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SAMSO TR 69-213 VOL. V

CLOSURE ANALYSIS AND TEST STUDY
VOLUME V

SUBSCALE OPERATING TEST REPORT

APPENDIX 3

TECHNICAL REPORT NO. [illegible]

31 JULY 1969

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THE RALPH M. PARSONS COMPANY
ENGINEERS-CONSTRUCTORS
LOS ANGELES
NEW YORK

SAMSO TR 69-213 VOL. V

CLOSURE ANALYSIS AND TEST STUDY
VOLUME V

SUBSCALE OPERATING TEST REPORT

APPENDIX 3

TECHNICAL REPORT NO. 4171-1

31 JULY 1969

Prepared for

DEPARTMENT OF THE AIR FORCE
SPACE AND MISSILE SYSTEMS ORGANIZATION
AIR FORCE SYSTEMS COMMAND
NORTON AIR FORCE BASE, CALIFORNIA

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THE RALPH M. PARSONS COMPANY

ENGINEERS-CONSTRUCTORS

PARSONS

LOS ANGELES
NEW YORK

FOREWORD

This final report, which is composed of Volumes I through VIII, contains the results of a research study conducted by The Ralph M. Parsons Company under the direction of John E. McCarney. The Ralph M. Parsons Company personnel making significant technical contribution to this effort include David M. Hopper, Philip R. Sands, Richard C. Mayer, and Philip Mannes.

The study was performed from 1 June 1967 to 31 July 1969 under Contract No. F04694-67-C-0105 for the Department of the Air Force, Space and Missile Systems Organization (AFSC), Norton Air Force Base, California 92409. The SAMSO project officers were Maj G. W. Barnes, Capt F. G. Harms, and 1st Lt H. S. Yoshioka. The Aerospace Corporation provided systems engineering and technical direction, with Warren Pfefferle acting as Technical Director.

This technical report has been reviewed and is approved.

Charles B. Totten
Acting Chief, Technology Section
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Project Officer, Technology Section
Facilities Development Branch

CLOSURE ANALYSIS AND TEST STUDY

INDEX OF VOLUMES

APPENDIX 3

SUBSCALE OPERATING TEST REPORT

ABSTRACT

This report covers the phase of the Closure Analysis and Test Study dealing with operating tests of subscale models of closure designs. Subscale tests investigating the functional operation of models of three different closure debris removal/actuator concepts were completed. These concepts were the Rise and Rotate, the Rise and Tilt, and the Single Hinge, which were selected from preliminary design studies of eleven concepts.

The investigation compared the operation of each concept under variable debris loads and conditions. From the tests performed, it is concluded that, except for frozen debris, the Rise and Rotate and the Single Hinge Concepts demonstrated satisfactory operation and debris handling capabilities and should be considered as candidates for further study and large-scale testing.

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1.0 INTRODUCTION

1.1 General Program Background

This report covers the phase of the Closure Analysis and Test Study dealing with operating tests of subscale models of closure designs. The tests involved the functional operation of models of three geometrically differing closure debris/removal/actuator concepts which were selected from preliminary design studies of eleven concepts. The three investigated in this report are the Rise and Rotate, the Rise and Tilt, and the Single Hinge Concepts. The investigation compared the operation of each concept under variable debris loads and conditions.

1.2 Program Objectives

The program objectives were to investigate, by the use of models, the important characteristics of the operation of the three closure concepts, to establish the relative operating effectiveness of the competing concepts, and to gain insight into full-scale operational problem areas. The investigation concentrated on the closure opening and the debris removal/exclusion mechanisms. The main objectives of the tests were:

- To determine whether or not the three concepts would operate as they had been designed.
- To evaluate the effects of incremental debris loading upon the concepts.
- To recommend a preferred concept for large-scale testing.

1.3 Success Criteria

A series of tests on a model was considered successful and complete if the following conditions were demonstrated:

- The concept could, or could not, operate successfully under simulations of post-attack conditions that can be expected to occur in full-scale operation.

. The debris removal/exclusion mechanism could, or could not, operate successfully under the debris conditions tested.

2.0 DESCRIPTION AND OPERATION OF EQUIPMENT

2.1 General

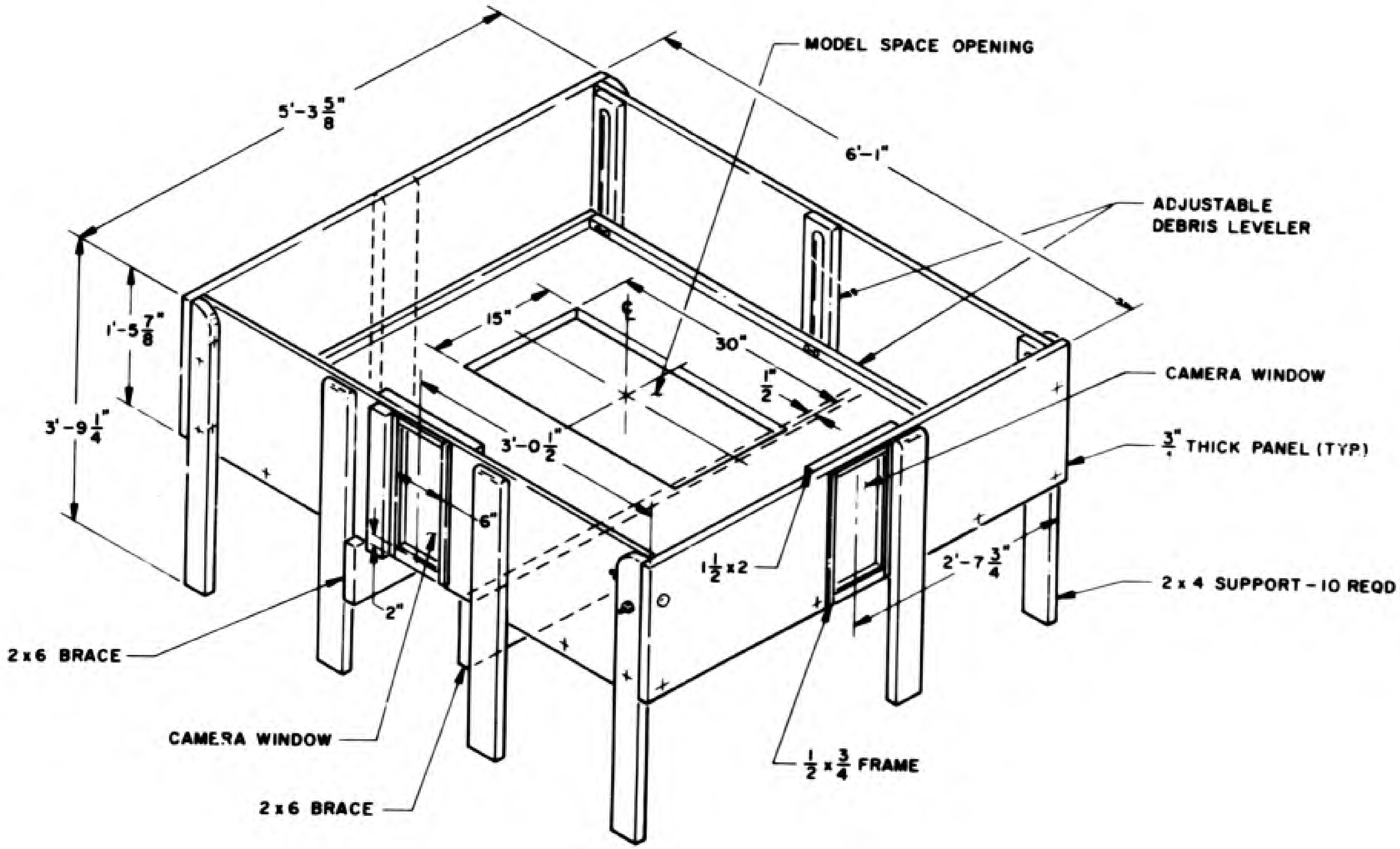
The test project was constrained to the extent that a full-size closure could be simulated by a model. A scale factor of 1/24 was selected for the subscale models of the first two concepts. The third closure model was an adaptation of the second model and accommodated an increase in size of the launch tube (from 15 feet clear span to 18 feet) called for in a change in the basic criteria. A scale factor of 1/30 resulted from this change.

The primary features of the actual designs that were modeled were the geometrical shape of the closure and the debris removal/exclusion method. No attempts were made to model the actual opening power source (hydraulic or gas-powered actuator) that might be used in a full-size closure.

During the test runs, the models were supported on beams, with the top surfaces flush with the floor of the test table (Figure 2-1). Walls surrounding the test table made it possible to run tests with debris depths up to 15 inches. Close-up motion pictures of the tests could be taken through two windows in the walls.

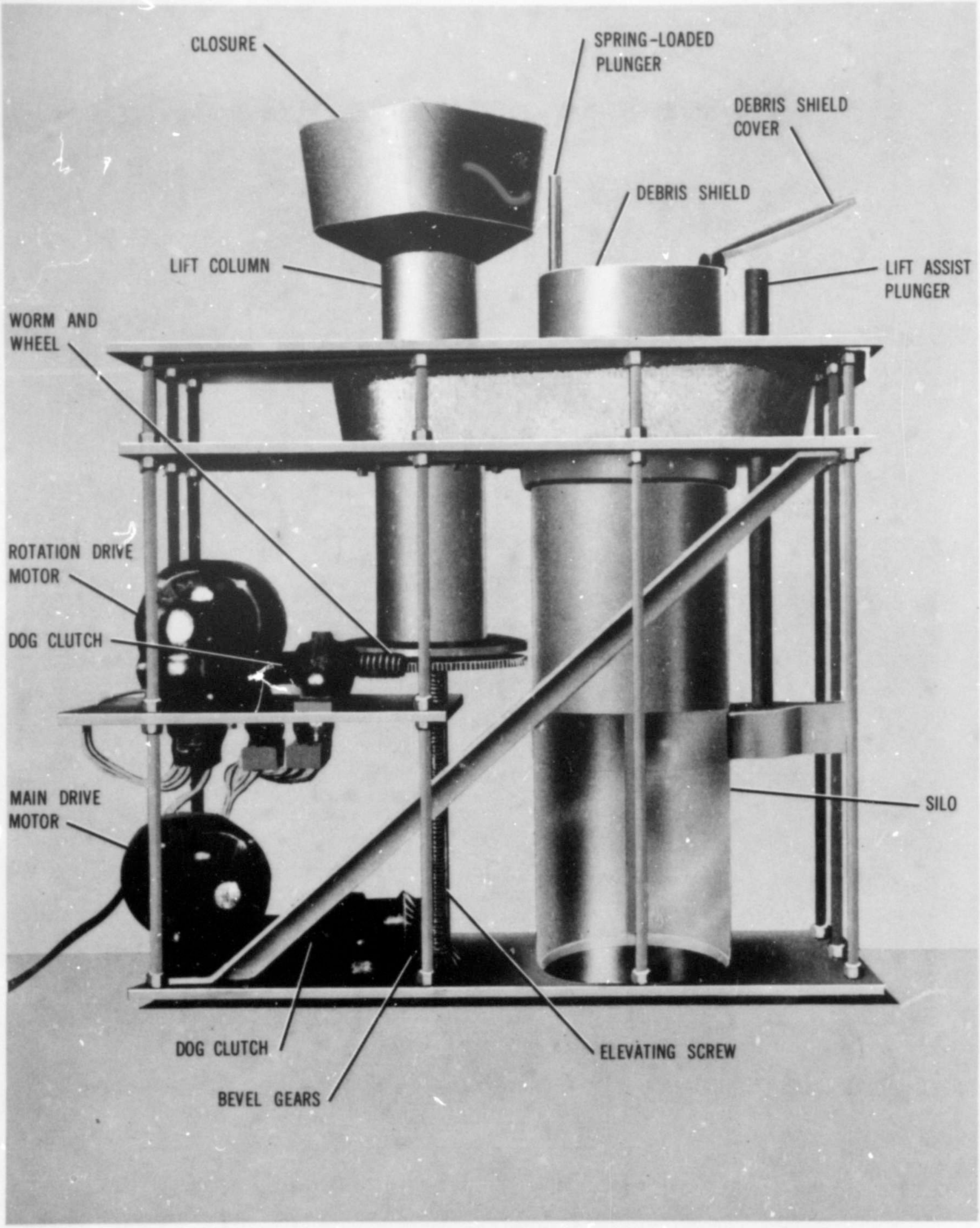
2.2 Rise and Rotate Concept

The model of the Rise and Rotate Concept was built as shown in Figure 2-2 and the main components (i.e., closure, lift column, debris shield, rotation mode drive train and assist cylinder) were represented. Power to raise the closure was furnished by a 1/8 horsepower gear motor driving an elevating screw



SUBSCALE OPERATING TEST - TEST TABLE

FIGURE 2-1



RISE AND ROTATE CONCEPT MODEL

FIGURE 2-2

through a clutch and a set of bevel gears. A spring plunger represented the assist cylinder. Another 1/8 horsepower gear motor was used to rotate the closure, driving through a dog clutch and a worm and wheel which engaged when the closure reached the upper limit of its vertical travel. The closure was designed to rotate through an angle of 85 degrees.

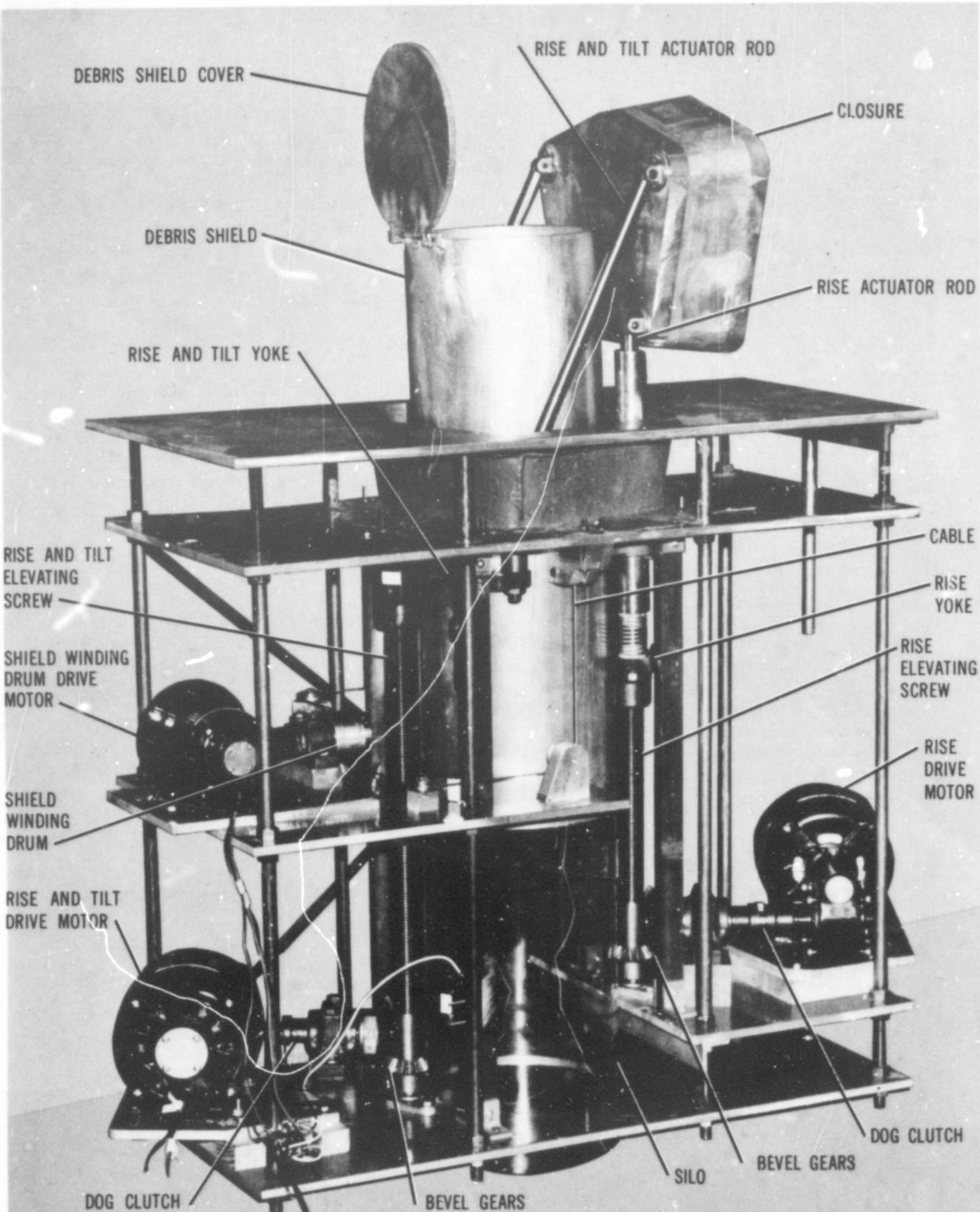
The debris shield was raised with the closure by means of a lug on the bottom of the closure which engaged with a tee-slot on the debris shield cover. When the debris shield reached its highest position, spring-loaded locks were engaged to retain the shield in the raised position during the rotation of the closure.

A spring-loaded plunger was fitted inside the debris shield to represent a stored-energy opening device. When the closure completed its 85 degrees of travel, the plunger released and the debris shield lid snapped open.

A removable insert was incorporated in the model to examine the effects of variations of the gap width between the closure and the surrounds.

2.3 Rise and Tilt Concept

The Rise and Tilt Concept model was built as shown in Figure 2-3, with all principal components represented. Power to raise the closure was supplied by two 1/8 horsepower motors, each driving an elevating screw as in the Rise and Rotate model. Unlike the previous model, the debris shield was raised independently by two cables and a drum driven by a 1/125 horsepower gear motor.



RISE AND TILT CONCEPT MODEL

FIGURE 2-3

The rise and tilt motion was sequenced into three distinct operations controlled by limit switches. In the first operation, all three gear motors worked in unison to raise the closure and the debris shield to a height of 7-3/4 inches. During the second operation, the 1/125 horsepower motor and one of the 1/8 horsepower motors were stopped, while the second 1/8 horsepower motor continued running until the closure was vertical. The third operation completed the sequence when the drum motor was restarted and the debris shield raised to its full height, at which time the cover was snapped open by a spring-loaded plunger.

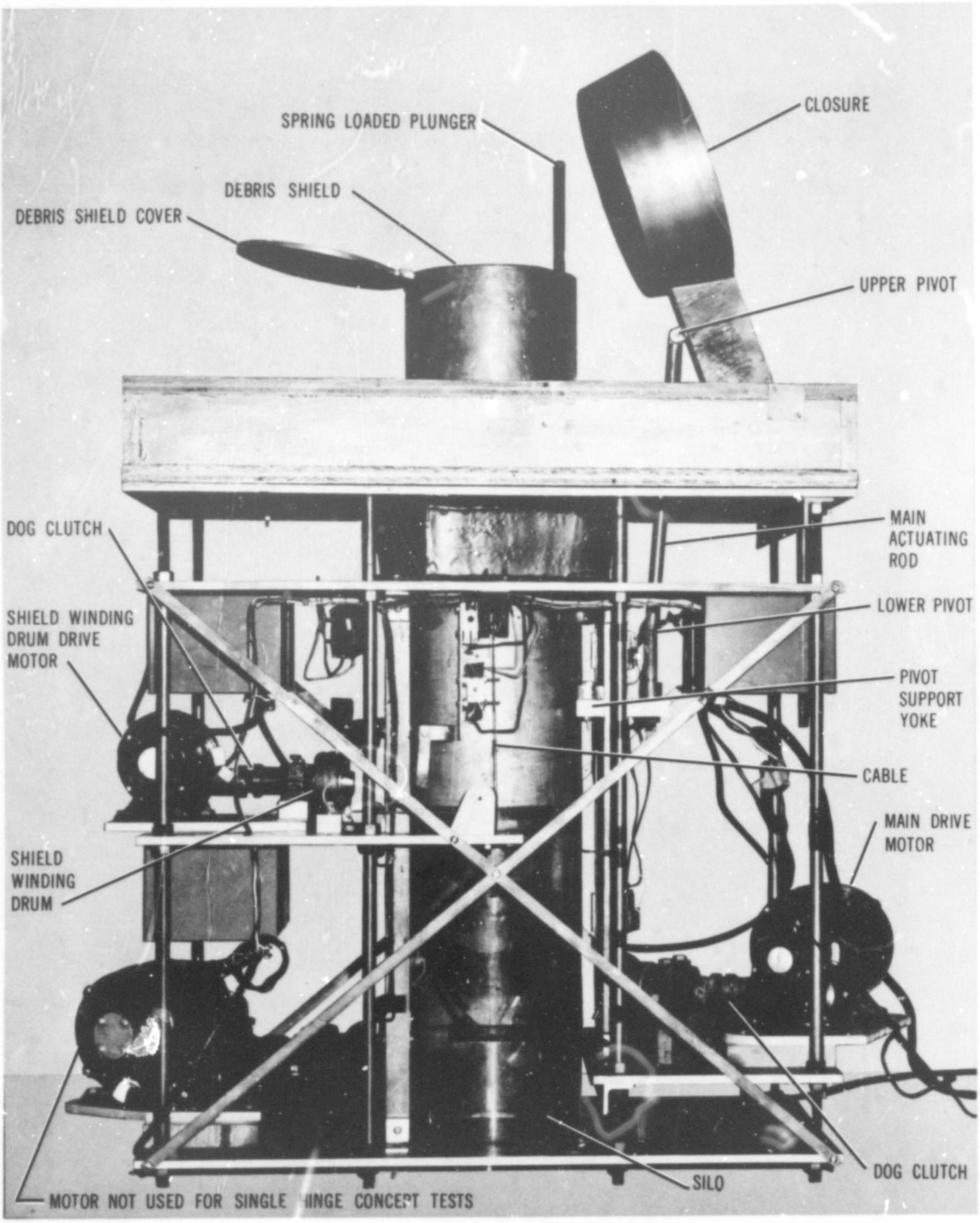
2.4 Single Hinge Concept

As shown in Figure 2-4, this model was incorporated into the basic mechanism originally assembled for the Rise and Tilt Concept. The drive mechanism was modified so that one of the 1/8 horsepower gear motors supplied the power to open the closure. Adjustments were made so that the debris shield operated in sequence with the closure.

The opening cycle commenced by starting the main drive motor, and a very short time later energizing the debris shield winding drum drive motor. The main motor shut off when the closure reached an angle of approximately 70 degrees with the horizontal; the shield motor shut off when the top of the debris shield reached a predetermined height. Originally, the height was 4.8 inches above the surface of the model, but was later increased to 5.8 inches. As in the previous tests, the debris cover snapped open at full height.

2.5 Instrumentation

To assist in the evaluation of the effects of incremental debris loading, power-time histories of the three concepts under different loading conditions were recorded by means of wattmeters.



SINGLE HINGE CONCEPT MODEL

FIGURE 2-4

The Rise and Rotate model was connected to a single recorder, as shown in Figure 2-5, as the motors operated sequentially. In addition to the wattmeters, the Rise and Rotate model was fitted with a displacement gauge to measure the vertical lift of the closure and a rotation gauge to measure its angular displacement.

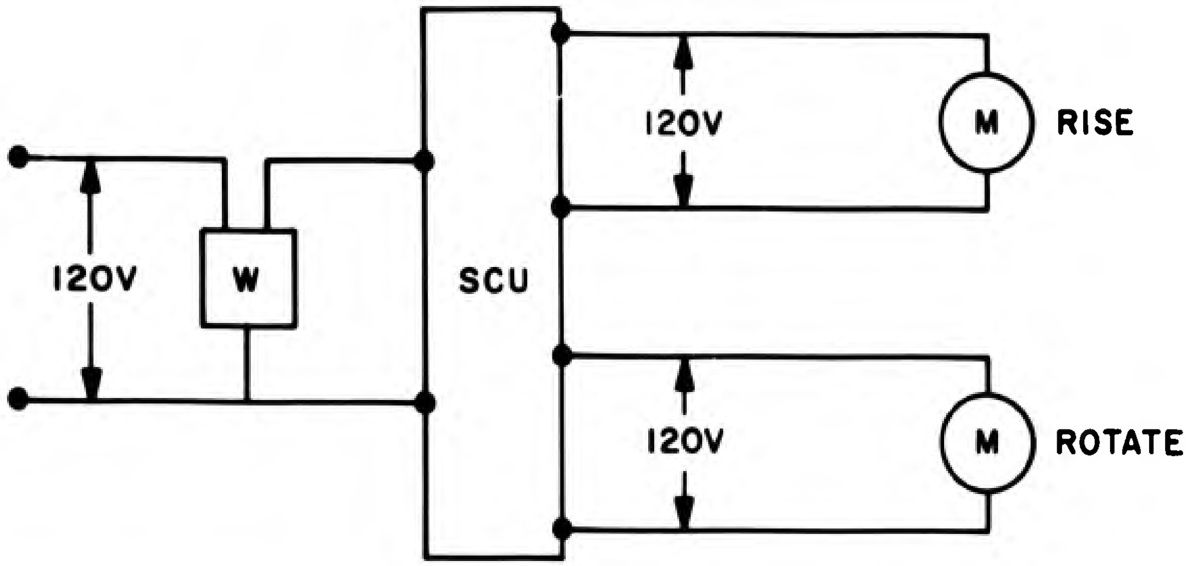
Because of the simultaneous operation of its three motors, the Rise and Tilt model had one recording wattmeter for each gear motor. The three wattmeters were connected as shown in Figure 2-6. No fixed gauges were used with this model, although the angle at which the closure came to rest was measured.

Figure 2-7 shows the wiring for the two wattmeters used in the Single Hinge Concept model tests. Two wattmeters were necessary since both motors operated simultaneously. As in the Rise and Tilt model tests, no fixed gauges were used, although the angle at which the closure came to rest was measured.

2.6 Test Procedure

The tests were performed to investigate the ability of the modeled closures to open as designed and to limit the intrusion of debris into the silo under simulated post-nuclear attack conditions. For each test run, all pertinent data was recorded on test data records (Figure 2-8), and power input versus time was recorded on strip charts as shown on Figure 2-9.

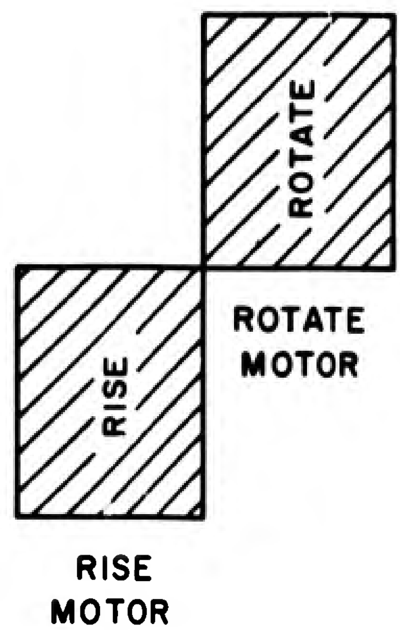
Simulated debris characteristics are given in Table 2-1 and test details are tabulated in Table 2-2. Initially, it was intended to perform a complete series of tests on the Rise and Tilt model. However, after a few tests with S3-100 dry sand, it became obvious that due to compaction of the debris against the edge of the closure, the model would not operate without modification of the operating geometry. Therefore, the tests were discontinued at a depth of 4 inches (see Table 2-2).



W – WATTMETER

M – MOTOR

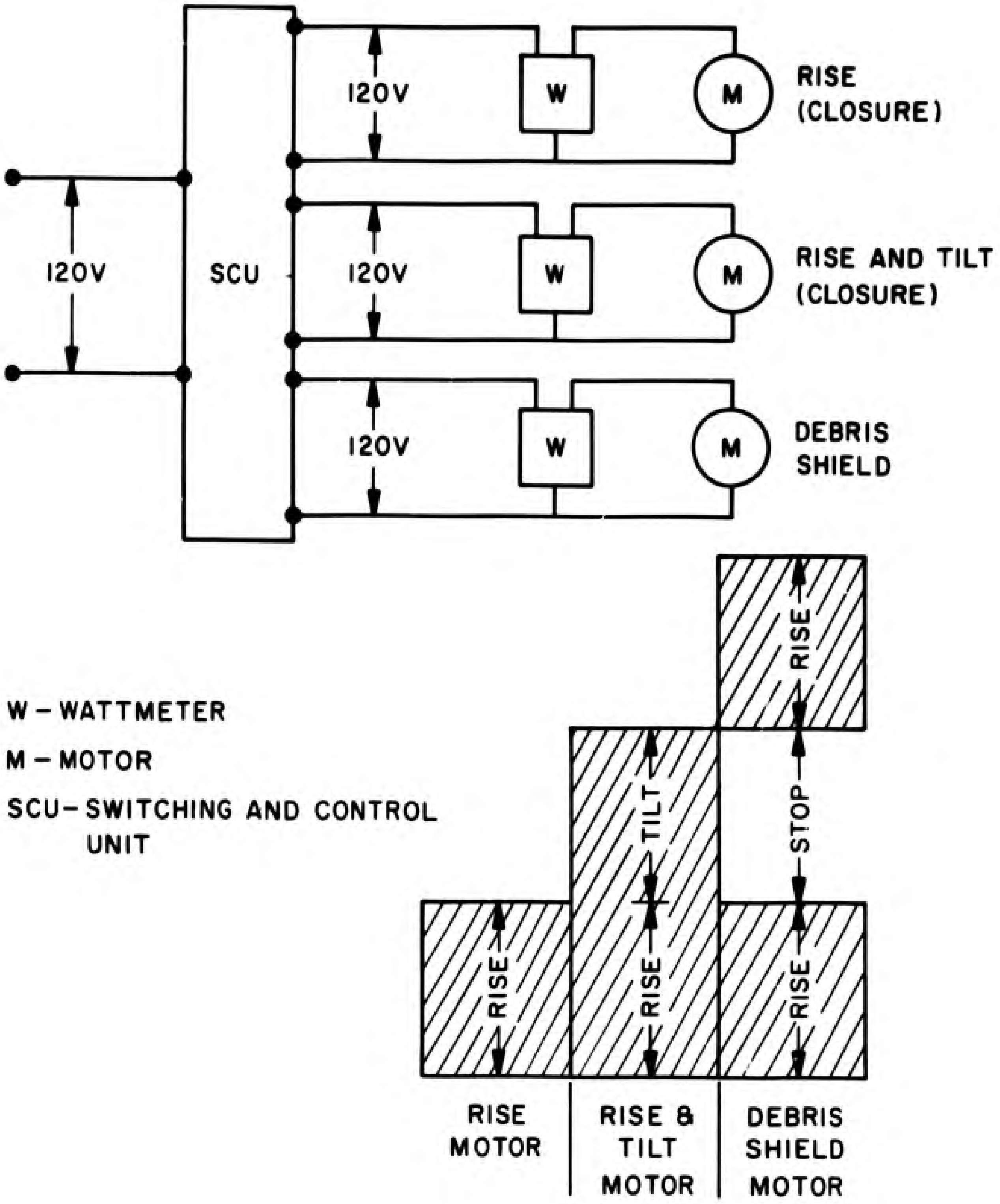
SCU – SWITCHING AND CONTROL UNIT



FUNCTION BLOCK DIAGRAM

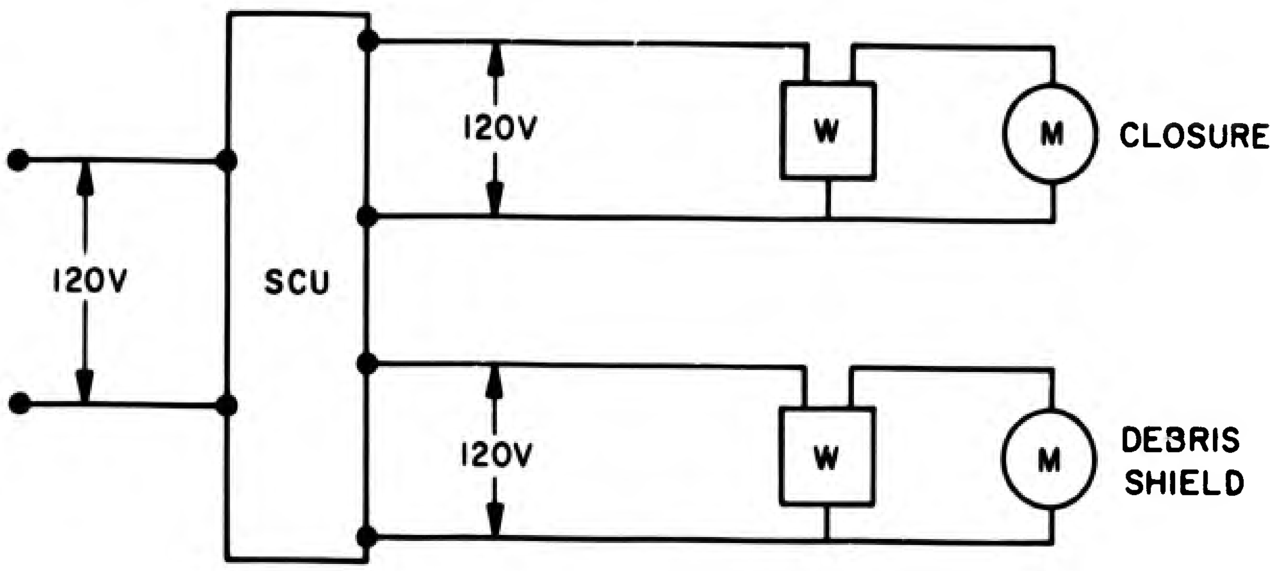
RISE AND ROTATE BLOCK DIAGRAM

FIGURE 2-5



RISE AND TILT BLOCK DIAGRAM

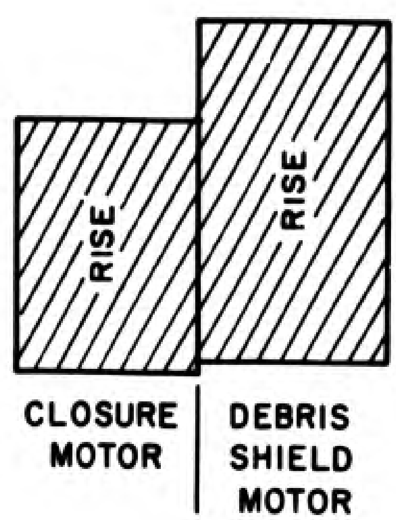
FIGURE 2-6



W- WATTMETER

M - MOTOR

SCU - SWITCHING AND CONTROL UNIT



FUNCTION BLOCK DIAGRAM

SINGLE HINGE BLOCK DIAGRAM

FIGURE 2-7

SUBSCALE OPERATING TEST

TEST DATA

DATE 4-12-68

TIME 1:35

TEST NO. 1-4

Test Series No. 1 Concept No. 3 - Rise and Rotate

Type of Debris Dry Sand 53-100 Debris Depth 4"

Film Record: ☐ Yes ☐ No Insert in Place: ☐ Yes ☐ No

Position:	Time (Seconds)	Height	Angle (Degrees)
Start Rise	1:04:00	12.0	-
Top of Rise	05:02	27.5	-
Start Rotation	05:03	27.5	0
End Rotation	05:22	-	88
Debris Reaches Equilibrium	04:52	-	-
Debris Shield Open	05:23	-	-

Power Input, Watts:

See Chart	Peak	Average
Rise		
Rotate		

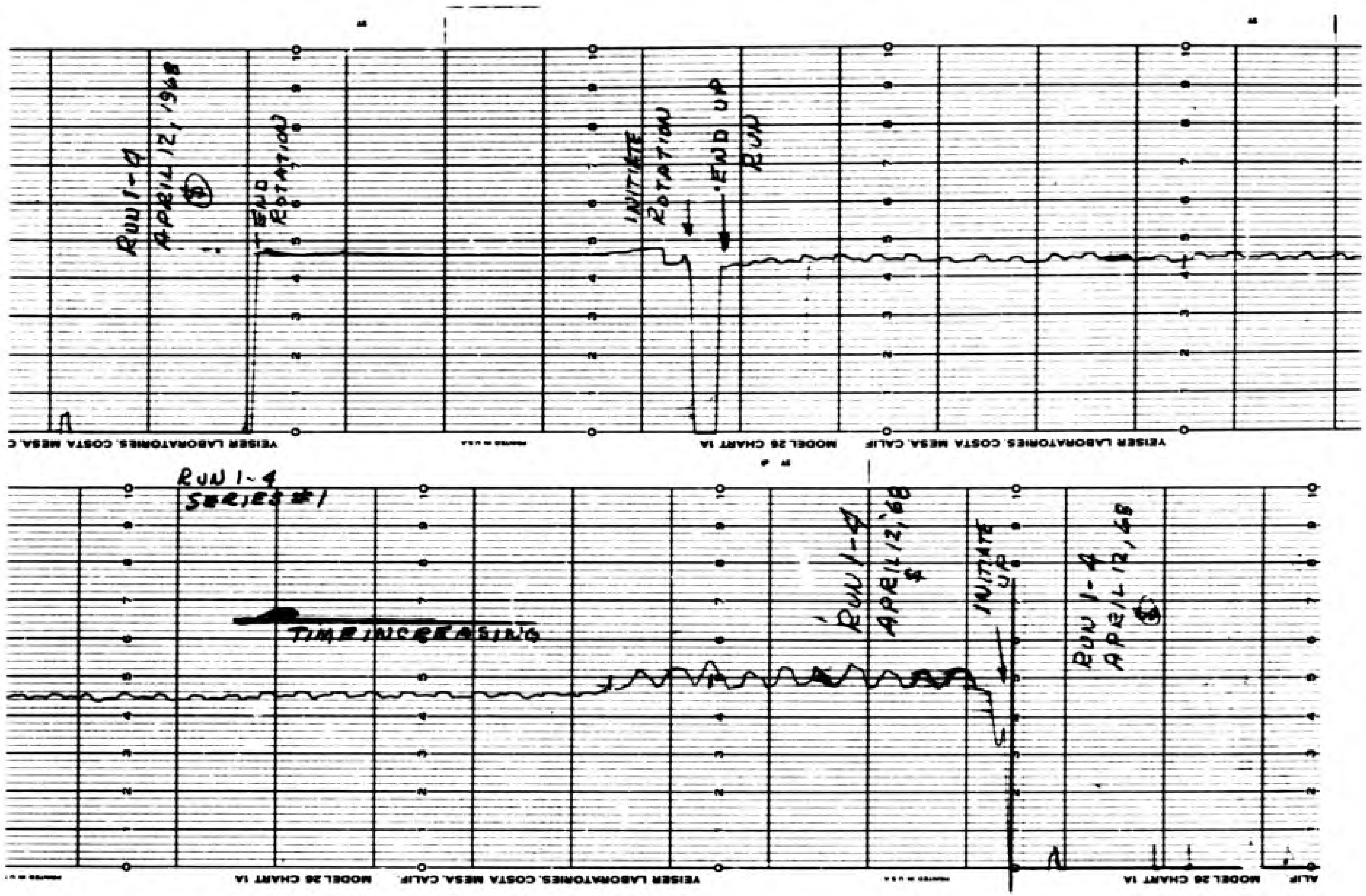
Debris Fallback: Weight Negative lbs.

Classification:

Passing Mesh Size	Percent

Remarks:

FIGURE 2-8 - TYPICAL TEST DATA RECORD



TEST SERIES NO. 1 - RISE AND ROTATE CONCEPT
RUN 1-4 - 4" DRY SAND

TYPICAL WATTMETER STRIP CHART

FIGURE 2-9

TABLE 2-1

SUBSCALE DEBRIS SPECIFICATION

Type of Debris	Mesh Size Minimum	Mesh Size Maximum
Sand (Dry)	#100	#4
Gravel (Dry)	# 20	3/8"
Sand/Gravel (Dry)	50/50 Mixture (by weight) of Above	
Sand (Wet)	#100	#4

The dry sand (S3-100) had the following composition:

Mesh Size	Passing
# 4	100 percent
# 10	25 percent - 75 percent
# 40	15 percent - 50 percent
# 80	5 percent - 20 percent
#100	0 percent - 5 percent

The dry gravel (S3-20) had the following composition:

Mesh Size	Passing
3/8"	100 percent
# 4	40 percent - 95 percent
#10	10 percent - 60 percent
#20	0 percent - 25 percent

TABLE 2-2

SUBSCALE OPERATING TEST DESCRIPTION

Test No.	Type of Debris	Debris Depth, inches	With 1-in. Removable Insert	Film Record	Remarks
Test Series No. 1 - Rise and Rotate - Concept No. 3					
1-0	-	0	X	-	Recorded for Each Test Run
1-1	Dry Sand	1	X	X	1. Power Input (Watts)
1-1a	"	1	-	X	a) Rise Motor
1-2	"	2	X	-	b) Rotate Motor
1-3	"	3	X	-	2. Elapsed Time (Seconds)
1-4	"	4	X	X	a) Rise
1-4a	"	4	-	X	b) Rotation
1-5	"	5	X	-	3. Closure Travel
1-6	"	7.5	X	-	a) Rise (Inches)
1-7	"	6	X	-	b) Rotation (Degrees)
					4. Debris Measurement
2-1	Dry Gravel	1	X	X	a) Around Closure Opening (Dimensioned Sketch)
2-1a	"	1	-	X	b) Fallback Weight (Lbs)
2-2	"	2	X	-	5. Anomalies
2-3	"	3	X	-	
2-4	"	4	X	X	
2-4a	"	4	-	X	
2-5	"	5	X	-	
2-6	"	7.5	X	-	
2-7	"	6	X	-	
3-1	Dry	1	X	X	
3-1a	50% Sand	1	-	X	
3-2	50% Gravel	2	X	-	
3-3	"	3	X	-	

TABLE 2-2 - SUBSCALE OPERATING TEST DESCRIPTION (CONTINUED)

Test No.	Type of Debris	Debris Depth, inches	With 1-in. Removable Insert	Film Record	Remarks
Test Series No. 1 - Rise and Rotate - Concept No. 3 (Continued)					
3-4	50% Gravel	4	X	X	
3-4a	"	4	-	X	
3-5	"	5	X	-	
3-6	"	6	X	-	
3-7	"	7.5	x	-	
4-6	Wet Sand	6	X	X	Composition: Dry Sand S3-100 Plus 15% Water by Weight
Special Tests					
3-5a (1st Run)	Boulders	5	X	X	Composition: 50% S3-20 Gravel 50% S3-100 Sand Mixture Plus 7 Ea. 5" Rocks 40 Ea. 2-1/2" Rocks 342 Ea. 1-1/2" Rocks
3-5a (2nd Run)	Boulders	5	X	X	Composition: As 3-5a (1st Run)
1-1	Frozen	1	X	-	Composition: Test Table Filled to 1" Depth S3-100 Sand 2 Gallons of Water Added 10 Ea. #5 Slabs Dry Ice Used to Freeze Mixture
1 - 3/8 (1st Run)	Frozen	3/8	X	-	Composition: S3-100 Dry Sand Plus 15% Water by Weight

TABLE 2-2 - SUBSCALE OPERATING TEST DESCRIPTION (CONTINUED)

Test No.	Type of Debris	Debris Depth, inches	With 1-in. Removable Insert	Film Record	Remarks
Test Series No. 1 - Rise and Rotate - Concept No. 3 (Continued)					
Special Test (Continued)					
1 - 3/8 (2nd Run)	Frozen	3/8	X	X	Composition: S3-100 Dry Sand Plus 15% Water by Weight
Test Series No. 2 - Rise and Tilt - Concept No. 10					
1-0	-	0		-	Recorded for Each Test Run 1. Power Input (Watts) a) Lift Actuator Motor b) Tilt Actuator Motor c) Shield Actuator Motor 2. Travel a) Closure Tilt (Degrees) 3. Debris Measurement a) Around Closure Opening (Dimensioned Sketch) b) Fallback Weight (Lbs) 4. Anomalies
1-2	Dry Sand	2		-	
1-3	"	3		-	
1-4	"	4		X	

TABLE 2-2 - SUBSCALE OPERATING TEST DESCRIPTION (CONTINUED)

Test No.	Type of Debris	Debris Depth, inches	With 1-in. Removable Insert	Film Record	Remarks
Test Series No. 3 - Single Hinge - Concept No. 11					
1-0	-	0		-	Recorded for Each Test Run 1. Power Input (Watts) a) Raise Actuatcr Motor b) Shield Actuator Motor 2. Travel a) Closure Tilt (Degrees) 3. Debris Measurement a) Around Closure Opening (Dimensioned Sketch) b) Fallback Weight (Lbs) 4. Anomalies
1-1	Dry Sand	0.8		-	
1-2	"	1.6		X	
1-3	"	2.4		-	
1-4	"	3.2		X	
1-5	"	4.0		-	
1-6	"	4.8		-	
1-7	"	6.0		X	

Because of time limitations, only one type of debris was used for testing the Single-Hinge Concept since, during earlier tests, only minor differences had been observed in the three types of debris. Dry sand was selected as providing representative test conditions. Four depths of debris up to 6 inches were tested (see Table 2-2).

Each model was allowed a wear-in period during which it was run a few times under no-load conditions and the wattmeters allowed to warm up. Additional no-load tests were made at various stages throughout the tests to check the effects of load on the models.

To preserve a visual record of the operation of each configuration, motion pictures were taken of selected runs in each series.

Debris configurations at the conclusion of each test run were recorded on sketches and, in certain cases, by still photographs.

2.7 Scale Factors

To determine proper scale factors relating the behavior of a subscale model to that of its full-scale counterpart, it is necessary to recognize the relationships listed below:

$$\text{Scale factor(S)} = \frac{\text{size of model structure}}{\text{size of full-scale structure}}$$

$$\text{Length (model)} = \text{length (full-scale)} \times S$$

$$\text{Area (model)} = \text{area (full-scale)} \times S^2$$

$$\text{Volume (model)} = \text{volume (full-scale)} \times S^3$$

The power scaling factor may be determined by simple dimensional analysis:

$$\text{Power} = \frac{\text{force x length}}{\text{time}}$$

Thus,

$$\text{Power (structure)} = \frac{\text{force (full-scale) x length (full-scale)}}{\text{time (full-scale)}}$$

$$= \frac{1/S^3 \text{ force (model) x } 1/S \text{ length (model)}}{\dfrac{\text{time (full-scale)}}{\text{time (model)}} \text{ x time (model)}}$$

If the opening time for the model and the structure are equivalent, we have the following power scaling relationship:

$$\text{Power (full-scale)} = 1/S^4 \text{ power (model)}$$

3.0 DISCUSSION AND TEST RESULTS

3.1 General

Considerable insight has been gained into the problems of designing a full-scale closure operating system capable of performing under the simulated post-attack debris environment. However, because of the small scale of the models, the test results are primarily qualitative rather than quantitative.

As expected, the wattmeter records showed an increase in power required to operate the models for each successive depth of debris. The effects of debris characteristics upon model performance are discussed in paragraph 3.5.

Test runs of the Rise and Rotate Concept demonstrated that less power was required to open the closure when the gap between the closure and its surrounds was increased from the nominal 0.040-inch width to a width of 1 inch.

Several problem areas encountered were common to all of the concepts tested; these are discussed below. Those problem areas peculiar to a specific configuration are detailed in subsequent sections of this report.

3.1.1 Debris Compaction

In the Rise and Tilt model tests, debris compaction, caused by the motion of the closure compressing debris into a confined space, significantly lessened the operating effectiveness of this model. However, with the Rise and Rotate and Single Hinge models, where the motion of the closure resulted in a lifting or plowing action through the debris, no serious interference developed.

3.1.2 Friction Effects

High frictional resistance was observed in those cases where sliding motion between parallel surfaces with small clearances occurred in the presence of debris. This problem was first encountered in an early test of the Rise and Rotate model when small debris particles entered the space between the debris shield and silo wall and prevented the shield from raising to the design level. As a result, the model design was revised to provide a seal between the debris shield and silo wall capable of preventing debris intrusion into this space. This design feature was later incorporated in the full-scale design.

3.1.3 Debris Intrusion

Debris intrusion was a related problem common to all design concepts. In addition to the jamming of the debris shield within the silo liner, problems were also encountered on the Rise and Rotate model with debris intrusion into the area between the assist cylinder and its rod, and between the debris shield and its cover. These problems were resolved either by providing, wherever possible, proper seals and gaskets rigidly supported to prevent debris intrusions or, in those instances where intrusion could not be prevented, by providing adequate clearance to allow the debris to fall or flow through the gap without appreciable tendency to jam.

3.1.4 Frozen Debris

Although tests with frozen debris were run with the Rise and Rotate model only, the problems encountered would be applicable to any configuration. It was found that, with the original test level of a 1-inch layer of frozen debris and the power available, the closure could not be raised.

During the second test run, the frozen debris level was reduced to 3/8 inch; however, the closure would not break away until the temperature of the frozen mass rose to 10°F and the lift drive was restarted repeatedly. As previously stated, the model power system was not sealed to the full-scale requirements; however, the tests clearly demonstrated the increase in breakaway force required for the frozen debris condition.

3.2 Rise and Rotate Concept

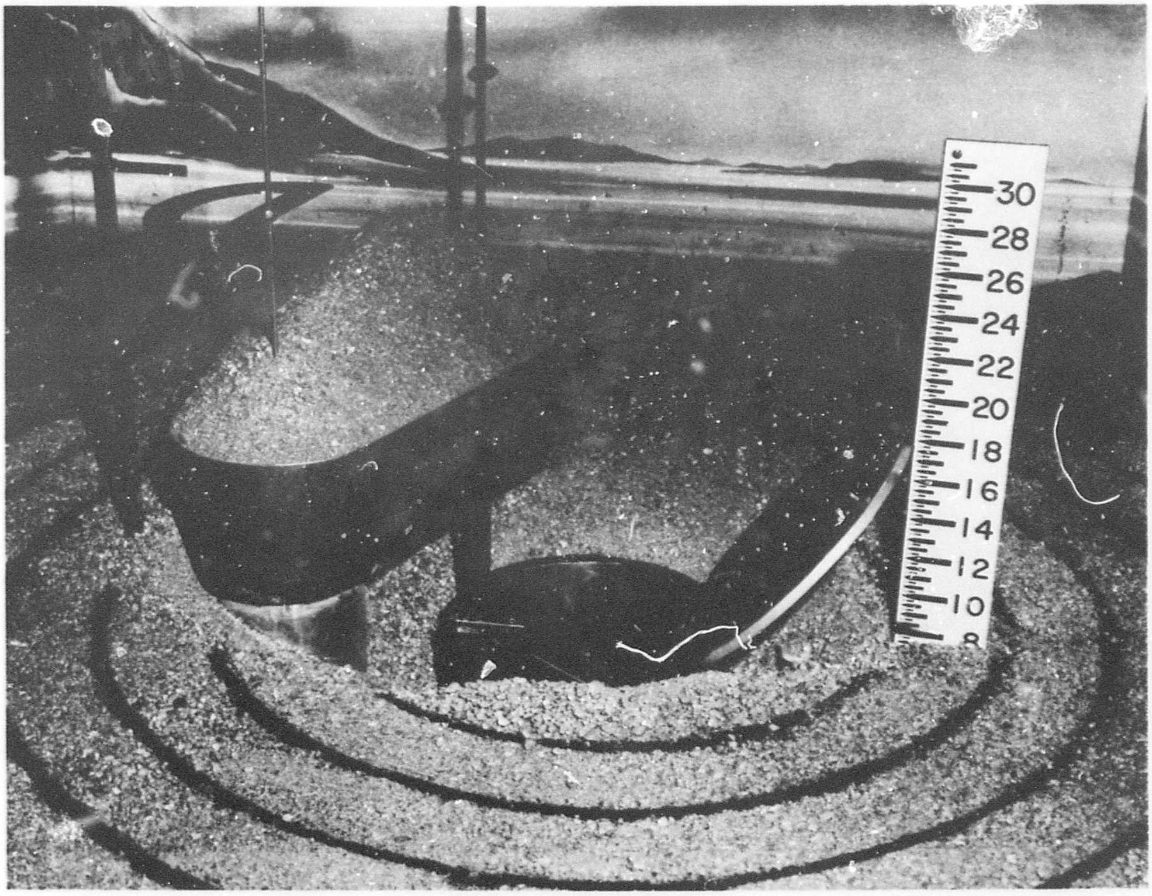
The Rise and Rotate Concept test runs were generally satisfactory and, except in the case of frozen debris, demonstrated the capability of the system to successfully manage varying levels of debris types, including dry sand, dry gravel, a mixture of equal parts of dry sand and gravel, a mixture of dry sand, gravel and rocks (simulating boulders), and wet sand. The accompanying illustrations (Figures 3-1 through 3-6) show the closure at the conclusion of test runs under each debris type.

Successively increasing depths of debris were applied to the closure to determine the upper limit of satisfactory operation. It was found that the model was sufficiently powered to effect the rise and rotation function to a debris depth of approximately 7-1/2 inches. However, the model was designed so that the debris shield was raised by means of an attachment to the underside of the closure rather than a separate shield lift drive, which limits the debris shield extension to the vertical travel of the closure. For this reason, at debris depths exceeding vertical closure travel, an excessive amount of debris flowed over the top of the shield into the silo.

3.2.1 Problem Areas

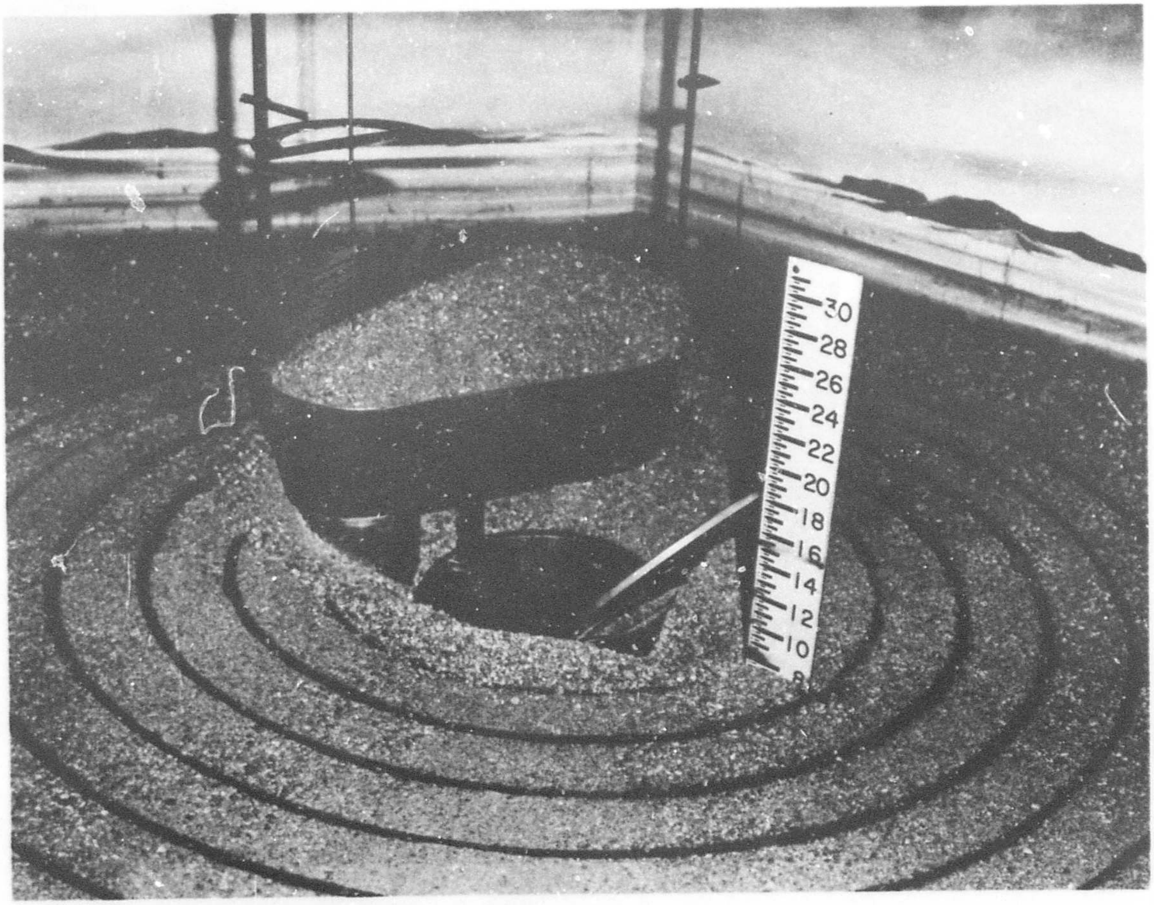
Certain other problems, in addition to those previously discussed, were peculiar to the Rise and Rotate Concept model.

The effect of debris intrusion between the debris shield and the silo and



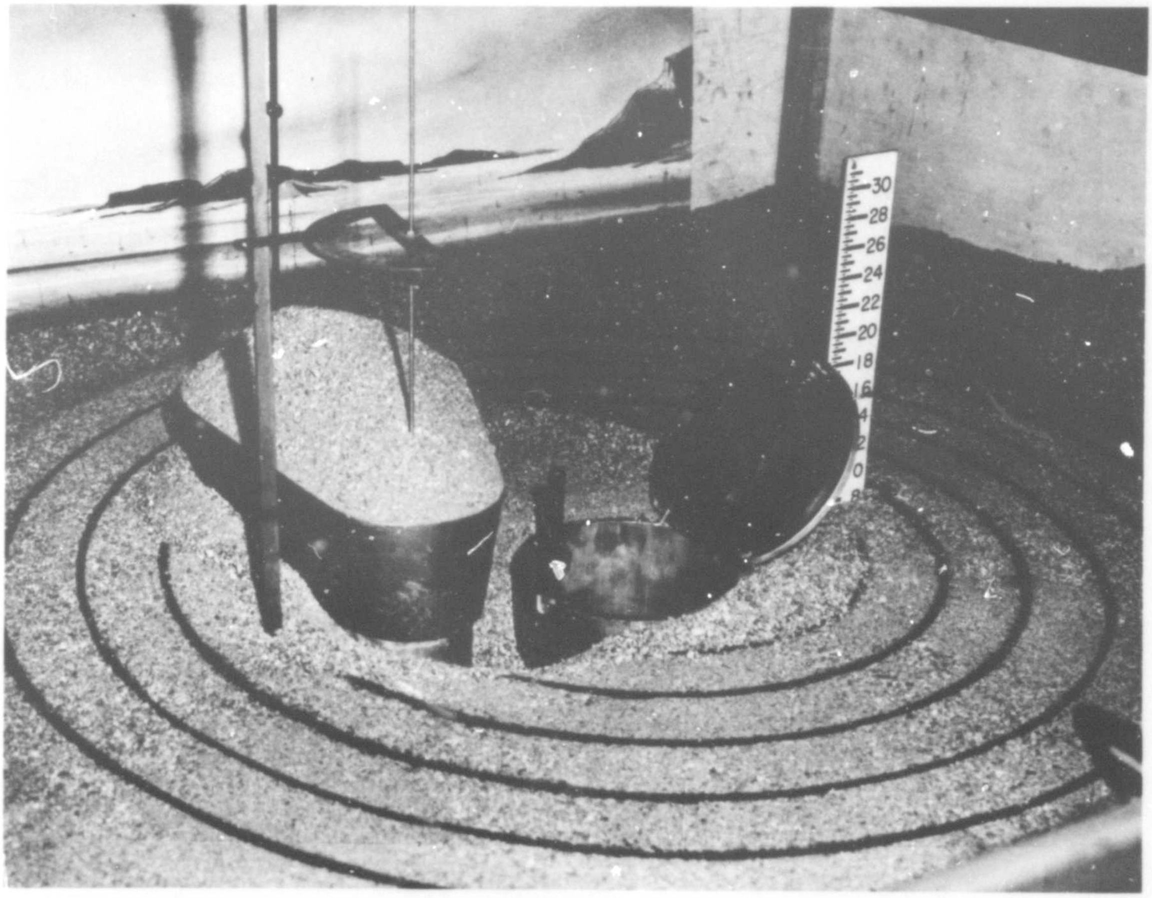
RISE AND ROTATE CONCEPT - DRY SAND

FIGURE 3-1



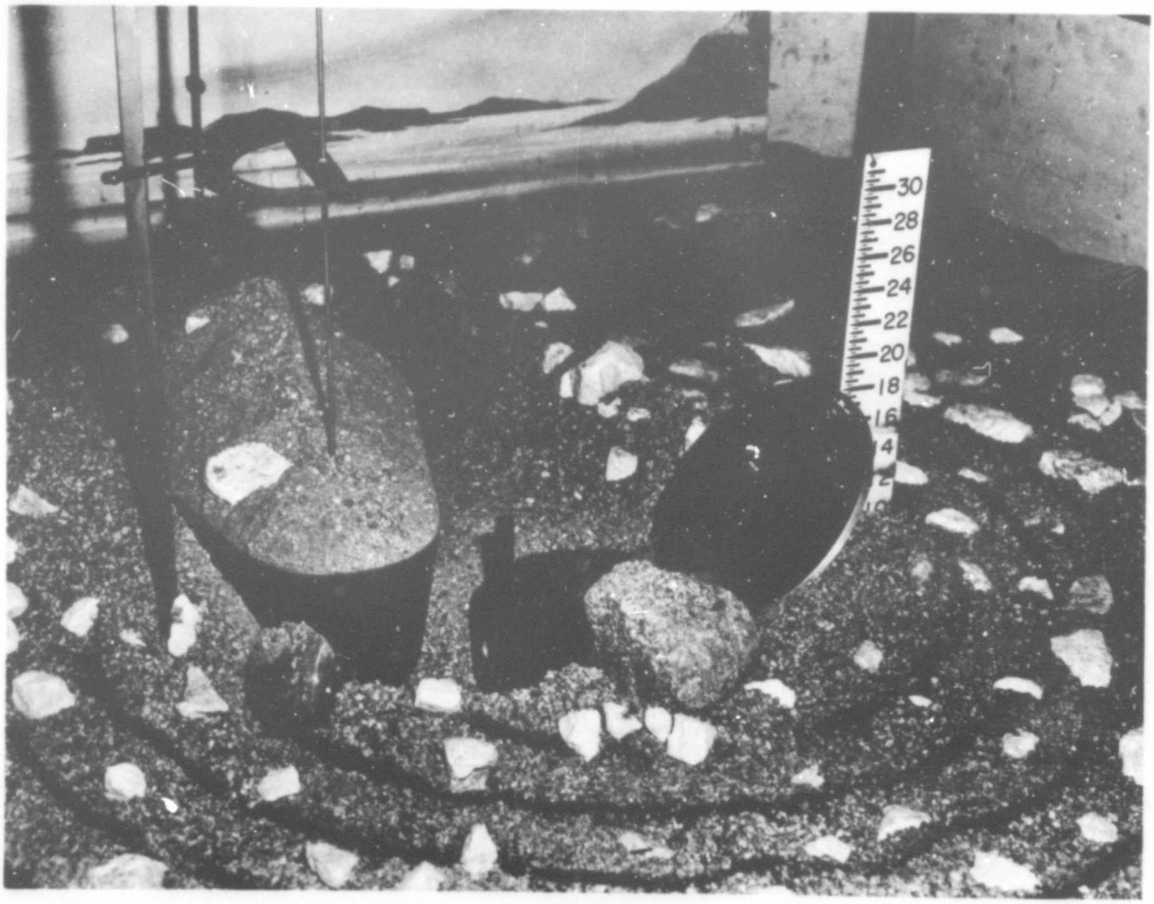
RISE AND ROTATE CONCEPT - DRY GRAVEL

FIGURE 3-2



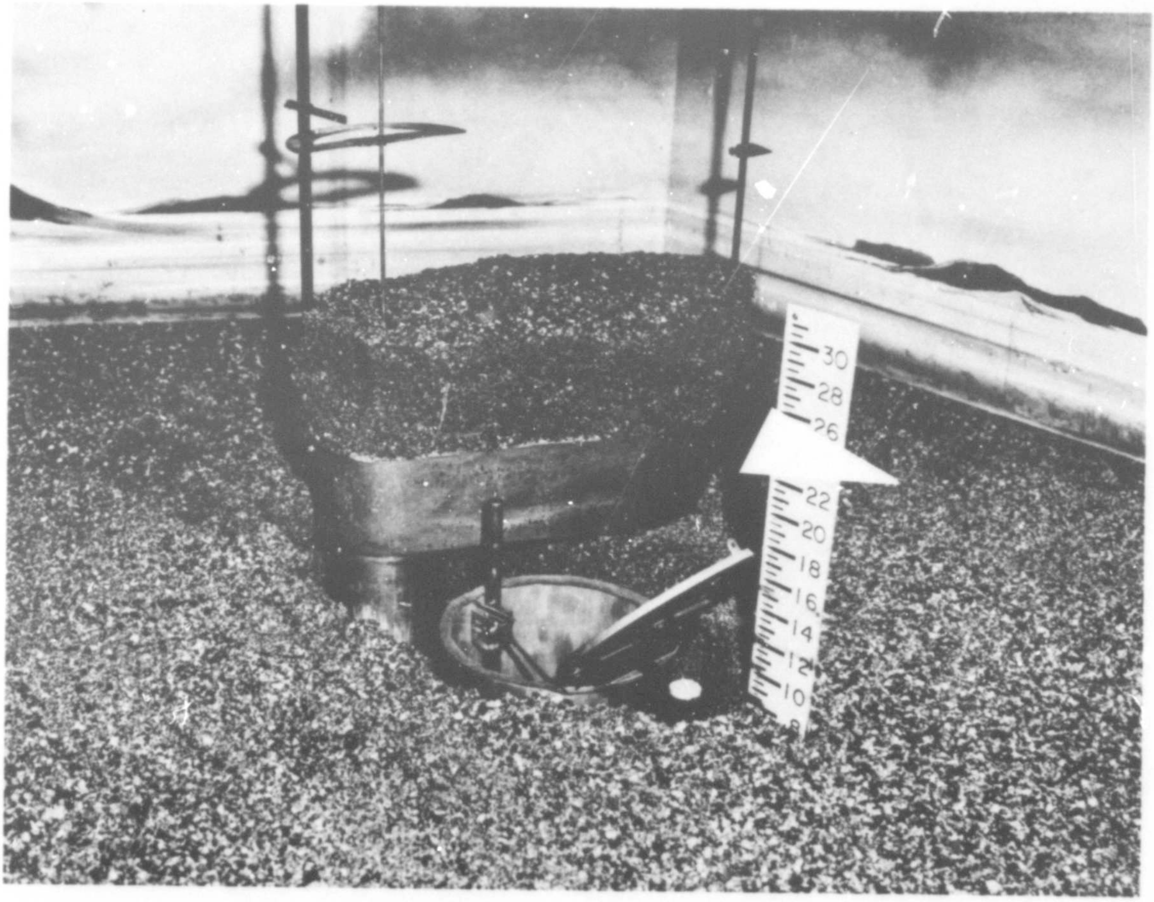
RISE AND ROTATE CONCEPT - DRY SAND AND GRAVEL

FIGURE 3-3



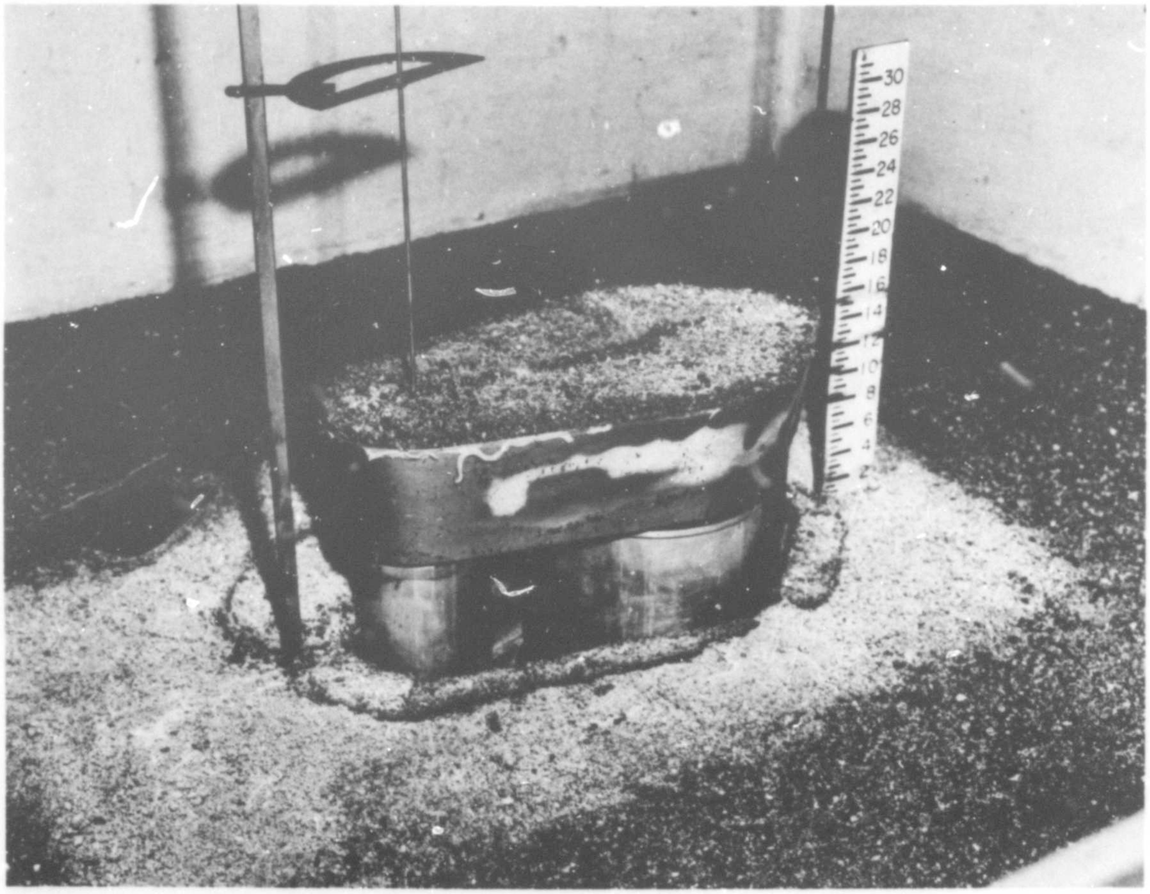
RISE AND ROTATE CONCEPT - DRY SAND, GRAVEL, AND BOULDERS

FIGURE 3-4



RISE AND ROTATE CONCEPT - WET SAND

FIGURE 3-5



RISE AND ROTATE CONCEPT - FROZEN SAND

FIGURE 3-6

its resultant jamming initially caused sufficient deflection in the shield cover to break the attachment and prevent the shield from being raised. This difficulty was overcome by providing a soft cellular rubber ring seal around the top of the silo to prevent debris intrusion.

The spring-loaded plunger, which was used only to simulate the action of the assist cylinder at the forward end of the closure, proved to be quite troublesome due to debris intrusion which caused jamming.

The sliding engagement of the rotate drive gear with the worm at the end of the lift cycle created operating problems throughout the test series, and required continual adjustment of the drive components and the limit switches controlling their relative positions.

3.3 Rise and Tilt Concept

The results of the Rise and Tilt Concept test runs demonstrated serious deficiencies in the capabilities of this model. When it was found that the closure could not be fully opened under 4 inches of dry sand, tests were terminated. This condition is shown in Figure 3-7.

3.3.1 Problem Areas

No difficulties were experienced during the rise cycle; however, as the closure was tilted, the debris spilled over the lowest edge and flowed into direct contact with the side of the closure. As the closure continued its tilting operating, the toe of the closure dug into the debris and loaded the tilt drive mechanism to the point where it could not move the closure to its full 90-degree design travel.

As a result of the experience gained during the previous (Rise and Rotate) test series, no mechanical difficulties were encountered with the debris shield. The provision of an independent debris shield drive eliminated its

RISE AND TILT CONCEPT - DRY SAND

FIGURE 3-7

dependence on the closure for lift and extended its capability to prevent debris fallback into the silo. However, it was found that at the 4-inch depth of dry sand, the dumping and compacting action of the closure upon the debris caused so much side load against the shield that its drive motor could not be restarted to raise the shield above its intermediate position.

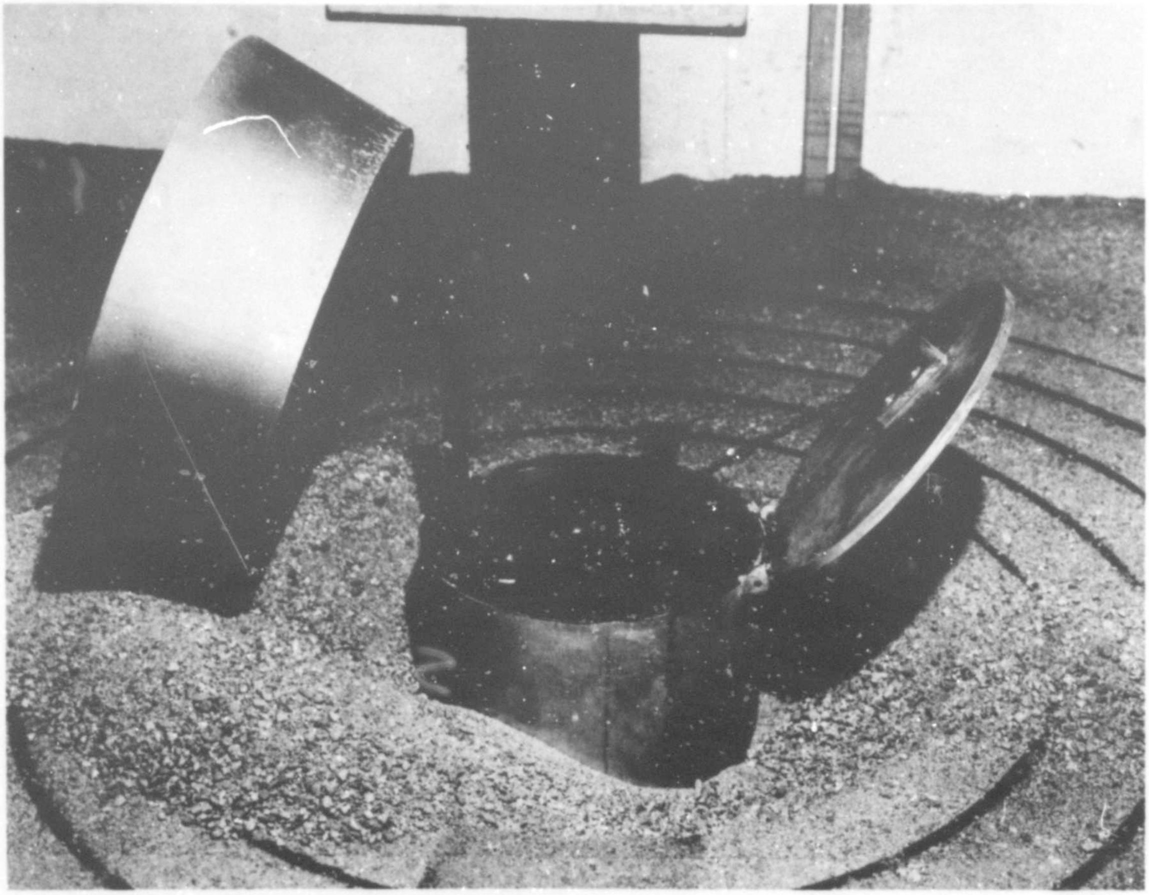
Other operating cycles were tested at the 4-inch depth in an effort to improve the operation of the system but these met with only partial success. As originally designed, the debris shield paces the closure to its full lift position and does not continue to rise until the closure tilt has been completed. This cycle was modified to allow the shield to rise and dwell at the 2-inch and 4-inch levels before being restarted, and also to allow the closure to complete its rise and tilt motion before starting the shield lift. Although these changes increased the space into which the debris could flow, thus reducing the compaction and jamming action, the operation was not appreciably improved. Therefore, further testing of this configuration was discontinued.

3.4 Single Hinge Concept

The results of the test runs of the 1/30-scale Single Hinge Concept were satisfactory and demonstrated the capability of the closure to handle varying depths of debris, as shown in Figure 3-8.

Wattmeter records for the closure drive motor showed a corresponding increase in power required to raise the model through each succeeding increased depth of debris.

Very little difference was observed in wattmeter records for the shield drive motor between the loaded and unloaded condition, except for



SINGLE HINGE CONCEPT - DRY SAND

FIGURE 3-8

the 6.0-inch test depth where approximately 1-1/2 inches of sand was deposited on the shield lid.

3.4.1 Problem Areas

At debris depths up to 3.2 inches, no major problems were encountered. Initially, at depths in excess of this amount, the inability of the debris shield to keep pace with the closure during the opening cycle resulted in a large volume of debris flowing onto the shield lid. The model design was modified by increasing the diameter of the winding drum and increasing the rise of the debris shield from 4.8 inches to 5.8 inches, which significantly reduced the volume of debris carried by the debris shield cover.

3.5 Debris Characteristics

From observations and measurements taken during the test runs, debris configurations at the completion of the operating cycle have been drawn. Figures 3-9, 3-10 and 3-11 show plans and centerline sections at two levels of dry sand debris for each of the three closure concepts tested.

As shown in Figures 3-2 and 3-3, respectively, dry gravel, and a mixture of equal parts of dry sand and gravel exhibited characteristics similar to that of dry sand. Except for local disturbances, the presence of rocks (simulating boulders) in the debris (Figure 3-4) did not appreciably change the configuration from that of the other dry test materials.

As illustrated in Figure 3-5, wet sand (S3-100 sand plus 15-percent water by weight) exhibited somewhat different characteristics in that it did not flow but acted as a cohesive mass, and its angle of repose was approximately 90 degrees rather than the 30-40 degree angle of repose for the same material dry. As would be expected, due to the added weight of debris which remained on the closure, greater power was required to actuate the closure through the wet sand than through the dry material.

4.0 CONCLUSIONS

The test series can be considered successful inasmuch as the models tested demonstrated conclusively whether or not a particular concept operated successfully under simulation of debris conditions that might be expected in full-scale operation.

From the tests performed it can be concluded that:

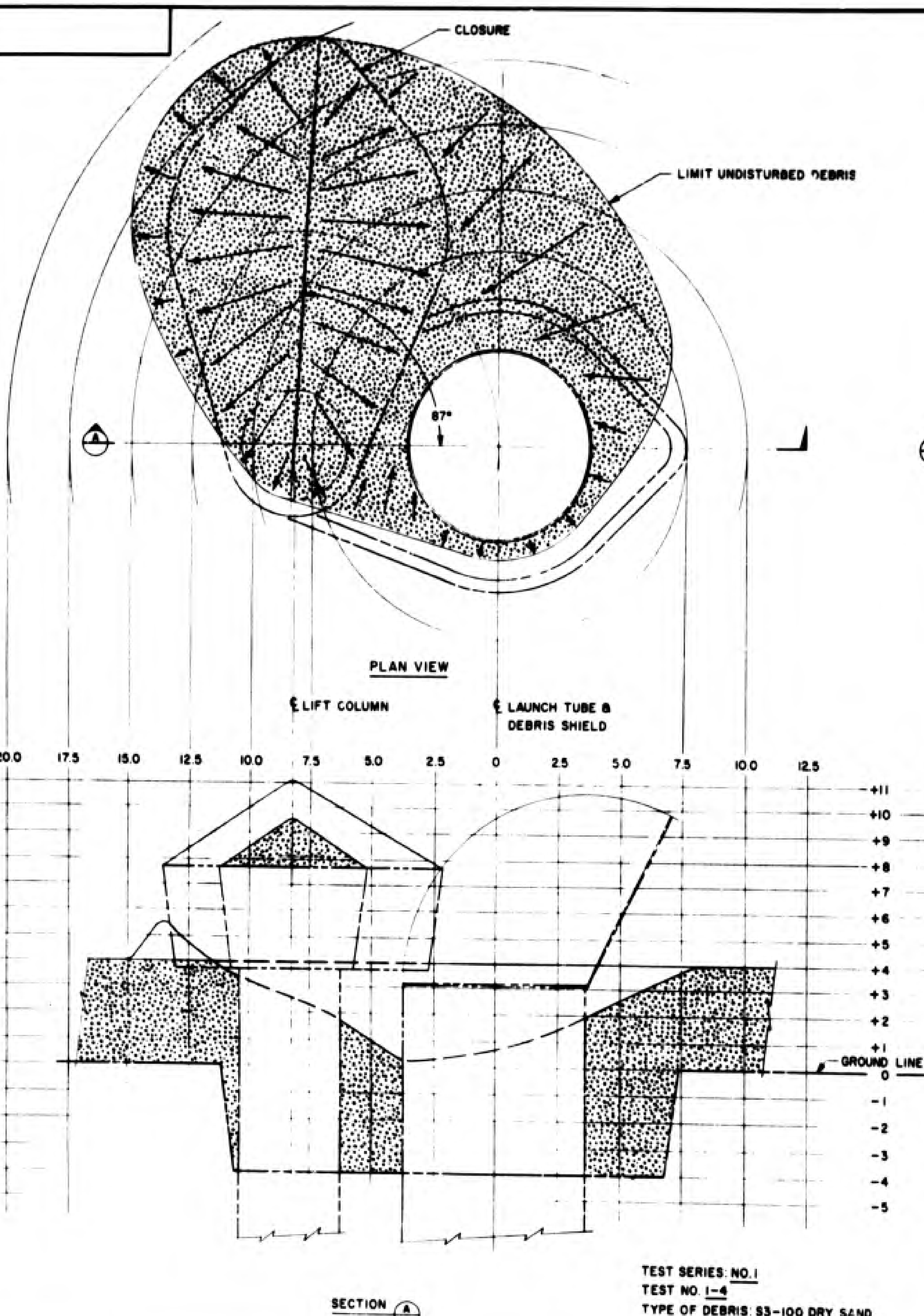
- Of the three concepts tested, the Rise and Rotate and the Single Hinge Concepts demonstrated satisfactory operation and debris handling capabilities. However, the Rise and Tilt configuration, as designed, was unable to cope with moderate depths of dry sand debris. It is recommended that the Rise and Rotate and Single Hinge Concepts be considered as acceptable candidates for further study and large-scale testing.
- As originally conceived, the Rise and Tilt Concept exhibited inherent operational weaknesses at moderate debris depths. These weaknesses could probably be overcome at a considerable increase in complexity in an already complex system. The modifications would entail changing the pivot point of the closure and providing two-speed operation of the tilt actuator. This would result in the toe of the closure plowing upward through the debris rather than the compacting action it exhibited in the tests. However, the added complications to the actuation and

control system that would be introduced, plus the further problems attendant with synchronizing the action of four actuators, make this concept unattractive for further consideration.

- Tests performed with the Rise and Rotate model under frozen debris demonstrated that the forces required to actuate the closure were in excess of the power provided by the model drive mechanism. It can be concluded that a similar condition would prevail for any of the other models tested, and that an auxiliary system would be required to generate the high breakaway forces required to penetrate a frozen debris layer.
- A debris shield system such as that employed in these concepts is an acceptable means of preventing debris intrusion or fallback into the missile silo. It is recommended that a debris shield system of this type be incorporated into future designs of closure concepts.
- The depth of debris which can be handled successfully by the closure concept is limited if the raising of the shield is accomplished by the lifting action of the closure as in the Rise and Rotate Concept. Conversely, an independent shield lift mechanism such as that used in the Single Hinge Concept increased the debris handling capabilities of the system by a factor of two or possibly more. It is recommended that further design and cost tradeoff studies be made to determine whether this increased debris handling capability justifies the added costs and complexities attendant upon the incorporation of an independent shield drive mechanism into the system.

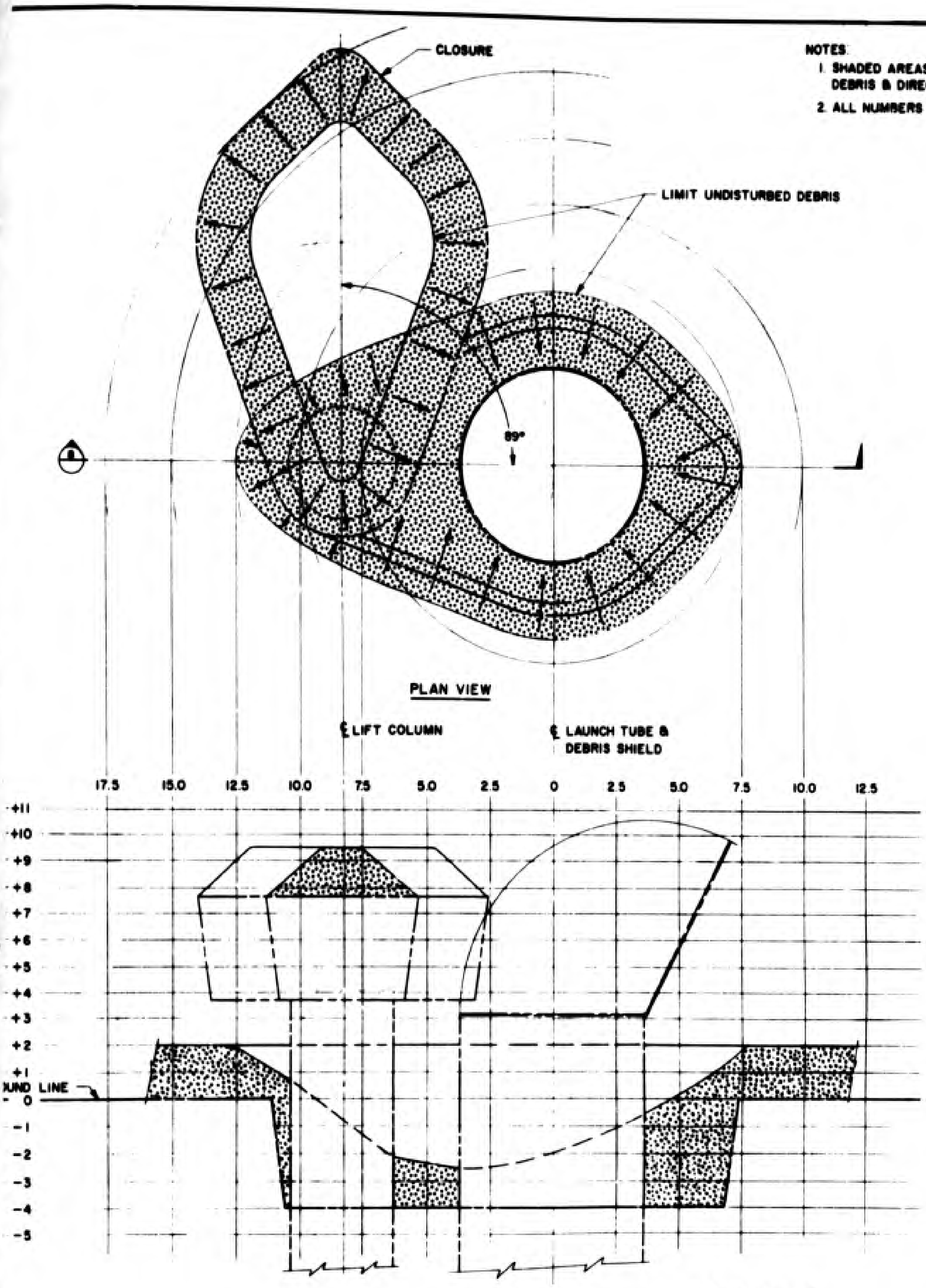
- Although more force is required to open the Single Hinge closure than the Rise and Rotate design, the simplicity of a single actuator system is recommended over the more complicated (sequenced) two-actuator system required to open the Rise and Rotate model.
- The Single Hinge Concept exhibited less sensitivity to variations in debris level than the Rise and Rotate Concept because the swept angle during opening is in a single plane. Because the Rise and Rotate closure traverses a 90-degree horizontal arc during the opening cycle, the bottom of the door must be elevated above the maximum debris level expected to avoid unpredictable force requirements for the horizontal actuation subsystem.
- Because of the small scale of the models, and the latitude allowed in their construction and method of actuation, the power readings obtained should be treated qualitatively rather than quantitatively.

* * * * *



TEST SERIES: NO. 1
TEST NO. 1-4
TYPE OF DEBRIS: S3-100 DRY SAND
DEBRIS DEPTH: 4 in.

A



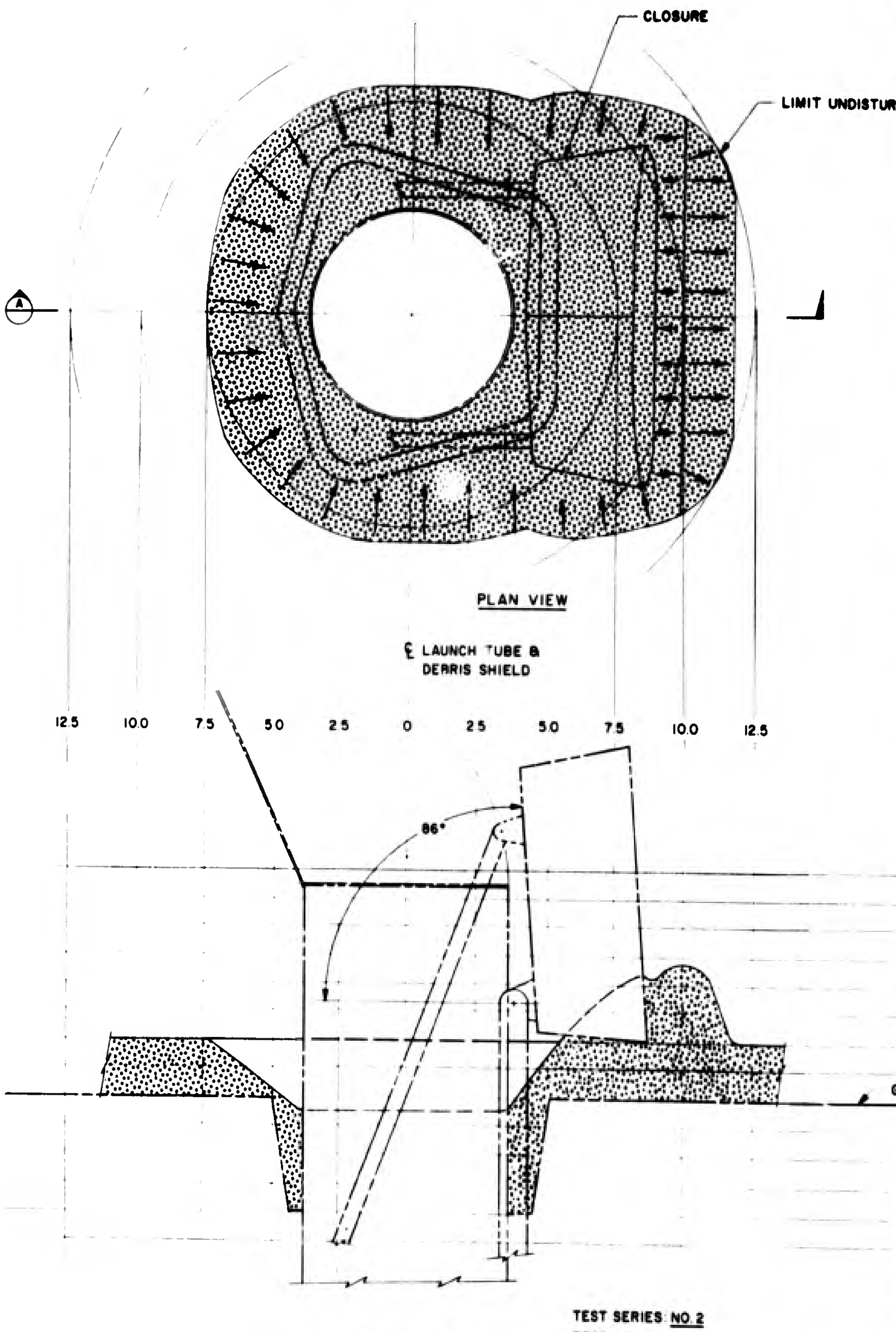
TEST SERIES: NO.1
TEST NO. 1-2
TYPE OF DEBRIS: 53-100 DRY SAND
DEBRIS DEPTH: 2 in.

SUBSCALE OPERATING TEST
RISE & ROTATE CLOSURE
DEBRIS CONFIGURATION

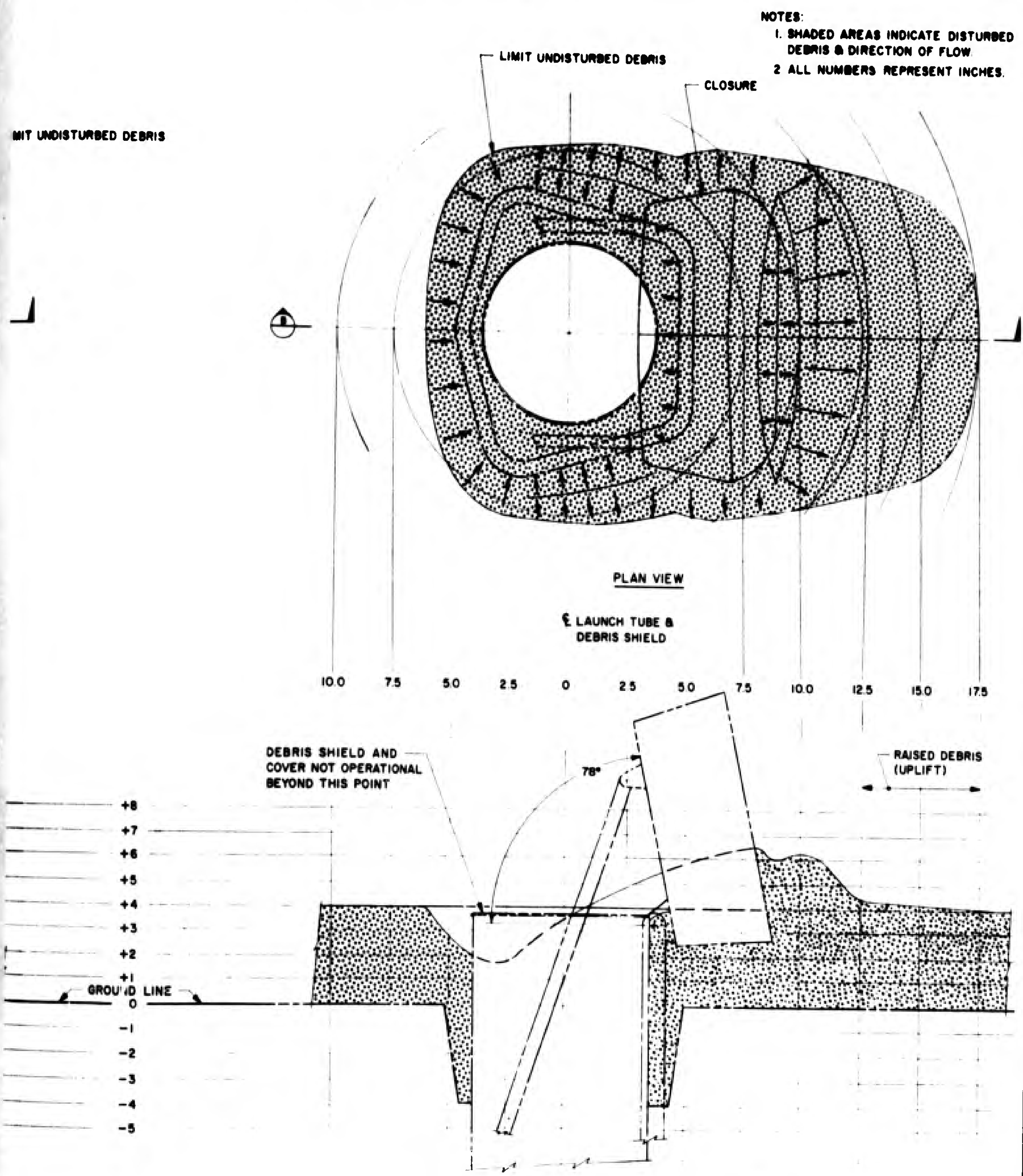
THE RALPH M. PARSONS COMPANY

FIGURE 3-9

B



TEST SERIES: NO. 2
TEST NO. 1-2
TYPE OF DEBRIS: S3-100 DRY SAND
DEBRIS DEPTH: 2 in.



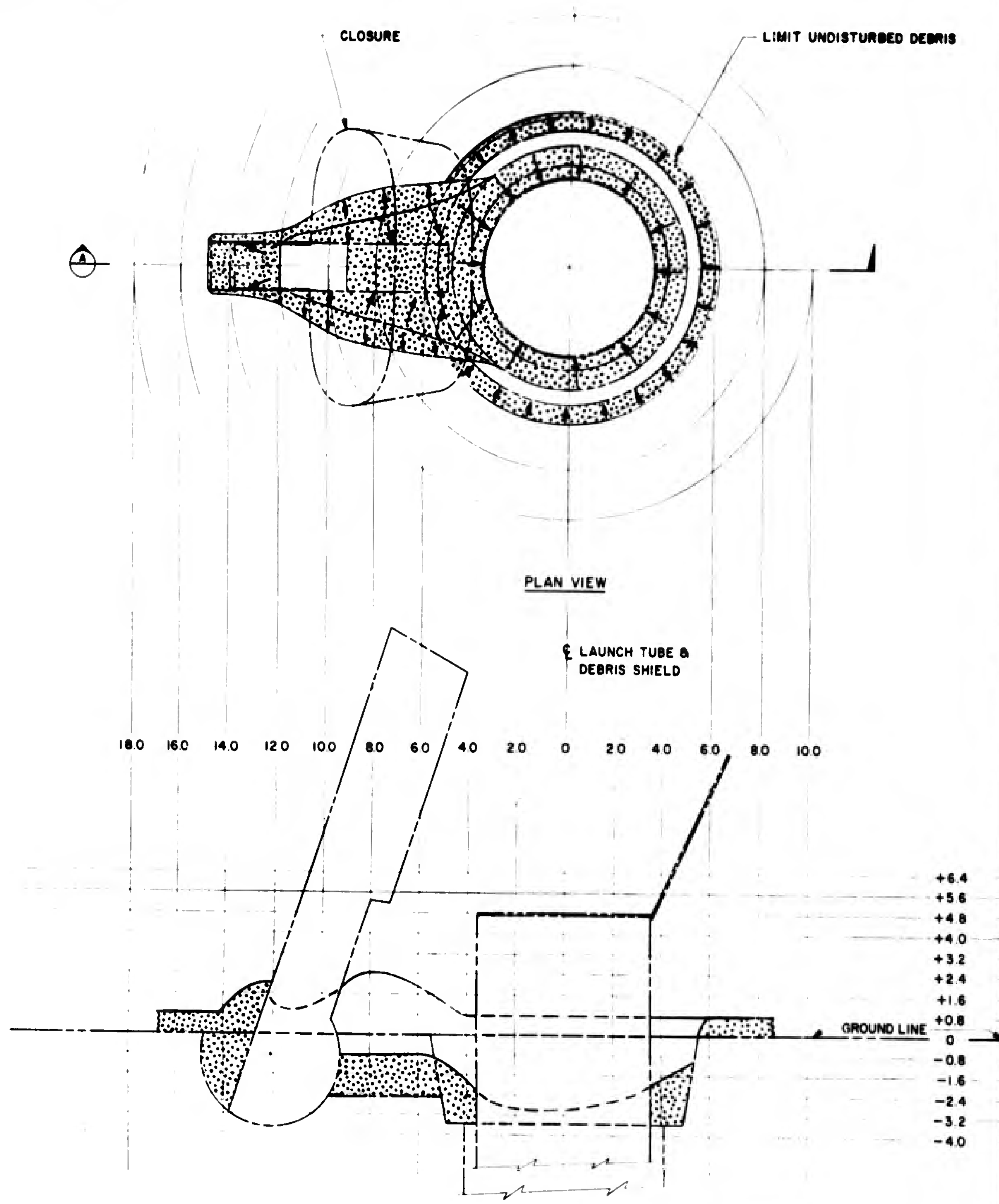
TEST SERIES NO. 2
TEST NO. 1-4(2)
TYPE OF DEBRIS: S3-100 DRY SAND
DEBRIS DEPTH: 4 in.

SUBSCALE OPERATING TEST
RISE & TILT CLOSURE
DEBRIS CONFIGURATION

THE RALPH M. PARSONS COMPANY
LOS ANGELES

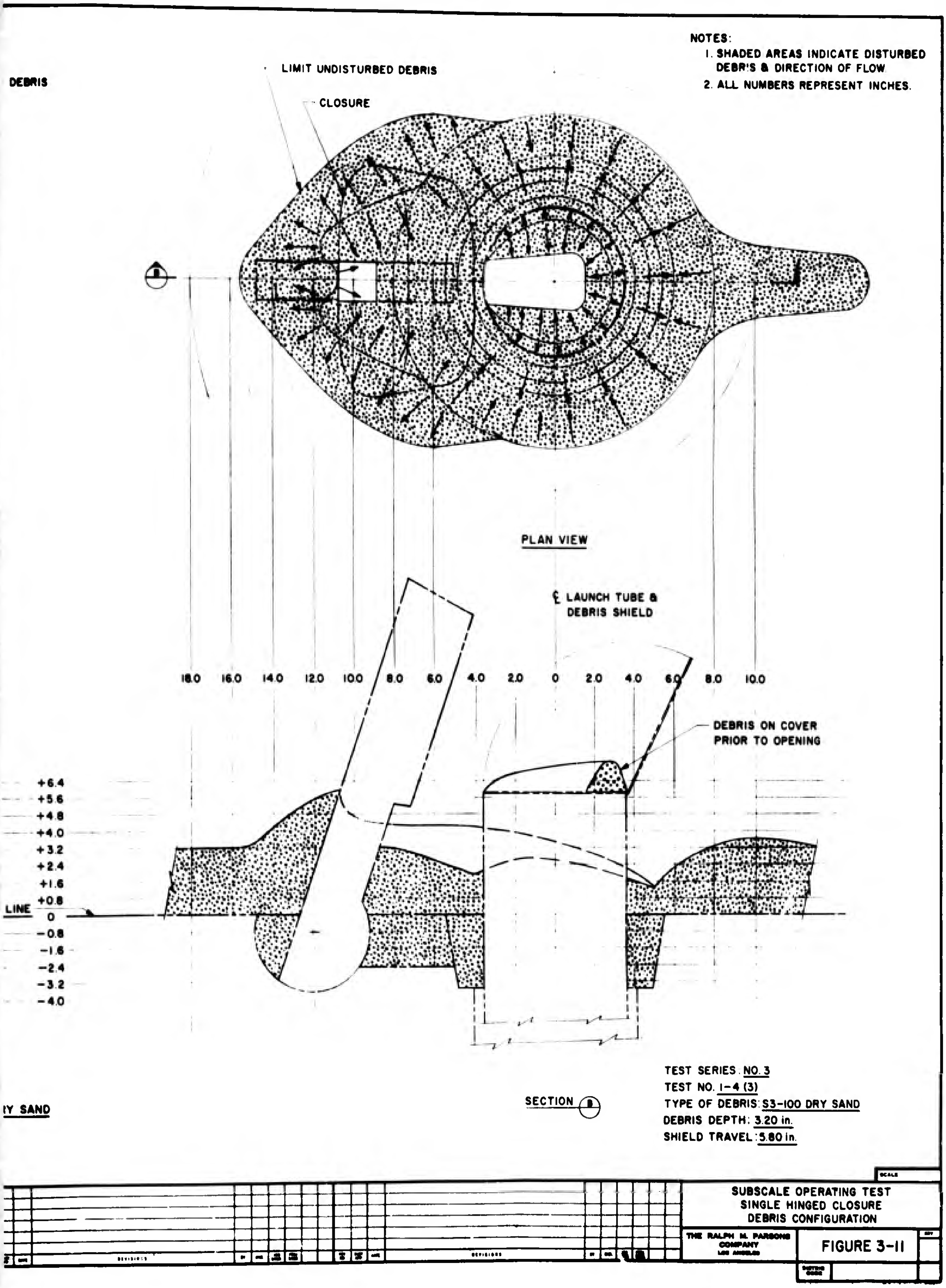
FIGURE 3-10

B



TEST SERIES: NO. 3
TEST NO. 1-1(1)
TYPE OF DEBRIS: S3-100 DRY SAND
DEBRIS DEPTH: 0.8 in.
SHIELD TRAVEL: 4.8 in.

A


NOTES:
1. SHADED AREAS INDICATE DISTURBED DEBRIS & DIRECTION OF FLOW
2. ALL NUMBERS REPRESENT INCHES.
DEBRIS
LIMIT UNDISTURBED DEBRIS
CLOSURE
PLAN VIEW
℄ LAUNCH TUBE & DEBRIS SHIELD
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
4.0
6.0
8.0
10.0
DEBRIS ON COVER PRIOR TO OPENING
+6.4
+5.6
+4.8
+4.0
+3.2
+2.4
+1.6
+0.8
LINE
0
-0.8
-1.6
-2.4
-3.2
-4.0
RY SAND
SECTION
TEST SERIES: NO. 3
TEST NO. 1-4 (3)
TYPE OF DEBRIS: S3-100 DRY SAND
DEBRIS DEPTH: 3.20 in.
SHIELD TRAVEL: 5.80 in.
SUBSCALE OPERATING TEST
SINGLE HINGED CLOSURE
DEBRIS CONFIGURATION
THE RALPH M. PARSONS COMPANY
LOS ANGELES
FIGURE 3-11

B

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13. ABSTRACT

This report covers the phase of the Closure Analysis and Test Study dealing with operating tests of subscale models of closure designs. Subscale tests investigating the functional operation of models of three different closure debris removal/actuator concepts were completed. These concepts were the Rise and Rotate, the Rise and Tilt, and the Single Hinge, which were selected from preliminary design studies of eleven concepts.

The investigation compared the operation of each concept under variable debris loads and conditions. From the tests performed, it is concluded that, except for frozen debris, the Rise and Rotate and the Single Hinge Concepts demonstrated satisfactory operation and debris handling capabilities and should be considered as candidates for further study and large-scale testing.

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Unclassified

Security Classification

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