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SANDIA SYSTEMATIC DECLASSIFICATION REVIEW

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BIMONTHLY PROGRESS REPORT OF LLD PARACHUTE RESEARCH DROP TEST PROGRAM (September-October 1956)

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T. Blanchard, Jr. - 5141

ABSTRACT

Preliminary results of the five parachute research drop tests for the period September-October 1956 are presented. Results of the thirty-three drop tests covering the period October 1955 through August 1956 are summarized in the Appendix.

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Case No. 669.02 March 15, 1957

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BIMONTHLY PROGRESS REPORT OF LLD PARACHUTE
RESEARCH DROP TEST PROGRAM
(September-October 1956)

INTRODUCTION

The three-fold purpose of the parachute research program is to prove the feasibility of using a parachute to lay a tactical weapon on the ground, to provide aircraft escape time for airburst tactical weapons, and to replace fins for weapon stabilization. Parachute sizes of 16-, 20-, 24-, 28-, and 40-foot diameter have been and are being tested to show feasibility for the laydown and the retarded (escape time) weapon system concepts. Development-type tests are being conducted for Organization 1200 for the proposed retarded version of the TX-28. Tests of small diameter parachutes (1.5 to 5 feet in diameter) will be conducted to investigate methods of parachute stabilization of finless bombs.

The purpose of this report is to present preliminary results of the drop tests conducted during the period September-October 1956. A brief summary of each test conducted during the period October 1955 through August 1956 is presented in Appendix B.

GENERAL

During September and October 1956, there were five tests made with parachutes in support of the laydown program. Two of these were for the parachute research program and the other three tests were for the retarded version of the TX-28 (Code 28 Program). The test vehicle used for these tests was designed for use in the parachute program. The vehicle is four finned, and has the over-all dimensions of 24-inch diameter and 178-inch length. The length does not include a 40-inch-long recovery spike. The test vehicle is shown in Figure 1.

Below is a short discussion of each of the five tests made during the September-October 1956 period.

RP-101 Test Results

Drop Date	September 13, 1956
Vehicle Weight	2323 pounds
Parachute Diameter	24-foot Ribbon

[redacted]

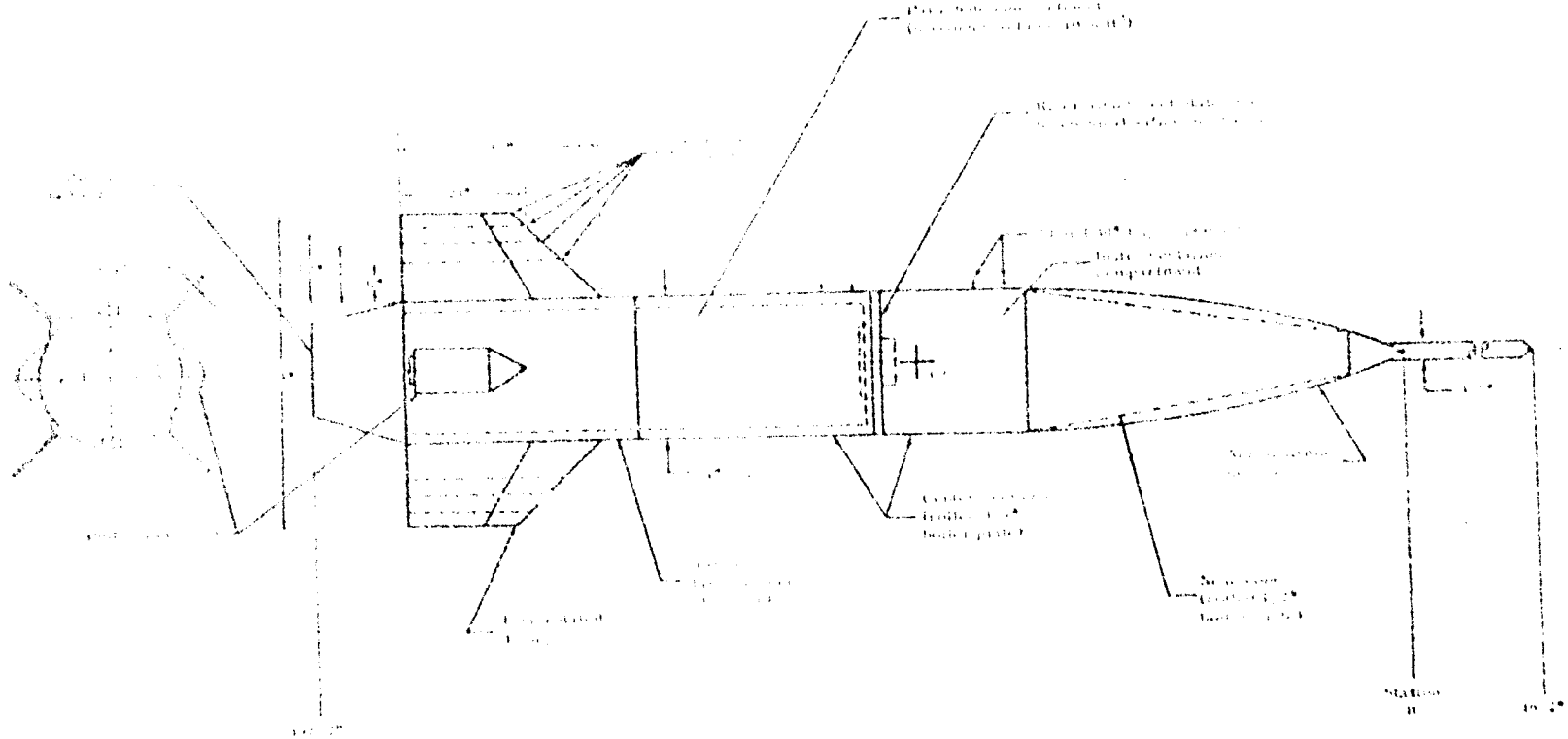

Figure 1 -- Sketch of Parachute Test Vehicle

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Pilot Chute Diameter	2.5-foot Guide Surface
Deployment Mach Number	0.77
Deployment Altitude	366 feet
Time of Fall	13.60 seconds
Terminal Velocity	102 ft/sec
Range	2710 feet

The first drop of Phase A of the Code 28 program was a successful drop with the exception of moderate damage to one panel of the chute. Even with the damage, the parachute inflated to its full second-stage diameter and as can be seen in Figure 2, the vehicle was recovered with no damage done. The failure on the canopy was probably caused by, as in several previous drops, the snatch force exerted upon the chute to accelerate it up to the speed of the vehicle. The deployment system itself worked very well with no damage to any of its components. Figure 3 is a photograph of the parachute used for RP-101, and shows the damaged area as well as the general construction of the canopy.

RP-102 Test Results

Drop Date	September 24, 1956
Vehicle Weight	2483 pounds
Parachute Diameter	24-foot Ribbon
Pilot Chute Diameter	2.5-foot Guide Surface
Deployment Mach Number	0.76
Deployment Altitude	910 feet
Time of Fall	14.23 seconds
Terminal Velocity	96 ft/sec
Range	2410 feet

This was the first drop to use a deployment bag with canopy ties as well as suspension line ties. The purpose of these ties was to accelerate the mass of the chute up to the velocity of the vehicle a little at a time, thus reducing the differential velocity between the chute and the vehicle and consequently reducing the snatch load. The principle of this operation is that a certain amount of energy is needed to break each set of ties as the amount of suspension line between the ties and the vehicle becomes tight. This energy tends to slow the parachute down in its rearward flight from the aft end of the vehicle. The same amount of energy is required to bring the parachute up to the velocity of the vehicle in the old and the new deployment systems, but in the new it exists as several smaller loads rather than one large snatch load. Although the system worked very well for this drop, the telemetry did not and the snatch load could not be measured. There was no damage to the parachute though, and the test was considered successful, as seen in Figure 4.

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Figure 2 -- RP-101

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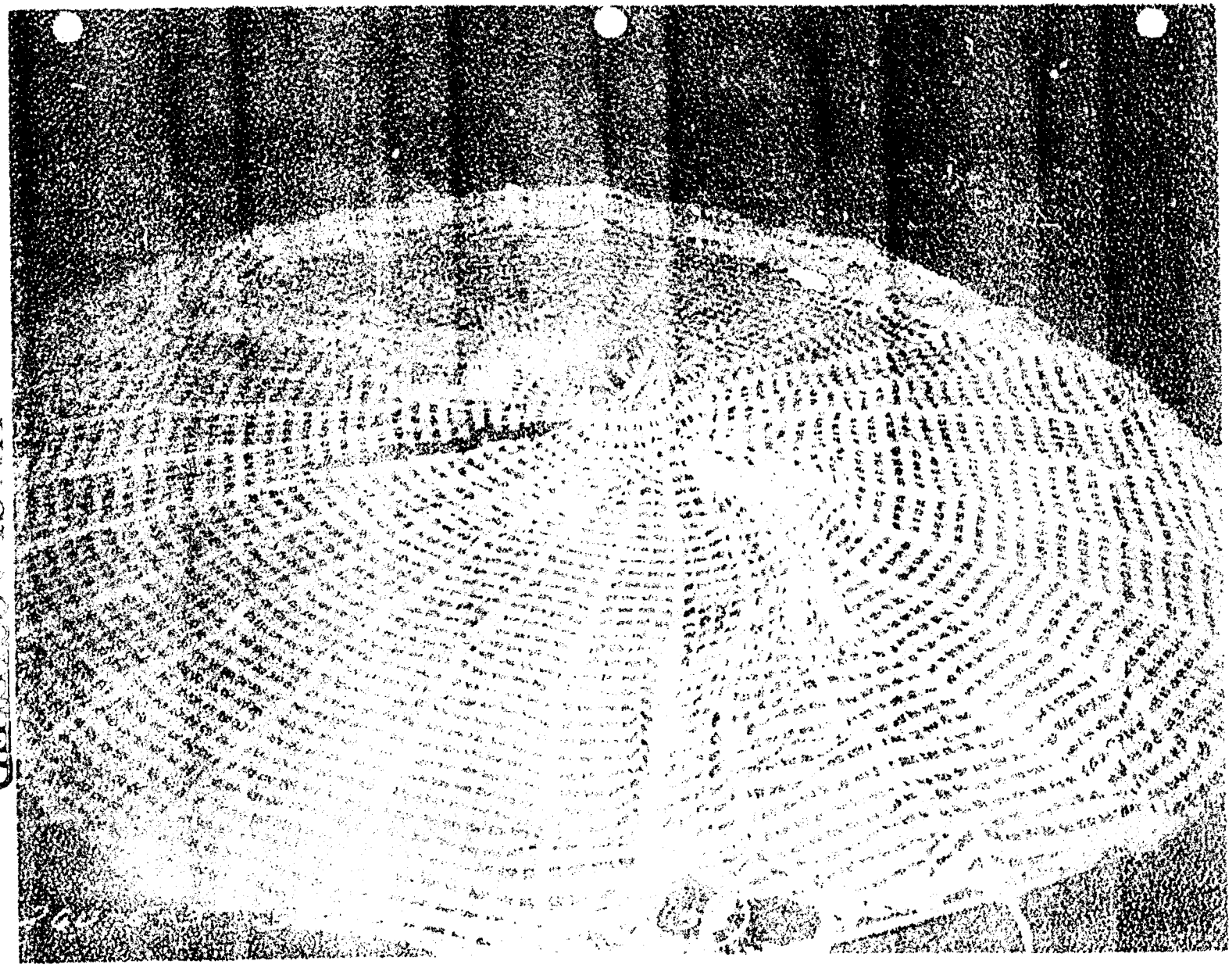

Figure 3 -- Photograph of the RP-101 Canopy Showing Damaged Area

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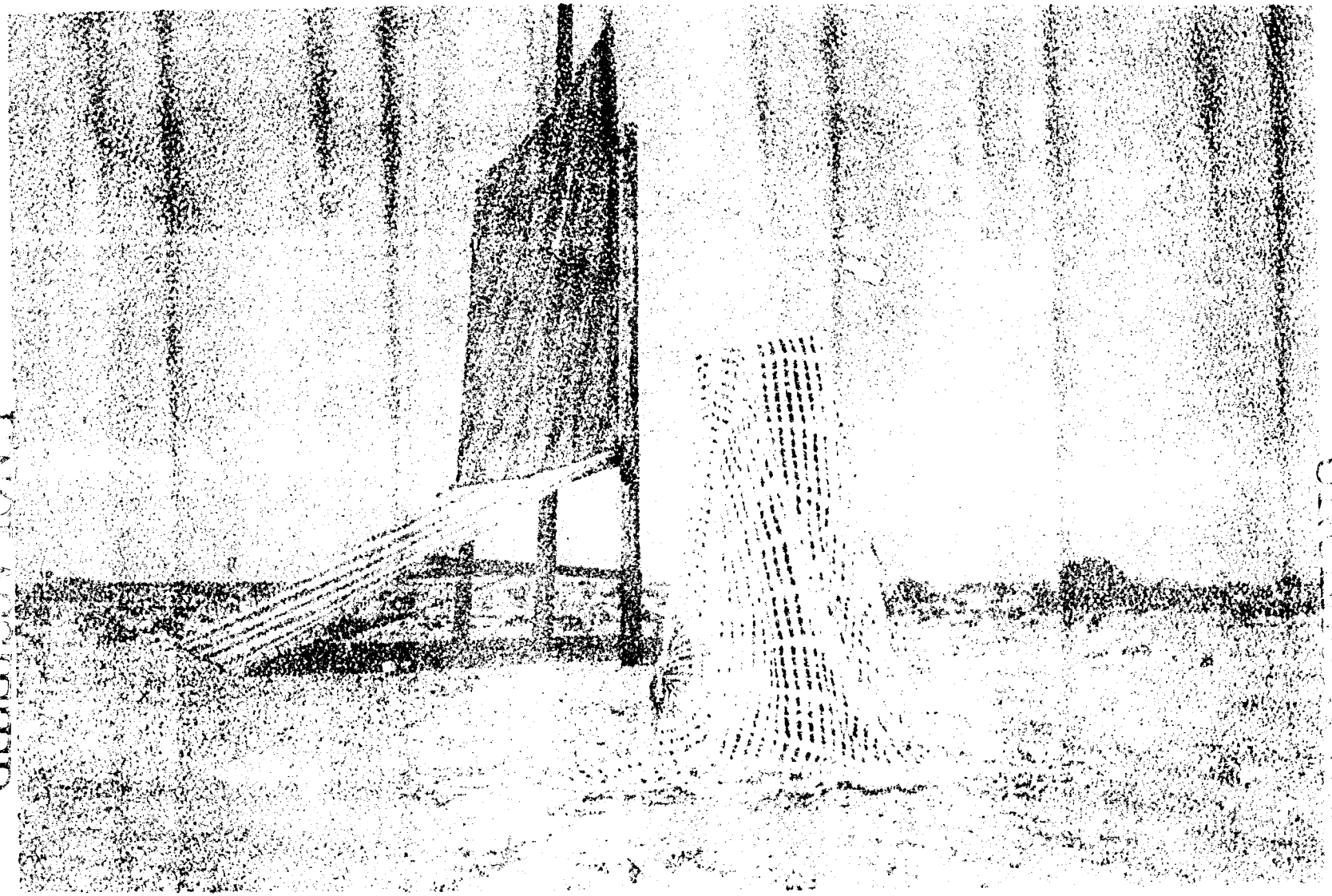

Figure 4 -- RP-102 (and Target)

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RP-29 Test Results

Drop Date	September 28, 1956
Vehicle Weight	2615 pounds
Parachute Diameter	16-foot Ribbon
Pilot Chute Diameter	2.0-foot Guide Surface
Deployment Mach Number	1.00
Deployment Altitude	5300 feet
Time of Fall	72.15 seconds
Terminal Velocity	140 ft/sec
Range	26,459 feet

RP-29 was an exact replica of RP-28 with the exception that a 2.0-foot pilot chute was used instead of a 3.0-foot pilot chute. From the obvious factors causing the line stretch loads, it appeared that ΔV (the differential velocity between the parachute mass and the test vehicle) would be the most logical to try to reduce. A method other than the one tried for RP-102 would be to reduce the pilot chute size, and thus have less drag area (C_DS) to pull the main canopy from the vehicle. This reduced C_DS should in turn reduce the ΔV, and finally reduce the amount of energy required to bring the parachute up to the speed of the vehicle. After evaluating 35-mm film records of the two drops, RP-28 and RP-29, it was seen that the 2.0-foot pilot chute of the RP-29 did reduce the ΔV. Investigation of the telemetry records showed that the snatch load (line stretch load) on the vehicle also was reduced. There was no damage to the main parachute of this test and since the test conditions of the two tests were identical, it was surmised that the reduction of the size of the pilot chute was a big step in the right direction to reducing the snatch loads. The parachute inflated well in both stages and the recovered vehicle is seen in Figure 5.

RP-30 Test Results

Drop Date	October 9, 1956
Vehicle Weight	2565 pounds
Parachute Diameter	20-foot Ribbon
Pilot Chute Diameter	2.0-foot Guide Surface
Deployment Mach Number	0.85
Deployment Altitude	4300 feet
Time of Fall	58.18 seconds
Terminal Velocity	119 ft/sec
Range	25,137 feet

This test was the first drop from 25,000 feet. The purpose was to obtain a dynamic pressure condition at deployment somewhere between the Mach 0.85

releases at 1000 feet altitude and the Mach 1.01 delayed drops from 40,000 feet. Although the Mach number was lower than 1.01, the dynamic pressure was not a great deal less than the dynamic pressure obtained on previous M = 1.01 drops. The test was successful with the deployment and parachute systems performing their duties very well. The vehicle made a good landing and was recovered in very good condition. Figure 6 is a photograph of the recovered RP-38 test vehicle.

RP-102 Test Results

Drop Date	October 23, 1956
Vehicle Weight	2410 pounds
Parachute Diameter	24-foot Ribbon
Pilot Chute Diameter	2.0-foot Guide Surface
Deployment Mach Number	0.81
Deployment Altitude	998 feet
Time of Fall	14.27 seconds
Terminal Velocity	101 ft/sec
Range	2791 feet

This was the third test of the Code 28 program. The test as a whole was successful except for two points: (1) There was excessive burning of the lining of the deployment bag, and the bag flaps, and (2) the vehicle toppled at impact. With regard to (1), even though there was burning of the bag, the canopy showed no damage either from burning or tearing. The bag was lined with nylon. The second point (2) was probably caused by high ground winds (21 fps). These caused the vehicle to topple with such rotational velocity that the vehicle bounced on its tail section, then [illegible] back to the [illegible] (Figure 7). The nose section of the vehicle was damaged beyond repair.

CONCLUDING REMARKS

Although there were fewer tests during this 2-month period than during some previous periods, nearly all the tests were "firsts" in a prospective field. RP-101 was the first drop of the first phase of parachute drops in support of the retarded TX-28 program. RP-102, the second test of this phase was the first test to use the new deployment with canopy sima. RP-99 was a repeat of a previous test, except that a smaller pilot chute was used to try to reduce the snatch force. The test was quite successful. RP-98 was the first drop from 25,000 feet altitude. The loads on the canopy during deployment were very close to the loads of similar drops from 40,000 feet altitude. RP-103 was another test to help prove the feasibility of the 24-foot-diameter canopy for the TX-28 program.

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Figure 6 -- KI-28

[redacted]

[redacted] [redacted]

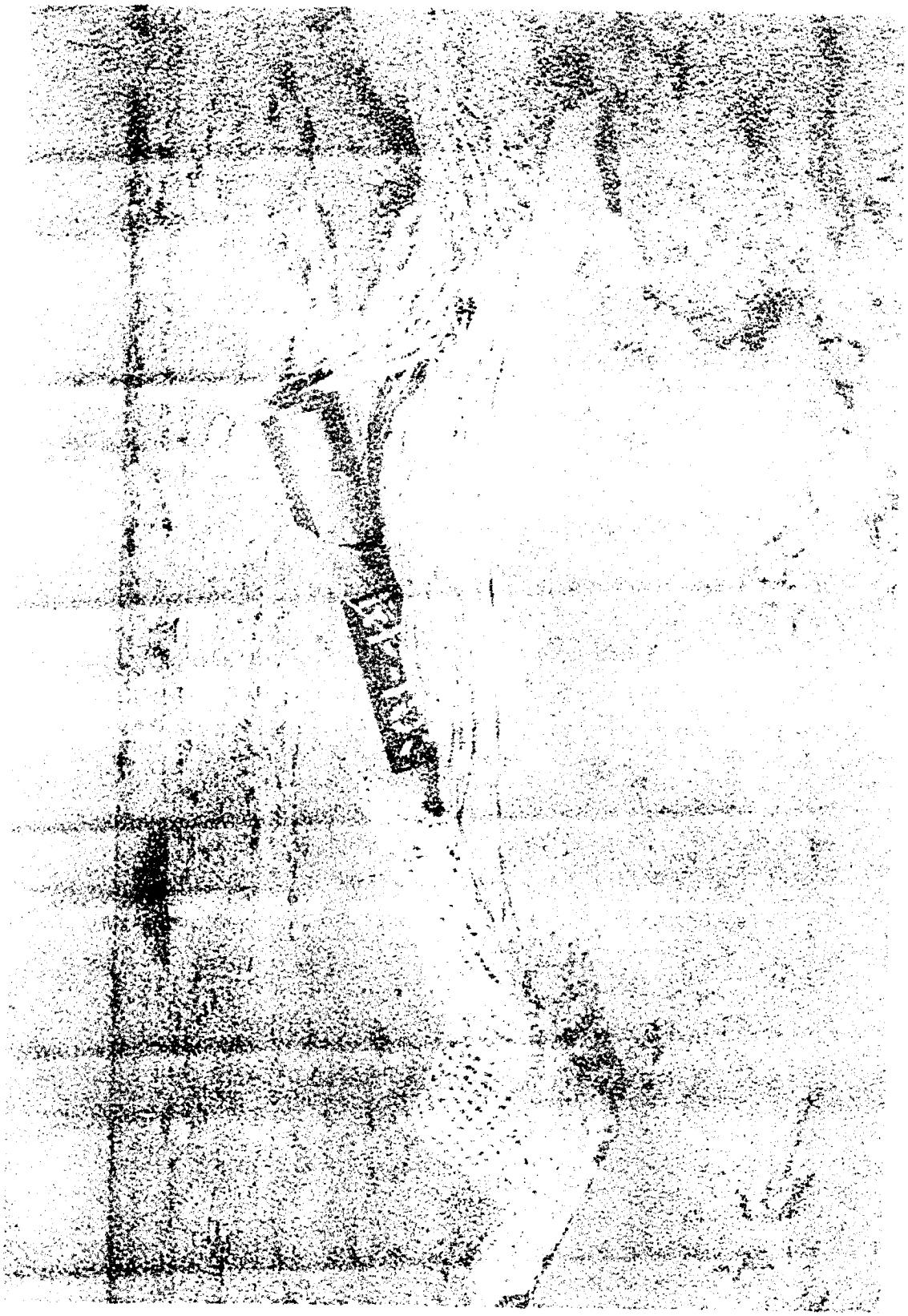

Figure 7 -- RP-103

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Most of the tests to date have been released from an F7U at speeds up to Mach = 0.86. Since these speeds are about as high as one can currently obtain from low-altitude releases and nearly all the parachutes to be tested have been tested at these speeds, the future will bring a larger percentage of high-altitude delayed-time parachute tests.

T. BLANCHARD, JR. - 5141

Case No. 669.02
March 19, 1957

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APPENDICES

A. SUMMARY SHEET

The summary sheet is a resume of the whole parachute program giving the most pertinent facts derived from each drop. Besides the geometric dimensions of the parachute system, the deployment conditions, impact velocities, ground range, actuation times and loads imparted on the vehicle by the chute are given in the sheet. The parachute dimensions include the constructed diameter, geometric porosity (area of space to area of cloth), reefing line length, and the pilot chute diameter. The deployment conditions, Mach number and altitude, as well as times, ground range and impact velocity give the physical characteristics of the trajectory. The three major loads, snatch load and first- and second-stage opening shocks, are tabulated to show the shock loads felt by the vehicle.

B. PREVIOUS TESTS

Since this is the first progress report of parachute research at Sandia Corporation, it was thought wise to present a short discussion of all the tests made to date, so the reader could determine the progress being made both in the deployment system and the test parameters of the canopies.

C. DATA EVALUATED FOR ALL TESTS

Listed in Appendix C are all the various types of data that are received or evaluated for each test. These data include all telemetered data, photographic data, and meteorological data, from which all the other information is derived.

D. TYPICAL EXAMPLES OF DATA EVALUATED

Presented in this appendix are six (6) plots showing typical data evaluated for each test. They are:

(1) Velocity and Mach (Figure 8) - shows the variation of velocity, Mach and altitude with time.

(2) Range and Drift (Figure 9) - a plot of range and drift versus altitude with time marks every second of time of fall.

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(3) Attitude Angle versus Time of Fall (Figure 10).

(4) Longitudinal Accelerations versus Time (Figure 11) - a plot showing the longitudinal accelerations recorded in the vehicle. These forces are caused by the various actions of the parachute. The first spike is caused by the snatch load, the second and third by the first-stage opening shock, and the last by the second-stage opening shock (parachute disreefing).

(5) Drag Area and Dynamic Pressure versus Time (Figure 12) - the values of C_DS being computed from the equation

$$C_DS = \frac{\text{(Vehicle weight, lbs) (longitudinal acceleration, g's)}}{\text{(Dynamic Pressure, lb/ft}^2\text{)}}$$

(6) Roll, Pitch and Yaw versus Time (Figure 13) - plots of the rate of motion in the three planes. The planes are fixed with respect to the test vehicle.

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APPENDIX A

PARACHUTE RESEARCH DROP TEST

TEST DATE	TEST NO.	VEHICLE WT (lbs)	PARACHUTE SYSTEM DIAMETER (ft)	PARACHUTE SYSTEM GEOMETRIC POROSITY (percent)	PARACHUTE SYSTEM REEFING LINE LENGTH (ft)	PARACHUTE SYSTEM PILOT CHUTE DIAMETER (ft)	PARACHUTE DEPLOYMENT CONDITIONS MACH NO.	PARACHUTE DEPLOYMENT CONDITIONS ALTITUDE, (MSL)(ft)	IMPACT VELOCITY ft/sec	GR RA (
'55 OCT	RP-1	2470	20	23.4	11.5	5	0.59	745	681	4,
NOV	RP-3	1750	20	23.4	11.5	5	0.60	6400	105	
DEC	RP-5	1736	16	20.0	11.5	5	0.65	6400	120	
	RP-2	2496	20	23.4	11.5	5	0.60	1441	118	3,
	RP-6	1757	16	20.0	11.5	5	0.69	1740	112	3,
'56 JAN	RP-7	1742	20	23.4	13	5	0.74	1260	97	4,
	RP-4	2528	16	20.0	13	5	0.81	1450	137	4,
	RP-8	2570	16	20.0	13	5	.83	1450	140	4
	RP-9	2380	16	20.0	13	5	0.86	8700	141	15
FEB	RP-10	2377	16	20.0	13	5	0.94	8650	142	2[illegible]
	RP-12	2492	24	24.4	24	5	0.94	8700	126	1[illegible]
MAR	RP-19	2502	16	20.0	NONE	[illegible]	0.7[illegible]	1380	13[illegible]	[illegible]
	RP-11	2577	24	24.4	24	3	0.80	1440	1[illegible]	[illegible]
	RP-20	2528	16	20.0	16	3	0.80	1610	138	
	RP-13	2568	20	23.4	19	3	0.80	1500	120	

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X A

P TEST DATA SUMMARY

	GROUND RANGE (ft)	*TIME, SECONDS: RELEASE TO T_2	*TIME, SECONDS: T_2 TO PARACHUTE INFLATION	*TIME, SECONDS: TIME OF FALL	PARACHUTE DRAG (LBS): SNATCH LOAD	PARACHUTE DRAG (LBS): 1st STAGE OPENING SHOCK	PARACHUTE DRAG (LBS): 2nd STAGE OPENING SHOCK	NOTES ON PERFORMANCE
	4,590	2.03	--	6.9	--	--	--	100-pound static line failed, vehicle total loss.
	--	2.03	--	16.3	--	--	--	Canopy instability of reefed chute
	--	2.03	--	17.5	--	--	--	Canopy instability of reefed chute
	3,834	2.03	0.59	16.9	10,900	[illegible],700	20,000	Canopy instability of reefed chute
	3,662	2.08	0.61	20.8	--	--	--	Canopy instability of reefed chute
	4,084	2.14	0.93	16.6	--	--	--	Good except deployment bag parted from canopy in vehicle
	4,756	2.03	0.77	16.2	[illegible]	36,600	30,700	Good except pilot chute failed
	[illegible]	1.39	0.64	16.1	[illegible]	44,500	24,900	Good except pilot chute parted from bag in vehicle
	18,2[illegible]	24.[illegible]	[illegible]	48.4	27,[illegible]	37,500	41,200	Good except pilot chute parted from bag in vehicle
	20,360	30.59	0.52	[illegible]	--	--	--	Good except pilot chute failed
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	72,500	[illegible]	Good except pilot chute parted from bag in vehicle
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NONE	Good
	2,4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11,000	Good
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Good
	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Good

[redacted]

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APPENDIX A (Cont'd)

TEST DATE	TEST NO.	VEHICLE WT (lbs)	PARACHUTE SYSTEM: DIAMETER (ft)	PARACHUTE SYSTEM: GEOMETRIC POROSITY (percent)	PARACHUTE SYSTEM: REEFING LINE LENGTH (ft)	PARACHUTE SYSTEM: PILOT CHUTE DIAMETER (ft)	PARACHUTE DEPLOYMENT CONDITIONS: MACH NO.	PARACHUTE DEPLOYMENT CONDITIONS: ALTITUDE, (MSL)(ft)	IMPACT VELOCITY ft/sec	GROUND RANGE (ft)	RELEASE TO [illegible]
APR	RP-14	2238	20	23.9	19	3	0.61	1515	112	3,[illegible]32	1.
	RP-22	2198	16	20.0	NONE	3	0.84	2003	145	2,983	1.
	RP-21	2423	16	20.0	16	3	0.[illegible]	8150	128	28,751	42.
	RP-24	2243	24	24.4	24	2.5	0.79	[illegible]	[illegible]	2,[illegible]	1.
	RP-25	2238	24	24.4	24	2.5	0.[illegible]	912	[illegible]	2,[illegible]	1.
MAY	RP-27	2388	40	21.[illegible]	[illegible]	3	0.58	1085	[illegible]	1,[illegible]42	0.
	RP-15	2293	24	21.7	19	3	0.74	600	213	3,600	[illegible]
	RP-16	2338	28	21.4	23	3	0.75	670	7[illegible]	2,[illegible]	1.
	RP-26	2568	24	24.[illegible]	19	3	0.[illegible]9	4900	235	26,[illegible]42	41.
JUNE	RP-17	2203	20	26.4	16	3	0.72	945	115	2,671	0.
	RP-31	2268	24	24.9	19	3	0.70	[illegible]	[illegible]	2,225	0.
	RP-32	2218	24	21.7	[illegible]	3	0.7[illegible]	1105	[illegible]	2,[illegible]	0.
JULY	RP-33	234[illegible]	[illegible]	24.[illegible]	[illegible]	3	0.75	[illegible]	78	1,[illegible]	0.
	RP-34	2177	20	23.[illegible]	[illegible]	3	0.[illegible]	[illegible]	11[illegible]	2,455	1
	RP-35	2227	20	26.4	16	3	0.81	940	112	2,615	1.
	RP-36	2343	28	21.4	23	3	0.7[illegible]	1047	7[illegible]	2,[illegible]	1.
AUG	RP-28	2[illegible]	16	20.0	14.5	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	RP-37	240[illegible]	28	24.3	23	3	0.74	1015	86	2,[illegible]	0.

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DIX A (Cont'd)

IMPACT VELOCITY (ft/sec	GROUND RANGE (ft)	TIME, SECONDS: RELEASE TO T_2	TIME, SECONDS: T_2 TO PARACHUTE INFLATION	TIME, SECONDS: TIME OF FALL	PARACHUTE DRAG (LBS): SNATCH LOAD	PARACHUTE DRAG (LBS): 1st STAGE OPENING SHOCK	PARACHUTE DRAG (LBS): 2nd STAGE OPENING SHOCK	NOTES ON PERFORMANCE
112	3,852	1.10	0.62	19.1	47,000	50,200	16,100	Good
145	2,683	1.16	0.48	19.6	46,400	125,000	NONE	Good despite major canopy failure
128	26,751	42.18	0.44	75.7	51,400	64,500	23,900	Good
[illegible]	2,700	1.10	0.76	15.6	33,900	55,700	11,100	Good
[illegible]	2,467	1.10	0.82	14.7	19,400	57,300	10,400	Good
[illegible]	1,642	0.60	1.23	21.6	21,700	56,000	56,700	Good
[illegible]	[illegible]	[illegible]	0.79	7.7	50,600	22,900	67,200	Major canopy damage because of jammed riser, vehicle recovered
[illegible]	2,396	0.61	0.98	19.5	67,300	37,900	16,900	Good despite major canopy damage
[illegible]	23,342	42.14	0.46	33.8	76,600	45,500	22,600	Good despite major canopy damage
[illegible]	3,472	0.64	0.80	14.2	15,400	15,200	37,800	Good
[illegible]	2,229	0.62	1.06	15.5	16,300	29,500	34,000	Good
[illegible]	[illegible]	0.62	0.70	15.8	22,400	46,300	43,200	Good
[illegible]	[illegible]	0.64	0.98	12.6	41,100	50,000	[illegible]	Good
[illegible]	2,435	[illegible]	[illegible]	17.1	[illegible]	37,000	45,600	Good
[illegible]	2,615	[illegible]	[illegible]	15.4	[illegible]	[illegible]	[illegible]	Good
[illegible]	2,581	[illegible]	1.21	16.1	[illegible]	[illegible]	37,600	Good despite major canopy damage
[illegible]	[illegible]	[illegible]	[illegible]	15.1	[illegible]	[illegible]	[illegible]	Good despite major canopy damage
[illegible]	2,607	[illegible]	[illegible]	16.2	[illegible]	[illegible]	[illegible]	Good despite major canopy damage

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APPENDIX A (Cont'd)

TEST DATE	TEST NO.	VEHICLE WT (lbs)	PARACHUTE SYSTEM DIAMETER (ft)	GEOMETRIC POROSITY (percent)	REEFING LINE LENGTH (ft)	PILOT CHUTE DIAMETER (ft)	PARACHUTE DEPLOYMENT CONDITIONS MACH NO.	ALTITUDE, (MSL)(ft)	IMPACT VELOCITY ft/sec	GROUND RANGE (ft)
SEPT	RP-101	2323	24	24.9	19	2.5	0.78	865	102	2,711
	RP-102	2483	24	21.7	19	2.5	0.76	915	96	2,41[illegible]
	RP-[illegible]	2615	16	20.0	14.5	2	1.09	5300	140	26,45[illegible]
OCT	RP-38	2565	20	26.4	16	2	0.98	4200	118	25,33[illegible]
	RP-103	2410	24	24.9	19	2	0.82	1000	101	2,79[illegible]

*The parachute is automatically deployed at time T_2.

[redacted]

APPENDIX A (Cont'd)

[illegible]	IMPACT VELOCITY ft/sec	GROUND RANGE (ft)	*TIME, SECONDS: RELEASE TO T_2	T_2 TO PARACHUTE INFLATION	TIME OF FALL	PARACHUTE DRAG (LBS): STATIC LOAD	1st STAGE OPENING SHOCK	2nd STAGE OPENING SHOCK	NOTES ON PERFORMANCE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.6	42,800	41,500	19,200	Good despite major canopy damage
96	2,410	0.65	0.80	14.2	--	--	--	--	Good
140	26,458	50.20	0.52	72.2	52,800	56,000	42,200	Good	
118	25,337	38.16		58.2	16,400	55,000	34,100	Good	
101	2,791	0.65	0.86	14.3	17,300	52,400	43,800	Good	

[redacted]

APPENDIX 5

RP-1 (Parachute Diameter, D = 20 feet, Deployment Mach Number, M_D = 0.60)

This, the first drop of the LLD program, was a total loss to the vehicle. The 100-pound static line connecting the tail cone to the pilot chute failed before pulling the pilot chute out of its pack, and the entire chute system failed to deploy before the vehicle reached the ground. The test proved that the automatic deployment system of test vehicle worked.

RP-2 (D = 20 feet, M_D = 0.60)

This drop was a repeat drop of RP-1 with the addition of a 2250-pound static line to replace the 100-pound line. The change caused the deployment system to function properly, but rolling of the vehicle was caused by a shape instability of the chute in the reefed condition. The chute was observed to have a very rapid, high-intensity breathing effect. Even with this effect in the first-stage chute, the second stage worked very well. The vehicle was in good condition after impact and all the telemetry equipment worked fine.

RP-3 (D = 20 feet, M_D = 0.60)

This drop was the same as RP-1 and RP-2 except that it was an uninstrumented drop made at the Los Lunas range. At this point in the program it was decided to first make "quick" drops before making fully instrumented tests of the configuration to check the parachute system. RP-3 was a successful drop except for the same reefed chute instability as in RP-2. There was no telemetry of this drop. The vehicle toppled at impact because of high ground winds.

RP-4 (D = 16 feet, M_D = 0.61)

There were two failures in this deployment system of this test: (1) Failure in the pilot chute suspension lines, and (2) failure of the mag bridle-pilot chute connecting line. Other than the two listed failures, this test was successful. The main canopy functioned properly in both stages, the telemetry worked and the vehicle remained upright after impact.

RP-5 (D = 16 feet, M_D = 0.65)

This was the second of the uninstrumented drops at Los Lunas. The same deployment system failures occurred in RP-5 as in RP-4. There was also twisting of the vehicle due to instability of the parachute in the reefed condition, as mentioned in RP-2, and -3. After the chute opened to its

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second stage, the twisting stopped. There was no telemetry and the vehicle remained upright after impact.

RP-6 (D = 16 feet, M_D = 0.66)

The same twisting occurred as on RP-5. This, too, was an uninstrumented drop and the vehicle remained upright after impact.

RP-7 (D = 20 feet, M_D = 0.74)

The deployment bag separated from the parachute before it left the vehicle, causing a much longer deployment time than usual. There was damage to 14 horizontal ribbons, probably caused by burning of the deployment bag as it came off the chute. The chute opened properly in both stages and the drop was successful. The vehicle was not instrumented with a telemetering package. It remained in a vertical position after impact.

RP-8 (D = 16 feet, M_D = 0.83)

Despite the fact that the pilot chute parted from the deployment bag before pulling it out of the vehicle, the parachute system deployed and the drop was successful. The telemetry worked well.

RP-9 (D = 16 feet, M_D = 0.86)

The first high-altitude delayed-action drop was successful except for the same deployment failure as RP-8. The vehicle was statically unstable at the high subsonic Mach numbers, but the instability did not affect the action of the chute. The telemetry functioned properly and the vehicle remained upright after impact, despite moderately high ground winds.

RP-10 (D = 16 feet, M_D = 0.94)

This drop was the second of the high-altitude tests. The deployment Mach number was 0.94. The pilot chute failed on this test, yet the operation of the system was good, the parachute giving full drag in both stages. The telemetry system did not record during the peak loads of the opening shocks. The vehicle was recovered from the upright position, but there was a slight break at the afterbody-canted body junction.

RP-11 (D = 24 feet, M_D = 0.80)

This was a good test with the deployment system and the telemetry equipment all functioning properly. The parachute system also worked properly

in both stages. Nine-inch fins instead of the usual twelve-inch fins were used on RP-11. The vehicle remained upright after impact.

RP-12 (D = 24 feet, M_D = 0.94)

Again, the pilot chute separated from the deployment bag before the bag was out of the vehicle. Otherwise the test was successful with all equipment working well and the test vehicle being recovered undamaged.

RP-13 (D = 20 feet, M_D = 0.80)

This test was a complete success, with all equipment functioning properly and the vehicle remaining vertical.

RP-14 (D = 20 feet, M_D = 0.81)

Again, the drop was successful with all equipment performing as expected and the vehicle standing up after impact.

RP-15 (D = 24 feet, M_D = 0.74)

There was moderate damage done to the parachute as it deployed because one of the risers jammed in the can and caused an upsetting load to be applied to the chute. Three of the panels of the chute were torn between the vent and the skirt. The damage to the chute appeared to occur when the chute opened in the second stage. Even though the vehicle toppled, it was not damaged severely and the equipment was reusable.

RP-16 (D = 28 feet, M_D = 0.75)

Again, there was moderate damage to the parachute. It is believed that the damage is caused at the time of line stretch or when the free trailing mass of the chute is brought up to the speed of the vehicle. There is a tremendous force exerted at this time upon the canopy. Other than the canopy failures, the results of the drop could be considered good, with the chute working in both stages, the telemetry giving a good record, and the vehicle not being damaged at impact.

RP-17 (D = 20 feet, M_D = 0.72)

Very good drop. This was the first vehicle using no tail fins for stabilization at release. It was apparent from the telemetered data that the vehicle pitched more than usual, but the parachute stabilized it almost immediately after opening. The parachute and the telemetry worked well for this drop and the vehicle remained upright after impact.

RP-19 (D = 16 feet, M_D = 0.79)

This was the first of two tests of a noureefed 16-foot chute. The parachute functioned very well. RP-19 was the last test to use a 5-foot pilot chute, and all subsequent tests will be made with 24-inch- and 30-inch-, or 36-inch-diameter pilot chutes. The vehicle remained vertical and the telemetry functioned properly.

RP-20 (D = 16 feet, M_D = 0.70)

The parachute functioned very well in both stages, but the vehicle toppled when the nose cone adapter broke at impact. The vehicle itself was not damaged. The rate gyros failed to operate during this test, but all the other instrumentation gave good data.

RP-21 (D = 16 feet, M_D = 0.99)

The first successful parachute test of the program to approach Mach 1 (0.99). The only damage to the vehicle at impact was the breaking off of the spike, yet the vehicle remained upright. The Pluto cameras did not function during the drop, but the telemetry data showed a complete record of the test.

RP-22 (D = 16 feet, M_D = 0.84)

This, the second of the noureefed chutes, did not function as well as the first. The canopy had numerous panel failures, probably caused at first stretch or by the shock of the canopy opening. Even with the drag reduction (approximately 20 per cent) caused by the damage, the parachute opened fully in both stages. The vehicle made a very smooth impact and remained upright. The Pluto cameras failed to operate for this test.

RP-24 (D = 24 feet, M_D = 0.79)

This drop was the first to use a 30-inch pilot chute, and was a successful test of both the parachute and the pilot chute. There was no damage to the main canopy and the vehicle made a very good recovery.

RP-25 (D = 24 feet, M_D = 0.70)

This was a successful drop with all equipment functioning as expected. This test was another test of 24-foot-diameter chutes, with no unusual telemeter changes. The recovery spike worked well -- the vehicle remaining in the vertical position after impact.

RP-26 (D = 24 feet, M_D = 0.99)

Another test where there was moderate damage of the parachute in two panels, and minor damage in several others, yet the canopy opened fully in both stages. The vehicle buried itself very deep in the ground upon impact, the impact velocity being 235 ft/sec. The telemetry gave good results of the test, even though the torn chute caused quite a bit of hash on the longitudinal accelerometer channels.

RP-27 (D = 40 feet, M_D = 0.58)

RP-27 was the first test of a 40-foot chute, and it performed very well. The chute lowered the vehicle so gently that the expendable spun aluminum nose fairing could be used again. The telemetry worked throughout the drop and even good impact readings were recorded.

RP-28 (D = 16 feet, M_D = 1.01)

There were two panels with moderate damage and several more with minor damage to the horizontal ribbons, yet the parachute performed as expected in both stages. It appeared again as though the damage might have occurred at line stretch. This was the first drop to use 15-inch span fins to try to stabilize the vehicle which had proved to be unstable with shorter fins in previous drops through the Mach 0.85 to 0.95 region. The new fins apparently stabilized the vehicle as there was very little oscillation of the vehicle through this range. The increased stability also increased the velocity because of the reduced drag of the vehicle.

RP-31 (D = 24 feet, M_D = 0.71)

This was the second drop of the program using no fins on the vehicle. Again the vehicle pitched through a large angle (50°) before the parachute deployed and stabilized it. The parachute functioned very well and there was no damage done during deployment.

RP-32 (D = 24 feet, M_D = 0.70)

Another successful drop, all the equipment functioning as expected. The parachute worked very well in both stages, and there was only minor damage to a few horizontal ribbons. The vehicle was recovered from the vertical position.

RP-33 (D = 28 feet, M_D = 0.75)

This was the first drop of the 28-foot-diameter chutes. The deployment and parachute systems performed very well during the test. The roll,

pitch and yaw rate gyros did not work throughout the drop, but the rest of the telemetry gave a good record.

RP-34 (D = 20 feet, M_D = 0.80)

All the equipment functioned properly throughout the drop, and the vehicle was recovered from an upright condition.

RP-35 (D = 20 feet, M_D = 0.81)

This vehicle fell over at impact, probably because of fairly high winds at the ground level (20 fps). All the telemetry, deployment and parachute equipment worked successfully for this drop.

RP-36 (D = 28 feet, M_D = 0.78)

This was a successful drop except for moderate canopy damage to two panels. It is thought that these damages are being caused by the large snatch load occurring at the time the suspension lines reach a stretched condition during deployment. A program is presently under way to try to reduce these loads. The parachute performed well despite the damages.

RP-37 (D = 28 feet, M_D = 0.78)

Another test with major damage in one panel. The damage appeared to be caused by the same action that damaged RP-36. The testing of the 28-foot chutes has temporarily been discontinued until the newly designed deployment bag could be proven to reduce the snatch load and probably eliminate the damage to the chutes. Other than the damages to the chute, the drop was successful.

APPENDIX C

Data Evaluated for a Typical Test

Included in this appendix are samples of the data acquired for each drop test of the LLD Parachute Research Program. The following is a list of all the data received from each test:

1. Documentary film

   a. 35-mm Mitchell camera movie film from at least two ground stations.

   b. 16-mm film from two ground stations.

   c. Askania Cine-theodolite film coverage of the entire drop.

   d. 16-mm movie film from two Pluto cameras located on either side of the aft end of the vehicle.

   e. Aircraft store-separation cameras.

   f. Still photographs of the vehicle and parachute system after impact, with emphasis on parachute or vehicle damages.

2. Copy of the telemetry record which includes the following information:

   a. Longitudinal accelerations* (minimum of four).

      (1) Two from accelerometers with a range of -10 to 30, 40, or 50 g's (depending upon the expected loads). (Statham strain-gage-type accelerometers have been used in addition to these. The Statham have a natural frequency response of approximately 500 cycles/second.)

      (2) One with a range of 0 to 10 g's.

      (3) One with a range of 0 to 5 g's. (Additional accelerometers may be added if desired.)

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* Blown-up telemetry records. All of the channels of the telemetry record which have accelerometer or gyro data are reproduced with enlarged scales so as to better facilitate reduction of the data from these channels.

b. Lateral accelerations* (2).

(1) Horizontal plane - ±10 g's.

(2) Vertical plane - ±10 g's.

c. Angular rates* (3). (Measured in fixed planes of the vehicle.)

(1) Roll

(2) Pitch

(3) Yaw

d. Sequence times - the time of release from aircraft and start of deployment of the parachute system are monitored to get accurate time sequences for data reduction.

e. The frame rates of the Pluto cameras are monitored so accurate film reduction is available.

3. Meteorological data. These data are recorded to get accurate atmospheric conditions during the test. These data include density, speed of sound, temperature, and pressure.

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* Blown-up telemetry records. All of the channels of the telemetry record which have accelerometer or gyro data are reproduced with enlarged scales so as to better facilitate reduction of the data from these channels.

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APPENDIX D

Typical Examples of Data Evaluated

The data of Appendix C are reduced to final data which are presented in the following forms:

1. Tabulations of longitudinal accelerometer readings - these data are tabulated throughout the drop for each accelerometer every .01 second, or so, with emphasis on peaks.

2. Digital plots of the data received from roll, pitch and yaw rate gyros are made on blown-up scales. These data are integrated over periods of time to measure the stability of the vehicle and the displacement of the vehicle at a given time.

3. From the Askania film, the range, drift due to winds, attitude angle of the vehicle, velocity, and Mach number are computed.

4. A plot of Mach number, velocity, and altitude versus time is also presented from the Askania results.

5. Dynamic pressure (q) is calculated from the air density and vehicle velocity.

6. The drag area (C_DS) of the chute system acting on vehicle is calculated from the longitudinal accelerometer data (1) and dynamic pressure (5).

7. The circular error data for each drop are recorded and later corrected for wind and trajectory error effects.

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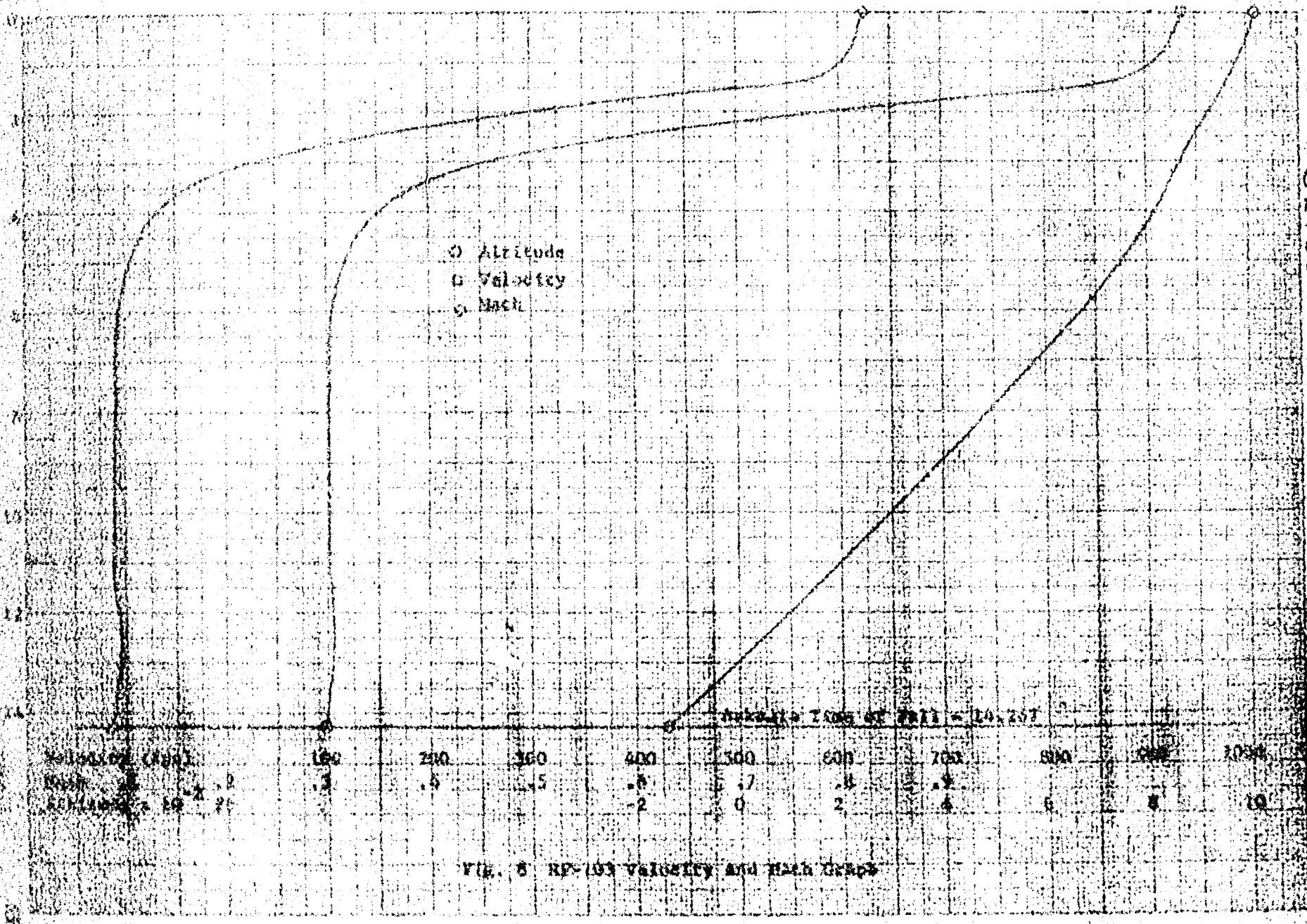

Fig. 8 RP-103 Velocity and Mach Graph

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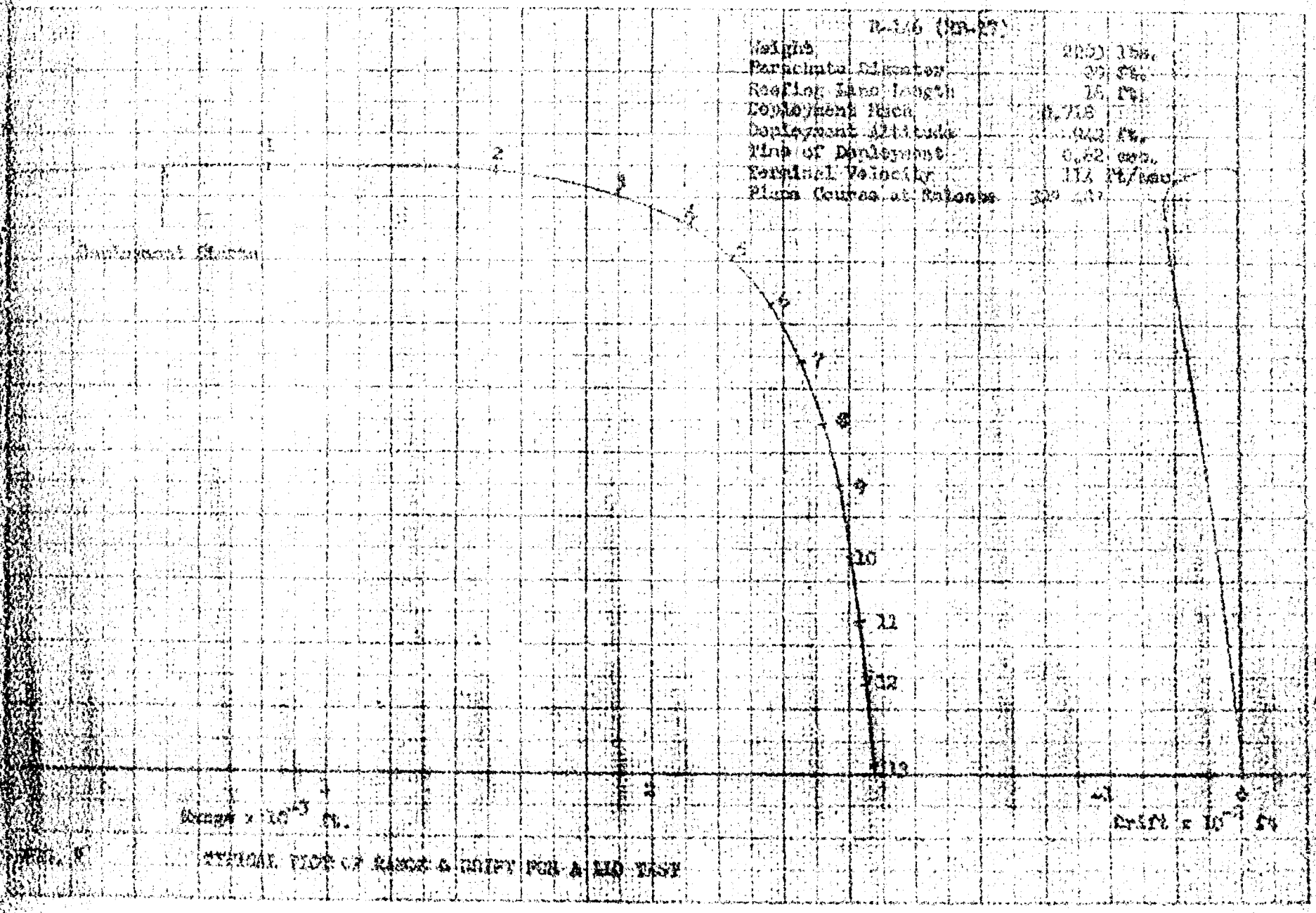

FIG. 8 TYPICAL PLOT OF RANGE & DRIFT FOR A LID TEST

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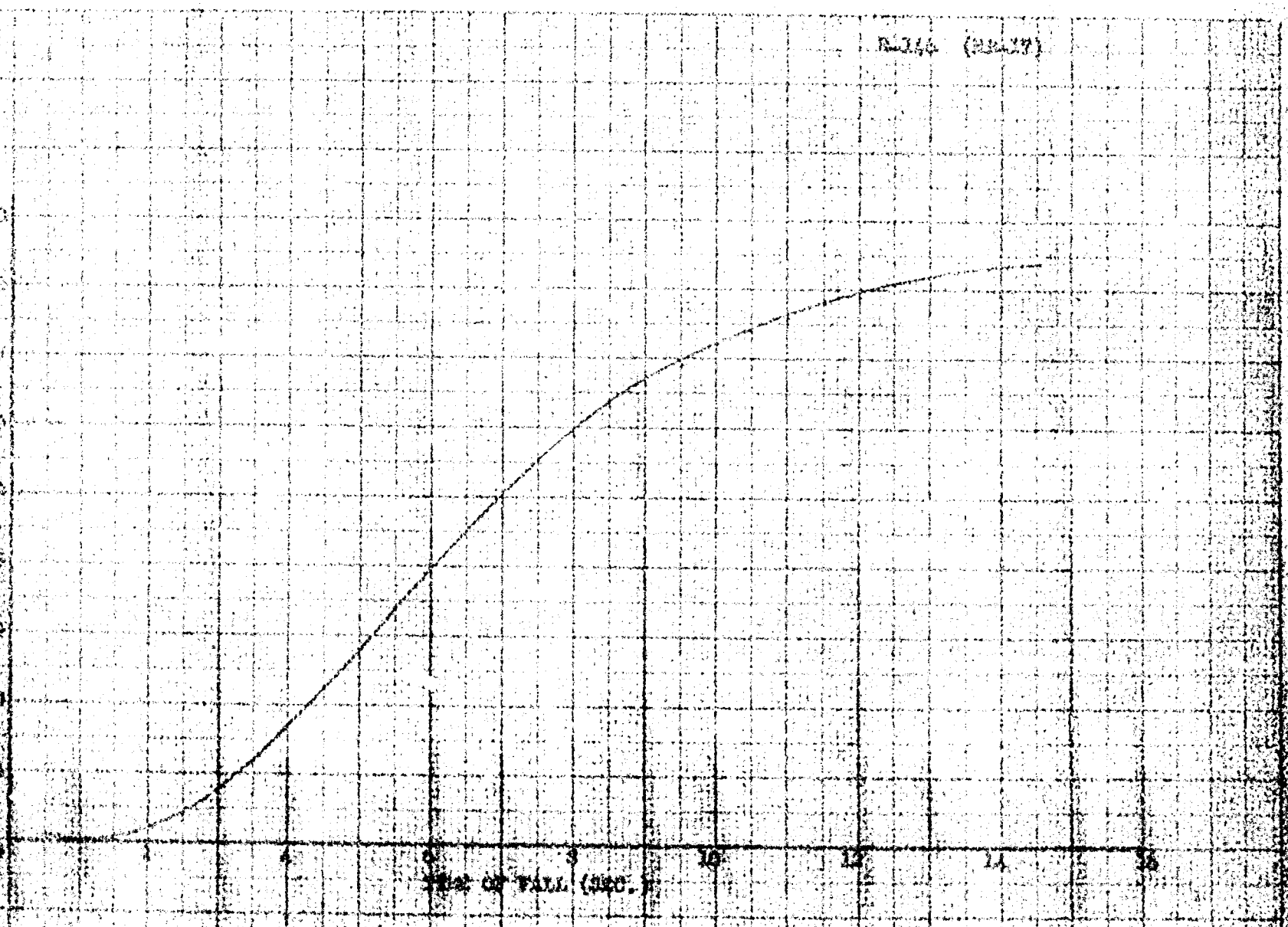

FIG. 11 TYPICAL PLOT OF ATTITUDE ANGLE VS. TIME FOR 1ST TEST

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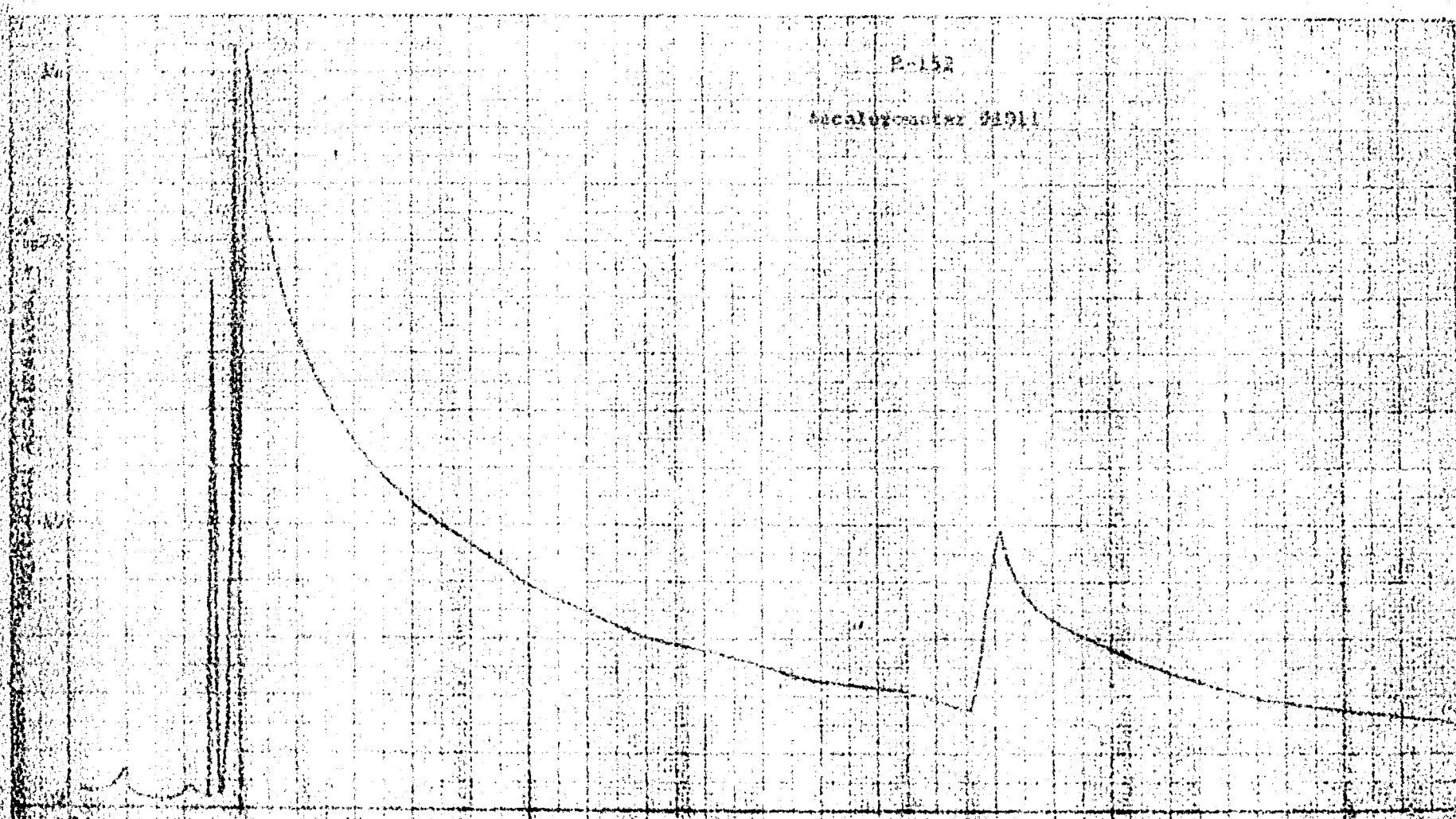

To convert from g's to pounds drag, use: D = 2423 x g

Fig. 11 Typical Plot of Longitudinal Acceleration vs Time

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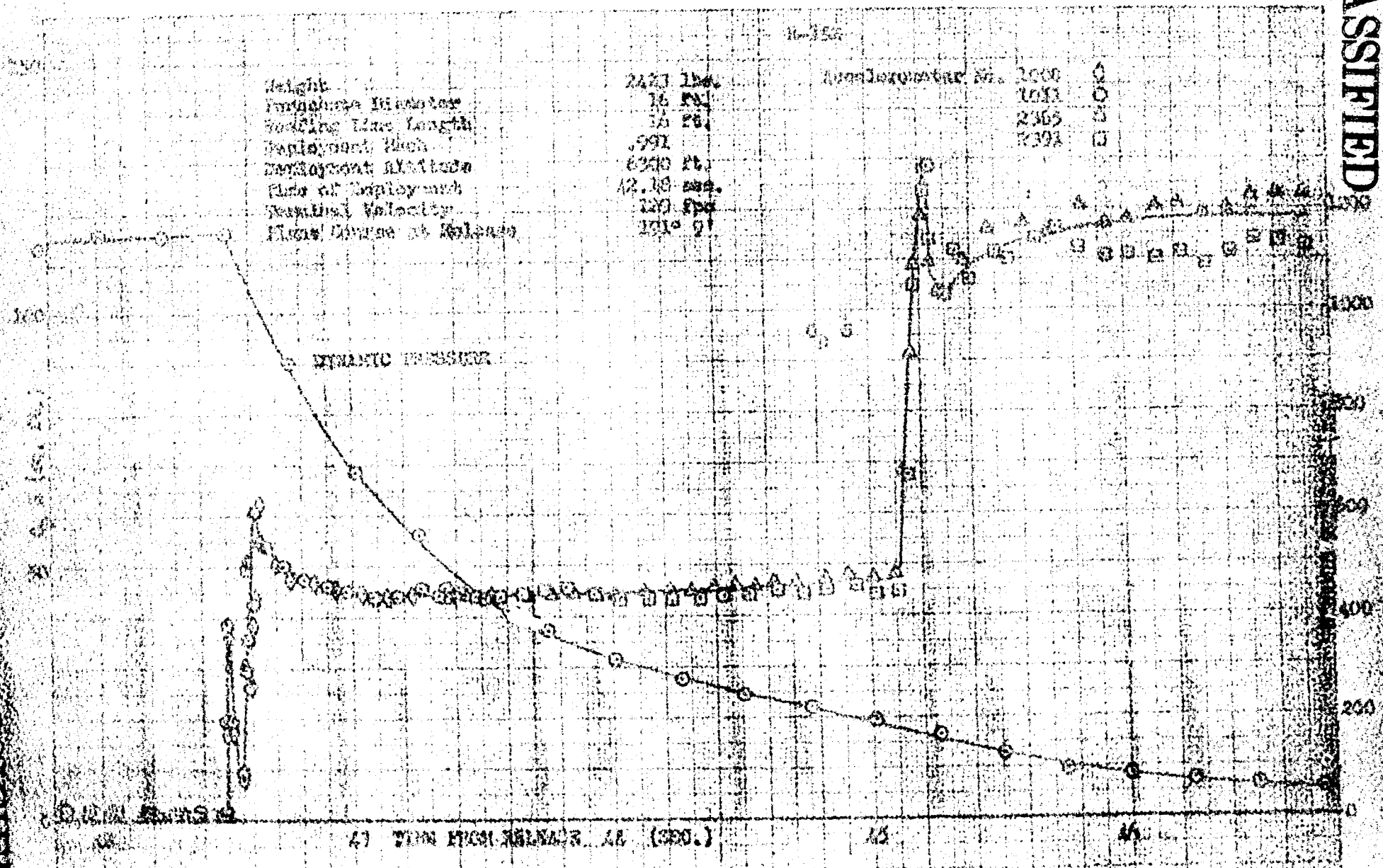

FIG. 13 TYPICAL PLOT OF DRAG AREA (C_D S) AND DYNAMIC PRESSURE

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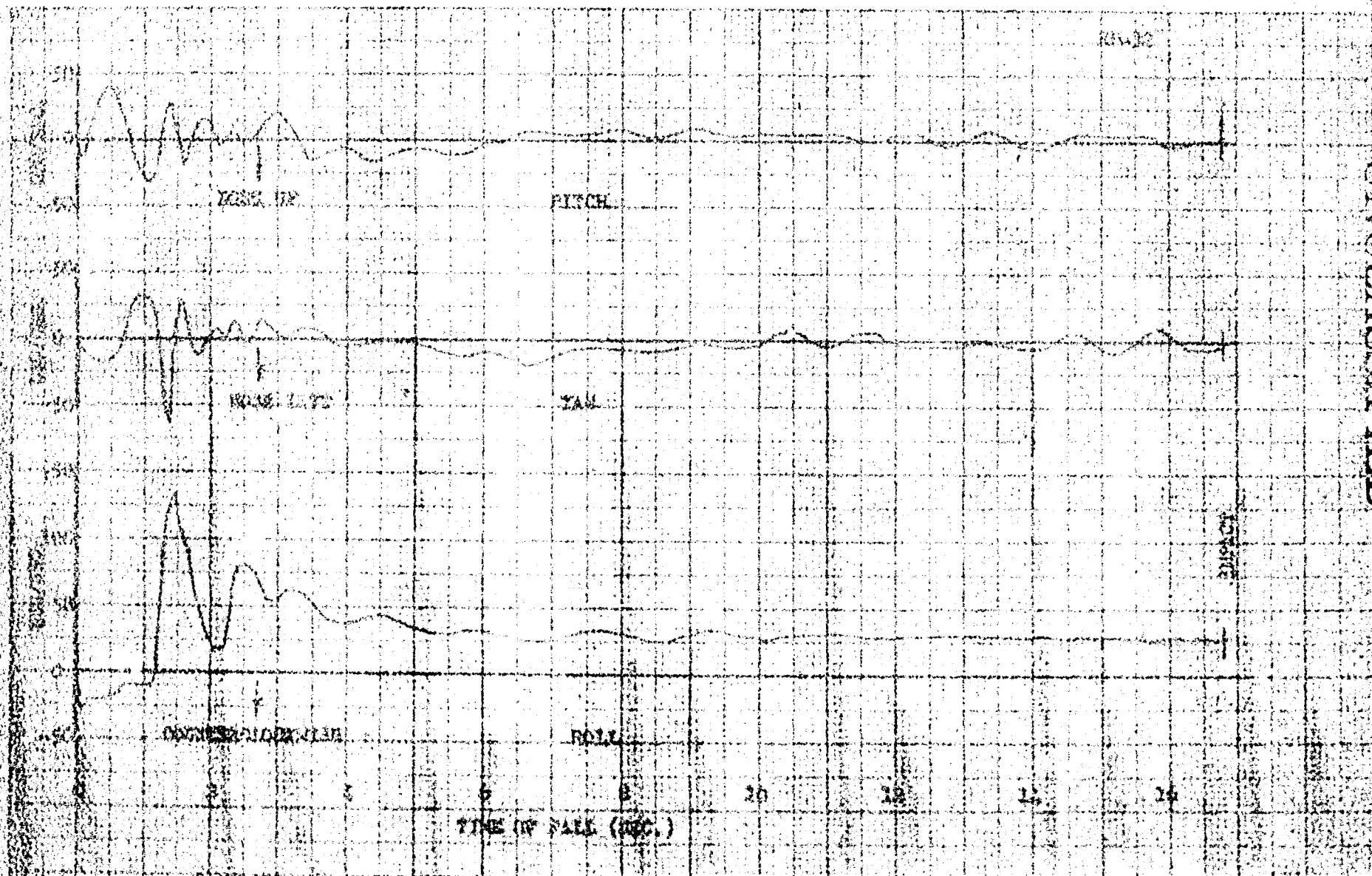

FIG. [illegible] TYPICAL TRACES OF PITCH, YAW AND ROLL RATE [illegible] DATA