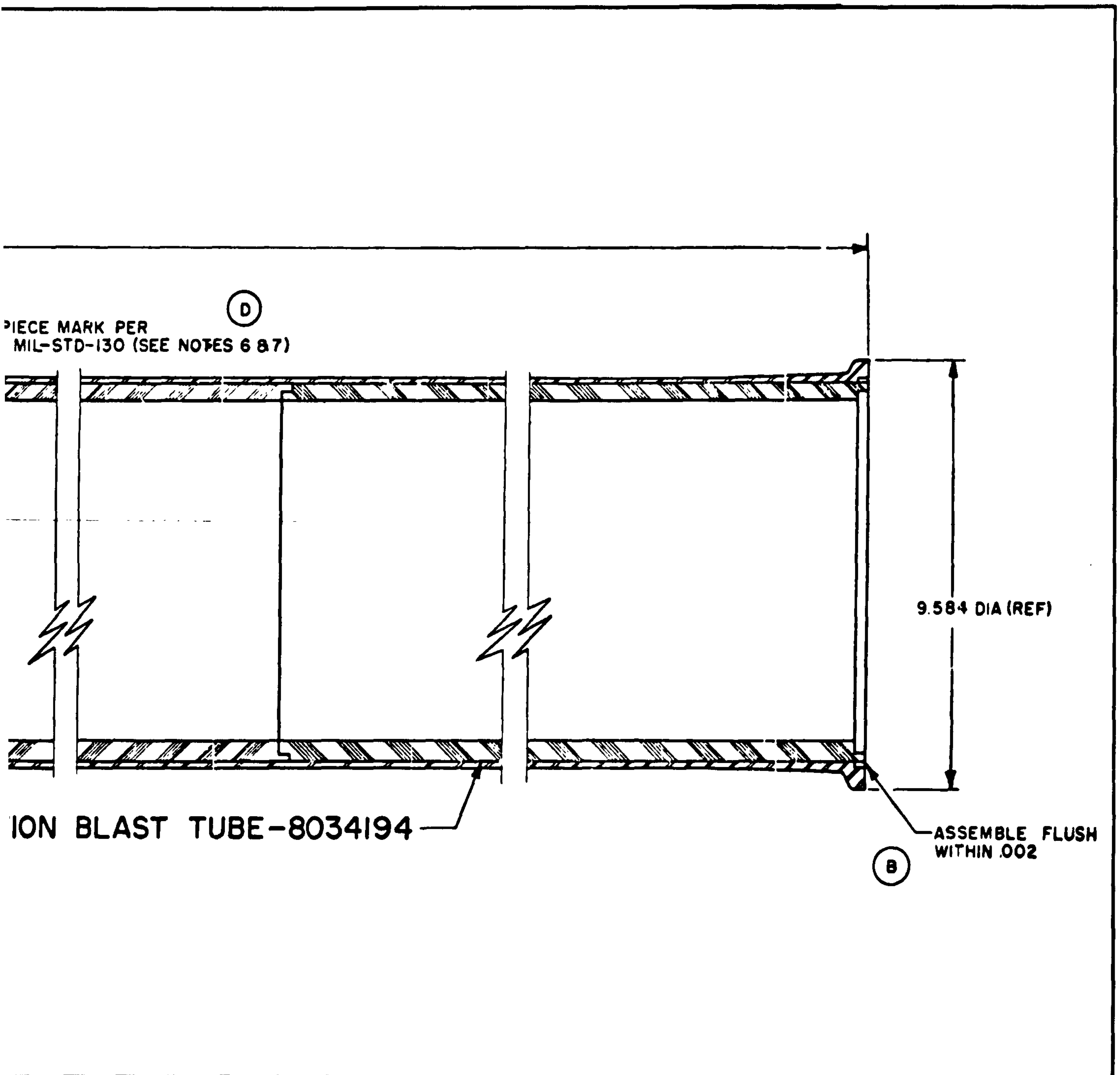


Figure 4. Blast Tube with Insulation Installed

3

been time-consuming and expensive. The liquid propellant system also had the advantage of being susceptible to control during firing and shutdown at any time during the run. The test assembly is shown in Figure 6.

The insulation samples used were tubular in shape: 1-inch inside diameter x 1.785 inch outside diameter x 12-inch long and enclosed in a steel tube. Insulating material molding conditions are in Appendix B. Flow rate was 0.9 pounds per second, temperature 3,500 °F, pressure 500 psi, and burning time 40 seconds. This test set-up approximated the wall thickness of currently used insulating units, and pressure, temperature, firing time, and flow rate per square inch of cross-sectional area of the blast tube. Six thermocouples were mounted on each test piece--three on a longitudinal axis on the outer surface of the insulation sample at three, six, and nine inches from the end of the tube; and three on the outer surface of the metal tube also at three, six, and nine inches from the end of the tube and 180° from the thermocouples on the insulation. Flanges were welded to each end of the metal tubes to mate with flanges attached to the test rocket motor and test nozzle.

Temperatures for the six thermocouples were recorded throughout firing and subsequent to firing until maximum temperatures were reached. Chamber pressure was recorded during firing. Flame temperature was calculated. Test pieces were weighed before and after firing to determine loss of material.

Since there was no method for making an absolute evaluation of the materials tested, Haveg Rocketon was used as a test control, and all data were compared to that obtained from this control.

TABLE I

BLAST TUBE INSULATING MATERIALS TESTED

1. Rocketon (asbestos-phenolic) supplied by Haveg Corporation, Wilmington, Delaware.

2. 41-RPD (asbestos-phenolic) supplied by Raybeston-Manhattan, Incorporated, Manheim, Pennsylvania.

3. 110-RPD (asbestos-phenolic) supplied by Raybestos-Manhattan, Incorporated, Manheim, Pennslyvania.

4. 150-RPD (asbestos-phenolic) supplied by Raybestos-Manhattan, Incorporated, Manheim, Pennsylvania.

5. 190-RPD (asbestos-phenolic) supplied by Raybestos-Manhattan, Incorporated, Manheim, Pennsylvania.

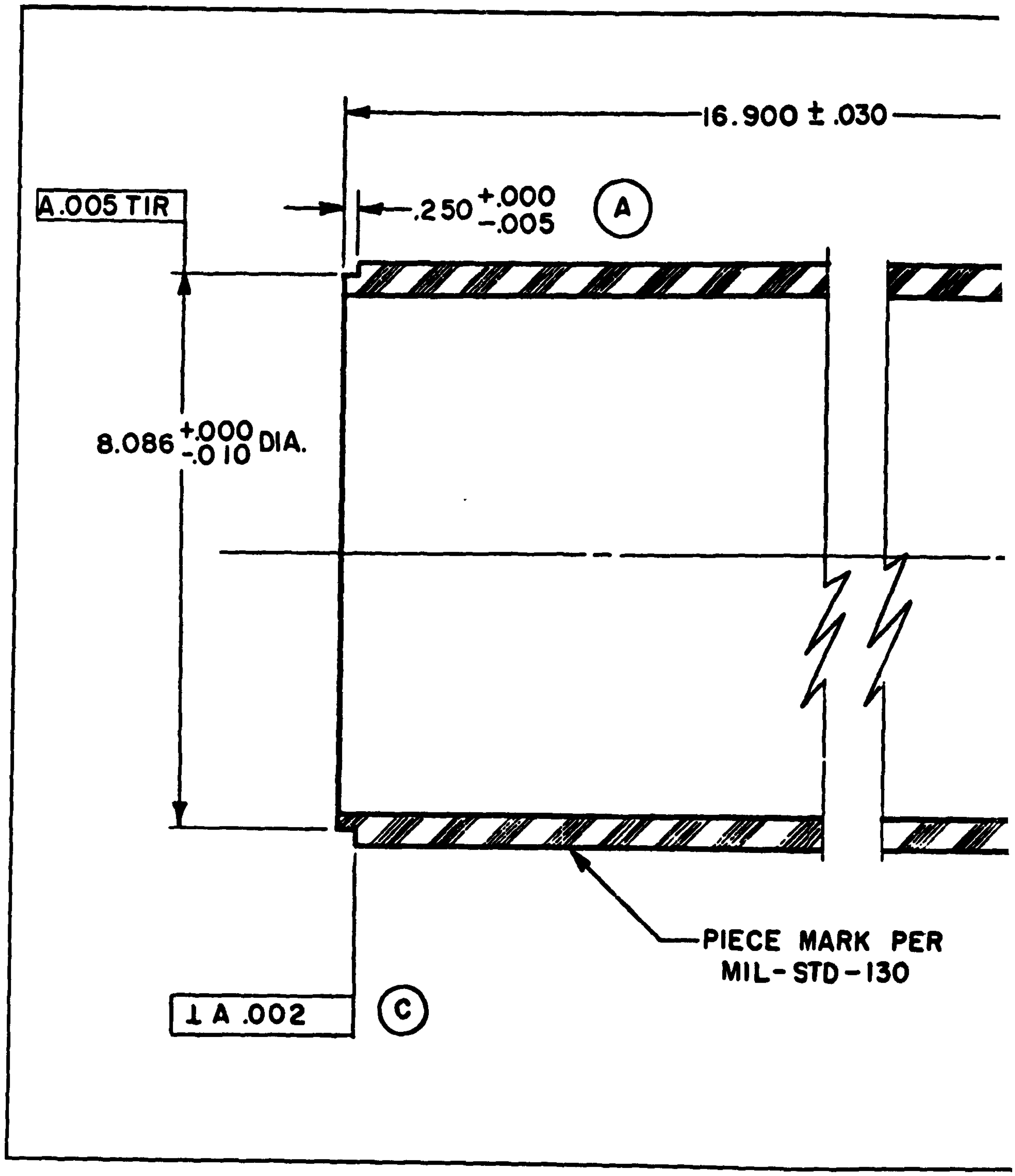
6. Durez 16771 (Glass-phenolic) supplied by Plastic Age Company, Saugus, California.

7. Asbestos cloth-phenolic supplied by Synthane Corporation, Oaks, Montgomery County, Pennsylvania.

8. Asbestos cloth-melamine supplied by Synthane Corporation, Oaks, Montgomery County, Pennsylvania.

Results

Of the eight insulations tested, four failed structurally during firing, necessitating shut-down, or experienced excessive loss of material and were not considered acceptable for the required application. Of the four remaining types of insulations, Raybestos-Manhattan 41-RPD produced test results comparable to Haveg Rocketon. Raybestos-Manhattan 150-RPD and 190-RPD evidenced structural adequacy and nominal ablation; however, the temperature rise for these materials was somewhat greater than for


16.900 ± .030
A .005 TIR
.250 +.000 -.005
A
8.086 +.000 -.010 DIA.
PIECE MARK PER
MIL-STD-130
⊥ A .002
C

1

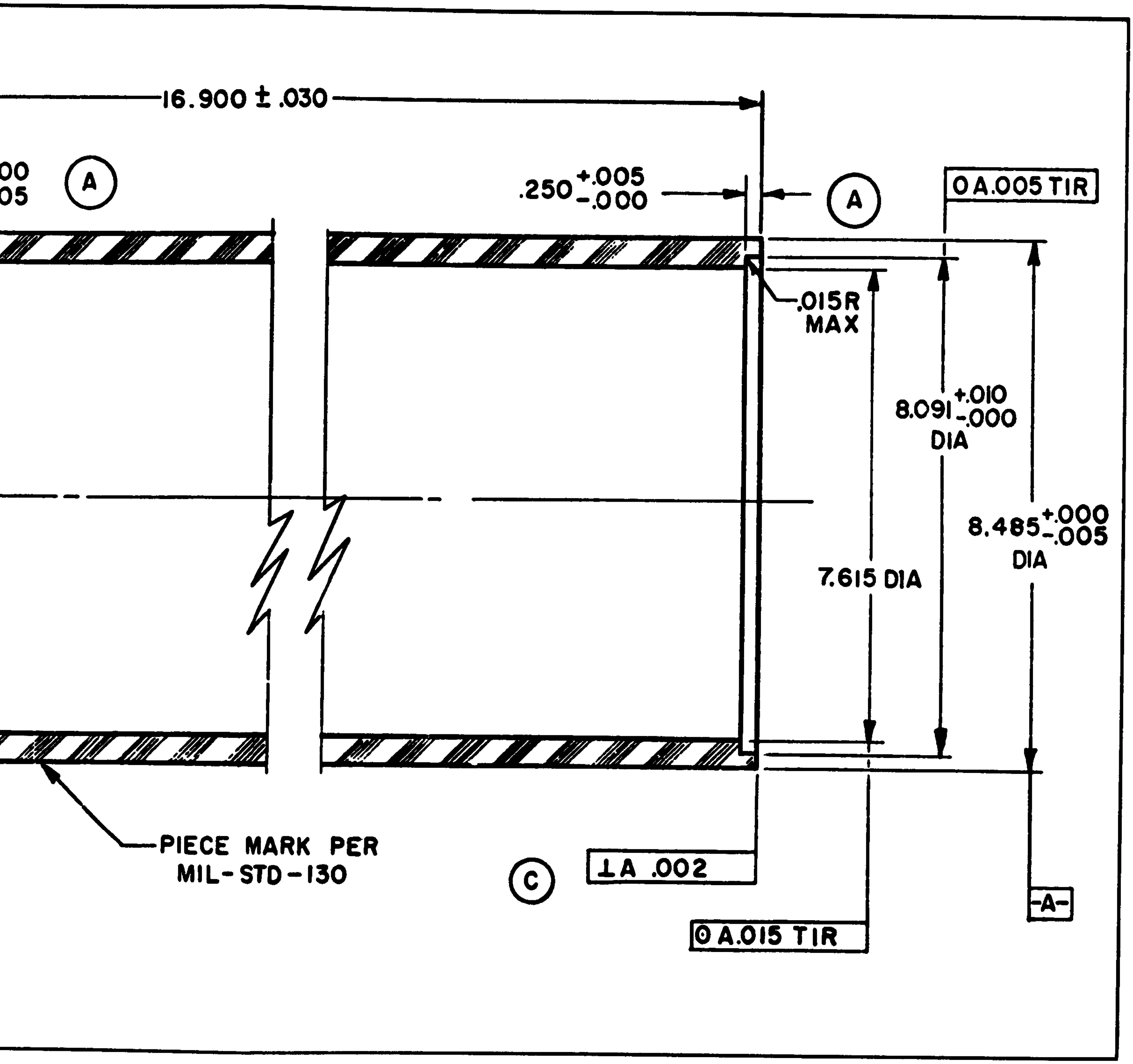


Figure 5. Blast Tube Insulation Section

2

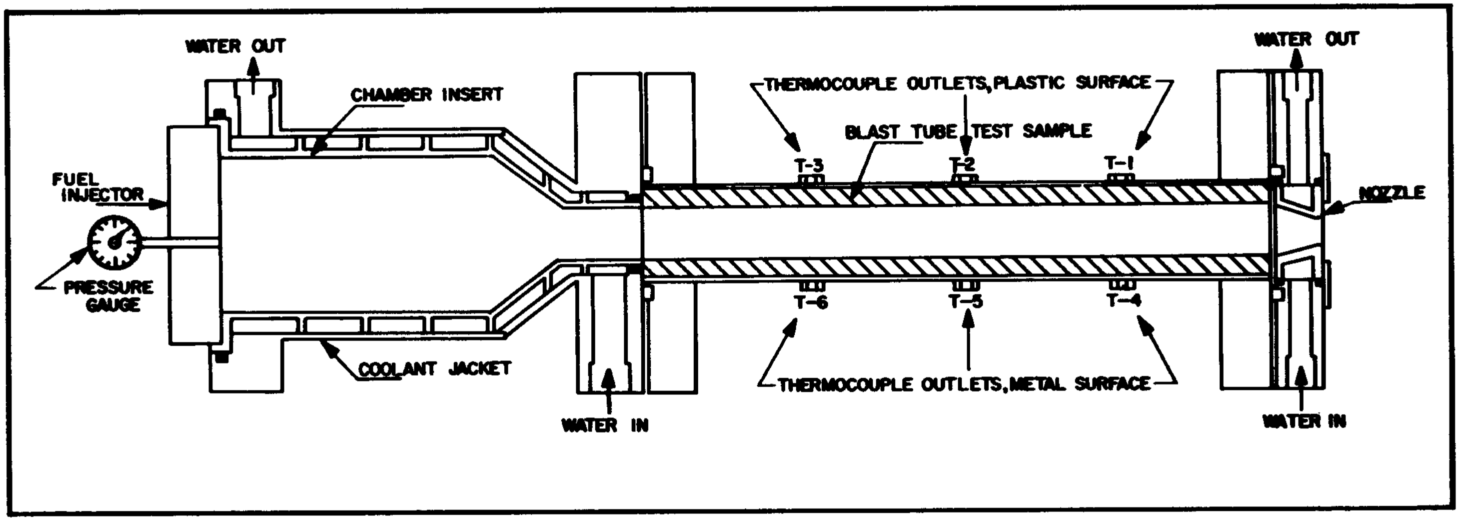


Figure 6. Blast Tube Insulation Assembly

Rocketon and 41-RPD. Temperature vs. time data are in Appendix F.

All test samples were sliced longitudinally for internal examination. In all cases, the upstream ends of the samples remained virtually intact. Further downstream, the insulation tube walls became progressively thinner until just before the outlet (nozzle) end at which point the wall thickness abruptly increased. Erosion, ablation, and charring had occurred in all the samples in varying amounts but were not constant throughout any single sample. Appreciable material had been lost during test. Therefore, a quantitative evaluation of these phenomena would be beyond the scope of this study.

TABLE II

VISUAL INSPECTION OF INSULATION TEST SAMPLES

Haveg Rocketon - Both test samples withstood the test firing without failure, although the first sample might be considered marginal since the insulation along a portion of the sidewall eroded down to the metal casing. The second sample evidenced a symmetric pattern of char and erosion.

Raybestos-Manhattan 150-RPD - The sample withstood the test with no sign of structural failure. The heat transfer rate was high; other characteristics appeared excellent.

Raybestos-Manhattan 100-RPD - Burn-through occurred after about 35 seconds of firing.

Raybestos-Manhattan 41-RPD - Both samples withstood test firing without failure. Patterns of erosion and char were symmetric.

Raybestos-Manhattan 190-RPD - Sample withstood test without structural failure. Char was relatively deep, and heat transfer rate relatively high.

Plastic Age, Durez 16771 - Samples were fabricated in two sections. First sample burned through on the upstream side of the joint in 34 seconds. Loss of material was excessive in both samples.

Synthane asbestos cloth, phenolic - First sample burned through in 31 seconds. Loss of material was excessive in both samples.

Synthane asbestos cloth, melamine - First sample burned through in 20 seconds. Second sample burned through in 24 seconds.

Percentage weight losses for the insulation samples which did not fail structurally are:

Material	Percentage loss
Rocketon	17.6*
41- RPD	19.4*
150 -RPD	18.4
190 -RPD	21.2

*Average of two samples.

Time vs. temperature curves were plotted for each material which did not fail during test. These curves were plotted for each thermocouple for comparative purposes. The initial rate of temperature rise was quite low, indicating the time lag experienced in heat transmission through the insulation material. Then the curves assumed an almost linear shape, indicating conduction as the controlling transmission factor. After propellant burn-out (40 seconds), and again with an appropriate time lag, the curves changed shape, indicating heat transfer from the metal tube to the atmosphere... primarily by radiation. This heat transfer is an exponential function of the temperature, and is so indicated by the curves. Both the rocket motor and the nozzle were water-cooled, which might have increased the rate of heat loss to some extent; however, the mass of metal comprising

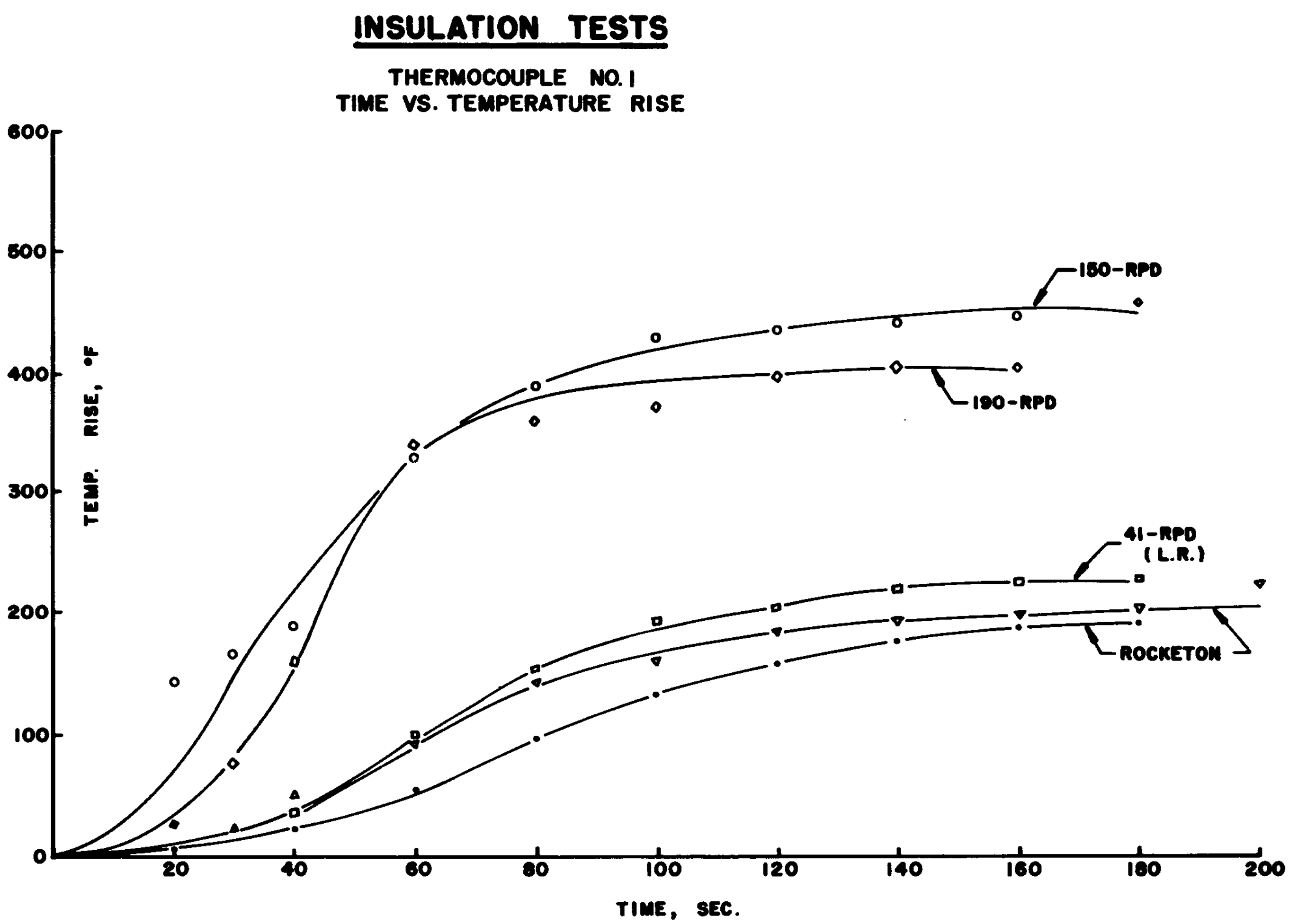


Figure 7. Insulation Tests

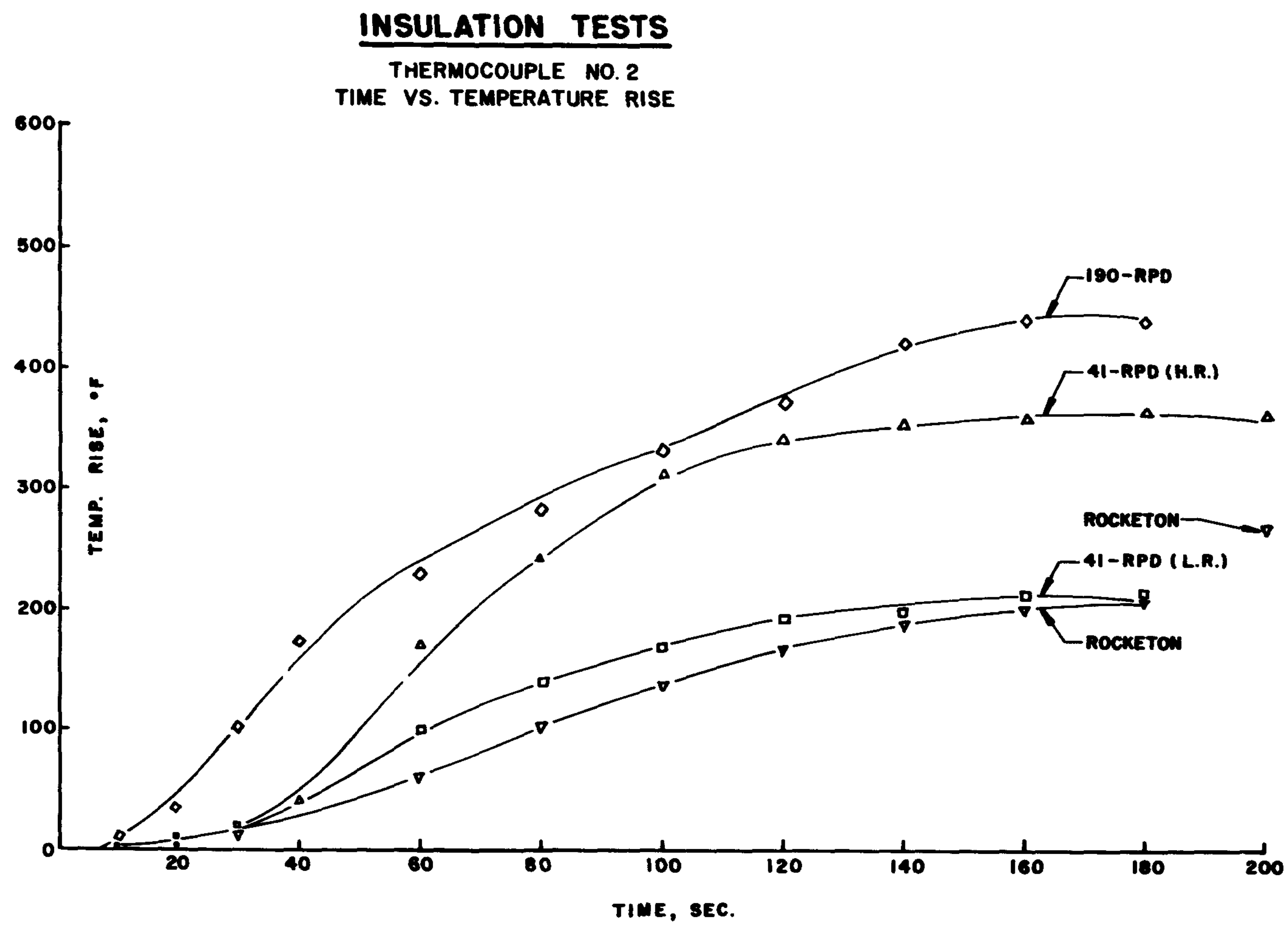


Figure 8. Insulation Tests

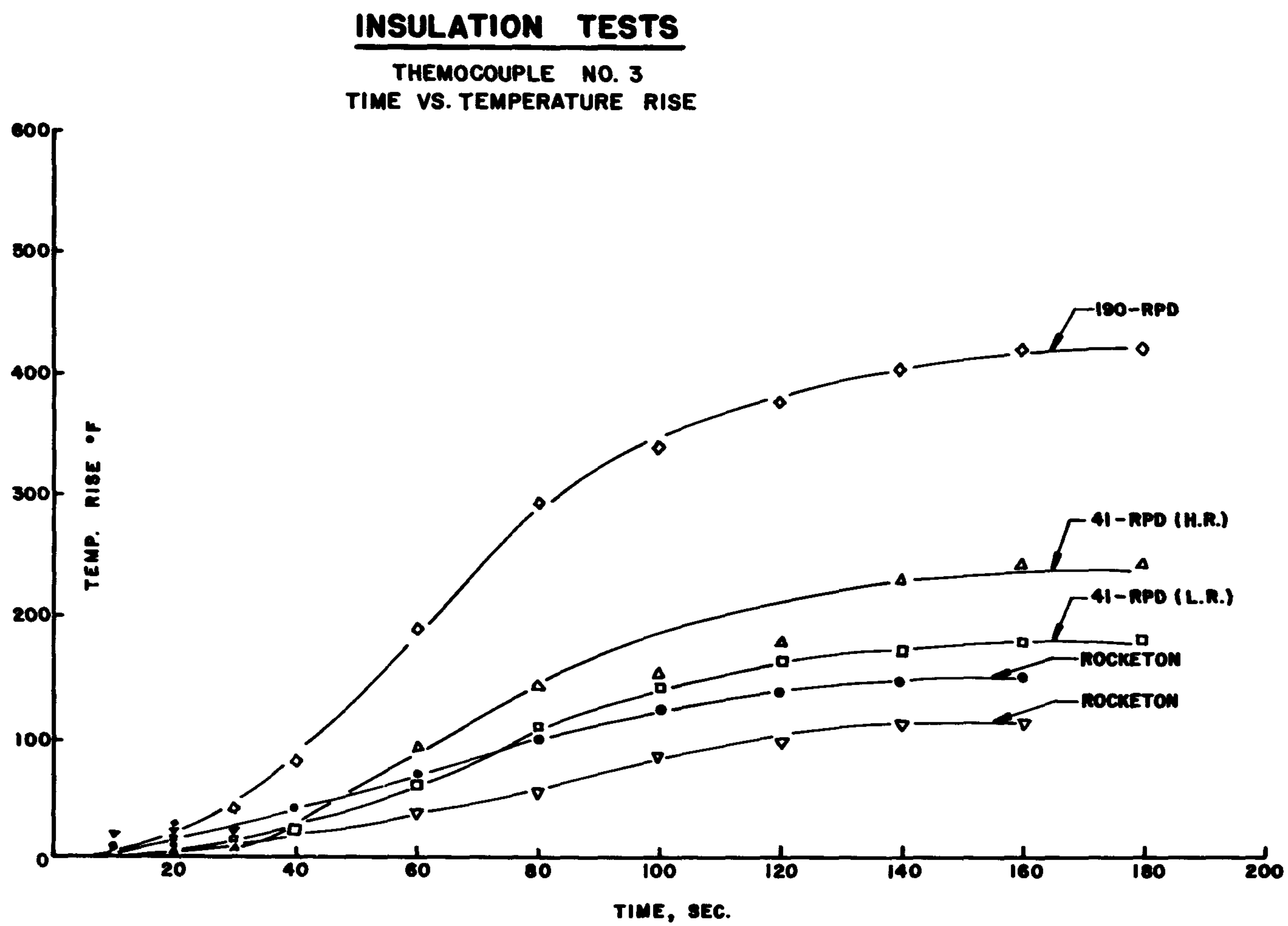


Figure 9. Insulation Tests

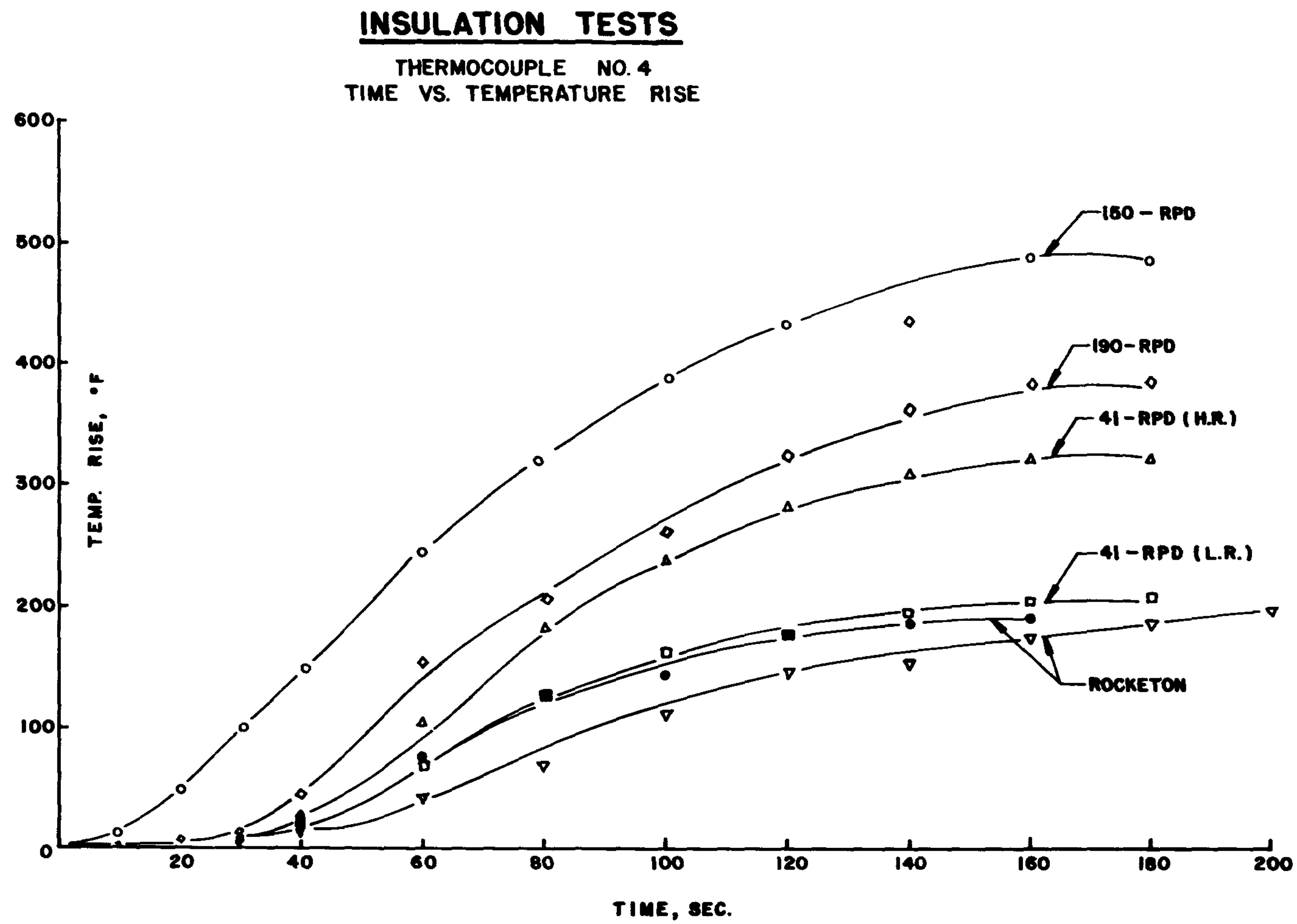


Figure 10. Insulation Tests

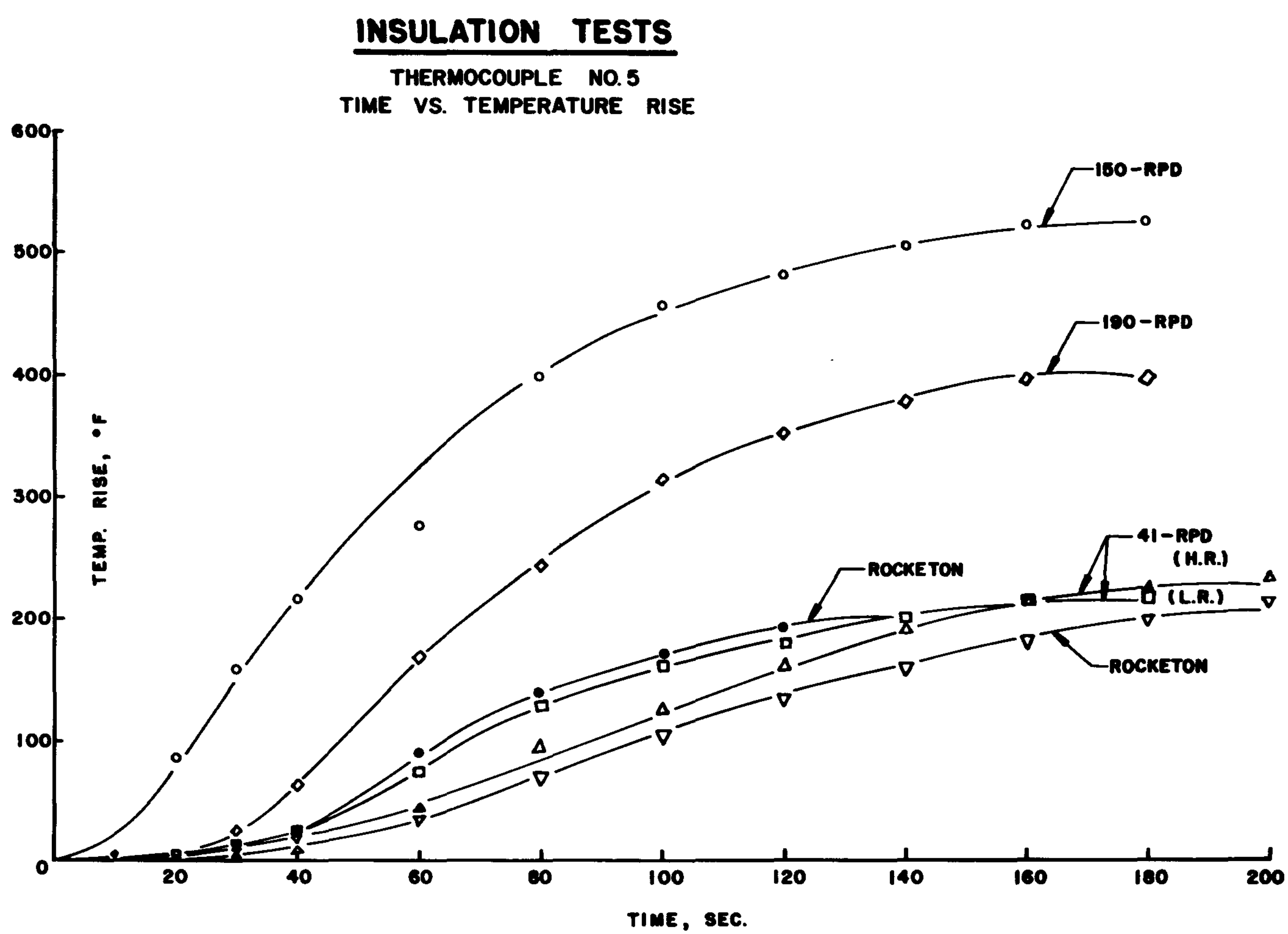


Figure 11 Insulation Tests

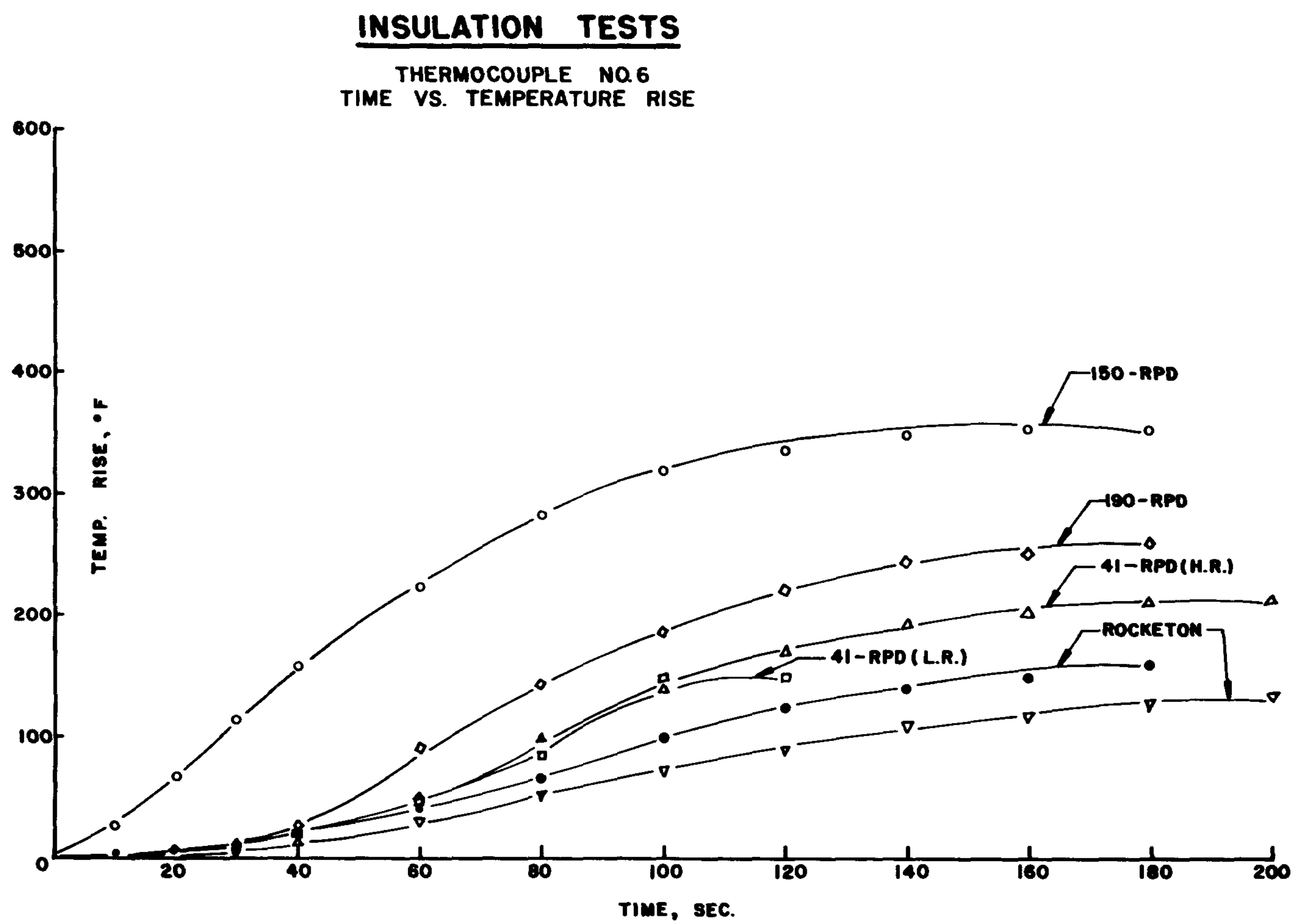


Figure 12. Insulation Tests

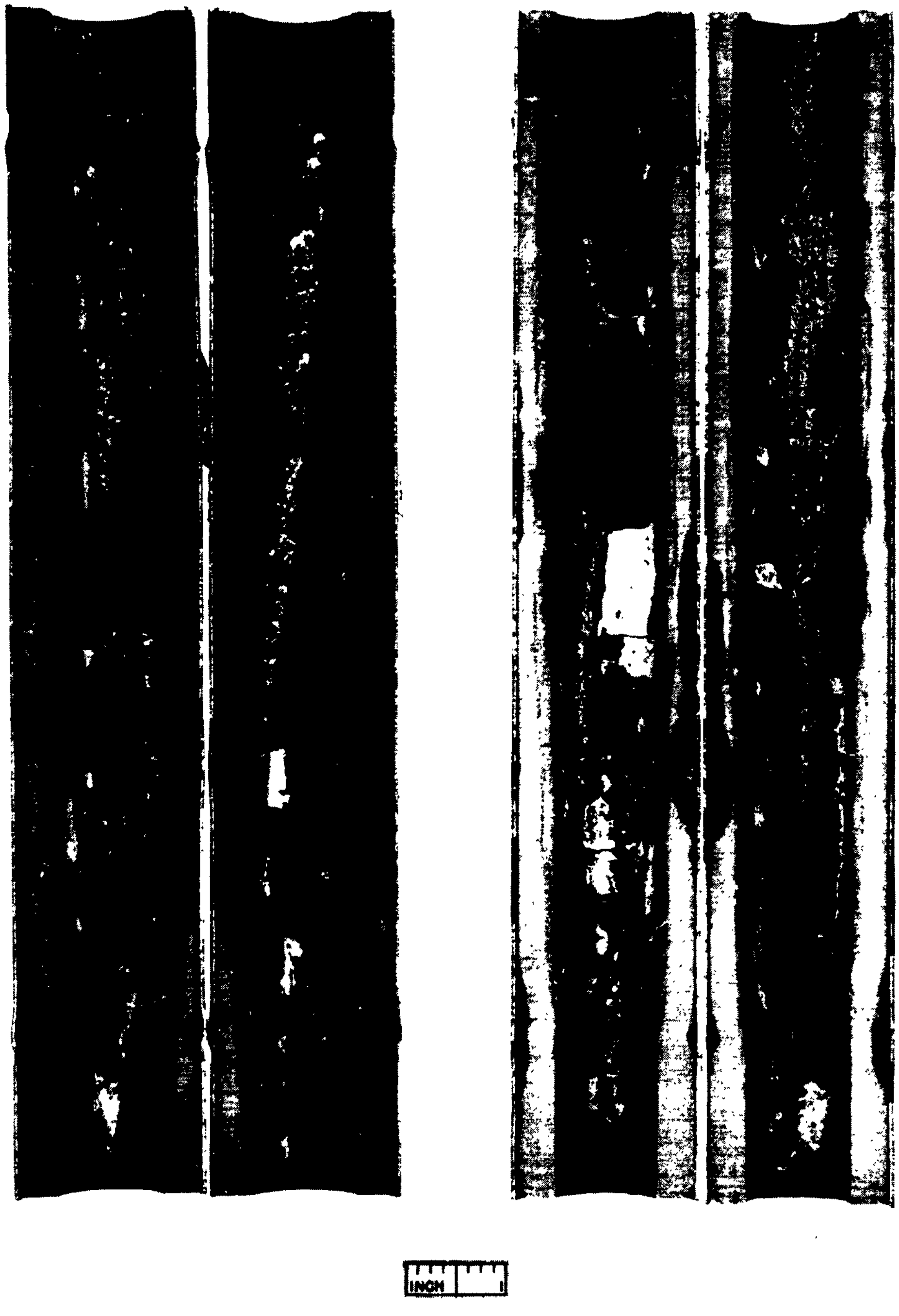


Figure 13. Haveg Rocketon

Figure 14. Raybestos - Manhattan 150 RPD

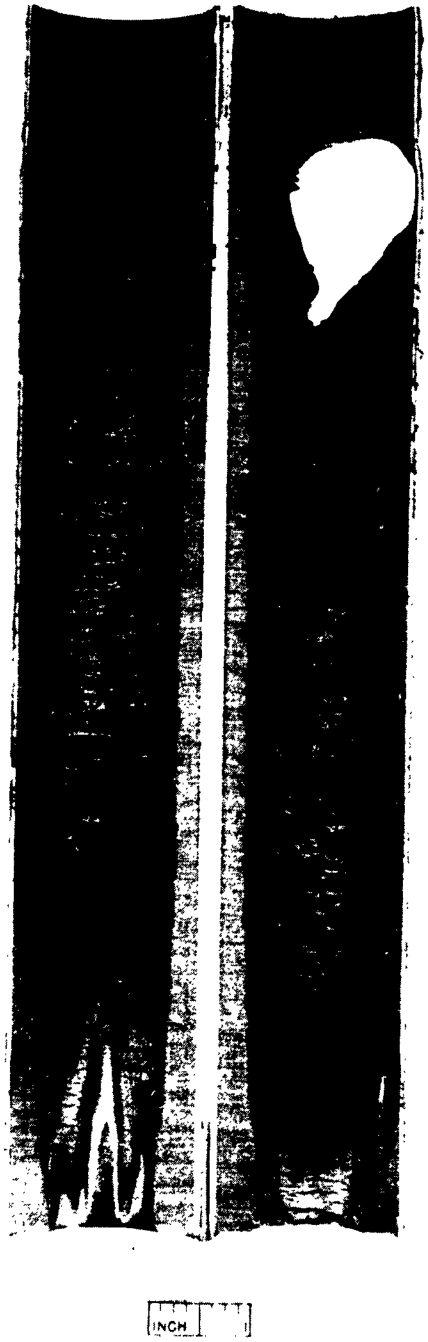


Figure 15. Raybestos - Manhattan 110 RPD

Figure 16. Raybestos - Manhattan 41 RPD

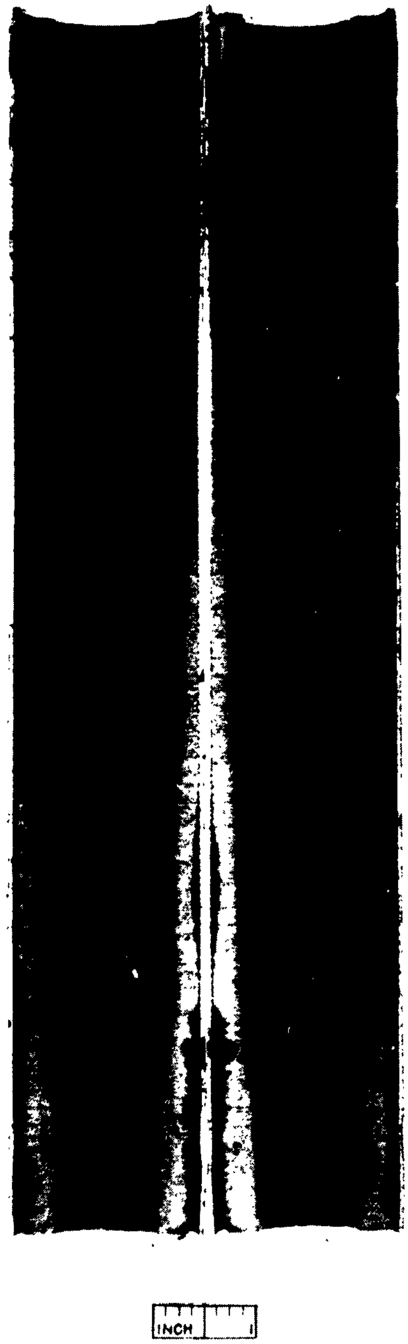


Figure 17. Raybestos - Manhattan 190 RPD

Figure 18. Plastic Age, Durez 16771

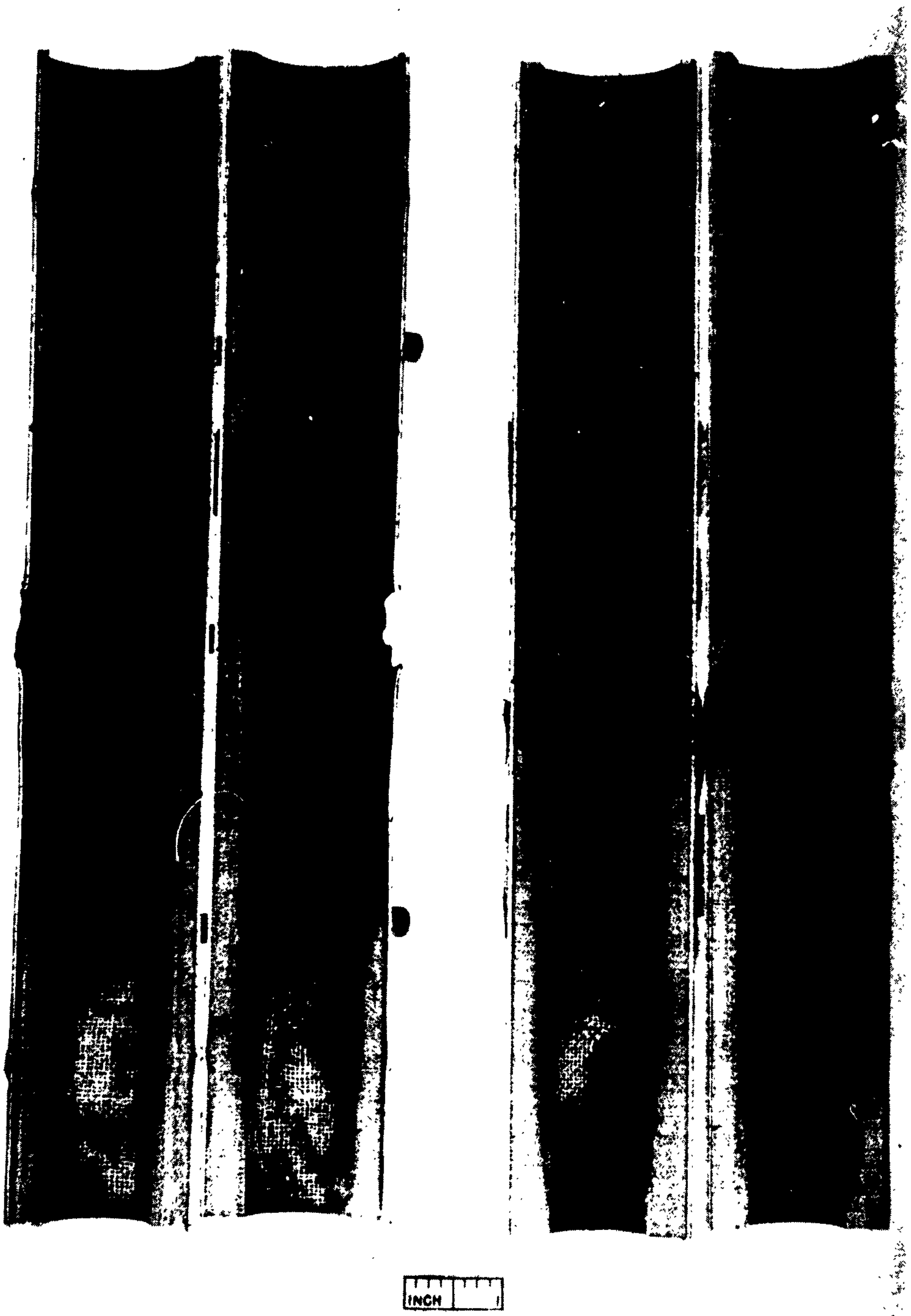


Figure 19. Synthane, Asbestos Cloth - Phenolic

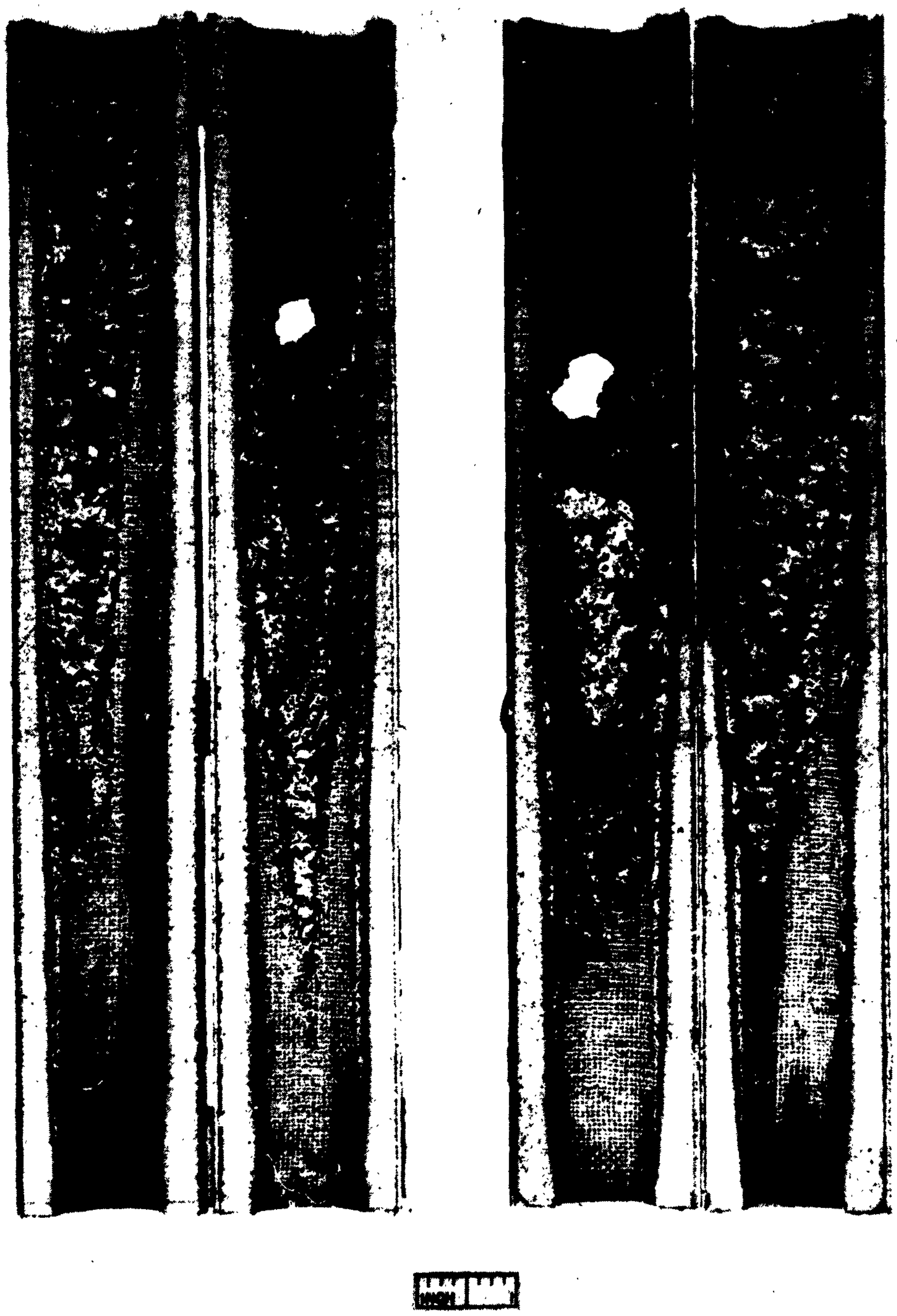


Figure 20. Synthane, Asbestos Cloth - Melamine

the flanges was capable of supplying sufficient heat to the cooling water to make any conductive effect from the metal tube small. Temperatures after maxima were not recorded.

The cost of blast tube insulation units, estimated by Raybestos-Manhattan, indicated a savings of about 50% if 41-RPD is substituted for Rocketon. An increased cost was anticipated for adapter insulation units if Raybestos-Manhattan material is used.

Recommendations

Based on the results of the investigation, it was recommended that full-scale testing of blast tube insulation units fabricated from 41-RPD material be initiated in static firings.

C. Liner Removal Study

The economical reclamation and re-use of statically fired motors would constitute a cost savings as well as a reduction in the number of motors which would have to be diverted from production to fulfill the static firing requirements.

Some metal parts reclamation was performed at the loading plant (Longhorn Ordnance Works in Marshall, Texas) during the pre-production phase of the project, but was later discontinued.

The primary reconditioning problem appeared to be the removal of the polysulfide rubber liner which bonds the propellant to the motor case. Investigation of past efforts in the area of liner removal from other motors indicated limited success. While removal of a substantial portion of the liner could be achieved with various solvent mixtures, toxicity, high temperature requirements, and residue removal remained as problems.

Laboratory tests were conducted to obtain one or more non-toxic solvents satisfactory for liner removal at ambient temperature with minimum solvent reclamation requirements. After these tests, chloroform (the solvent considered best for the purposes) was tested with a fired gas generator, and a motor reconditioning process was suggested.

Steel coupons (2" x 2") bonded with RDL-PD-107B polysulfide rubber (1/8" thick) were subjected to the action of a number of commercially available solvents and solvent mixtures. The results are in Table III.

Methylene chloride and chloroform completely removed the rubber liner in six hours at room temperature. The rubber broke up into small pieces which settled to the bottom of the container (Figure 24). Solvent mixtures containing chloroform (Nrs. 12, 13, 14, Table III) completely removed the rubber after a four-hour treatment. In this case the solvent mixture penetrated the rubber liner to the steel-rubber interface and the rubber was easily peeled from the steel coupon (Figure 23). Of the three mixed solvents evaluated, the one consisting of chloroform, glycerin and ethanel (No. 12) was the most effective.

These experiments were carried out at room temperature. (See Appendix G for test procedure.) An increase in temperature to the boiling point of the solvent appeared to have little effect on the rate of dissolution. Glycerine, which had no effect at room temperature, completely removed the rubber liner in two minutes at the boiling point (290°C). The dissolution of the liner was accompanied by a disagreeable odor.

A number of rubber-bonded steel coupons were heated over a Bunsen flame to scorch and burn the rubber. These specimens were then soaked in chloroform and solvent Mixture No. 12. The results were exactly the same as with the unburned specimens.

In one experiment it was found that approximately 1.6% of the rubber was dissolved in the chloroform.

The solvents which had the greatest effect on the rubber liner are commercially available. With the exception of ethanol, the current price is in the range of 12 cents (methylene chloride) to 34 cents (dimethyl sulfoxide) per pound. The price of ethanol depends on the grade used.

CONCLUSIONS

On the basis of small-scale laboratory experiments there should be no difficulty in removing the polysulfide rubber liner using either methylene chloride, chloroform or solvent mixtures #12, 13 or 14 (Table III). These solvents are commercially available and are in use industrially.

The thickness of the rubber liner (1/8") on the samples examined is greater than that present in M30 Rocket Motors. Therefore, the time required for liner removal from the actual motors probably will be less than that reported.

Motor Reconditioning Unit (Figure 25)

Fresh solvent is poured from drums into the sump. Motor bodies are placed vertically in cradles, and the piping is connected to them. Solvent is pumped into the motor bodies until it begins to run out of the overflow line, indicating that the motor bodies are full. The valves on the motor body inlet lines are closed, and the pump is shut off. The motor bodies are then permitted to soak for the time required for liner removal. When the soaking period is completed, the motor body drain valves are opened allowing the solvent to drain back into the sump. If necessary, the motors

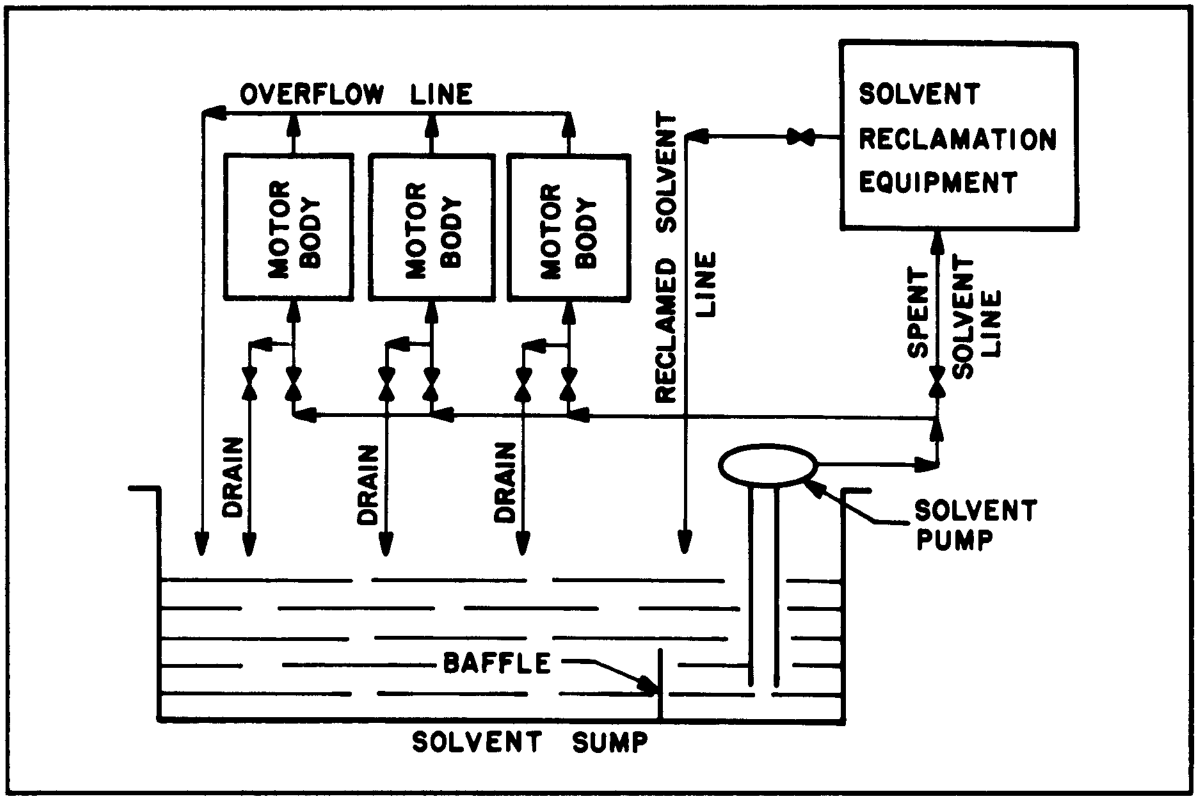


Figure 25. Schematic Of Motor Reconditioning Unit

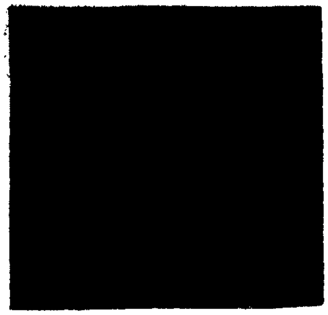


FIGURE 21

FIGURE 22

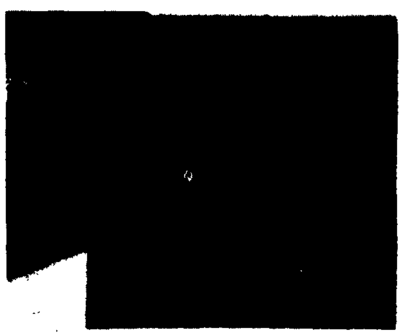


FIGURE 23

FIGURE 24

Figure 21. Specimen of rubber bonded to steel
Figure 22. Steel specimen after removal of rubber
Figure 23. Peeling off rubber after solvent #12 treatment
Figure 24. Rubber residue after solvents #1 and #2 treatment

Figure 24

TABLE III

ACTION OF SOLVENTS ON POLYSULFIDE RUBBER LINER

SOLVENT		B. P., °C	REMARKS
1.	Methylene chloride	40	Rubber disintegrated within six hours at room temperature.
2.	Chloroform	61	Rubber disintegrated within six hours at room temperature.
3.	Glycerine	290	No action at room temperature. Rubber completely removed in two minutes at boiling point.
4.	Benzene	80	Rubber softened, but not removed.
5.	o-Dichlorobenzene	180	Rubber disintegrated within two days at room temperature.
6.	Morpholine	126	Rubber swollen and softened, but not removed.
7.	60/40 ethyl/propyl nitrate	96	At first there is no apparent effect, but after 24 hour immersion and drying, the rubber can be peeled off.
8.	Carbon disulfide	46	Rubber softened, but not removed.
9.	Dimethyl sulfoxide	190	Rubber dissolves slowly.
10.	Dimethyl formamide	153	Very little action.
11.	Ethanol asturated with NaOH	-	Very little action.

TABLE III (Cont'd)

SOLVENT		B. P., °C	REMARKS
12.	*Chloroform, 36% Glycerin, 36% Ethanol, 28%	-	Rubber peeled off after four hour soak at room temperature.
13.	*Chloroform, 50% Morpholine, 50%	-	Rubber peeled off after four hour soak at room temperature.
14.	*Chloroform, 50% dimethyl sulfoxide, 50%	-	Rubber peeled off after four hour soak at room temperature.

*Although these three solvent mixtures had the same action on the polysulfide rubber, Mixture #12 appeared to be the most effective.

can be flushed with solvent by closing the drain valves, opening the inlet valves, and pumping through the motors and overflow line. This flow system can also be used if it is found that more effective liner removal can be achieved by continuous circulation of solvent. The motor bodies are removed, washed, and returned to storage following the cycle.

The sump baffle prevents excessive flow of liner particles into the pump, but allows a continuous flow of solvent. A number of reconditioning cycles is anticipated before the solvent loses sufficient strength to be an effective liner removal agent.

Smaller parts may be placed in a wire basket and immersed in the solvent in the sump for liner removal.

If solvent reclamation is necessary, the spent solvent is pumped to the solvent reclamation section, which would probably consist of a filter or distillation apparatus. Reclaimed solvent is returned to the sump. Fresh solvent make-up also is added to the sump as required. Then, the unit is ready for additional cleaning cycles.

The system is sufficiently flexible to accommodate fewer than the three motor bodies shown (Figure 25). Or, more motor bodies can be reconditioned by increasing the number of piping leads.

D. CORROSION STUDY

An accelerated corrosion study was conducted to support: (1) field storage operations and (2) loading plant operations in pre-loading and post-loading storage of the M30 Rocket Motor. While no corrosion severe enough to make stored motors unuseable has been reported, corrosion in instances of severe storage conditions has started and could, in relatively long-term storage, propagate sufficiently to raise doubts as to the useability of stored motors, if not affect their functional reliability. Some corrosion of uncoated metal parts occurs regularly at the loading plant. Although corrosion is removed or the affected parts are rejected prior to packing, this situation inhibits loading plant operations to some extent.

Before the corrosion study was initiated, the ARGMA Field Service representative was contacted to determine which, if any, components of the M30 Rocket Motor were subject to corrosion during storage and the extent and effects of corrosion. Field Service advised that periodic inspections of stored motors were made and that there were no adverse reports concerning corrosion. At a later date, a motor (S/N L-533) was returned from an overseas installation in Formosa where it had been inadvertently dropped from a height of about 10 feet while in the shipping container. The wooden container had been severely damaged, and rusting of exposed, unpainted metal parts was noted. After disassembly, inspection, and reassembly, this motor was successfully fired.

Corrosion was occurring regularly on the unpainted flange surfaces, while in the loading plant. This corrosion must be removed before the motors are crated. The cadmium plated Gask-O-Seals which seal the coupling between the aft end of the motor case and the forward end of the blast tube also were found to be corroding -- apparently due to the deterioration of the rubber ring sections of the seals. However, this corrosion problem was eventually alleviated by the substitution of stainless steel for cadmium plated steel.

It was decided that the most effective study could be accomplished by determining whether any additional areas are particularly vulnerable to corrosion and then testing a number of corrosion inhibiting treatments with a view toward the selection of a single inhibitor which would be effective in all areas subject to corrosion.

A blast tube and nozzle assembly was placed in an environmental chamber and subjected to 95% Relative Humidity and 160°F for four weeks.

The assembly was periodically inspected until signs of rust appeared. Disassembly and inspection revealed blistering and discoloration of the paint and corrosive pitting of the unpainted flange surfaces. None of the damage was sufficient to make the motor inoperable.

After a review of the modes of corrosion and the techniques for inhibiting corrosion, a coating procedure was chosen as the most applicable technique for protecting the areas susceptible to rusting. The coatings listed in Table IV were selected as being representative of types which can be applied cold by either spraying, brushing, or dipping, and which can be cured either at elevated temperature or at room temperature, thus providing maximum flexibility for application with minimum controls both in-plant and in the field. The test procedure is outlined in Appendix H.

TABLE IV

CORROSION INHIBITING COATINGS TESTED

Coating	Supplier
1. Sicon Aluminum 7x2070	Midland Industrial Finishes Company Waukegan, Illinois
2. Sicon Aluminum 3x245	Midland Industrial Finishes Company Waukegan, Illinois
3. Drygalv	American Solder and Flux Company Philadelphia, Pennsylvania
4. Zincilate	Industrial Metal Protectives, Inc. Dayton, Ohio
5. Nox-Rust 920	Daubert Chemical Company Chicago, Illinois
6. *Aberdeen Proving Ground Composition	

* Aberdeen Proving Ground Report CCL-40, Composition for Rapid and Simultaneous Derusting, Degreasing, and Ruse-Proofing of Ferrous Surfaces at Ambient Temperatures, 8 January 1958.

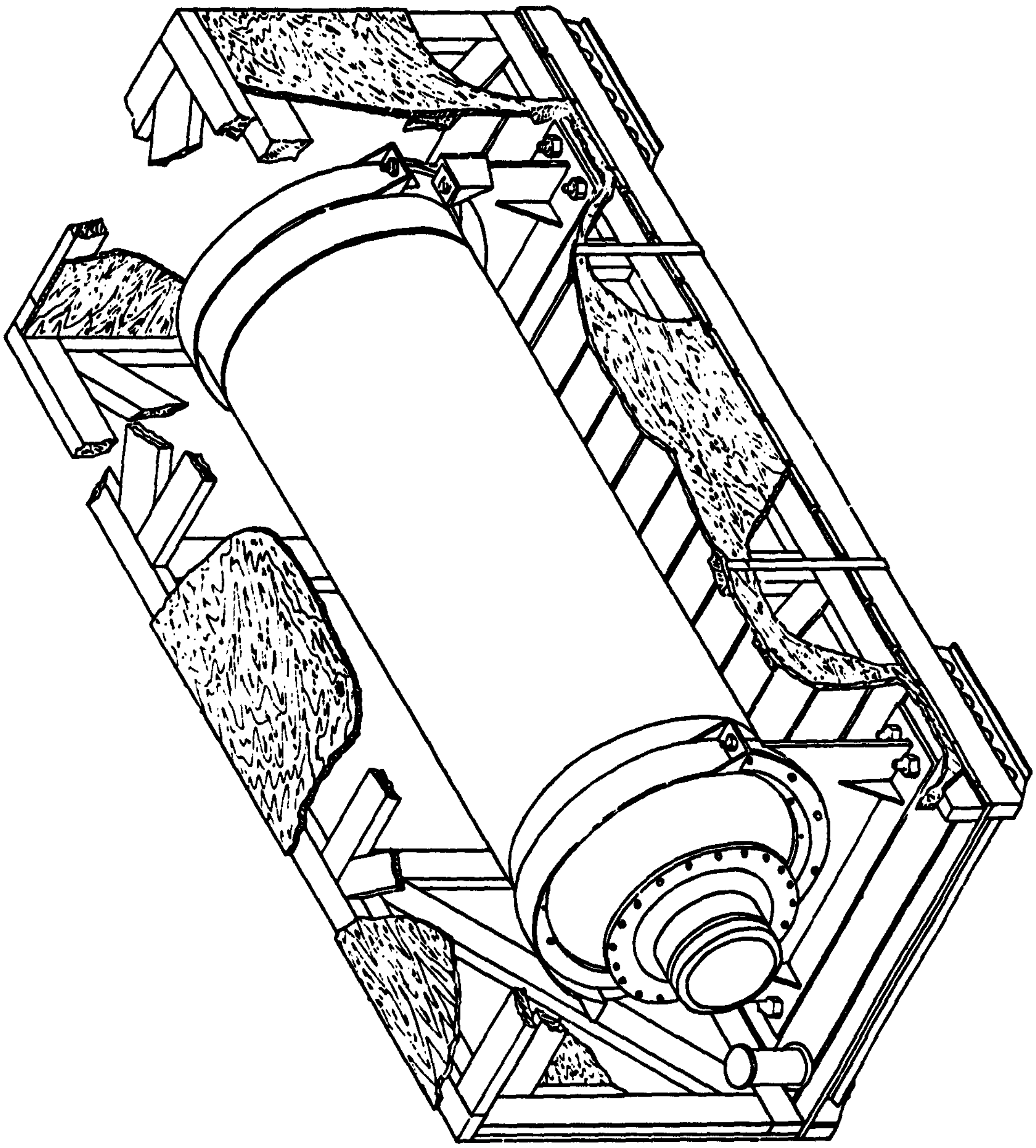


Figure 26. Crated Motor

E. TEMPERATURE GRADIENT STUDY

The minimum temperatures for firing and storage have been established as 0°F and -10°F, respectively. Under field conditions in which low temperature is experienced, heated igloos are provided for storage. For the purpose of this study, minimum heated storage temperature was considered to be 40°F. The motors, when removed from heated storage, cool to the ambient temperature.

In this series of tests, a crated motor with nine thermocouples imbedded in the grain at various distances from the periphery was thermally conditioned until the grain temperature stabilized at 40°F. The conditioning temperature was then lowered to a predetermined point and maintained until the entire grain temperature dropped to within 10°F of the conditioning temperature, time vs. temperature recordings being made throughout. The grain temperature was then raised to the initial temperature (40°F). This procedure was repeated for several low temperatures. Two additional thermocouples were used to record the crate and the conditioning chamber temperatures. A complete description of the test procedure is given in Appendix I; test data are given in Appendix J.

Data were reduced and plotted for each time-temperature path of the cooling process (Figure 35). The slopes of the curves (dT/dt, where T is the temperature and t is the time) would indicate the cooling rate at any point on the curves. Low temperature firing and storage limiting curves (Figure 27) were developed by cross-plotting as described in Appendix K. These limits were based on the thermocouple located one-half inch from the periphery and considered reasonably accurate since the temperature gradient across the final half-inch of propellant was small and the propellant is insulated from the casing wall by a polysulfide rubber liner.

The shipping and storage crate was found to offer little thermal protection as it was mounted on skids, permitting air to circulate underneath, and the bottom of the crate was slatted with 3/8 inch openings between slats. Apparently some stratification occurred in the crate with the warmer air rising to the top; however, the crate temperature differential was small.

Conclusions

Periodic field inspection of stored motors is generally sufficient to disclose deterioration caused by corrosion before the metal parts become unuseable, thus making minor maintenance the primary field consideration. Exceptional cases in which containers are severely damaged during unusual handling conditions can be detected and remedied as they occur.

Based on tests on several types of coatings, it is concluded that all of the coatings tested are satisfactory for limited or temporary corrosion protection. Any of the coatings may be overcoated if greater protection is desired or if the cosmetic effect of a particular color paint is preferred. Coating is simple enough to be performed at any echelon.

The following order of utility is suggested by the test results:

1. Sicon Aluminum 3x245
2. Sicon Aluminum 7x2070
3. Drygalv
4. Zincilate
5. Nox-Rust 920
6. APG Composition

All of the coatings may be applied cold by brush, spray, or dip as single or multiple coats. They can be heat cured or air dried. Since they cannot be washed or rubbed off, they offer protection for the uncoated surfaces which is superior to the grease currently being used. The build-up produced by these coatings is insufficient to make their removal from mating surfaces necessary.

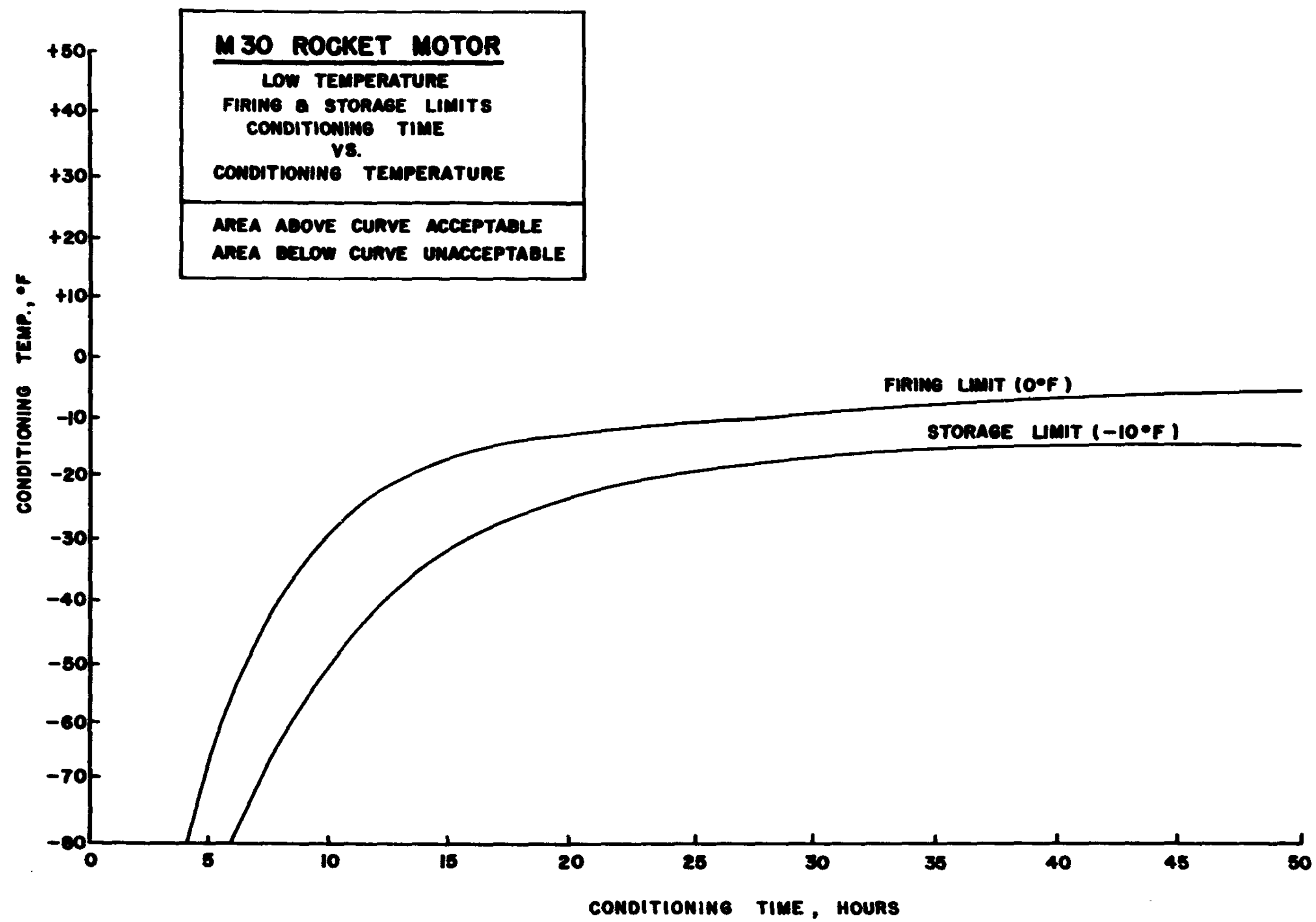


Figure 27. M30 Rocket Motor

REFERENCES

1. "Unit Finds Hidden Pipe Defects," Steel Magazine Sept 1 1958.

2. Vreeland, Wood and Clark, A Study of the Mechanism of the Delayed Yield Phenomenon (Transactions of the ASM, Vol. 45, 1953).

3. Wood and Clark, Delayed Yield in Annealed Steels of Very Low Carbon Content (Transactions of the ASM, Vol. 44, 1952).

4. Methods for Hydrostatic Testing of Compressed Gas Cylinders. Compressed Gas Association, Pamphlet C-1, 1949.

5. Gladkovskii, "Effect of Hydrostatic Pressure upon the Hardness of Carbon Steel," Fizida Metalov I Metallovednie, Vol. 3, 1956.

6. Durelli, Dally and Morse, "Experimental Study of Large-Diameter Thin-Wall Pressure Vessel," Experimental Mechanics, Vol. 1, No. 2, Feb 1961.

7. Bowers, Quirk, Harp and Duckworth, Investigation of Erosion-Resistant Materials for Boosted Fired Solid Propellant Rocket Nozzles (Battelle Memorial Institute, August 1957).

8. Final Report: R&D of Large Solid Propellant Rocket Motor (Martin Co. Contract A-2800, Thiokol, Redstone).

9. Mannheimer and Shibley, Oxygen-Alcohol Test for Insulating Material - A memorandum on a screening test for rocket motor blast tubes (Plastec Report No. 2, OTS PB 161948, Picatinny Arsenal).

10. Kadanoff, Radiative Transport Within an Ablating Body - (To be published in ASME Transactions, Journal of Heat Transfer), June 1961, a pre-print.

APPENDICES

APPENDIX A

CALCULATIONS FOR HYDROSTATIC TEST PRESSURE

APPENDIX A

Calculations for Hydrostatic Test Pressure

The following motor characteristics (nominal) were used for calculations:

Average internal pressure (at 140°F initial temperature)	516 psi
Maximum expected instantaneous pressure (at 140°F)	700 psi
Hydrostatic Test Pressure	900 psi
Blast tube yield strength (minimum)	60, 000 psi
Blast tube yield strength (maximum)	140, 000 psi
Case assembly yield strength (minimum)	145, 000 psi
Case assembly yield strength (maximum)	170, 000 psi
Blast tube diameter	8.75 in
Blast tube wall thickness (minimum)	0.103 in
Motor case diameter	28.00 in
Motor case wall thickness (minimum)	0.100 in

Ratio of test pressure to average internal pressure during firing

$= \frac{900 \text{ psi}}{516 \text{ psi}} = 1.74$

Ratio of test pressure to maximum expected instantaneous pressure

$= \frac{900 \text{ psi}}{700 \text{ psi}} = 1.29$

Internal pressure required to stress the blast tube to its minimum yield strength $= \frac{2St}{D} = \frac{2x\ 60,000 \times .103}{8.75} = 1410$ psi.

Internal pressure required to stress the motor case to its minimum yield strength $= \frac{2St}{D} = \frac{2 \times 145,000 \times .100}{28.00} = 1035$ psi.

Minimum permissible efficiency for the motor case longitudinal weld

$= \frac{900 \text{ psi}}{1035 \text{ psi}} = 87\%$

(1) The above calculations are based upon the condition of simultaneous minimum wall thickness and minimum yield strength. The approximate formula $S_y = \left(\frac{PD}{2tn}\right)$ was used, in which:

S_y = yield strength

P = pressure

D = diameter

t = wall thickness

n = weld efficiency

(2) Since the metal temperature is limited to a maximum of 300°F during and following firing, no reduction in yield strength is considered to take place due to temperature.

APPENDIX B

MOLDING CONDITIONS FOR FABRICATION

OF

TEST SPECIMENS

APPENDIX B

Molding Conditions for Fabrication of Test Specimens

ROCKETON

Haveg phenolic resin, asbestos filler, resin content 43% ± 2%.

Molding compound applied to mandrel by low-pressure spinning technique.

Cured on mandrel in autoclave, varying time-temperature cycle.

Machined to final OD. Process proprietary.

41-RPD

Phenolic resin, asbestos filler (Pyrotex felt, chrysotile fiber base, 99% minimum asbestos).

Resin content:

High-resin sample: 40-45%

Low-resin sample: 25-30%

Resin-impregnated Pyrotex felts wrapped on mandrel tube winding machine under tension, pressure indeterminate:

Cure (no pressure):	4 hr. at 300°F
Post cure (off mandrel):	8 hr. at 350°F
	24 hr. at 400°F

Machined to final OD.

110-RPD

Phenolic-asbestos molding compound

Resin content: 42%

Mold temperature: 325°F

Mold pressure: 3, 000 psi

Molding time: 60 minutes

Post cure: 4 hr. at 300°F

8 hr. at 350°F

150-RPD

Phenolic-asbestos molding compound

Resin content: 38-42%

Asbestos-chrysotile fiber: minimum 99% asbestos

Mold pressure: 4,000 psi

Mold cycle: 2 hr. at 300°F, cool to 250°F under pressure, remove press; no post-cure.

190-RPD

Phenolic-asbestos molding compound

Resin content: 35-36%

Mold pressure: 3,000 psi

Cure: 2 hr. at 300°F

Post cure: 8 hr. at 300°F

8 hr. at 350°F

PHENOLIC-ASBESTOS CLOTH

Bakelite phenolic varnish

No. 1611 asbestos cloth

Resin content: 35%

Resin-impregnated cloth wrapped on mandrel under tension and pressure.

Curing cycle: 6 hr. at 320°F

Machined to final OD.

MELAMINE-ASBESTOS CLOTH

American Cyanamid melamine resin

No. 1611 asbestos cloth

Resin content: 35%

Resin-impregnated cloth wrapped on mandrel, molded at 1800 psi for one hour at 320°F.

DUREZ 16771

Phenolic chopped glass fiber molding compound

Phenolic resin: one step

Resin content: 35%

Molding pressure:

Cure: 30 min. at 310°F

Post cure: 16 hr. at 350°F

APPENDIX C

DESIGN PARAMETERS

FOR

SIMULATED ROCKET MOTOR BLAST-TUBE TESTS

APPENDIX C

Design Parameters for Simulated Rocket Motor Blast-Tube Tests

Fuel system: 2 to 1 (by volume) water-isopropyl alcohol solution, liquid oxygen as oxidizer.

Chamber temperature: 3,500°F

Chamber pressure rate: 500 psi

Propellant flow rate: total 0.90 lb/sec

Oxygen flow rate: 0.40 lb/sec

Fuel flow rate: 0.50 lb/sec

Oxidizer/fuel ratio by weight: 0.80

Average molecular weight chamber gases: 23.46

Ratio of specific heats: 1.18

Characteristic velocity: 4,480 ft/sec

Throat area: 0.250 sq in.

Diameter throat: 0.564 in.

Sample length: 12.000 ± 0.030 in.

Sample OD: 1.765 ± 0.005 in.

Sample ID: 1.000 ± 0.010 in.

Casing OD: 1.895 ± 0.020 in.

Casing ID: 1.780 ± 0.010 in.

APPENDIX D

ROCKET MOTOR

PROPULSION DATA AND SAMPLE DATA

APPENDIX D

Rocket Motor Propulsion Data and Sample Data

Sample	L	ODs	IDs	ODc	IDc	Pc	Wp	O/F	td	teq	Tch
Rocketon 1	11.920	1.765	1.005	1.885	1.788	510 ± 10	0.867	1.08	40.3	39	3200
Rocketon 2	11.980	1.765	1.003	1.885	1.781	510 ± 5	0.789	0.70	40	38	3620
41-RPD (HR)	12.002	1.769	1.005	1.883	1.788	520 ± 5	0.851	0.82	40	38	3480
41-RPD (LR)	12.008	1.770	1.000	1.883	1.783	505 ± 5	0.853	0.70	38	36	3620
150-RPD	11.953	1.765	1.012	1.883	1.788	510 ± 5	0.792	0.756	40.0	39	3550
190-RPD	11.960	1.758	1.002	1.883	1.785	520 ± 5	0.747	0.82	41	39	3480

Explanation of column heads:

L - Length of sample, in.

ODs - Outside-diameter sample, in.

IDs - Inside-diameter sample, in.

ODc - Outside-diameter casing, in.

IDc - Inside-diameter casing, in.

Pc - Chamber pressure, psi

Wp - Total propellant flow rate, lb/sec

O/F - Oxidizer/fuel ration, by weight

td - Duration time, sec

teq - Equilibrium time, sec

Tch - Theoretical stagnation chamber temperature, °F, corrected for Pc and O/F

APPENDIX E

DETERMINATION OF FLOW RATE AND NOZZLE THROAT DIAMETER FOR SIMULATED BLAST TUBE

APPENDIX E

Determination of Flow Rate and Nozzle Throat Diameter for Simulated Blast Tube

In the M30 Motor, approximately 2,100 lb of propellant burns in 30 sec., resulting in an average flow rate of 70 lb/sec. The inside diameter of the blast tube insulation is 7.615 in. Thus, the gas flow is 1.54 lb/sec/in.^{2} of cross sectional area. To simulate this flow with the 1 in. I. D. insulation test samples, a flow rate of 1.21 lb/sec. would be required. Upon advise that propellant burning times substantially over 30 sec. were being recorded, the test firing time was adjusted to 40 sec. and the test motor flow rate to 0.9 lb/sec.

To determine the nozzle throat diameter, the characteristic velocity was calculated to be 4,480 ft/sec. from the equation

$$c^* = \frac{\sqrt{gkRT}}{k\sqrt{\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}} = \frac{\sqrt{32.2\ (1.18)\left(\frac{1544}{23.46}\right)(3500 + 460)}}{1.18\sqrt{\left(\frac{2}{1.18+1}\right)^{\frac{1.18+1}{1.18-1}}}}$$

$c^* = 4,480$ ft/sec.

And the throat area was calculated to be 0.25 in.^{2} from the equation

$$c^* = \frac{PA_tg}{W}, \qquad A_t = \frac{c^*W}{Pg} = \frac{4480\ (0.9)}{500\ (32.2)}$$

$A_t = .250$ in.^{2}

where c^* characteristic exhaust velocity, ft/sec.

$g = 32.2$ ft/sec.^{2}

k=specific heat ratio

R = gas constant, $\frac{1544}{M}$

M = molecular weight

T = temperature, °R.

P = chamber pressure, psi

A_t = nozzle throat area, in.^{2}

W = flow rate, lb/sec.

An undersized nozzle (0.497 in. diam.) was used in a checkout run to verify the calculations. Data were recorded, and the nozzle diameter calculation adjusted using the equation

$$D_2 = D_1 \left(\frac{T_2}{T_1}\right)^{1/4} \left(\frac{M_1}{M_2}\right)^{1/4} \left(\frac{P_1}{P_2}\right)^{1/2} \left(\frac{W_2}{W_1}\right)^{1/2}$$

$$= 0.497 \left(\frac{3960}{3780}\right)^{1/4} \left(\frac{24.28}{23.43}\right)^{1/4} \left(\frac{520}{500}\right)^{1/2} \left(\frac{0.900}{0.771}\right)^{1/2}$$

D_2 = .559 in.

D_2 was determined as 0.559 in., and the test nozzle was machined to this diameter.

APPENDIX F

INSULATION TEMPERATURE DATA

APPENDIX F

Insulation Temperature Data

Subsequent to preliminary firings for calibrating the test equipment and instrumentation and establishing proper propellant flow conditions, the following firing tests were conducted with the insulating materials listed below:

a. Haveg, Rocketon, Sample No. 1 (S/N 27675)

b. Haveg, Rocketon, Sample No. 2 (S/N 27676)

c. Raybestos-Manhattan, 41-RPD (high resin content)

d. Raybestos-Manhattan, 41-RPD (low resin content)

e. Raybestos-Manhattan, 110-RPD

f. Raybestos-Manhattan, 150-RPD

g. Raybestos-Manhattan, 190-RPD

h. Durez, 16771, Sample No. 1

i. Durez, 16771, Sample No. 2

j. Synthane, Asbestos Cloth-Phenolic, Sample No. 1

k. Synthane, Asbestos Cloth-Phenolic, Sample No. 2

l. Synthane, Asbestos Cloth-Melamine, Sample No. 1

m. Synthane, Asbestos Cloth-Melamine, Sample No. 2

FIRING TEST DATA FOR HAVEG, ROCKETON, SAMPLE No. 1 (S/N 27675)

Temperature Rise

Time	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	5		4	3	3	3
		Failed				
20	6		6	6	6	6
30	11		39	11	12	11
40	19	to	41	16	14	18
60	56		68	72	90	43
80	101	operate	98	126	140	66
100	134		122	141	171	102
120	161		137	176	193	124
140	178		143	184	203	141
160	190		149	189		149
180	193					159

FIRING TEST DATA FOR HAVEG, ROCKETON, SAMPLE No. 2 (S/N 27676)

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	3	3	17	3	3	3
20	6	6	17	5	6	5
30	17	12	20	8	9	9
40	31	42	22	15	18	15
60	97	61	35	41	36	30
80	143	102	53	67	70	53
100	162	133	84	112	104	72
120	185	167	94	143	133	88
140	194	188	109	162	158	108
160	198	196	109	178	180	118
180	204	205		185	198	127
200	226	265		195	213	133
210				198	220	135

FIRING TEST DATA FOR RAYBESTOS-MANHATTAN, 41-RPD (HR)

Temperature Rise

Time	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
20	3	3	2	2	2	2
30	23	11	8	6	5	4
40	49	40	19	22	9	14
60	failed	171	89	103	45	50
80		241	140	182	94	98
100		311	151	238	125	141
120		340	178	281	160	170
140		351	227	309	191	193
160		354	242	320	213	204
180		363	240	320	223	209
200		361			234	214

FIRING TEST DATA FOR RAYBESTOS-MANHATTAN, 41-RPD (LR)

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	3	3	3			
20	9	9	6	3	5	5
30	21	18	10	13	10	9
40	35	43	24	25	25	20
60	97	97	59	69	75	48
80	153	142	107	126	130	85
100	194	168	138	160	162	148
120	205	192	163	177	180	148
140	220	200	169	192	198	
160	228	210	175	202	212	
180	228	210	180	207	217	

FIRING TEST DATA FOR RAYBESTOS-MANHATTAN, 110-RPD

Temperature Rise

Time	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	2	4	4	2	2	Failed to Operate
20	84	57	38	16	17	
30	169	69	109	110	131	
40	Failed Burn-out	282	Failed Burn-out	163	262	
60		295		182	347	
80		375		311	387	
100		409		335	405	
120		429		343	411	
140				343		
160						
180						

FIRING TEST DATA FOR RAYBESTOS-MANHATTAN, 150-RPD

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	*	Failed	Failed	11	25	28
20	144	to	to	48	85	69
30	168	Operate	Operate	106	160	115
40	191			149	217	160
60	332			246	277	224
80	390			322	399	285
100	430			388	457	321
120	437			431	484	337
140	443			434	508	348
160	449			487	525	354
180	461			487	529	354

* Reading was erratic

FIRING TEST DATA FOR RAYBESTOS-MANHATTAN, 190-RPD

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	6	9	9			
20	27	38	22		6	5
30	78	97	42	10	25	9
40	160	173	76	44	63	25
60	340	228	189	152	167	92
80	360	280	291	204	244	145
100	372	329	338	262	313	185
120	397	372	375	323	351	220
140	405	419	400	362	378	245
160	405	438	420	385	395	253
180		438	420	385	399	261

FIRING TEST DATA FOR DUREZ, 16771, SAMPLE No. 1

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10						
20	3	3	6	8	7	5
30	9	9	10	13	48	56
40	19	30	28	17	135	173
60	86	157	47	69	336	266
80	147	303	70	122	387	erratic
100	183	383	119	183	390	310
120	226	413	140	206	382	310
140	242	420	158	225		
160	240	413	172	230		

FIRING TEST DATA FOR DUREZ, 16771, SAMPLE No. 2

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	12	9	10	-	-	-
20	18	14	15	3	6	5
30	19	20	20	5	12	9
40	78	56	28	39	43	20
60	248	242	72	224	208	95
80	277	297	127	324	290	125
100	309	328	164	365	326	153
120	338	360	204	385	354	170
140	355	402	235	395	385	190
160	373	450	262	395	408	193
180	398	494	288	402	452	200
200	390	528	298	409	462	206
210	-	562	306	409	509	213

FIRING TEST DATA FOR SYNTHANE, ASBESTOS CLOTH-PHENOLIC, SAMPLE No. 1

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	2	4	2	-		-
20	5	7	5	7	5	5
30	20	27	16	14	12	11
40	108	Failed	Failed	36	29	20
60	173	Burn-out	Burn-out	86	79	43
80	207			126	132	78
100	211			147	176	112
120	199			147	179	136
140				152	172	154
160						165
180						177
200						182

FIRING TEST DATA FOR SYNTHANE, ASBESTOS CLOTH-PHENOLIC, SAMPLE No. 2

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	3	3	3	3	3	2
20	20	31	18	8	8	5
30	81	115	50	25	26	16
40	288	284	168	118	111	70
60	434	330	230	188	180	107
80	431	344	268	230	232	153
100		345	288	251	267	186
120		345	295	264	294	210
140			297	266	309	223
160			300	266	317	234
180			300		320	238

FIRING TEST DATA FOR SYNTHANE, ASBESTOS CLOTH-MELAMINE, SAMPLE No. 1

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	6	6	13	3	5	9
20	23	28	38	8	12	21
40	Failed Burn-out	216	153	32	49	54
60		268	186	72	92	87
80		238	186	105	129	110
100			189	110	145	130
120			199	133	158	142
140			212	141	167	148
160			212	145	170	150
180				148	170	150

FIRING TEST DATA FOR SYNTHANE, ASBESTOS CLOTH-MELAMINE, SAMPLE No. 2

Temperature Rise

TIME	TC No. 1	TC No. 2	TC No. 3	TC No. 4	TC No. 5	TC No. 6
Sec	°F	°F	°F	°F	°F	°F
10	3	3		3	3	3
20	22	45	15	10	14	9
30	45	165	37	21	25	13
40	285	397	125	97	130	60
60	363	443	151	164	190	76
80	363	415	173	206	230	107
100	311	390	178	233	256	120
120			178	250	269	133
140				250	274	140
160					274	140

APPENDIX G

EXPERIMENTAL PROCEDURE

FOR THE

DETERMINATION OF A SUITABLE LINER SOLVENT

APPENDIX G

Experimental Procedure for the Determination of a Suitable Liner Solvent

The rubber formulation prepared (as directed in Military Specification RDL-PD-107B) consisted of:

Thiokol polysulfied LP-3A	73.30%
quinone dioxine	4.90%
diphenyl guanidine	0.49%
magnesium oxide	3.05%
sulfur	0.15%
carbon black	18.11%

The ingredients were thoroughly mixed with mortar and pestle and a portion applied to 2" x 2" steel (4130) coupons, and cured at 75° C for 48 hours. After curing, the thickness of the rubber liner was approximately 1/8". The samples were then placed in a mason jar, covered with the solvent, allowed to stand at room temperature, and examined at the end of various time intervals.

APPENDIX H

CORROSION STUDY TEST PROCEDURE

APPENDIX H

Corrosion Study Test Procedure

Panels were cut from 4130 sheet steel and coated with the corrosion inhibitors listed below. Each coating was brushed on cold as a single coat and air dried at room temperature. The panels then were divided into two groups--one group being subjected to temperature-humidity testing and the other to salt spray testing. Uncoated panels were used as test controls.

Salt spray tests were conducted for 100 hours using a 20% salt solution. Temperature-humidity testing was performed for 104 hours on the following cycle:

16 hours at 160°F and 95% RH
8 hours at -40°F
16 hours at 160°F and 95% RH
8 hours at -40°F
16 hours at 160°F and 95% RH
8 hours at -40°F
32 hours at 160°F and 95% RH

Following is a tabulation of the results of these tests:

Corrosion Panel Test (First Series)

Coating	Temperature-Humidity Cycling	20% Salt Spray
Sicon Aluminum 7x2070	Slight rust in spots. No pitting.	Some rust and discoloration. No pitting.
Sicon Aluminum 3x245	Slight rust and discoloration. No pitting.	Some rust and pitting.
Drygalv	Some rust and discoloration. Slight pitting on some samples.	Some rust and pitting.
Zincilate	Slight rust in spots. No pitting.	Some rust and discoloration. Slight pitting.
Nox-Rust 920	No rust, discoloration, or pitting.	Heavy rust Some pitting.
APG Composition	Some rust and discoloration. No pitting.	Heavy rust Some pitting.
Uncoated	Heavy rust and pitting.	Heavy rust and pitting.

The test panels were cleaned and recoated as before, and an additional series of temperature-humidity and salt spray tests was conducted under closer control. Temperature-humidity tests were run in accordance with Federal Test Method Standard Number 141, Method 6201; temperature was maintained at 120°F, and relative humidity at a minimum of 95%. After 100 hours of testing, none of the coatings showed any significant deterioration. Therefore, testing was continued for an additional 70 hours, at which time moderate discoloration of some of the samples was noted, but this was not sufficient to disqualify any of the coatings. Salt spray tests were conducted in accordance with Federal Test Method Standard Number 141, Method 6061, using 5% salt solution, for 72 hours. This test caused some deterioration of all of the coatings and severe corrosion of several.

Following is a tabulation of the results of these tests:

Corrosion Panel Test (Second Series)

Coating	Temperature-Humidity	5% Salt Spray
Sicon Aluminum 7x2070	Slight discoloration. No rust or pitting.	Discoloration. Rust on some samples. No pitting.
Sicon Aluminum 3x245	Slight discoloration. No rust or pitting.	Discoloration. Slight rust on some samples. No pitting.
Drygalv	No discoloration, rust, or pitting.	Rust. No pitting.
Zincilate	Slight rust on some samples. No pitting.	Rust. No pitting.
Nox-Rust 920	Slight rust on some samples. No pitting.	Rust. No pitting.
APG Composition	Some discoloration. Slight rust on some samples. No pitting.	Rust and pitting.
Uncoated	Rust and pitting.	Heavy rust and pitting.

The results of tests in which the painted surface of the blast tube was scratched, and various positions of the scratched area coated with different types of corrosion inhibitors and then subjected to 160°F and 95% RH, confirmed the results of the tests run on the test panels.

APPENDIX I

TEMPERATURE GRADIENT TEST PROCEDURE

APPENDIX I

Temperature Gradient Test Procedure

The propellant for the M30 Rocket Motor, loaded by Longhorn Ordnance Works, was cast with nine iron-constantan thermocouples imbedded in the cylindrical section of the grain (Figure 28). The thermocouple lead wires, each 20 feet long, were brought out through the nozzle. The nozzle opening then was insulated with fiberglass and sealed with tape.

The outputs from the nine thermocouples imbedded in the grain, and on one thermocouple sensing air temperature within the wooden packing crate and on one thermocouple sensing the storage temperature--were fed directly to a Multiple Station Weston Recorder and recorded on Stations 1 through 9, respectively. Air temperature within the wooden packing crate was recorded on Station 10, and the conditioning box temperature on Station 11.

The recorder was adjusted for a chart speed of0.4 inches per minute and a print rate of one station per minute.

The Weston Multiple Station, Model 6702, Recorder is a potentiometer type instrument. The basic function of the potentiometer circuit is to balance the potential drop over a known part of a slidewire against the voltage being measured. The unbalanced voltage is amplified and converted by means of a reed-type vibrator to a small alternating potential. This potential is again amplified to provide sufficient energy to operate a two-phase, reversible-type balancing motor which restores equilibrium to the measuring circuit. A reading at equilibrium is recorded on a strip chart directly in degrees fahrenheit.

The motor was pre-conditioned for approximately 168 hours at 40°F before subjecting it to the first extreme temperature storage condition.

Then, the motor was subjected to each of the six conditioning temperatures shown below. In each case, the storage temperature was 10°F colder than the required final grain temperature. A tolerance of ±5°F was maintained on each temperature change.

CONDITIONING TEMPERATURES

+40° to 0°F

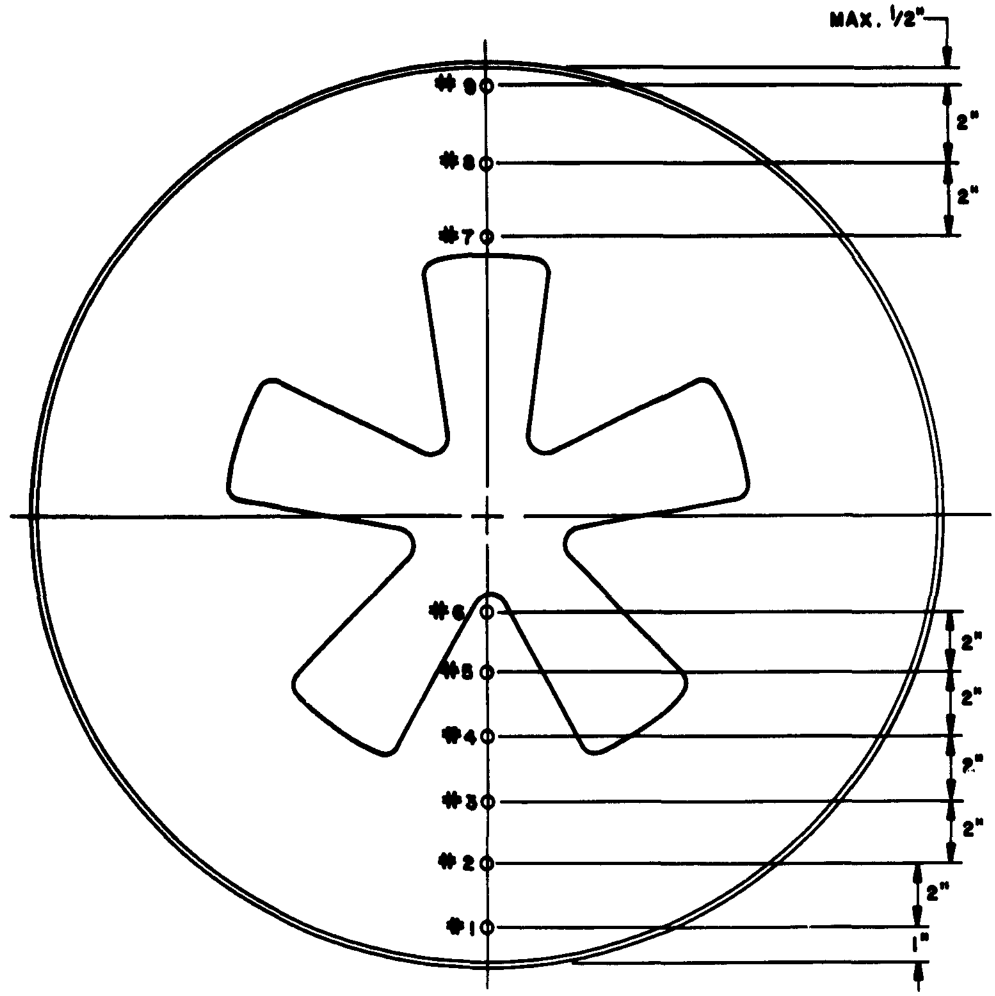
+40° to -15°F

+40° to -30°F

+40° to -45°F

+40° to -60°F

+40° to -75°F



THEMOCOUPLE POSITIONS
FOR TEMPERATURE - GRADIENT TESTS

Figure 28.

PROPELLANT GRAIN TEMPERATURE
VS.
CONDITIONING TIME
CONDITIONING TEMPERATURE 0°F

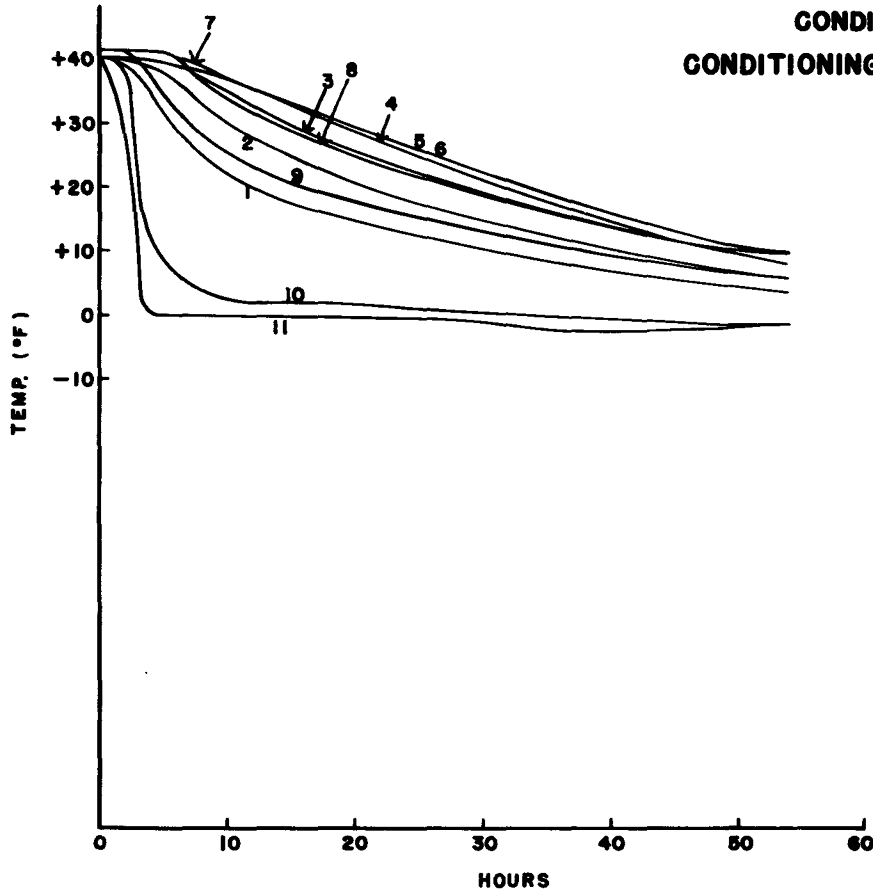


Figure 29.

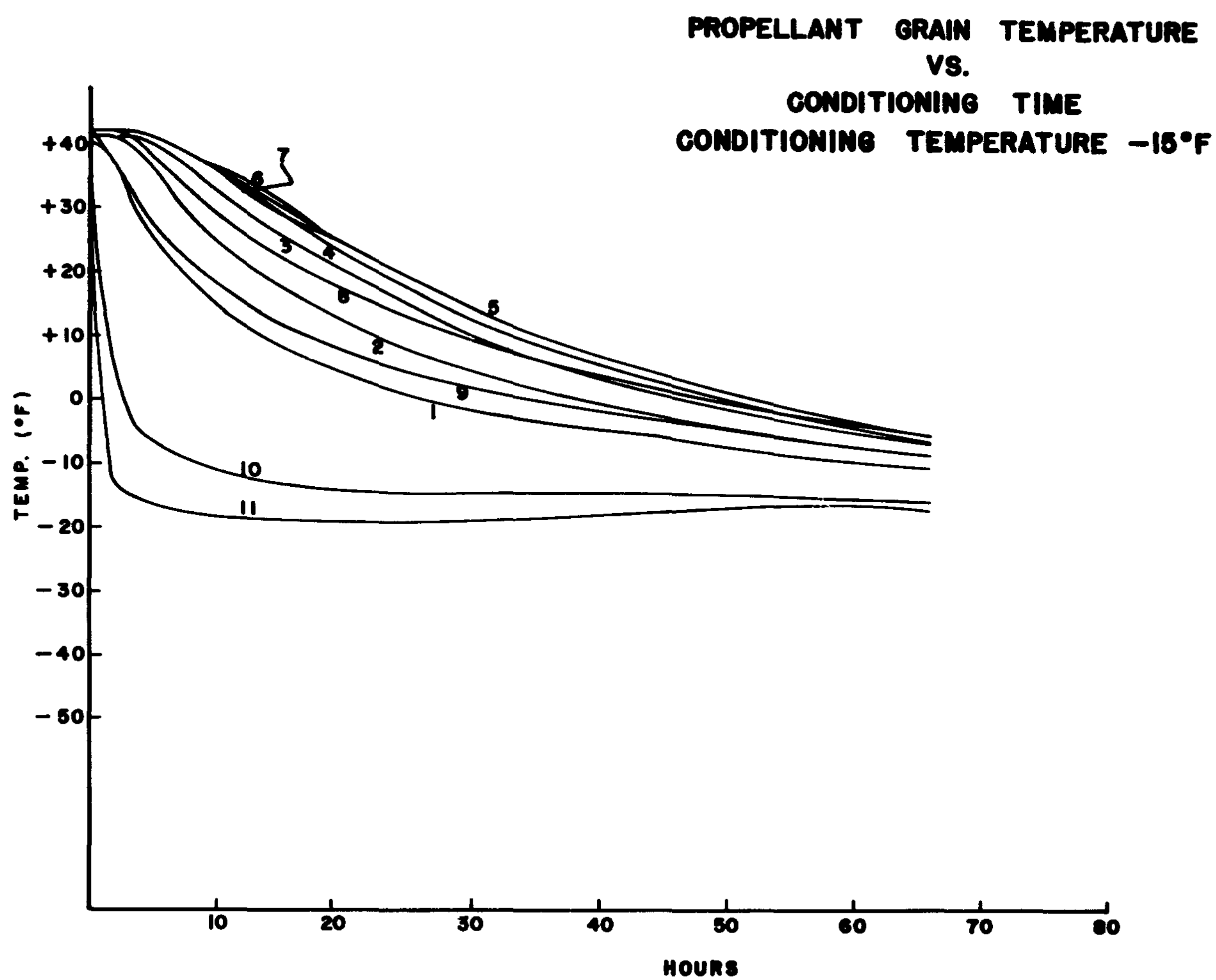

PROPELLANT GRAIN TEMPERATURE
VS.
CONDITIONING TIME
CONDITIONING TEMPERATURE —15°F
TEMP. (°F)
+40
+30
+20
+10
0
−10
−20
−30
−40
−50
10
20
30
40
50
60
70
80
HOURS
1
2
3
4
5
6
7
8
9
10
11

Figure 30.

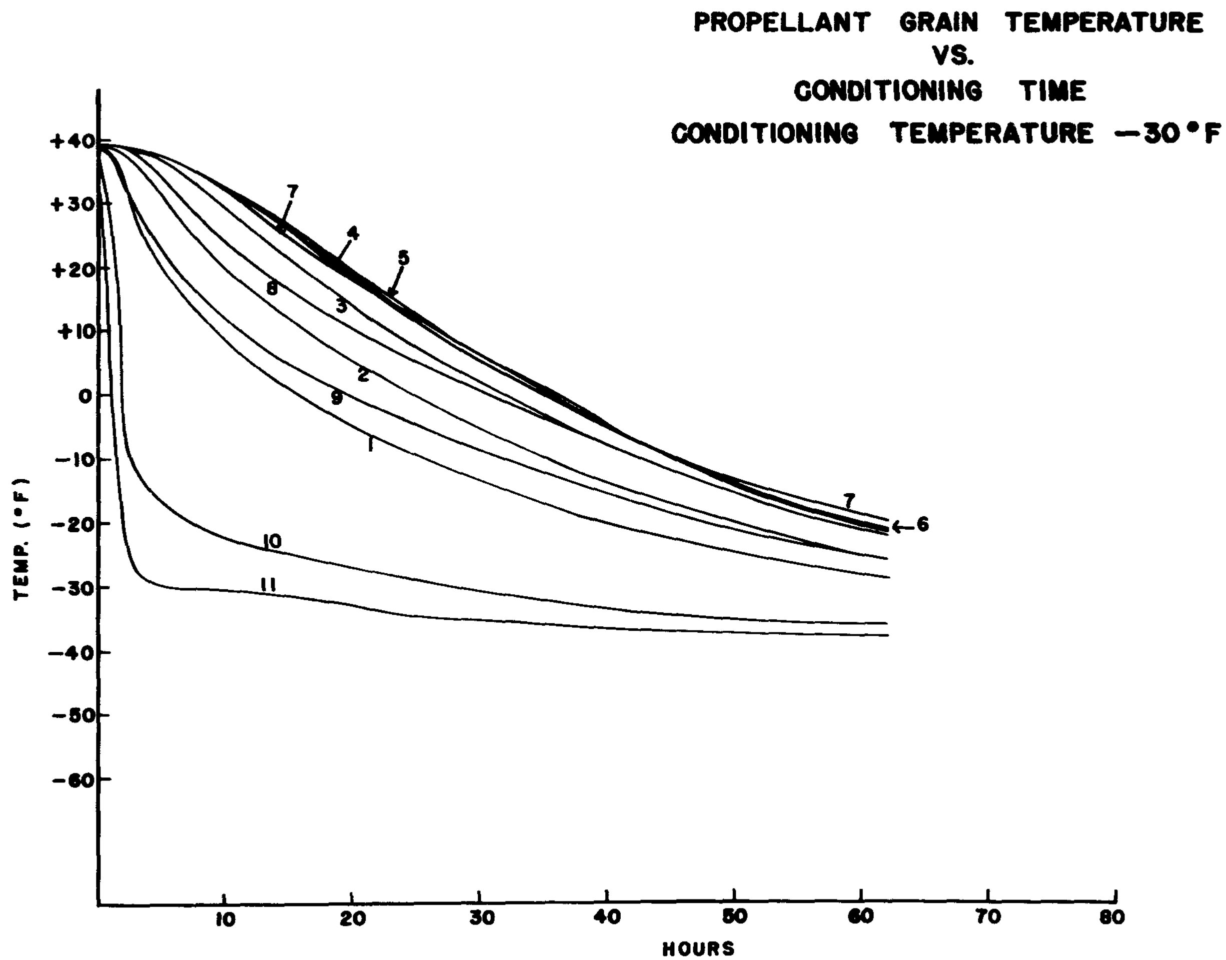

PROPELLANT GRAIN TEMPERATURE
VS.
CONDITIONING TIME
CONDITIONING TEMPERATURE —30°F
TEMP. (°F)
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
HOURS
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
10
11

Figure 31.

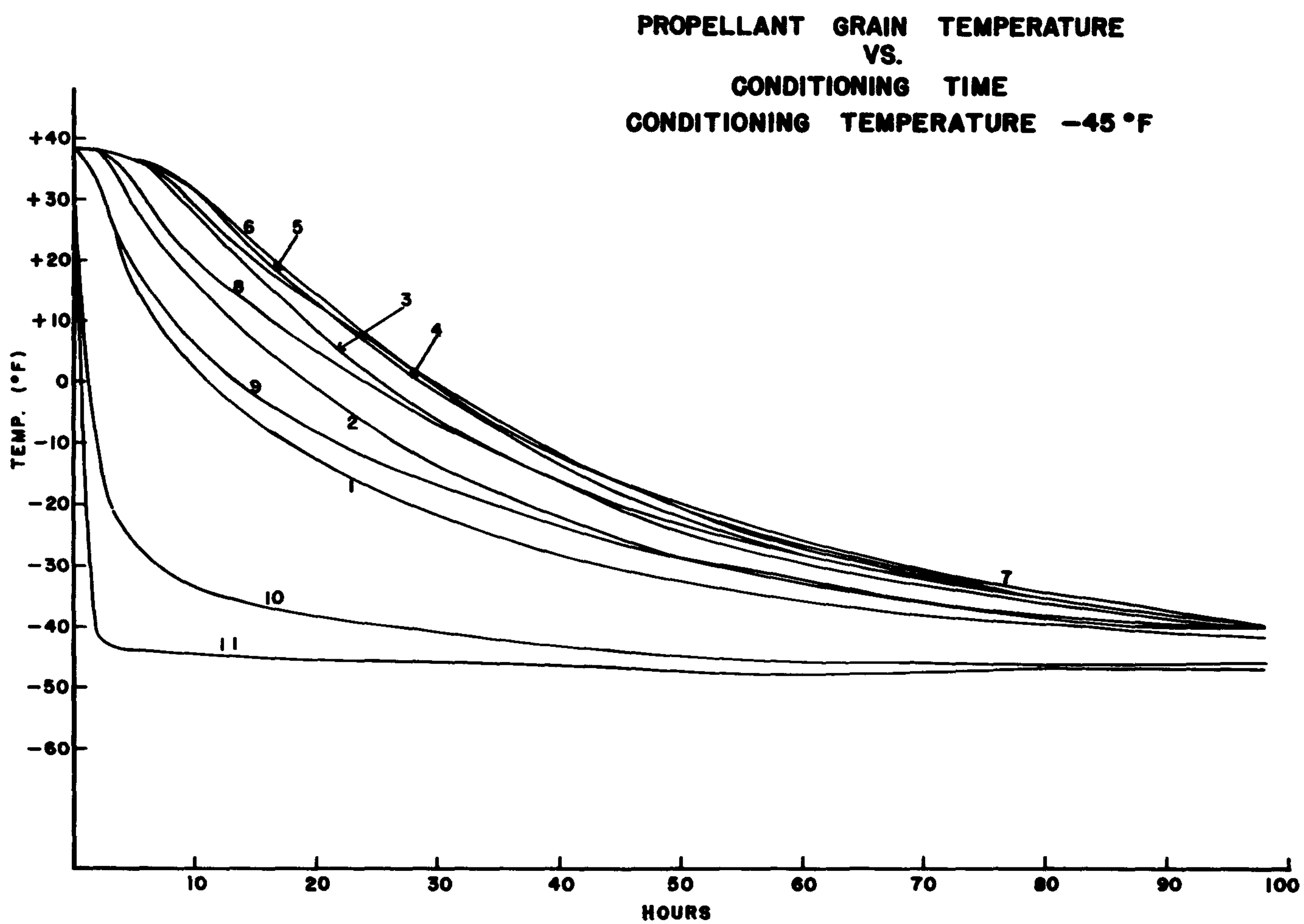
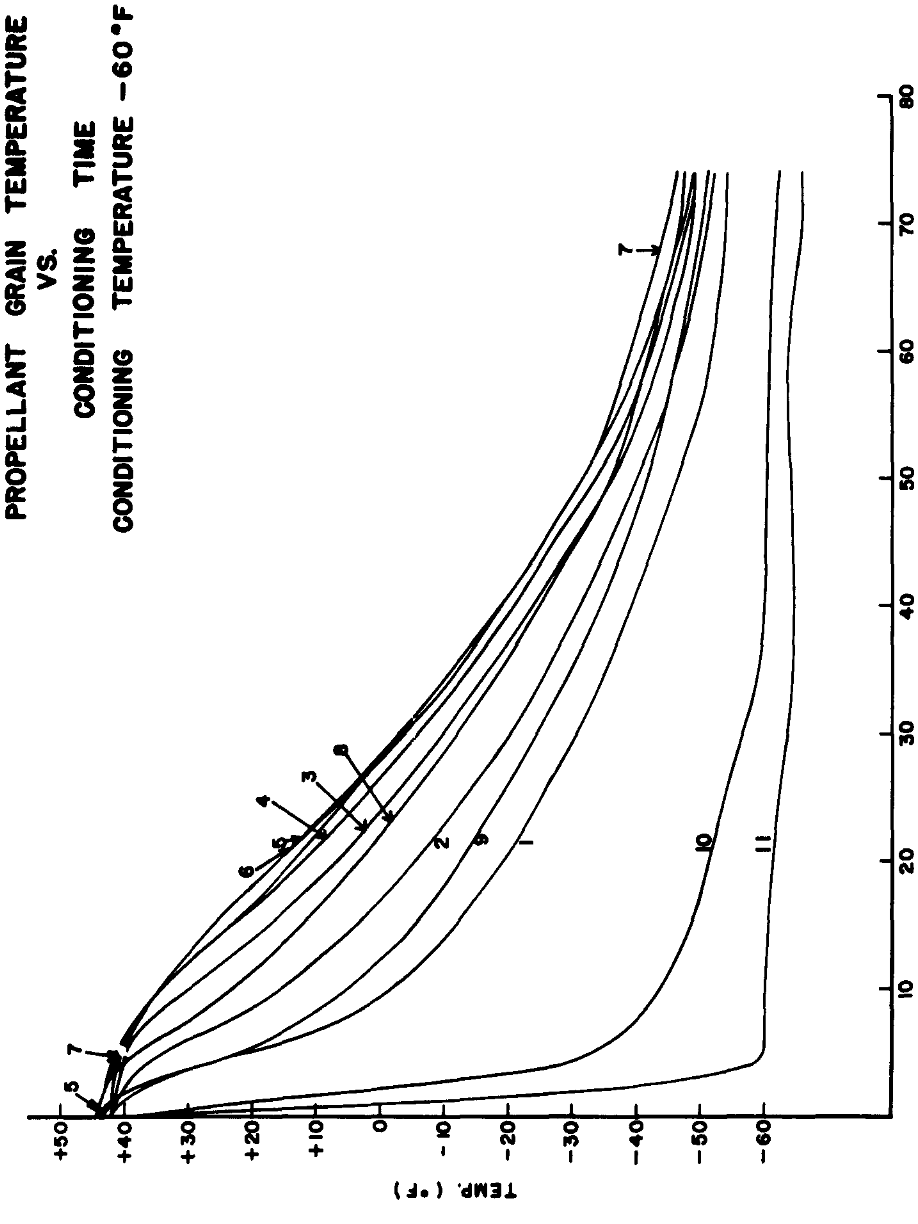

PROPELLANT GRAIN TEMPERATURE
VS.
CONDITIONING TIME
CONDITIONING TEMPERATURE −45 °F
TEMP. (°F)
+40
+30
+20
+10
0
−10
−20
−30
−40
−50
−60
HOURS
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11

Figure 32.



PROPELLANT GRAIN TEMPERATURE
VS.
CONDITIONING TIME
CONDITIONING TEMPERATURE -60°F
TEMP. (°F)
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
HOURS
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
10
11

Figure 33.

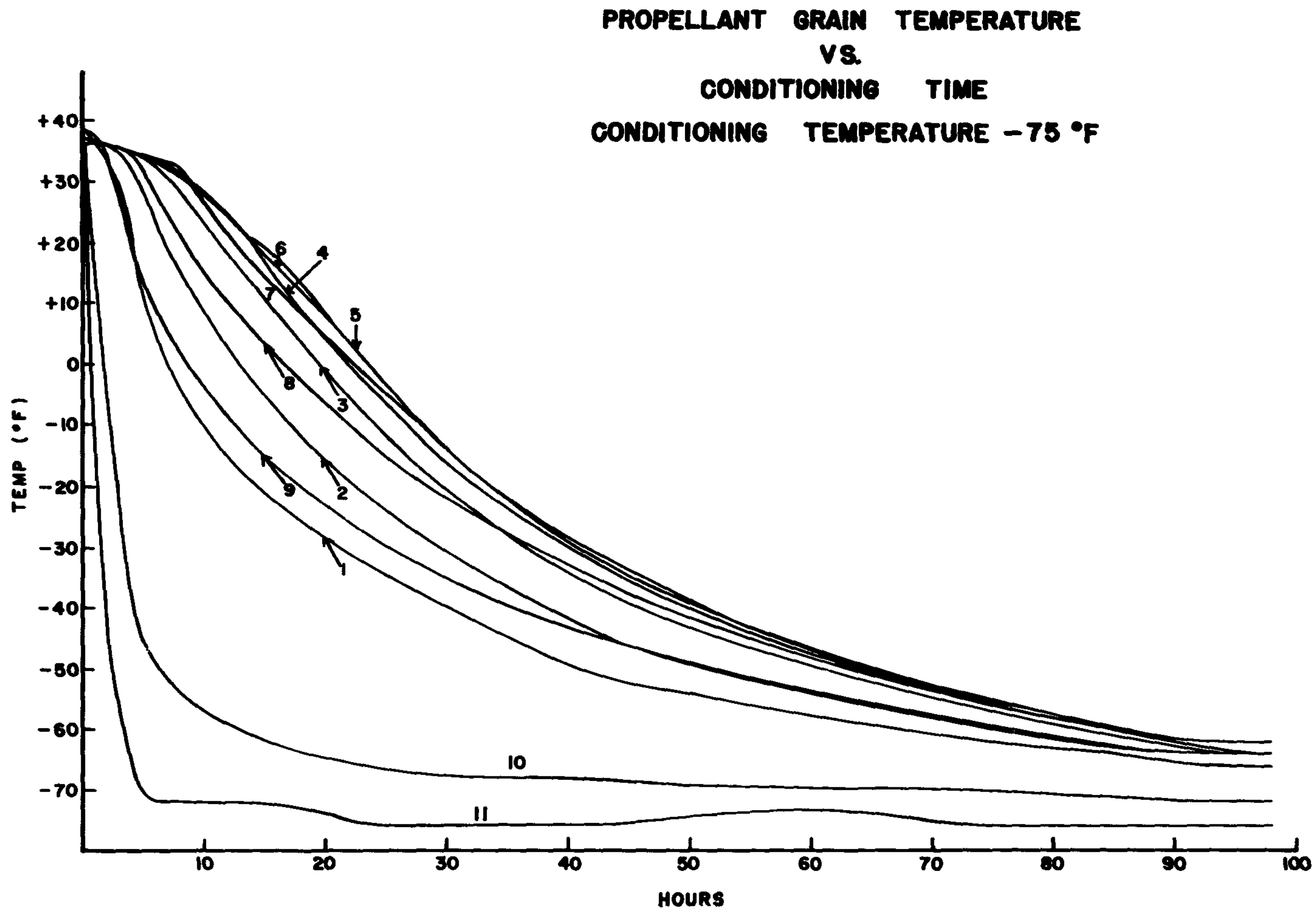

PROPELLANT GRAIN TEMPERATURE
VS.
CONDITIONING TIME
CONDITIONING TEMPERATURE -75 °F
TEMP (°F)
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
10
20
30
40
50
60
70
80
90
100
HOURS
1
2
3
4
5
6
7
8
9
10
11

Figure 34.

APPENDIX J

TEMPERATURE GRADIENT TEST DATA

TABLE I

Temperature Gradient Test Data

Time, hrs.	Temperature Conditioning °F.	Thermocouple Designation:	Thermocouple Temperature, Degrees Fahrenheit 1	2	3	4	5	6	7	8	9	10
0	40		40	40	40	40	40	40	41	41	41	40
			Conditioning temperature changed to 0° ± 5°F									
2	28		39	39	40	40	40	40	41	41	41	37
4	0		35	39	39	40	40	40	41	41	37	11
6	0		29	37	39	39	39	39	40	40	32	7
8	0		26	33	37	38	38	38	39	36	28	4
10	0		22	30	35	37	37	37	37	34	25	3
12	0		20	28	34	35	36	36	36	32	23	3
14	-1		18	26	32	33	34	34	34	30	22	2
16	0		17	24	29	32	32	32	32	28	20	2
18	0		16	22	28	30	31	31	31	26	19	2
20	-1		15	21	26	29	30	30	30	25	18	1
22	0		14	19	24	27	28	28	28	23	17	1
24	0		13	18	23	25	26	26	26	22	16	1
26	0		12	17	22	24	25	25	25	21	15	1
28	1		11	16	21	23	24	24	24	20	14	2
30	0		11	15	19	21	22	22	22	19	14	0
32	-2		10	14	18	20	21	21	21	18	12	0
34	-2		9	13	17	18	19	19	19	16	11	0
36	-2		8	12	16	17	18	18	18	16	11	0
38	-1		8	12	15	16	17	17	17	15	10	0
40	-2		7	11	14	15	16	16	16	14	9	-1
42	-2		6	10	12	13	15	15	15	13	8	-0
44	-3		6	9	12	12	14	14	14	12	8	-2
46	-2		5	8	11	12	13	13	13	12	8	-2
48	-2		5	8	10	11	12	12	12	11	8	-1
50	-2		5	7	10	10	11	11	11	11	7	-2
52	-1		4	7	9	9	10	10	10	10	6	-1
54	-1		4	6	8	10	10	10	10	10	6	-1

TABLE Ia

Time, hrs.	Temperature Conditioning °F.	Thermocouple Designation:	Thermocouple Temperature, Degrees Fahrenheit									
			1	2	3	4	5	6	7	8	9	10
0	38		40	41	41	42	42	42	42	42	42	38
			Temperature changed to -15° ± 5°F									
2	-13		37	41	41	42	42	42	42	42	37	4
4	-15		28	38	41	42	42	42	42	40	30	-5
6	-17		22	33	39	40	40	40	40	36	25	-7
8	-17		18	28	36	38	38	38	38	32	21	-9
10	-18		16	24	33	36	36	36	36	29	17	-11
12	-19		12	22	30	33	34	34	33	26	15	-12
14	-18		9	19	28	31	32	32	31	23	13	-13
16	-19		7	16	24	28	29	29	28	21	11	-13
18	-19		5	14	22	25	26	26	26	19	10	-14
20	-19		4	12	19	23	24	24	24	17	8	-15
22	-19		3	10	17	21	22	22	15	15	6	-16
24	-20		2	8	17	18	19	19	19	13	5	-17
26	-17		0	7	14	16	18	18	18	13	5	-14
28	-20		-1	5	12	14	16	16	16	11	3	-15
30	-19		-2	4	10	12	14	14	14	9	2	-15
32	-18		-3	3	8	11	12	12	12	8	1	-15
34	-18		-3	2	6	9	10	10	10	7	0	-15
36	-19		-3	1	5	8	9	9	9	6	0	-15
38	-18		-4	0	4	7	8	8	8	5	0	-15
40	-18		-5	-1	3	5	6	6	6	4	-1	-15
42	-18		-5	-1	2	4	5	5	5	3	-3	-15
44	-18		-6	-2	1	3	4	4	4	2	-3	-15
46	-17		-7	-3	0	2	3	3	3	1	-4	-15
48	-19		-7	-4	-1	0	1	2	2	0	-4	-16
50	-17		-8	-5	-2	0	0	0	1	0	-5	-16
52	-16		-9	-5	-2	-1	0	0	0	-1	-5	-16
54	-17		-9	-6	-3	-2	-1	-1	-1	-2	-6	-16
56	-16		-9	-7	-4	-3	-2	-2	-2	-3	-7	-16
58	-18		-10	-7	-5	-4	-3	-3	-3	-3	-7	-16
60	-19		-10	-8	-6	-5	-4	-4	-4	-4	-8	-17
62	-16		-10	-8	-6	-5	-4	-4	-4	-4	-8	-16
64	-17		-11	-8	-7	-6	-5	-4	-4	-5	-8	-16
66	-18		-11	-9	-7	-7	-6	-6	-6	-6	-9	-16

TABLE Ib

Time, hrs.	Temperature Conditioning °F.	Thermocouple Designation: 1	2	3	4	5	6	7	8	9	10
		Thermocouple Temperature, Degrees Fahrenheit									
0	38	39	39	39	39	39	39	39	39	39	38
		Temperature changed to -30° ±5°F									
2	-20	34	38	38	39	39	39	39	39	34	0
4	-29	24	34	38	38	38	38	38	36	26	-14
6	-30	17	29	36	37	37	37	37	32	20	-18
8	-30	12	24	33	35	35	35	35	28	16	-20
10	-30	8	20	29	32	31	31	32	24	12	-22
12	-31	5	16	26	30	30	30	28	21	8	-23
14	-31	3	13	23	27	28	28	26	18	6	-23
16	-31	0	10	20	24	25	25	23	15	4	-24
18	-31	-2	8	17	21	22	22	21	13	2	-25
20	-33	-4	5	14	18	19	19	18	11	0	-27
22	-36	-6	3	11	15	16	16	15	8	-2	-29
24	-35	-13	-4	4	9	12	11	11	2	-8	-34
26	-35	-10	-1	7	10	11	11	11	4	-5	-29
28	-35	-12	-3	4	8	9	9	9	3	-7	-30
30	-35	-13	-5	2	5	7	7	7	0	-8	-30
32	-35	-14	-7	0	3	4	4	4	-1	-10	-31
34	-35	-16	-9	-2	1	2	2	2	-3	-11	-32
36	-34	-17	-11	-4	-1	0	0	0	-4	-12	-32
38	-36	-19	-13	-7	-3	-2	-2	-2	-7	-14	-32
40	-36	-20	-14	-9	-6	-5	-5	-5	-8	-16	-33
42	-36	-21	-16	-10	-8	-7	-7	-7	-10	-17	-34
44	-35	-21	-16	-12	-9	-8	-8	-8	-12	-18	-34
46	-36	-22	-18	-13	-11	-10	-10	-10	-13	-18	-34
48	-36	-24	-19	-15	-13	-12	-12	-12	-14	-20	-34
50	-35	-25	-21	-17	-15	-14	-13	-13	-16	-21	-34
52	-36	-25	-21	-18	-16	-15	-15	-15	-17	-22	-36

TABLE Ic

Time hrs.	Temperature Conditioning °F.	Thermocouple Designation:	Thermocouple Temperature, Degrees Fahrenheit									
			1	2	3	4	5	6	7	8	9	10
0	38		38	38	38	38	38	38	38	38	38	38
			Temperature changed to -45° ±5°F									
2	-42		32	38	38	38	38	38	38	38	32	-11
4	-42		20	32	37	37	37	37	37	32	22	-24
6	-44		12	26	35	36	36	36	36	30	15	-30
8	-44		6	20	30	34	34	34	33	24	10	-32
10	-44		2	16	27	31	31	31	29	20	6	-34
12	-45		-2	12	23	27	28	28	26	17	2	-35
14	-44		-5	8	19	23	24	24	22	13	-1	-35
16	-45		-8	4	15	20	21	21	19	10	-4	-36
18	-45		-11	1	12	16	18	18	14	8	-6	-36
20	-46		-13	-2	8	12	14	14	13	4	-8	-38
22	-47		-15	-4	5	10	12	12	12	4	-10	-38
24	-48		-17	-7	3	6	8	8	8	0	-12	-40
26	-46		-19	-10	-1	3	5	5	5	-3	-14	-40
28	-46		-20	-12	-4	0	2	2	2	-5	-16	-40
30	-46		-22	-14	-6	-2	-1	-1	-1	-7	-17	-41
32	-48		-24	-16	-8	-4	-2	-2	-2	-9	-19	-42
34	-49		-25	-17	-10	-7	-6	-6	-6	-11	-20	-42
36	-46		-26	-19	-13	-9	-8	-8	-8	-12	-21	-42
38	-48		-27	-21	-15	-12	-10	-10	-10	-14	-23	-42
40	-46		-28	-22	-16	-14	-12	-12	-12	-16	-24	-42
42	-48		-30	-24	-18	-16	-14	-14	-14	-18	-24	-43
44	-47		-31	-26	-20	-18	-16	-16	-16	-20	-26	-44
46	-47		-32	-26	-22	-19	-18	-18	-18	-21	-27	-44
48	-46		-32	-28	-23	-21	-20	-20	-19	-22	-28	-45

TABLE Ic (CONT'D)

Time, hrs.	Temperature Conditioning °F.	Thermocouple Designation:	1	2	3	4	5	6	7	8	9	10
			Thermocouple Temperature, Degrees Fahrenheit									
50	-48		-33	-29	-24	-22	-21	-21	-20	-24	-29	-45
52	-48		-33	-30	-26	-24	-22	-22	-21	-25	-29	-44
54	-46		-36	-30	-27	-24	-24	-24	-23	-25	-30	-45
56	-48		-35	-31	-28	-26	-25	-25	-24	-26	-31	-44
58	-49		-35	-32	-28	-27	-26	-26	-25	-27	-32	-44
60	-48		-36	-33	-30	-28	-27	-27	-26	-28	-32	-46
62	-48		-36	-34	-30	-30	-28	-28	-28	-30	-34	-46
64	-48		-37	-34	-31	-30	-29	-29	-28	-30	-34	-45
66	-48		-38	-34	-32	-31	-30	-30	-30	-30	-34	-45
68	-47		-38	-36	-33	-32	-32	-32	-30	-32	-36	-46
70	-48		-38	-36	-34	-33	-32	-32	-32	-32	-36	-46
72	-48		-39	-37	-34	-33	-32	-32	-32	-32	-36	-46
74	-46		-39	-37	-35	-34	-33	-33	-32	-32	-36	-46
76	-47		-40	-37	-36	-34	-34	-34	-33	-34	-37	-46
78	-46		-40	-38	-36	-35	-35	-34	-34	-34	-38	-46
80	-48		-40	-38	-37	-36	-36	-36	-35	-35	-38	-46
82	-47		-40	-39	-37	-37	-36	-36	-36	-36	-38	-46
84	-48		-40	-39	-38	-37	-36	-36	-36	-36	-39	-48
86	-46		-41	-40	-38	-38	-37	-37	-36	-36	-39	-46
88	-47		-41	-40	-39	-38	-38	-38	-38	-38	-40	-46
90	-48		-42	-40	-40	-38	-38	-38	-38	-38	-40	-46
92	-46		-42	-40	-40	-39	-38	-38	-38	-38	-40	-46
94	-47		-42	-40	-40	-40	-38	-38	-38	-38	-40	-47
96	-48		-42	-41	-40	-40	-39	-39	-39	-39	-40	-46
98	-46		-42	-41	-40	-40	-40	-40	-40	-40	-40	-46

TABLE Id

Time, hrs.	Temperature Conditioning °F.	Thermocouple Designation:	1	2	3	4	5	6	7	8	9	10
			Thermocouple Temperature, Degrees Fahrenheit									
0	40		42	42	42	42	44	44	44	44	44	40
			Temperature changed to -60° ± 5°F									
2	-28		38	40	41	42	42	42	43	43	39	4
4	-58		26	37	40	41	41	41	42	40	28	-28
6	-60		14	30	39	40	40	38	40	35	18	-37
8	-60		5	22	34	38	38	38	38	29	11	-41
10	-60		-1	16	30	34	34	34	34	24	5	-43
12	-60		-6	11	25	30	31	31	30	18	0	-46
14	-60		-10	6	20	26	28	28	25	14	-4	-47
16	-61		-14	2	16	21	24	24	21	10	-7	-49
18	-61		-16	-2	11	16	20	20	17	7	-10	-50
20	-61		-19	-6	7	12	15	15	16	3	-12	-51
22	-60		-21	-9	3	8	11	11	10	0	-15	-51
24	-63		-23	-12	0	4	8	8	7	-3	-17	-53
26	-64		-26	-14	-3	1	4	4	4	-6	-20	-54
28	-63		-28	-18	-7	-2	0	0	0	-9	-22	-56
30	-65		-31	-21	-12	-7	-4	-4	-4	-13	-25	-58
32	-64		-32	-23	-13	-9	-8	-8	-8	-16	-28	-58
34	-65		-34	-25	-16	-12	-10	-10	-10	-18	-29	-59
36	-63		-36	-28	-19	-16	-12	-12	-12	-20	-30	-59
38	-64		-37	-29	-22	-18	-16	-16	-16	-22	-32	-60
40	-65		-39	-31	-24	-20	-19	-19	-19	-24	-34	-60
42	-85		-40	-33	-26	-23	-21	-21	-21	-26	-36	-71
44	-94		-45	-36	-28	-26	-24	-24	-24	-28	-40	-81
46	-68		-50	-40	-32	-28	-27	-27	-26	-32	-44	-69
48	-61		-50	-42	-34	-31	-30	-30	-29	-34	-44	-63
50	-63		-50	-44	-37	-34	-32	-32	-32	-36	-44	-62
52	-64		-49	-44	-39	-36	-35	-35	-34	-38	-44	-60
54	-64		-49	-45	-40	-38	-37	-36	-36	-39	-44	-62
56	-64		-50	-46	-42	-40	-38	-38	-37	-40	-45	-61
58	-64		-50	-46	-42	-41	-40	-40	-38	-40	-46	-61
60	-65		-51	-48	-44	-42	-41	-41	-40	-41	-46	-61
62	-63		-52	-48	-45	-44	-42	-42	-41	-42	-47	-61
64	-64		-52	-48	-46	-45	-44	-44	-42	-44	-48	-61
66	-65		-53	-49	-47	-46	-45	-45	-43	-44	-49	-62
68	-66		-53	-50	-48	-47	-46	-46	-44	-45	-49	-62
70	-66		-53	-51	-48	-48	-47	-47	-45	-46	-50	-62
72	-66		-54	-52	-49	-49	-48	-48	-46	-47	-51	-62
74	-65		-54	-52	-49	-49	-49	-48	-47	-48	-51	-63

TABLE Ie

Time, hrs.	Temperature Conditioning °F.	Thermocouple Designation:	1	2	3	4	5	6	7	8	9	10
			Thermocouple Temperature, Degrees Fahrenheit									
0	40		38	38	36	36	36	36	37	37	38	38
			Temperature changed to -75°± 5°F									
2	-42		34	36	36	36	36	36	36	36	34	-4
4	-66		20	32	35	35	35	35	35	34	20	-36
6	-72		6	23	32	33	33	32	33	28	10	-48
8	-72		-4	16	28	31	31	32	32	21	2	-54
10	-72		-8	8	23	28	28	28	26	16	-4	-56
12	-72		-16	2	18	22	24	24	21	10	-8	-59
14	-73		-20	-3	12	20	20	20	16	5	-13	-62
16	-74		-23	-8	8	14	18	16	12	1	-16	-62
18	-73		-26	-12	3	8	12	12	8	-1	-20	-62
20	-74		-28	-15	-1	4	8	8	4	-6	-22	-61
22	-75		-31	-18	-6	0	3	3	0	-10	-26	-64
24	-76		-34	-22	-10	-5	-1	-1	-2	-14	-28	-66
26	-76		-36	-25	-14	-8	-6	-6	-6	-16	-30	-66
28	-76		-40	-28	-18	-13	-10	-10	-10	-20	-33	-67
30	-76		-42	-32	-21	-16	-14	-14	-14	-23	-36	-68
32	-76		-44	-34	-24	-20	-18	-18	-18	-26	-38	-68
34	-76		-44	-36	-26	-22	-20	-20	-20	-28	-38	-68
36	-76		-46	-38	-28	-25	-24	-24	-24	-29	-40	-68
38	-74		-48	-40	-32	-28	-26	-26	-27	-31	-42	-68
40	-74		-49	-41	-34	-30	-28	-28	-28	-33	-44	-70
42	-76		-51	-44	-37	-34	-32	-32	-32	-36	-46	-71
44	-76		-52	-46	-39	-36	-34	-34	-34	-38	-47	-72
46	-78		-54	-48	-42	-37	-38	-36	-36	-41	-50	-72
48	-78		-56	-50	-44	-41	-40	-40	-40	-44	-51	-72

TABLE Ie (CONT'D)

Time, hrs.	Temperature Conditioning °F.	Thermocouple Designation:	Thermocouple Temperature, Degrees Fahrenheit 1	2	3	4	5	6	7	8	9	10
50	-74		-54	-48	-43	-40	-39	-39	-38	-42	-48	-70
52	-74		-54	-50	-44	-42	-40	-40	-40	-43	-50	-68
54	-74		-55	-50	-46	-44	-42	-42	-42	-44	-50	-70
56	-76		-56	-52	-48	-46	-44	-44	-44	-46	-52	-70
58	-74		-56	-52	-48	-46	-46	-46	-44	-48	-52	-70
60	-74		-58	-54	-52	-48	-48	-46	-46	-48	-54	-70
62	-74		-58	-54	-51	-50	-48	-48	-48	-48	-54	-68
64	-74		-58	-56	-52	-50	-50	-50	-48	-50	-54	-70
66	-76		-60	-56	-52	-50	-50	-50	-50	-52	-56	-70
68	-76		-60	-57	-54	-52	-52	-52	-50	-52	-56	-70
70	-78		-60	-58	-56	-54	-54	-54	-54	-54	-58	-70
72	-74		-61	-58	-56	-55	-54	-54	-52	-54	-58	-70
74	-76		-62	-60	-56	-56	-54	-54	-54	-54	-58	-70
76	-74		-62	-60	-58	-56	-56	-56	-56	-56	-60	-70
78	-76		-62	-60	-58	-58	-56	-56	-56	-56	-60	-70
80	-76		-64	-60	-60	-58	-58	-58	-56	-56	-60	-70
82	-78		-64	-62	-60	-60	-58	-58	-58	-58	-62	-72
84	-74		-64	-62	-60	-60	-60	-60	-58	-58	-62	-72
86	-76		-64	-62	-62	-60	-60	-60	-60	-60	-62	-72
88	-76		-64	-64	-62	-60	-60	-60	-60	-60	-62	-72
90	-76		-66	-64	-62	-62	-62	-62	-60	-60	-64	-72
92	-76		-66	-64	-64	-62	-62	-62	-62	-62	-64	-72
94	-78		-66	-64	-64	-64	-62	-62	-62	-62	-64	-72
96	-76		-66	-66	-64	-64	-62	-62	-62	-62	-64	-72
98	-76		-66	-64	-64	-64	-64	-62	-62	-62	-64	-72

APPENDIX K

DETERMINATION OF FIRING AND STORAGE TEMPERATURE LIMITS BY CROSS-PLOTTING

APPENDIX K

Determination of Firing and Storage Temperature Limits by Cross-Plotting

Grain Temperature vs. Conditioning Time data for Thermocouple No. 9, one-half inch from the grain periphery, were extracted from the results of the runs made at each conditioning temperature and plotted as a family of curves, using the conditioning time as the abscissa and the grain temperature as the ordinate (Figure 35). To establish a point for plotting the low-temperature firing limit curve, the intersection of a grain temperature curve in the family and the 0°F conditioning temperature line is first determined. This point represents the conditioning time required to reduce the grain temperature from 40°F to 0°F (minimum firing temperature). From this point a vertical (constant time) line is projected to intersect the temperature line corresponding to the temperature of the grain temperature curve under consideration. This point represents the time required for the grain temperature, stabilized at 40°F, to drop to 0°F at Thermocouple No. 9 when subjected to a particular conditioning temperature.

This procedure was followed to plot a point based on each of the family of grain temperature curves except the one for 0°F. The curve plotted through these points represents the low-temperature firing limit. The low-temperature storage limit curve was similarly plotted by using the -10°F conditioning temperature line instead of the 0°F conditioning temperature line. These limit curves were transferred to a separate curve for clarity (Figure 27).

To use the curves, a known conditioning temperature and time combination is plotted as a point. If the point falls on or above the firing limit curve, the effective grain temperature is not below the minimum firing limit (0°F). If the curve falls on or above the storage limit curve, but below the firing limit curve, the effective grain temperature is below the minimum firing limit (0°F), but not below the minimum storage limit (-10°F).

To determine the approximate effective grain temperature when below the minimum firing temperature, additional curves were plotted at 10°F increments in a manner similar to that of the firing limit curve.

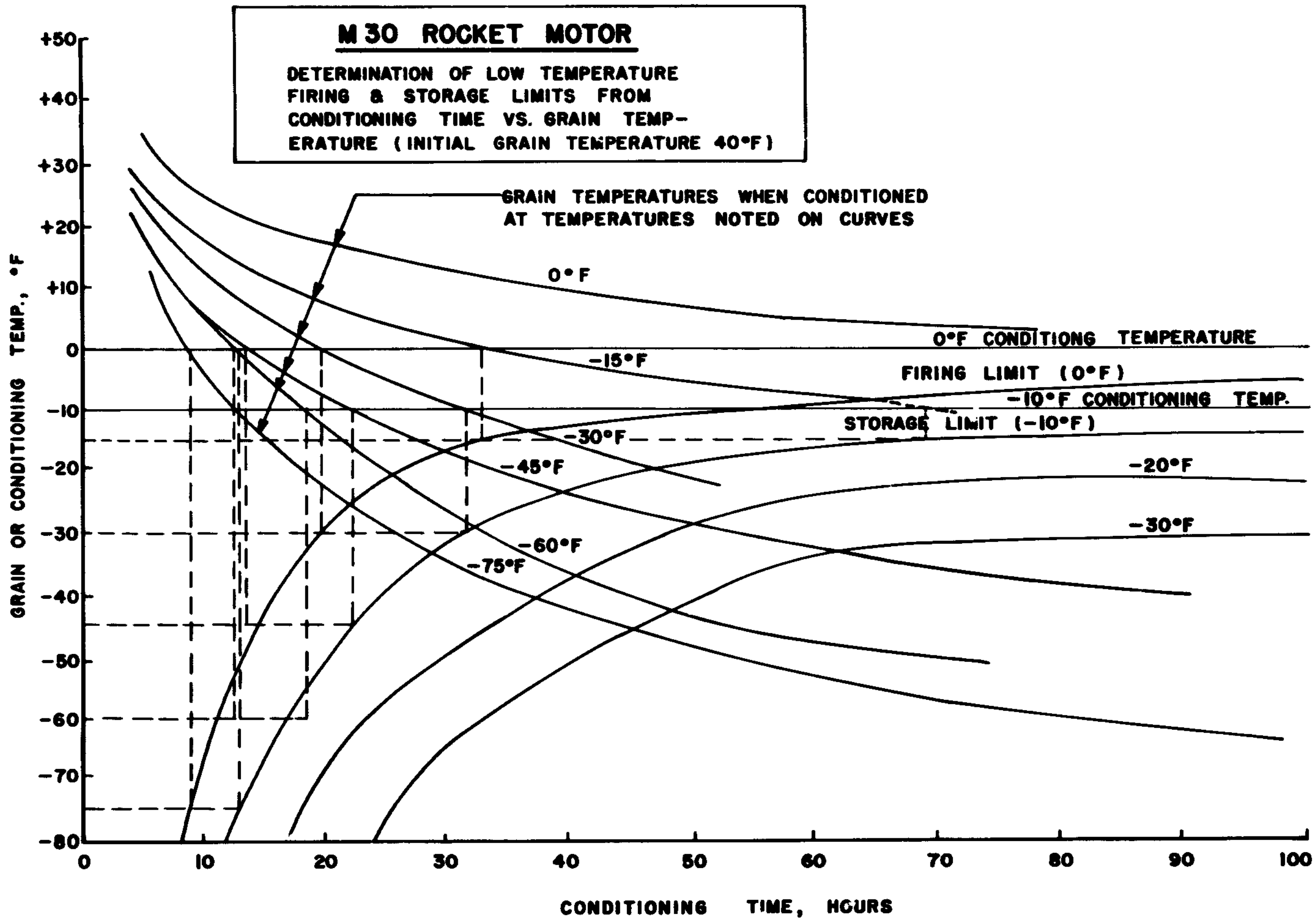

M 30 ROCKET MOTOR
DETERMINATION OF LOW TEMPERATURE FIRING & STORAGE LIMITS FROM CONDITIONING TIME VS. GRAIN TEMPERATURE (INITIAL GRAIN TEMPERATURE 40°F)
GRAIN TEMPERATURES WHEN CONDITIONED AT TEMPERATURES NOTED ON CURVES
0°F
-15°F
-30°F
-45°F
-60°F
-75°F
0°F CONDITIONG TEMPERATURE
FIRING LIMIT (0°F)
-10°F CONDITIONING TEMP.
STORAGE LIMIT (-10°F)
-20°F
-30°F
GRAIN OR CONDITIONING TEMP., °F
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
10
20
30
40
50
60
70
80
90
100
CONDITIONING TIME, HOURS

Figure 35.

ABSTRACT DATA

ABSTRACT

AD ____________________ Accession No. __________

Picatinny Arsenal, Ammunition Group
Dover, New Jersey

PRODUCTION ENGINEERING OF METAL AND OTHER INERT PARTS FOR M30 ROCKET MOTOR FOR NIKE HERCULES MISSILE

Harold Mannheimer

Technical Report DC-TR: 5-61, December 1961
51 pp, diagrams, graphs, photographs, tables.
Unclassified Report

The hydrostatic test requirements for the motor case were thought to be somewhat excessive; an analytical study was conducted which resulted in recommendations that certain test requirements be reduced. The blast tube and adapter insulation was a single source, expensive item; other likely materials were selected and tested with the result that a less expensive, alternate material was recommended.

Some of the metal parts can be reclaimed after static firing if the liner which bonds the propellant to the metal parts can be removed safely and economically; tests disclosed a non-toxic solvent which will remove or loosen the liner material at ambient temperature. Motor metal parts were subjected to a corrosive atmosphere to determine areas susceptible to corrosion; several corrosion inhibiting coatings were tested and evaluated.

Tests were conducted on a loaded motor in a low temperature environment to determine the rate of temperature change in the grain and the time that the rocket motor can be exposed to extreme temperatures without falling below the specified firing or storage temperature limits.

UNCLASSIFIED

1. Rocket motors Production.

I. Mannheimer, Harold.
II. M30 Rocket motors.
III. NIKE HERCULES.
IV. Code no. 4120.12.-0601.700
V. Project no. PA-11-3D1.

UNITERMS

Production
Rocket motors
Materials
M30
Nike Hercules
Mannheimer, H.
Code no. 4120.12.-0601.700
Project no. PA-11-3D1.

AD ______________ Accession No. ______________

Picatinny Arsenal, Ammunition Group
Dover, New Jersey

PRODUCTION ENGINEERING OF METAL AND OTHER INERT PARTS FOR M30 ROCKET MOTOR FOR NIKE HERCULES MISSILE

Harold Mannheimer

Technical Report DC-TR: 5-61, December 1961 51 pp, diagrams, graphs, photographs, tables.
Unclassified Report

The hydrostatic test requirements for the motor case were thought to be somewhat excessive; an analytical study was conducted which resulted in recommendations that certain test requirements be reduced. The blast tube and

over)

UNCLASSIFIED

1. Rocket motors
   Production

I. Mannheimer, Harold
II. M30 Rocket motors
III. NIKE HERCULES
IV. Code No. 4120.12.-0601.700
V. Proj No. PA-11-3D1

UNITERMS

Production
Rocket motors
Materials
M30
Nike Hercules

UNCLASSIFIED

AD ______________ Accession No. ______________

Picatinny Arsenal, Ammunition Group
Dover, New Jersey

PRODUCTION ENGINEERING OF METAL AND OTHER INERT PARTS FOR M30 ROCKET MOTOR FOR NIKE HERCULES MISSILE

Harold Mannheimer

Technical Report DC-TR: 5-61, December 1961 51 pp, diagrams, graphs, photographs, tables.
Unclassified Report

The hydrostatic test requirements for the motor case were thought to be somewhat excessive; an analytical study was conducted which resulted in recommendations that certain test requirements be reduced. The blast tube and

over)

UNCLASSIFIED

1. Rocket motors
   Production

I. Mannheimer, Harold
II. M30 Rocket motors
III. NIKE HERCULES
IV. Code No. 4120.12.-0601.700
V. Proj No. PA-11-3D1

UNITERMS

Production
Rocket motors
Materials
M30
Nike Hercules

UNCLASSIFIED

AD ______________ Accession No. ______________

Picatinny Arsenal, Ammunition Group
Dover, New Jersey

PRODUCTION ENGINEERING OF METAL AND OTHER INERT PARTS FOR M30 ROCKET MOTOR FOR NIKE HERCULES MISSILE

Harold Mannheimer

Technical Report DC-TR: 5-61, December 1961 51 pp, diagrams, graphs, photographs, tables.
Unclassified Report

The hydrostatic test requirements for the motor case were thought to be somewhat excessive; an analytical study was conducted which resulted in recommendations that certain test requirements be reduced. The blast tube and

over)

UNCLASSIFIED

1. Rocket motors
   Production

I. Mannheimer, Harold
II. M30 Rocket motors
III. NIKE HERCULES
IV. Code No. 4120.12.-0601.700
V. Proj No. PA-11-3D1

UNITERMS

Production
Rocket motors
Materials
M30
Nike Hercules

UNCLASSIFIED

AD ______________ Accession No. ______________

Picatinny Arsenal, Ammunition Group
Dover, New Jersey

PRODUCTION ENGINEERING OF METAL AND OTHER INERT PARTS FOR M30 ROCKET MOTOR FOR NIKE HERCULES MISSILE

Harold Mannheimer

Technical Report DC-TR: 5-61, December 1961 51 pp, diagrams, graphs, photographs, tables.
Unclassified Report

The hydrostatic test requirements for the motor case were thought to be somewhat excessive; an analytical study was conducted which resulted in recommendations that certain test requirements be reduced. The blast tube and

over)

UNCLASSIFIED

1. Rocket motors
   Production

I. Mannheimer, Harold
II. M30 Rocket motors
III. NIKE HERCULES
IV. Code No. 4120.12.-0601.700
V. Proj No. PA-11-3D1

UNITERMS

Production
Rocket motors
Materials
M30
Nike Hercules

UNCLASSIFIED

adapter insulation was a single source, expensive item; other likely materials were selected and tested with the result that a less expensive, alternate material was recommended.

Some of the metal parts can be reclaimed after static firing if the liner which bonds the propellant to the metal parts can be removed safely and economically; tests disclosed a non-toxic solvent which will remove or loosen the liner material at ambient temperature. Motor metal parts were subjected to a corrosive atmosphere to determine areas susceptible to corrosion; several corrosion inhibiting coatings were tested and evaluated.

Tests were conducted on a loaded motor in a low temperature environment to determine the rate of temperature change in the grain and the time that the rocket motor can be exposed to extreme temperatures without falling below the specified firing or storage temperature limits.

UNCLASSIFIED

UNITERMS

Mannheimer, H.
Code No. 4120.12.0601.-700
Proj No. PA-11-3D1

UNCLASSIFIED

adapter insulation was a single source, expensive item; other likely materials were selected and tested with the result that a less expensive, alternate material was recommended.

Some of the metal parts can be reclaimed after static firing if the liner which bonds the propellant to the metal parts can be removed safely and economically; tests disclosed a non-toxic solvent which will remove or loosen the liner material at ambient temperature. Motor metal parts were subjected to a corrosive atmosphere to determine areas susceptible to corrosion; several corrosion inhibiting coatings were tested and evaluated.

Tests were conducted on a loaded motor in a low temperature environment to determine the rate of temperature change in the grain and the time that the rocket motor can be exposed to extreme temperatures without falling below the specified firing or storage temperature limits.

UNCLASSIFIED

UNITERMS

Mannheimer, H.
Code No. 4120.12.0601.-700
Proj No. PA-11-3D1

UNCLASSIFIED

adapter insulation was a single source, expensive item; other likely materials were selected and tested with the result that a less expensive, alternate material was recommended.

Some of the metal parts can be reclaimed after static firing if the liner which bonds the propellant to the metal parts can be removed safely and economically; tests disclosed a non-toxic solvent which will remove or loosen the liner material at ambient temperature. Motor metal parts were subjected to a corrosive atmosphere to determine areas susceptible to corrosion; several corrosion inhibiting coatings were tested and evaluated.

Tests were conducted on a loaded motor in a low temperature environment to determine the rate of temperature change in the grain and the time that the rocket motor can be exposed to extreme temperatures without falling below the specified firing or storage temperature limits.

UNCLASSIFIED

UNITERMS

Mannheimer, H.
Code No. 4120.12.0601.-700
Proj No. PA-11-3D1

UNCLASSIFIED

adapter insulation was a single source, expensive item; other likely materials were selected and tested with the result that a less expensive, alternate material was recommended.

Some of the metal parts can be reclaimed after static firing if the liner which bonds the propellant to the metal parts can be removed safely and economically; tests disclosed a non-toxic solvent which will remove or loosen the liner material at ambient temperature. Motor metal parts were subjected to a corrosive atmosphere to determine areas susceptible to corrosion; several corrosion inhibiting coatings were tested and evaluated.

Tests were conducted on a loaded motor in a low temperature environment to determine the rate of temperature change in the grain and the time that the rocket motor can be exposed to extreme temperatures without falling below the specified firing or storage temperature limits.

UNCLASSIFIED

UNITERMS

Mannheimer, H.
Code No. 4120.12.0601.-700
Proj No. PA-11-3D1

UNCLASSIFIED

FOR ERRATA

AD 273 573

THE FOLLOWING PAGES ARE CHANGES

TO BASIC DOCUMENT

AD 273 573

H-481

GENERAL REPORT SUMMARY SHEET

Propulsion Parts Solid Fuel Engines 1. GENERAL CLASS NAME COMPLETE	3A. REASON FOR TEST: To provide improved production processes and techniques for mass production, etc.	CARD 1 OF 4	INTEREST CATEGORY: * A 2. REPORT NO. 565.00.00.00-N5-04 (MAJ. CLASS. | SUB-CLASSES | ORIG. | SEQ.)
3. ORIGINATOR'S REPORT TITLE Production Engineering Of Metal And Other Inert Parts For M30 Rocket Motor For Nike Hercules Missile (H. Mannheimer)			4. ORIGINATOR'S REPORT NO. DC-TR: 5-61 5. TEST COMPL. DAY | MO. | YR. REPT. COMPL. Dec. 1961 6. PROGRAM OR WEP. SYST.

24. OUTLINE, TABLE OF CONTENTS, SUMMARY, OR EQUIVALENT DESCRIPTION:

SUMMARY

The Scope of Work, as originally issued (May 1958) by the Army Rocket and Guided Missile Agency (ARGMA), encompassed a complete production engineering study on the motor metal parts, a pilot lot, and a description of manufacture in addition to the studies outlined in Section I. However, the funding authorization was not sufficient to cover the entire program included in the Scope of Work. Additional funding was anticipated (sufficient to permit conducting the program) and the bulk of the phases to be contracted out were held in abeyance pending receipt of the additional funding, although the preparatory processing for competitive bidding on the production engineering study was completed. Meanwhile, several phases were initiated which could be performed by Picatinny Arsenal and did not require a "knowledge contract". At a later date, ARGMA advised that because of the cutback in the Nike Hercules program, additional funding for the production engineering study would not be authorized. At this time, a revised Scope of Work (dated 7 April 1959) was submitted by ARGMA to Picatinny Arsenal. The revised Scope of Work excluded the tasks which would have required an extensive metal parts production engineering "knowledge contract" and permitted concentration of effort on the tasks listed in Section I.

Briefly, the tasks accomplished were:

a. Hydrostatic Pressure Test Study--The hydrostatic test requirements for the motor case were thought to be somewhat excessive. An analytical study was conducted which resulted in recommendations that certain test requirements be reduced.

b. Alternate Insulation Study--The blast tube and adapter insulation was a single source, expensive item. Other likely materials were selected and tested. A less expensive, alternate material was recommended.

c. Liner Removal Study--Some of the metal parts can be reclaimed after static firing if the liner which bonds the propellant to the metal parts can be removed safely and economically. Tests disclosed a non-toxic solvent which would remove or loosen the liner material at ambient temperature.

d. Corrosion Study--Motor metal parts were subjected to a corrosive atmosphere to determine areas susceptible to corrosion. Several corrosion inhibiting coatings were tested and evaluated on the basis of effectiveness and practicability for in-plant and field use.

e. Temperature Gradient Study--Tests were conducted on a loaded motor in a low temperature environments to determine the rate of temperature change in the grain and the time that the rocket motor can be exposed to extreme temperatures without falling below the specified firing of storage temperature limits.

1. GENERAL CLASS NAME COMPLETE: Propulsion Parts, Solid Fuel Engines

CARD 1 OF 4 — 2. REPT. NO. 565.00.00.00-N5-04 (MAJ. CLASS. | SUB-CLASSES | ORIG. | SEQ.)

22. SIGNED [signature]

23. IDEP CONTRACTOR: Picatinny Arsenal | SUBCONTRACTOR

IDEP FORM NO. 17: 10-61

* TO BE COMPLETED BY DDC ONLY

H-481/1

GENERAL REPORT SUMMARY SHEET

INTEREST CATEGORY: * 4

1. GENERAL CLASS NAME COMPLETE: Propulsion Parts Solid Fuel Engines	CARD *2 OF 4	2. REPORT NO. 565.00.00.00- N5 -04 (MAJ. CLASS. / SUB-CLASSES / ORIG. / SEQ.)
3. ORIGINATOR'S REPORT TITLE: Production Engineering Of Metal And Other Inert Parts For M30 Rocket Motor For Nike Hercules Missile (H. Mannheimer)	3A. REASON FOR TEST: To provide improved production processes and techniques for mass production, etc.	4. ORIGINATOR'S REPORT NO: DC-TR: 5-61
		5. TEST COMPL. DAY / MO. / YR.; REPT. COMPL. 12 61
		6. PROGRAM OR WEP. SYST.

24. OUTLINE, TABLE OF CONTENTS, SUMMARY, OR EQUIVALENT DESCRIPTION:

1. GENERAL CLASS NAME COMPLETE: Propulsion Parts Solid Fuel Engines

CARD *2 OF 4

2. REPT. NO. 565.00.00.00 - N5-04 (MAJ. CLASS. / SUB-CLASSES / ORIG. / SEQ.)

22. SIGNED	23. IDEP CONTRACTOR	SUBCONTRACTOR
Arthur Koop	Picatinny Arsenal	

IDEP FORM NO. 17:10-61

* TO BE COMPLETED BY DDC ONLY

H-481/2

GENERAL REPORT SUMMARY SHEET

INTEREST CATEGORY: * A

Propulsion Parts Solid Fuel Engines 1. GENERAL CLASS NAME COMPLETE	3A. REASON FOR TEST	CARD *3 OF 4	2. REPORT NO. 565.00.00.00- N5-04 (MAJ. CLASS. / SUB-CLASSES / ORIG. / SEQ.)
3. ORIGINATOR'S REPORT TITLE Production Engineering Of Metal And Other Inert Parts For M30 Rocket Motor For Mike Hercules Missile (H. Mannheimer)	To provide improved production processes and techniques for mass production, etc.		4. ORIGINATOR'S REPORT NO DC-TR: 5-61 5. TEST COMPL. DAY / MO. / YR. REPT. COMPL. 12 61 6. PROGRAM OR WEP. SYST.

24. OUTLINE, TABLE OF CONTENTS SUMMARY, OR EQUIVALENT DESCRIPTION:

1. GENERAL CLASS NAME COMPLETE: Propulsion Parts Solid Fuel Engines

CARD *3 OF 4

2. REPT. NO. 565. 00.00.00-N5-04 (MAJ. CLASS. / SUB-CLASSES / ORIG. / SEQ.)

22. SIGNED	23. IDEP CONTRACTOR	SUBCONTRACTOR
Arthur Koop	Picatinny Arsenal	

IDEP FORM NO. 17: 10-61

* TO BE COMPLETED BY DDC ONLY

H-481/3

GENERAL REPORT SUMMARY SHEET

INTEREST CATEGORY: * A

Propulsion Parts **Solid Fuel Engines** 1. GENERAL CLASS NAME COMPLETE	3A. REASON FOR TEST **To provide improved production processes and techniques for mass production, etc.**	CARD *4 OF 4	2. REPORT NO. 565.00.00.00-N5-04 (MAJ. CLASS. / SUB-CLASSES / ORIG. / SEQ.)
3. ORIGINATOR'S REPORT TITLE **Production Engineering Of Metal And Other Inert Parts For M30 Rocket Motor For Nike Hercules Missile (H. Mannheimer)**			4. ORIGINATOR'S REPORT NO DC-MR: 5-61 5. TEST COMPL. DAY / MO. / YR. REPT. COMPL. 12 61 6. PROGRAM OR WEP. SYST.

24. OUTLINE, TABLE OF CONTENTS, SUMMARY, OR EQUIVALENT DESCRIPTION:

1. GENERAL CLASS NAME COMPLETE
Propulsion Parts Solid Fuel Engines
CARD *4 OF 4
2. REPT. NO. 565.00.00.00-N5-04 (MAJ. CLASS. / SUB-CLASSES / ORIG. / SEQ.)

22. SIGNED	23. IDEP CONTRACTOR	SUBCONTRACTOR
Arthur Koop	Picatinny Arsenal	

IDEP FORM NO. 17: 10-61

* TO BE COMPLETED BY DDC ONLY

AD 273 573

END CHANGE PAGES