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## HERCULES POWDER COMPANY

INCORPORATED

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25 May 1963

IN REPLY  
REFER TO: 1/4/10-3577

Headquarters  
Ballistic Systems Division  
Air Force Systems Command  
Norton Air Force Base  
California

Attention: BSRPQ-1

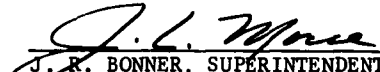
Subject: Final Report Test Plan Cut-Up Motor SD-25, Report Number MTO-162-164,  
dated 25 May 1963, Contract AF 04(647)-243; WS-133A

Reference: Exhibit "D"

Gentlemen:

In accordance with Exhibit "D," to Contract AF 04(647)-243,  
one copy of the subject report is hereby submitted.

Very truly yours,

  
J. R. BONNER, SUPERINTENDENT  
A. F. CONTRACT SUPPORT *JB*

JRB:JLMORSE:dd

1 Encl (Copy No. 1 of Report No. MTO-162-164)

cc: J. L. ShROUT (wo/encl)

W. E. Howell (wo/encl)  
Wilmington

J. E. Greer (wo/encl)  
Wilmington

Technical Operating Report  
B O B Approval No.

FINAL REPORT  
TEST PLAN CUT-UP MOTOR SD-25  
MTO-162-164

WEAPON SYSTEM 133A

25 May 1963

Contract Number AF 04(647)-243  
Exhibit D

Prepared by

HERCULES POWDER COMPANY  
CHEMICAL PROPULSION DIVISION  
Bacchus Works  
Magna, Utah

Prepared for

HEADQUARTERS  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
Los Angeles, California

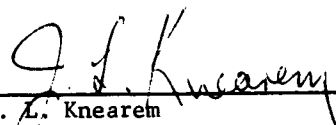
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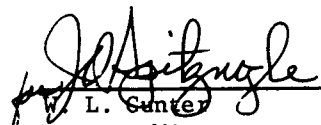
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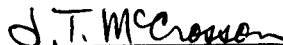
Date May 25, 1963

FINAL REPORT  
TEST PLAN CUT-UP MOTOR SD-25

Weapon System 133A

  
\_\_\_\_\_  
J. L. Knearem  
Superintendent  
Wing II Minuteman

  
\_\_\_\_\_  
W. L. Gunter  
Manager Minuteman  
Project

  
\_\_\_\_\_  
J. McCrosson  
Senior Development Engineer

#### FOREWORD

This report outlines the work accomplished at the Bacchus Works of the Hercules Powder Company for the continued development of Rocket Motor M-57E1, Minuteman third stage.

Authority for the preparation of this report was obtained from Exhibit D, of Contract AF 04(647)-243.

#### ABSTRACT

The purpose of this report is to present a logical means of dissecting and testing Minuteman third stage M-57E1 Rocket Motor samples. This test plan outlines the test objectives, motor cut-up sequences, sample machining procedures, chemical and physical testing requirements to be followed for motor cut-up SD-25. The prime objective of this test is the determination of case-bond strength and propellant physical properties.

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## SECTION I

### INTRODUCTION

This test plan incorporates a number of procedures necessary for adequate physical and chemical analysis of the M-57E1 motor.

Basically, the full scale motor will be prepared for dissection by marking, then segmented, environmentally conditioned, and finally each segment or sample channeled through a series of physical and chemical tests to examine the effects of loading and motor-to-motor variation.

Testing in conjunction with SD-25 will be conducted as part of the Continued Development Program outlined in Exhibit D of Contract AF 04(647)-243. Work under this program is directed towards improving the overall performance of the third stage M-57E1 motor originally developed and tested under the Research and Development and Preliminary Flight Rating Tests Programs outlined in Exhibit A of the Contract.

SECTION II  
MOTOR DISSECTION

A. INTRODUCTION

The following procedure will introduce the reader to the steps necessary in the dissection of the full-scale M-57E1 motor.

B. METHOD OF APPROACH

1. Cutting Instructions

The following steps should be carefully followed in preparing, marking, and cutting segments from the full-scale motor.

NOTE

Step numbers refer to corresponding numbers on the operator's worksheet.

- (a) Step 1-1. Remove the forward skirt.
- (b) Step 1-2. Make cuts in the full-scale motor case as illustrated in Figures 1 through 7. Mark each quarter of the cylinder to be cut with the following information, as shown in Figure 2.
- (c) Step 1-2.1. Mark the forward end of each quarter cylinder "FWD."
- (d) Step 1-2.2. Mark each quarter cylinder with its cylinder letter according to Figure 1.
- (e) Step 1-2.3. Mark each quarter cylinder with corresponding port number.
- (f) Step 1-3. Cut the motor into cylinders as shown in Figure 1.
- (g) Step 1-4. Peel Spiralloy and insulation material from the aft dome.
- (h) Step 1-5. Cut cylinders A and E in half as shown in Figures 1, 2, 3 and 7. One-half of each cylinder must contain quarters 1 and 2 and the other must contain quarters 3 and 4. The half which contains quarters 3 and 4 will be referred to as "half 34."

- (i) Step 1.6. Cut cylinders B, C, and D into quarters as shown in Figures 4, 5, and 6. Cuts B-2 and C-2 must be made on a line halfway between ports 3 and 4. Cut D-1 must be made on a line which runs between ports 2 and 3. This cut line must be 5 in. from the closest outside edge of TT port 3 as shown in Figure 6. Make sure each quarter is marked according to above steps 1.2.1, 1.2.2, 1.2.3 and Figure 2.
- (j) Step 1.7. On half A-34, mark off, label, and cut sections A-1, A-2, A-3, A-4, A-5 and A-6 as shown in Figure 3 and 13. Sections A-1, A-3, A-4 and A-5 will be cut from quarter number 4. Label the forward edge of section A-1 "FWD." Write "OUT" on that edge of each of the sections A-2, A-3 and A-4 which is most distant from the case centerline.
- (k) Step 1.8. On half A-12, mark off, label, and cut 4 by 6 in. sections A-7 and A-8 as shown in Figure 3. Write "OUT" on that edge of both A-7 and A-8 which is most distant from the case centerline.
- (l) Step 1.9. On quarter B-4, mark off, label, and cut the 6 by 6 by 3-1/2 in. section B-4 as shown in Figure 4. Write "FWD" on the forward edge of B-4.
- (m) Step 1.10. Mark off and cut triangular section of propellant from quarter B-1, B-2, B-3, and B-4 as shown in Figure 4. The outer section of each of these quarters will be sent to Hill Air Force Base, Sample Machining, where case bond samples will be removed.
- (n) Step 1.11. On quarters C-3, and C-4 mark off, label, and cut sections C-1, C-2, C-3, C-4, C-5, and C-6 as shown in Figure 5. Sections C-1, C-2, C-3 and C-5 will be cut from quarter C-4. Write "FWD" on the forward edge of section C-1. Write "OUT" on that edge of each of the sections C-2, C-3 and C-4 which is most distant from the case centerline.
- (o) Step 1.12. Mark off and cut triangular sections of propellant from quarters C-1 and C-2 as shown in Figure 4. The outer section of each of these quarters will be sent to Hill Air Force Base, Sample Machining, where case bond samples will be prepared.

- (p) Step 1.13. On quarter D-4 mark off, label, and cut sections D-1 and D-2 as shown in Figure 6. Write "FWD" on the forward edge of section D-1.
- (q) Step 1.14. Mark off and make cuts D-4, D-5, D-6 and D-7 as shown in Figure 6. Each cut line must be 5 in. from the closest outside edge of the adjacent TT port. The sections of quarters D-1, D-2, D-3 and D-4 which contain the TT ports will be labeled "D-1-T," "D-2-T," "D-3-T," and "D-4-T." The sections of quarters D-1, D-2, D-3, and D-4 which do not contain the TT ports will be labeled "D-1-C," "D-2-C," "D-3-C," and "D-4-C." The forward edge of each of these sections will be labeled "FWD."
- (r) Step 1.15. On half E-34, mark off, cut and label sections E-1, E-2, E-3, and E-4 as shown in Figure 7. Sections E-1, E-3 and E-4 will be cut from the quarter which contains port 4. Write "FWD" on the forward edge of section E-1. Write "OUT" on that edge of each of the sections E-2, E-3, and E-4 which is most distant from the case center line.
- (s) Step 1.16. All sections will be sent to Sample Machining at Hill Air Force Base after they have been properly cut, marked and wrapped in aluminum foil.
- (t) Step 1.17. All motor segments and scrap propellant pieces which are not sent to Sample Machining will be routed to storage.

## 2. Machining Procedure

Sample extraction of the full-scale motor by precision methods, is as follows:

- (a) Step 2.1. Sections A-1, B-1, C-1, D-1, and E-1 are aft-to-forward sections. "FWD" will be written on the forward edge of each section during cutting. Slabs will be cut from aft to forward and numbered as shown in Figure 8. For example, the slabs taken from section D-1 would be numbered "D-1-1," "D-1-2," "D-1-3," etc.
- (b) Step 2.2. Sections A-2, A-3, A-4, A-7, A-8, C-2, C-3, C-4, E-2, E-3 and E-4 are "out-to-in" sections ("OUT" has been written on that edge of each section which was most distant from the case centerline.) Slabs will be cut from out to in and numbered as shown in Figure 9.

- (c) Step 2.3. Slabs cut from each sample should be temporarily packaged together and kept in correct order at all times.
- (d) Step 2.4. Machine a standard 1/4 in. JANAF "dog-bone" from each of the slabs prepared according to machining procedures 2.1 and 2.2. Number each dog-bone sample as shown in Figure 10. Each dog-bone sample should have the same identification number as the slab from which it is machined. Route all JANAF samples to the Bacchus C.P. Laboratory for analysis.
- (e) Step 2.5. Cut a 5 by 0.187 by 0.187 in. strand burning sample from each of the slabs prepared according to machining procedures 2.1 and 2.2. (See Figure 10.) A tag containing an identification number will be attached to either end of each sample. The identification number for each sample will be the same as the number of the slab from which it is cut. Route strand burning samples to the old Dynamite Laboratory for analysis.
- (f) Step 2.6. Number each JANAF scrap piece with the identification number of the slab from which it is taken. The scrap pieces are to be grouped in fives in the order in which they are removed. (See Figure 10.) Route scraps to the Bacchus C.P. Laboratory for analysis.
- (g) Step 2.7. Machine as many 4 by 4 by 4 in. case bond samples as possible from the outer sections of quarters B-1, B-2, B-3, B-4, C-1, C-2, C-3, and C-4. Also, machine as many 4 by 4 by 4 in. case bond samples as possible from sections D-1-C, D-2-C, D-3-C, and D-4-C. These samples will be numbered clockwise around the case as shown in Figures 11 and 12. Machine each sample as shown in Figure 11. Spiralloy will be carefully peeled from each case bond sample before detailed machining.
- (h) Step 2.8. Machine disc samples from sections A-5, A-6, C-5, C-6, and D-2 as shown in Figure 13. Label both discs taken from a section with the number of that section.
- (i) Step 2.9. Machine and number 6 TT flap samples from each of sections D-1-T, D-2-T, D-3-T, and D-4-T as shown in Figure 14.
- (j) Step 2.10. After machining, all samples will be wrapped in aluminum foil and marked for identification.

SECTION III  
TEST PROCEDURE

A. INTRODUCTION

Physical and chemical tests will be run on the samples previously prepared. The physical and chemical properties will be used as criteria in examining the effects of loading and motor-to-motor variation.

Prior to test, all samples will be environmentally conditioned as outlined in Section III, Method No. 3, of the Bacchus Laboratory Procedures Manual.

Physical testing procedures are documented in the Bacchus Laboratory Procedures Manual. The particular tests are described in the Sections and Methods listed below:

B. TYPES OF SAMPLES

The types of samples covered in this test plan are as follows:

1. Propellant Samples

Tests will be conducted on propellant samples to determine the uniformity of propellant physical properties at 90° intervals in motor section B of Figure 1. Testing procedures are outlined in Section III, Method 3, of the Bacchus Laboratory Procedures Manual.

High Rate Tensile tests will be conducted at the Hill Air Force Base Propellant Testing Facility whereas stress relaxation testing will be performed at Bacchus Works.

2. JANAF Dog-bone Samples

The following physical property data will be obtained from JANAF dog-bone samples. (Refer to Bacchus Laboratory Procedures Manual.)

<u>Sample Analysis</u>	<u>Procedure</u>
Tensile strength	Section III, Method 3
Percent elongation	Section III, Method 3
Modulus of elasticity	Section III, Method 3
Hardness	Section III, Method 21

For each consecutive group of five dog-bone samples, a chemical laboratory sample will be taken. The data from these samples will be analyzed in the same manner as data from the dog-bone samples.

### 3. Strand-burning Samples

Strand-burning samples will be tested for burning rate. The following tests will be performed on scraps listed in the referenced Bacchus Laboratory Machining Procedures.

<u>Sample Analysis</u>	<u>Procedure</u>
Taliani	Section III, Method 20
Percent nitroglycerin	Section II, Method 9
Percent 2-NDPA	Section II, Method 1
Percent resorcindl	HDX1-331
Percent triacetin	Section II, Method 26
Density	Section V, Method 21
Aluminum content	Section II, Method 33

The strand-burning samples will be arranged in consecutive groups of 10. Each group of 10 will represent a sample. The data from these samples will then be compared to determine whether there are significant differences among:

- (a) Motors
- (b) The axial low rate propellant samples
- (c) Diametric low rate propellant samples
- (d) Low rate propellant diametric vs low rate propellant axial samples
- (e) Same as (a), (b), and (c) but with high rate propellant samples
- (f) Interface samples



The preceding analysis will show whether there is a difference in the propellant burning rate among motors and among locations within motors. If differences are detected, their magnitude will be calculated and presented.

#### 4. Disc Samples

Testing of disc samples is specified by MTI-24T, 26 July 1960. The disc samples will be tested for dynamic shear modulus of the dynamic testing section of the Structural Dynamics Group. The dynamic shear modulus will be determined at 70° F.

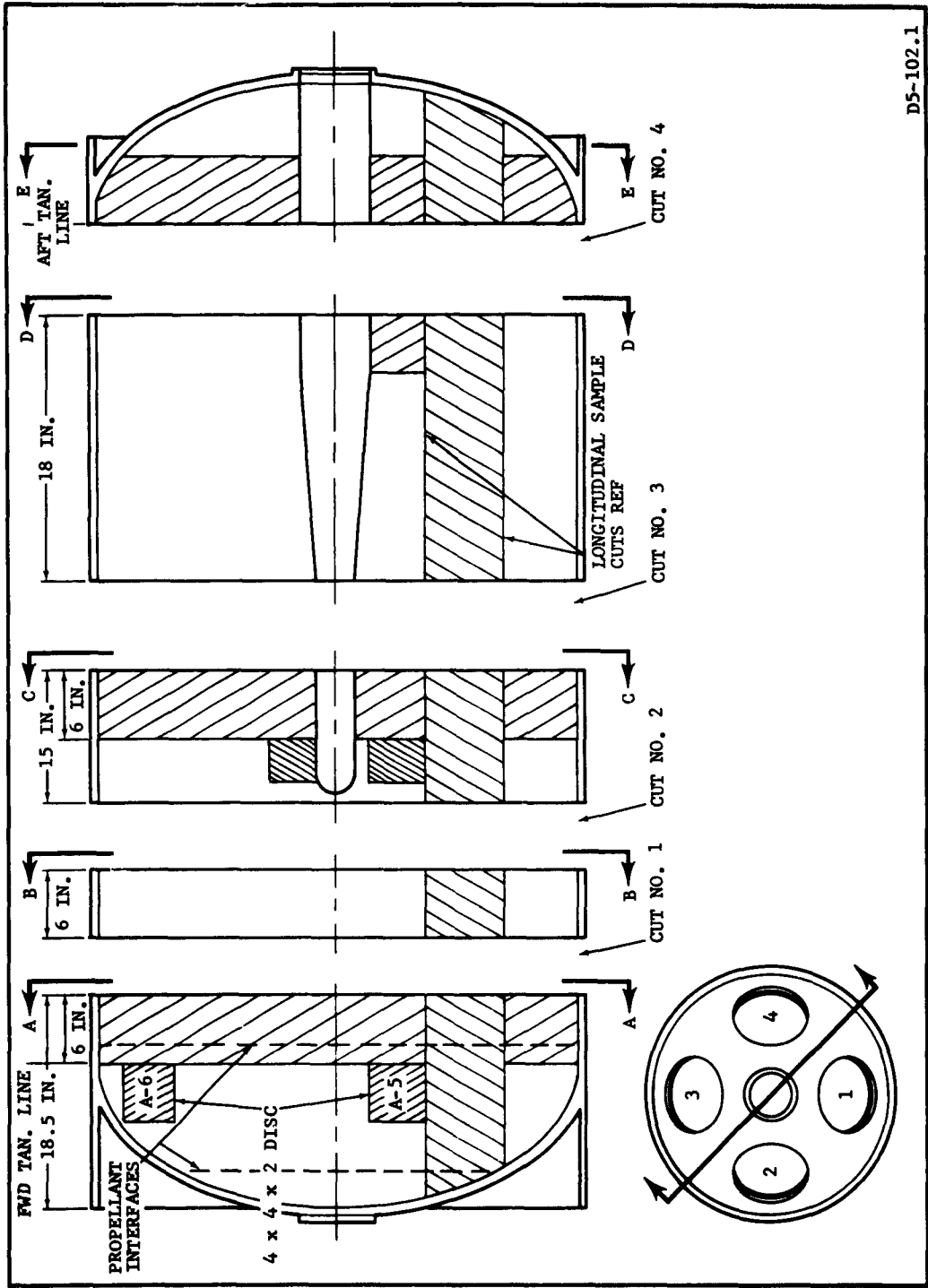
The data from the six disc locations within a motor will be analyzed to determine whether there is a difference among motors and among locations within motors for the dynamic properties of the propellant. Where significant differences are detected, their magnitude will be calculated and presented.

#### 5. Case-bond Samples

Case-bond samples will be tested for tensile strength in accordance with Method 6 as outlined in Section III of the Bacchus Laboratory Procedures Manual. In addition, photographs will be taken of the case bond samples after the tensile strength pull test to provide a record of the mode of failure of each sample. The photographs will contain a view of the two "break" surfaces of each sample placed side-by-side plus views of any other partial breakage caused by the pull.

The case-bond samples will be analyzed to determine whether there is a difference in case-bond tensile strength from motor-to-motor and whether there is a difference circumferentially within each motor. Furthermore, samples will be analyzed to determine if there is a difference in case-bond samples from failure mode to failure mode. Where idiosyncrasies exist, their magnitude will be analyzed.

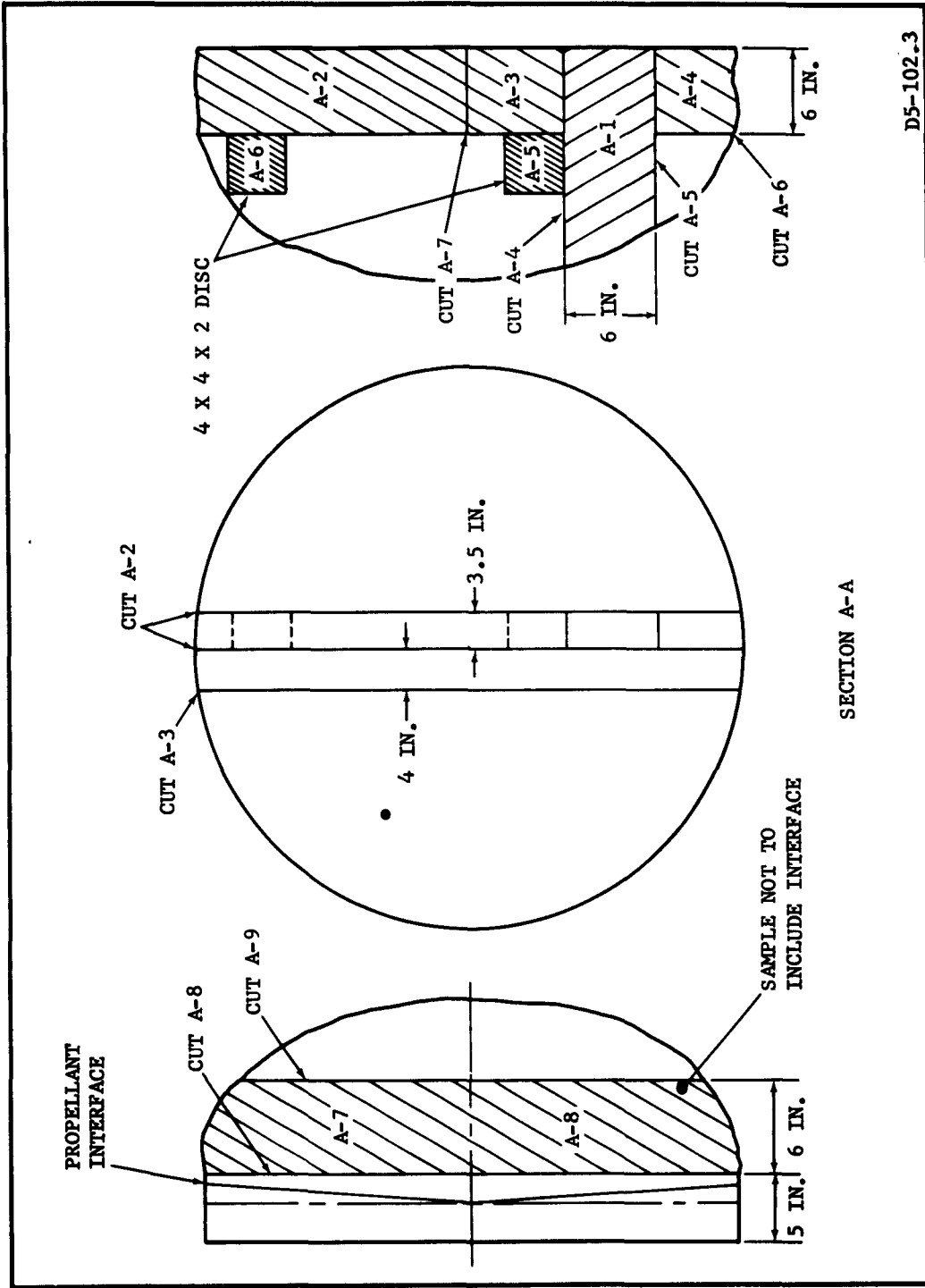
The bond strength of the propellant to shrinkage liner shall be determined as described in the Bacchus Laboratory Procedures Manual, Section III, Method 6.



D5-102.1

Figure 1. Full Scale Motor Case Cut into Sections "A" thru "E"

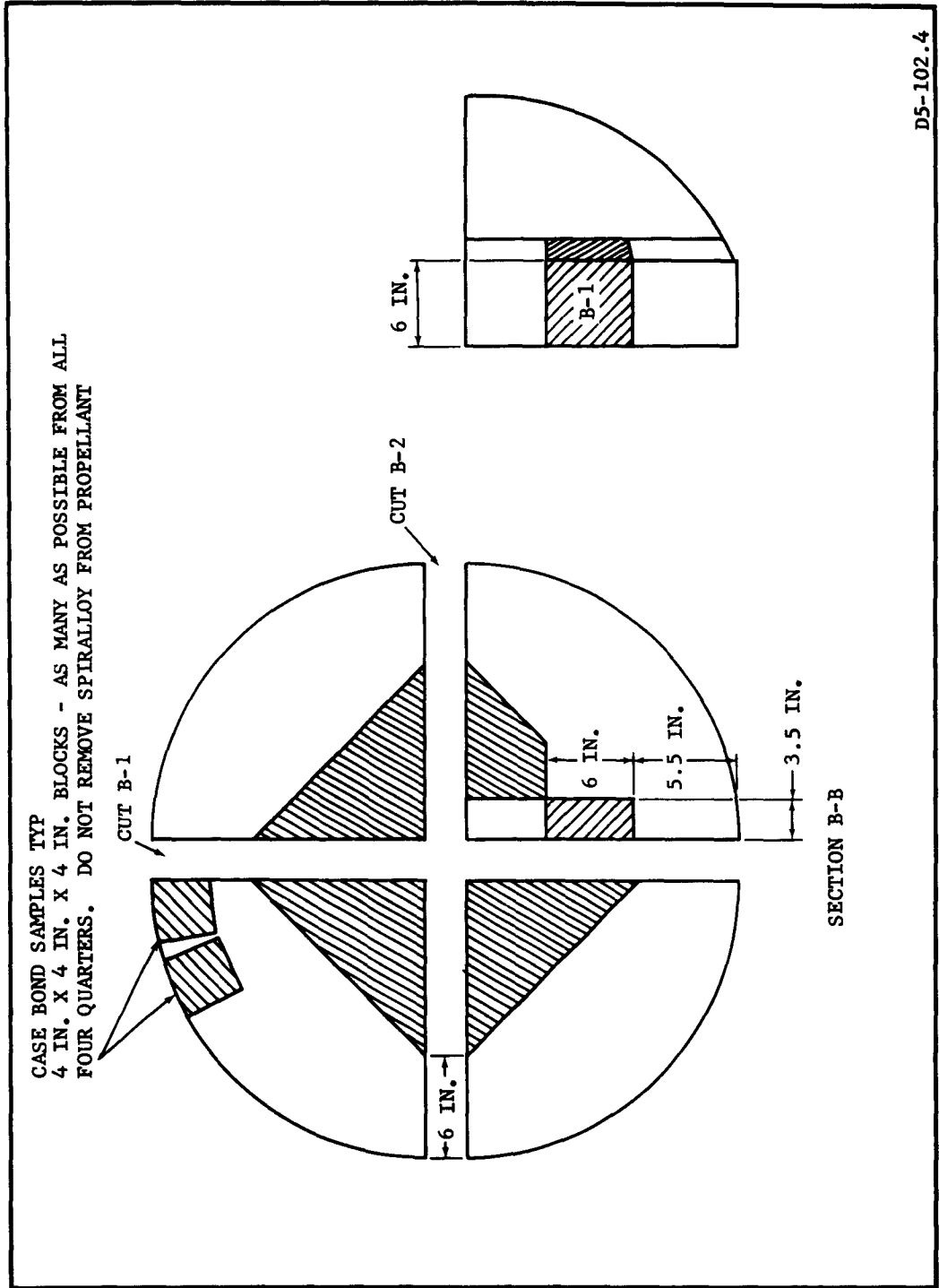




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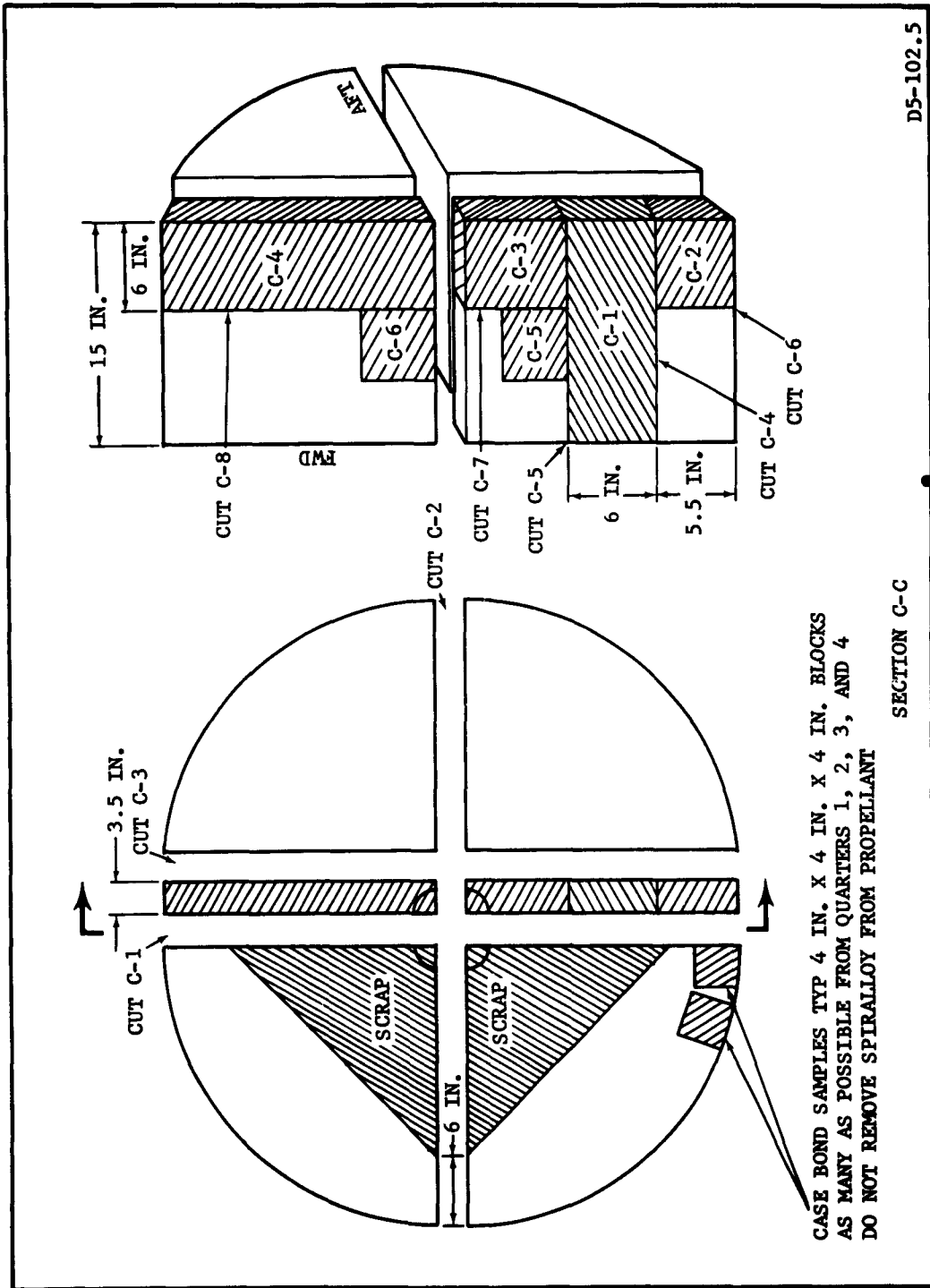
Figure 3. Section Cut "A" and Samples

CASE BOND SAMPLES TYP  
 4 IN. X 4 IN. X 4 IN. BLOCKS - AS MANY AS POSSIBLE FROM ALL  
 FOUR QUARTERS. DO NOT REMOVE SPIRALLOY FROM PROPELLANT



D5-102.4

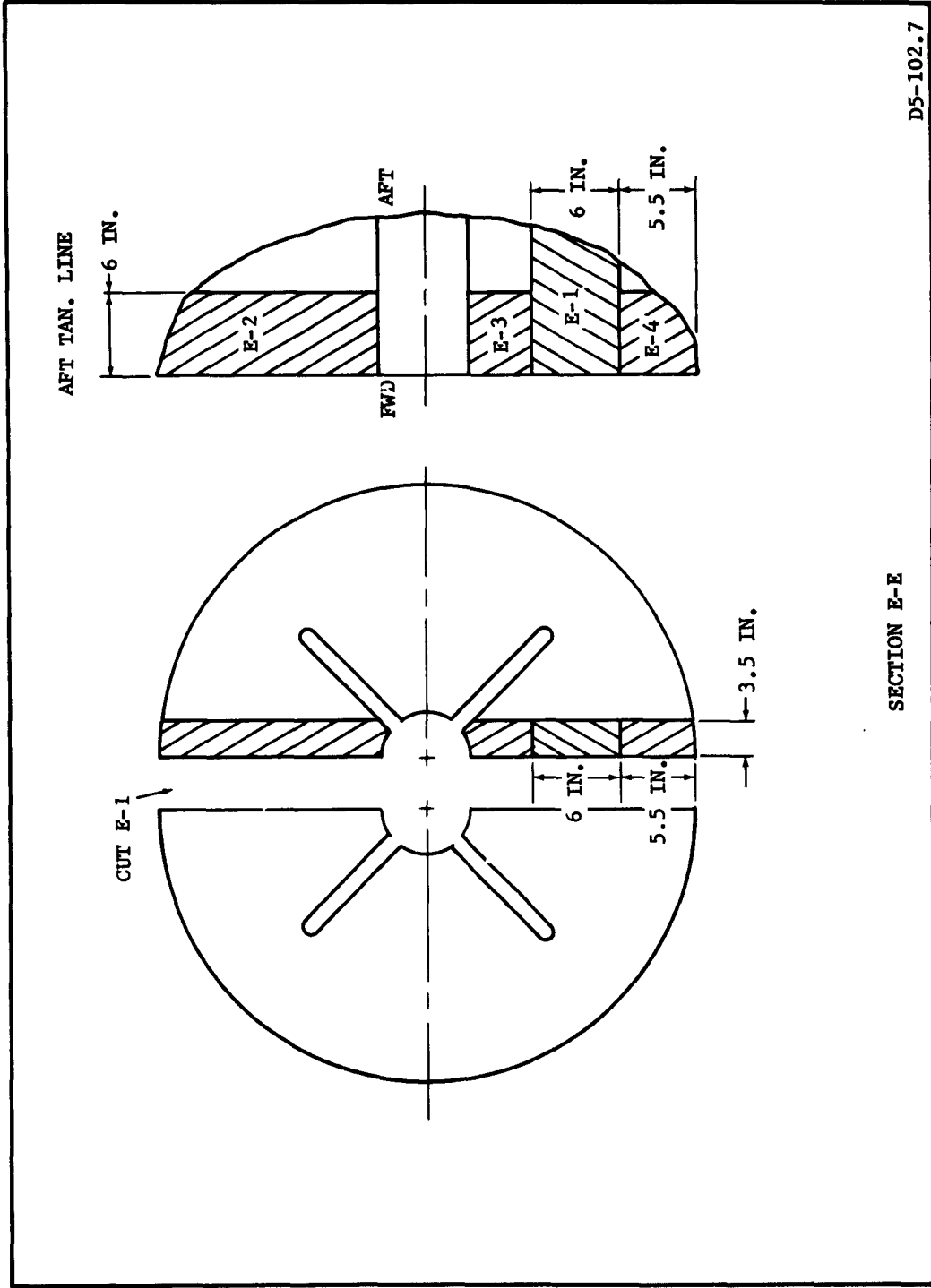
Figure 4. Section Cut "B" and Samples



D5-102.5

Figure 5. Section Cut "C" and Samples





D5-102.7

SECTION E-E

Figure 7. Section Cut "E" and Samples



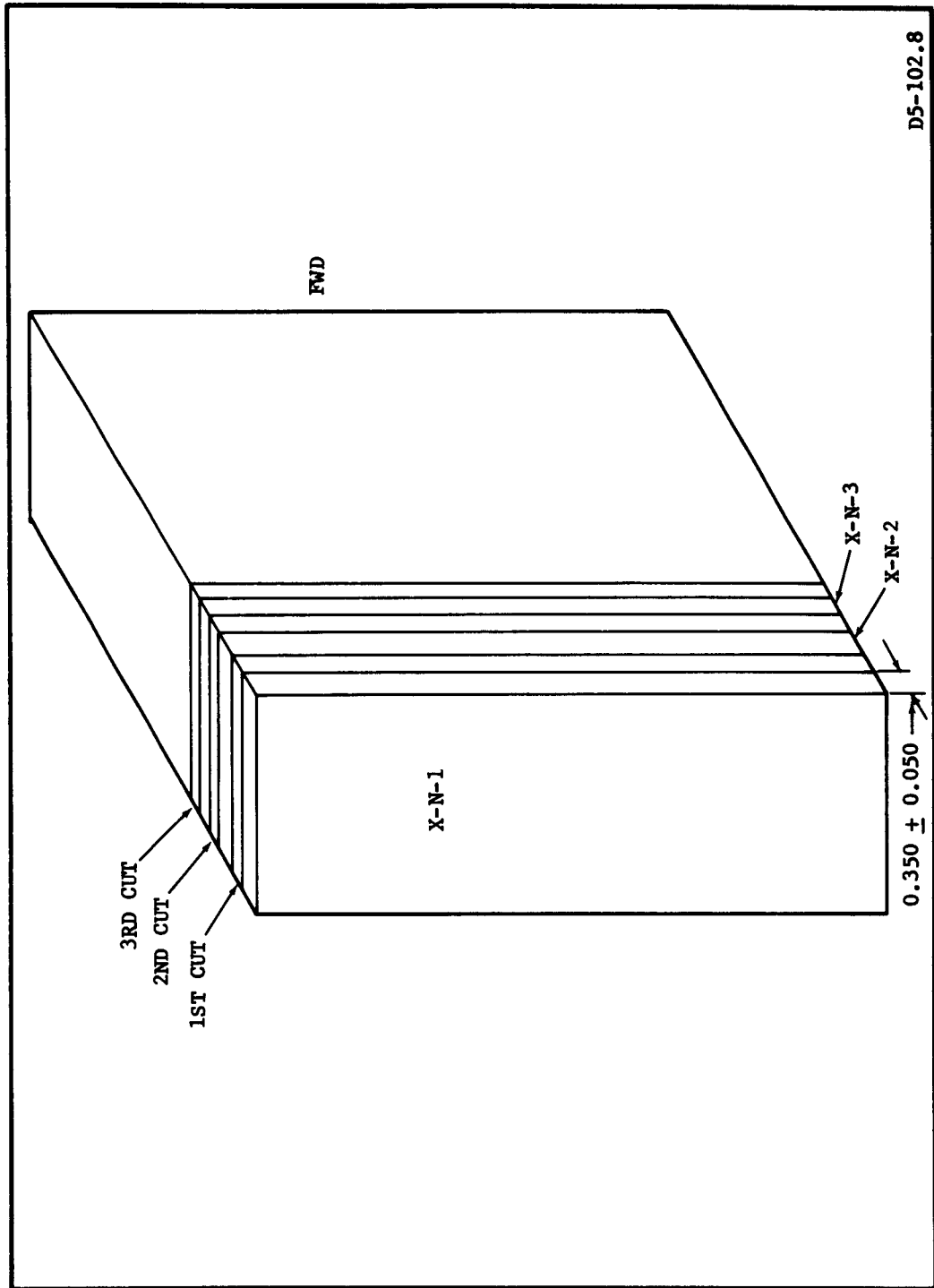


Figure 8. Aft to Forward Samples

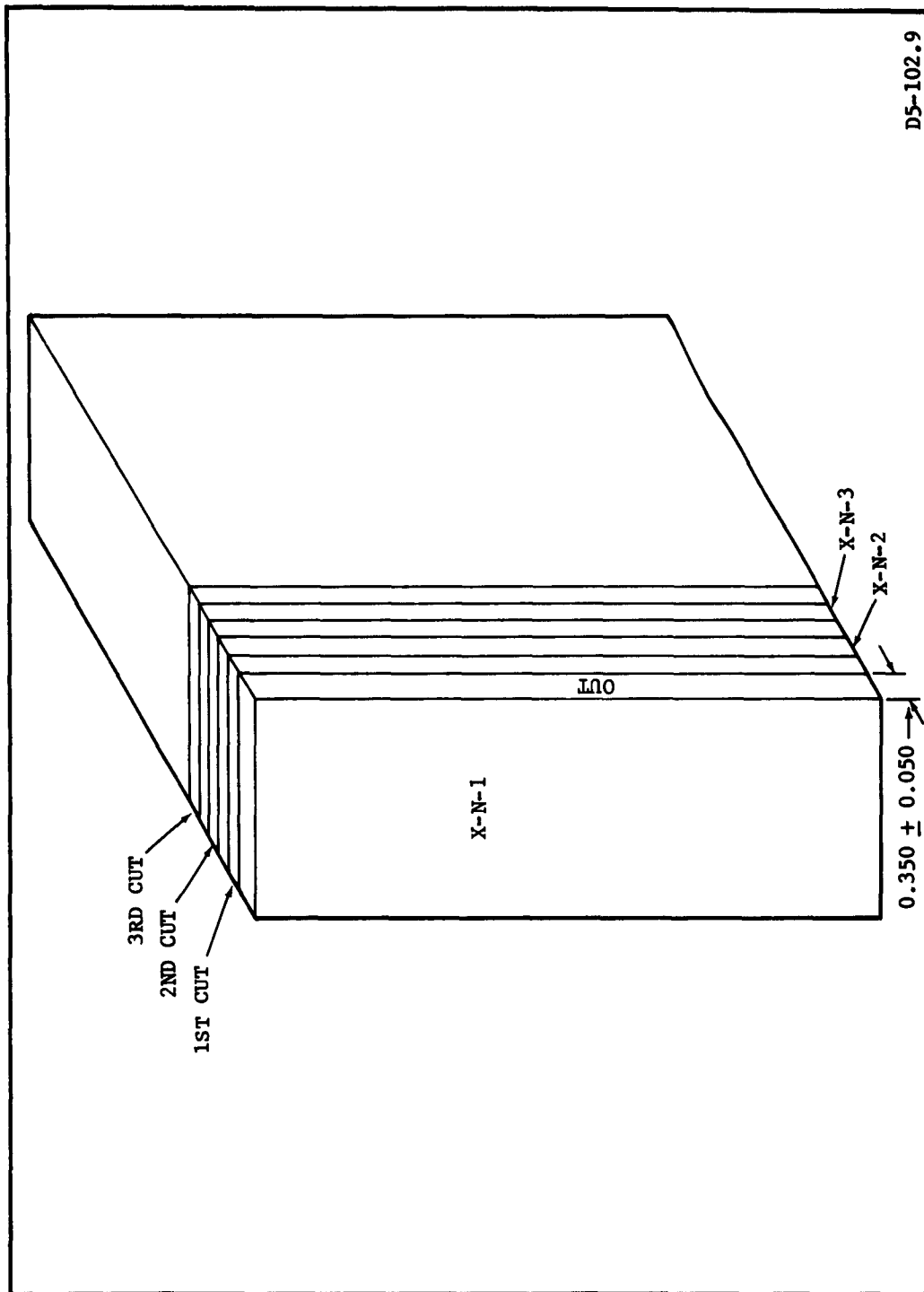
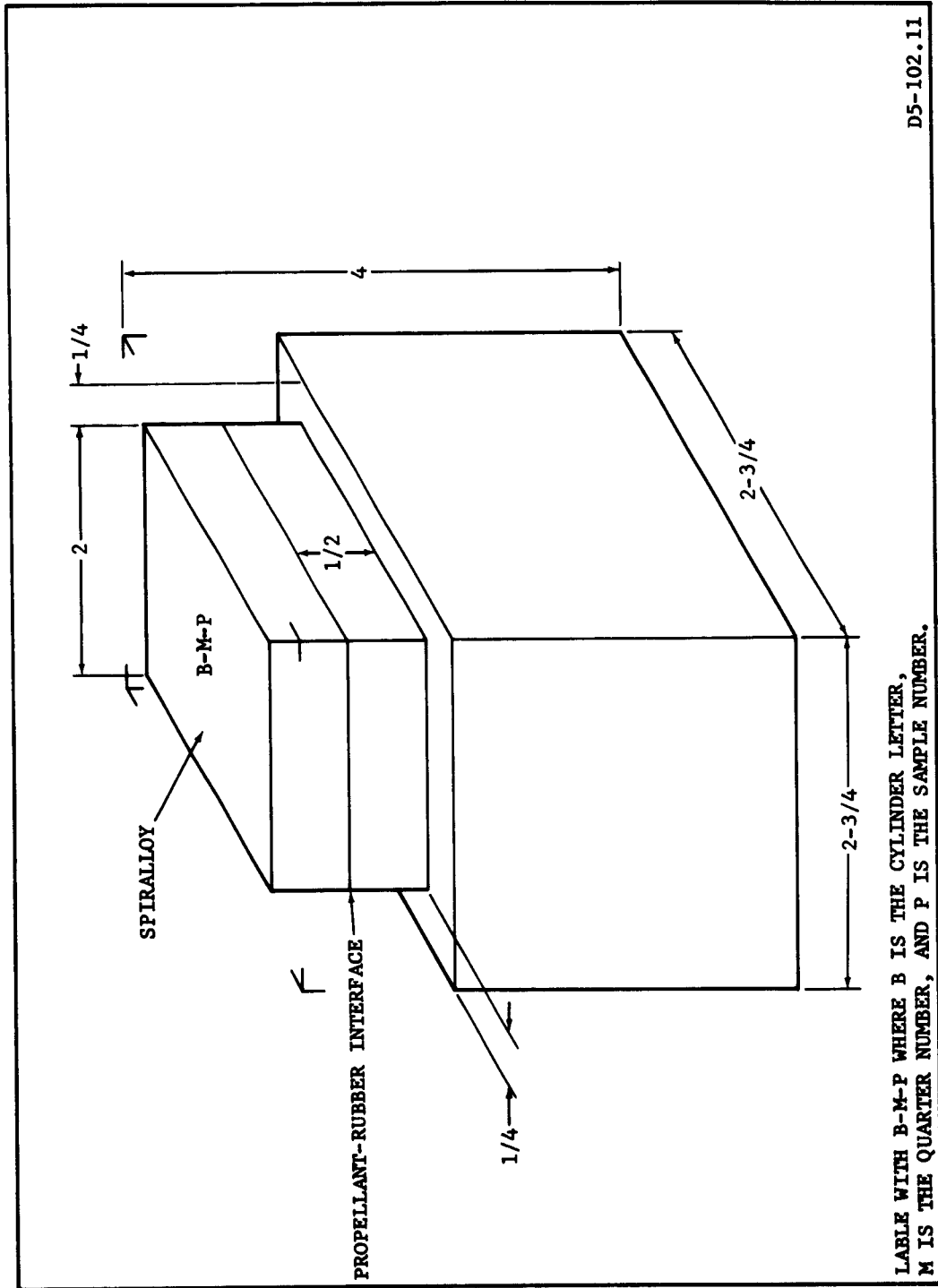


Figure 9. Out to In Samples

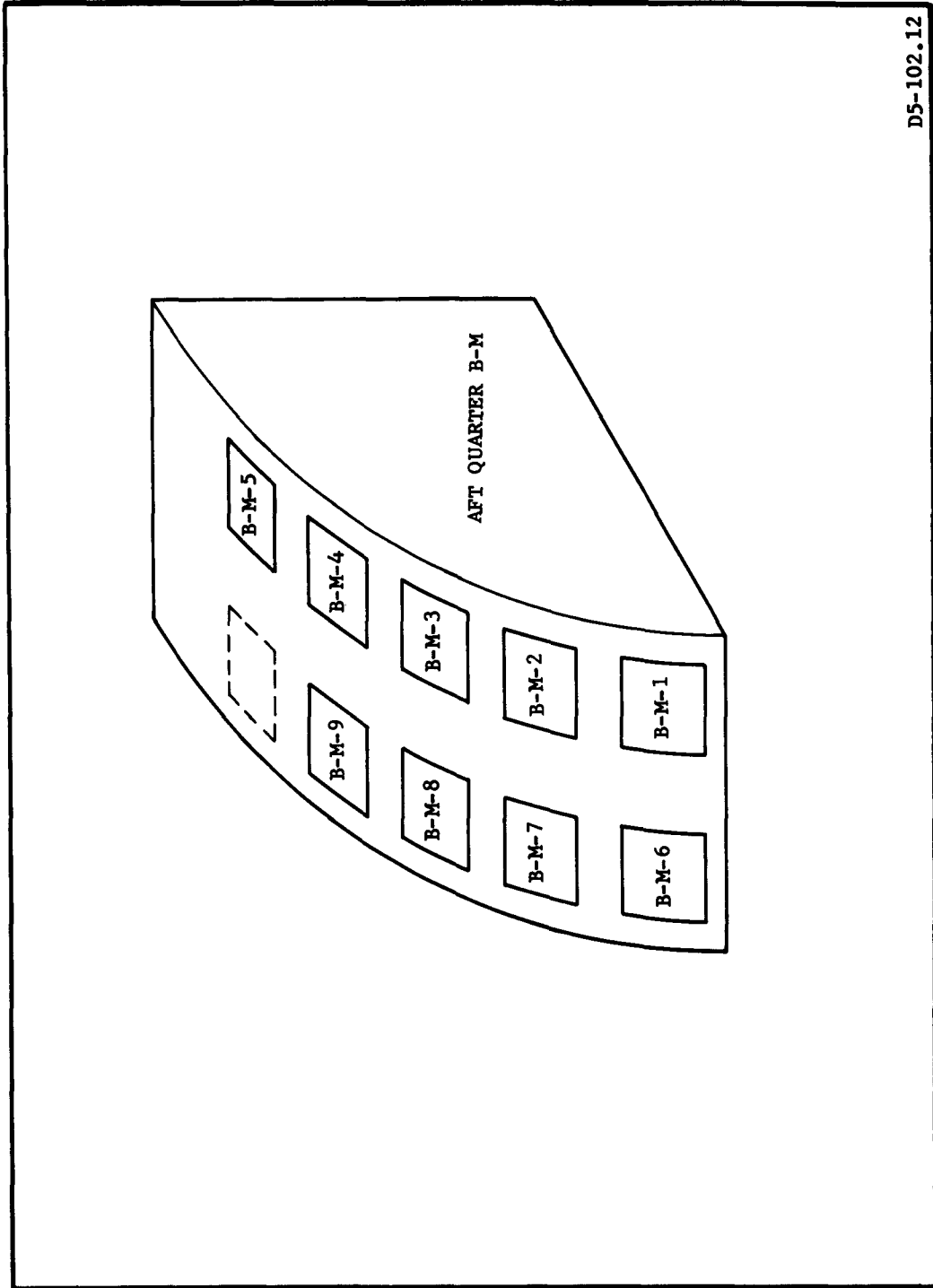




D5-102.11

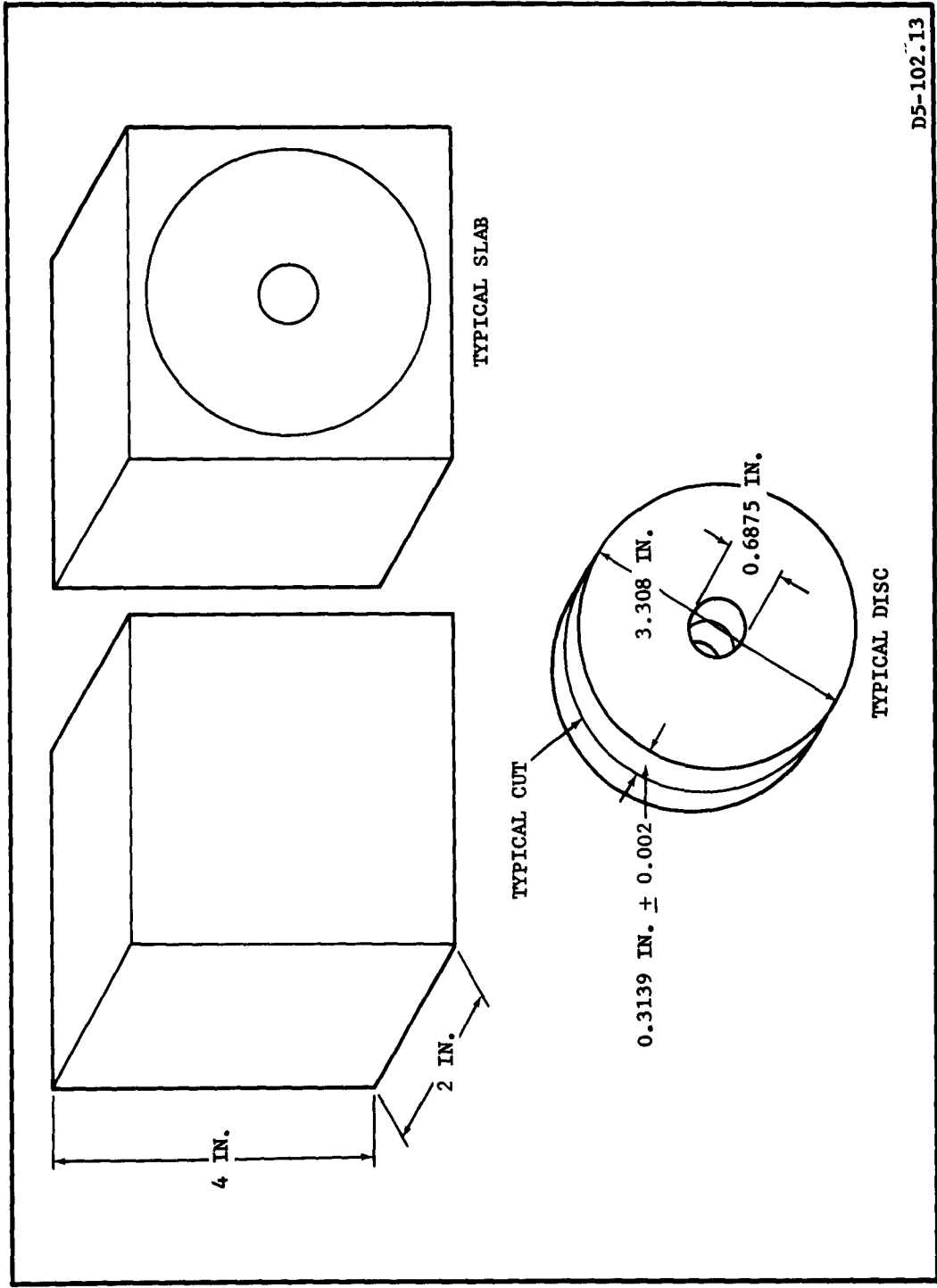
TABLE WITH B-M-P WHERE B IS THE CYLINDER LETTER,  
M IS THE QUARTER NUMBER, AND P IS THE SAMPLE NUMBER.

Figure 11. Case-Bond Samples



D5-102.12

Figure 12. Aft Quarter "B-M" Case Bond Samples



D5-102.13

Figure 13. Disc Sample

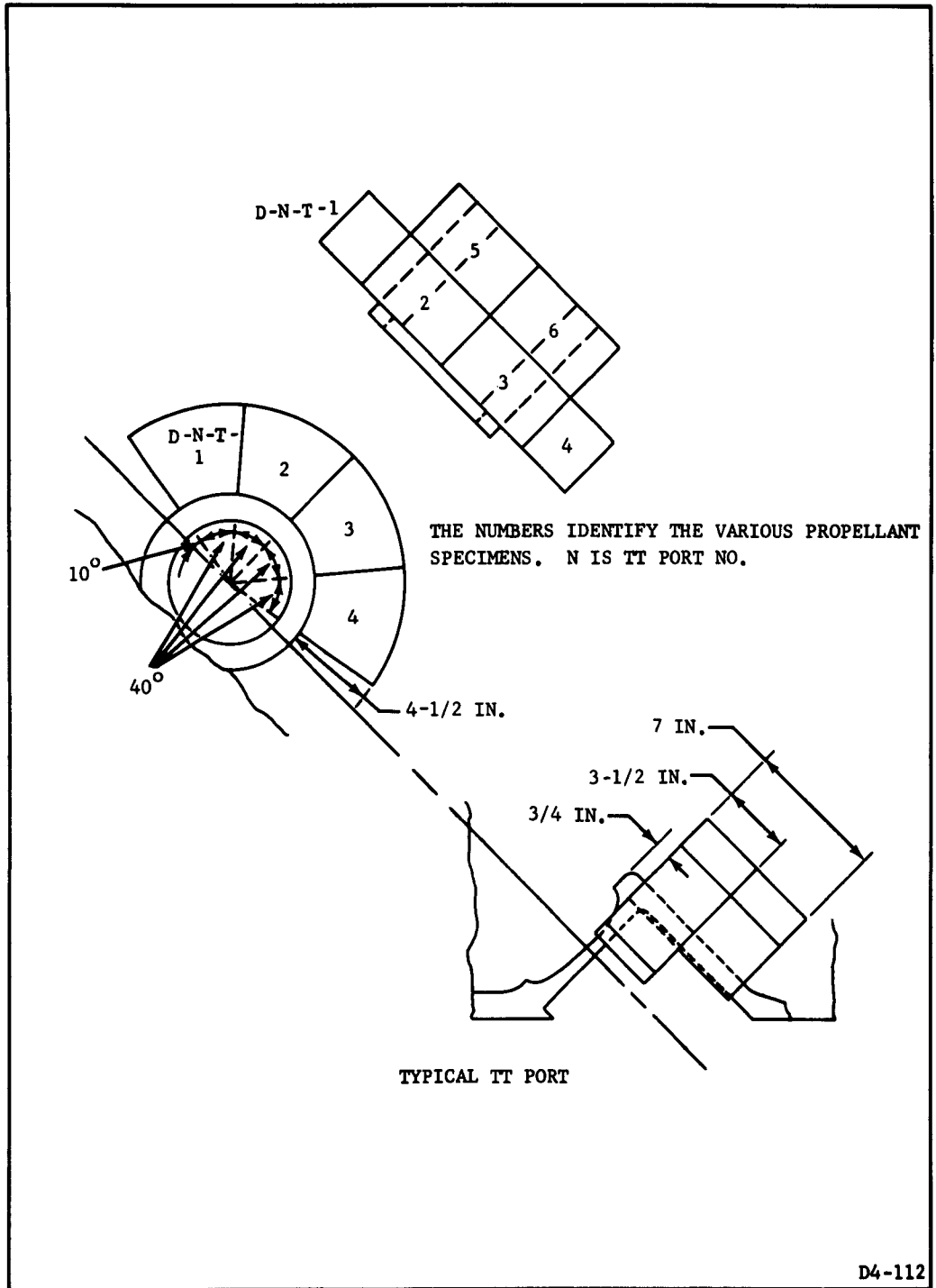


Figure 14. Specimen Location TT Port Area

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MTO-162-164

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