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ARDE-PORTLAND, INC.

100 WEST CENTURY ROAD

PARAMUS, NEW JERSEY

QUARTERLY TECHNICAL REPORT No. 1

PERIOD: June 1, 1962 to September 1, 1962

CRYOGENIC STRETCH FORMING OF SOLID PROPELLANT ROCKET CASES

Prepared For

United States Army

Contract DA-30-069-ORD-3501

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I. OBJECTIVE

To produce experimental flight weight solid propellant rocket cases of the Pershing configuration, by the cryogenic stretch forming process.

II. SUMMARY

The present program is an outgrowth of ARDE-PORTLAND's previous work under Contract No. DA-30-069-ORD-3099, Task A, "Development of Ultra High Strength Rocket Motor Cases by Cryogenic Stretch Forming". The feasibility of producing high strength cases by this process was demonstrated under that contract. The present objective is to develop the process to the point where a predetermined, complex configuration can be produced while retaining the high strength achieved in the earlier prototype cases. Figure 9 is a sketch showing the configurational features being investigated. These features consist of:

A. 1.66:1 elliptical forward head

B. Conical aft end closure with nozzle attachment ring

C. Skirts, fore and aft

D. Eccentric ports in the forward head

During this first three-month period, an overall program plan was evolved, and procurement-fabrication effort was initiated. This effort has thus far touched on the "elliptical head", "skirt attachment", and "aft closure" features of the motor case. At the end of the first month, the contract was modified to include the task of developing the Pershing motor case configuration. As initially written, the contract called for a series of small cases to be built for test firing. In the interim since the first monthly report, considerable thought has been given to the features which must be developed for the Pershing case. It is now clear that certain of these features must receive more attention than originally anticipated. A revised program plan

reflecting current thinking on number of vessels required and the schedule for these vessels is therefore included with this report.

III. PERIOD ACTIVITY

A. PROGRAM PLAN

A revised program plan is included in the appendix. This plan shifts the emphasis to those features presenting the most formidable problems. Although the plan differs slightly from the plan submitted in Monthly Report No. 1, the end date remains the same. The principal changes from the original program plan are outlined below:

1. The number of preform configurations required to develop the forward elliptical head has been increased from four to six, and these have been accelerated in the schedule.
2. Work on multiple ports and the aft head will be held back somewhat to take advantage of the data from the elliptical head work. The number of configurations on both multiple ports and aft head has been increased from two to three.
3. Material procurement for the full-scale cases has been moved back to permit thorough metallurgical evaluation of the heats being considered for procurement. Fabrication of the first simple, full-scale vessel has also moved back for this reason.
4. Two items were added to the schedule under "Full-Scale Development Cases". These were "Fabrication of the Forming Tank" and "Fabrication of the Forming Die".

B. AFT HEAD

Design of the first aft head configuration was completed and released for fabrication. This design employs the "dog-bone" principle (see discussion of "Elliptical Forward Head"), modified to produce a stretched shape approaching the 45° cone of the aft closure. Figure 1 is a sketch of the composite head being used. Note that a section of cylinder is attached to the upper cone. This is intended to be a "booster" to help the large port opening of the cone to grow at the same time that the internal pressure is tending to cause the cone to bulge. It is hoped that the net effect will be to have the cone remain straight while pulling up to the desired 45° angle. The next configuration will be adjusted in geometry and material, depending on the results achieved with this initial attempt. For instance, if the cone remains too shallow, the remedy could be a more ductile material in the cylinder, to help pull the inside diameter up and out, and/or a steeper cone angle in the preform. In addition, data on the general plastic behavior of cones from the elliptical head investigation will be utilized in the designs. The first configuration is scheduled to be stretched early in October.

C. SKIRT ATTACHMENT:

The initial approach to the skirt attachment problem will be to weld the skirt in place after the basic vessel is stretched. As a result of work initiated by ARDE-PORTLAND prior to the present contract, it will be possible to evaluate the feasibility of this approach quite rapidly. A vessel has been built with a thickened ring in the cone of an early-type composite head. This thickened ring has a lip to which a skirt may be welded after stretching. This vessel (Serial #419) was successfully stretched, but the desired head shape was not achieved. During the past month, it was decided to weld a skirt onto this vessel. Although the position of the skirt lip was such that the skirt could not be perfectly flush to the cylinder, this test will evaluate whether the weld can be strengthened. A hydrotest was performed prior to welding the skirt so that the nominal yield strength would be known for comparison. The skirt was welded to the vessel during this period and will be subjected to a restretch in the near future to strengthen the weld. Fig. 2 is a photograph of Vessel #419 with the skirt welded on. The next monthly report will contain the results of this test along with hydrotest results to evaluate whether full strength has been restored.

D. ELLIPTICAL FORWARD HEAD:

Fabrication of four configurations for development of the elliptical forward head is in progress. ARDE-PORTLAND's approach to this problem has been to make the "preform" vessel with a welded composite head comprised of simple cones and discs which can be readily fabricated. Prior to receipt of the current contract, ARDE-PORTLAND did considerable development work on heads made by this technique. Figure 3 shows the types of composite head which were investigated. A summary of the test results with these designs is tabulated below:

Configuration	Results
Basic Composite Head	Cylinder was incorporated into Curvature of head. General shape approached hemispherical.
Spool Piece	Slight improvement. The spool-like transition section of more ductile 302 stainless steel stretched more readily at the cone juncture but did not go flush.
Dog-Bone	Outer diameter of cone was increased almost to cylinder final diameter in preform. A second cone was used for a transition section into the preform cylinder diameter which was smaller, giving a "dog-bone" appearance. This change resulted in an essentially flush cylinder but the head contour was only slightly flatter than hemispherical.

This data indicates that the "dog-bone" design was the most promising shape. The behavior of the "dog-bone" preform during stretching may be seen in the series of sequence photographs (from the preform to the final pressure), included in the appendix. The head falls short of achieving the flat 1.66:1 ellipse required for the Pershing configuration, but the results indicate the flattening effect of the "dog-bone" approach.

E. <u>FORMING TANK</u>:

In preparation for cryogenic stretching of full-scale cases, a forming tank was designed and released for fabrication. This is a simple, stainless steel insulated container to hold the liquid nitrogen bath in which the vessel and the stretch die will be immersed. The Pershing case is larger in diameter than any that has been stretched thus far, and for this reason the new forming tank will be required. Since fabrication has already been initiated, the forming tank will be ready well in advance of the first full-scale stretch scheduled for early in December.

F. <u>MATERIALS</u>:

Sufficient quantities of suitable 301 and 302 stainless steel are now on hand at the South Portland, Maine, plant to conduct the sub-scale development phase of the program. Procurement of the large quantity of material required for the full-scale work has been delayed to permit as thorough an evaluation as possible of the material to be procured. Heat No. E72370 from Eastern Stainless Steel Corporation was evaluated and was shown to have a desirable combination of properties. Cryogenic stress-strain characteristics, cryogenic ultimate strength, and room temperature response to cryogenic working were all considered in the evaluation. Unfortunately, the quantity of Heat No. E72370 presently available is not sufficient for the needs of the program. Eastern Stainless has agreed to pour a new melt of similar chemistry. Procurement of material from this new heat is being initiated at this writing. Figure 8 shows a plot of the uniaxial cryogenic stress-strain curve for Heat No. E72370. A room temperature response curve is superimposed on the stress-strain curve. For this plot, the strain scale represents the cryogenic prestrain applied to the tensile coupon while the stress scale represents the resulting room temperature strength. The delay in procuring material will push back the first full-scale stretch date by about three weeks but should not materially affect the remainder of the program.

IV. WORK PROJECTED FOR THE NEXT QUARTER

During the forthcoming quarterly period, it is anticipated that the following effort will take place:

A. All six scheduled forward head configurations will be completed and stretched.

B. Two multiple port designs will be fabricated and stretched.

C. The skirt attachment vessel described in this report will be re-stretched and a hydrotest performed to evaluate the strength level. An additional configuration will also be completed in the next quarter.

D. The first aft head configuration will be completed and stretched. A second configuration will also be completed and stretched.

E. The first configuration for development of the nozzle attachment ring will be fabricated and stretched.

F. The forming tank for stretching of full-scale cases will be fabricated.

G. Material procurement for the full-scale phase of the program will be completed.

H. The first simple, full-scale case will be fabricated and stretched.

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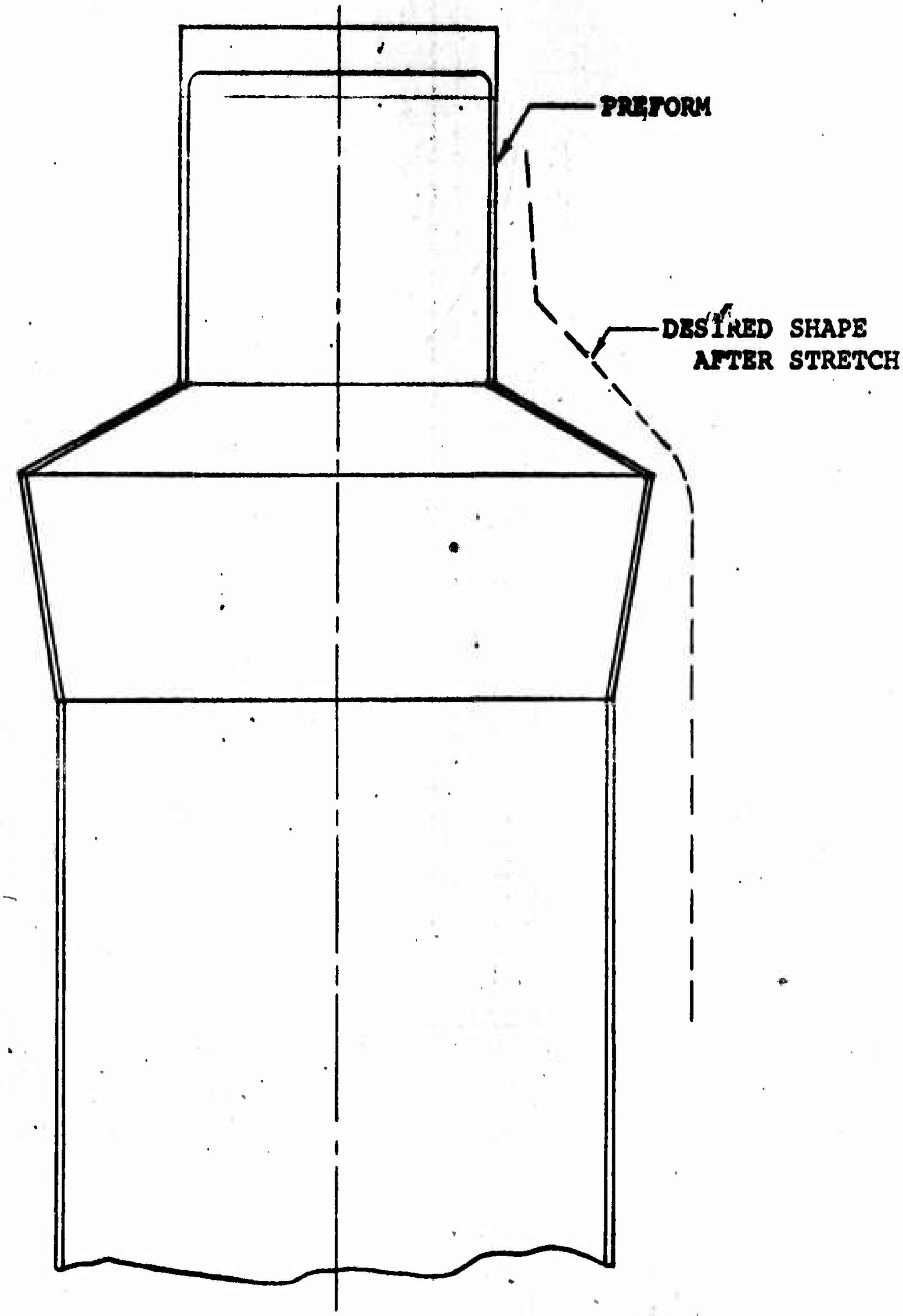
APPENDIX



AFT HEAD PREFORM DESIGN

Figure 1

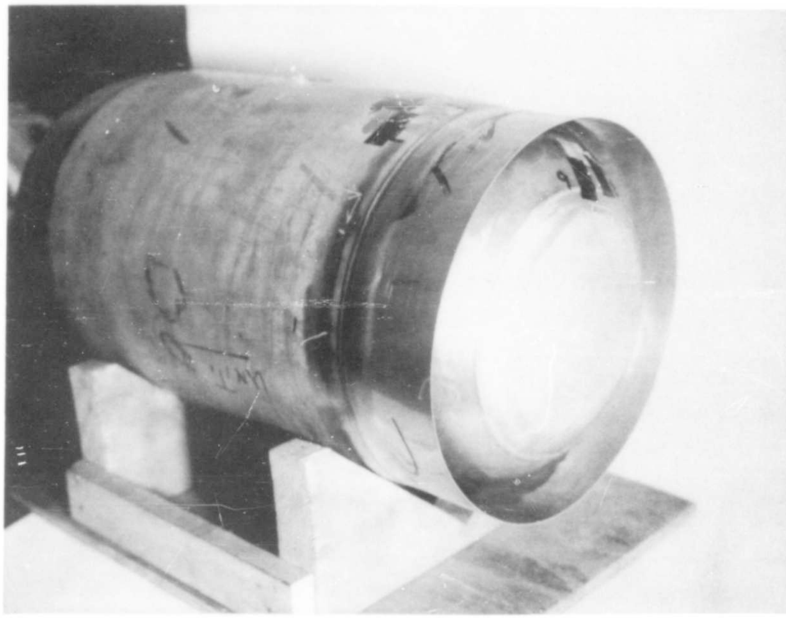
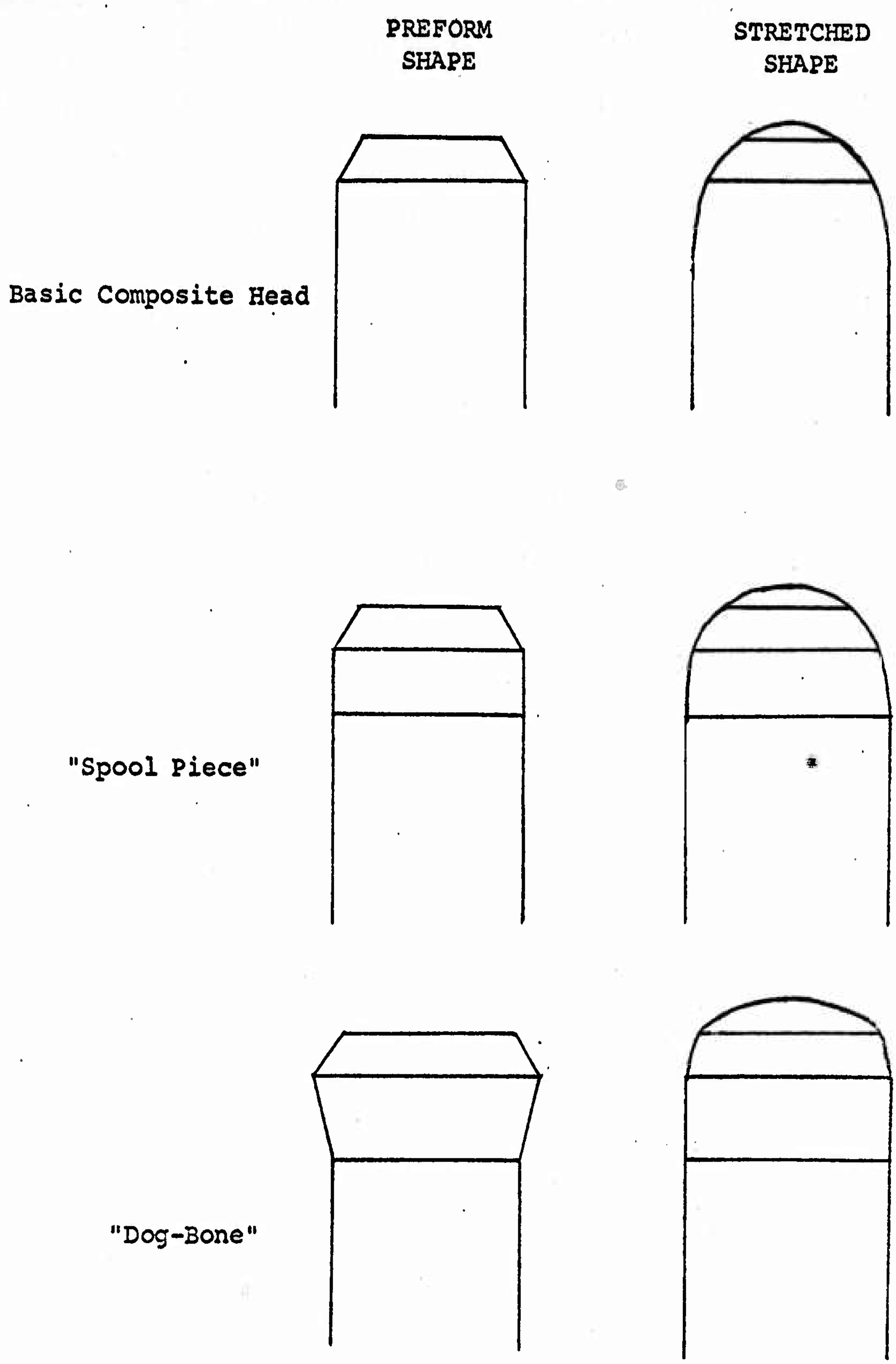


Figure 2 - Vessel No. 419 With Skirt Welded to Composite Head



COMPOSITE HEAD SHAPES

FIGURE 3

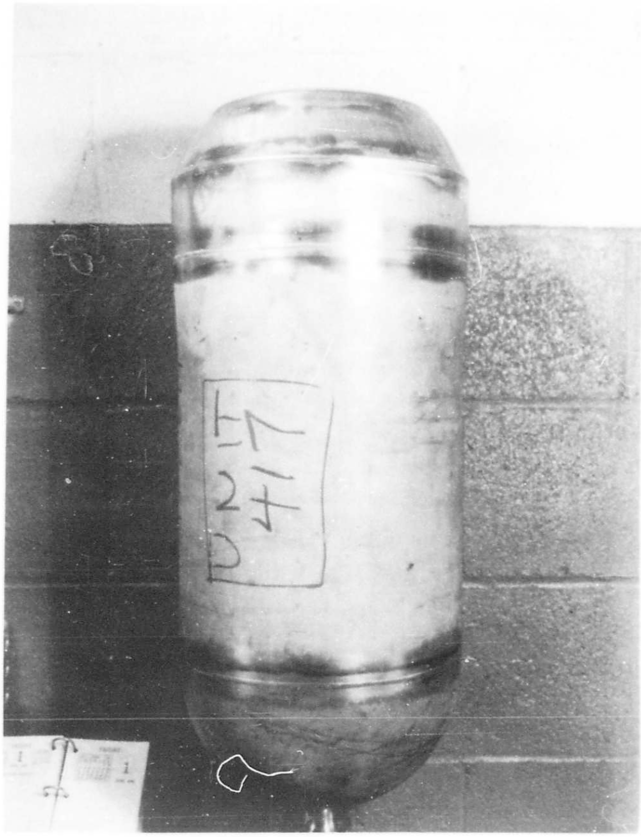


Figure 4 - Vessel #417 Preform

Figure 5 - Vessel #417 Stretched at 1000 psi.

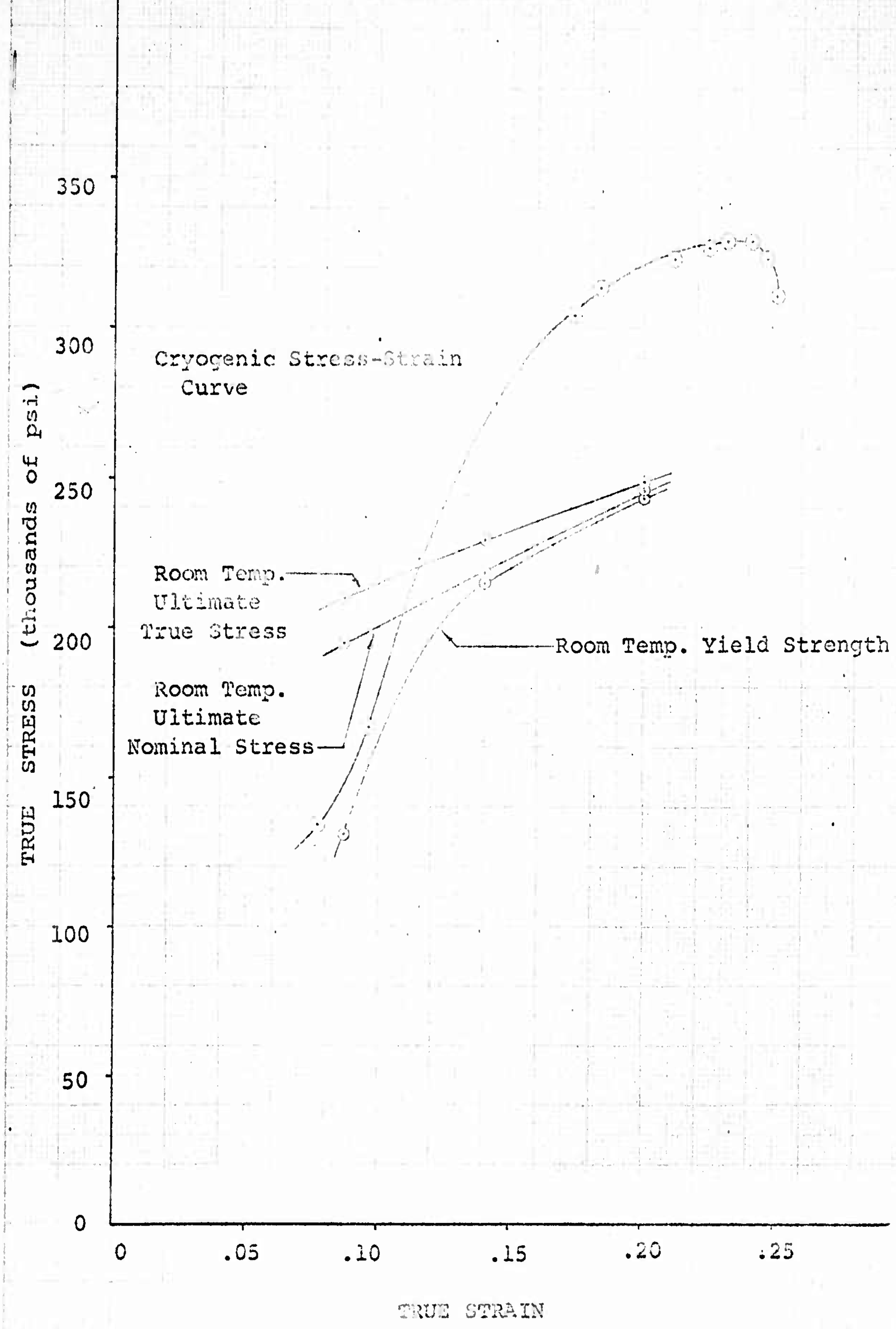
Figure 6 - Vessel #417 Stretched at 1750 psi.

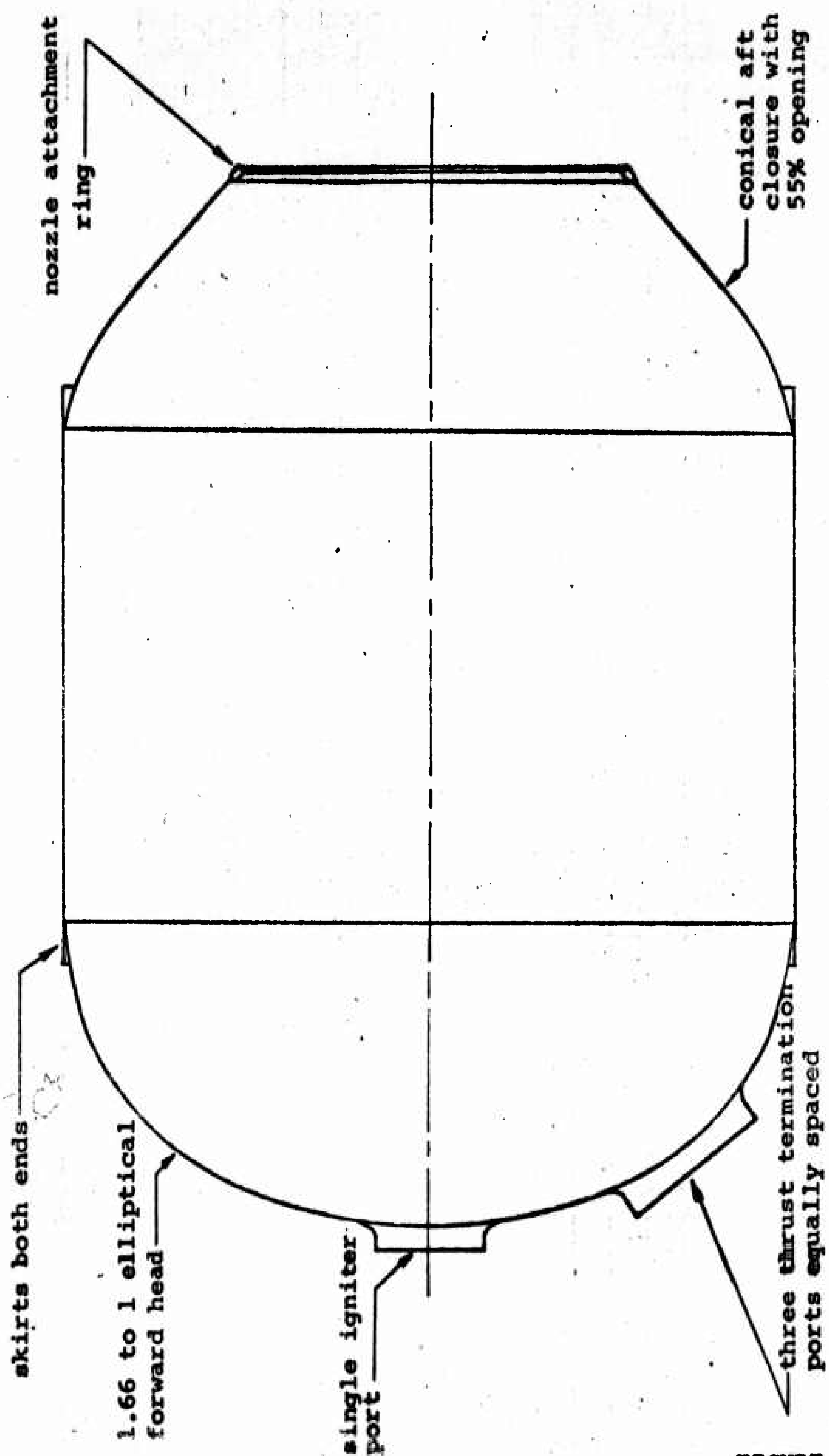
Figure No. 7 - Vessel #417 Stretched
at 2000 psi

FIGURE 8

CRYOGENIC STRESS-STRAIN CHARACTERISTICS

HEAT No. E72370





SKETCH OF THE PERSHING MOTOR CASE

FIGURE 9

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Start of Program

SUB-SCALE CASES

Elliptical Forward Head D D D D

Multiple Ports

Skirt Attachment

Aft Head

Nozzle Attachment Ring

Complete Sub-scale Pershing Case for Delivery

FULL-SCALE DEVELOPMENT CASES

Forming Tank

Material Procurement

Stretch Die

Head Procurement

Cylindrical Vessel - simple heads

Cylindrical Vessel - complete forward head

Cylindrical Vessel - complete aft head

FULL-SCALE FLIGHT WEIGHT CASES

Experimental Pershing Case with all Features

CODE

D Design

Fabrication

S Stretch

No. of Vessels

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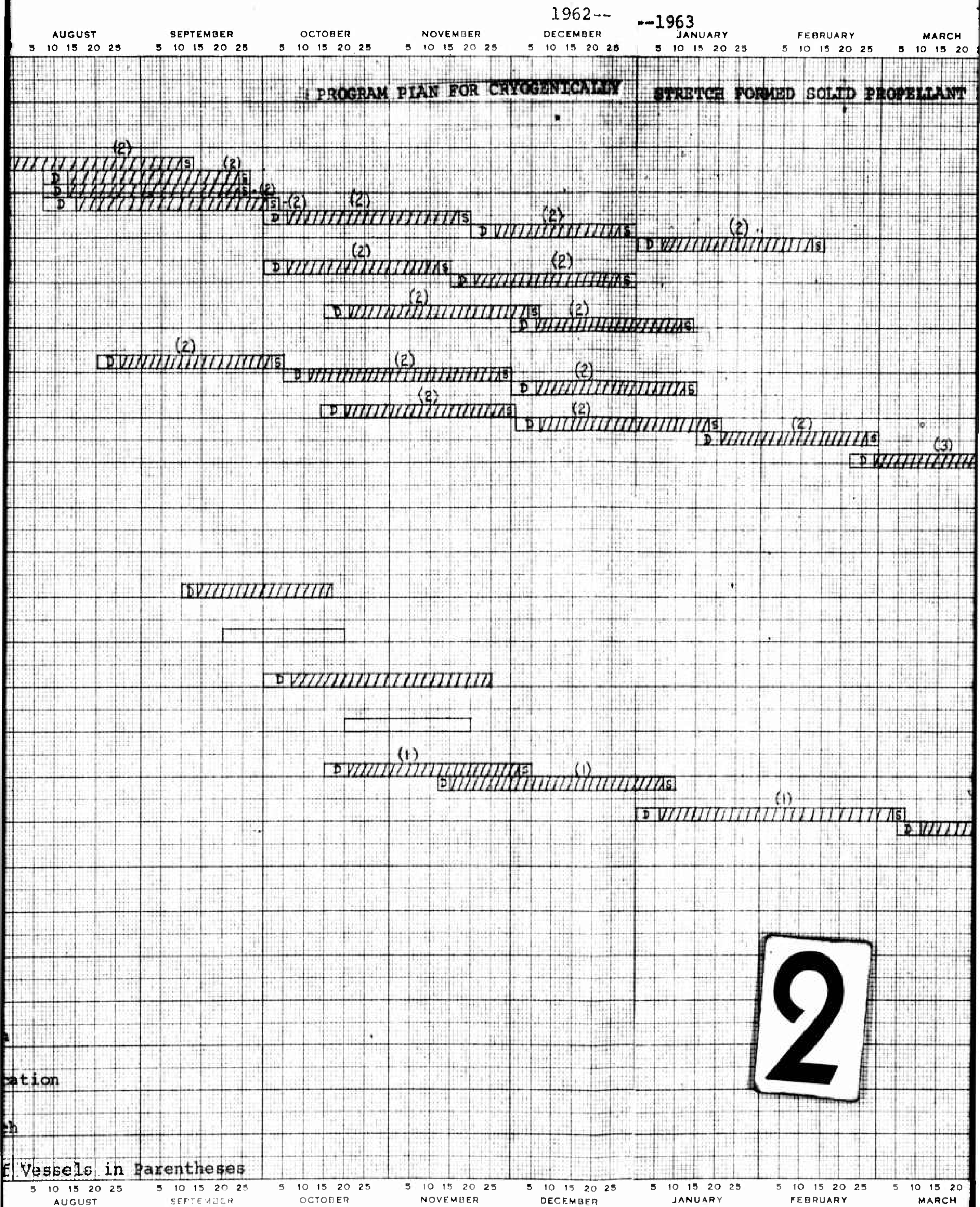

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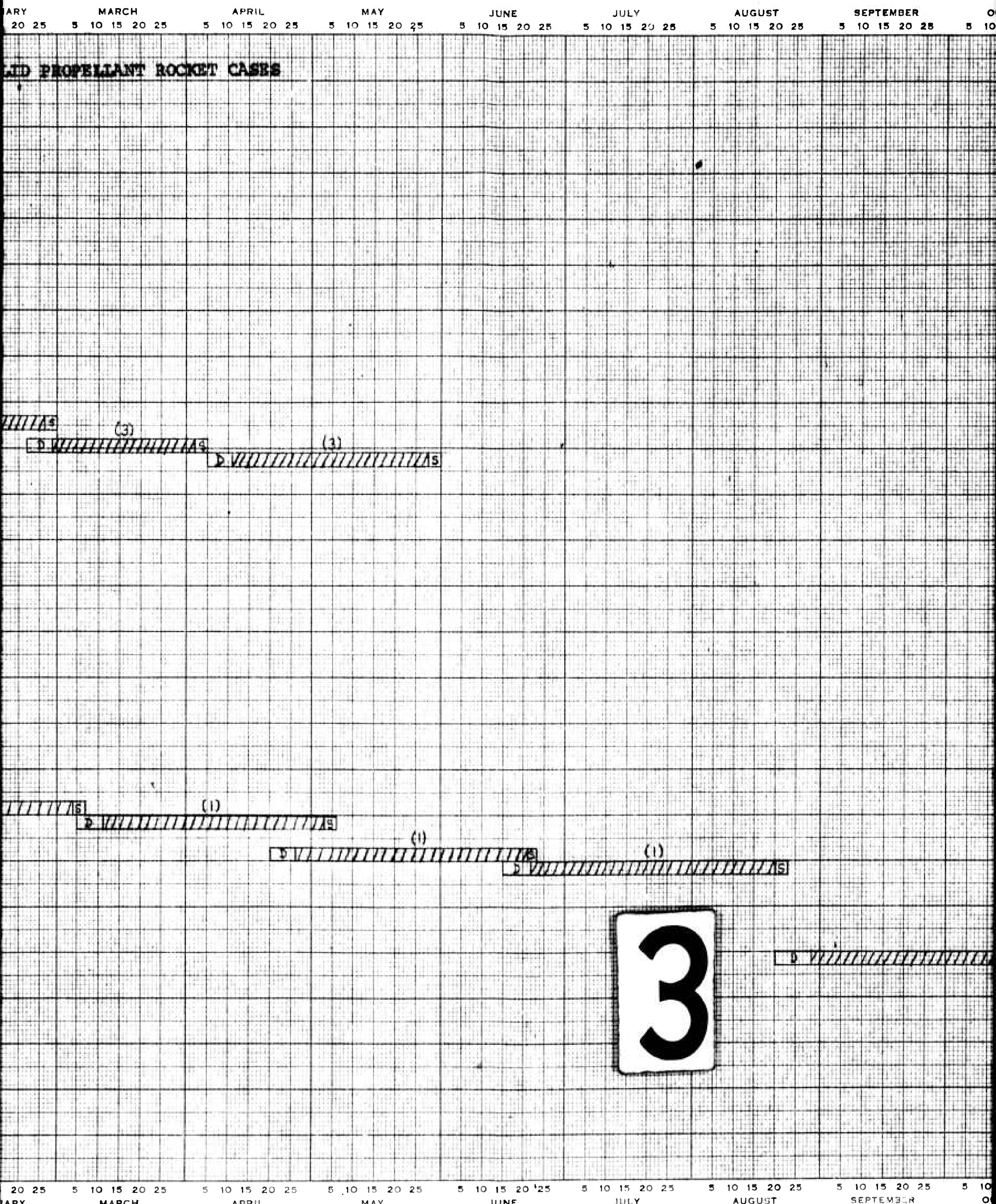

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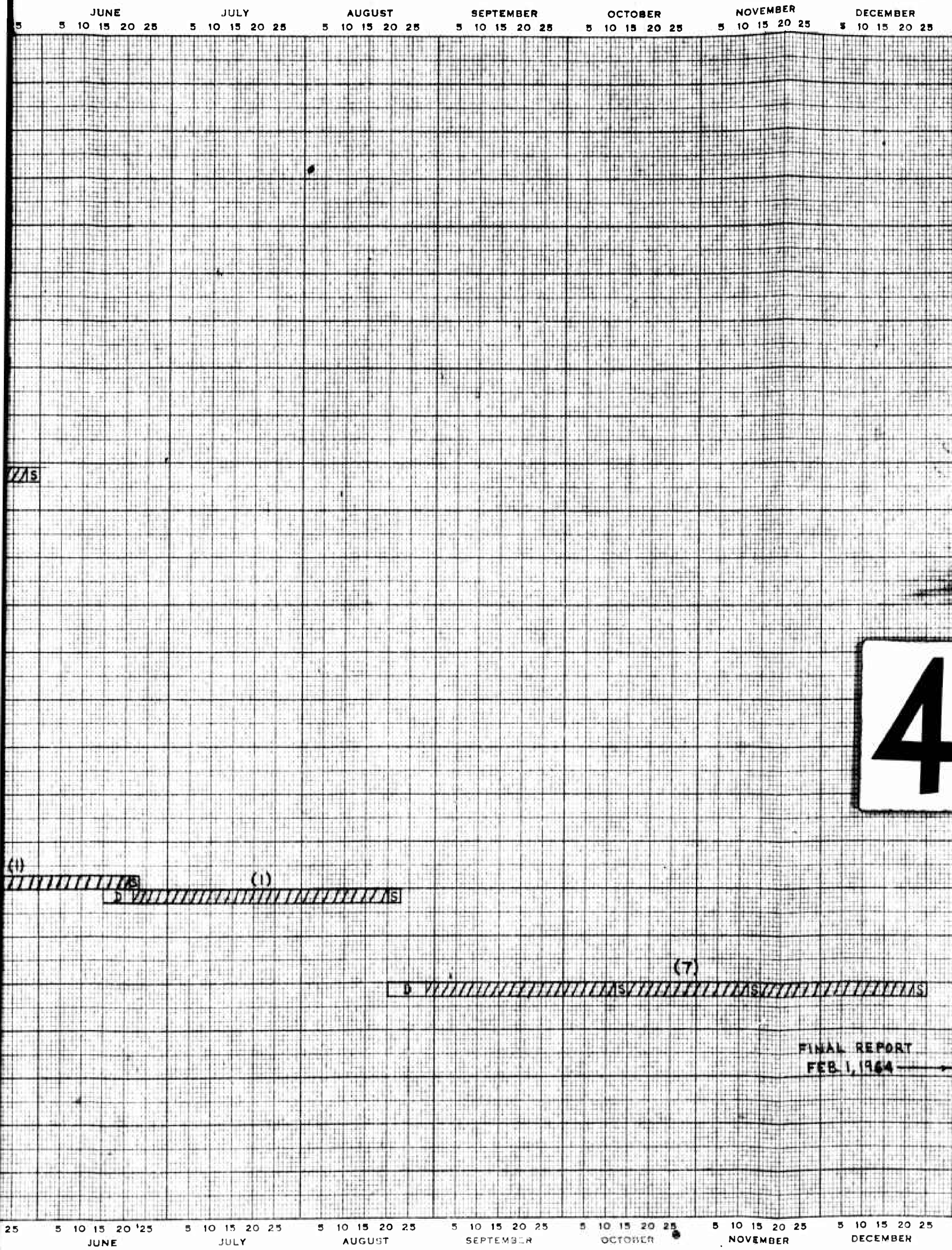
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