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SPACE SHUTTLE ORBITER CREW HATCH JETTISON TEST USING A 0.0405-SCALE MODEL (16-0) IN THE TEXAS A&M LOW SPEED WIND TUNNEL (OA362)

SPACE SHUTTLE AERGTHERMODYNAMIC DATA REPORT

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by

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Prepared under NASA Contract Number NAS9-17840

by

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for

NAVIGATION, CONTROL & AERONAUTICS DIVISION

JOHNSON SPACE CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HOUSTON, TEXAS

WIND TUNNEL TEST SPECIFICS:

NASA SERIES NUMBER:	OA-362
MODEL NUMBER:	16-0
TEST DATES:	June 15, 1987 through June 22, 1987
OCCUPANCY HOURS:	48

FACILITY COORDINATOR:

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ABSTRACT

This report contains post-test information for the Space Shuttle Orbiter Crew Hatch Jettison Test OA362 which was conducted in the Texas A&M Low Speed Wind Tunnel from 6/15/1987 to 6/22/1987.

The test objective was to verify that the crew hatch, once jettisoned, would clear the orbiter under various simulated flight conditions. Several model hatches were used with the 0.0405-scale orbiter (Model 16-0). The model's angle of attack was set at 10, 15, and 20 degrees while the sideslip had values of -5, 0, and +5 degrees. The full scale Qbars that were simulated were 105, 128, 160, and 210 psf.

In the hatch jettison mechanism itself, the plunger pressure was varied to achieve horizontal velocities of 3, 5, 7, and 20.1 feet per second model scale, and the plunger location was varied to achieve a variety of rotational velocities.

The orbiter model was subjected to 122 runs with 13 different hatches. Of these, 60 were good runs.

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INTRODUCTION

This report presents information for the Crew Hatch Jettison Test (OA-362) which was conducted in the Texas A&M Low Speed Wind Tunnel. The test was performed with a 0.0405-scale Space Shuttle Orbiter (Model 16-0) from 6/15/1987 to 6/22/1987.).

The purpose for this test was to verify that the crew hatch, once jettisoned would clear the orbiter. This objective was tested under several different jettison conditions and flow field conditions.

There were two major variables when dealing with the jettison conditions. The first was the initial horizontal velocity of the hatch. This was determined by the force of the plunger used to eject the hatch. The second variable was the initial rotation of the hatch. This was needed to test to what extent a failure of a hatch thruster cartridge or an asymmetry of the three thrusters would have on the hatch trajectory. This was simulated by jettisoning the hatch with various plunger positions that were off-center of the c.g. of the hatch.

The different flowfield conditions were created when the desired tunnel wind speed and model angles of attack of 10, 15, and 20 degrees and sideslip angles of -5, 0, and +5 degrees were attained. The full scale dynamic pressures that were simulated were 105, 128, 160, and 210 psf. The model scale dynamic pressures that were derived from these were 8.0, 9.7, 12.2, and 16.0 respectively (see Table I).

MODEL DESCRIPTION

The test article was a 0.0405-scale model of the 140C modified Space Shuttle Orbiter designated Model 16-0. This orbiter model utilized blended wing-body design with a double delta wing, full span split elevons, a center line vertical tail with rudder and speedbrake, a canopy, a body flap, and orbital maneuvering system (OMS) pods. During the test it was assumed that the landing gear (main and nose) would be retracted when the hatch was jettisoned. Therefore, the landing gear was not included on the model. The orbiter model also included an ejector assembly to release and jettison the hatch. This assembly was housed in a cavity shell that was installed to simulate the crew hatch opening and some exposed internal volume (Figure 1b).

The release mechanism inside the cavity consisted of a fused screw "burn bolt". It secured the hatch in place against the ejection force which was preset. For the hatch to be released, the bolt was broken by passing a high electrical current through its fused section. The current was delivered by a Rockwell provided 1200 joule capacitive-discharge system. It was operated at about 42-joules during the test.

The jettison mechanism was a pneumatic cylinder/piston/plunger arrangement with a stroke of 0.324 inches. The cylinder pressure and plunger position was varied to adjust the initial horizontal and rotational velocities.

The model hatch was constructed of aluminum with the external shape cast from a dense foam ("Litecast") in order to obtain the incompressible scaled mass properties of the full scale hatch (mass, inertia, and c.g.). Fine tuning of the mass properties was done with lead "B.B.'s".

The model was mounted upright (wings level) on a double strut structure which was attached to the underside of the wing. These struts were fixed to the tunnel's turntable (Figures 1c and 1d) which was responsible for controlling the model's sideslip angle. A stub sting was extended from the rear of the model and fixed to a third strut (Figure 1a). It was this third strut that was responsible for the pitching of the model. The "burn bolt" power cables and the jettison mechanism pneumatic line were routed up the rear strut/sting assembly and into the model.

The following nomenclature will be used to designate the various model components:

COMPONENT	DESCRIPTION
B62	Baseline - 140C orbiter fuselage
B63	Simulated crew hatch jettison (L.H. fwd.)
G20	Vehicle - 101 orbiter nose and main landing gear (retracted)
M16	-140C orbiter OMS/RCS pods
N28	-140C orbiter OMS nozzles for M16
W127	Baseline -140C orbiter wing
F10	-140C orbiter body flap
E55	-140C orbiter elevons with flipper doors for W127
V8	-140C orbiter vertical tail
R5	-140C orbiter rudder for V8

DATA REDUCTION

Instrumentation utilized for this test consisted of pressure measuring and photographic equipment.

To record the hatch jettison cylinder pressure, a Rockwell high pressure transducer (Statham PA822, 0-300 psia) was provided. The output was approximately 0.1 mV/psi @10V excitation with gaseous nitrogen used as a pressure source (K bottle).

The photographic requirements included video footage and still photographs (to show installation). The video footage was acquired from two high speed video cameras (200 frames/sec). One camera was mounted above and the other was mounted facing the hatch side of the model. They were both time correlated and in sync with the tunnel lighting. The video tapes were run through a motion analyzer at the Texas A&M University for reduction to provide X-Y-Z positions and the velocities (horizontal and rotational) of the hatch.

TEST CONDITIONS

The PA822 high pressure transducer was calibrated from 0 to 150 psig in 30 psi steps.

The hatch jettison mechanism was calibrated at Rockwell, NAAO. The results showed that the system zero was at X=0 and Z=-0.025 assuming that the door center was at X=Z=0.

After installation, several static runs were made (61-63, 91-93, 102, 117-118, 121-122) as well as a few general system checkout runs (1-5). The details of these runs are shown in the run schedule.

The full scale dynamic pressures that were simulated were 105, 128, 160, and 210 psf. To achieve these conditions, the tunnel was operated as follows:

SIMULATED FLIGHT QBAR (psf)	VELOCITY (f/s)	MACH NUMBER	q (psf)
105	82	0.07	8.0
128	88	0.08	9.7 *
160	101	0.09	12.2
210	116	0.10	16.0

* 80% OF TESTING

The test points were taken at 10, 15, and 20 degrees angle of attack (85% at 15 degrees) and at -5, 0, and +5 degrees angle of sideslip (70% at 0 degrees). The order of these tests, as well as preliminary results, can be seen in the run schedule (Table IV).

The primary variables throughout the test were the simulated hatch horizontal (EVh) (see Figures 3a and b) and rotational velocities. The plunger offsets, which controlled the initial rotational velocities, can be seen in Figure 2. The theoretical conversions to actual rotational velocities at hatch separation are shown in Figure 3c.

TEST FACILITY DESCRIPTION

The Texas A&M University Low Speed Wind Tunnel is an unpressurized air-medium facility capable of attaining continuously variable test section dynamic pressures from 0 to 100 pounds per square foot. The wind tunnel is of the closed-circuit, single-return type having a rectangular test section ten feet wide and seven feet high. Reynolds numbers are variable up to 1.84×10^6 per foot. Models are supported in the test section by either a sting or struts depending upon the test requirements.

REFERENCES

***Reports*--**

STS 87-0088, "Pretest Information for Space Shuttle Orbiter Flow Field Survey Wind Tunnel Test OA-357 of the Model 16-0 in the Texas A&M University Low Speed Wind Tunnel," March 1987.

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"Low Speed Wind Tunnel Facility Handbook, Texas A&M University," January 1985.

***Letters*--**

WTL-87-027, "Design Requirements for a SSV Hatch Jettison Test at Texas A&M University (TAMU)," March 1987.

SAS/AERO/86-235, "Test Requirements-Jettisoned Crew Hatch Wind Tunnel Test," 30 October 1987.

***Drawings*--**

SS-A01185, "Model Assembly #16-0"

SS-A01186, "Wing Assembly - 0.0405 Scale Orbiter Wing"

SS-A01127, "Vertical Tail - 0.0405 Scale Orbiter"

SS-A01191, "OMS Pod, Details - 0.0405 Scale Orbiter"

SS-A01328, "Model Assembly #16-0, 0.405 Scale SSV Orbiter (OML)"

SS-A01329, "Wing Assembly #16-0, 0.0405 Scale SSV Orbiter"

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SS-A01600, "Landing Gear Assembly, 0.0405 Scale Orbiter #16-0"

SS-A02303-1, "Hatch Details & Assembly, 0.0405 SSV 16-0", 27 April 1987

SS-A02303-2, "Actuator Assembly & Details - 0.0405 SSV 16-0", 26 April 1987.

C.O. No SS-2783-314, "Modification to Hatch Opening and List of Items to be completed for Model Shipment", 29 May 1987.

TABLE I

DYNAMIC PRESSURE SCALING

$$\frac{q_M}{q_F} = \frac{\rho_M}{\rho_F} (SCALE)$$

SCALE = 0.0405

FOR AN ALTITUDE OF 20,000 FT.

$$\frac{\rho}{\rho_o} = 0.5332$$

$$\frac{q_M}{q_F} = \left(\frac{1}{0.5332}\right)(0.0405) = 0.075956$$

QBAR MODEL SCALE = QBAR FULL SCALE X 0.075956

QBAR FULL SCALE	QBAR MODEL SCALE
105 PSF	8.0 PSF
128	9.7
160	12.2
210	16.0

DATA SHEET

DEVIATION: WT. = -1% to -5%
I_{yy} = +2% to -4%
X_{cg} = 0
Z_{cg} = -.007" to +.008"

DESIGN: WT. = .0363 lb
I_{yy} = 3.269E-6 Sl-ft^2

DOOR NO.	WT, (lb)	I_{YY} ($\times 10^6$) (Sl-ft^2)	X_{CG}	Z_{CG}	REMARKS
1	.0345	3.183	+.002	-.005	
2	.0343	↓	↓	-.078	DON'T HAVE
3	.0346	3.140	0	0	USED FOR CK-OUT
4	.0346	3.312		↓	USED FOR CK-OUT
5	.0349	3.269		-.004	
6	.0349			-.007	
7	.0349	↓		-.005	
8	.0353	3.291		-.006	
9	.0351	↓		-.007	
10	.0348	3.269			
11	.0348	↓		↓	
12	.0352	3.291		-.005	
13	.0348			+.002	
14	.0352			+.001	
15	.0350			-.002	
16	.0347	↓		↓	
17	.0350	3.267		+.001	
18	.0352	↓		↓	
19	.0347	3.288		+.004	
20	.0347	3.267		-.005	
21	.0350	3.288		-.006	
22	.0349			↓	
23	.0348	↓		-.003	
24	.0351	3.181		-.004	LOOSE
25	.0350	3.224		+.003	
26	.0350	↓		+.004	
27	.0349	3.291		↓	
28	.0348	3.269		-.002	SLIGHTLY LOOSE
29	.0352	3.312		-.005	
30	.0351	3.291		-.004	
31	.0352			↓	
32	.0350			-.004	
33	.0350	↓		+.003	
34	.0352	3.312		-.002	
35	.0349	3.269		-.005	
36	.0352	3.291		-.004	
37	.0352	3.312	↓	-.005	

TABLE II

HATCH MASS PROPERTIES

DEVIATION: WT. = -1% to -5%
I_{yy} = +2% to -4%
X_{cg} = 0
Z_{cg} = -.007" to +.008"

DESIGN: WT. = .0363 lb
I_{yy} = 3.269E-6 Sl-ft^2

DATA SHEET

DOOR NO.	WT. (lb)	I_{YY} ($\times 10^6$) (Sl-ft^2)	X_{CG}	Z_{CG}	REMARKS
38	.0351	3.291	0	-.007	
39	.0351	↓		-.005	
40	.0351	3.312		-.005	
41	.0352	3.334		-.004	
42	.0353	3.312		-.005	
43	.0353	↓		-.002	
44	.0350	3.269		-.004	
45	.0352	3.183		-.002	SLIGHTLY LOOSE
46	.0350	3.247		+.001	
47	.0352	3.226		0	
48	.0349	3.291		-.003	
49	.0354	↓	↓	+.006	
50	NO DOOR #50				
51	.0359	3.247	+.082	0	VERY LOOSE
52	.0356	↓	+.085		
53	.0350	3.269	+.088		SLIGHTLY LOOSE
54	.0356	3.140	-.080		VERY LOOSE
55	.0354	3.269	-.079		SLIGHTLY LOOSE
56	.0354	3.247	-.078	↓	SLIGHTLY LOOSE
57	.0356	↓	0	+.082	
58	.0352	3.291		+.081	
59	.0353	3.269		+.083	
60	.0353			-.084	
61	.0356	↓		-.082	
62	.0354	3.204		-.078	
63	.0354	3.269		-.004	
64	.0352	3.312		-.003	
65	.0354	3.269		+.003	
66	.0350	↓		-.003	
67	.0352	3.291		-.001	
68	.0352	↓	↓	-.001	

TABLE II
(CONC.)

HATCH MASS PROPERTIES

TABLE III

SUMMARY OF GOOD TEST RUNS

SEE FIG 2

α	β	δ_{BAR}	EV_H	RUN #	NEAR HIT	HIT	PLUNGER OFFSET	
10	-5	9.7	7	31			A	
				58			C	
		12.2	3	33			A	
			5	32			A	
		16.0	3	41			A	
	0	9.7	7	30			A	
				57			C	
15	-5	9.7	5	45			A	
				50			B	
			7	71			D	
			10.1	23			A	
				72			E	
	0	8	5	99	✓ WT		N	
			7	28			A	
				54			B	
			10.1	29			A	
				65			D	
		9.7	5	26			A	
				47			B	
			7	24			A	
				53			C	
				78			F	
				81			H	
				84			J	
				87			L	
				89			M	
				95			N	
				100	✓ OMS		O	
				109	✓ OMS		Q	
				119*		✓ OMS	Q	* RUN W/.012" BOUNDARY LAYER TRIP
			10.1	27			A	
				64			D	
				73			E	
				80			G	
				82			I	
				86			K	
				88			L	

WT → WING TIP
OMS → OMS POD

FORM 40-Z REV. 12-64

TABLE III (CONCLUDED)

SEE FIG 2

α	β	QBAR	EV_H	RUN #	NEAR HIT	HIT	RUNNER OFFSET		
15	0	9.7	10.1	90			M		
				106	√ BODY WING		P		
		12.2	7	33			A		
				55			C		
			10.1	14			A		
				66			D		
		16.0	5	116	√ CMS		Q		
			7	46			A		
				56			C		
				96			N		
				110	√ CMS		Q		
			10.1	40			A		
				67			D		
	+5	9.7	5	43			A		
				52			B		
			10.1	44			A		
		16.0	5	115		√ NEAR HATCH	Q		
			7	114	√ CMS				
20	-5	9.7	7	35			A		
				59			C		
	0	9.7	7	36			A		
				60			C		

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hatch # used		Notes
6/15 1	15	0	9.1	7.0	X = 0.0 Z = 0.0	BL	1		CHECKOUT RUN (ELECTRODE ON BOTTOM)
2									" "
3									" "
4									" "
5									" " FINAL CHECKOUT RUN 6/15 P.M.
6/16 6			9.7	5.0			6		FIRST SCHEDULED TEST RUN 6/16 A.M. MISFIRE
7				5.0					MISFIRE NEXT RUN IS #9, THEN BACK TO #8
8				7.0					
9				5.0					GOOD RUN NEXT IS #8
10				10.1					
11			8.0	7.0					
12			8.0	10.1					

TABLE IV

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hitch # used		Notes
13	15	0	12.1	7.0	X=0.0 Z=0.0	BL	6		
14			12.1	10.1					
15			16.0	7.0					HATCH MOTION HORIZONTAL IN TUNNEL FOR THE HIGH QBAR, DECREASES WITH QBAR
16			16.0	10.1					
17			16.0	10.1			8		REPEAT OF 16 DUE TO CAMERA POSITIONING HATCH #8 BROKE ON ITS FIRST RUN (HIT SIDE WALL)
18		+5	9.7	5.0			6		POSITIVE BETA IS NOSE LEFT
19		+5		10.1					
20		-5		5.0					
21		-5		10.1					
22		-5		10.1					REPEAT OF #21 DUE TO CAMERA POSITIONING
23		-5		10.1					REPEAT OF #22 DUE TO CAMERA POSITIONING ONE ROTATION BY WINGTIP. HATCH HIT WINDOW APPEARS THAT HATCH DOES MOVE SLIGHTLY UPSTREAM WITH THE NEGATIVE BETA
24		0		7.0					REPEAT OF #8 DUE TO CAMERA PROBLEM

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hitch # used		Notes
25	15	0	9.7	5.0	X=0.0 Z=0.0	BL	9		Repeat of #9 Misfire
26				5.0					Repeat of #9. Closer to wingtip than EV=7.0. Seems to be large difference between EV=5 and
27				10.1					Repeat of #10 due to camera problem
28			8.0	7.0					Repeat of #11 due to camera problem
29			8.0	10.1					Repeat of #12 due to camera problem Hit window relatively quickly
6/17 30	10		9.7	7.0					First low alpha run. Closer to wing level than $\alpha = 20°$. Still large wingtip clearance
31		-5	9.7	7.0					Close to wing level again
32			12.0	5.0					Still clears wingtip easily
33			12.0	3.0					Lowered EV further to try and hit wingtip – just cleared. High horizontal trajectory. Electrode changed before
34	20		9.7	7.0					
35				7.0					Repeat of #34 due to camera position
36		0		7.0					

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hitch # used		Notes
37	15	0	12.1	7.0	X=0.0 Z=0.0	BL	9		Repeat of 13 but results did not repeat Trajectory above vertical tail + out of camera view
38			12.1						Repeat of 13 again. Trajectory much lower - repeated #13's results
39			16.0						Repeat of #15 due to camera problem (TV coverage)
40			16.0	10.1			10		Repeat of #17 due to camera problem Just missed side wall
41	10	-5	16.0	3.0					Supposed worst case for wingtip clearance for baseline condition. Trajectory near OMS pod height - still cleared wingtip easily
42	15	0	16.0	7.0					Repeat of #15 (#39 inadvertently erased) Trajectory fairly high due to high qbar
43		+5	9.7	5.0					Repeat of #18 due to camera problem
44		+5		10.1					Repeat of #19 due to camera problem
45		-5		5.0					Repeat of #20 due to camera problem
46		0			X=+.036 Z=-.042				MISFIRE FIRST $\dot{\theta} \neq 0$ RUN
47									REPEAT OF #46. Checked continuity before run - OK. Trajectory fairly high for this low qbar. Wingtip clearance appears to be less than equivalent $\dot{\theta}=0$ case
4[illegible]									Rerun of #47 for repeatab[illegible] sake MISFIRE

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hatch # used		Notes
49	15	0	9.7	5.0	X=+.076 Z=-.042	BL	10		Rerun of #48 due to misfire
50		-5							
51		+5							
52		+5							Repeat of #51 due to camera problem
6/18 53		0		7.0	X=+.026 Z=-.029				First $\dot{\theta}$=14.9, EV=7 run
54			8.0						$\dot{\theta} \neq 0$ firings appear to rotate a little further from vertical
55			12.1						
56			16.0				12		This new hatch really flew around in net on this run
57	10		9.7						Trajectory at OMS pod level even with α = 10°
58	10	-5							
59	20	-5							
60	20	0							

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_o	β_o	QBAR	EV_{H}	Plunger Offset (in)	TP	Hatch # used		Notes
61	0	0	0	7.0	x=+.026 z=-.029	BL	12		Static Fire Out of Camera range
62	0	0	0	7.0	" "				Repeat of 61 due to camera problem
63	0	0	0	10.1	x=+.018 z=-.020				Static Fire to check rotation again
64	15	0	9.7						First Run at $\dot{\theta}$=14.9, EV=10.1 Hit window on Styrofoam Protector
65			8.0						Hit Window upstream of Protector
66			12.1						Hit window further back in tunnel than #65. Lost Hatch in Tunnel
67			16.0				13		Trajectory pretty high. Hit on wide mesh portion of net
68		5	9.7						Hit side wall. High trajectory for this qbar. Hit top portion of net
69		-5							Hit side window
70		0		7.0	x=~~0.0~~ +.020 z=~~+.040~~ -.020				Trajectory moves downward noticeably with top TP. Out of camera view
71				7.0	" "				Repeat of 70 due to camera problem Trajectory not quite as low as #70
7[illegible]				10.1	x=0.0 z=+.025				Very high trajectory Out of camera view quick

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hatch # used		Notes
73	15	0	9.7	10.1	x = 0.0 z = +.025	T	13		Repeat of #72. Counterclockwise rotation Low Trajectory – Very Strange
74	↓	↓	↓	↓	↓	↓	↓		Repeat #72 again: Counterclockwise rotation, low trajectory, hit side wall
75									Repeat #72 [illegible] install that lines up well. [illegible], low.
76									Repeat #72 again. New electrode installed that lines up well. Rotates Counterclockwise, low
77									Repeat #72 again. Counterclockwise, low.
78				7.0	x = 0.0 z = -.040	B	14		
79				7.0	" "	↓	↓		
80				10.1	x = 0.0 z = -.025				
81				7.0	x = +.040 z = 0.0	F	16		First rotation is very quick, then back to old mode
82				10.1	x = +.025 z = 0.0	↓	↓		Close to side wall. Doesn't seem to rotate as quickly initially as #81 did
83				7.0	x = +.105 z = 0.0				Misfire
84				7.0	" "				Repeat of #83. Low Trajectory Spinning faster, More rotation away from vertical than

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hatch # used		Notes
85	15	0	9.7	10.1	x = +.075 z = 0.0	F	16		Misfire
86	↓	↓	↓	10.1	" "	F	↓		Repeat #85 Out of Camera Frame Low Trajectory but will not be repeated
87	↓	↓	↓	7.0	x = +.130 z = 0.0	MAX FORWARD	↓		Low Trajectory
88	↓	↓	↓	10.1	" "	MAX FORWARD	↓		Lower than #87. Broke hatch Little quicker rotation than #87
89	↓	↓	↓	7.0	x = 0.0 z = -.060	MAX BOTTOM	17		High trajectory very obvious w/TP @ bottom Actuator doesn't reach req'd value for even $\dot{\Theta}$ = 8 rad/sec
90	↓	↓	↓	10.1	↓	↓	↓		Spins more sideways than any other previous run. High trajectory
91	0	↓	0	↓	↓	↓	↓		Static Run to check rotation Tough to see with Sparks
92	↓	↓	↓	↓	↓	↓	↓		Repeat #91 with tunnel lights on to reduce spark dominance
93	↓	↓	↓	7.0	x = 0.0 z = +.110	MAX TOP	↓		Static Test, Got $\dot{\Theta}$ = 26 rad/sec from film
94	15	↓	9.7	↓	↓	↓	↓		Lowest trajectory thus far (Wing level or below) Holds spin on a horizontal axis Left Camera Side View
95	↓	↓	9.7	↓	↓	↓	↓		Repeat #94 for Camera view Below wing. Left side view again
	↓	↓	16.0	↓	↓	↓	↓		Trying to hit wing with high gear Trajectory just above wing, still clears tip

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hatch # used		Notes
97	15	0	8.0	3.0	X=0.0 Z=+.110	MAK TOP	17		Trying to hit wing with low qbar, low EV per Mitch (Misfire)
98				3.0			18		Repeat 97 Misfire
99				5.0					Repeat 97. Fairly close to wingtip Went to 5.0 ft/s EV to get hatch out
100			9.7	7.0	X=-.040 Z=0.0	A			Electrode moved to side. Trajectory very close to OMS pod. Went over wing. Rotated clockwise. Out of camera view
101			9.7						Repeat 100 Rotated Counterclockwise
102	0		0						Rotation Check Looks pretty close to predicted
6/22 103	15		9.7						Clockwise Rotation. Over wing close to body. Cleared wingtip
104				10.1	X=-.025 Z=0.0		20		Misfire
105									Repeat #104 Misfire (No spark)
106									Close to body, barely over wing (Repeat #104) Out of camera frame
107									Repeat #104
108									Repeat #104 again. Counterclockwise rotation. Cleared wingtip. High trajectory

TABLE III (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in.)	TP	Hatch # used		Notes
109	15	0	9.7	7.0	x=-.115 z=0.0	MAX AFT	20		Clockwise Rotation. Very close inboard close to OMS pod
110		0	16.0						Clockwise Rotation. Very close to OMS po[d] (saw shadow)
111		-5							Started clockwise + went to counter flat for quite a while. High as vertical tail top. Very inboard
112		-5					30		Repeat of 111 - Clarence didn't like hatch fit. Similar trajectory to 111 but higher
113		+5							Misfire
114		+5							Repeat #113. Just above OMS pod. Rode body all the way back. Clockwise rotation
115		+5		5.0			33		Hit twice near the hatch. Hit hatch [on] 1st bounce. 2nd bounce gave it counter clockwise rotation - then cleared easily
116		0		5.0					Over OMS pod. Started clockwise [along] fuselage near hatch, went to counter clockwise
117	0		0	7.0					Static Run Estimated $\dot{\Theta}_H$ at 31 rad/s from film
118	0		0	5.0					Static Run Estimated $\dot{\Theta}_H$ at 21 rad/s from film
119	15		9.7	7.0					Run with boundary layer trip. Trajectory between OMS pod and wing. May have ticked OMS pod (.012" trip)
120	0		0	7.0	x=+.105 z=0.0	F			Static Run Estimated $\dot{\Theta}_H$ at 31 rad/sec [illegible] film

TABLE IV (CONTINUED)

ACTUAL RUNS PERFORMED

Run #	α_0	β_0	QBAR	EV_H	Plunger Offset (in)	TP	Hitch # used		Notes
121	0	0	0	10.1	x = +.105 z = 0.0	F	33		Static Run $\dot{\theta}_H$ at 52 rad/s from film
122	0	0	0	10.1	x = +.075 z = 0.0	F	33		Static Run $\dot{\theta}_H$ at 31 rad/s from film

TABLE IV (CONCLUDED)

FIGURE 1a
MODEL INSTALLATION SHOWING STING/STRUT ASSY.

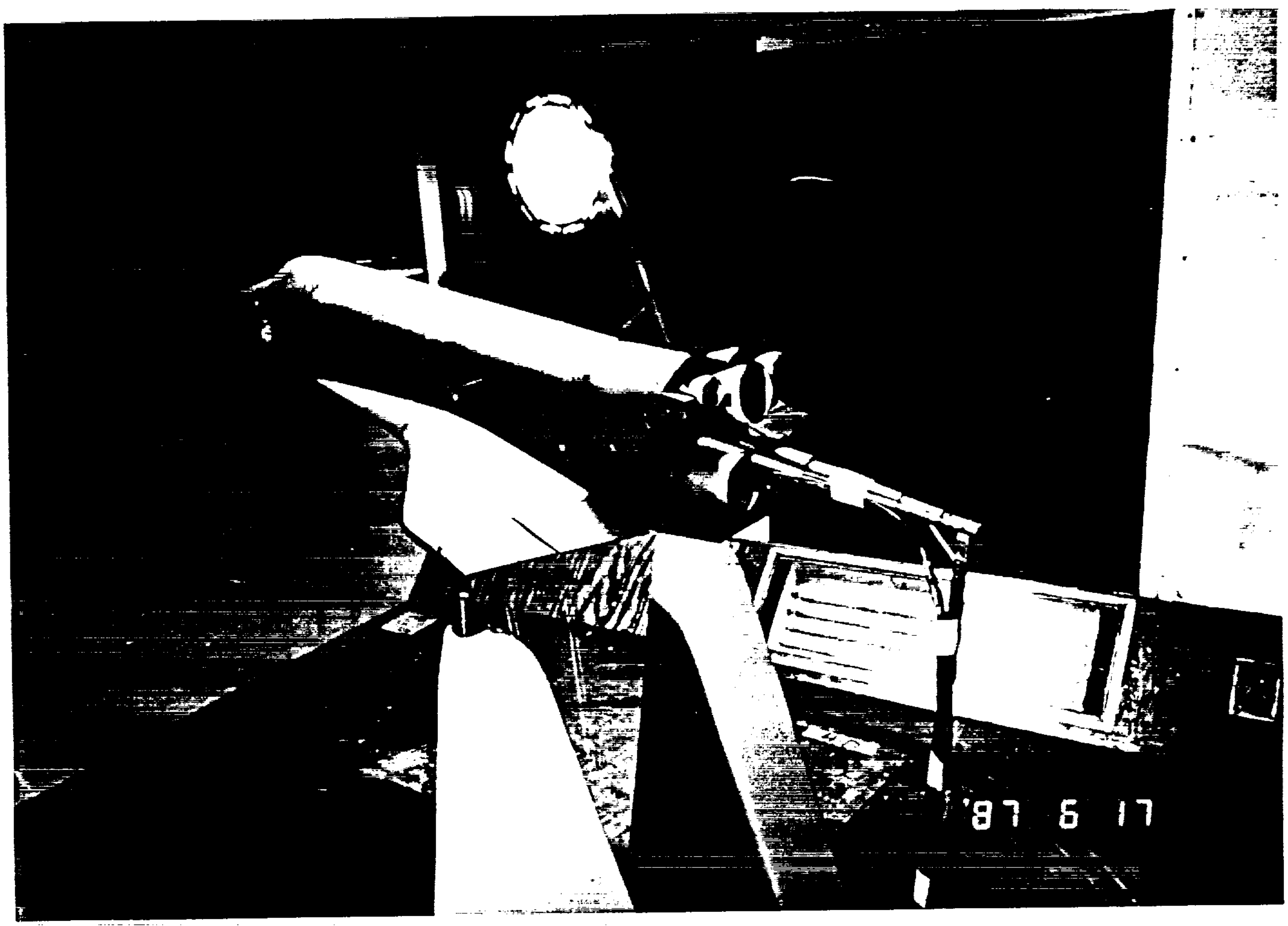


FIGURE 1b
MODEL SHOWING "CAN" AND PLUNGER ASSY.

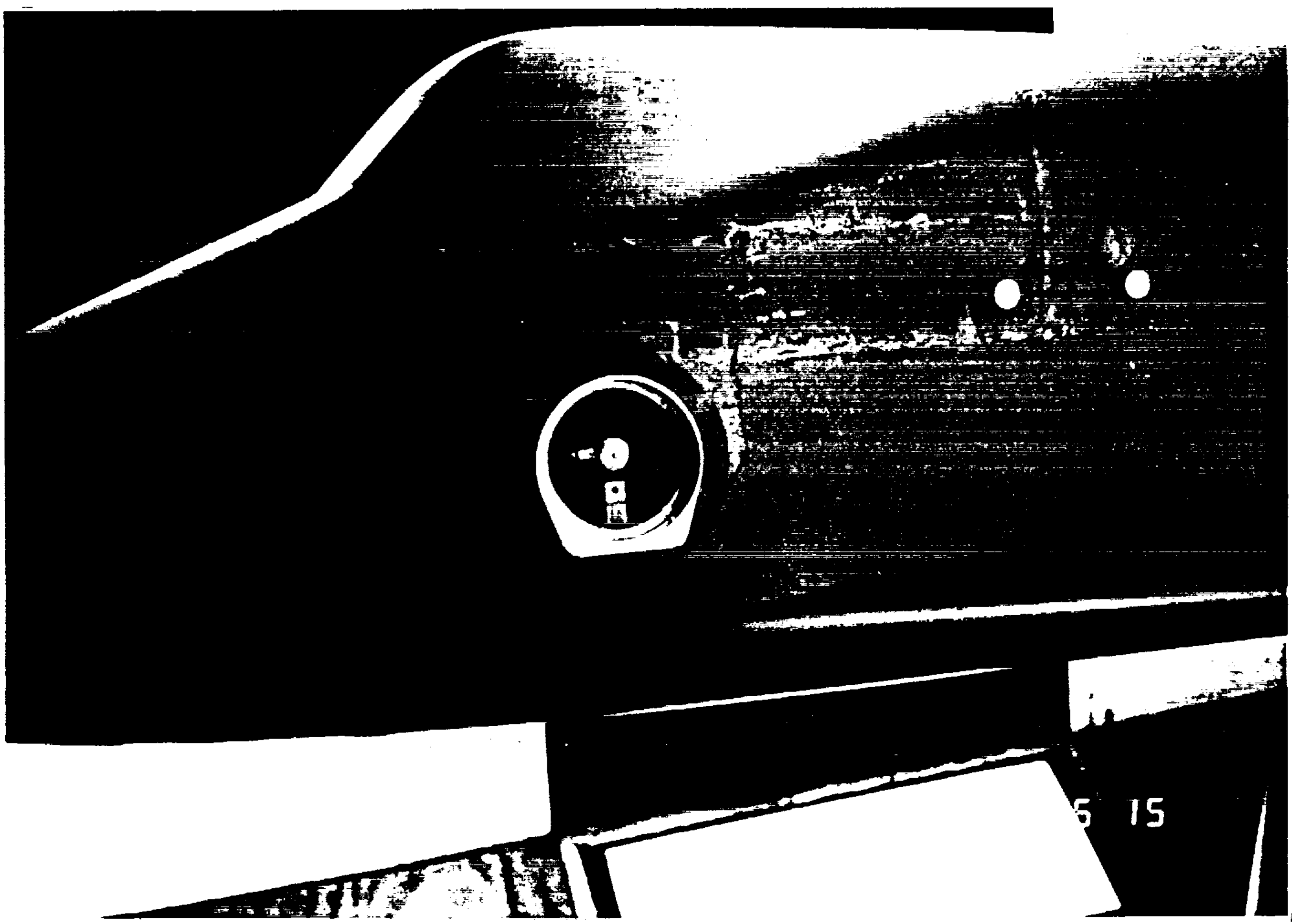


FIGURE 1c

MODEL INSTALLATION SHOWING STRUT LOCATIONS AND TURNTABLE - FRONT VIEW

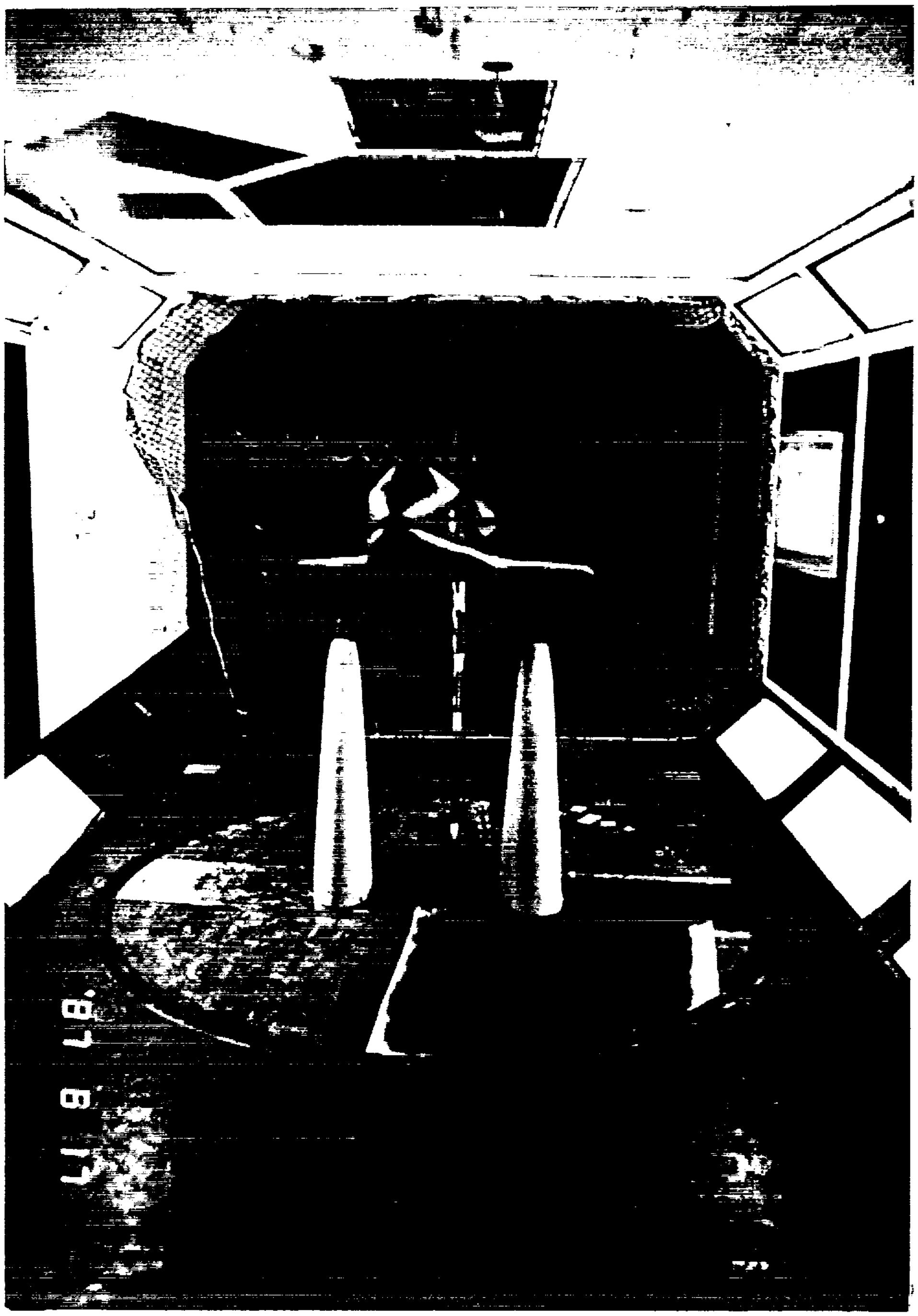
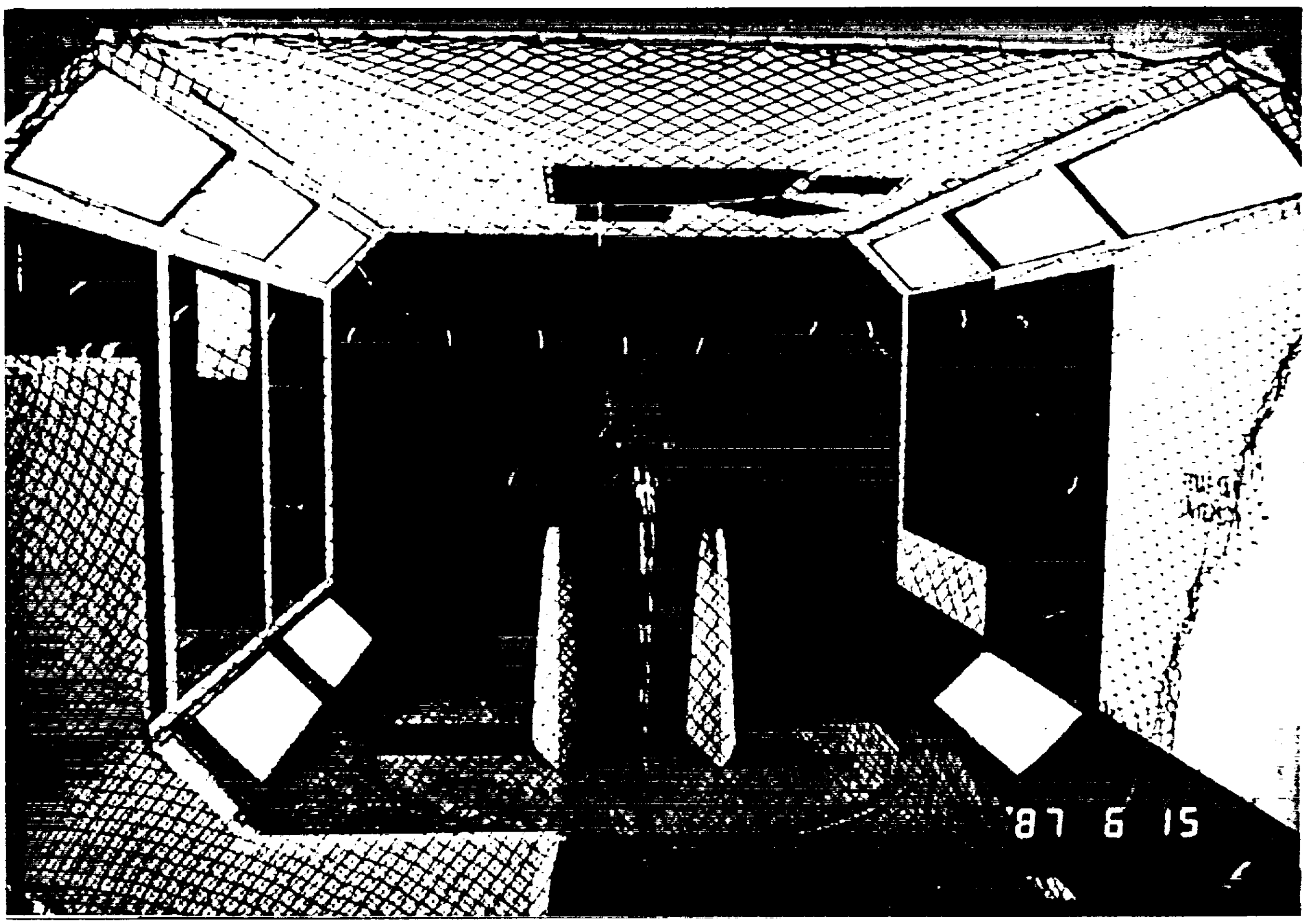


FIGURE 1d

MODEL INSTALLATION SHOWING STRUT LOCATIONS
AND TURNTABLE - REAR VIEW



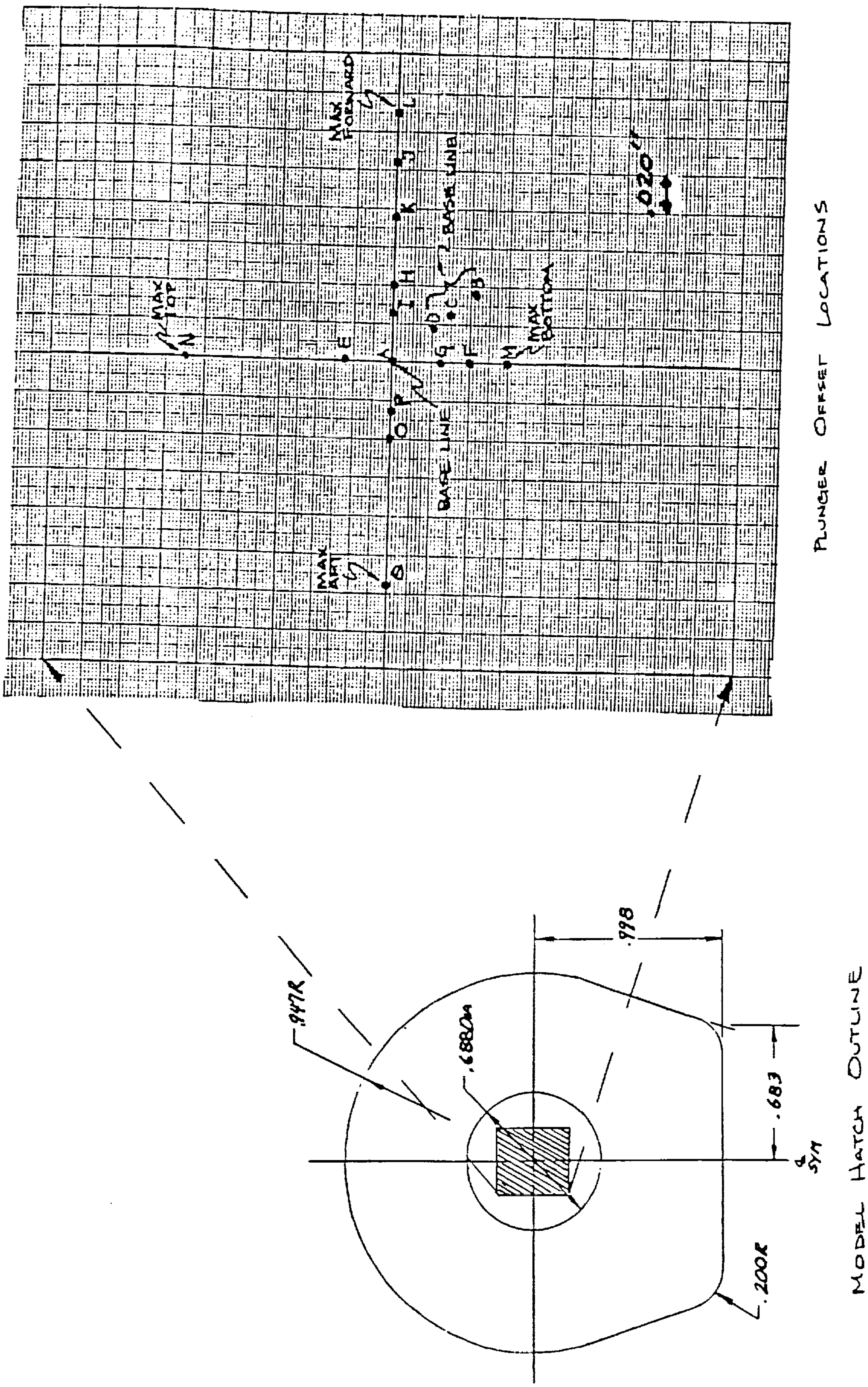
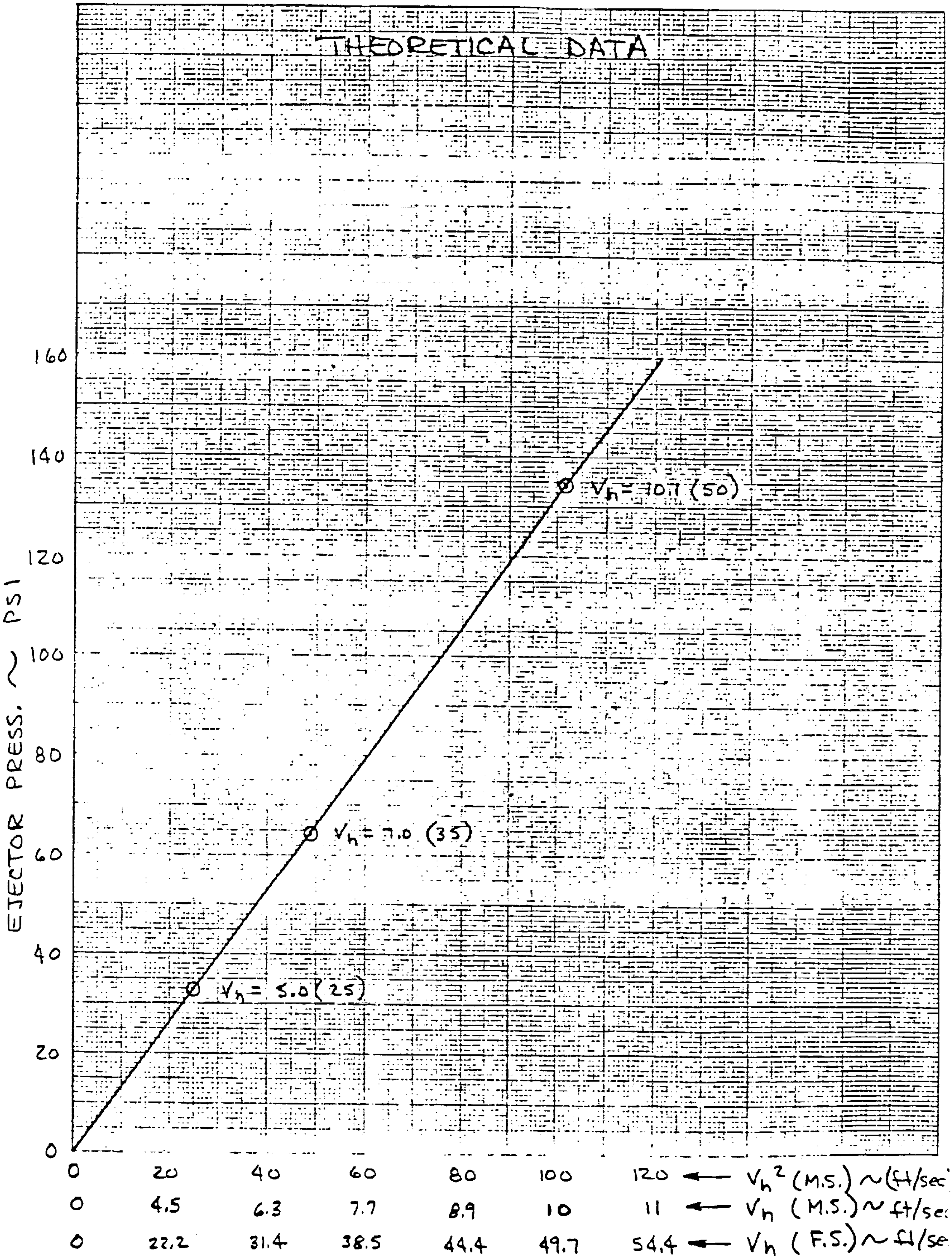


FIGURE 2 PLUNGER OFFSET LOCATIONS



THEORETICAL DATA
EJECTOR PRESS. ~ PSI
0
20
40
60
80
100
120
140
160
$V_h = 5.0$ (25)
$V_h = 7.0$ (35)
$V_h = 10.7$ (50)
0 20 40 60 80 100 120 ← V_h^2 (M.S.) ~ (ft/sec
0 4.5 6.3 7.7 8.9 10 11 ← V_h (M.S.) ~ ft/se
0 22.2 31.4 38.5 44.4 49.7 54.4 ← V_h (F.S.) ~ ft/se

FIGURE 3a

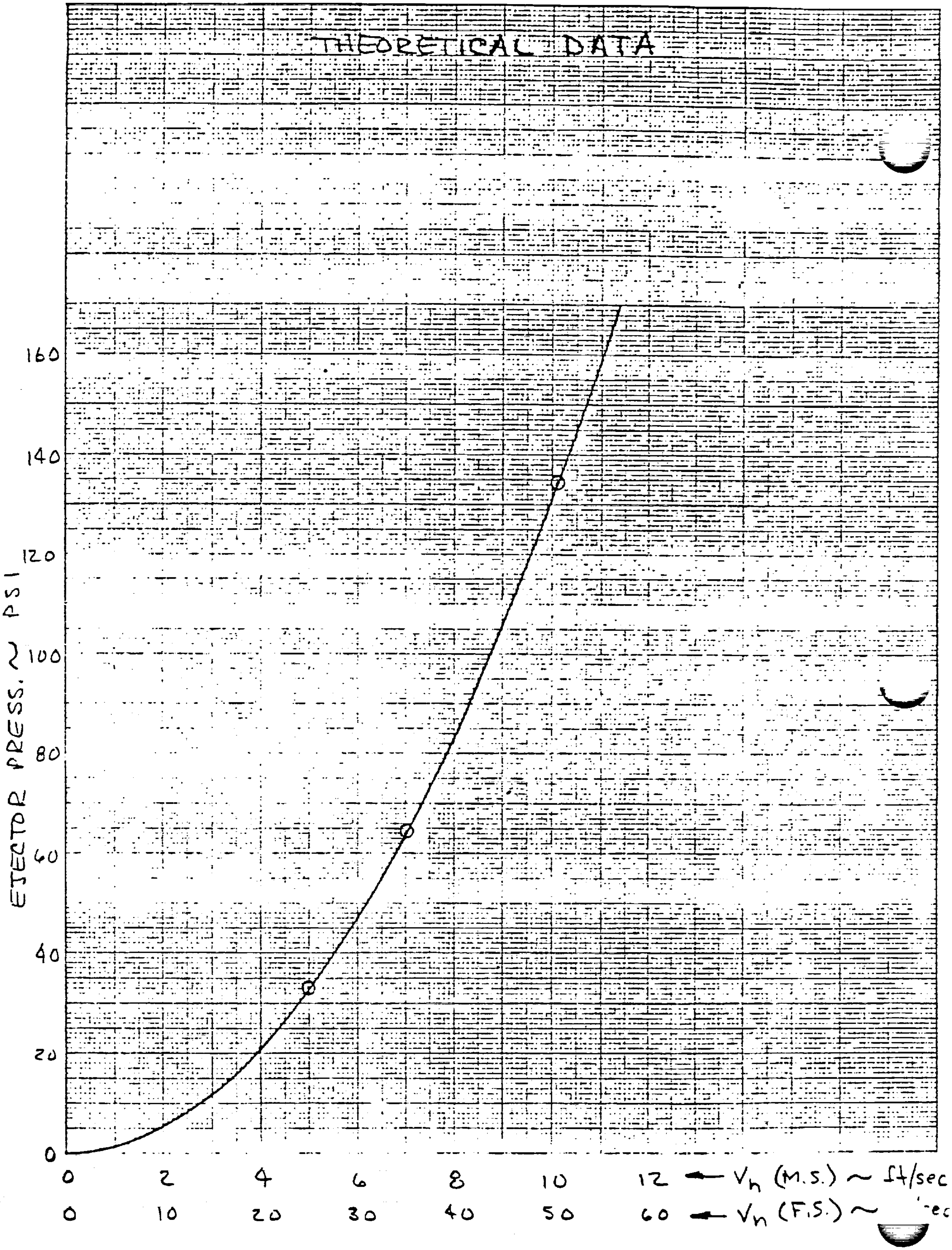

THEORETICAL DATA
EJECTOR PRESS. ~ PSI
0
20
40
60
80
100
120
140
160
0 2 4 6 8 10 12 ← Vh (M.S.) ~ ft/sec
0 10 20 30 40 50 60 ← Vh (F.S.) ~

FIGURE 3b

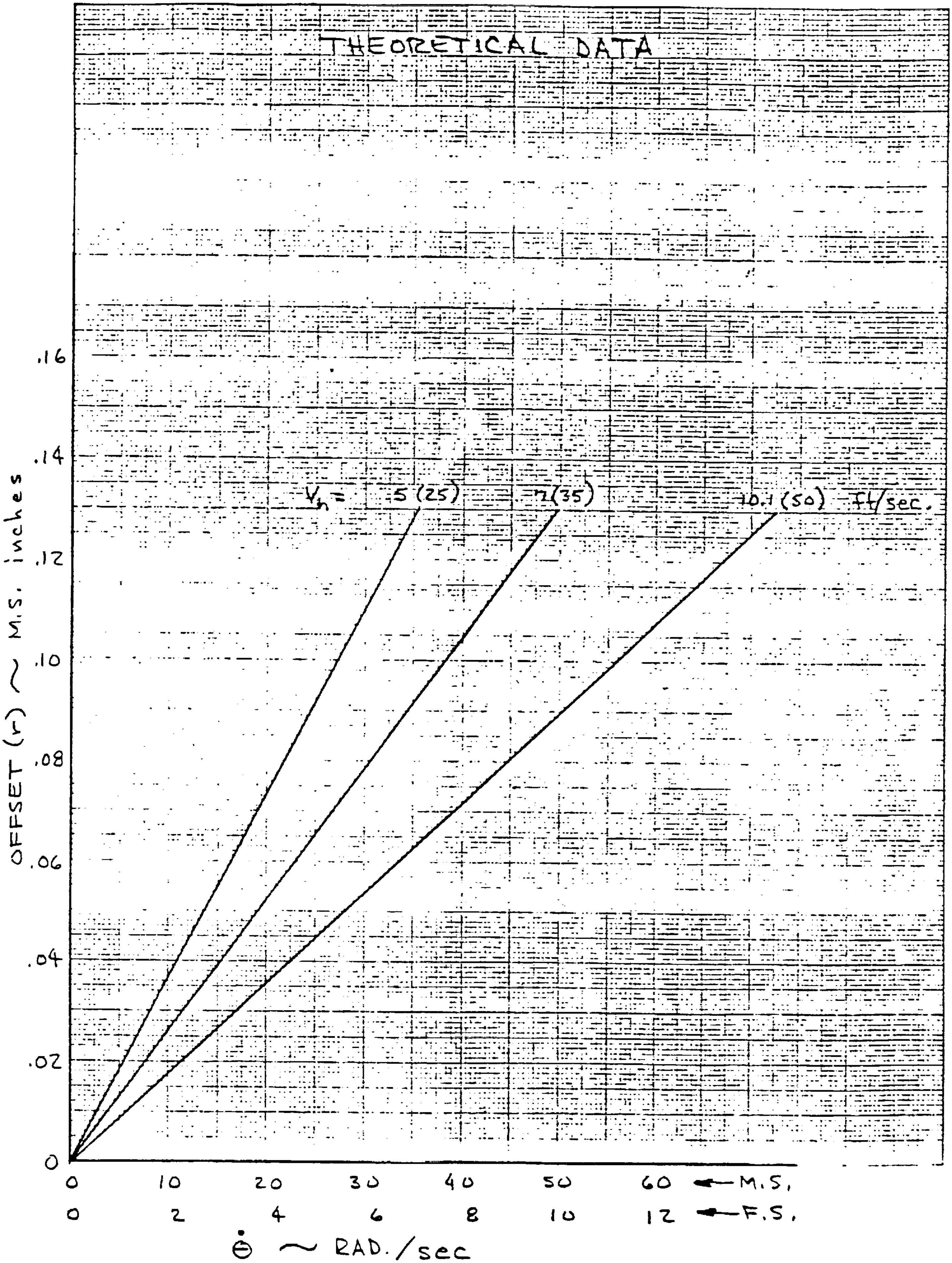

THEORETICAL DATA
V_h = 5 (25)
7 (35)
10.1 (50) ft/sec.
.16
.14
.12
.10
.08
.06
.04
.02
0
OFFSET (r) ~ M.S. inches
0 10 20 30 40 50 60 ← M.S.
0 2 4 6 8 10 12 ← F.S.
$\dot{\Theta}$ ~ RAD./sec

FIGURE 3c