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TANK FRAGMENTATION TEST

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SUMMARY

A photographic study of a simulated Tank Fragmentation Test was made at the Lewis Research Center's Space Power Facility for USAF-AFSC/SAMSO. Sixteen disks and four spheres were ejected from a test article mounted in a vertical orientation 110 ft above a target installed on the test chamber floor. The test was performed at a chamber pressure of 25 microns. Velocities at impingement on the target ranged from 88 to 120 ft/sec; corresponding ejection velocities at the exit plane of the Ejector Assembly ranged from 29 to 87 ft/sec. Tumble axes of the disks were expected to be all in the north-south direction; the majority of those measured were, while some were skewed from this direction, the maximum observed being 90°. A typical measured tumble rate was 2.4 turns/sec. The dispersion pattern measured on the target was reasonably regular, and measured approximately 16 ft east-to-west by 11 ft north-to-south.

INTRODUCTION

Presented here is a description and the results of a simulated Tank Fragmentation Test carried out at the NASA Lewis Research Center's Space Power Facility, located near Sandusky, Ohio. The program was performed by Space Power Facility Division personnel at the request of USAF-AFSC/SAMSO. The test article was built by the Space Data Corporation of Phoenix, Arizona, for SAMSO. The in-chamber time period was from December 1972 through January 1973. The test itself was performed January 17, 1973.

The test program reported here is a ground test, in a vacuum environment, simulating a flight test of an identical test article, planned for early 1973. While other flight tests have utilized the same basic concept, the specific hardware configuration tested at the Space Power Facility has not been used before.

TEST ARTICLE AND OPERATIONAL CONCEPT

The test article was designed and built by the Space Data Corporation to meet AFSC/SAMSO operational requirements. Flight operation will occur under exo-atmospheric and near zero-gravity conditions. Thermal conditions were not a consideration in the ground test simulation.

The test article consists of 20 tubes containing 16 disks, eight aluminum and eight stainless steel, and four teflon spheres. All disks were one inch in diameter and 0.1 inch thick; the spheres were one inch in diameter. The tubes were arranged in a rectangular array approximately one square foot in cross section. The overall length of the assembly was about 30 inches, and its weight was 46 pounds. All 20 objects are ejected simultaneously from the tube array by pistons actuated by gas pressure built up when a small detonator is fired. Nominal ejection velocity was predetermined to be about 60 ft/sec. In addition, the test article was designed to eject the disks at a predetermined tumble rate, and with a single specific orientation of all tumble axes. The tube array is arranged to produce a slightly diverging pattern of ejected objects; it is called the Ejector Assembly, and a photograph of it is shown in figure 1.

Figure 2 shows how the ejected objects were held in the tubes. Near the end of travel, the spring-clamps moved outward, freeing the disks and spheres. For details of this test article concept and design, consult cognizant personnel at the Space Data Corporation.

The test configuration used at the Space Power Facility is described in more detail below; however, note that the ejected objects were to impinge on target a minimum of 100 ft from the Ejector Assembly.

OBJECTIVES OF THE GROUND TANK FRAGMENTATION TEST

From the standpoint of the Space Power Facility staff, the objectives of this test were as follows:

1. Measure the velocities of the disks and spheres at impingement on the target. Determine the ejection velocities.

2. Measure the tumble rate of the disks, and if possible, ascertain the orientation of the tumble axes.

3. Measure the dispersion pattern produced by impingement of the ejected objects on a target perpendicular to the Ejector Assembly axis, at a known distance from the Ejector Assembly exit plane.

4. List any anomalies which occurred.

Interpretation of any test results in terms of flight performance, or as to any design modification implications to the Ejector Assembly is the responsibility of AFSC/SAMSO and its contractor, the Space Data Corporation.

TEST CONFIGURATION AT THE SPACE POWER FACILITY

For the ground verification test, the major test facility requirements were:

1. Sufficient vacuum capability to eliminate aerodynamic effects.

2. The need for at least 100 ft separation between the Ejector Assembly and the target and data cameras to obtain useful data.

3. A large area (in the arrangement used, the chamber floor) to mount the target and data cameras.

The Space Power Facility has been briefly described elsewhere; essentially, it is a large controlled environment chamber, 100 ft in diameter and 122 ft high, being a domed cylinder configuration with a flat floor at ground level. Altitudes from ambient to orbital (10^{-7} torr range) can be obtained in this chamber. A wide range of test chamber temperatures is available also (temperature simulation was not required for this test). An external photograph of the facility is shown in figure 3.

The sketch of figure 4 shows the configuration used for the Tank Fragmentation Test. The view shown is looking south, across the east-west centerline of the chamber. The Ejector Assembly was mounted on the facility polar crane trolley, near the apex of the chamber dome. It was oriented vertically, such that the disks and spheres were ejected downward, impinging on a target on the chamber floor. The actual distance from the exit plane of the Ejector Assembly to the target surface was 110 ft. The Dispersion Pattern Target was squared-drafting paper mounted on a wooden frame 20 by 30 ft in area. The paper was supported by fine wires strung across

the target frame. The frame positions the target 2 feet above several layers of an energy-absorbing material (cellulose packing wadding) distributed in the floor of the target box, to prevent any bouncing which could have resulted in a target puncture from the wrong side. The dispersion pattern was obtained by measuring the places where the ejected spheres and disks pierced the target paper and landed in the energy-absorbing material below.

Four high-speed motion picture cameras (nominally 1000 frames/sec) and associated floodlighting were mounted along the north edge of the target area, as shown in figure 5. Both the cameras and the Ejector Assembly Detonator required 28 vdc power; the floodlights required 110 vac. This power is readily available in the chamber. Camera run time was approximately 4 seconds. Table I lists the cameras, film linear speeds, lenses used, etc., in the test. All cameras were mounted inside sealed aluminum containers maintained at one atmosphere of air pressure. Each camera was provided with timing signals. These signals allowed the recording of the Ejector Assembly Detonator firing and the IRIG-A (Inter-Range Instrumentation Group-A) timing code along the edges of the film. This arrangement and equipment was used in the Skylab Payload Shroud Test Program (ref. 1) at the Space Power Facility. All camera optic axes were oriented horizontally across the expected target impingement area. Two cameras with wide angle lenses provided nearly complete coverage of the area while two cameras with high resolution lenses allowed measurements of good precision on individual disks and spheres to be made. The expected spin axes of the disks was in the north-south direction; i.e., the disks would be edge-on to the cameras. The optic axes of the cameras were 2.3 ft above the target surface.

The entire Tank Fragmentation Test configuration was set up in the east half of the chamber, since installation of test support equipment for the upcoming Centaur Standard Shroud jettison tests was proceeding in the west half of the chamber.

TEST CONTROL SYSTEM

In addition to the cameras and containers, the test control system used was that available from the Skylab Payload Shroud Jettison Test Program. The essential part of this system was the Discrete Events Programmer, which has the capability of sequencing up to 12 events, and is calibrated

to 0.01 sec. For this test, the camera floodlighting was turned on and off manually while the remaining events were automatically sequenced by the programmer. Sequencing was as follows:

Floodlights on	Test Conductor Command
Programmer start	0 sec
Start all cameras	5.00 sec
Fire command	6.00 sec
(Disks and spheres entire camera field of view)	7.00-7.5 sec
System safe commands (28 vdc off)	10.00 sec
Floodlights off	Test Conductor Command

TEST PROCEDURE

When all installations and checkouts were complete, a brief pretest review was held. Following the review, execution of the test procedures was initiated. All operations from closing the chamber on through posttest safety and engineering inspection were governed by detailed checksheet-type procedures (most of these are standard Space Power Facility operating procedures). All operations were controlled by the test conductor. The detonator was fired at 16 hours, 57 minutes on January 17, 1973 in the sequencing outlined above. The test chamber pressure at the time of the test was 25 microns. Following the test, the chamber was returned to ambient pressure and an inspection made. Posttest observations were as follows:

1. All 20 ejected objects were accounted for.

2. One aluminum disk failed to penetrate the target paper (struck target paper directly over a support wire).

3. One sphere bounced back through the target paper.

4. The dispersion pattern appeared reasonable.

TEST RESULTS

Figure 6 presents the identification and orientation scheme used for the ejected objects in this test. Also indicated is the view field of each camera. Note that objects #9 (sphere) and #17 were not photographed by any of the cameras; this had no effect on the validity or usefulness of the test results.

Velocities

Velocities of the ejected disks and spheres were measured via the photographic film as the objects crossed the optic axes of the cameras, 2.3 ft above the target surface. The vertical distance from these axes to the exit plane of the ejector assembly was 107.7 ft. Meaningful measurements of individual velocities could only be made for those objects photographed by the high resolution cameras. A manually-operated Vanguard photographic data analyzer was used in determining these velocities.

Since all ejected objects had a maximum dimension of one inch, and each was at a different distance from the cameras, the objects themselves were used to calibrate vertical distance in their own trajectory planes. Thus, the measurement of objects close to the cameras (larger image) may be expected to be more accurate than those distant from the cameras. However, no attempt was made to estimate the precision of any velocity measurement.

Table II lists the velocities of each ejected object measured individually, approximately at impingement on the target. Also shown are the velocities at exit from the Ejector Assembly, calculated from these impingement velocities knowing the distance between (107.7 ft).

Although no measurements were made for the stainless steel disks, study of the wide angle camera film indicated that their velocities would be essentially the same as those measured, since the whole pattern of spheres and disks passed through the camera fields approximately in a planar array which remained (by visual inspection) horizontal.

Tumbling of Disks

The Ejector Assembly was designed to eject the disks all with the same tumble axis (north-south, in this test

configuration), and with a very low tumble rate. Table III gives estimations of the tumble axis orientation for all disks for which such estimations were possible. For some disks, it was clearly evident that the tumble axes were not north-south; but only very approximate estimates could be made.

Since tumble rates were supposed to be very low, to measure any required a considerable length of travel through the camera field of view. This implied use of the wide angle lens camera film, and a very small image to study. On the film of camera #2, object #8 was observed to be clearly spinning, and with enough travel distance to be measurable. The image was clear enough to make reasonable measurements. Thus, only this disk was measured for tumble rate. The result was 2.4 turns/sec. This was higher than planned.

Dispersion Pattern

The dispersion pattern formed by impingement and (except in one case) penetration of the disks and spheres on the target is shown in figure 7. It can be seen that the measurements resulted in a reasonably regular array being indicated. The maximum outside dimensions of the pattern are shown and are 15'-10" east to west and 10'-8" north to south. The location of the projection of the axis of the overhead Ejector Assembly through the target is also indicated. This "ground zero" is seen to be 4" north and 5" east of the center of the enveloping rectangle, indicating a possible tilting of the Ejector Assembly in both the north-south and east-west directions of between 0.15° and 0.20° (9 to 12 min of arc). This was not considered significant.

CONCLUSIONS

A photographic study of a simulated Tank Fragmentation Test was made at the Lewis Research Center's Space Power Facility for USAF-AFSC/SAMSO. Sixteen disks and four spheres were ejected from a test article mounted in a vertical orientation 110 ft above a target installed on the test chamber floor. The test was performed at a chamber pressure of 25 microns. Velocities at impingement on the target ranged from 88 to 120 ft/sec; corresponding ejection velocities at the exit plane of the Ejector Assembly ranged from 29 to 87 ft/sec. Tumble axes of the disks were expected to be all in the north-south direction; the majority of those measured

were, while some were skewed from this direction, the maximum observed being 90°. Single disk was measured for tumble rate; the result was 2.4 turns/sec. The dispersion pattern measured on the target was reasonably regular, and measured approximately 16 ft east-to-west by 11 ft north-to-south.

REFERENCE

1. Daye, Charles J.: Skylab Payload Shroud Jettison Tests. NASA TN D-6913, 1972.

TABLE I.-CAMERA DATA

Camera	Lens	Speed at T_o, frames/sec	Speed in data range, frames/sec
1 (east)	Hi-Res	787	1111
2	Wide angle	526	667
3	Hi-Res	690	909
4 (west)	Wide angle	---	----

TABLE II.-TANK FRAGMENTATION TEST SUMMARY OF VELOCITY MEASUREMENTS

	Velocities, ft/sec									
OBJECT NO.	1	2	3	4	11	12	13	14	15	16
VELOCITY AT IMPINGEMENT (ft/sec)	101.8	100.8	88.3	120.5	102.8	110.0	118.5	106.3	119.8	116.7
EJECTION VELOCITY (ft/sec)	61.3 disk	56.7 disk	29.4 disk	86.8 disk	60.2 sphere	71.6 sphere	84.4 disk	66.0 disk	85.6 disk	81.4 disk

TABLE III.-SPIN AXIS ORIENTATION SUMMARY

Disk No.	Tumble Axis Orientation
1	90°*
2	23°
3	49°
4	---
5	---
6	---
7	---
8	N-S 2.4 turns/sec
13	N-S
14	N-S
15	N-S
16	N-S
17	---
18	---
19	---
20	---

*Estimate of horizontal angle between actual spin axis and north-south direction. All indications are very approximate.

N-S means tumble axis North-South.

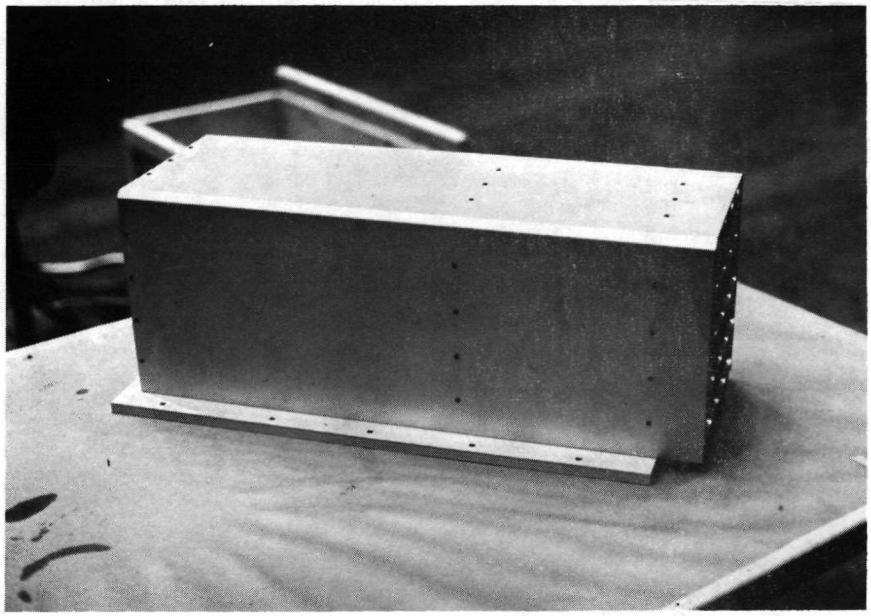

Figure 1. - Ejector assembly.

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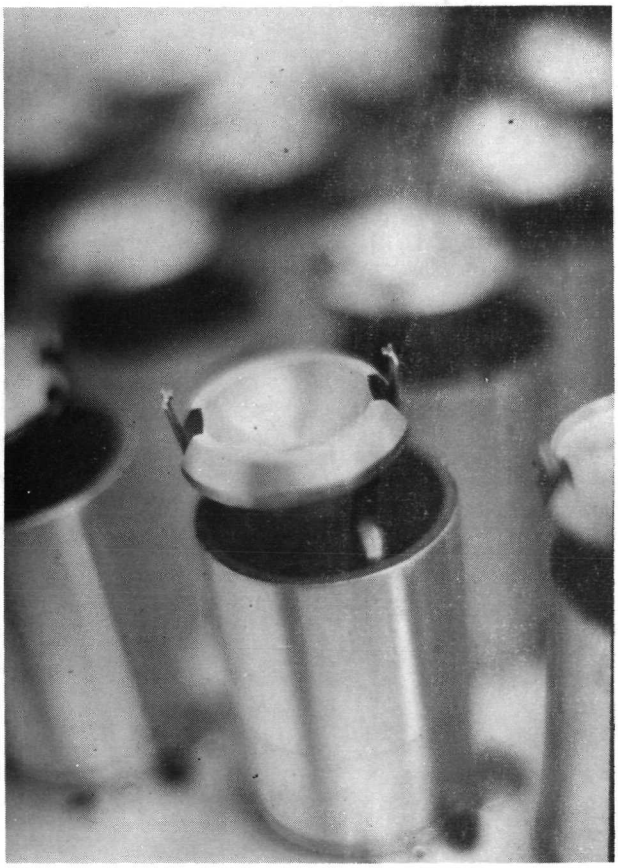

Figure 2. - Exit plane of ejector assembly after test showing how discs and spheres were held in place.

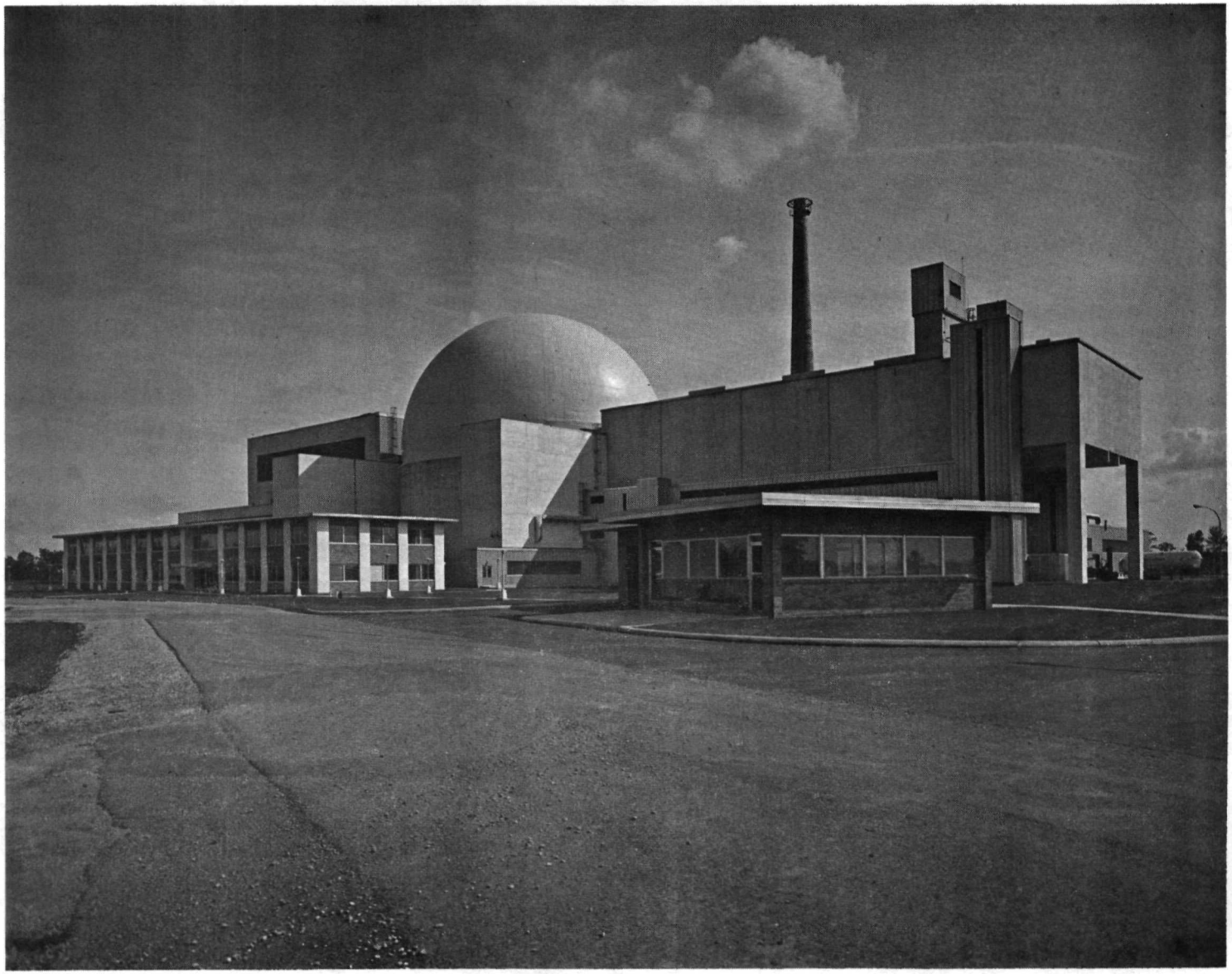

Figure 3. - Lewis Research Center's Space Power Facility.

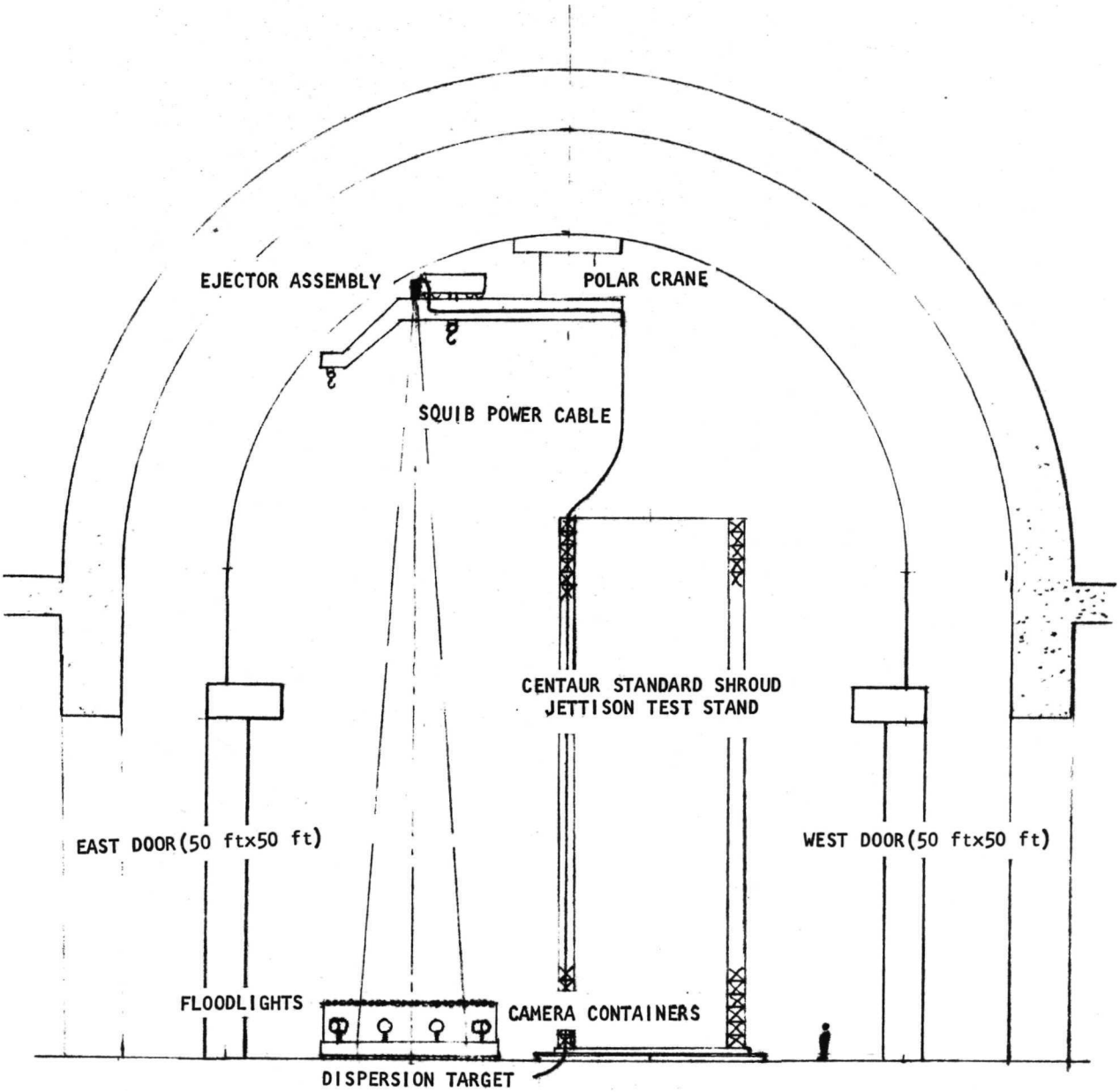

Figure 4. Tank Fragmentation Test Configuration in Lewis Research Center's Space Power Facility

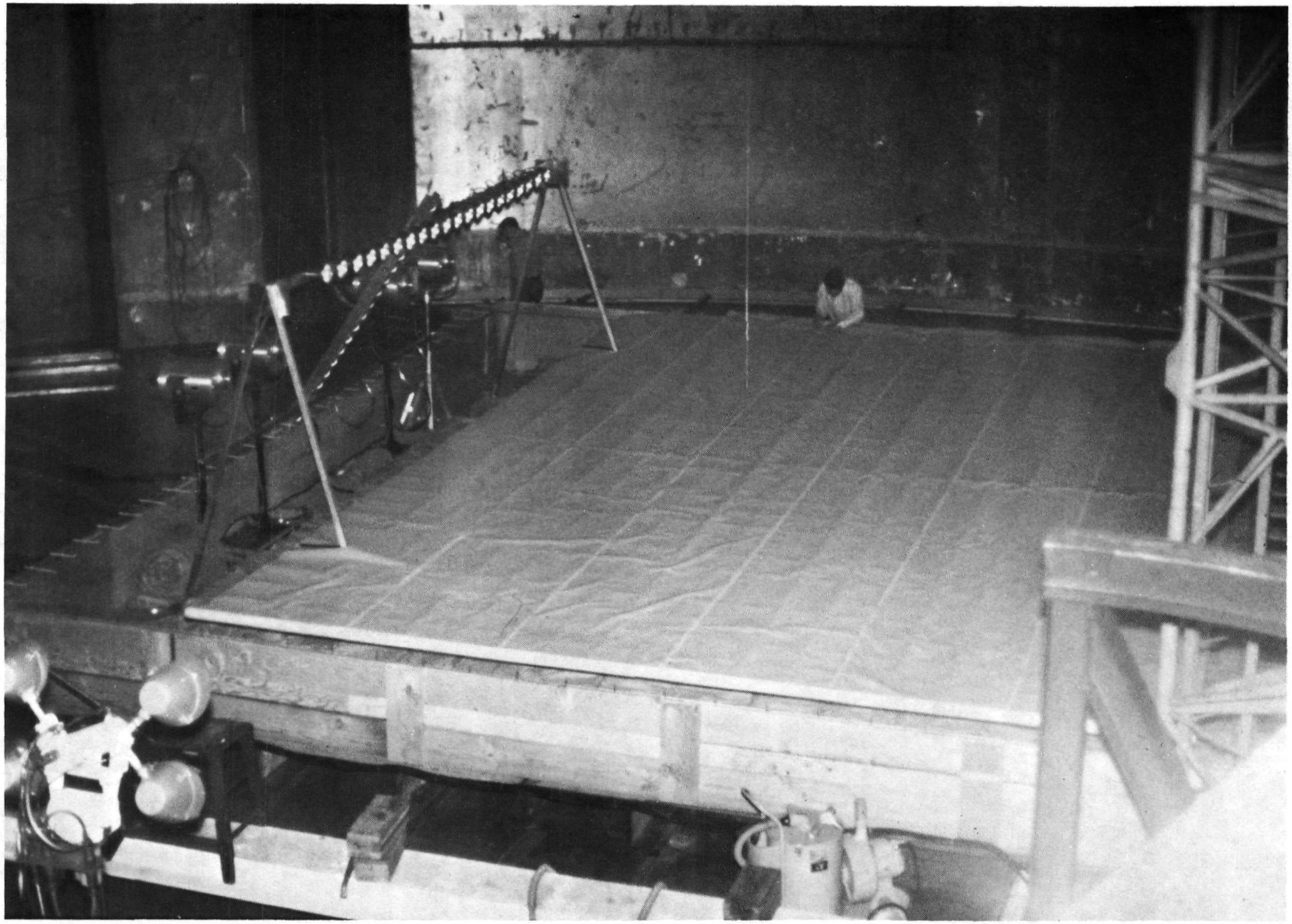

Figure 5. - Dispersion target, floodlights and cameras in place in the east half of the Space Power Facility.

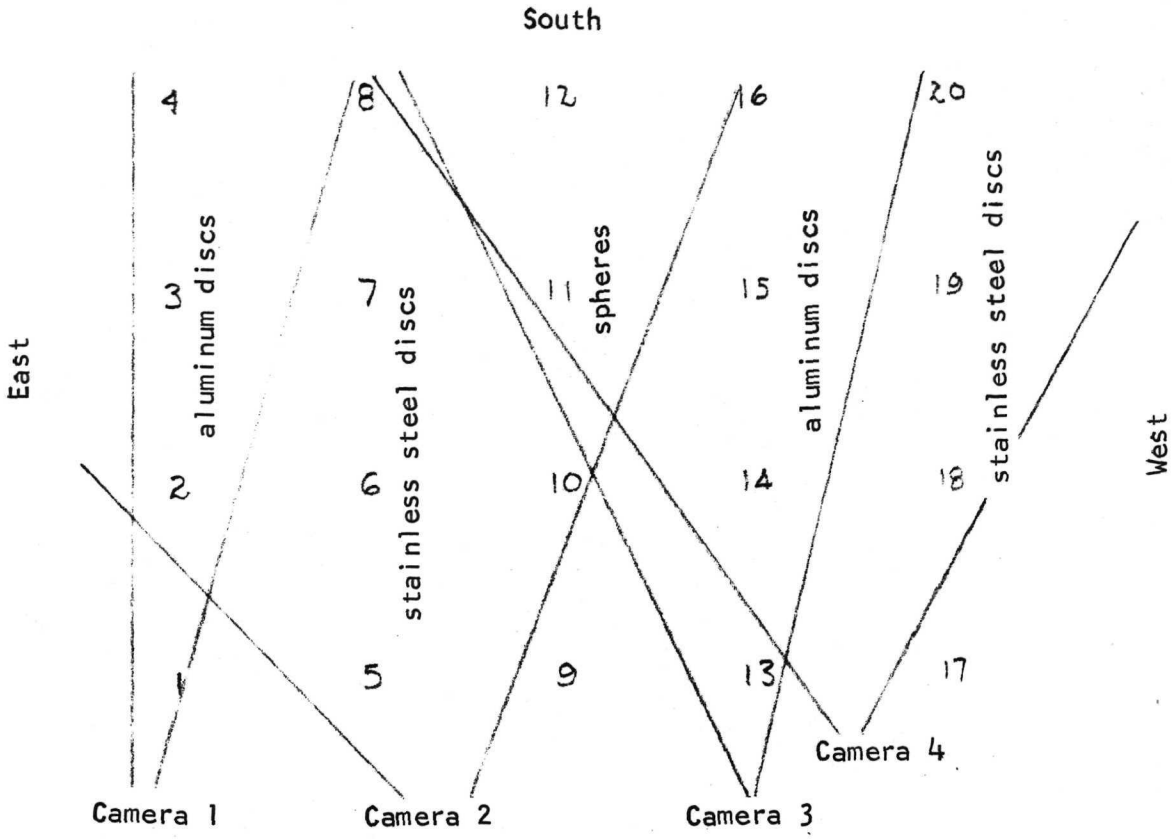

Figure 6. Identification Scheme for Discs and Spheres (Looking Down)
Also shows field of view of cameras

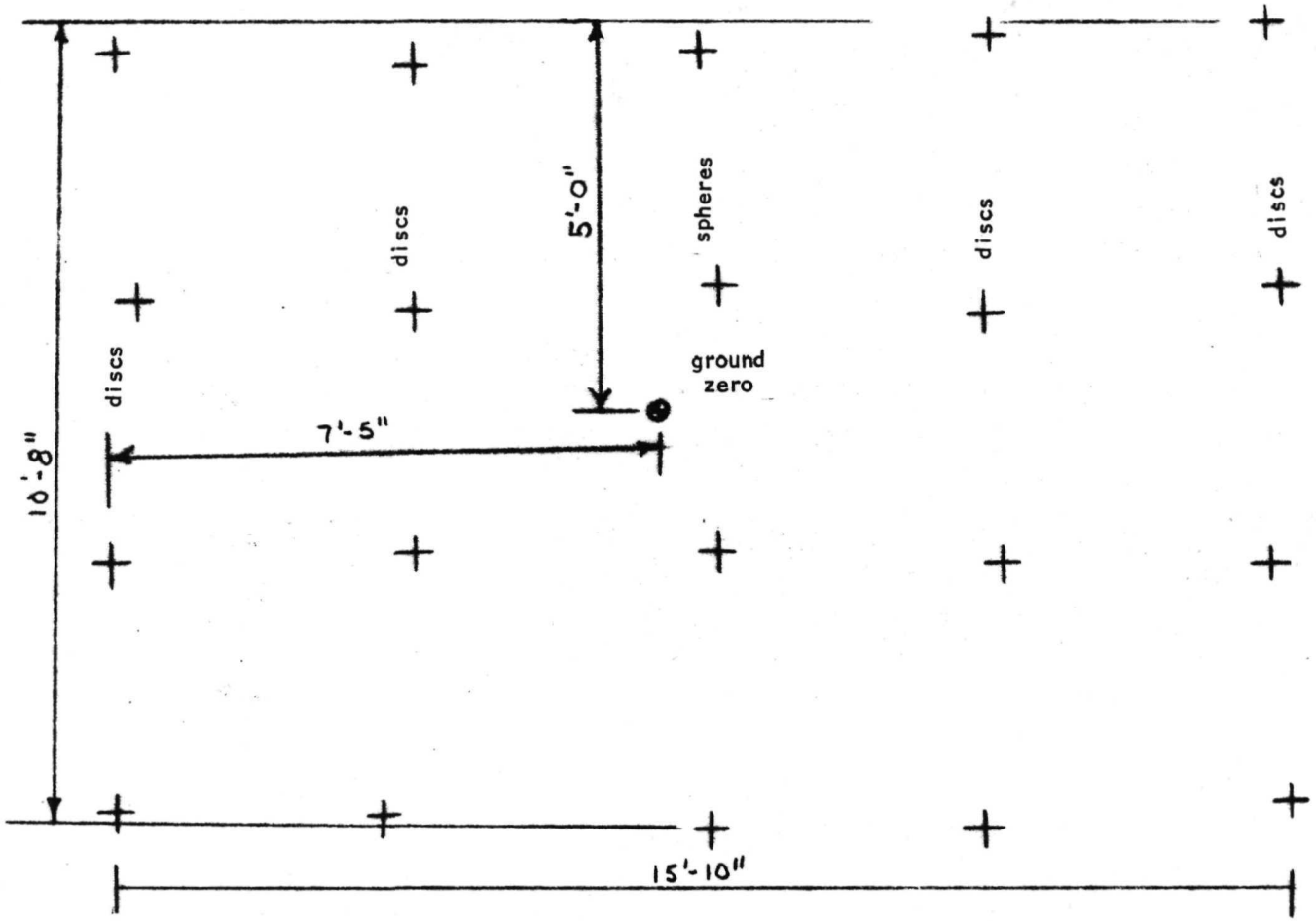

Figure 7. Tank Fragmentation Test
Dispersion Pattern