TECHNICAL NOTE TN-SM-83-12

(NASA-CR-170901) TEST REPORT FOR MSFC TEST NO. 83-2: PRESSURE SCALED WATER IMPACT TEST OF A 12.5 INCH DIAMETER MODEL OF THE SPACE SHUTTLE SOLID ROCKET BOOSTER FILAMENT WOUND CASE AND EXTERNAL TVC PCD (Chrysler Corp.) N84-10181

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TEST REPORT

FOR

MSFC TEST No. 83-2

PRESSURE SCALED WATER IMPACT TEST OF A 12.5 INCH DIAMETER MODEL OF THE SPACE SHUTTLE SOLID ROCKET BOOSTER FILAMENT WOUND CASE AND EXTERNAL TVC PCD

SEPTEMBER 1983

SHUTTLE TECHNOLOGY

HUNTSVILLE ELECTRONICS DIVISION
CHRYSLER CORPORATION

TECHNICAL NOTE TN-SM-83-12

TEST REPORT
FOR
MSFC TEST #83-2

CONTRACT NAS8-35017

PRESSURE SCALED WATER IMPACT TEST OF A 12.5 INCH DIAMETER MODEL OF THE SPACE SHUTTLE SOLID ROCKET BOOSTER FILAMENT WOUND CASE AND EXTERNAL TVC POD

SEPTEMBER 1983

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HUNTSVILLE, ALABAMA

FOREWORD

This report represents results of Pressure Scaled Water Impact Test, using a 12.5 inch diameter model of the Space Shuttle Solid Rocket Booster (SRB) configured to represent the Filament Wound Case (FWC) and Trust Vector Control (TVC) Pod.

The tests were conducted in May/June 1983 by Chrysler Corporation, for NASA/MSFC at the Hydroballistics Facility of the Naval Surface Weapons Center, White Oak, Maryland.

Results include local surface pressures in the model aft skirt/motor case region, simulated nozzle actuator force moments, and overall vehicle acceleration dynamics.

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SECTION I - INTRODUCTION

Water impact tests using a 12.5 inch diameter model representing a 8.56 percent scale of the Space Shuttle Solid Rocket Booster configuration were conducted May/June 1983 at the Naval Surface Weapons Center, White Oak, Maryland.

The two primary objectives of this SRB scale model water impact test program were:

1. Obtain cavity collapse applied pressure distributions for the 8.56 percent rigid body scale model FWC pressure magnitudes as a function of full-scale initial impact conditions at vertical velocities from 65 to 85 ft/sec, horizontal velocities from 0 to 45 ft/sec, and angles from -10 to +10 degrees.

2. Obtain rigid body applied pressures on the TVC pod and aft skirt internal stiffener rings at initial impact and cavity collapse loading events. In addition, nozzle loads were measured. Full scale vertical velocities of 65 to 85 ft/sec, horizontal velocities of 0 to 45 ft/sec, and impact angles from -10 to +10 degrees simulated.

A total of 47 tail first drops were made during this test. Model entry conditions were Froude scaled vertical velocities of approximately 65 to 85 ft/sec, with horizontal velocities up to 45 ft/sec and impact angles from -10 to +10 degrees. These tests were conducted at scaled atmospheric pressures (1.26 psia or 65 mm.Hg).

This report contains a description of the model, test program, test facility, test equipment, instrumentation system, data reduction procedures, and test results.

SECTION II - MODEL DESCRIPTION

The model used for this test program was a 8.56% Froude scaled rigid body simulation of the STS-1 configuration of the Space Shuttle 146 inch diameter solid rocket booster. It consists of a 12.5 inch diameter cylindrical body section 88.7 inches long and a short 18 degrees flared skirt for an overall model length of 102.5 inches.

The forward end of the model is closed with a flat bulkhead and the aft end has a hemispherical bulkhead with a 3.9 to 1 area ratio nozzle. Figures 1, 2 and 3 illustrate the model geometry and principal dimensions. This configuration represents the SRB with the nozzle extension jettisoned.

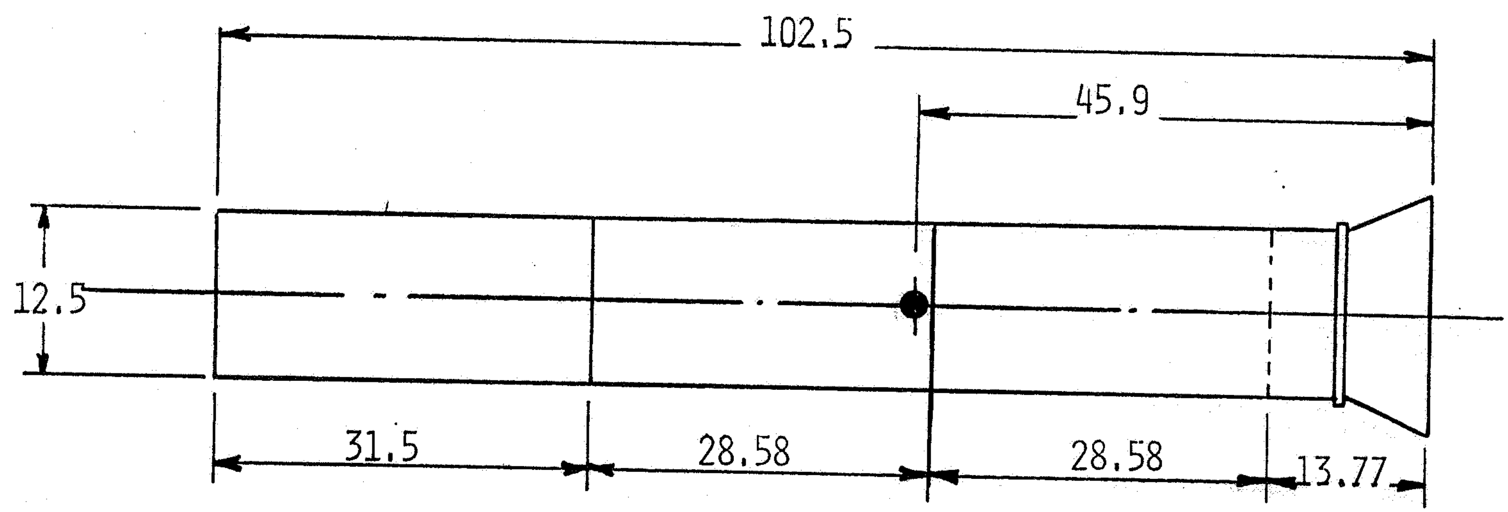
The model was fabricated from 2219 aluminum with a skin thickness of .08 inches. The forward cylindrical body sections were rolled and welded with machined flanges and stiffener rings at the end of each component. The aft body section, skirt, bulkhead, bellmouth and nozzle were machined from aluminum billets. The frontal area, geometry, and location of aft skirt stiffener rings were simulated on the model. After installing instrumentation and ballast the model had the following mass characteristics:

Weight ------------ 88.5 lbs

Moment of Inertia - 27.3 slug sq.ft.

CG Location ------- 45.9 from base

The above measurements were made without the instrument cable attached to the model. The instrument cable was supported independently of the model prior to each of the 47 free fall drops, therefore no weight of the instrument cable is considered.



8.56% MODEL

WEIGHT = 88.5

INERTIA = 27.3 SLUG-FT^2

FIGURE 1. MODEL OVERALL CONFIGURATION

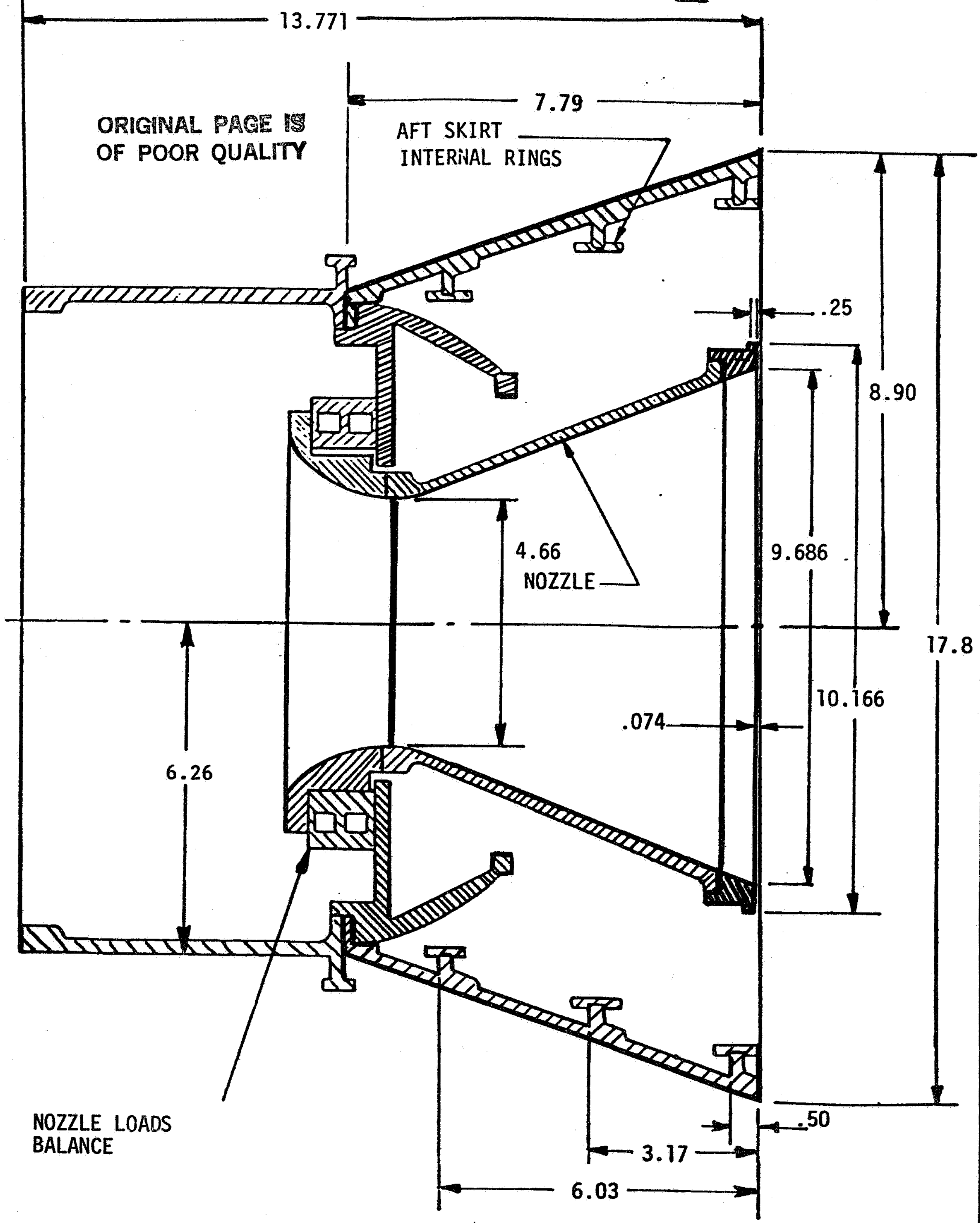


FIGURE 2. AFT ASSEMBLY (BARRELL)
MODEL GEOMETRY

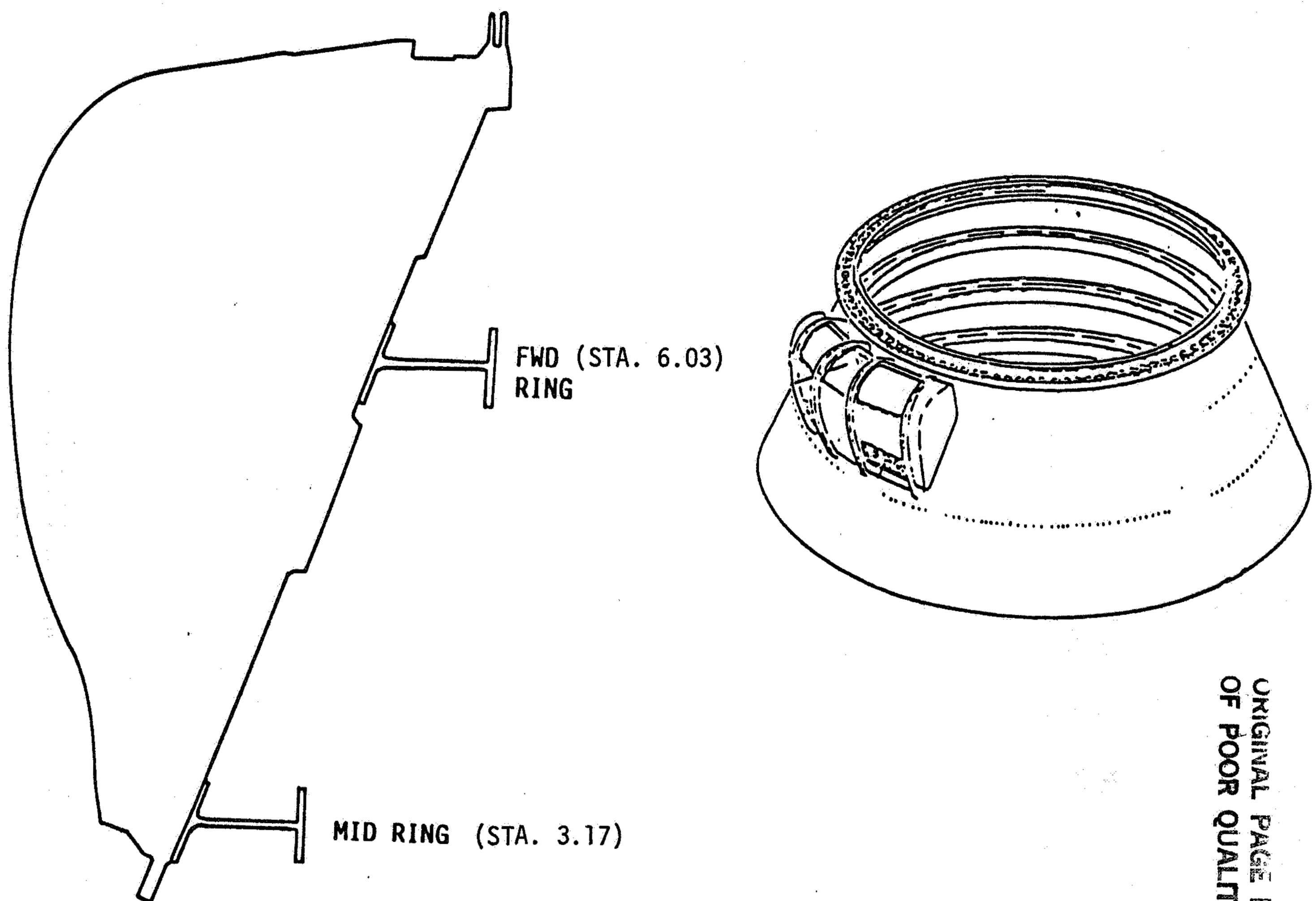


FIGURE 3 TVC POD CONFIGURATION
8.56% SCALE MODEL

SECTION III - ELECTRICAL INSTRUMENTATION

The model was instrumented with 51 transducers. These consisted of 5 crystal type accelerometers, 38 piezoelectric pressure transducers, a 4 component force balance which measured nozzle loads, and 4 uniaxial foil strain gage located on the actuators to measure their bending moments. These transducers along with their location and function are listed in Table I and illustrated in Figure 4 through 19.

Figure 9 shows model accelerometer locations. These consisted of axial, pitch, and yaw accelerometers. Three accelerometers were located at the model center of gravity and two on the aft bulkhead. Accelerometer sign convention is positive axial toward the model nose and positive pitch toward top centerline.

The model nozzle and bellmouth were attached to the aft bulkhead through a 4 component strain gage force balance. This balance encircled the bellmouth one inch forward of the nozzle throat and was of a moment cage design so that forces and moments are measured by individual strain gage bridges. This balance measured axial force, normal force, pitching moment, and yawing momewnt. All forces and moments are referenced to the balance moment center which is one inch forward of the nozzle throat and on nozzle centerline.

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Figure 20 shows the balance sign convention. Model instruments were water proofed with a combination of scotch cast epoxy resin, RTV and silicone grease. To protect pressure transducers from thermal shocks, the diaphrams were recessed approximately 1/16 of an inch below the model skin and covered with RTV. All instruments were bench calibrated prior to installation in the model and were check calibrated through the model instrument system after all wiring had been completed.

Transducer signals were transmitted from the model through instrument cables that attached to model top centerline near the C.G. These cables were approximately 100 feet long. The instrument cables were made up of 20 conductor and 12 conductor shielded, 20 gage teflon insulated wire and a power cable. All instruments used a 5 volt common power which was connected to the individual transducers through a terminal strip. Pressure, acceleration and strain gage outputs from the instrument cable were fed through appropriate couplers or signal conditioners/amplifiers into two, 28 channel, FM tape recorders. Data was recorded at 30 IPS, wide band, (108 KHZ center frequency). IR16"B" time was recorded on channel 14 and 28 of each recorder.

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MEAS NO.	MEAS TYPE	RANGE	LOCATION	REMARKS
EA1	PCB	500 G's	MID BODY - AXIAL	ALL RUNS
EA2	MODEL H302-A04		AFT BODY - AXIAL	ALL RUNS
EP1	QUARTZ ACCELEROMETERS		MID BODY - PITCH	ALL RUNS
EP2			AFT BODY - PITCH	ALL RUNS
EY1			AFT BODY - YAW	ALL RUNS
SA1	BALDWIN SR4		NOZZLE LOAD - AXIAL	ALL RUNS
SN2	STRAIN GAGES		NOZZLE LOAD - NORMAL	ALL RUNS
SP3			NOZZLE LOAD - PITCH	ALL RUNS
SY4			NOZZLE MOMENT - YAW	ALL RUNS
D01	PCB PIEZOTRONICS	100 PSIG	STATION 33.0 - Ø = 0° (TDC) STATION 9.3 - Ø = 0° (TDC)	RUNS 1 THRU 11 RUNS 12 THRU 47
D02	HIGH FREQ MODEL		STATION 25.0 - Ø = 0° (TDC)	ALL RUNS
D03	H13A22 PRES		STATION 17.1 - Ø = 0° (TDC)	ALL RUNS
D04	TRANSDUCERS		STATION 16.0 - Ø = 0° (TDC)	ALL RUNS
D05			STATION 14.5 - Ø = 0° (TDC)	ALL RUNS
D06			STATION 12.5 - Ø = 0° (TDC)	ALL RUNS
D07			STATION 10.8 - Ø = 0° (TDC)	ALL RUNS
D08			STATION 25.0 - Ø = 180°	ALL RUNS
D09			STATION 16.0 - Ø = 15°	ALL RUNS

TABLE I INSTRUMENTATION

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MEAS NO.	MEAS TYPE	RANGE	LOCATION	REMARKS
D10	PCB		STATION 16.0 $\emptyset = 30^o$	ALL RUNS
D11	PIEZOTRONIC HIGH FREQ		STATION 16.0 $\emptyset = 60^o$	ALL RUNS
D12	MODEL H113A24		STATION 16.0 $\emptyset = 180^o$ (BDC)	ALL RUNS
D13	PRES. TRANSDUCER		STATION 16.0 $\emptyset = 270^o$	ALL RUNS
D14			STATION 16.0 $\emptyset = 315^o$	ALL RUNS
D15			STATION 16.0 $\emptyset = 345^o$	ALL RUNS
D16			STATION 10.8 $\emptyset = 15^o$	ALL RUNS
D17			STATION 10.8 $\emptyset = 30^o$	ALL RUNS
D18			STATION 10.8 $\emptyset = 60^o$	ALL RUNS
D19			STATION 10.8 $\emptyset = 180^o$ (BDC)	ALL RUNS
D20			STATION 10.8 $\emptyset = 270^o$	ALL RUNS
D21			STATION 10.8 $\emptyset = 315^o$	ALL RUNS
D22			STATION 10.8 $\emptyset = 345^o$	ALL RUNS
D23			STATION 17.1 $\emptyset = 15^o$	ALL RUNS
D24			STATION 17.1 $\emptyset = 345^o$	ALL RUNS
D25			STATION 14.5 $\emptyset = 15^o$	ALL RUNS
D26			STATION 14.5 $\emptyset = 345^o$	ALL RUNS
D27			STATION 12.2 $\emptyset = 15^o$	ALL RUNS
D28			STATION 12.5 $\emptyset = 345^o$	ALL RUNS
D29			STATION 35.75 $\emptyset = 0^o$ (TDC) ON OUTSIDE SKIN - AFT	ALL RUNS

TABLE I INSTRUMENTATION

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MEAS NO.	MEAS TYPE	RANGE	LOCATION	REMARKS
P01	PCB PIEZOTRONICS HIGH FREQ MODEL H113A44 PRES. TRANSDUCERS		TVC POD-TOP (TDC) STATION 9.3 Ø = 0^o (TDC)	RUNS 1 THRU 5 AND 12 THRU 47 RUNS 6 THRU 11
P02			TVC POD-CENTER (TDC) STATION 4.47 Ø = 354.0^o	RUNS 1 THRU 5 AND 12 THRU 47 RUNS 6 THRU 11
P03			TVC POD-BOTTOM (TDC)	RUNS 1 THRU 5 AND 12 THRU 47 NOT RECORDED 6 THRU 11
P04			TVC POD-END STATION 11.65 Ø = 348.35^o	RUNS 1 THRU 5 AND 12 THRU 47 RUNS 6 THRU 11
P05			TVC POD END	RUNS 1 THRU 5 AND 12 THRU 47 NOT RECORDED 6 THRU 11
P06			BULKHEAD Ø = 0^o (TDC)	ALL RUNS
P07			FWD RING BOTTOM Ø = 0^o (TDC)	ALL RUNS
P08			MID RING BOTTOM Ø = 0^o (TDC)	ALL RUNS
P09			AFT RING BOTTOM Ø = 0^o (TDC)	ALL RUNS

TABLE I INSTRUMENTATION (Continued)

MEAS NO.	MEAS TYPE	RANGE	LOCATION	REMARKS
SXR1	BLH UNIAXIAL CONSTANTAN FOIL STRAIN GAGE		ROCK ACTUATOR $\emptyset = 315^{o}$	ALL RUNS
SYZ1			ROCK ACTUATOR $\emptyset = 315^{o}$	ALL RUNS
SXR2			TILT ACTUATOR $\emptyset = 225^{o}$	ALL RUNS
SYZ2			TILT ACTUATOR $\emptyset = 225^{o}$	ALL RUNS

TABLE I INSTRUMENTATION (Concluded)

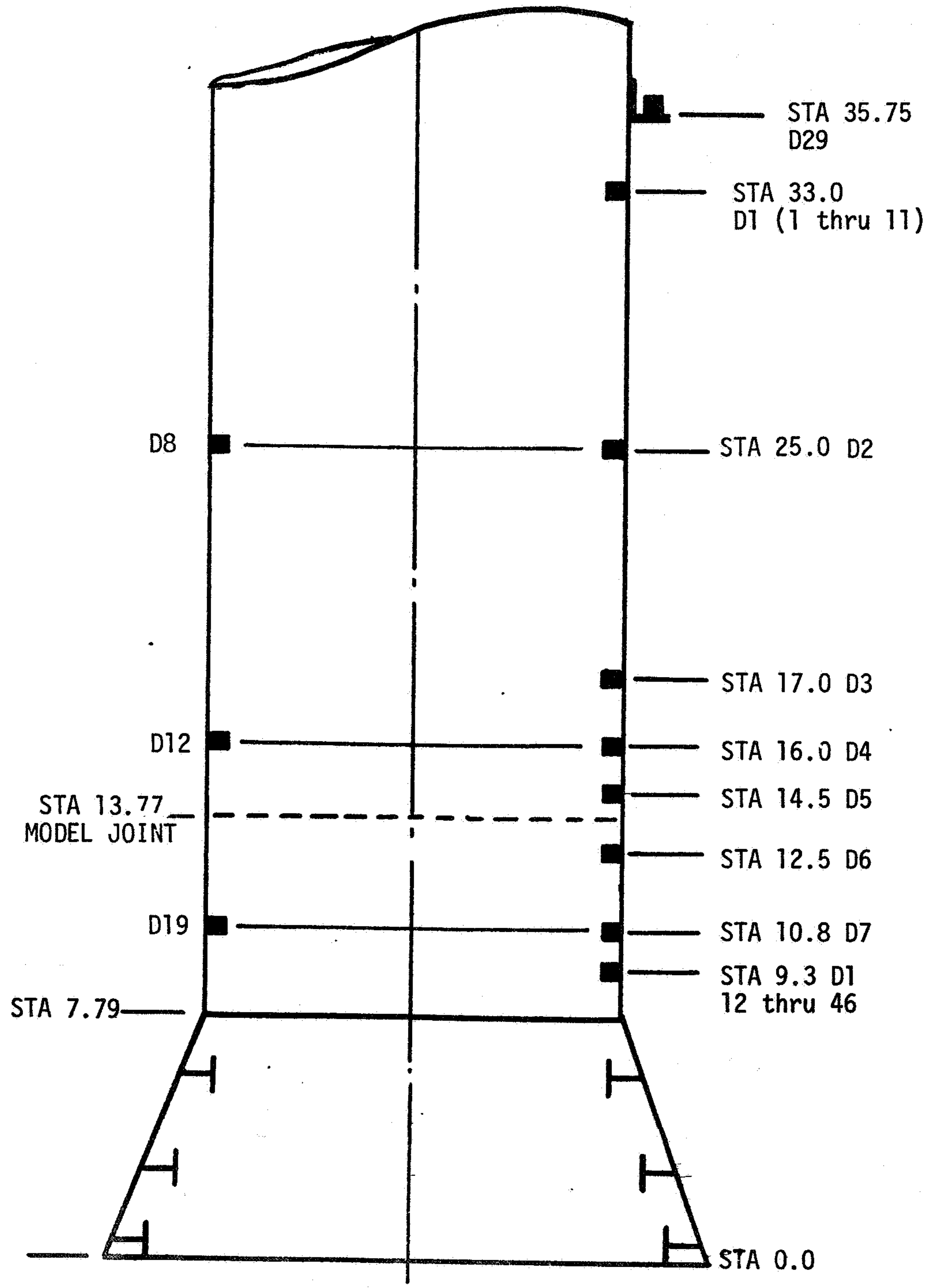
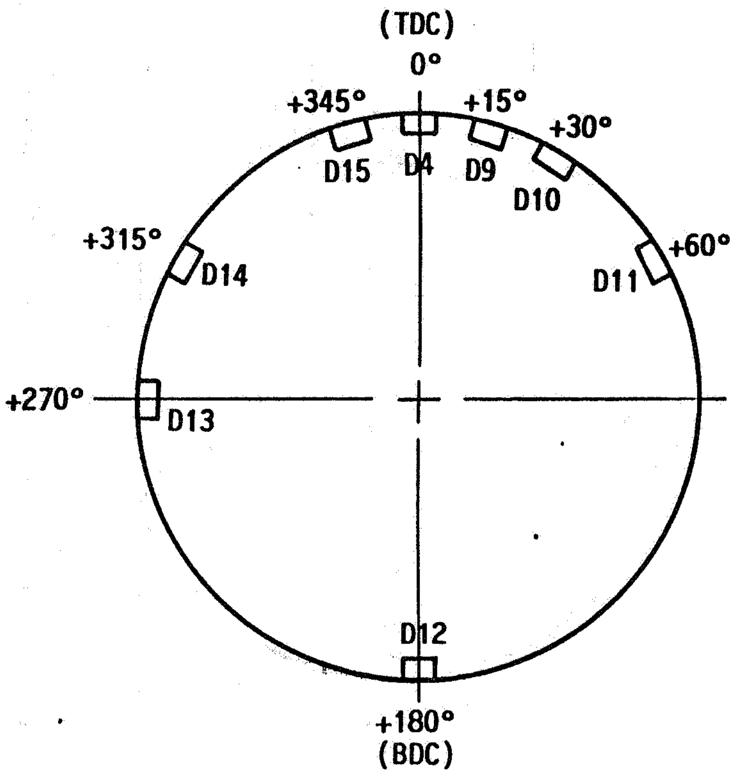
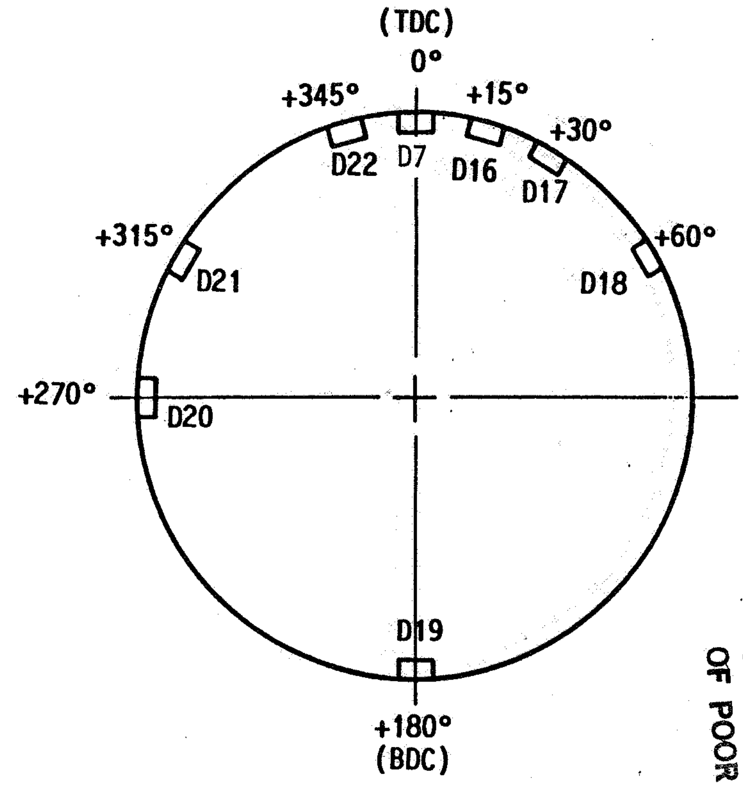


FIGURE 4. SRB FWC SCALE PRESSURE TRANSDUCER LOCATIONS



XSTA = 16.0



XSTA = 10.8

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FIGURE 5 SRB FWC SCALE MODEL PRESSURE TRANSDUCER LOCATIONS

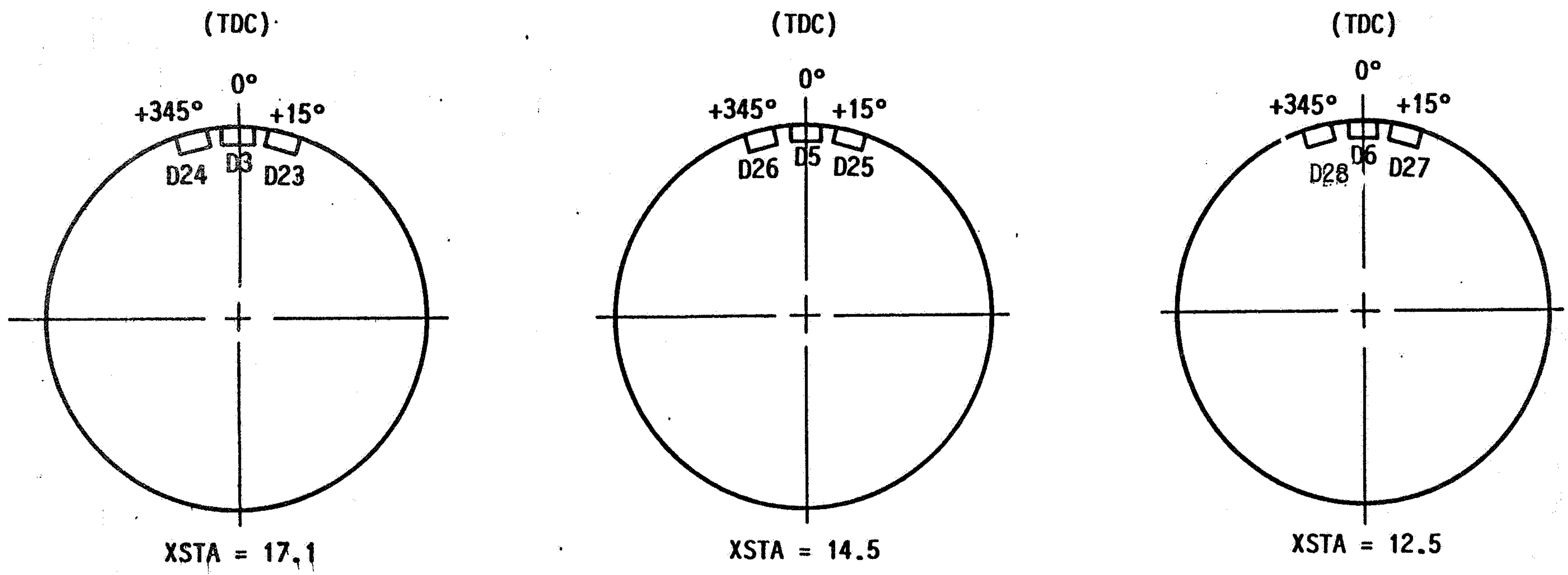

FIGURE 6 SRB FWC SCALE MODEL PRESSURE TRANSDUCER LOCATIONS

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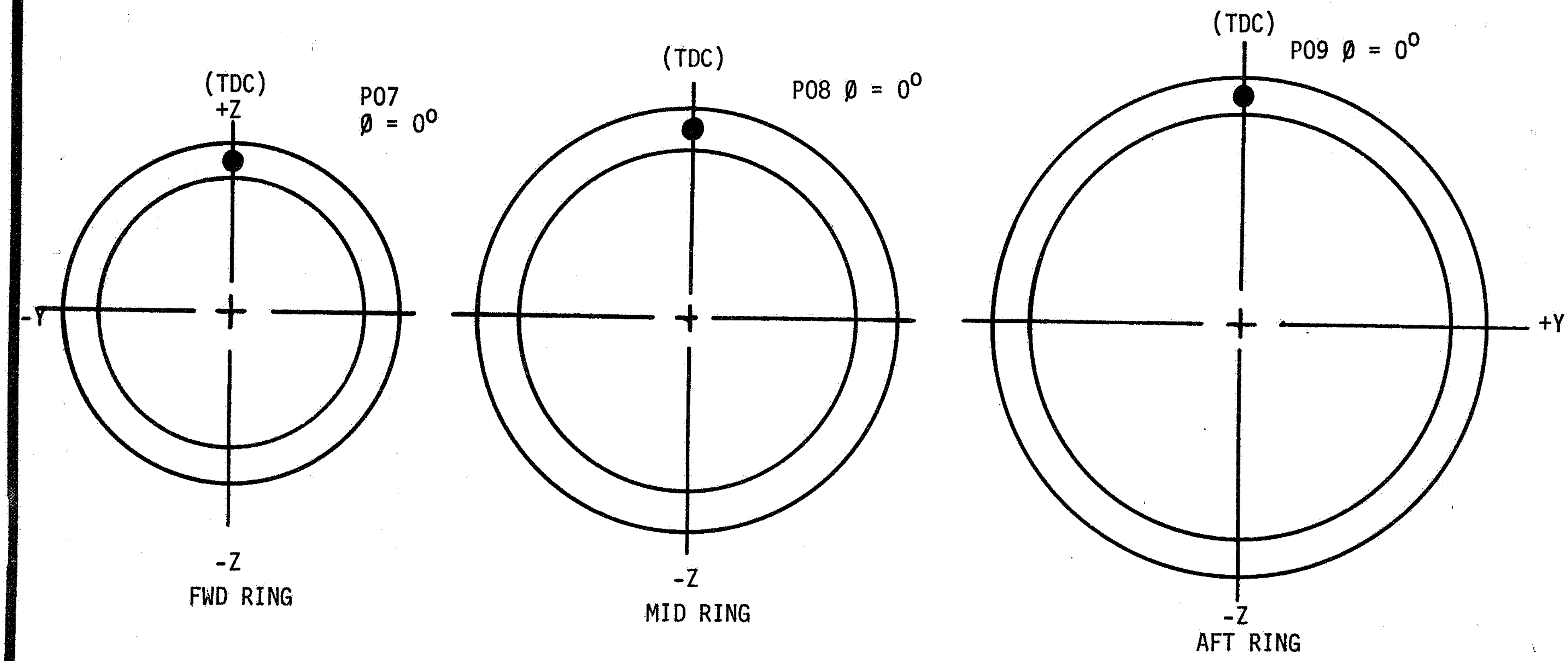

FIGURE 7 AFT. SKIRT RING PRESSURE TRANSDUCER LOCATIONS

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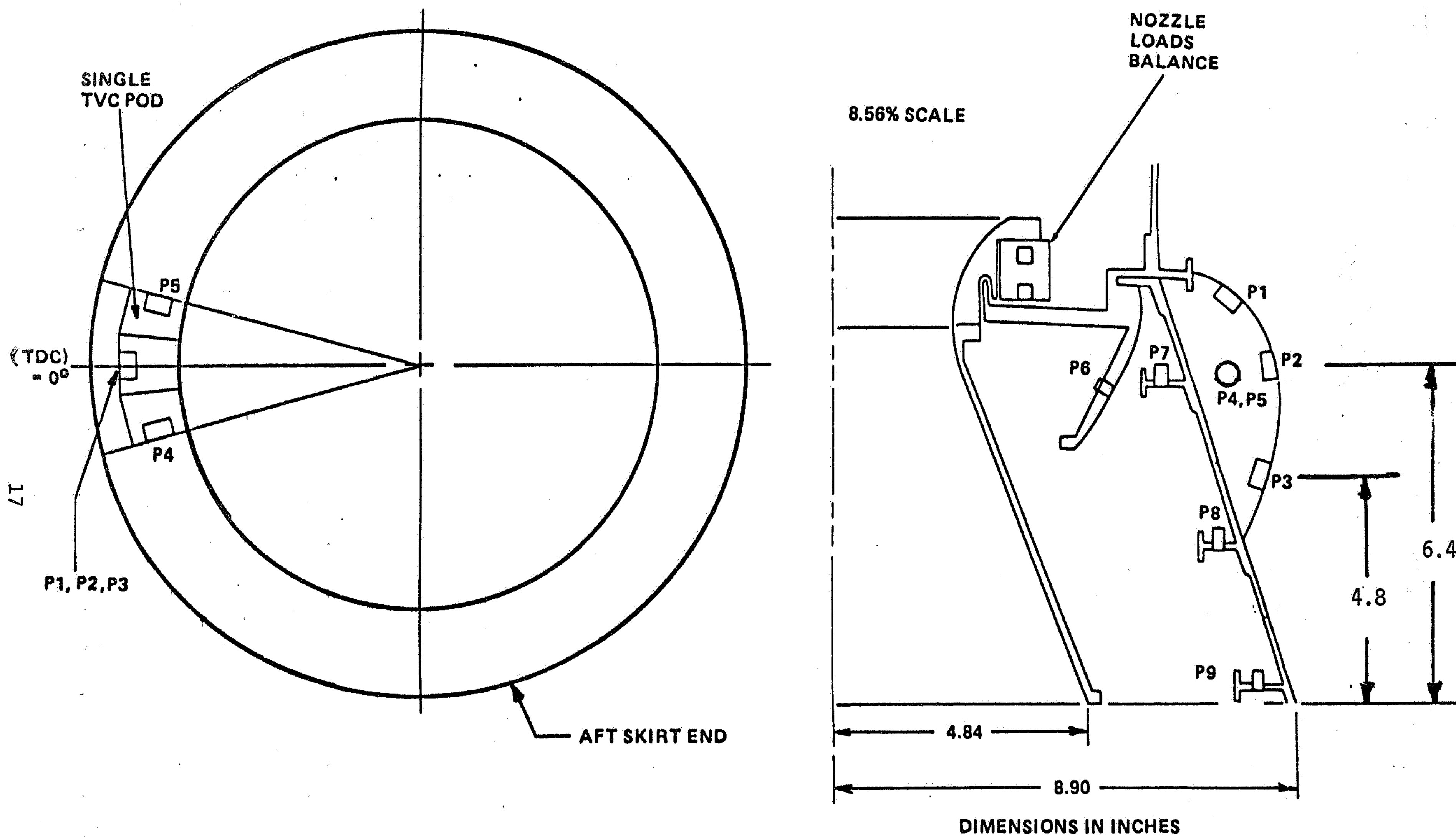

FIGURE 8   TVC POD SCALE MODEL PRESSURE TRANSDUCER LOCATIONS

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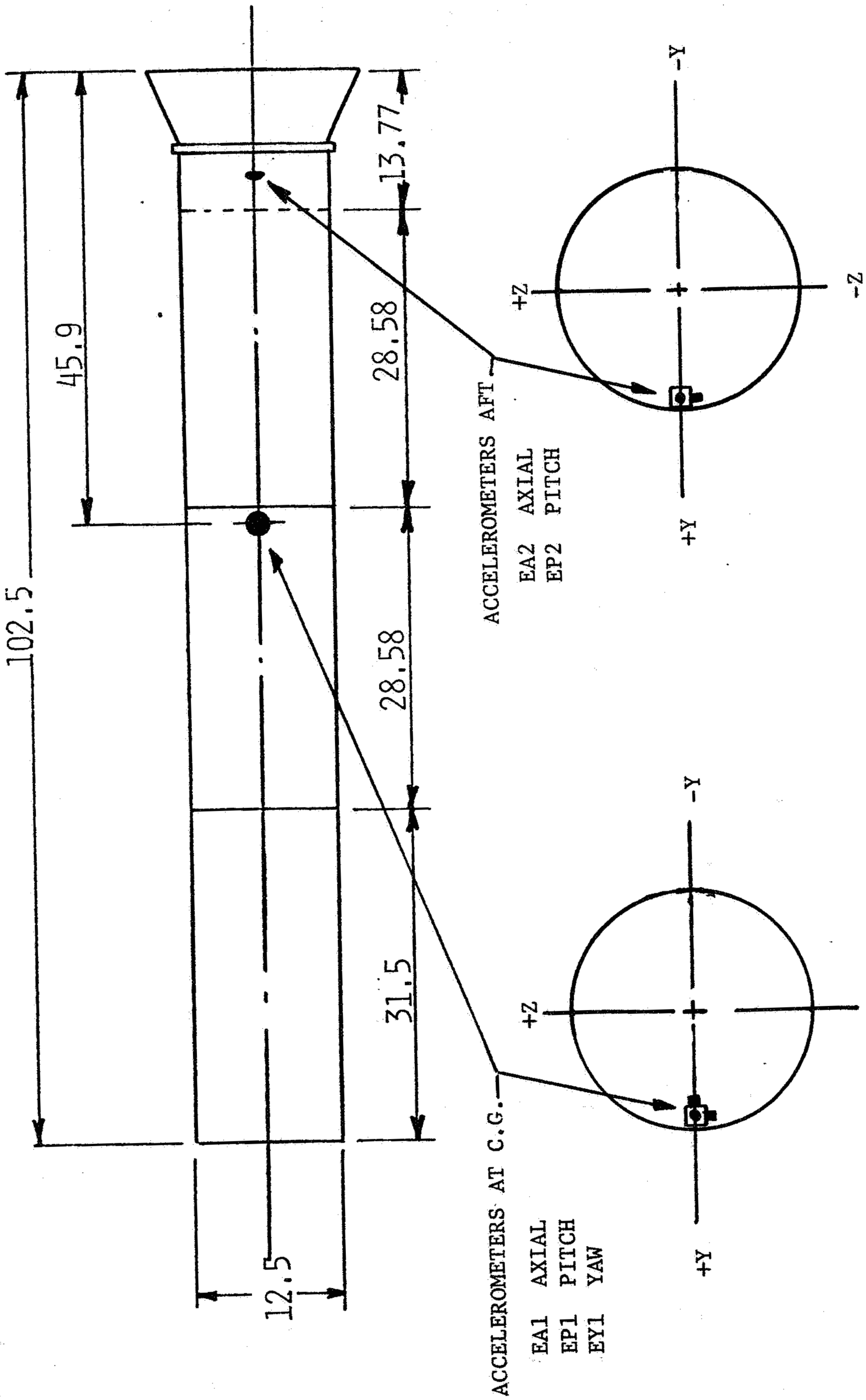

FIGURE 9 ACCELEROMETERS

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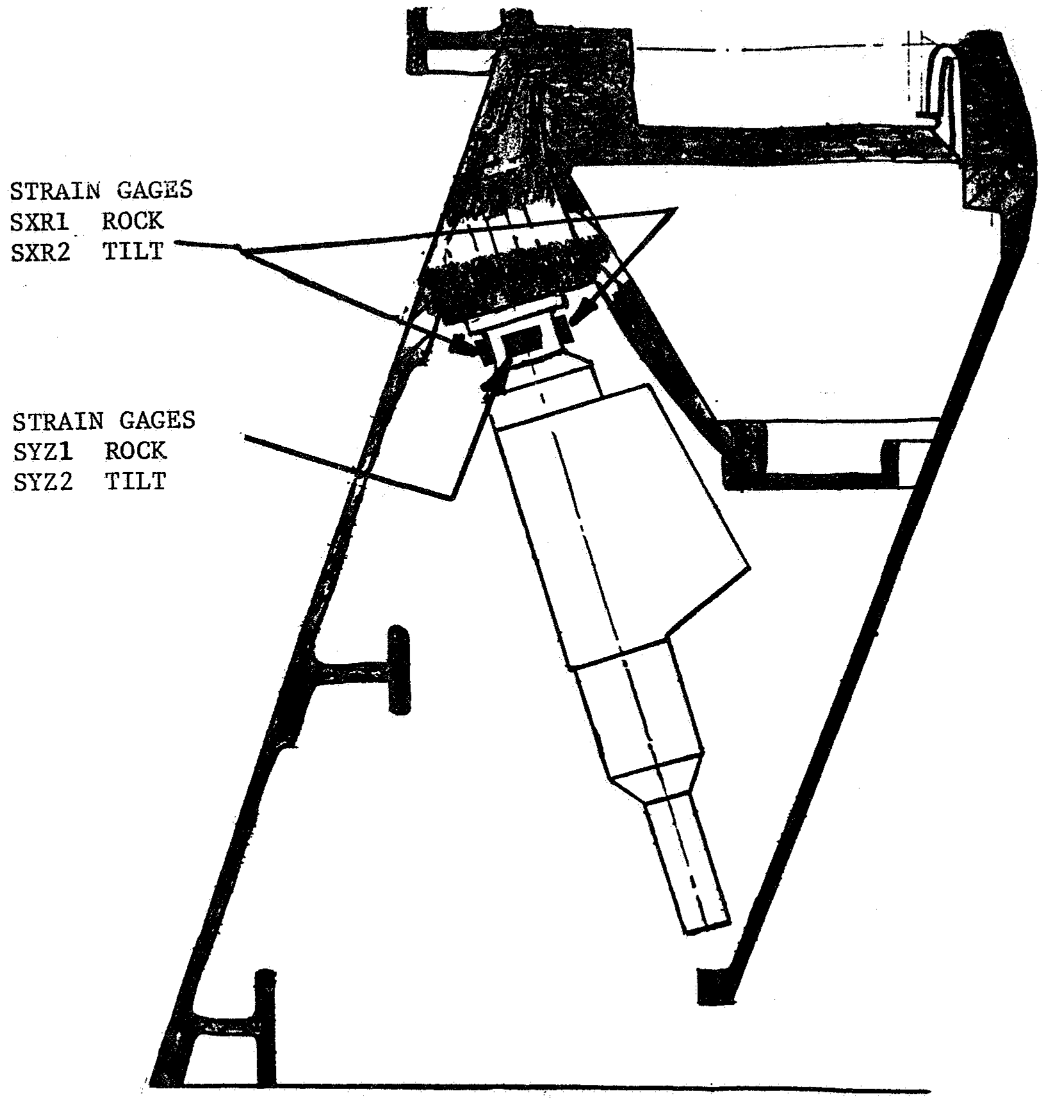

FIGURE 10

ACTUATOR TRANSDUCER LOCATIONS

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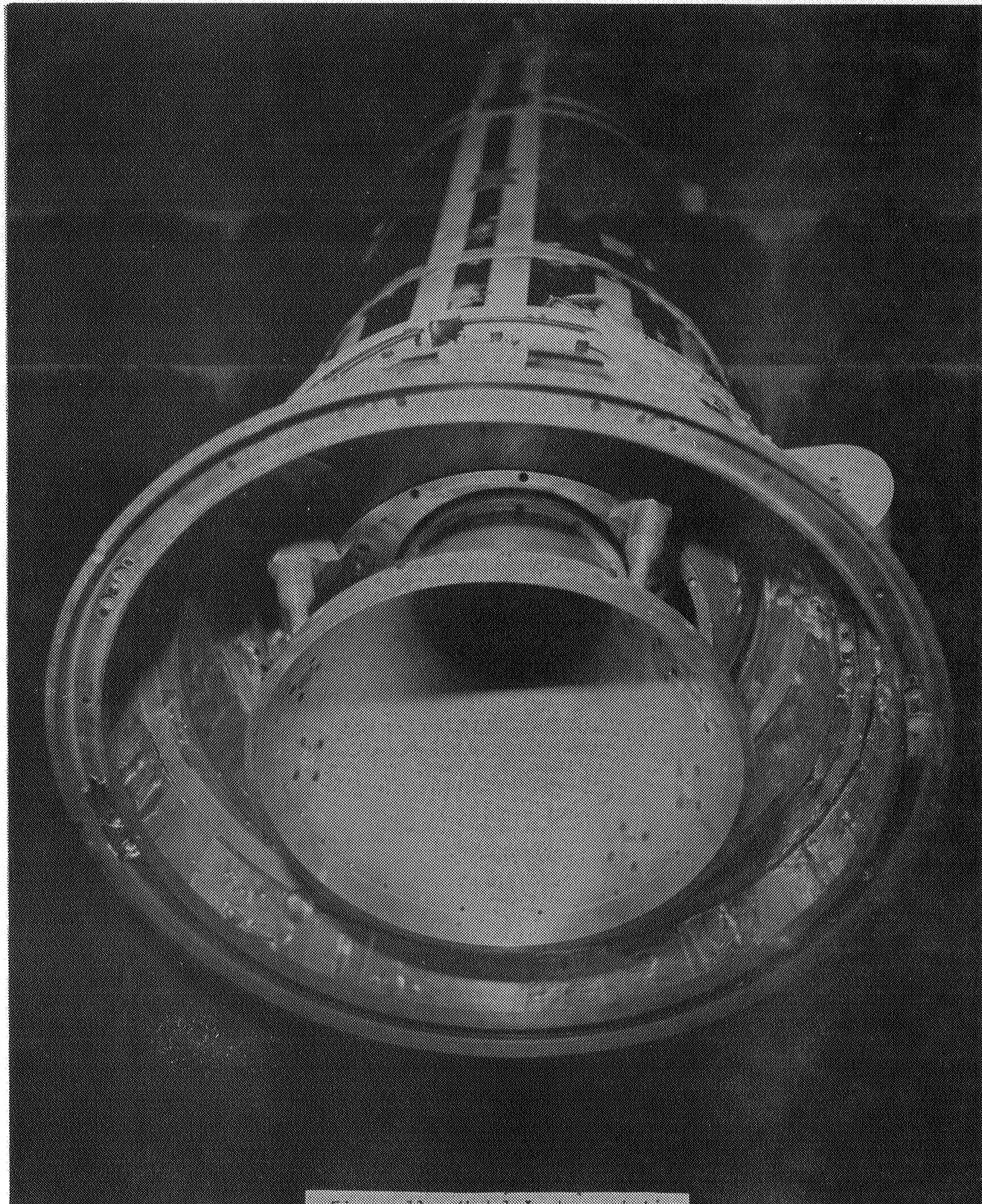

Figure 11. Model Instrumentation

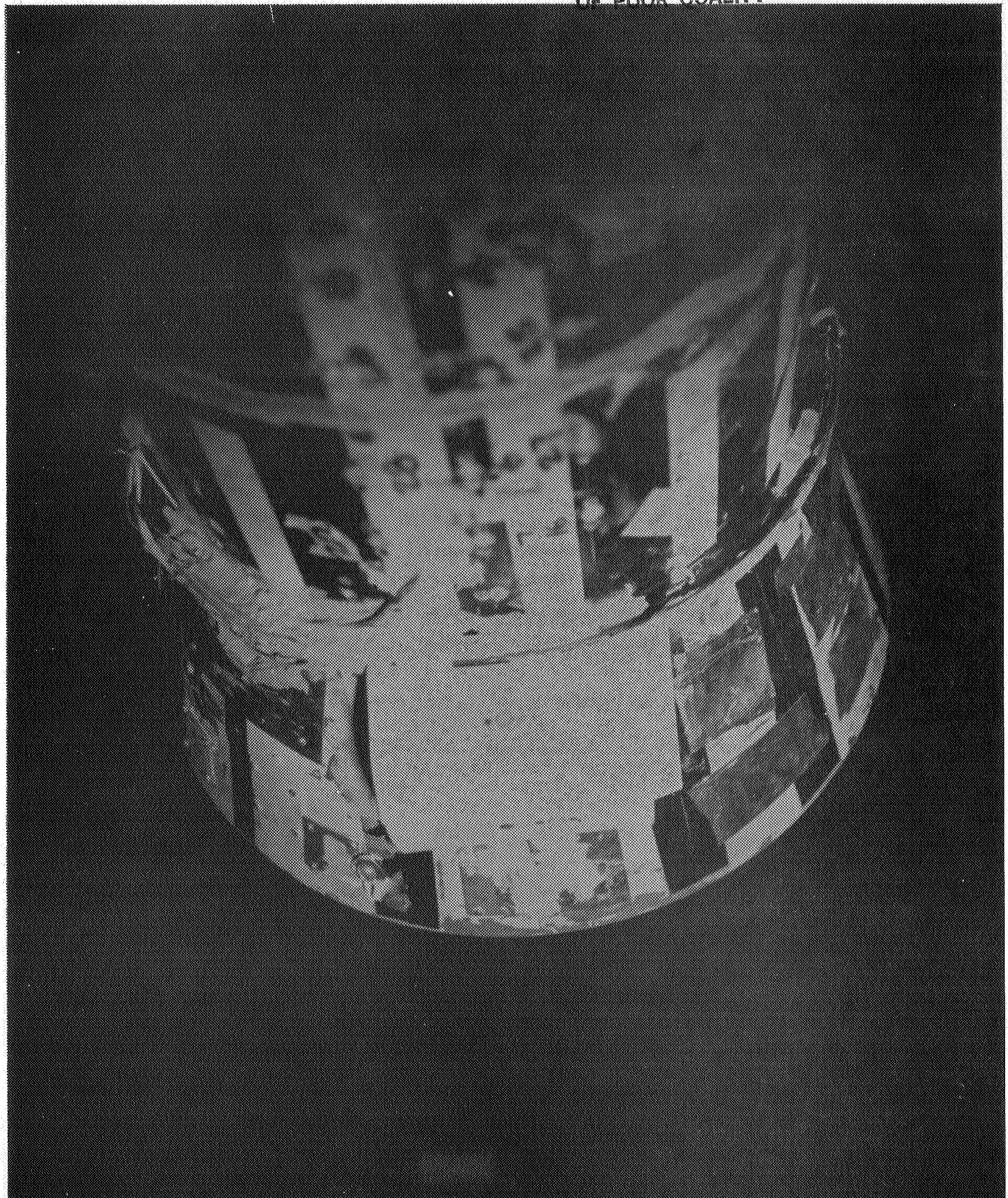

Figure 12. Model Instrumentation

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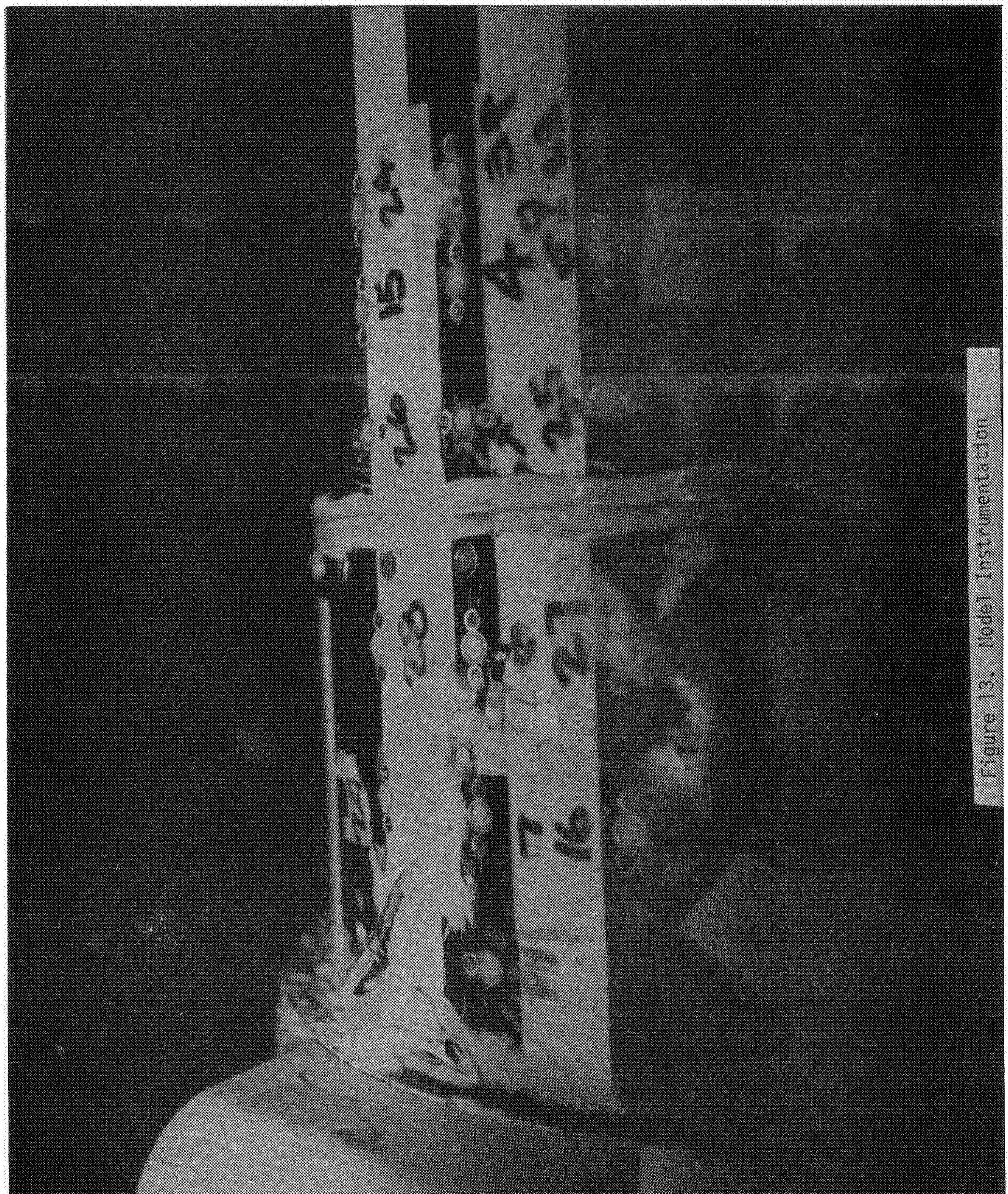

Figure 13. Model Instrumentation

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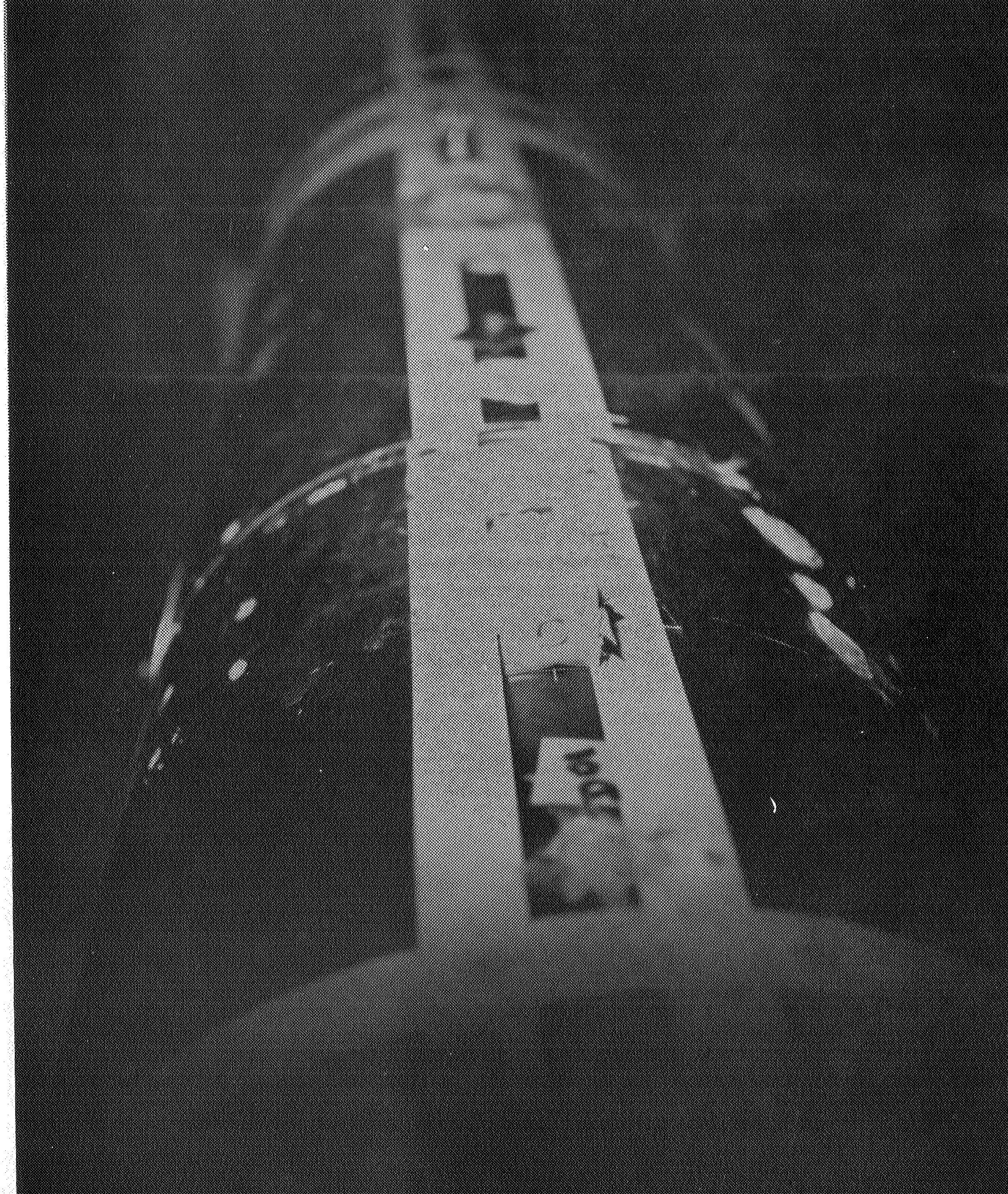

Figure 14. Model Instrumentation

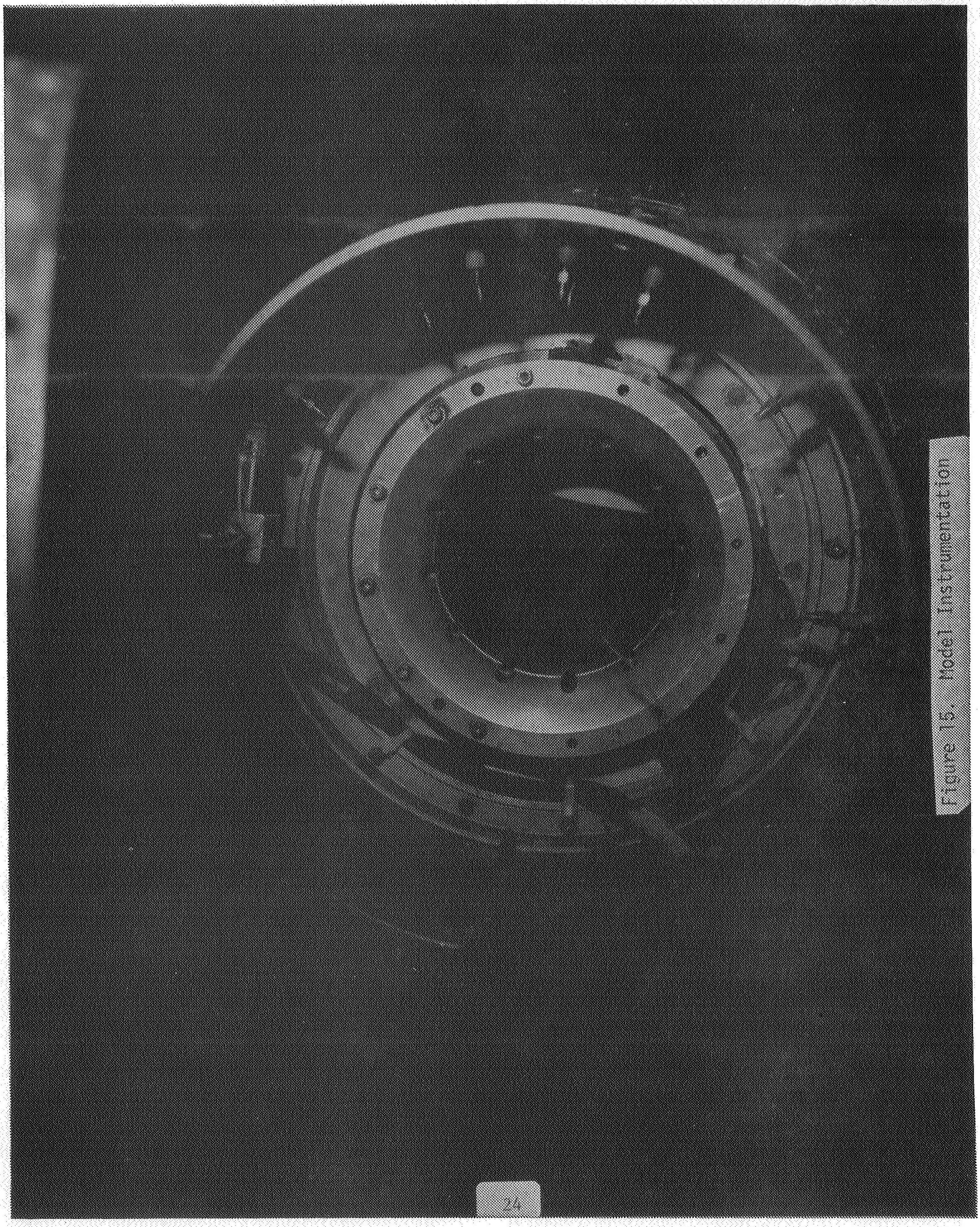

Figure 15. Model Instrumentation

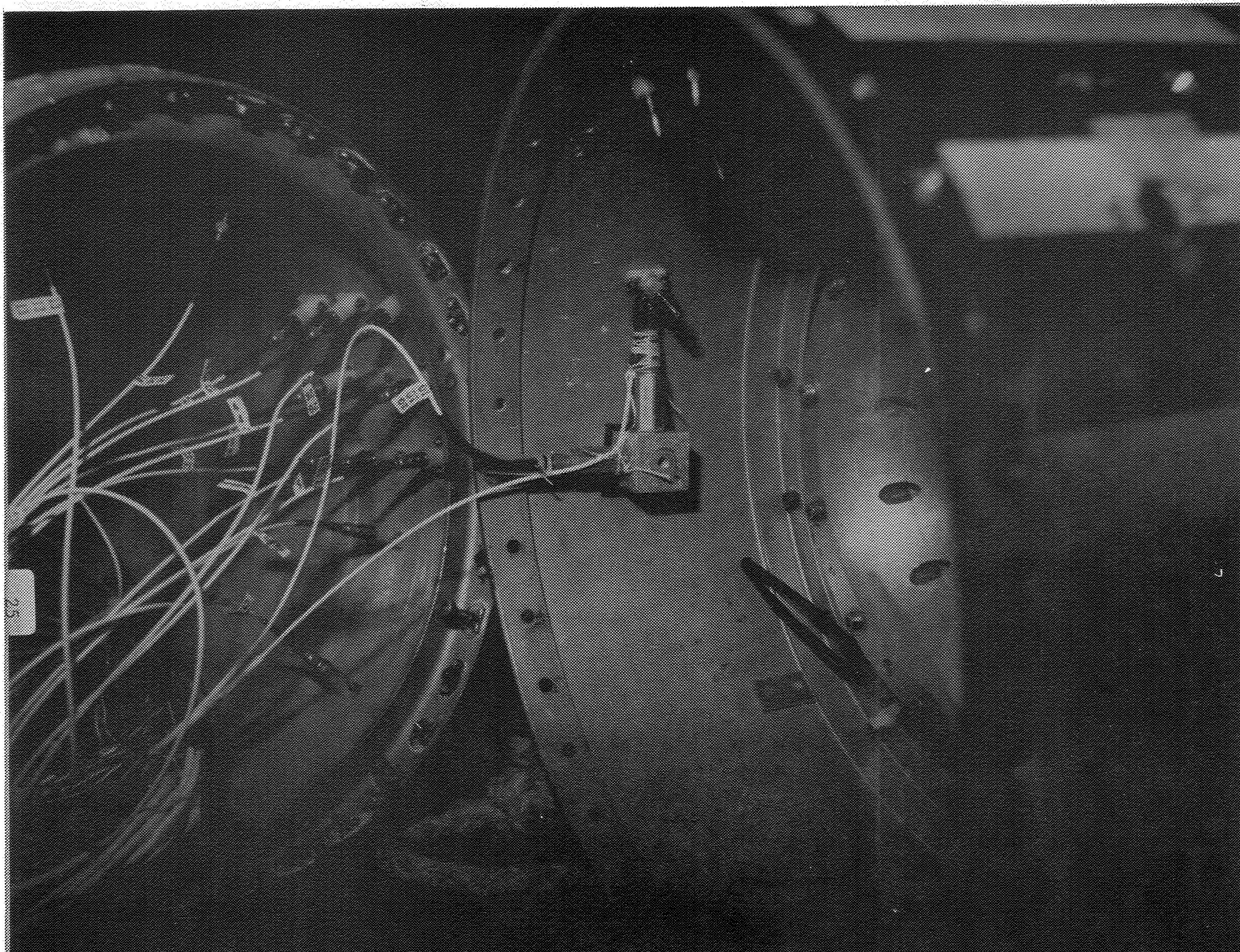

Figure 16. Model Instrumentation

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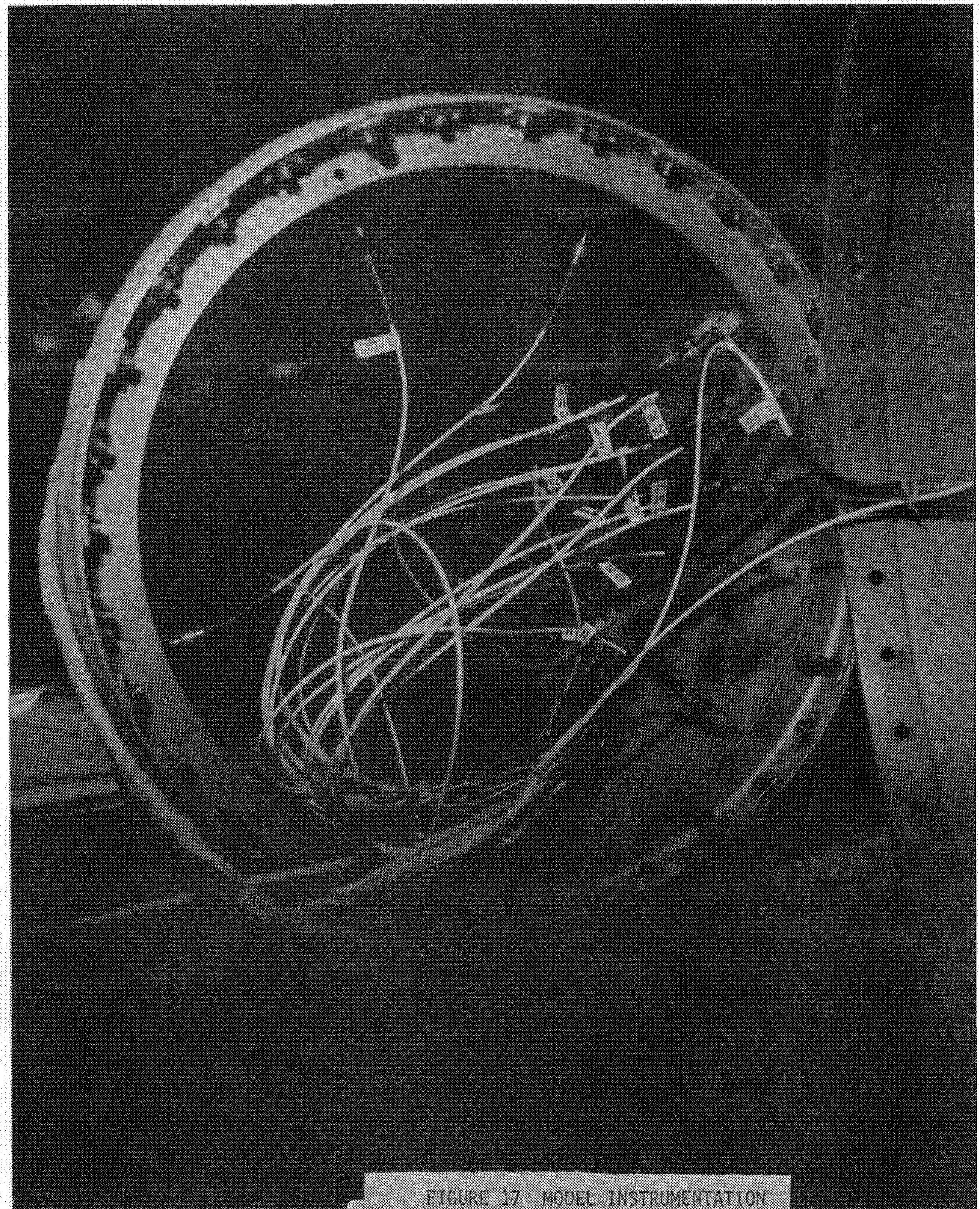

FIGURE 17 MODEL INSTRUMENTATION

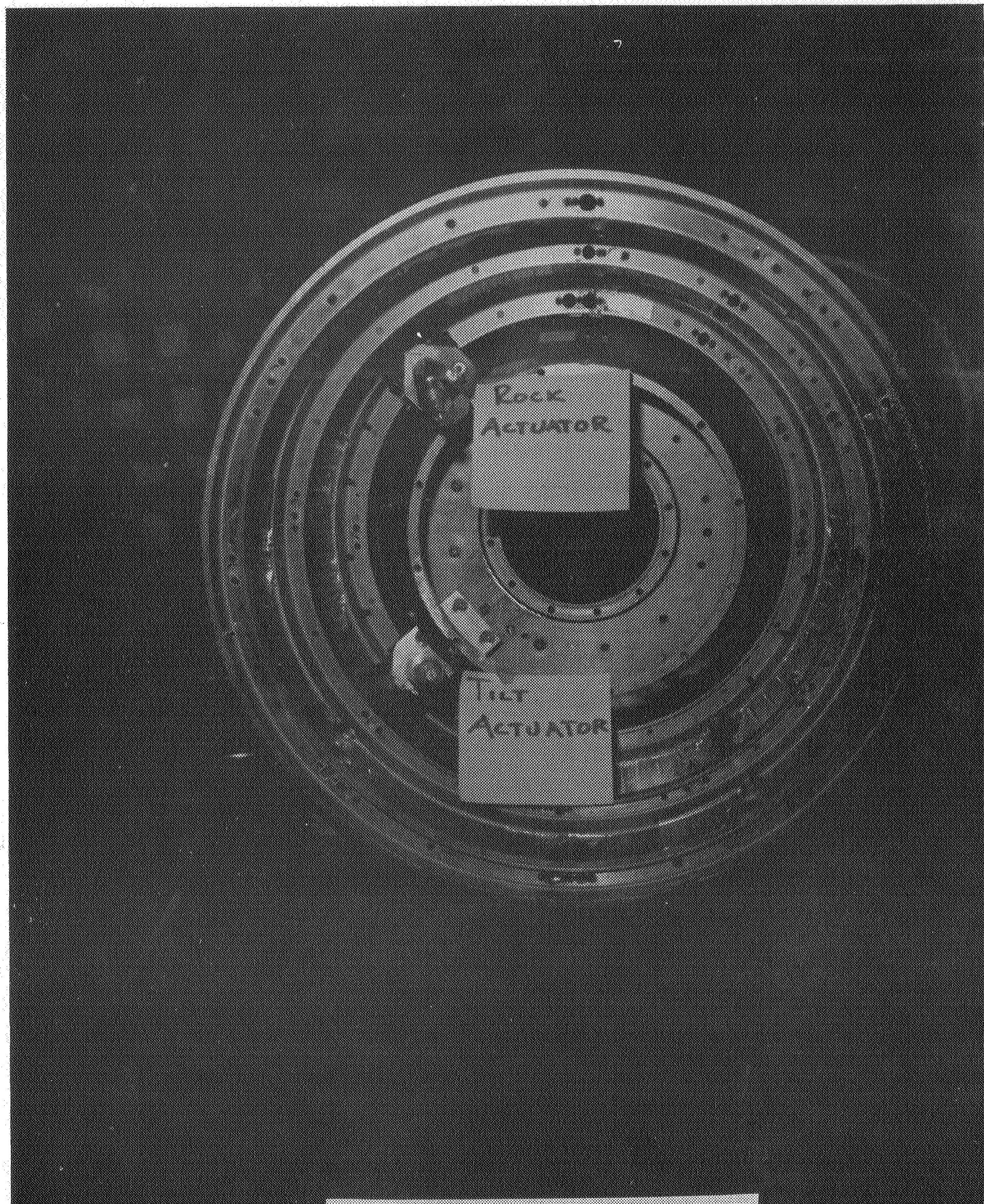

FIGURE 18 MODEL INSTRUMENTATION

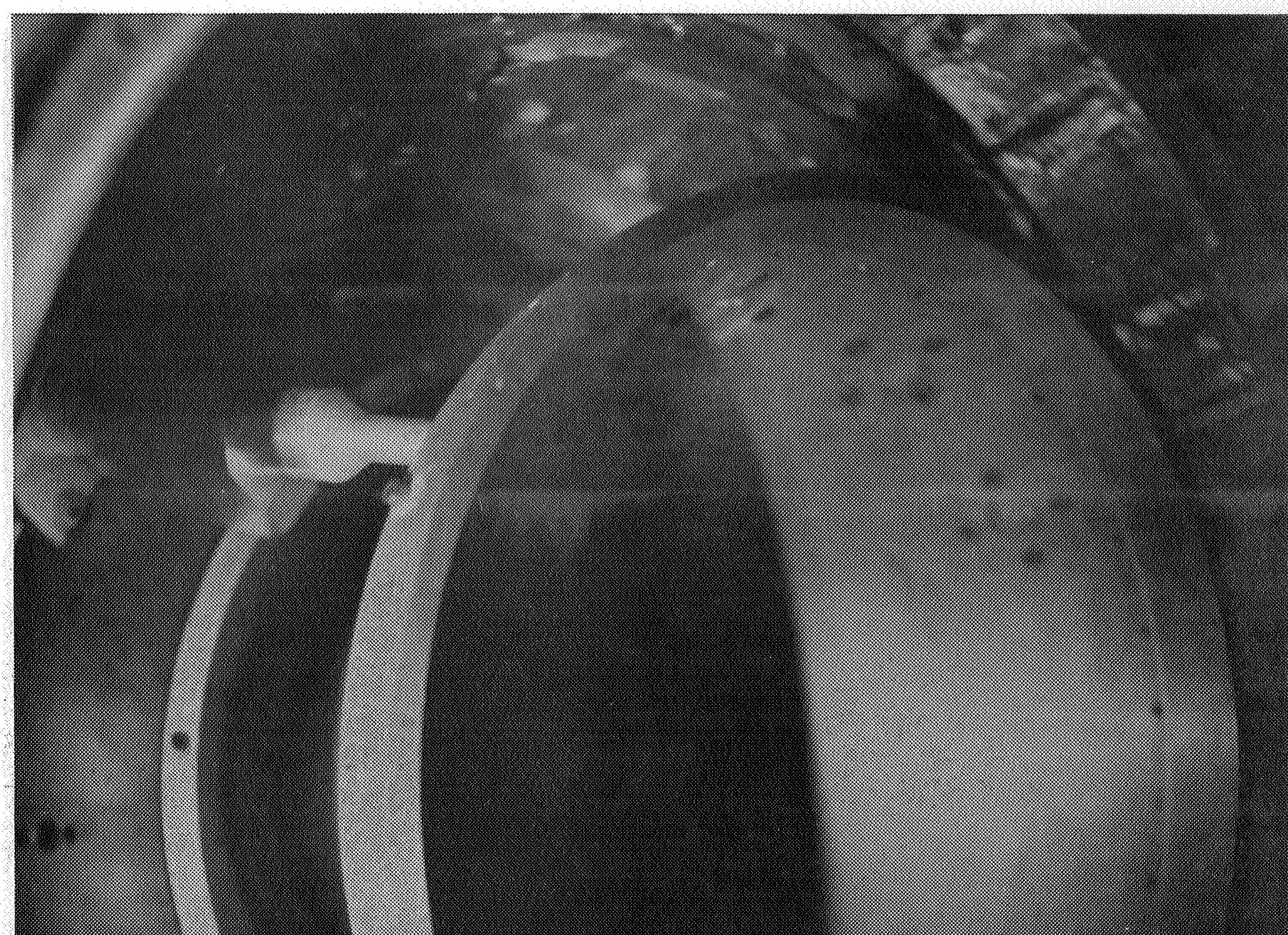

FIGURE 19 MODEL INSTRUMENTATION

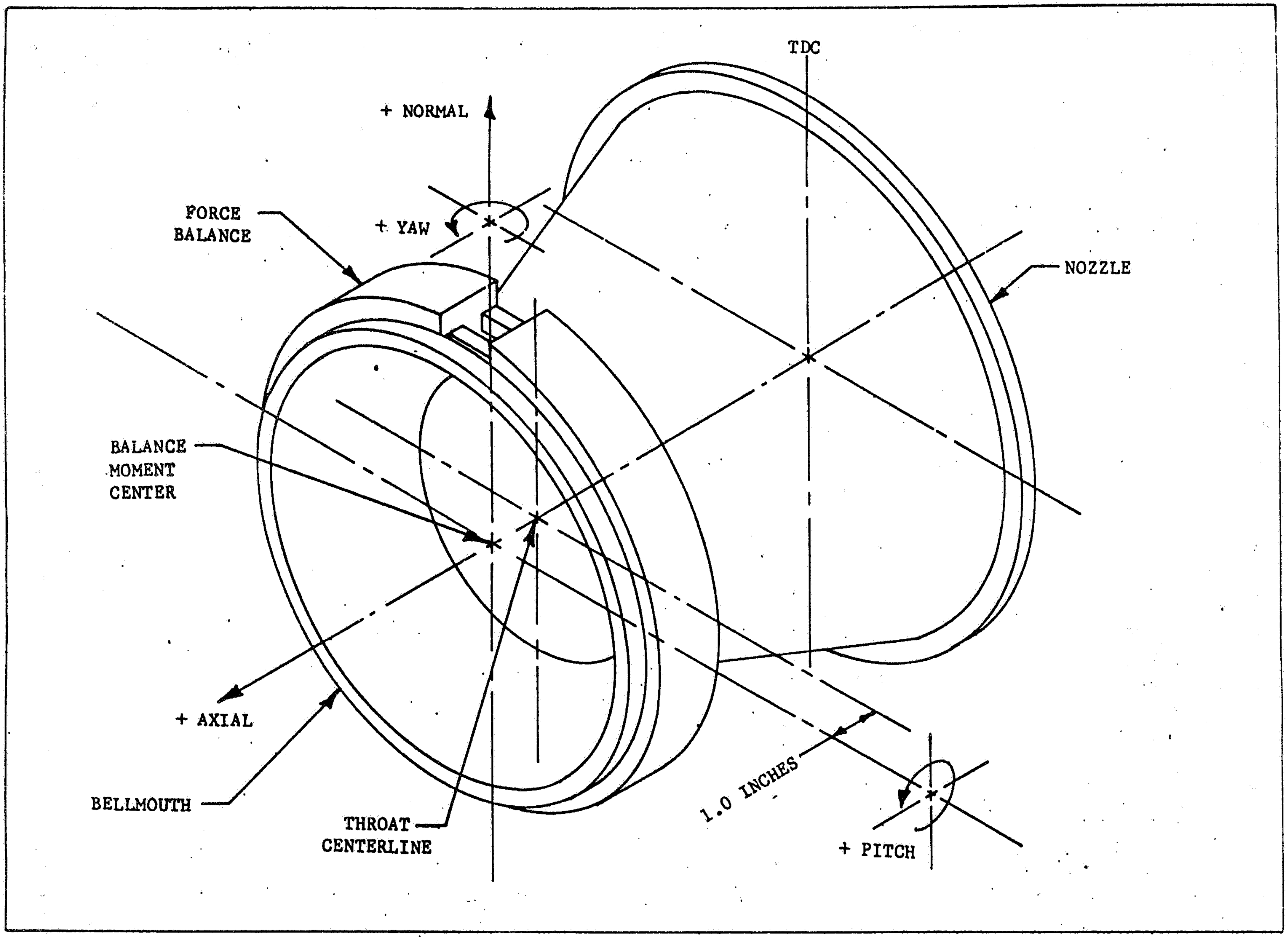

FIGURE 20- NOZZLE FORCE BALANCE AXIS SYSTEM

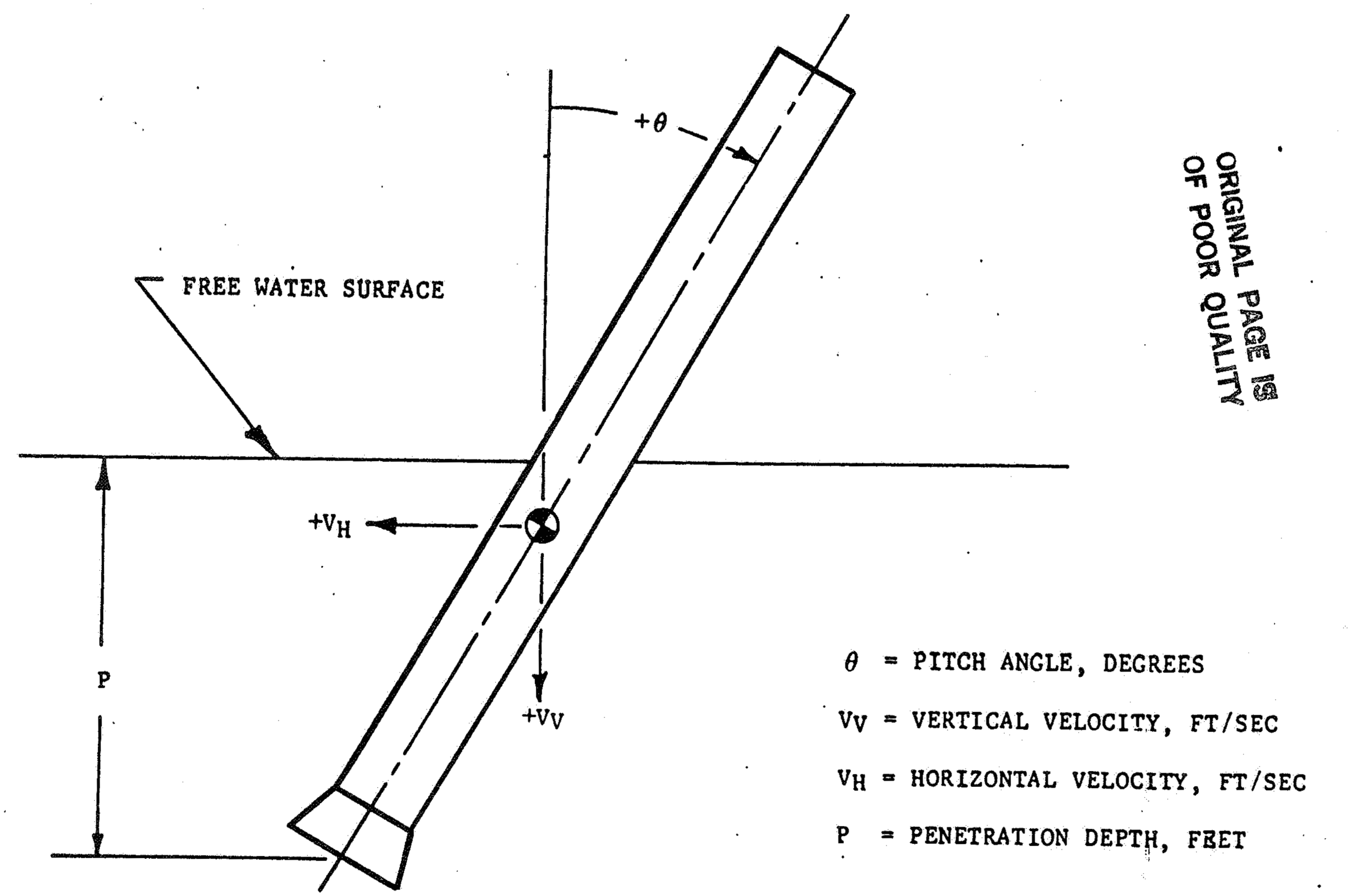

FIGURE 21- MODEL AXIS SYSTEM

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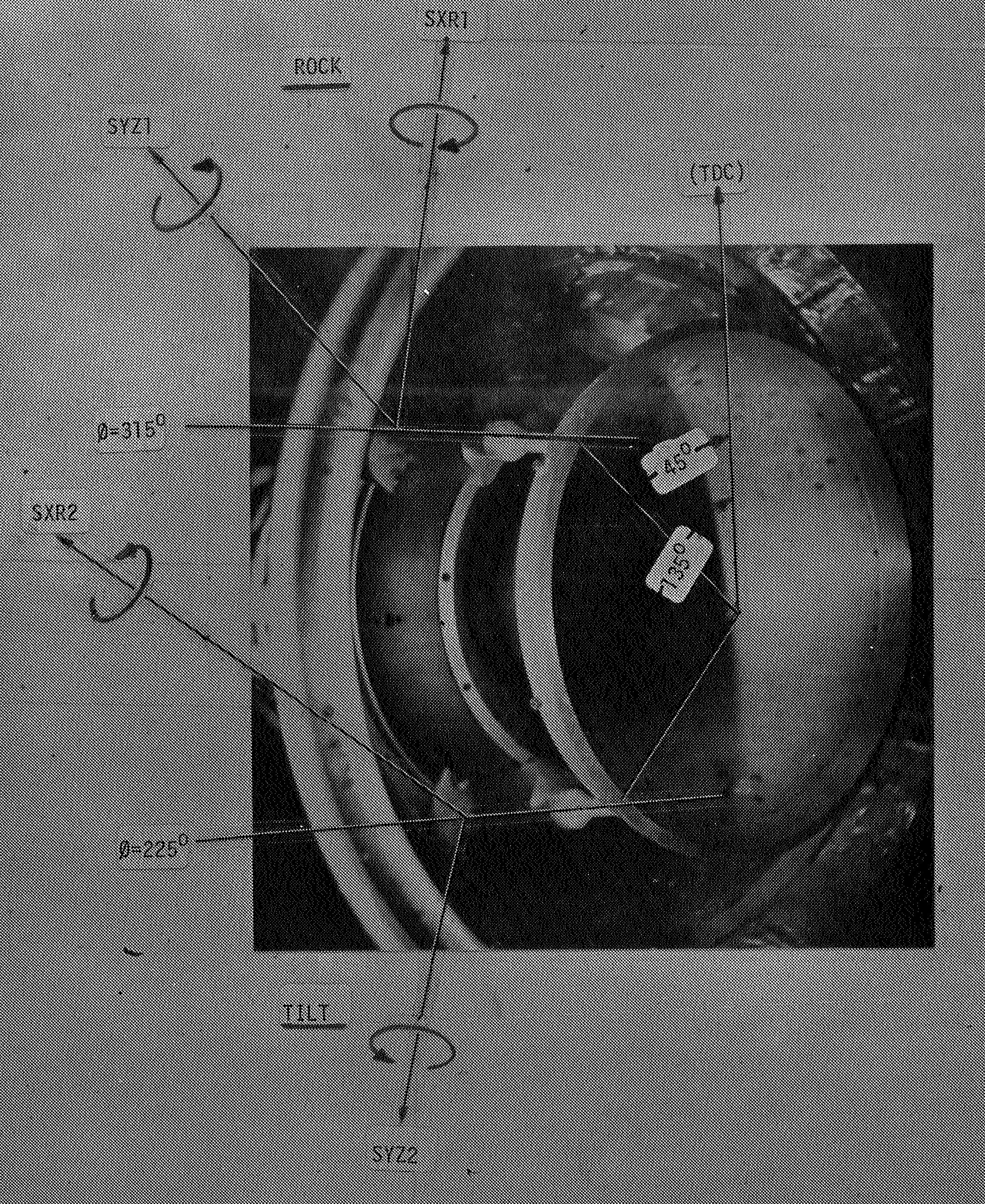

FIGURE 22

SIGN CONVENTION AND ARRANGEMENT
OF ACTUATOR TRANSDUCERS

SECTION IV - TEST FACILITY

This test was conducted in the Hydroballistics Tank at the U.S. Naval Surface Weapons Center, White Oak, Maryland. This tank is 35 feet wide, 100 feet long and 75 feet deep with a water depth variable from zero to 65 feet. To preserve water clarity the tank is lined with stainless steel and the water is continuously filtered. A two foot thick reinforced concrete honeycomb structure surrounds the tank and is designed to permit reduction of air pressure above the water for model scaling. Steam ejectors located on the building roof are used to evacuate the tank for pressure scaled test.

Depending upon water level, access to the tank is obtained either through a door in the bottom of the tank, two personnel hatches in the ceiling, or by removing one of nine 3-foot diameter gun ports located in the north wall and ceiling. Work inside the tank is performed from either a raft, a catwalk, or a movable bridge 6.5 feet high by 10 feet wide which spans the 35 foot width of the tank at the 61 foot elevation. For photographic or visual observations 16 inch diameter portholes are located 11 feet on center in the tank floor, walls, and ceiling. Figures 23, 24 and 25 are illustrations of the hydroballistics tank.

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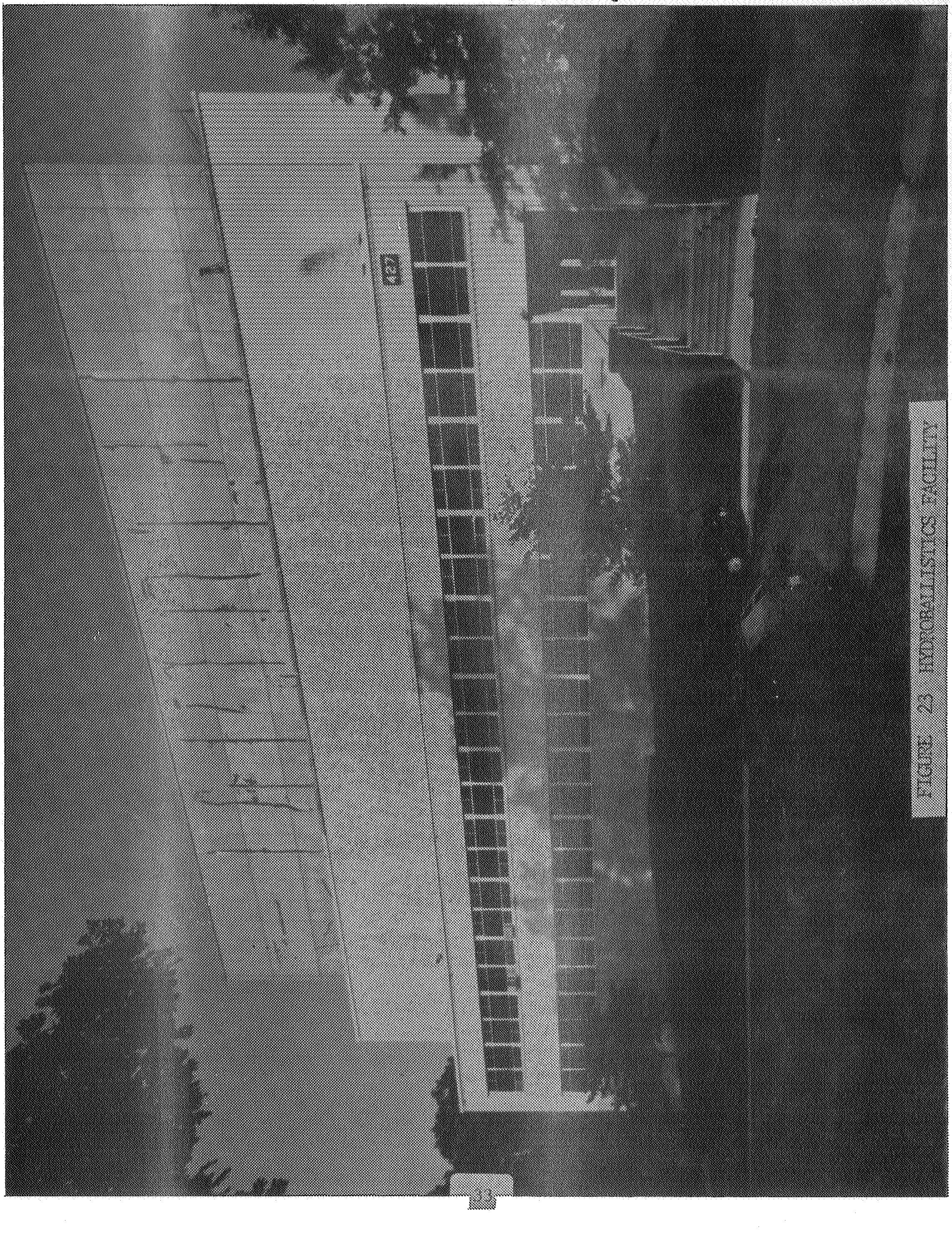

FIGURE 23 HYDROBALLISTICS FACILITY

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HYDROBALLISTICS TANK

The Hydroballistics Tank provides experimental data on water entry, simulating the performance of any missiles which enter the water after supersonic flight. Studies can also be made of underwater launching and water exit and of powered, maneuverable, scaled models of submarines and torpedoes. The massive, reinforced concrete honeycomb around the tank is designed to permit reduction of air pressure above the water for cavitation scaling. Two hundred 16-inch diameter glass windows in the tank walls permit photography and visual observations. Guns launch models into the tank through 3-foot ports in the end, top, and bottom. The stainless steel tank lining preserves the clarity of the extensively-filtered one and three-quarter million gallons of water.

The 4-inch powder guns use a saboting technique which prevents powder gases and contaminants from entering the tank. A fire-control system permits the automatic sequencing of 30 timing operations to actuate instrumentation during a launching.

The hydrodynamicist or engineer may participate in basic and applied research concerning water entry and exit phenomena, utilizing NOL's multimillion dollar hydroballistics facility. The Laboratory is interested in such things as the forces and moments that missiles experience when entering the water at high velocity; the motion of missiles during water entry and while riding in the water-entry cavity; and acoustic studies of the signals generated during cavity collapse.

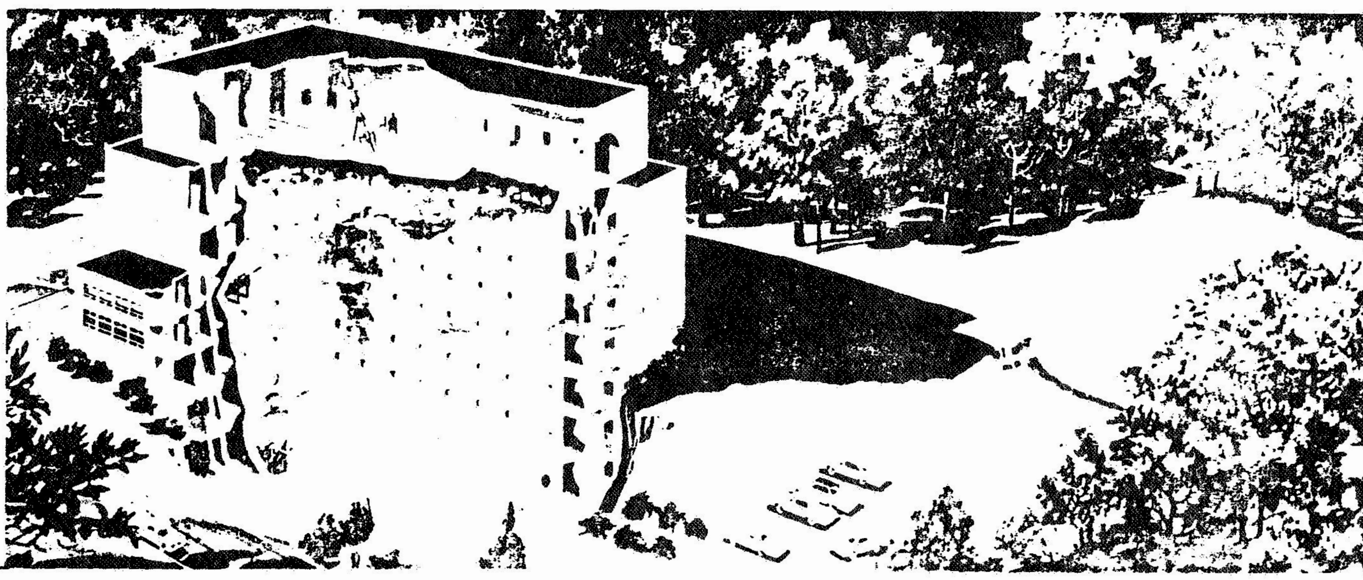
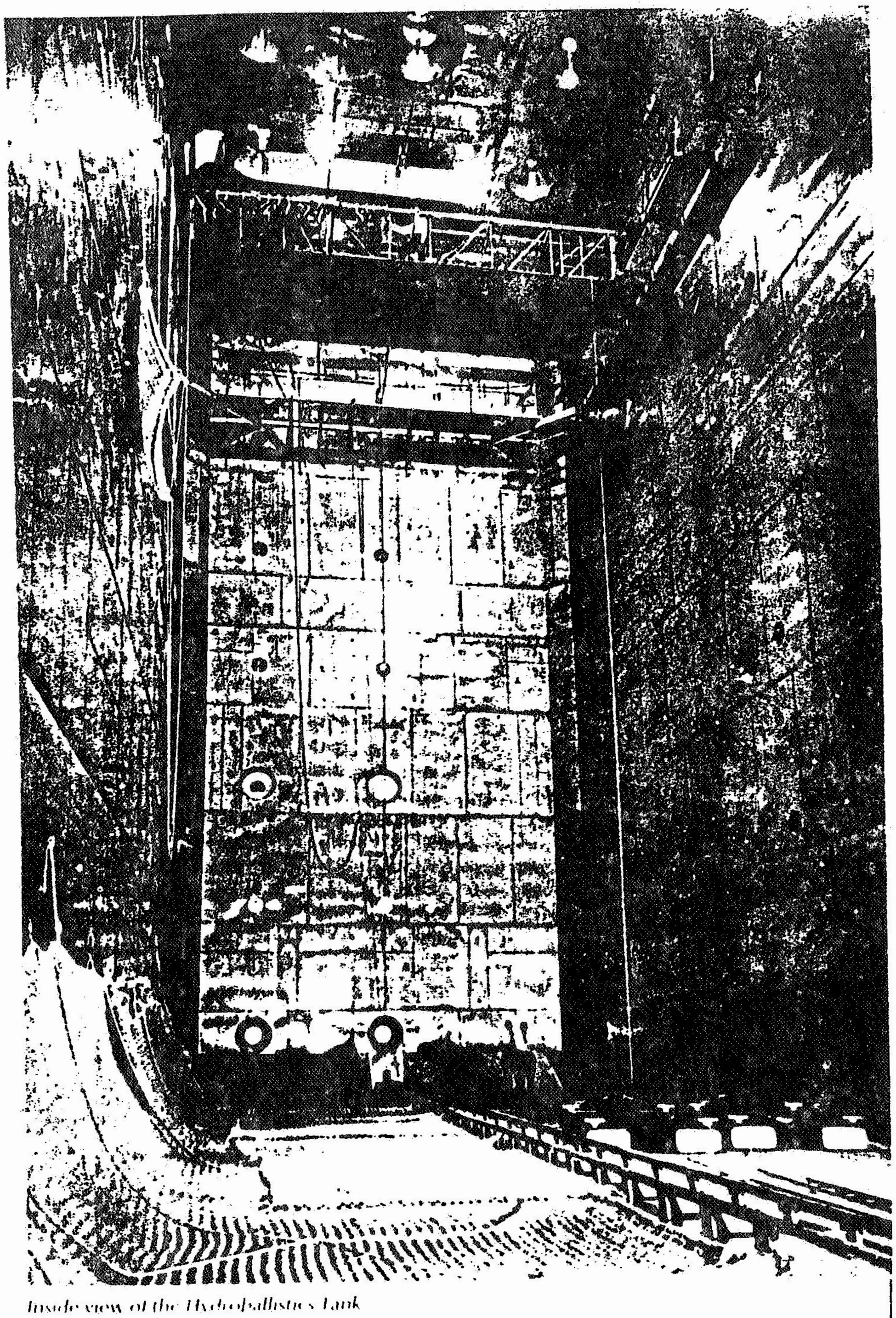


Figure 24. SECTIONAL VIEW OF HYDROBALLISTICS TANK

Operating Characteristics

Tank length	100 feet
Tank width	35 feet
Tank height	75 feet
Water depth	65 feet
Launcher	Powder gas guns (compressed gas launcher for low velocities)
Projectile	3 inch, 6 pounds maximum
Velocity	3000 feet per second
Firing angle	Vertical to horizontal
Instrumentation	Fire control unit to synchronize launcher-camera operation, multi-channel tape recorder system to monitor telemetry signals, optical whip recorder to measure angular motion of water entry, high speed 16 mm and 35 mm cameras to record the entire model trajectory.



Inside view of the Hydroballistics Tank

Figure 25. INSIDE VIEW OF HYDROBALLISTICS TANK

SECTION V - PHOTOGRAPHIC INSTRUMENTATION

Photographic coverage for this test was provided by two high speed 16mm data cameras, and one 16mm documentary camera. The data cameras were set up in and perpendicular to the model pitch and yaw planes in port holes 504 and 524 which were located at the water surface. They were sighted so that the lens centerline was at the water surface to permit split water line viewing above and below water with each camera. Both cameras ran at approximately 250 FPS, used a 1/650 sec. exposure time, had a 60 CPS timing signal and were force processed one stop.

The documentary camera was located in port hole 624 which was 41 feet in front of and 11 feet above the model impact point.

The tank lighting consisted of 7 banks of 12 bulbs each below the water and 2 banks of 12 bulbs each and 4 light bars with 2 bulbs each above the water line. All bulbs were 650 watt. A blue vinyl back drop 25 ft. wide by 20 feet long was suspended from the bridge to improve tank lighting. The west wall of the tank had been previously covered with white vinyl.

SECTION VI - TEST PROGRAM

Water impact tests using a 12.5 inch diameter scale model of the Space Shuttle SRB were conducted at the U.S. Naval Surface Weapons Center, White Oak, Maryland, from May 7, 1983 through May 23, 1983. These tests were conducted in accordance with Marshall Space Flight Center document "Test Requirements for the SRB 8.56% Scale Model Water Impact Test Program." (Reference 1 & 2).

During the test program a total of 47 drops were made. 44 drops were made at a scaled atmospheric pressure of 1.26 psia and 3 drops were made without pressure scaling at P_a = 14.7 psia.

The model configuration was varied as noted in the Test Program (Table II) to the following:

CONFIGURATIONS:

I Baseline - TVC Pod on lee side, actuators at 225 degrees and 315 degrees.

I/180 Baseline - Except instrumentation cable connector relocated 180 degrees to BDC

II Pod Removed

This test program was conducted at Froude scale impact velocities simulating the full scale vertical velocities of 65, 75 and 85 ft/sec. and horizontal drift velocities of 0, 15, 22.5, 30, and 45 ft/sec. at impact angles of 0, 5 and 10 degrees. Table II lists programmed model impact conditions by order of drop number and Table III lists the drop numbers as a function of model impact condition. Actual test conditions achieved are defined in Table IV as measured by the 250 FPS photographic data.

The model test velocities were Froude scale values of full scale as shown below:

DROP TEST VELOCITIES

VERTICAL VELOCITIES FPS		HORIZONTAL VELOCITIES FPS	
FULL SCALE	MODEL SCALE	FULL SCALE	MODEL SCALE
65	19.02	15	4.4
75	21.94	22.5	6.6
85	24.9	30	8.8
		45	13.2

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TABLE II TEST PROGRAM
(MODEL SCALE VALUES)

CONF. NO.	TEST NUMBER	VERTICAL VELOCITY FT/SEC	HORIZONTAL VELOCITY FT/SEC	IMPACT ANGLE - θ DEGREES	ROLL ANGLE - θ DEGREES	TEST PRESSURE mm.HG.
I	1	21.94	8.8	0	180	65
	2	21.94	8.8	0	180	65
	3	21.94	4.4	0	180	65
	4	21.94	4.4	+5	180	65
	5	21.94	4.4	-5	180	65
II	6	21.94	4.4	0	180	65
	7	21.94	8.8	0	180	65
	8	21.94	4.4	-5	180	65
	9	21.94	8.8	+5	180	65
	10	21.94	0	0	0	65
	11	21.94	0	-5	180	65
I	12	21.94	0	-5	180	65
	13	21.94	0	0	0	65
	14	21.94	0	+10	0	65
	15	21.94	0	-10	0	65
	16	21.94	0	-5	0	65
	17	21.94	8.8	0	0	65
	18	21.94	8.8	-5	0	65
	19	21.94	8.8	-10	0	65
	20	24.9	0	0	0	65
	21	24.9	0	+5	0	65
	22	24.9	0	+10	0	65
	23	24.9	0	-10	0	65

TABLE II TEST PROGRAM
(MODEL SCALE VALUES)

CONF. NO.	TEST NUMBER	VERTICAL VELOCITY FT/SEC	HORIZONTAL VELOCITY FT/SEC	IMPACT ANGLE – θ DEGREES	ROLL ANGLE – Ø DEGREES	TEST PRESSURE mm.HG.
I	24	21.94	8.8	0	180	65
	25	21.94	13.2	0	0	65
	26	21.94	8.8	+5	180	65
	27	21.94	13.2	+5	180	65
	28	19.02	0	0	180	65
	29	21.94	0	+5	180	760
	30	21.94	0	+5	180	760
	31	21.94	0	+5	180	760
	32	19.02	0	-10	180	65
	33	19.02	0	-5	180	65
	34	21.94	4.4	0	180	65
I_{180}	35	21.94	4.4	-5	180	65
	36	21.94	4.4	+5	180	65
	37	21.94	8.8	+10	180	65
	38	21.94	8.8	-5	180	65
	39	21.94	13.2	0	180	65
	40	21.94	6.6	0	180	65
	41	24.94	4.4	0	180	65
	42	24.94	8.8	0	180	65
	43	24.94	6.6	0	180	65
	44	24.94	8.8	+5	180	65
	45	24.94	13.2	+5	180	65
	46	24.94	4.4	-5	180	65
	47	24.94	8.8	-5	180	65

TABLE III
TEST NUMBER MATRIX

CONF. NO.	FULL SCALE VERTICAL VELOCITY	FULL SCALE HORIZONTAL VELOCITY	MILLIMETERS MERCURY P_∞	ROLL ANGLE Ø	IMPACT ANGLE (θ DEGREE) TEST NUMBER				
					-10	-5	0	5	10
	75	0	65	180	-	12	-	-	-
		15	65	180	-	5	3	4	-
		30	65	180	-	-	1,2,24	-	-
		45	65	180	-	-	-	-	-
I	75	0	65	0	15	16	13	-	14
		15	65	0	-	-	-	-	-
		30	65	0	19	18	17	-	-
		45	65	0	-	-	25	-	-
	85	0	65	0	23	-	20	21	22
		15	65	0	-	-	-	-	-
		30	65	0	-	-	-	-	-
		45	65	0	-	-	-	-	-

TABLE III
TEST NUMBER MATRIX

CONF. NO.	FULL SCALE VERTICAL VELOCITY	FULL SCALE HORIZONTAL VELOCITY	MILLIMETERS MERCURY P_∞	ROLL ANGLE ϕ	IMPACT ANGLE (θ DEGREE) TEST NUMBER				
					-10	-5	0	5	10
II	75	0	65	180	-	11	-	-	-
		15	65	180	-	8	6	9	-
		30	65	180	-	-	7	-	-
		45	65	180	-	-	-	-	-
	75	0	65	0	-	-	10	-	-
$^{I}/_{180}$	65	0	65	180	32	33	28	-	-
	75	0	760	180	-	-	-	29,30,31	-
	75	0	65	180	-	-	-	-	-
		15	65	180	-	35	34	36	-
		22.5	65	180	-	-	40	-	-
		30	65	180	-	38		26	37
		45	65	180	-	-	39	27	-

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TABLE III
TEST NUMBER MATRIX

CONF. NO.	FULL SCALE VERTICAL VELOCITY	FULL SCALE HORIZONTAL VELOCITY	MILLIMETERS MERCURY P_∞	ROLL ANGLE ϕ	IMPACT ANGLE (θ DEGREE) TEST NUMBER				
					-10	-5	0	5	10
I/180	85	0	65		-	-	-	-	-
		15	65		-	46	41	-	-
		22.5	65		-	-	43	-	-
		30	65		-	47	42	44	-
		45	65		-	-	-	45	-

CONFIGURATIONS:

I Baseline - TVC Pod on lee side, actuators at 225 degrees and 315 degrees.

I/180 Baseline - Except instrumentation cable connector relocated 180 degrees to BDC

II Pod Removed

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TABLE IV PHOTOGRAPHIC DATA

TEST NUMBER	CONFIGURATION NUMBER	VERTICAL VELOCITY FT/SEC		HORIZONTAL VELOCITY FT/SEC		IMPACT ANGLE θ DEGREES		ROLL ANGLE DEGREES		TEST PRESSURE mm.Hg.
		NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	
1		21.94		8.8		0		180		65
2		21.94		8.8		0		180		65
3	I	21.94		4.4		0		180		65
4		21.94		4.4		+5		180		65
5		21.94		4.4		-5		180		65
6		21.94		4.4		0		180		65
7		21.94		8.8		0		180		65
8	II	21.94		4.4		-5		180		65
9		21.94		8.8		+5		180		65
10		21.94		0		0		0		65
11		21.94		0		-5		180		65
12		21.94		0		-5		180		65
13		21.94		0		0		0		65
14		21.94		0		+10		0		65
15		21.94		0		-10		0		65
16		21.94		0		-5		0		65
17		21.94		8.8		0		0		65
18	I	21.94		8.8		-5		0		65
19		21.94		8.8		-10		0		65
20		24.9		0		0		0		65
21		24.9		0		+5		0		65
22		24.9		0		+10		0		65
23		24.9		0		-10		0		65

TABLE IV PHOTOGRAPHIC DATA

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TEST NUMBER	CONFIGURATION NUMBER	VERTICAL VELOCITY FT/SEC		HORIZONTAL VELOCITY FT/SEC		IMPACT ANGLE θ DEGREES		ROLL ANGLE DEGREES		TEST PRESSURE mm.Hg.
		NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	NOMINAL	MEASURED	
24	I	21.94		8.8		0		180		65
25	I	21.94		13.2		0		0		65
26	I/180	21.94		8.8		+5		180		65
27	I/180	21.94		13.2		+5		180		65
28	I/180	19.02		0		0		180		65
29	I/180	21.94		0		+5		180		760
30	I/180	21.94		0		+5		180		760
31	I/180	21.94		0		+5		180		760
32	I/180	19.02		0		-10		180		65
33	I/180	19.02		0		-5		180		65
34	I/180	21.94		4.4		0		180		65
35	I/180	21.94		4.4		-5		180		65
36	I/180	21.94		4.4		+5		180		65
37	I/180	21.94		8.8		+10		180		65
38	I/180	21.94		8.8		-5		180		65
39	I/180	21.94		13.2		0		180		65
40	I/180	21.94		6.6		0		180		65
41	I/180	24.94		4.4		0		180		65
42	I/180	24.94		8.8		0		180		65
43	I/180	24.94		6.6		0		180		65
44	I/180	24.94		8.8		+5		180		65
45	I/180	24.94		13.2		+5		180		65
46	I/180	24.94		4.4		-5		180		65
47	I/180	24.94		8.8		-5		180		65

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SECTION VII - TEST OPERATIONS

This pressure scaled water impact test was conducted using the SRB model launcher (Figure 26) fabricated under the direction of Chrysler in 1974. For this test it was removed from storage at the NSWC, White Oak, MD, where it was refurbished, installed, and calibrated, by Chrysler personnel. The launcher's two major components are the horizontal support beam and the model carriage release dolley. The structures were fabricated of 1.5 inch square 6061 aluminum tubing with a combined weight of approximately 400 lbs. Installation and assembly of the SRB model launcher was accomplished in April 1983 it was attached to the movable bridge within the tank with (4) I-Beams. The tank water level was lowered to the 24-foot elevation and the gun port hatch adjacent to the loading dock was removed for access to the tank. The horizontal support beam, model carriage, I-Beams, rails, work platforms, and dummy model were moved into the tank and placed on a raft. This raft was moved to center tank and tied below the bridge. The gun port hatch was replaced and tank pumps used to raise the water for assembly of the launcher. This required approximately 8 hours. Calibration and testing started May 1st and ended May 23rd after 47 test drops with varied vertical and horizontal velocities. Vertical velocities were varied by changing the travel of the model carriage. The carriage dolley was propelled (on rails) along the horizontal support beam through the release cam assembly, by means of a 426 lb. drop weight. The carriage dolley held the model in a spring loaded clamp that opened when it contacted the release cam assembly, Figures 27 through 31. The clamp was also used for variation of model impact angle. The release cam assembly, Figures 32 through 37, was attached to the horizontal support beam with 2-2" "C" clamps. Cam locations were pre-determined during calibration horizontal velocities and a model drop "free fall window" was established. Calibration was accomplished using a dummy model for approximately 15 calibration drops. The drop weight was the only propelling force used for the launcher and was shackled to a 3/8 inch wire rope 12 ft. long with a 1/2 inch round dog on the end. The instrumented model was initially loaded into the launcher through a port hole (in the top of the test facility) directly into the model carriage dolley clamps, using an overhead crane, located outside and above the tank top. The carriage dolley clamp was positioned under the port hole near the end of the horizontal beam. Once the model was initially loaded inside the tank the port hole cover was replaced. Subsequent loadings were accomplished using the same over head crane but with a cable that was lowered thru a small hole in the port hole cover. After model loading the line was removed and a cap placed on the hole.

The model was held in the carriage dolley clamp by two launching lugs secured to the model sides, Figure 39. To insure correct angle and tight fit (4) bolts on each clamp were used to snug the clamp around the lugs (Figure 30). When the model was secured in the dolley clamp, the dolley was then backed up along the horizontal beam a predetermined distance established for the desired horizontal velocity. Once the dolley was in the proper location the release cam assembly was "C" clamped to the horizontal beam at a predetermined calibration location. This release cam assembly was equipped with three circuits, including pencil leads on 2" centers. A knife type blade on the dolley was used to break the leads, and circuits, thus allowing the carriage horizontal velocities to be calculated. Three velocities were calculated; (1) prior to release, (2) at release, (3) after release. This circuitry was checked before closing the tank. With the cam assembly in place, the excess instrument cable was then hung on a drop arm located on the underside of dolley. This removed all weight of the cable from the model. (Figure 26 & 38). It should be noted at this time that considerable problems were encountered during this test with the model rolling. A number of tests had to be rerun due to unacceptable model roll prior to water impact. Much of this problem was overcome by loading the instrument cable on the drop arm to create a spring effect to counteract the roll. A roll of 15 degrees was considered acceptable.

The final loading procedure was to hang the drop weight. This was accomplished using a winch located on the underside of the tank top above the drop weight. The winch hook was lowered to pick up the drop weight, lifting it to allow the wire rope attached to the weight, (dog end) to be wrapped around and inserted into a hole in the spool, of the chain drive sprocket, and brake assembly.

The spool, chain drive sprocket, and disc brake were mounted on a 1-inch shaft, Figures 40 through 43. This assembly was used to drive the dolley along the horizontal beam tracks through a chain attached to the carriage dolley. The disc brake part of this assembly was used to hold the loaded drop weight, release the weight, and assist in the stopping of the carriage dolley after model release. Once the wire rope was wrapped the correct numbers of turns and the dog installed in the spool, the weight was then lowered to hang from the spool by the wire rope, and held by the disc brake.

Two stop ropes were attached to the drop weight. One was used as a stop; to prevent the weight from falling to the bottom of the tank, the other was a backup. When the disc brake was released the weight pulled on the wire rope wrapped on the spool thus propelling the dolley along the horizontal beam through the release assembly, dropping the model into the water within the free fall window (Figure 50). A retrieval line secured to the top of the model was used to raise the model from the water after pressure drops, before venting of the tank. This was accomplished with a second winch located inside the tank and operating remotely from the data control area. (Figures 47 and 49).

Zero horizontal velocity test drops were accomplished without the use of the horizontal launcher. A solenoid release mechanism installed in the special porthole cover was used, Figures 44 through 46.

The model was hung with a wire rope attached to a ring that was dropped from a pin released by the solenoid. Angles and velocities were varied by changing the length of the wire rope (model height) and the angle at which the model was held. A wood support (2x4) attached to the movable bridge was used to hold the cable drop arm, Figure 49.

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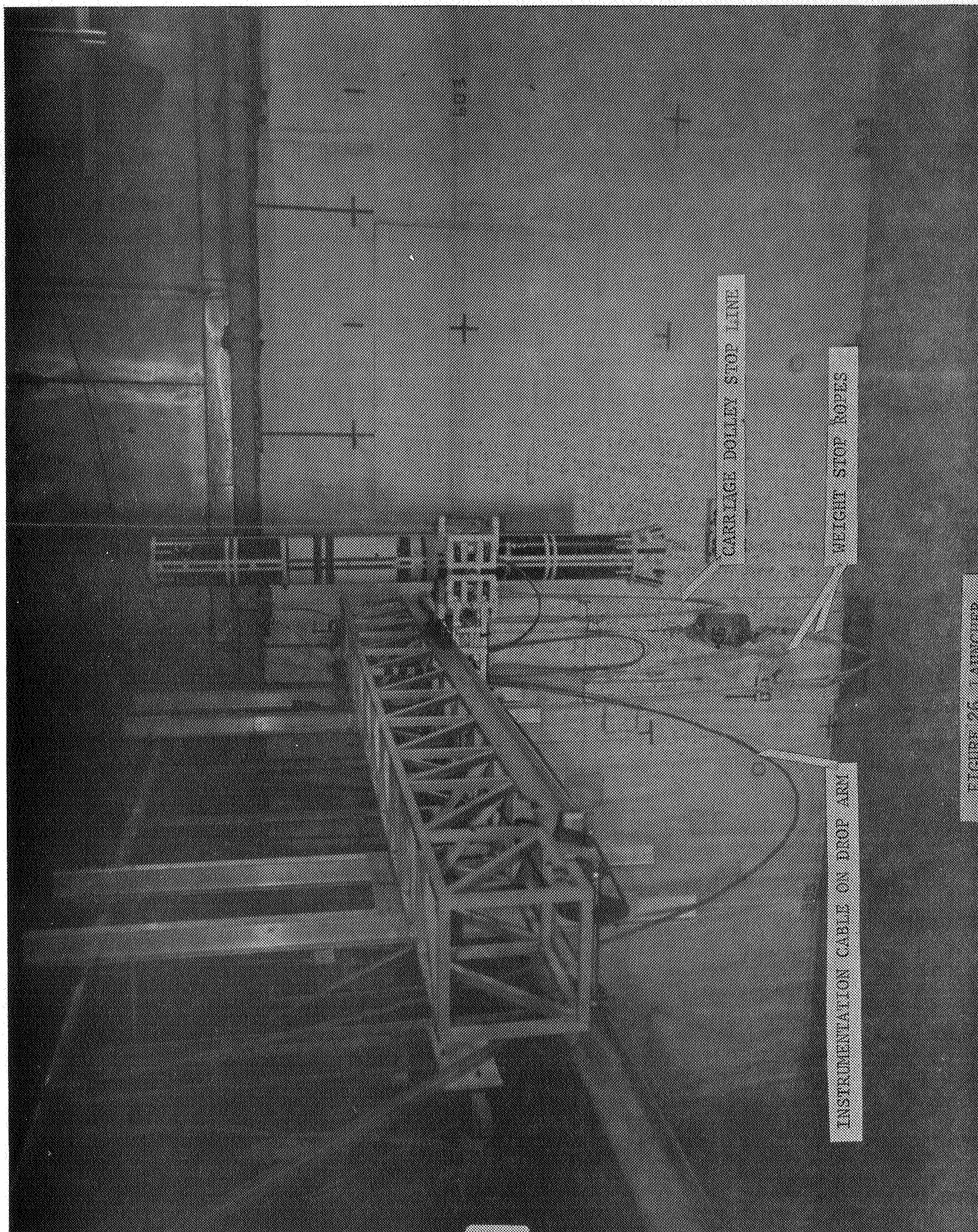

FIGURE 26 LAUNCHER

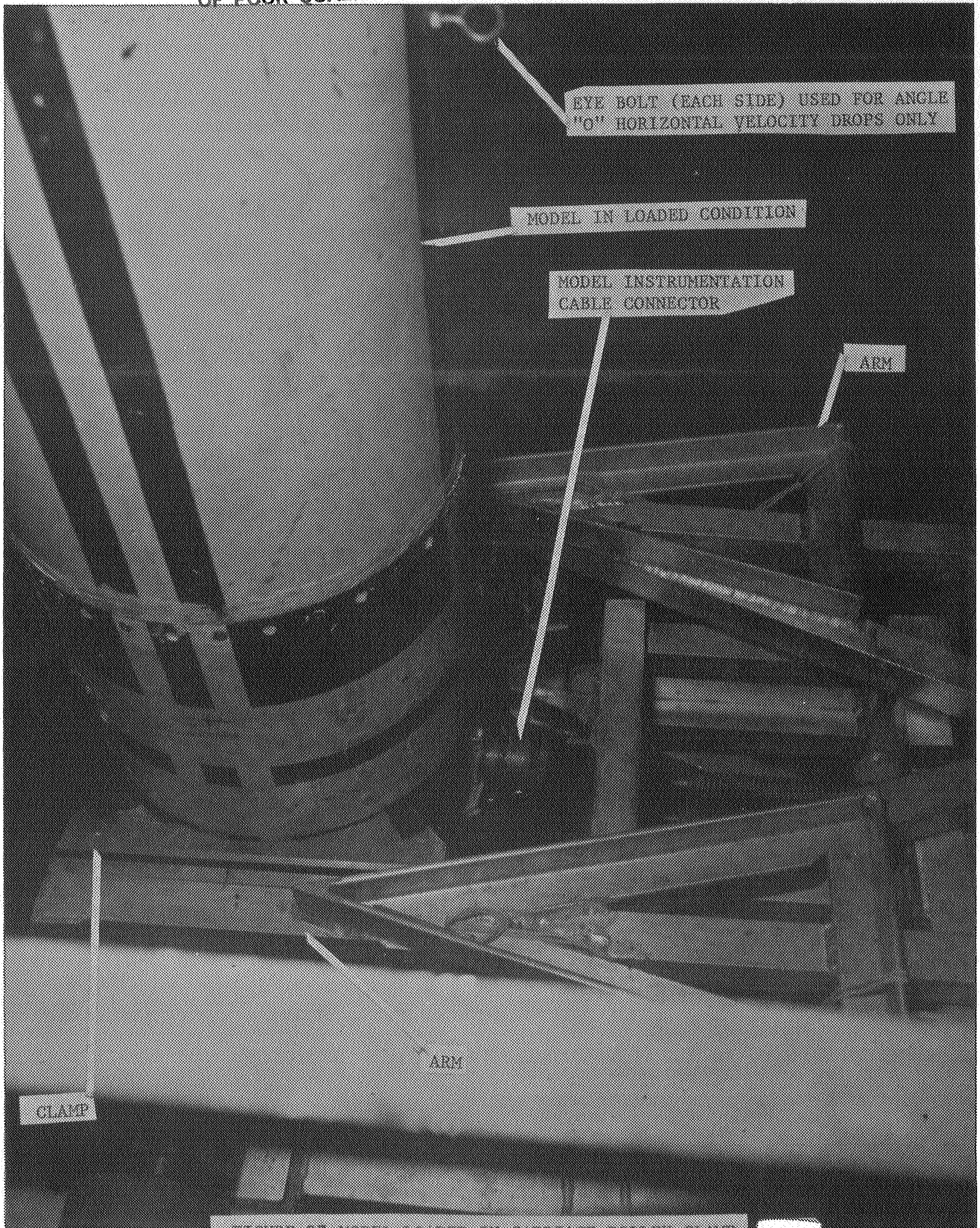

FIGURE 27 MODEL LOADED IN CARRIAGE DOLLEY CLAMP

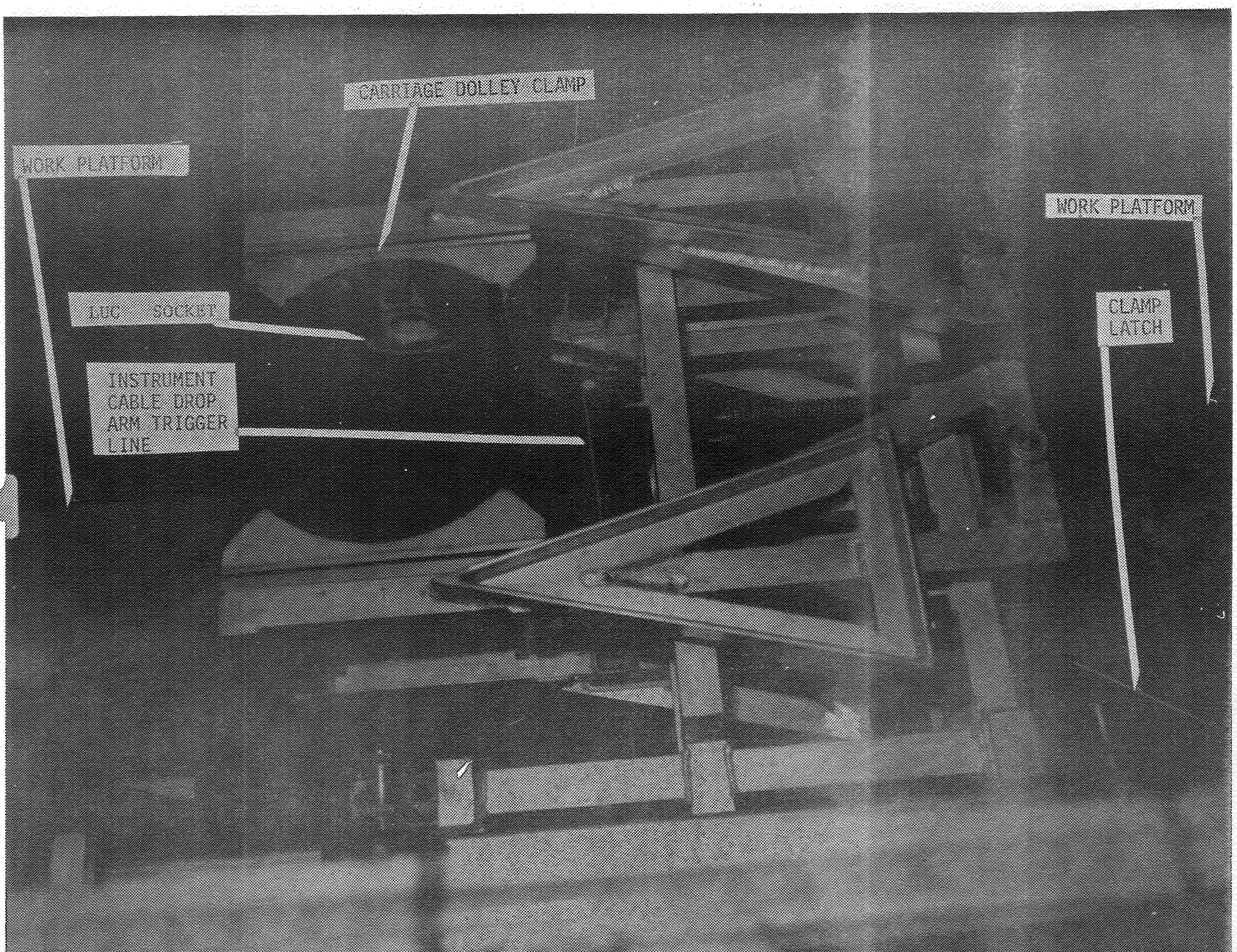

FIGURE 28 CARRIAGE DOLLEY CLAMP

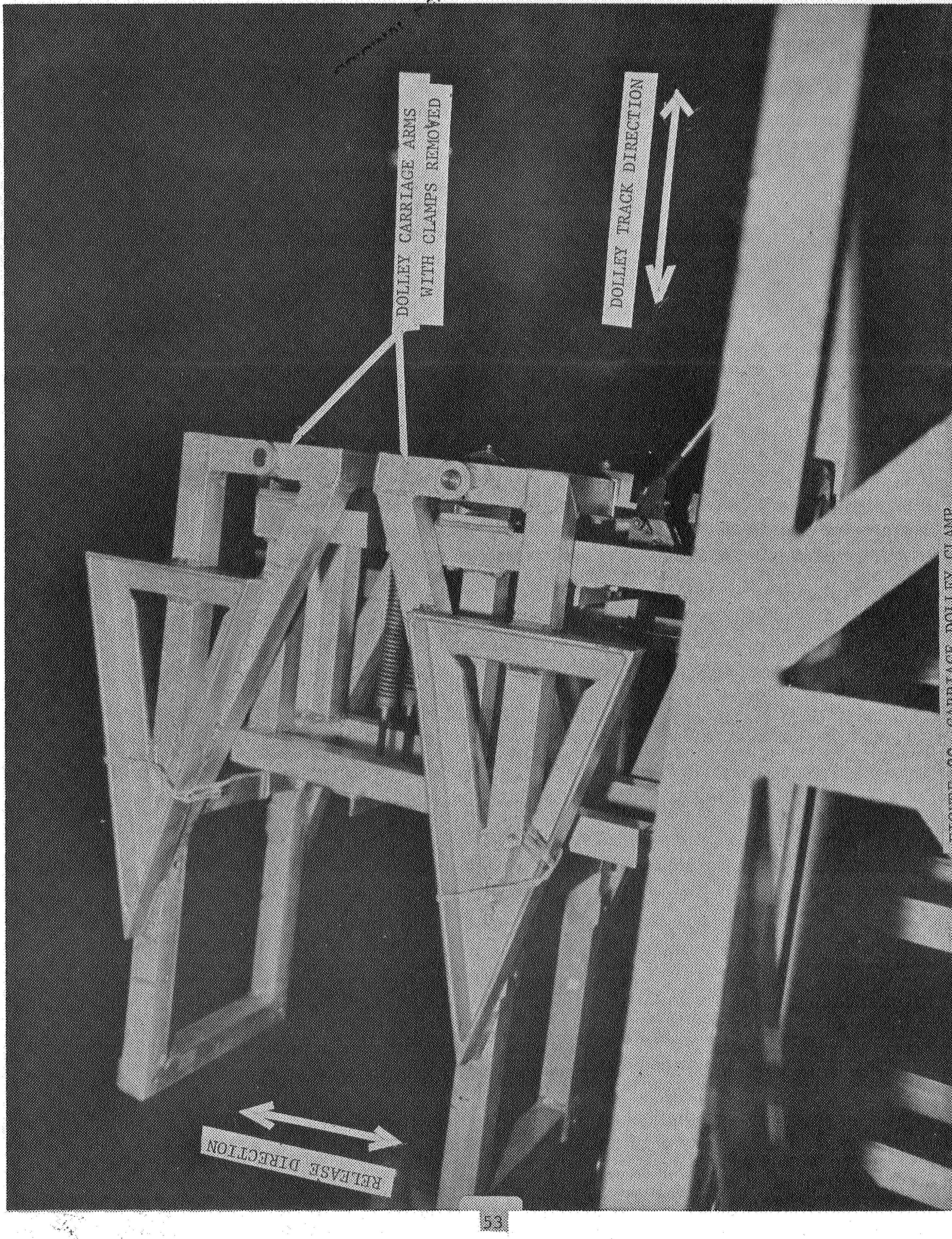

FIGURE 29 CARRIAGE DOLLEY CLAMP

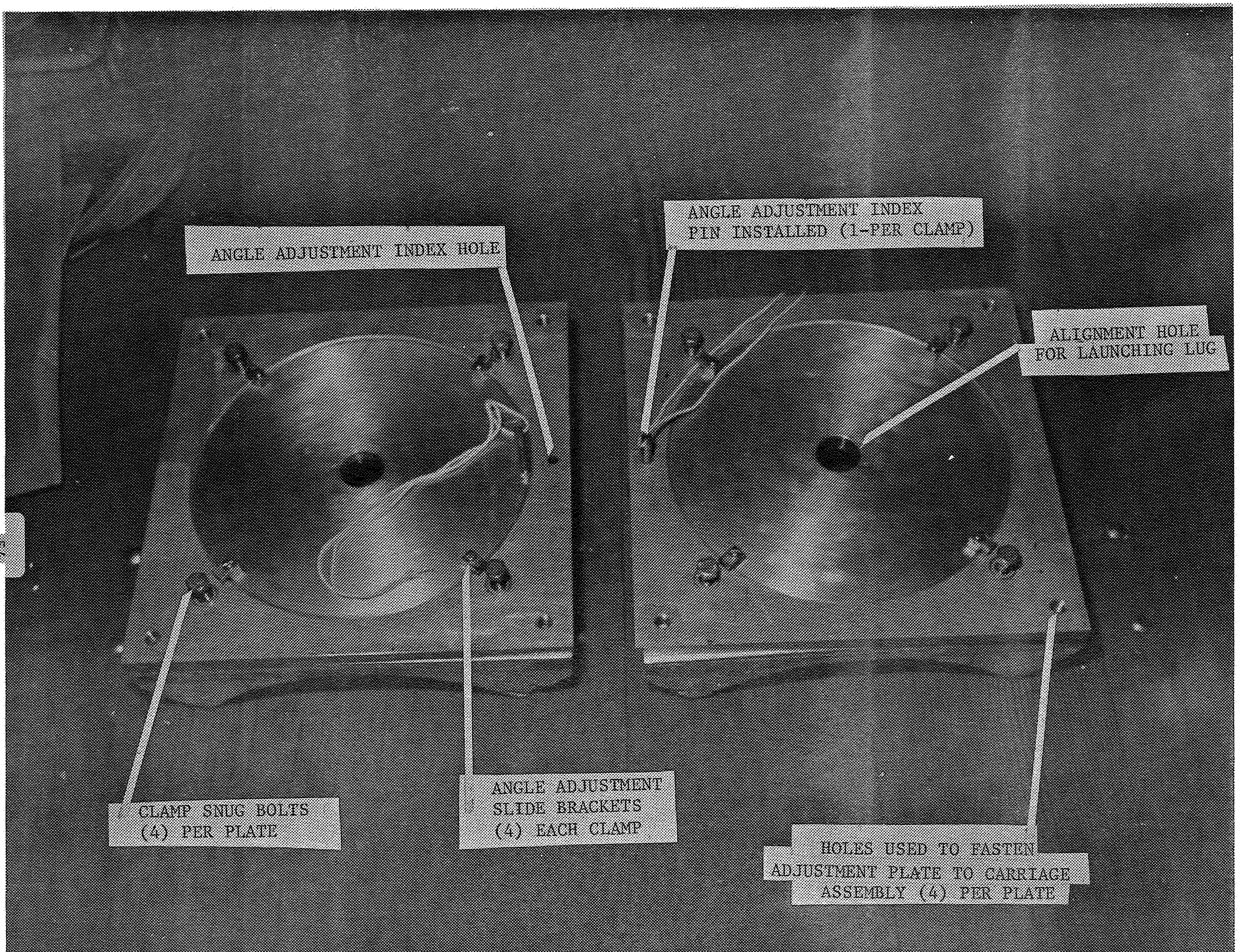

FIGURE 30 CLAMPS (ADJUSTMENT SIDE VIEW)

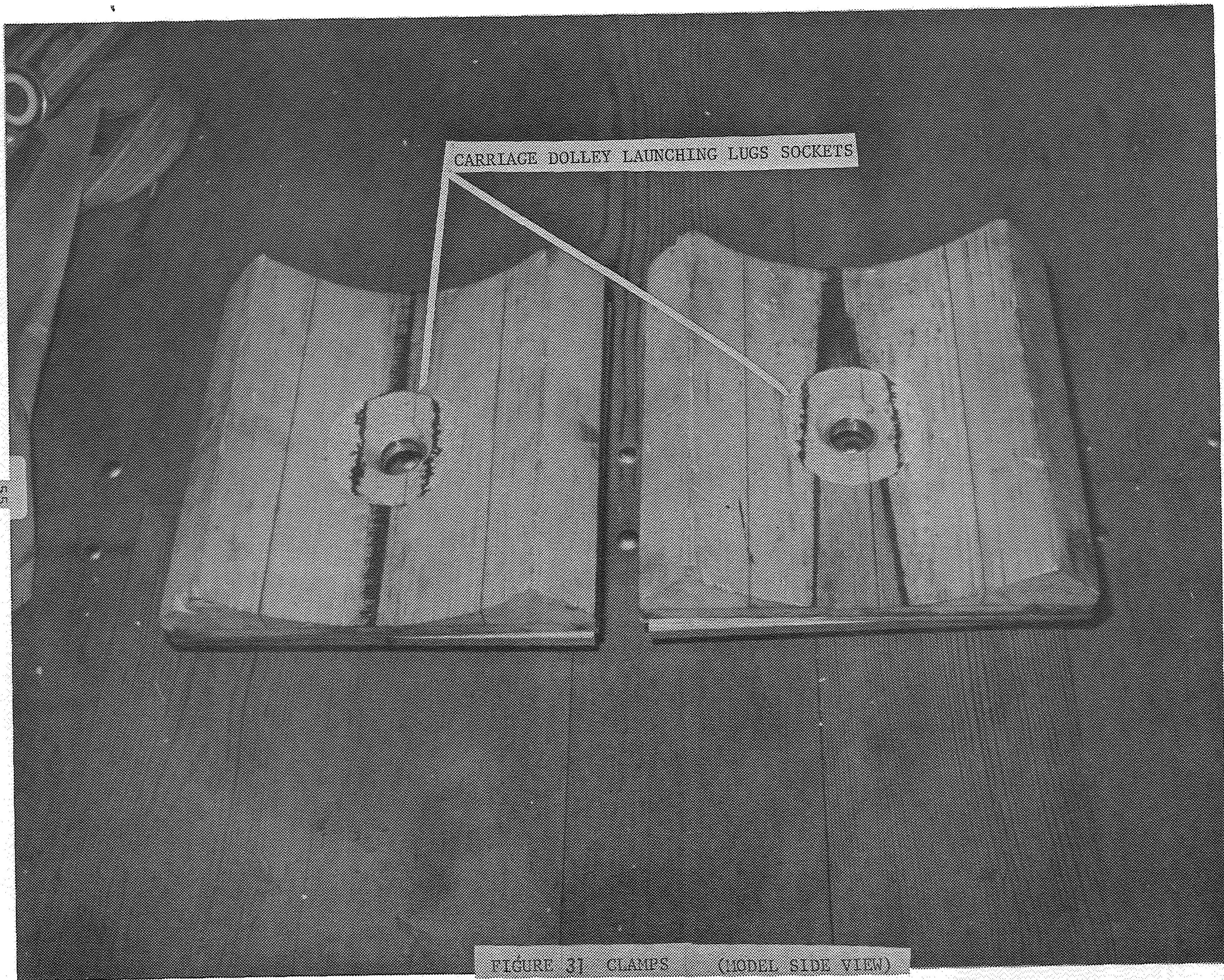

FIGURE 31 CLAMPS (MODEL SIDE VIEW)

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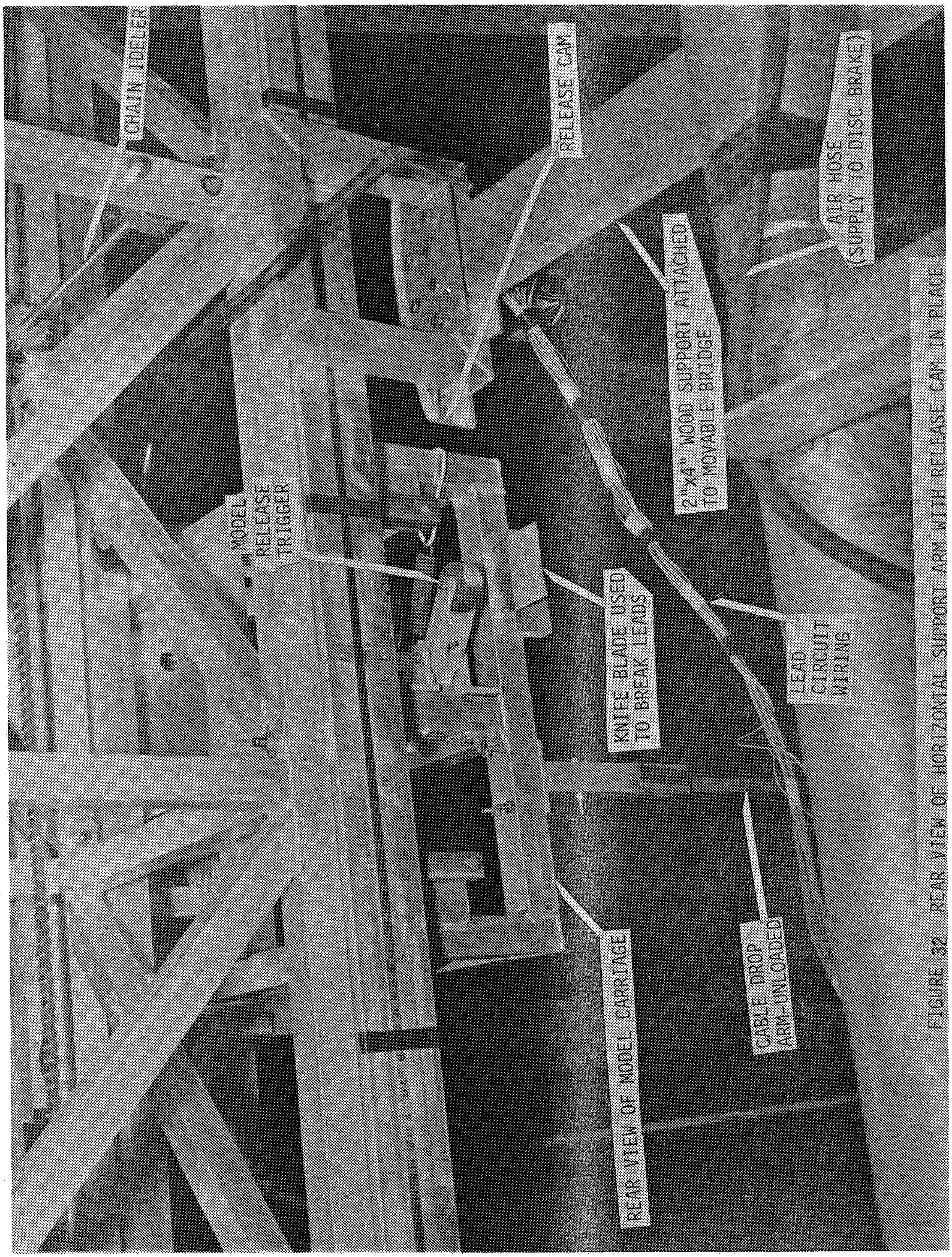

FIGURE 32 REAR VIEW OF HORIZONTAL SUPPORT ARM WITH RELEASE CAM IN PLACE

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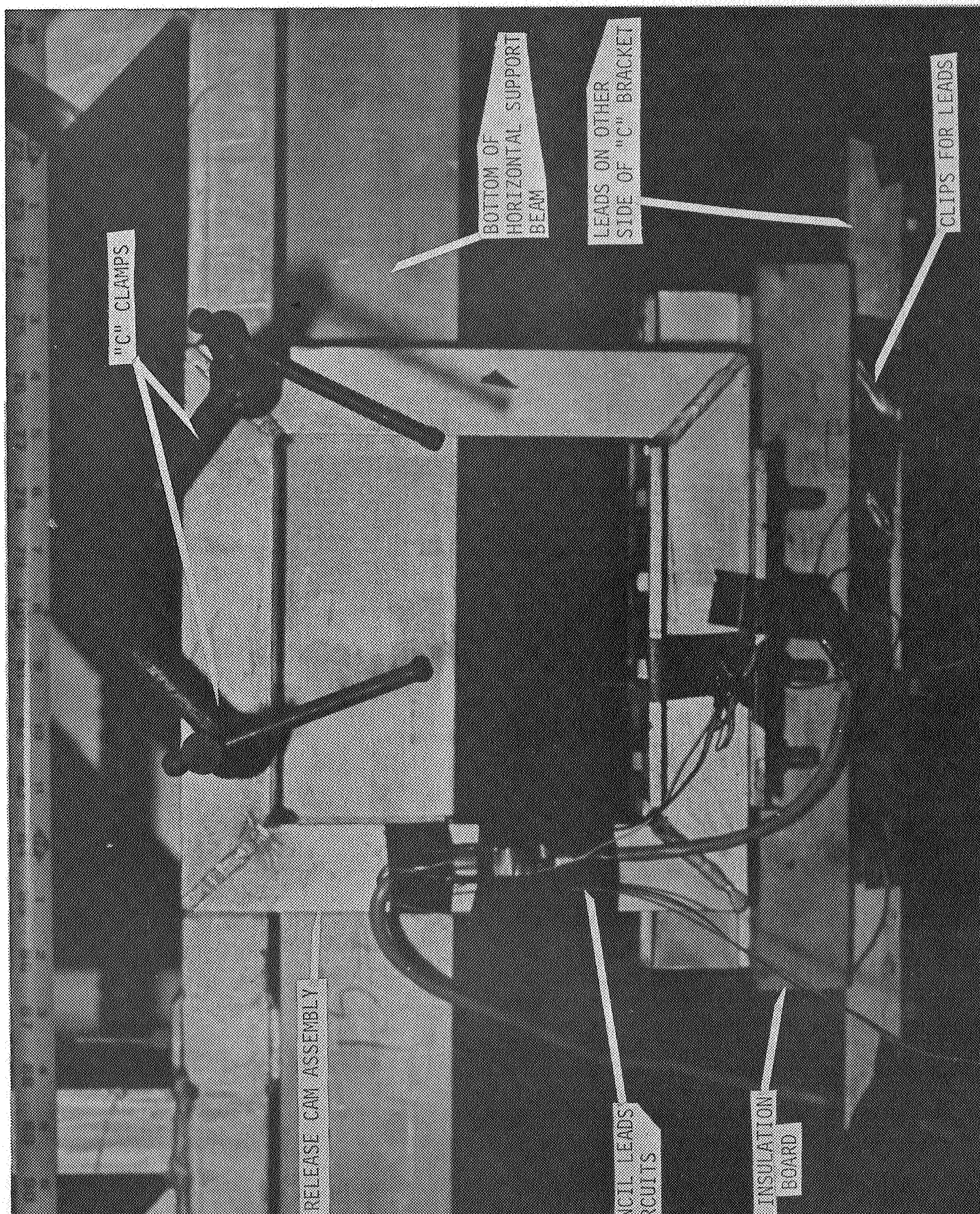

FIGURE 33 REAR VIEW OF RELEASE CAM ATTACHED TO HORIZONTAL SUPPORT BEAM
(AWAY FROM MODEL)

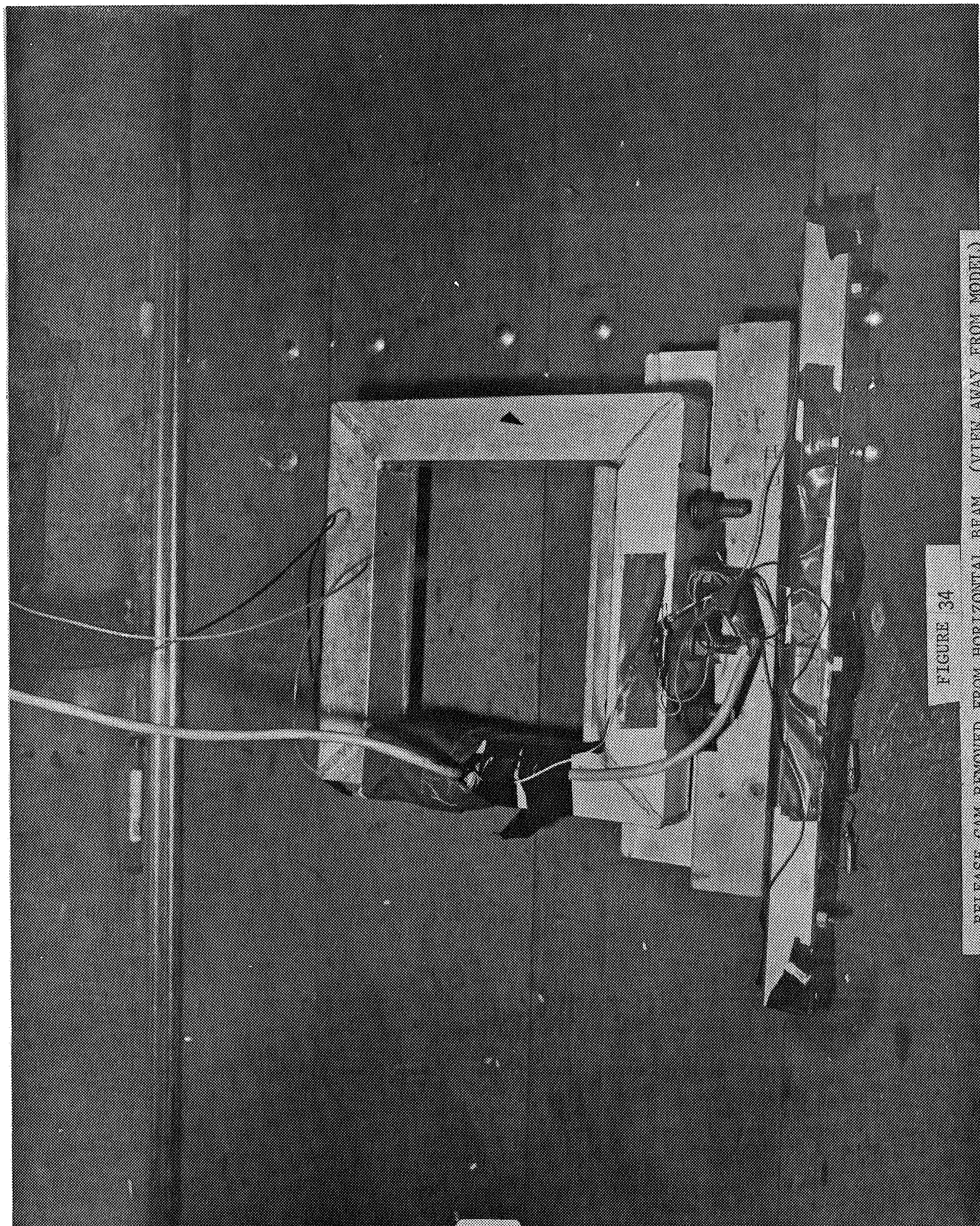

FIGURE 34
RELEASE CAM REMOVED FROM HORIZONTAL BEAM (VIEW AWAY FROM MODEL)

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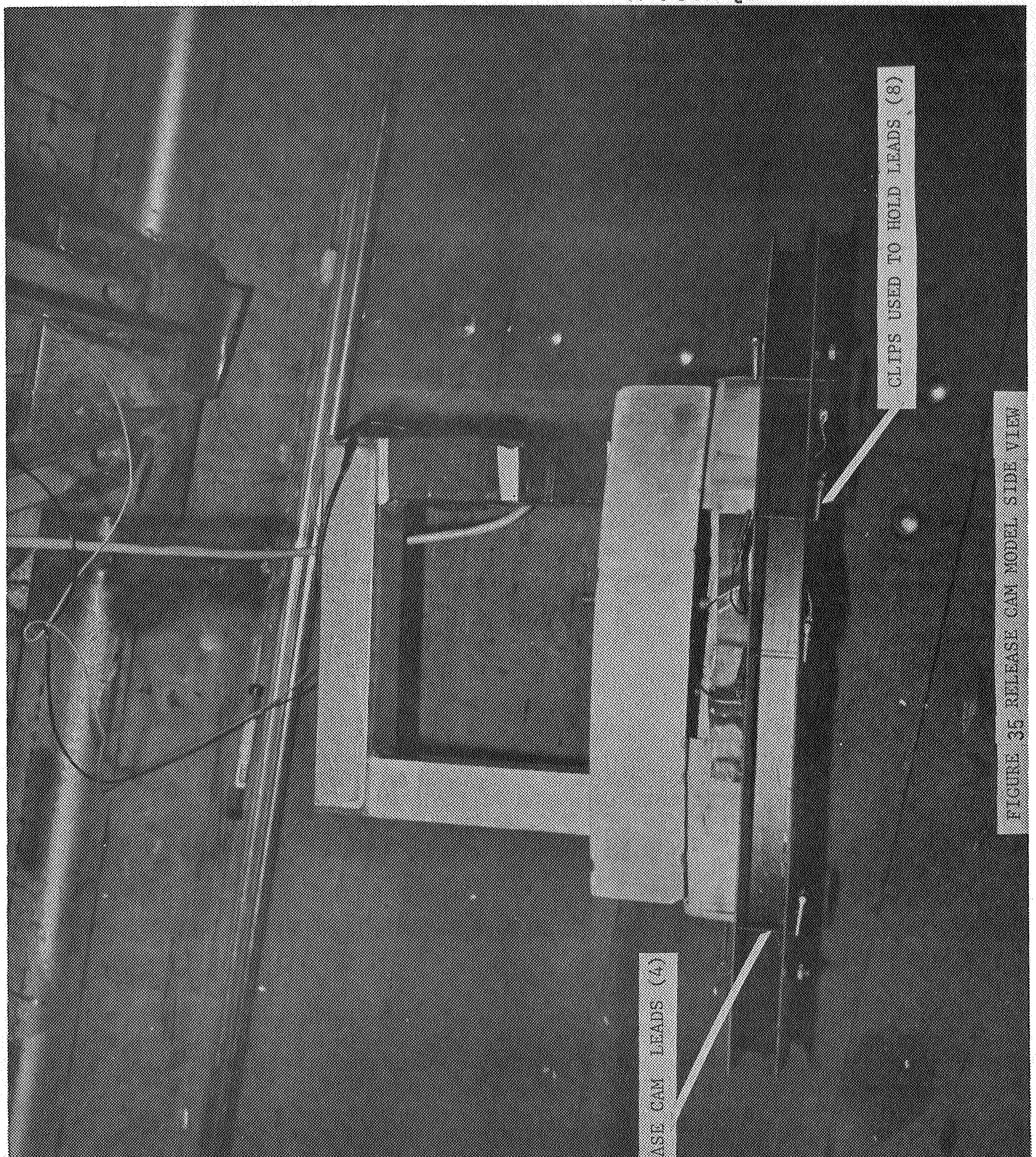

FIGURE 35 RELEASE CAM MODEL SIDE VIEW

FIGURE 36 ADJUSTING DOLLEY CLAMP TO RECEIVE MODEL FOR ANGLE DROP TESTS

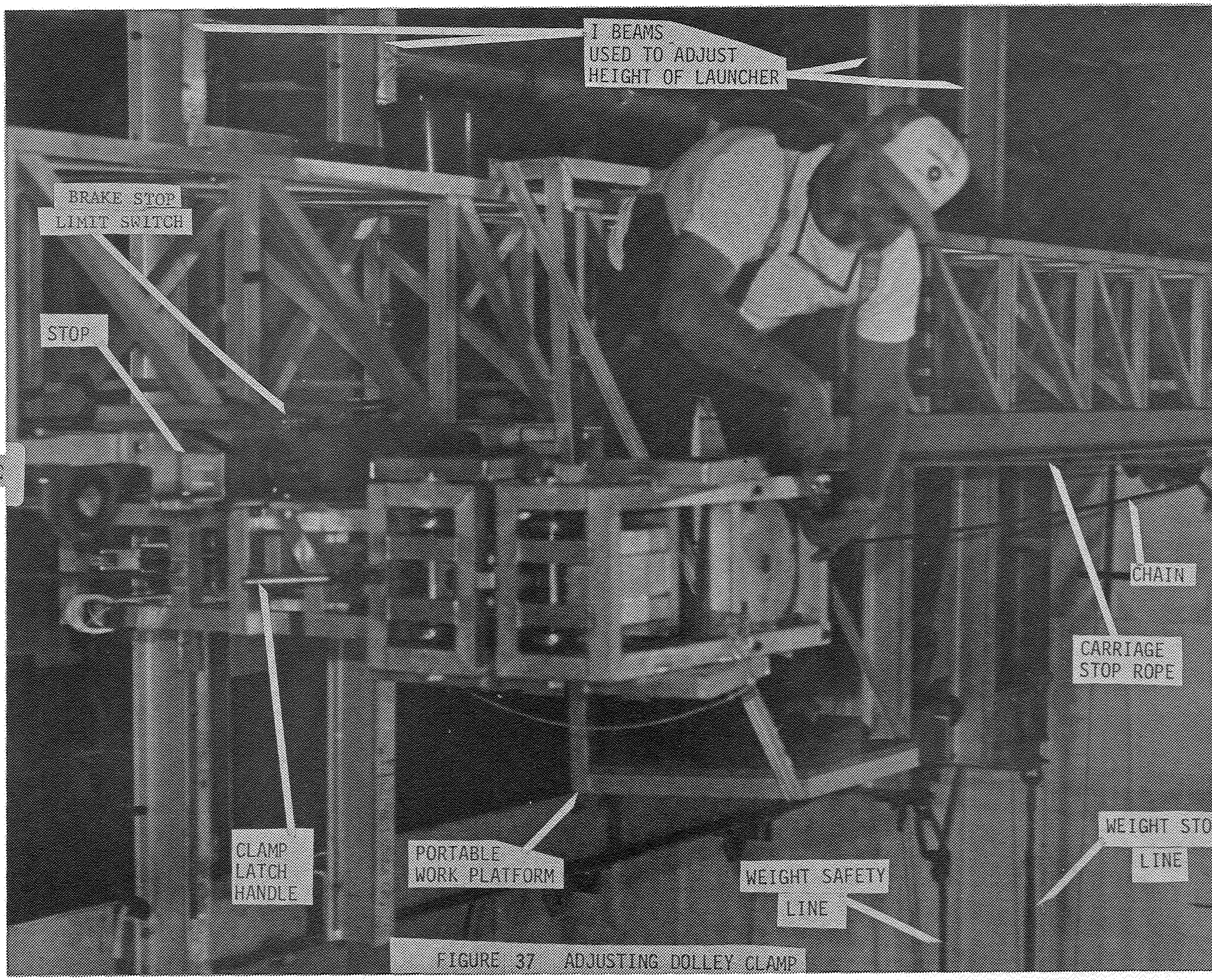

FIGURE 37 ADJUSTING DOLLEY CLAMP

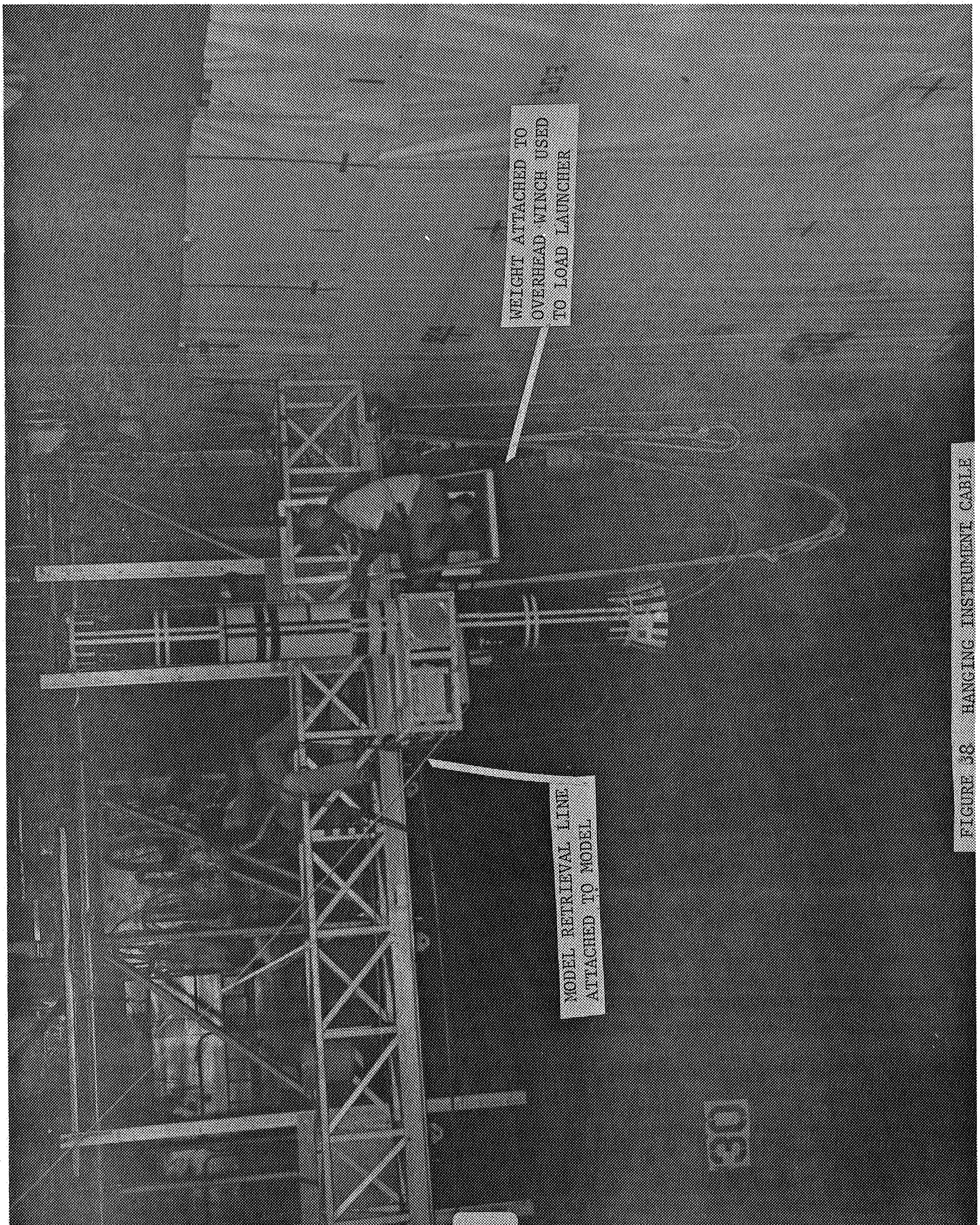

FIGURE 38 HANGING INSTRUMENT CABLE

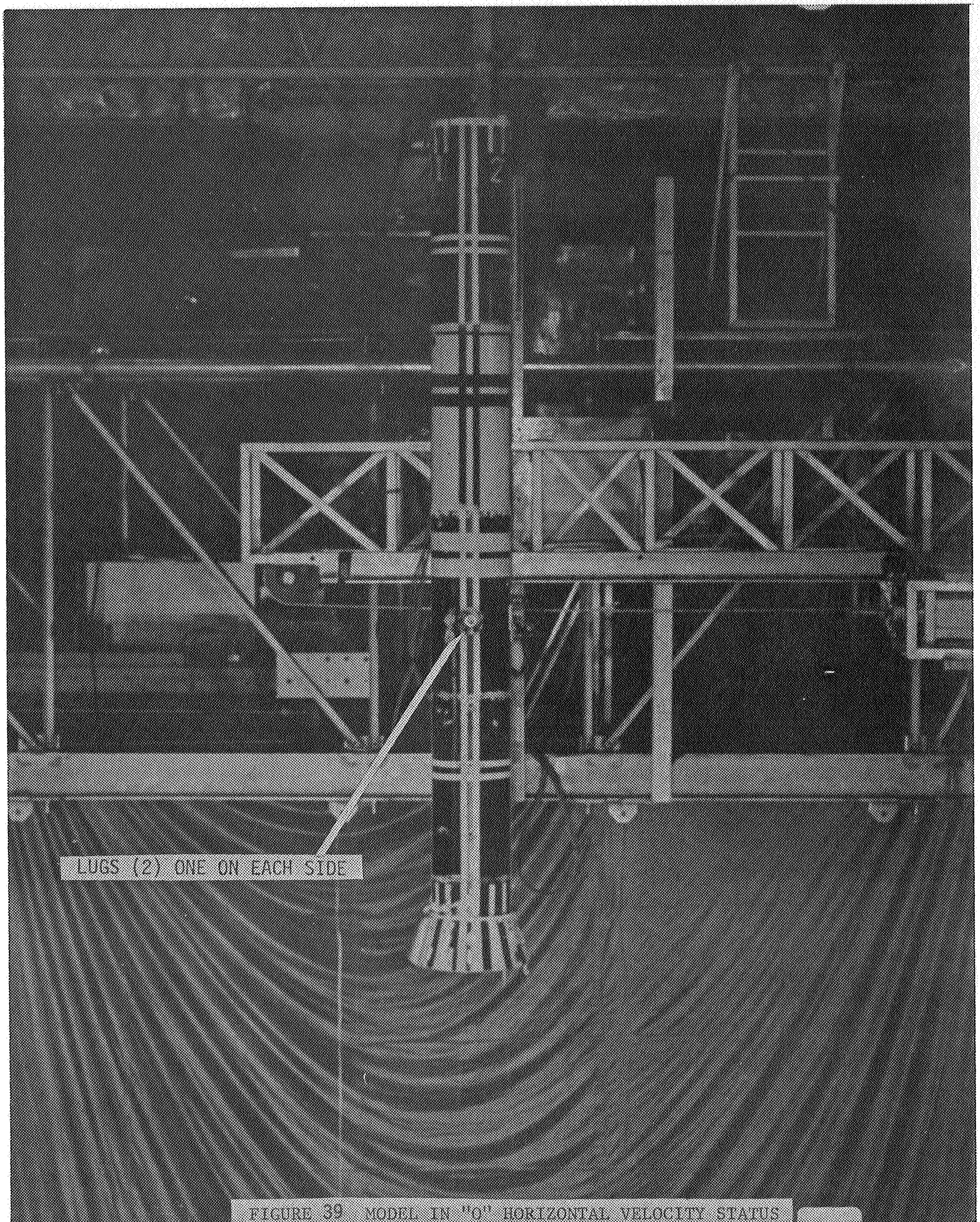

FIGURE 39 MODEL IN "O" HORIZONTAL VELOCITY STATUS

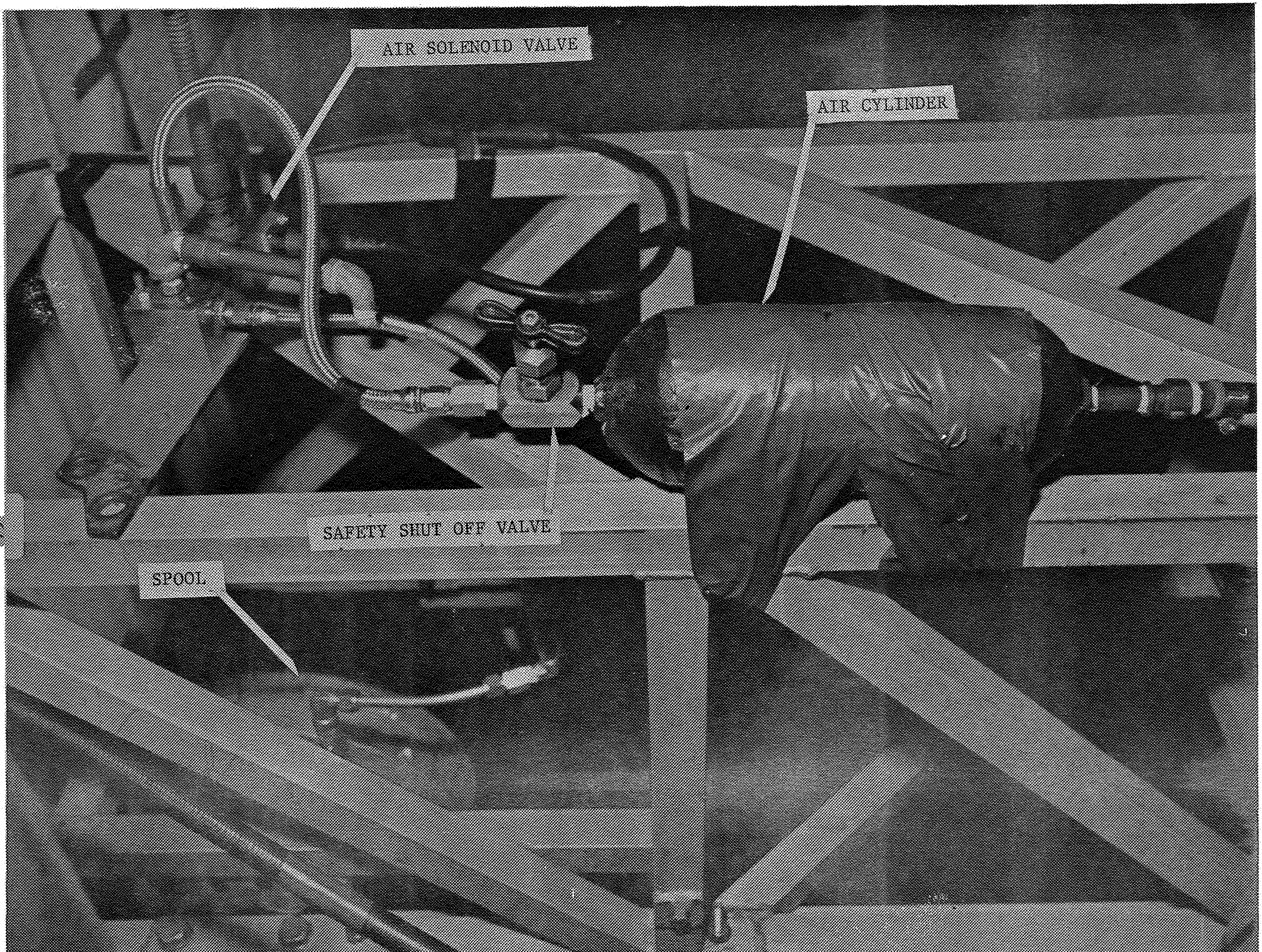

FIGURE 40 SPOOL, CHAIN DRIVE SPROCKET, AND DISC BRAKE ASSEMBLY

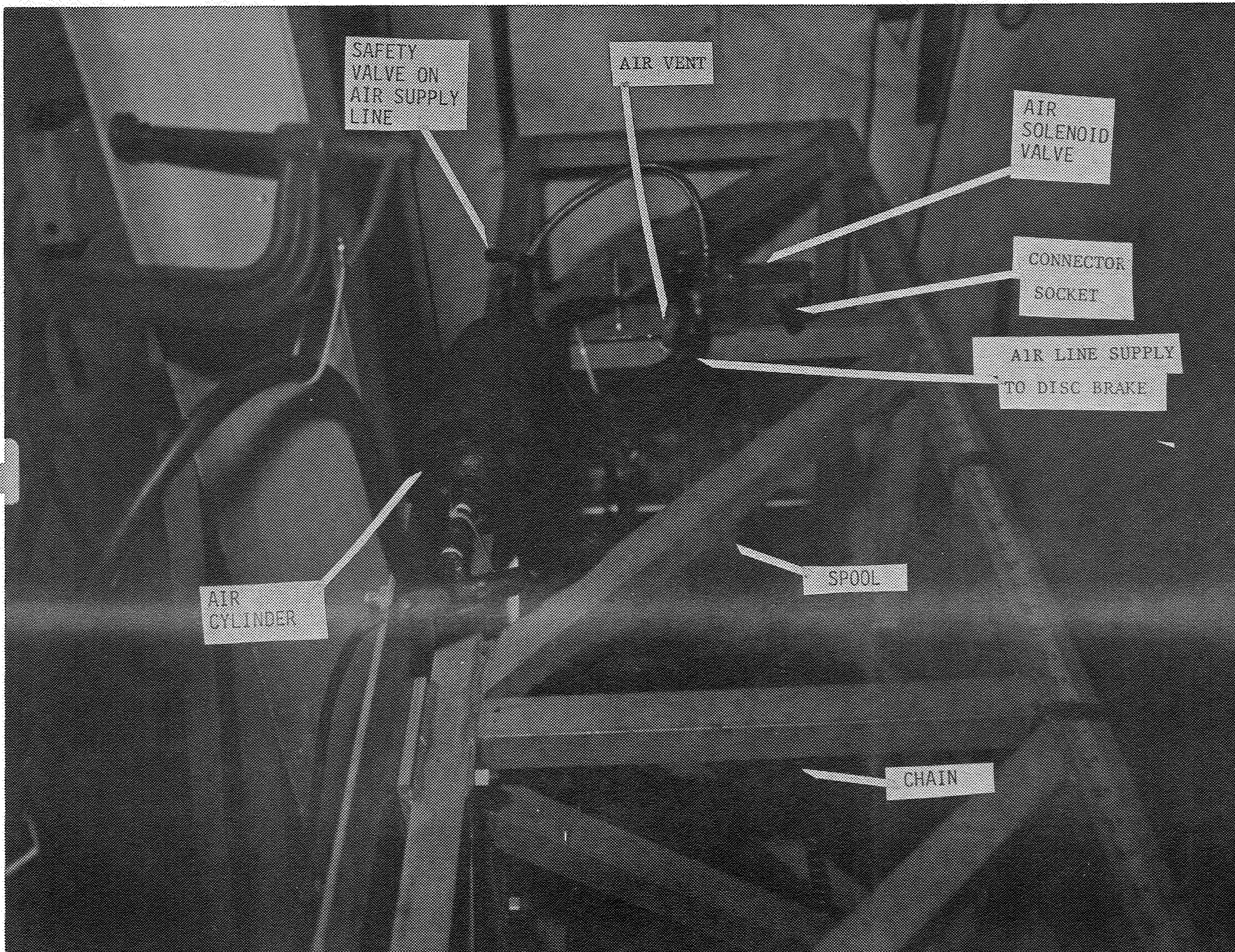

FIGURE 41 VIEW LOOKING DOWN AT CHAIN DRIVE ASSMEBLY

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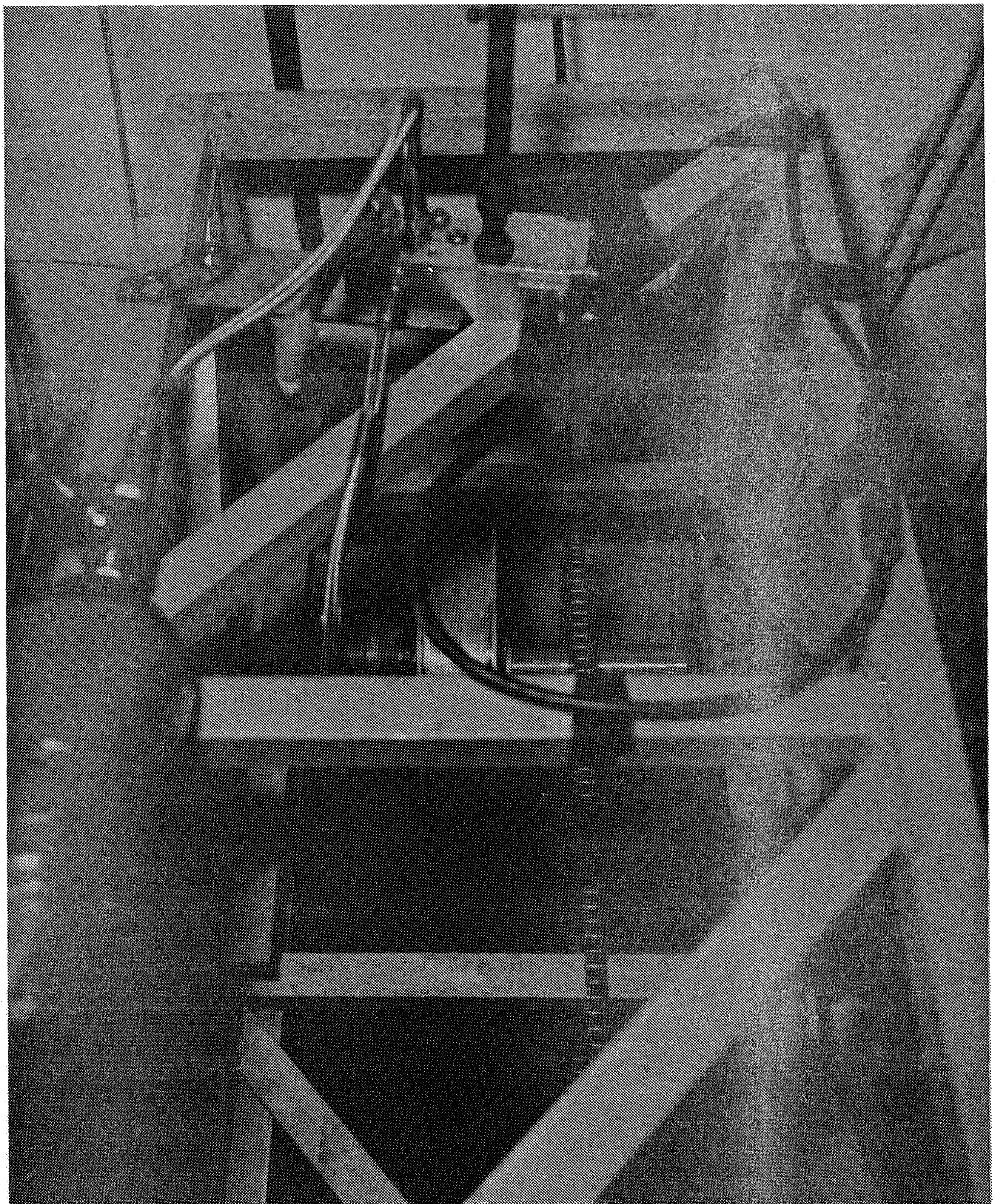

FIGURE 42 VIEW LOOKING DOWN

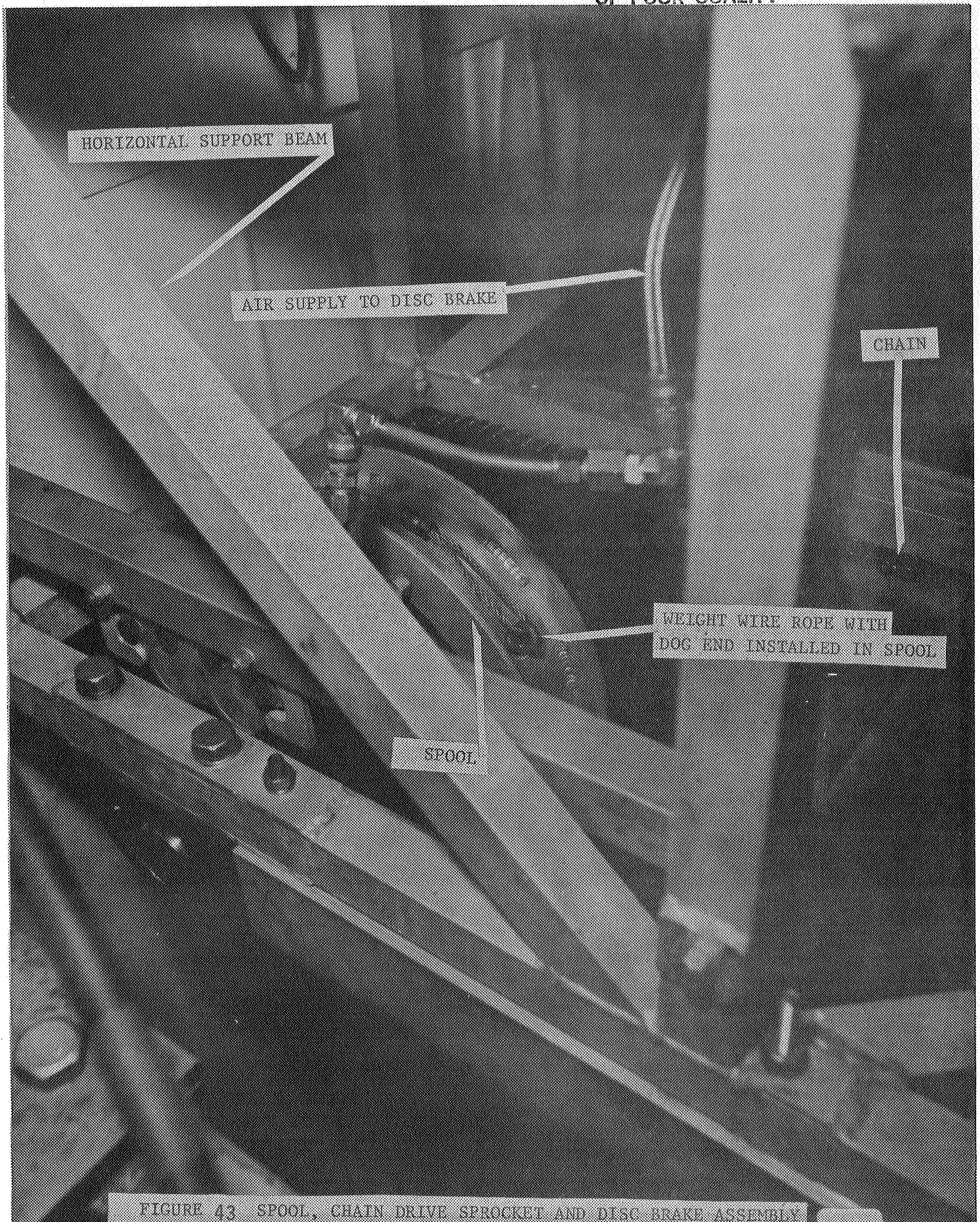

FIGURE 43 SPOOL, CHAIN DRIVE SPROCKET AND DISC BRAKE ASSEMBLY

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FIGURE 44 VIEW OF PORTHOLE WITH SPECIAL COVER IN PLACE

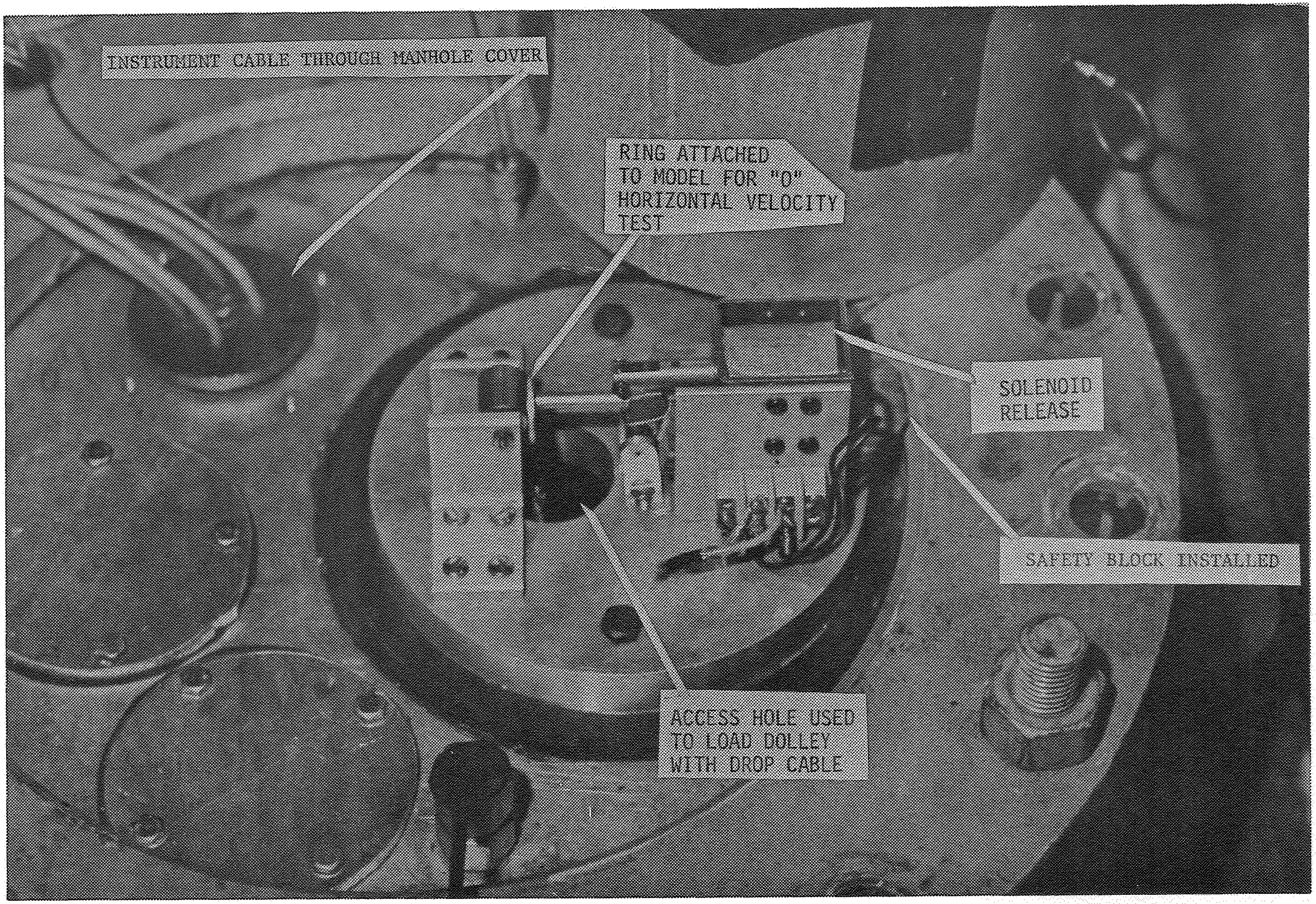
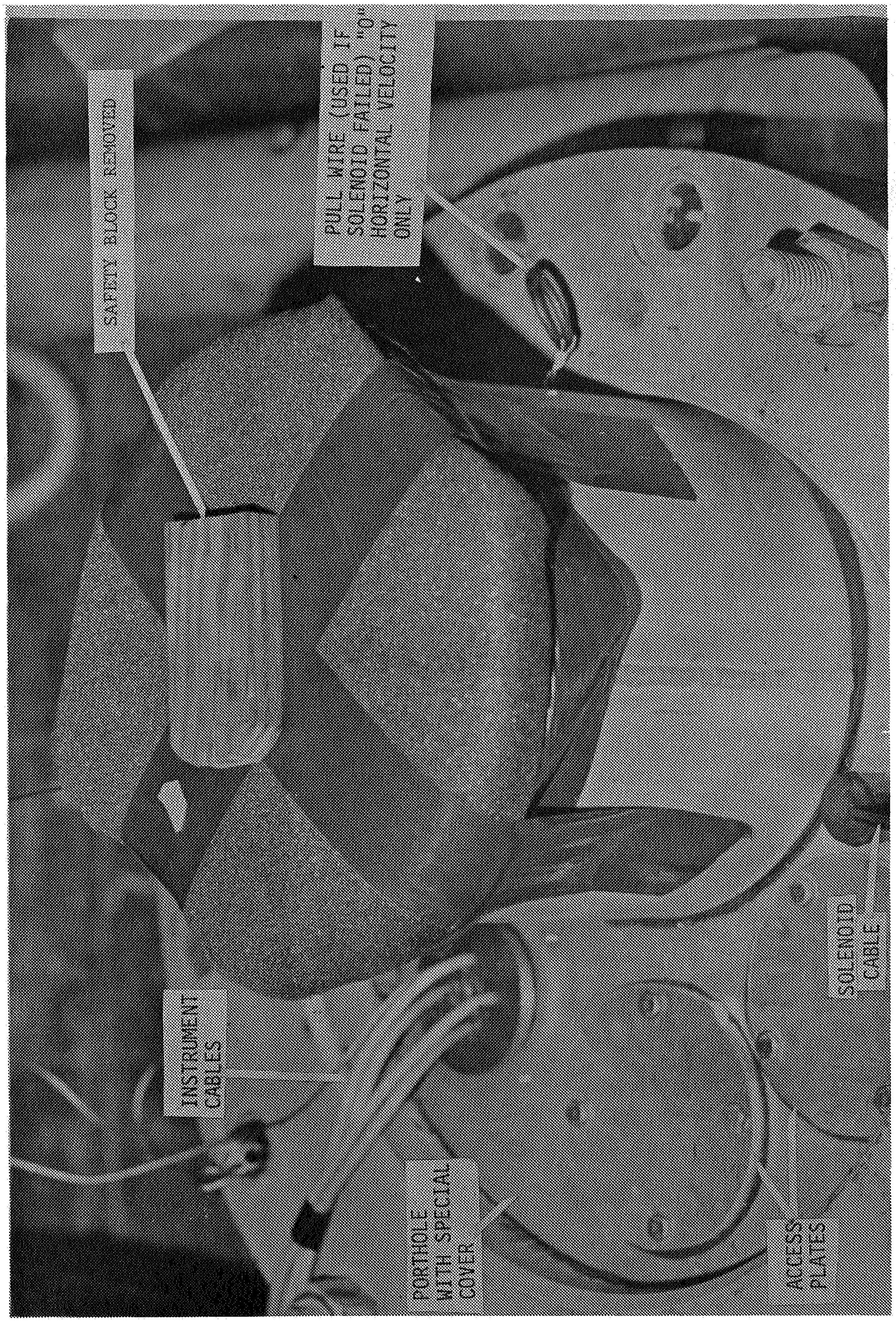


FIGURE 45 PORTHOLE WITH COVER REMOVED


SAFETY BLOCK REMOVED
PULL WIRE (USED IF SOLENOID FAILED) "0" HORIZONTAL VELOCITY ONLY
INSTRUMENT CABLES
PORTHOLE WITH SPECIAL COVER
ACCESS PLATES
SOLENOID CABLE

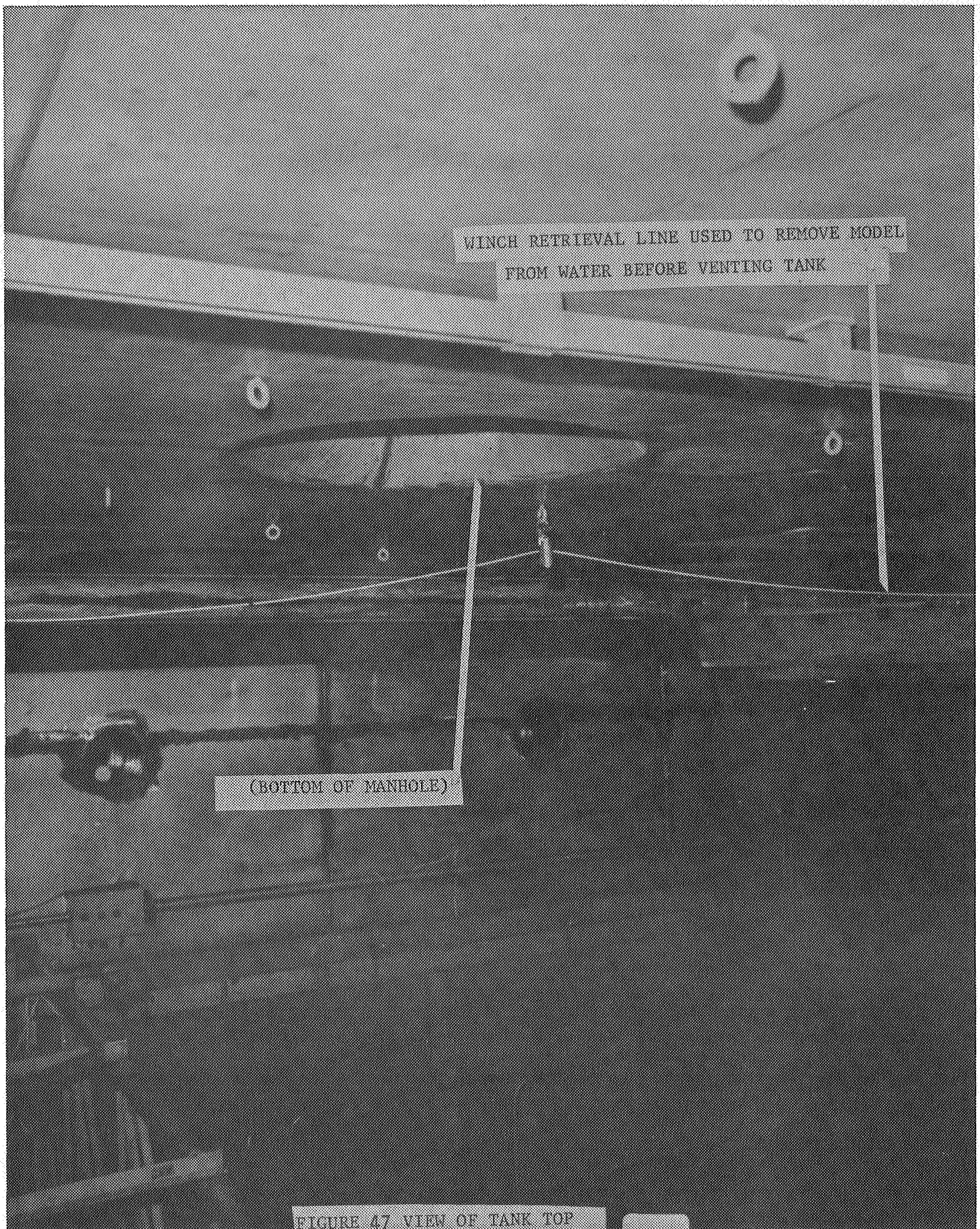


FIGURE 47 VIEW OF TANK TOP

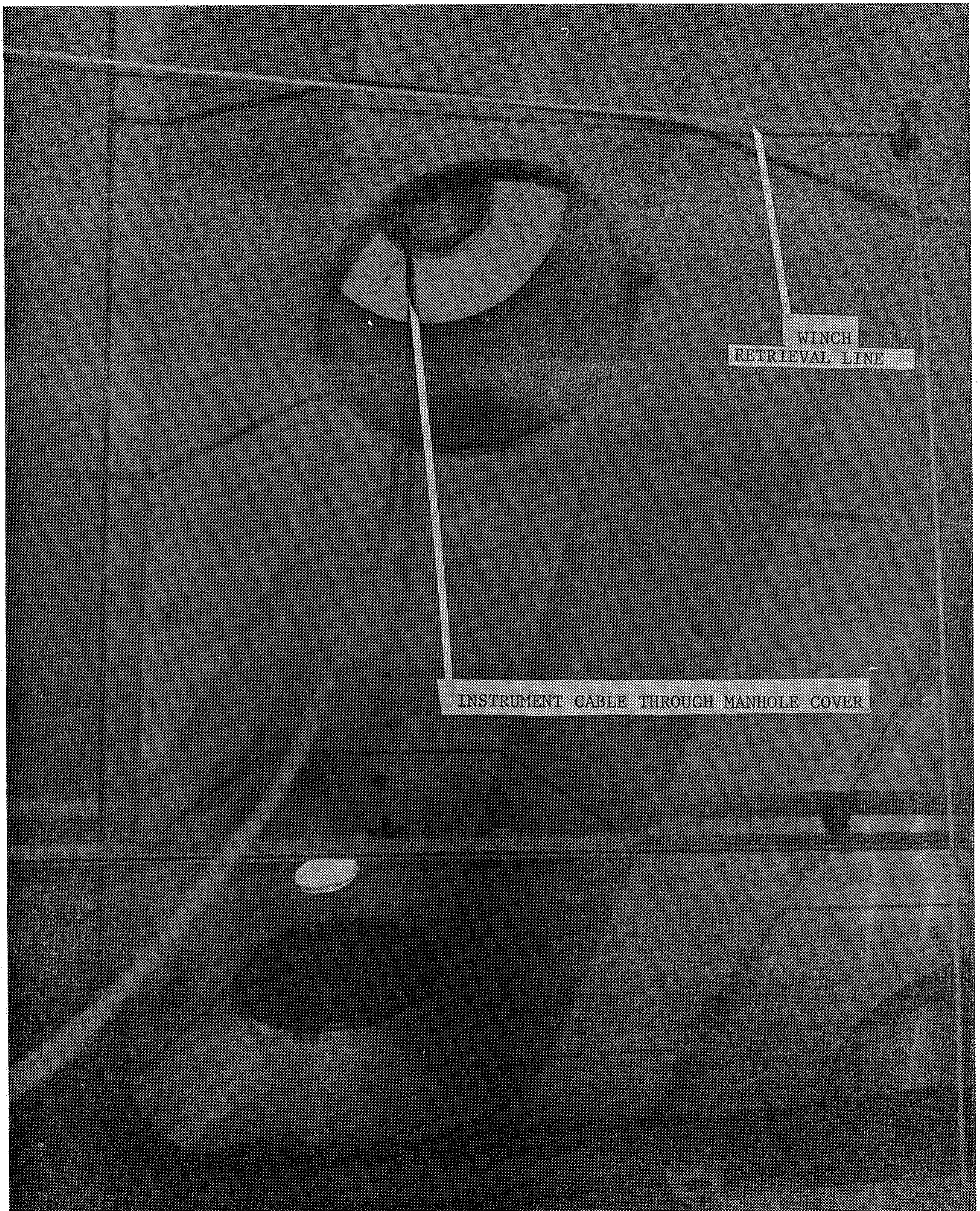


FIGURE 48 VIEW OF MANHOLE FROM WITHIN TANK

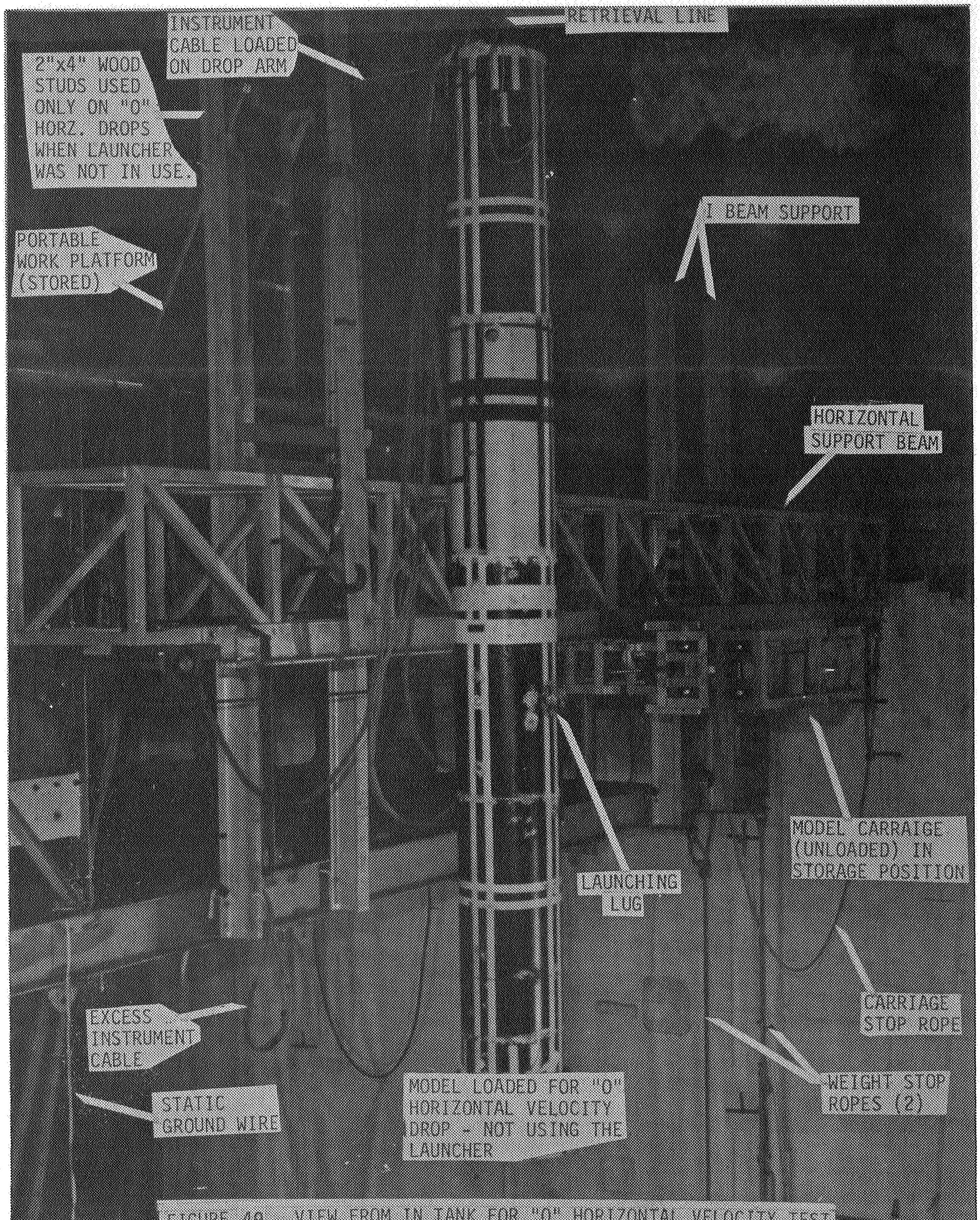


FIGURE 49 VIEW FROM IN TANK FOR "0" HORIZONTAL VELOCITY TEST

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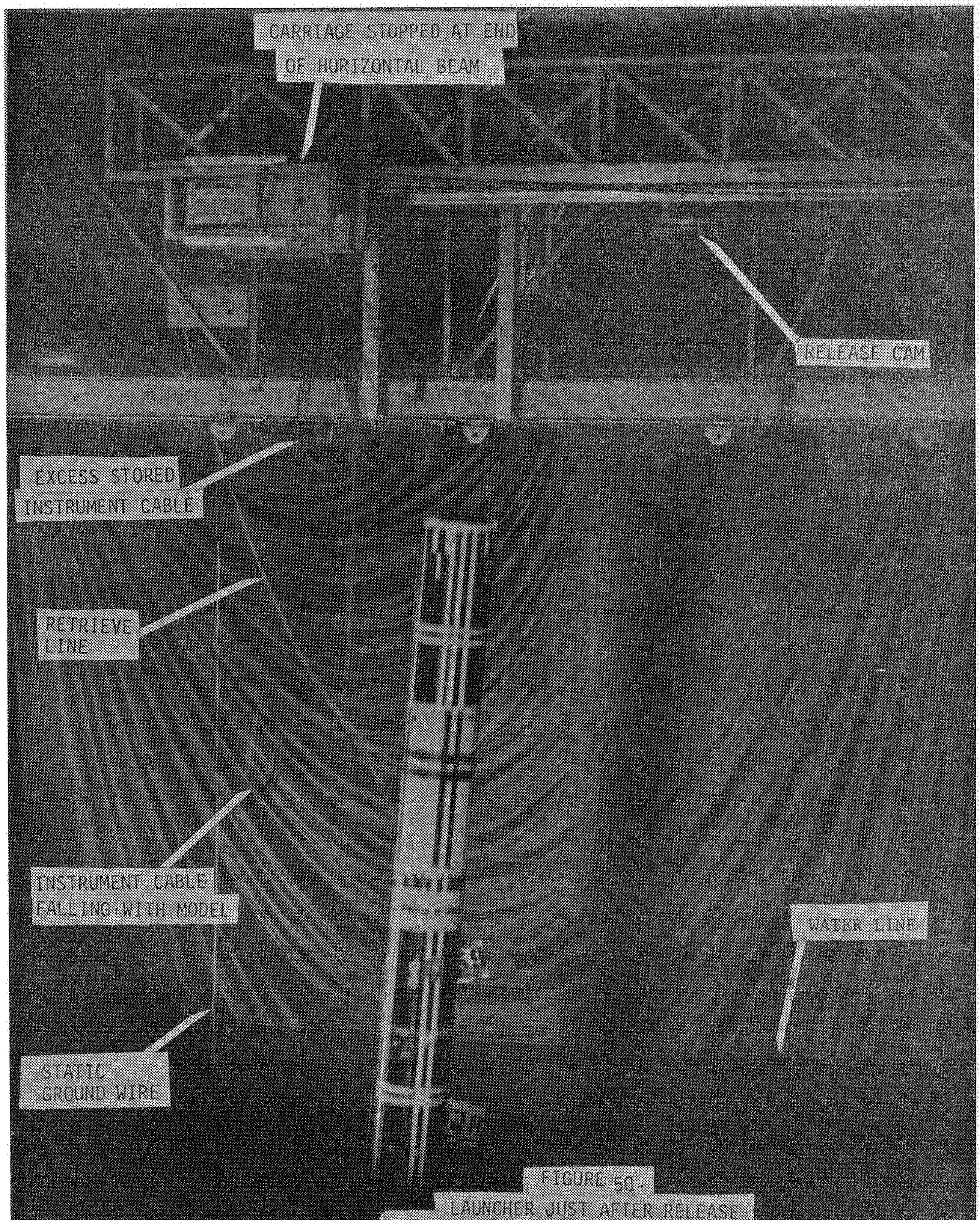

FIGURE 50.
LAUNCHER JUST AFTER RELEASE

SECTION VIII – TRANSDUCER DATA REDUCTION

The first phase of data reduction was accomplished at the MSFC computation laboratory. The data tapes were demodulated, filtered with 5000 HZ low pass filters, digitized at 10,000 samples per second and converted to engineering units. Digital tapes containing the data from each test drop were forwarded to the Slidell Computer Center for further processing and plotting.

Transducer data in this report are presented in numerical order, 1 plot per page, for each test drop. Time zero on the plots is approximately .3 to .4 seconds prior to release. The zero reference time differs for each run. Approximately 50 milliseconds of data at 10,000 samples per second are presented for each measurement. Each time slice is chosen to illustrate the largest magnitude load event. All transducers are biased to zero at time zero. Units on the plots are g's for accelerations, psig for pressures, and pounds or inch pounds for actuator loads.

It should be noted that the nozzle force data has not been corrected for balance interactions or for "g" loads. The interaction corrections are small, generally being less than 1%, the "g" corrections, however, are a substantial magnitude and should be considered when using the data. These corrections are: 6.9 # normal/g pitch, 6.9 # axial/g axial, 5.865 in-# pitch/g pitch, and 8.988 in-# yaw/g axial.

Figure 51 presents a typical set of data for Run #30. The Appendix contains a complete set of all digitized data plots for all valid test runs.

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REFERENCES

1. Marshall Space Flight Center Document Test Requirement for SRB Filament Wound Case (FWC) Rigid Body Scale Model Cavity Collapse Water Impact Test Program March 16, 1983, ED 22-83-48

2. Marshall Space Flight Center Document Test Requirements for SRB Thrust Vector Control (TVC) Pod Rigid Body Scale Model Water Impact Test Program, March 1983, ED 22-83-49

3. Marshall Space Flight Center unpublished document - Test Requirements for SRB Aft Skirt Segment Simulation Water Impact Test Program, January 1983.

4. Chrysler Corp. Technical Note, TN-FT-75-58, Pressure-Scaled Water Impact Test of a 12.5-inch Diameter Model of the Space Shuttle Solid Rocket Booster (SRB), MSFC Test No. TMS-333 April 1975.

5. Chrysler Corp. Technical Note TN-SM-82-3, Pressure-Scaled Water Impact Test of a 12.5-inch Diameter Model of the STS-1 Space Shuttle Solid Rocket Booster (SRB), MSFC Test 881 May 1982

6. Chrysler Corp. Technical Note TN-SM-82-5, Pressure-Scaled Water Impact Test of a 12.5-inch Diameter Model of the STS Space Shuttle Solid Rocket Booster (SRB), MSFC Test 82-1 May 1982

7. Chrysler Corp. Technical Note TN-SM-82-9, Pressure-Scaled Water Impact Test of a 12.5-inch Diameter Model of the STS-1 Space Shuttle Solid Rocket Booster (SRB), MSFC Test 82-2 August/September 1982

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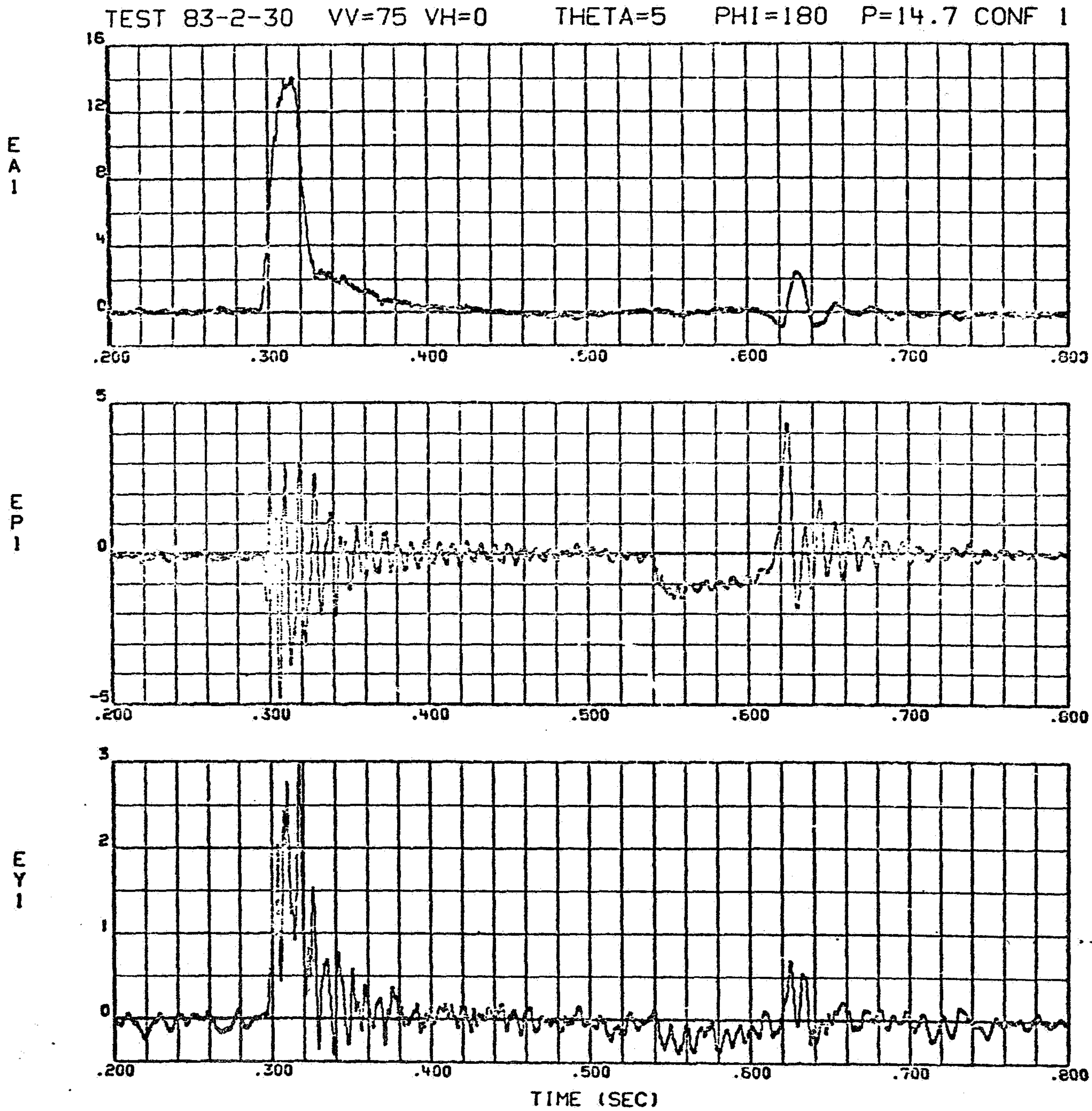

Figure 51. Data Sample Run

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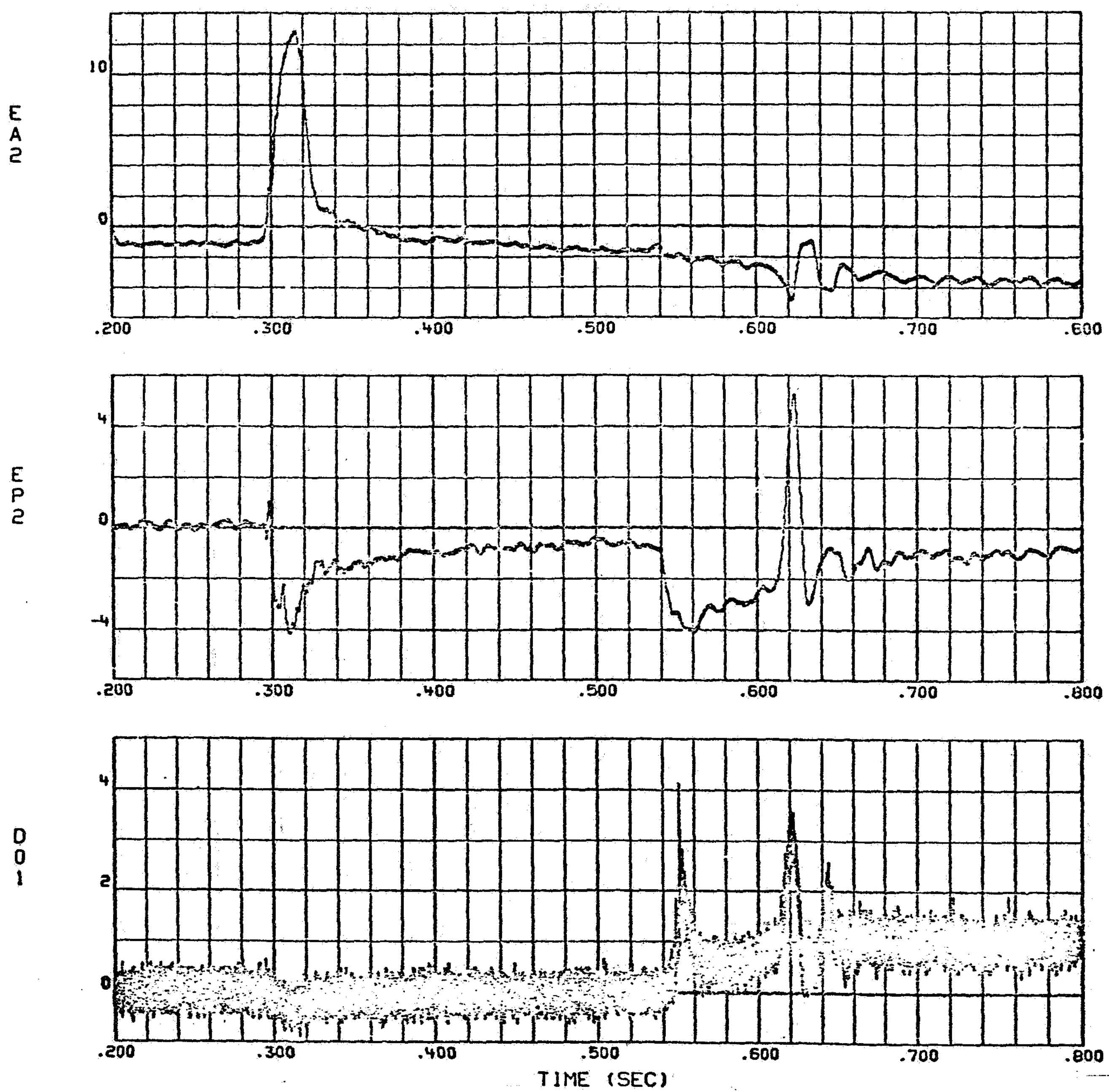

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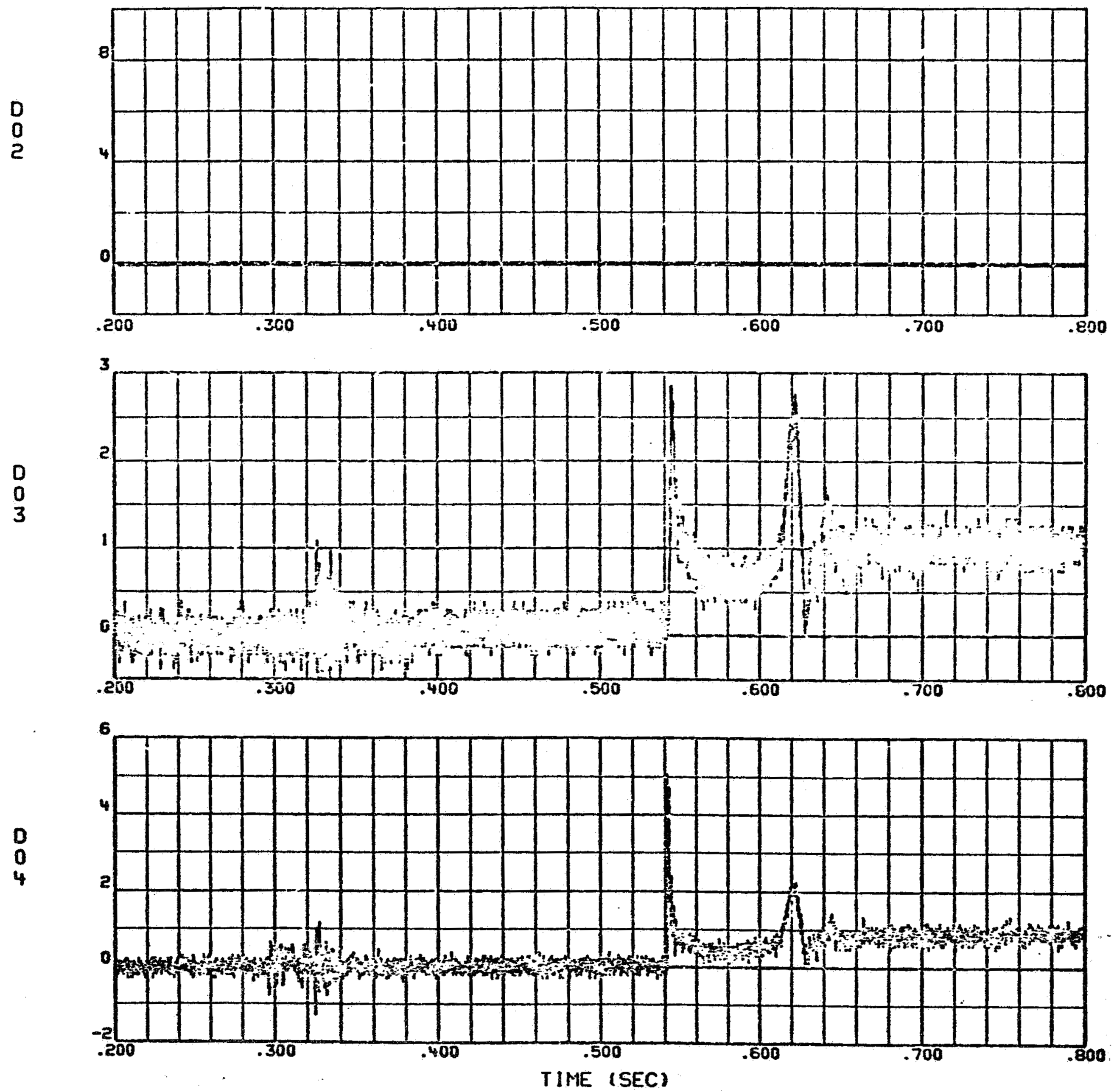

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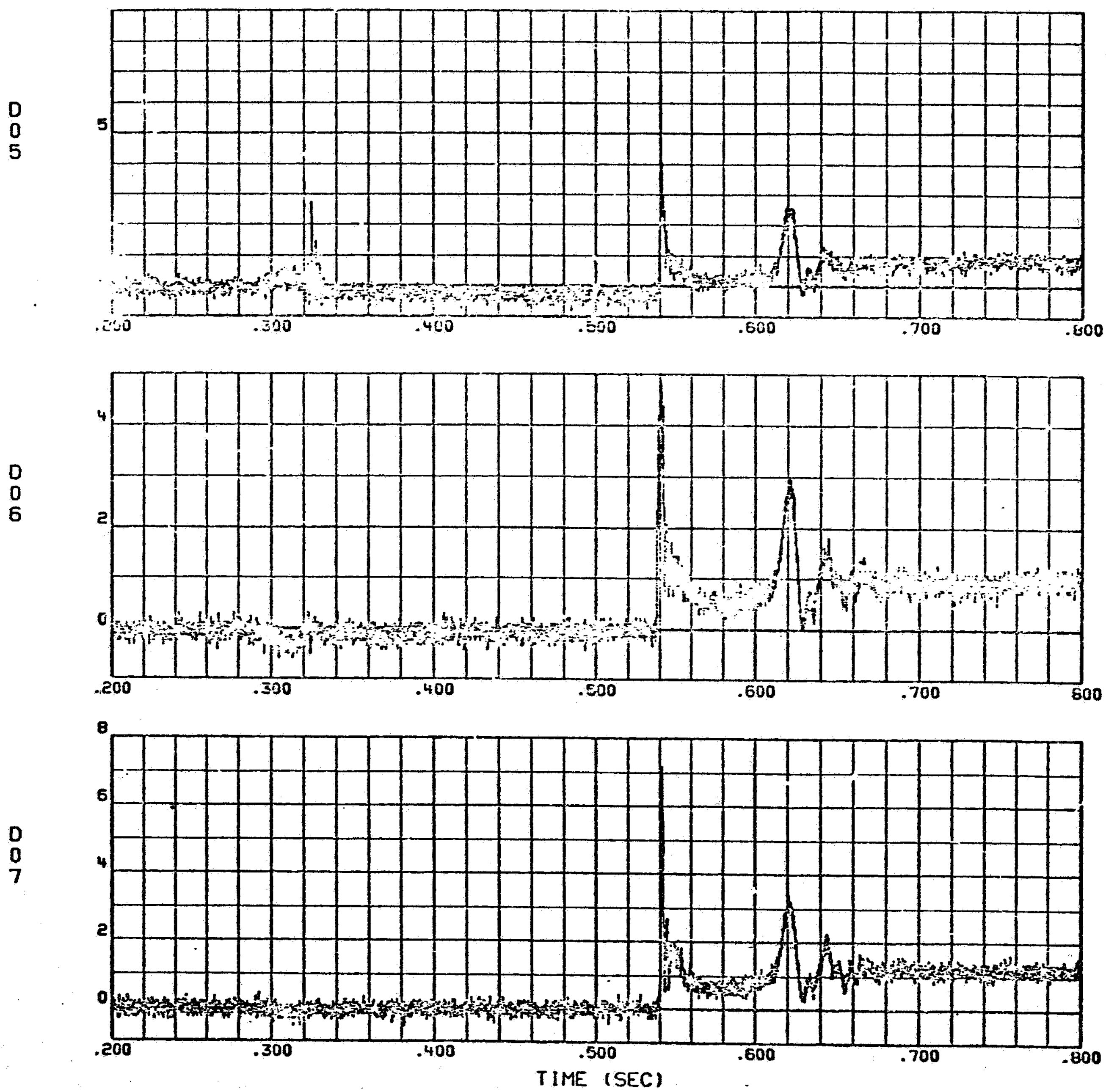

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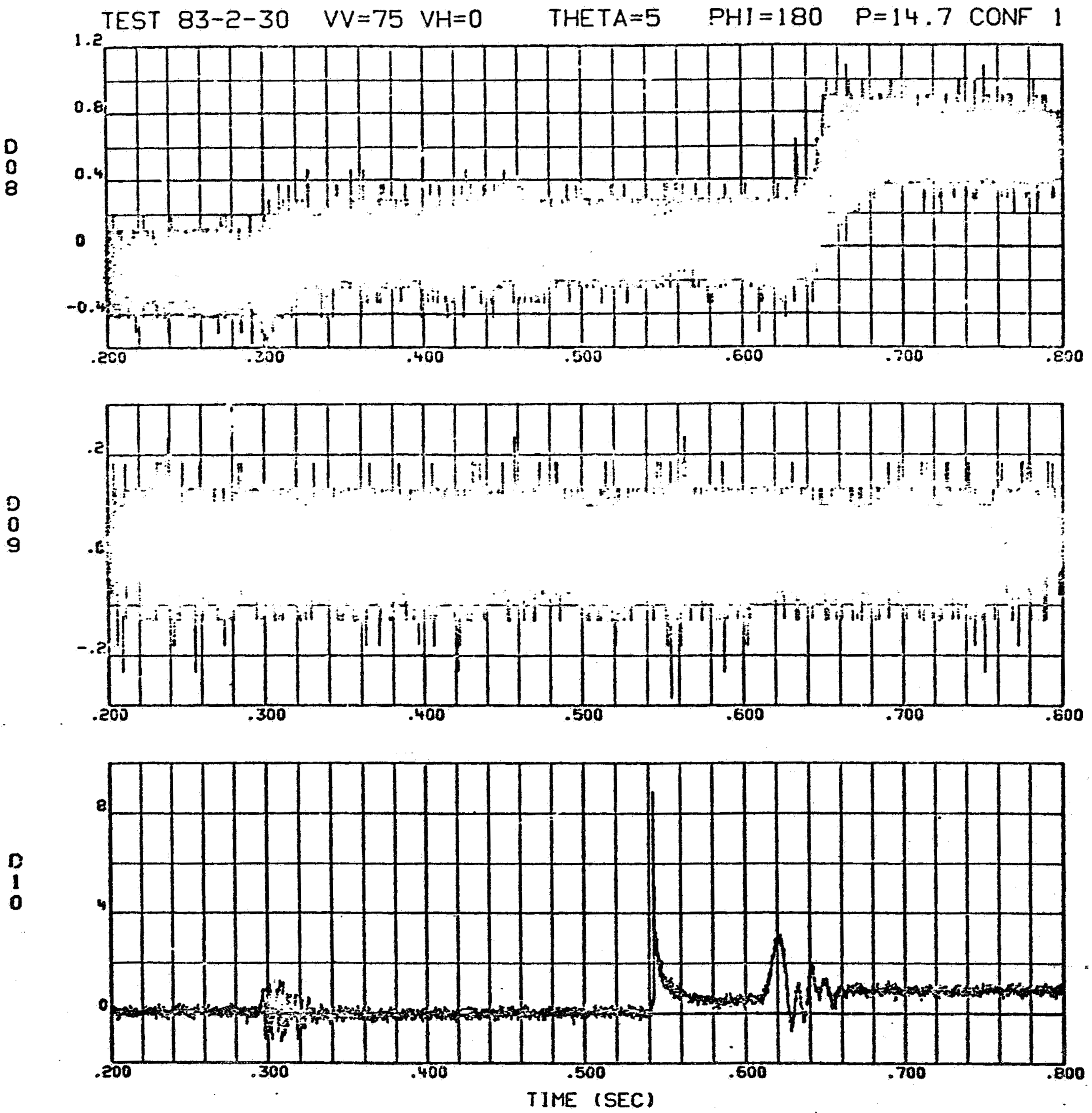
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1.2
0.8
0.4
0
-0.4
D08
.200
.300
.400
.500
.600
.700
.800
.2
.0
-.2
D09
8
4
0
D10
TIME (SEC)

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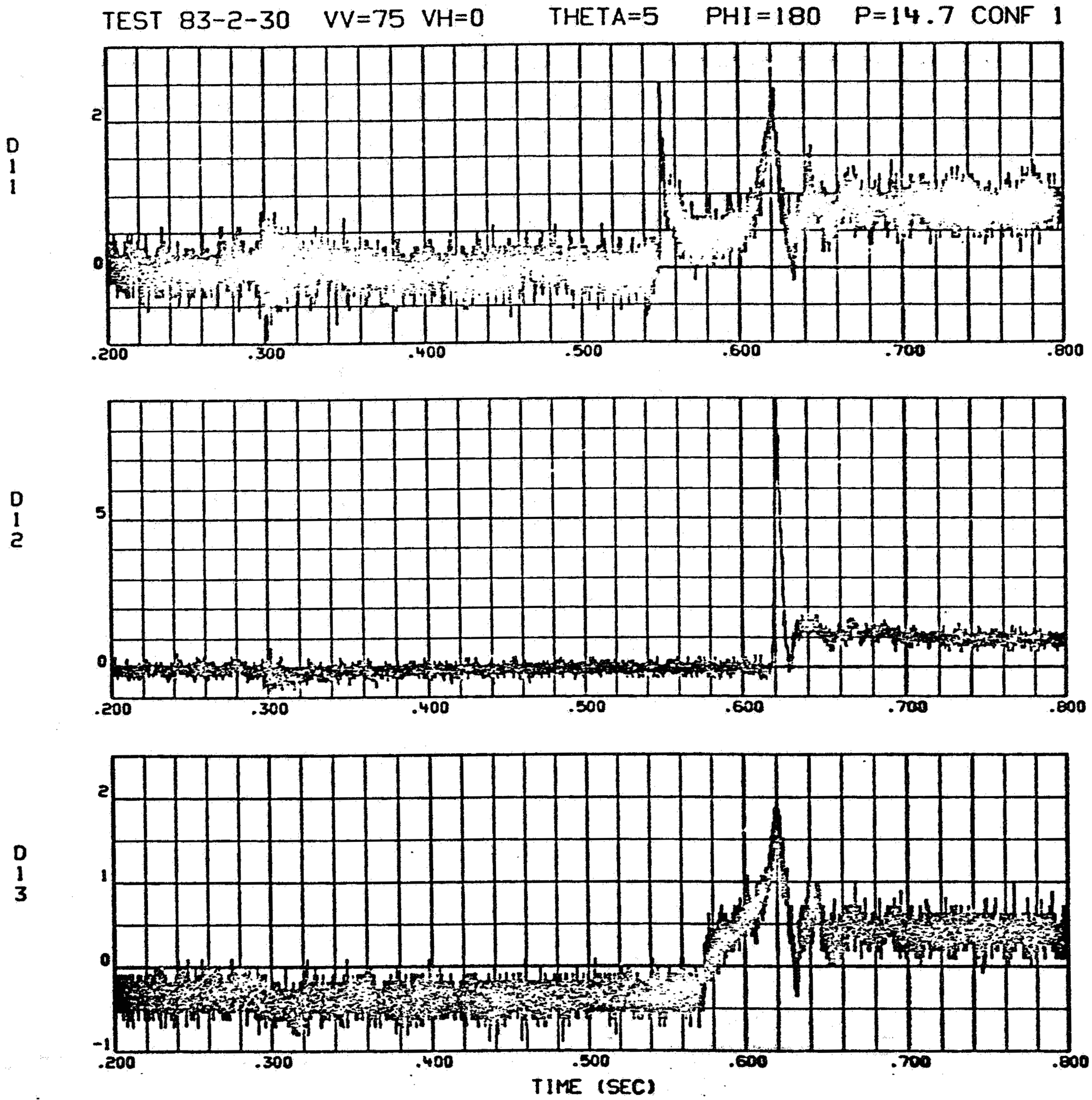

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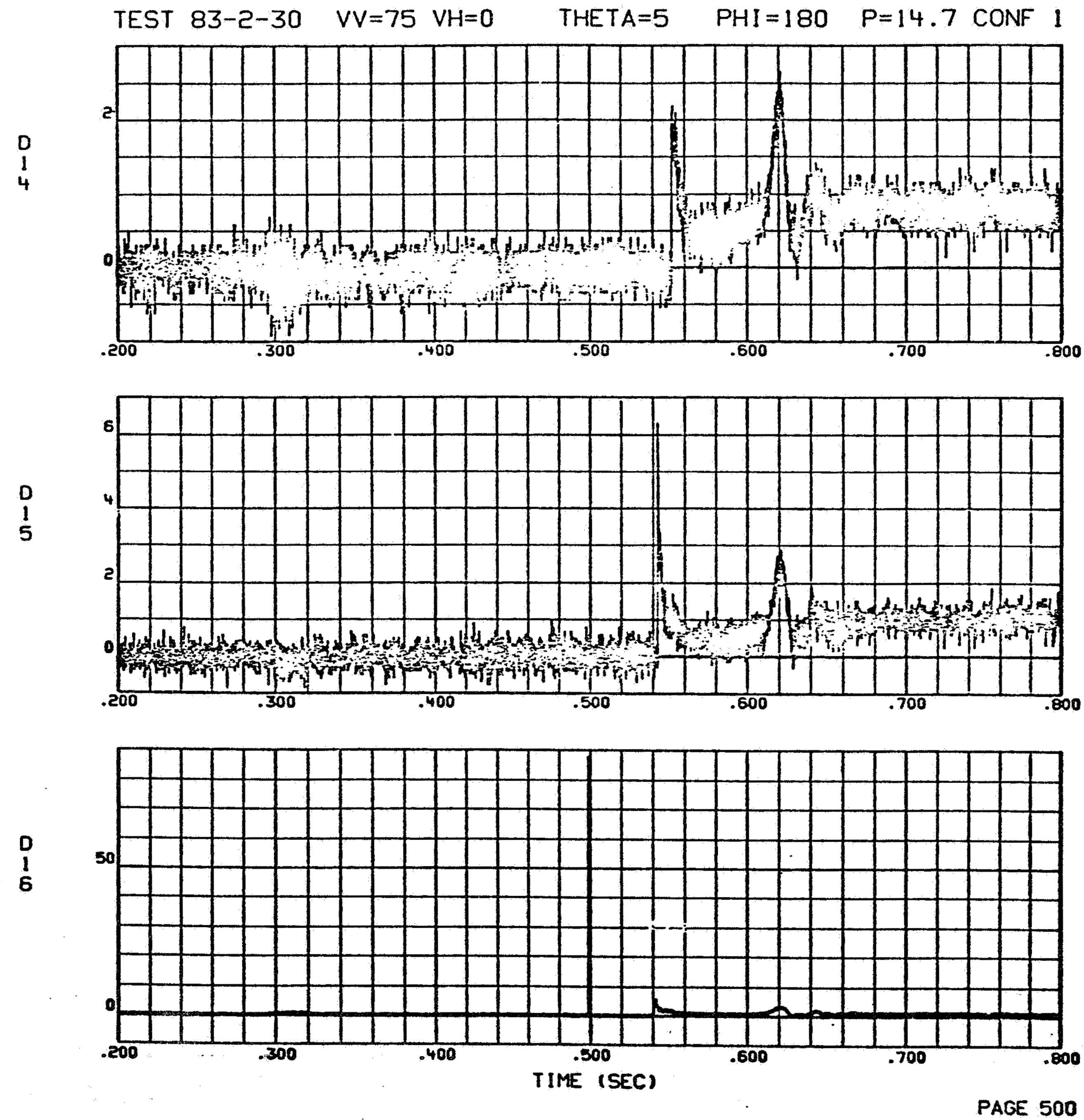

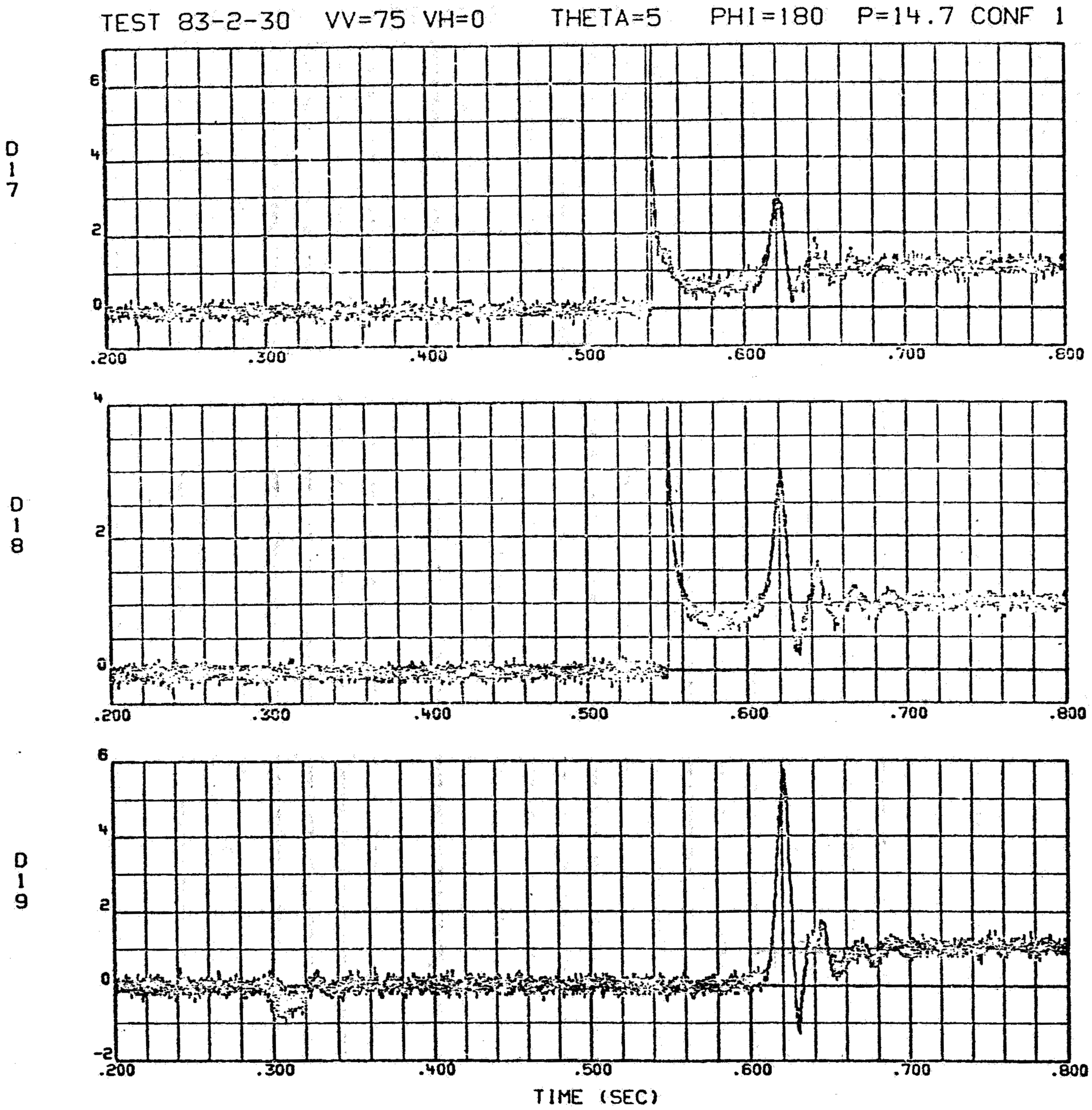
TEST 83-2-30 VV=75 VH=0 THETA=5 PHI=180 P=14.7 CONF 1
D17
D18
D19
TIME (SEC)
.200
.300
.400
.500
.600
.700
.800
6
4
2
0
-2

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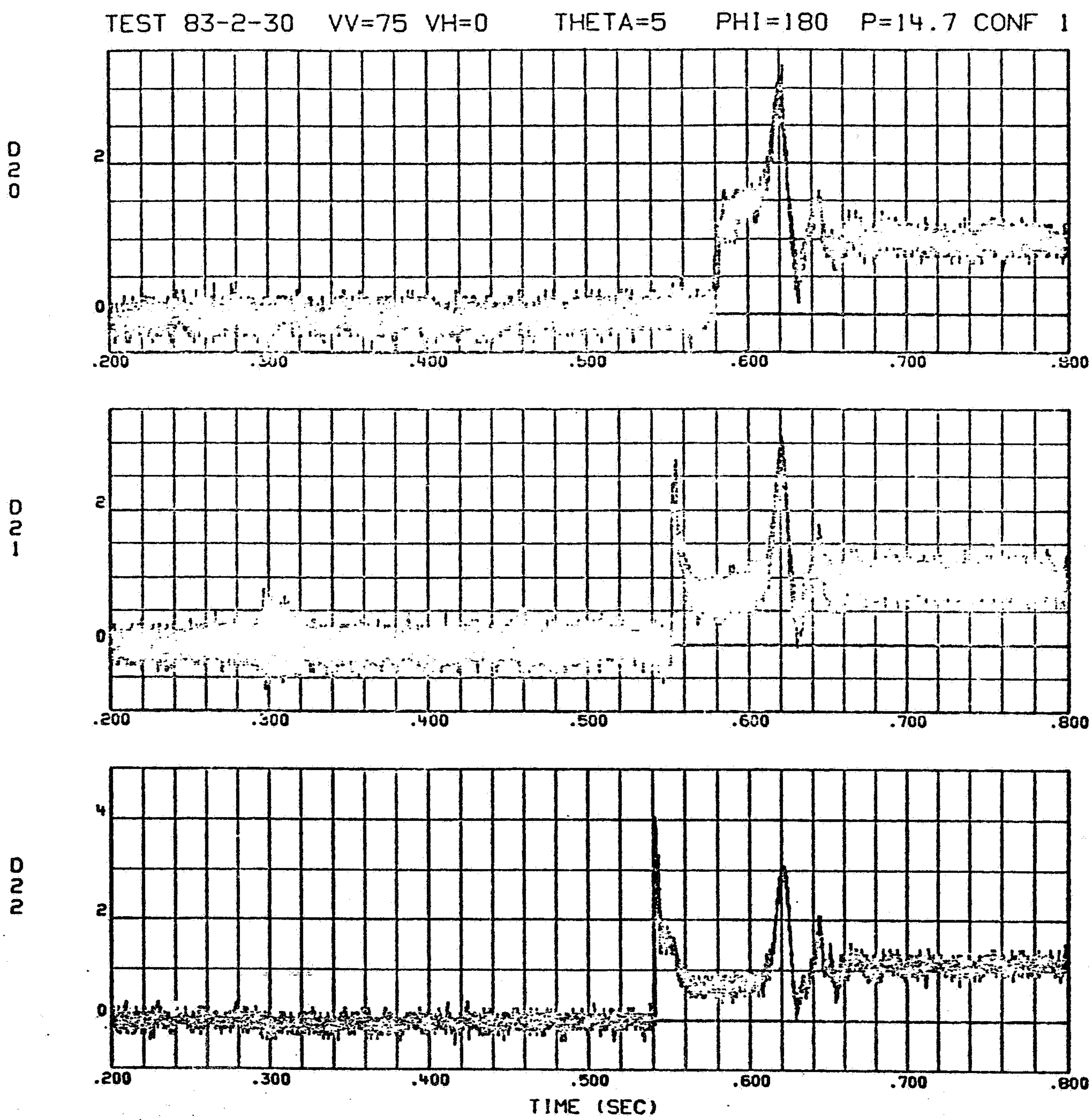

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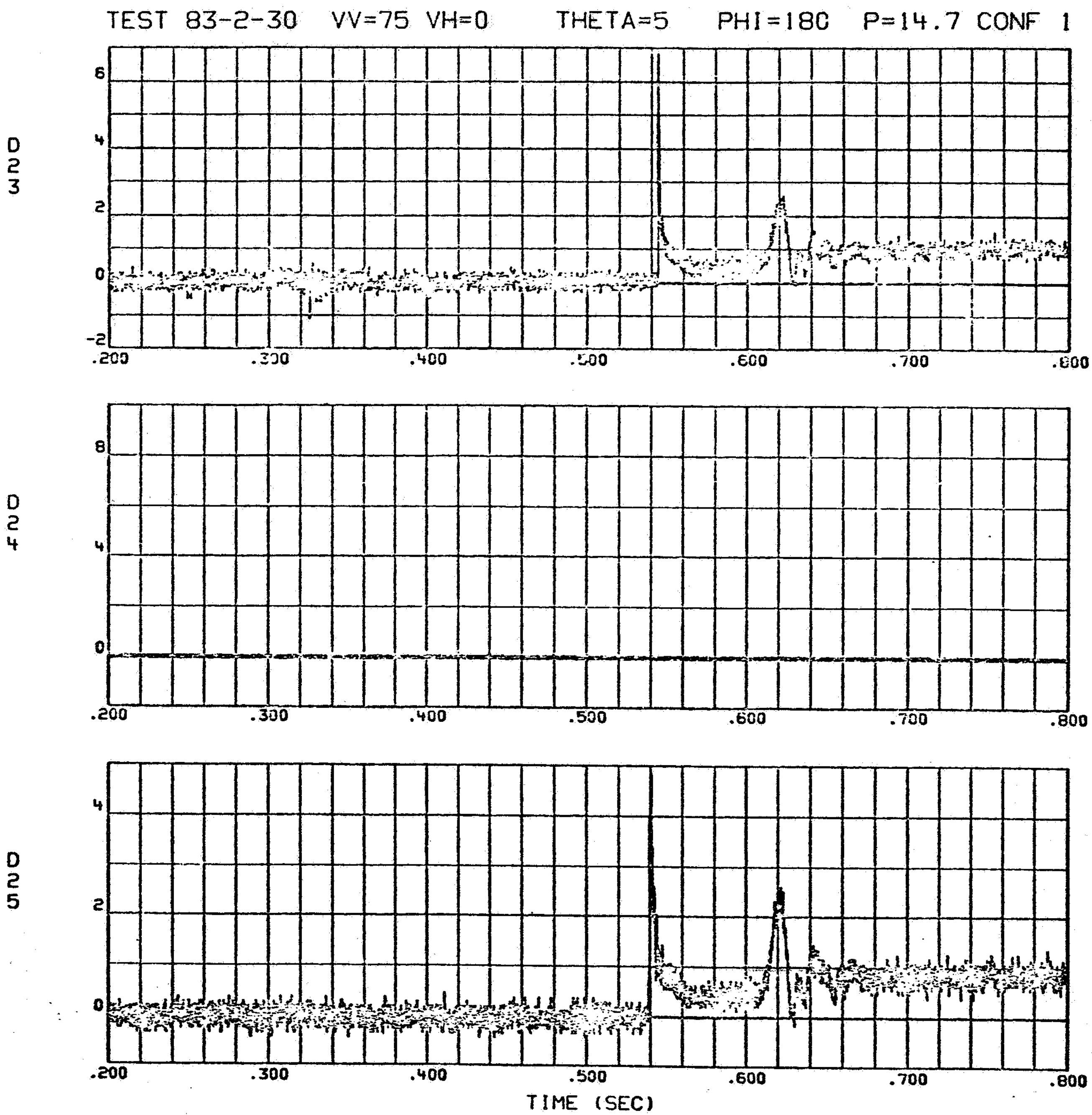

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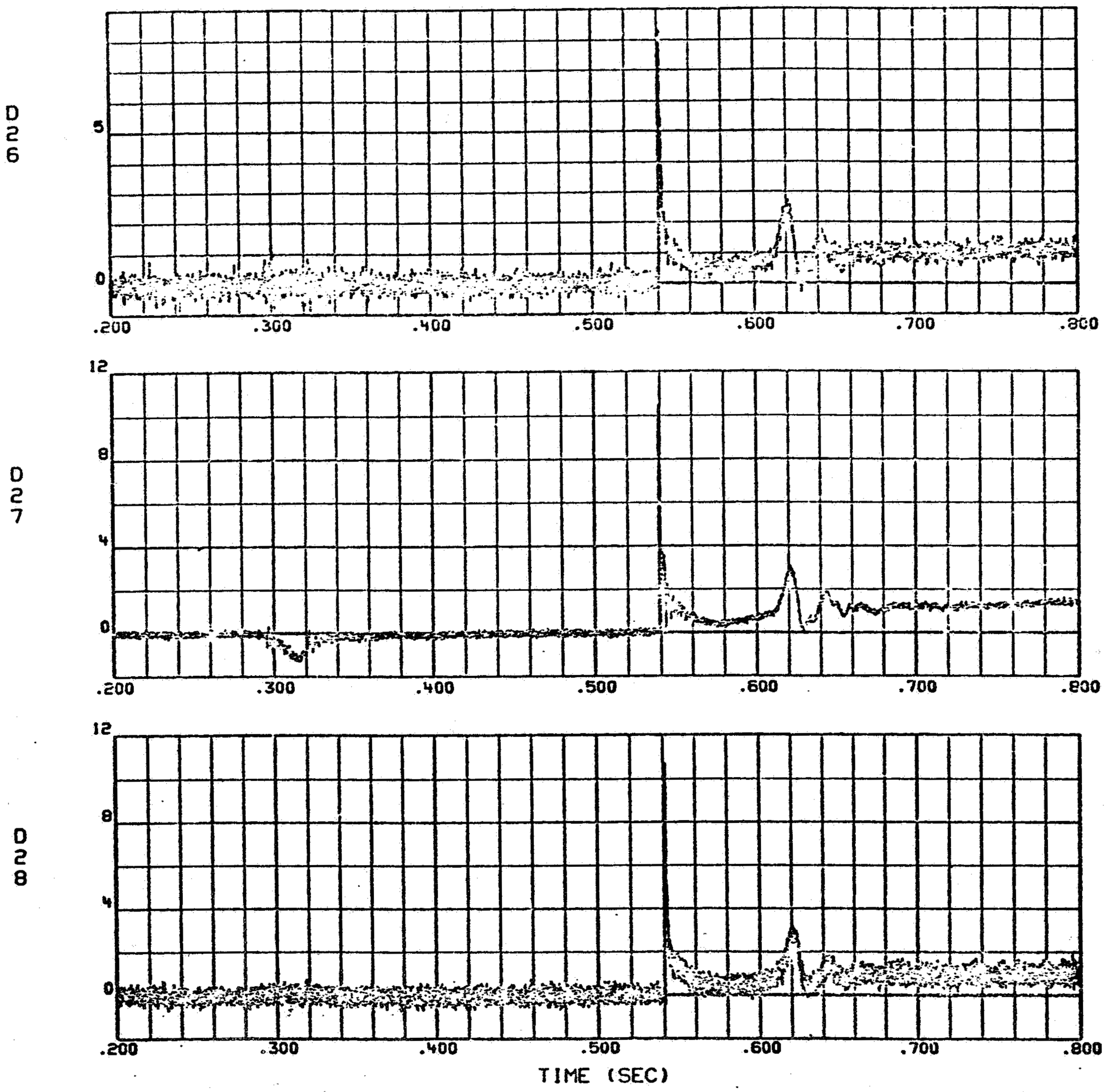
TEST 83-2-30 VV=75 VH=0 THETA=5 PHI=180 P=14.7 CONF 1



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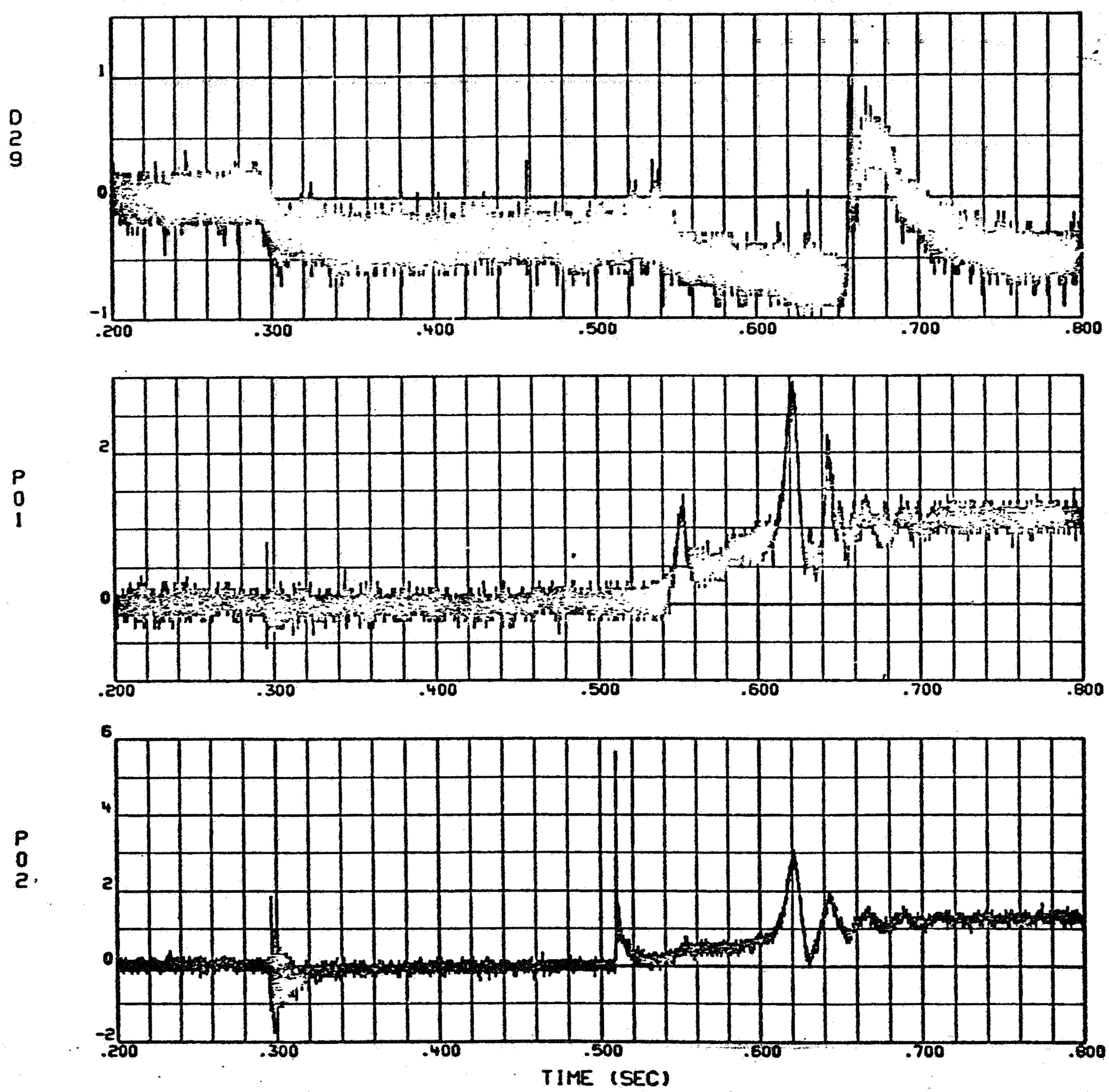

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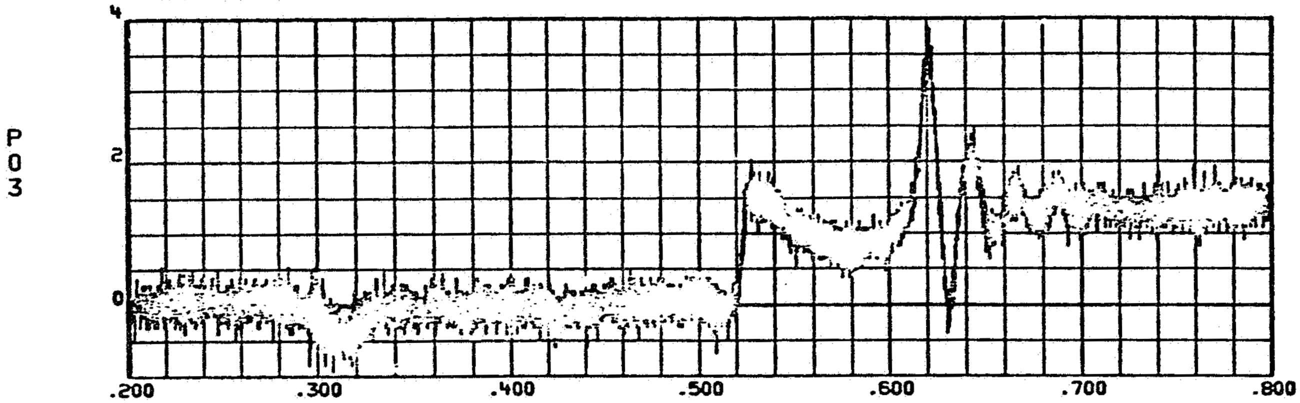

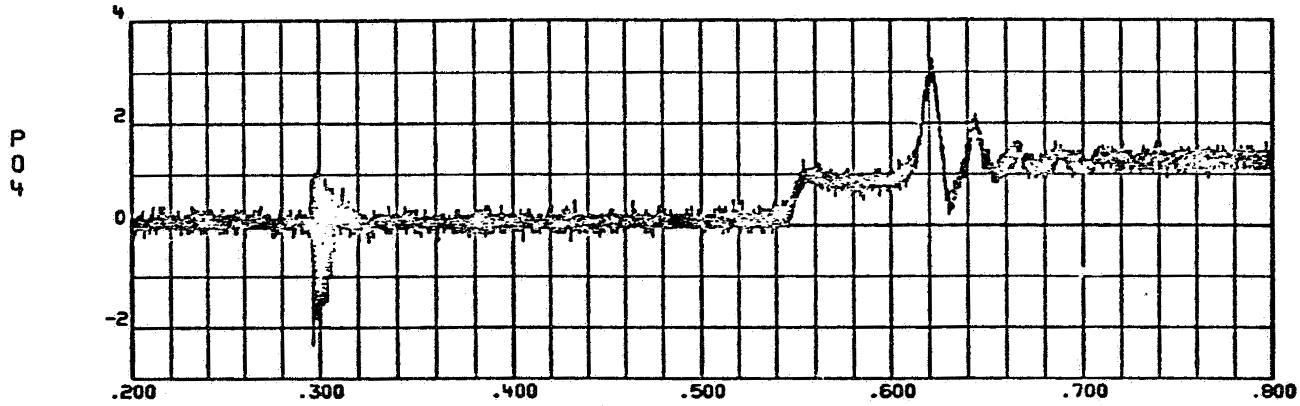

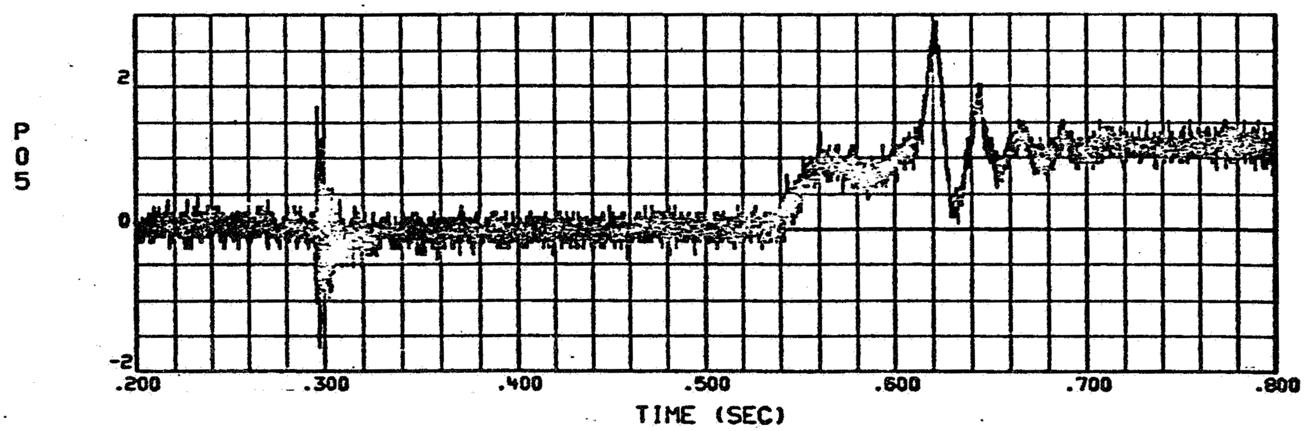

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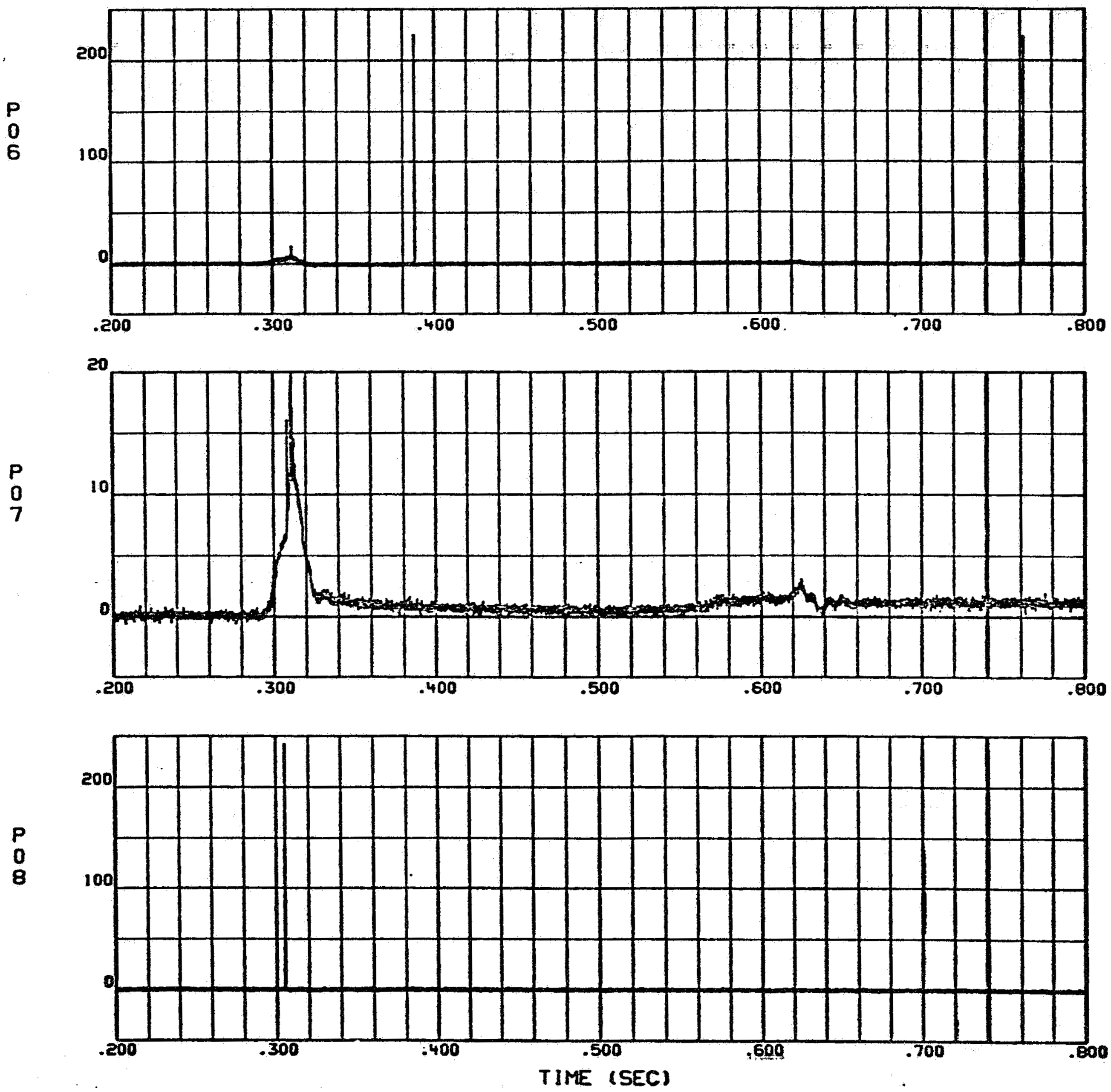
TEST 83-2-30 VV=75 VH=0 THETA=5 PHI=180 P=14.7 CONF 1



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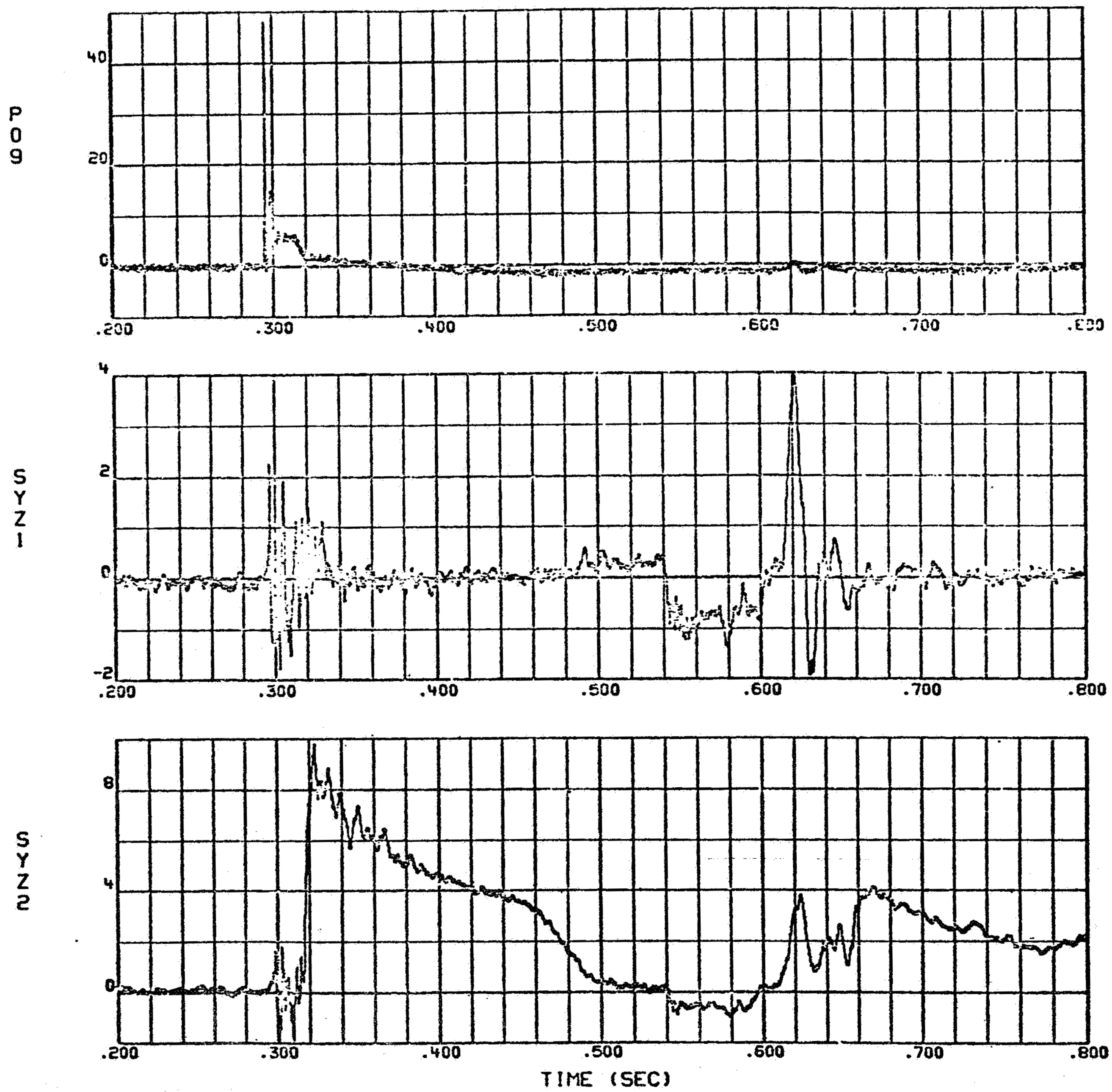
C-2

TEST 83-2-30 VV=75 VH=0 THETA=5 PHI=180 P=14.7 CONF 1



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