NASA-CR-65037

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GENERAL MOTORS CORPORATION

GM DEFENSE RESEARCH LABORATORIES

AEROSPACE OPERATIONS DEPARTMENT

EXPERIMENTAL INVESTIGATIONS OF SIMULATED METEOROID DAMAGE TO VARIOUS SPACECRAFT STRUCTURES

PROGRESS REPORT NO. 3

FOR PERIOD ENDING 31 JANUARY 1965

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GPO PRICE $ ______

OTS PRICE(S) $ ______

Hard copy (HC) 1.00

Microfiche (MF) .50

CONTRACT NAS 9-3081

1 FEBRUARY 1965

Prepared for NASA/Manned Spacecraft Center
Houston, Texas

Scope of Program

The physics of interaction of a meteoroid with a relatively thin metallic shield and the damaging effects of the debris that passes through the shield will be investigated using analytical and experimental techniques. The influence of particle and target density, porosity, and heats of fusion and vaporization will be included in the investigation; and the relative efficiency of various structural concepts compared. The range of impact velocities to be investigated experimentally will be up to 8.0 km/sec. The primary objective of the investigation is the establishment of design criteria and equations to define the penetration mechanics of meteoroids into typical spacecraft structures.

Accomplishments During the Reporting Period

The computer program describing the response of a circular plate to an axially-symetric impulsive load has been completed and debugged. The program is now being used to compute necessary backup plate thicknesses for meteoroid protection over the same range of variables as the previous "strip approximation" program. Preliminary results indicate good comparison between thicknesses determined by each of the programs. These calculations are continuing.

Experimental Results

During the reporting period, experiments were performed to further define the behavior of the momentum multiplication factor, MV/mv, as a function of impact velocity, shield thickness, spacing and projectile properties. Shots D-995 and D-1224 with pyrex projectiles show no marked change from the results obtained using aluminum projectiles.

Using cadmium for projectiles and shields has allowed the attainment of the debris through the shield in the form of solid, liquid or vapor. The tests using cadmium (D-1019, D-1046 and D-1230) show no large change from the results obtained using aluminum projectiles and shields. However, D-1045 shows a higher multiplication factor than obtained with aluminum. This is the only cadmium shot fired in which all the debris was in the form of vapor. The value of momentum multiplication measured, 1.42, is considerably less than the limit of 2.0 obtained, assuming a perfectly elastic collision of the vapor debris with the backup target.

Two shots have been fired to investigate the effect of the spacing between the shield and backup. These tests, D-996 and D-1225, with 1.27 centimeter spacing and 2.54 centimeter spacing respectively, gave quite different results for the momentum multiplication factor. The values obtained differ by the maximum error assigned to these tests, $\pm$ 4%.

In general, the momentum multiplication factor seems to be dependent upon the state of the debris and the amount of cratering that takes place in the backup sheet. The effect of spacing has not been satisfactorily determined.

Two experiments were performed to determine the momentum distribution on the backup. In these experiments, the backup is cut into two pieces and these pieces are mounted on independent ballistic pendulums. The momentum imparted to each piece of the backup is then measured. The experiments were performed at approximately 7.2 kilometers per second with 3.18 millimeter aluminum spheres impacting against 0.635 millimeter aluminum shields with 5.08 centimeter spacing between the shield and the backup. The results are summarized below:

Radius of measurement from center of impact	Momentum measured kg meters/sec	Area meters^2	$\frac{\text{Momentum}}{\text{Area}}$ kg/meter sec
0 to 0.953 cm	0.178	2.86×10^{-4}	623
0 to 2.54	0.359	20.1×10^{-4}	178
0 to 5.08	0.446	80.9×10^{-4}	55.2
0.953 to 5.08	0.268	78.0×10^{-4}	34.4
2.54 to 5.08	0.087	60.8×10^{-4}	14.4
0.953 to 2.54	0.170	17.2×10^{-4}	98.8

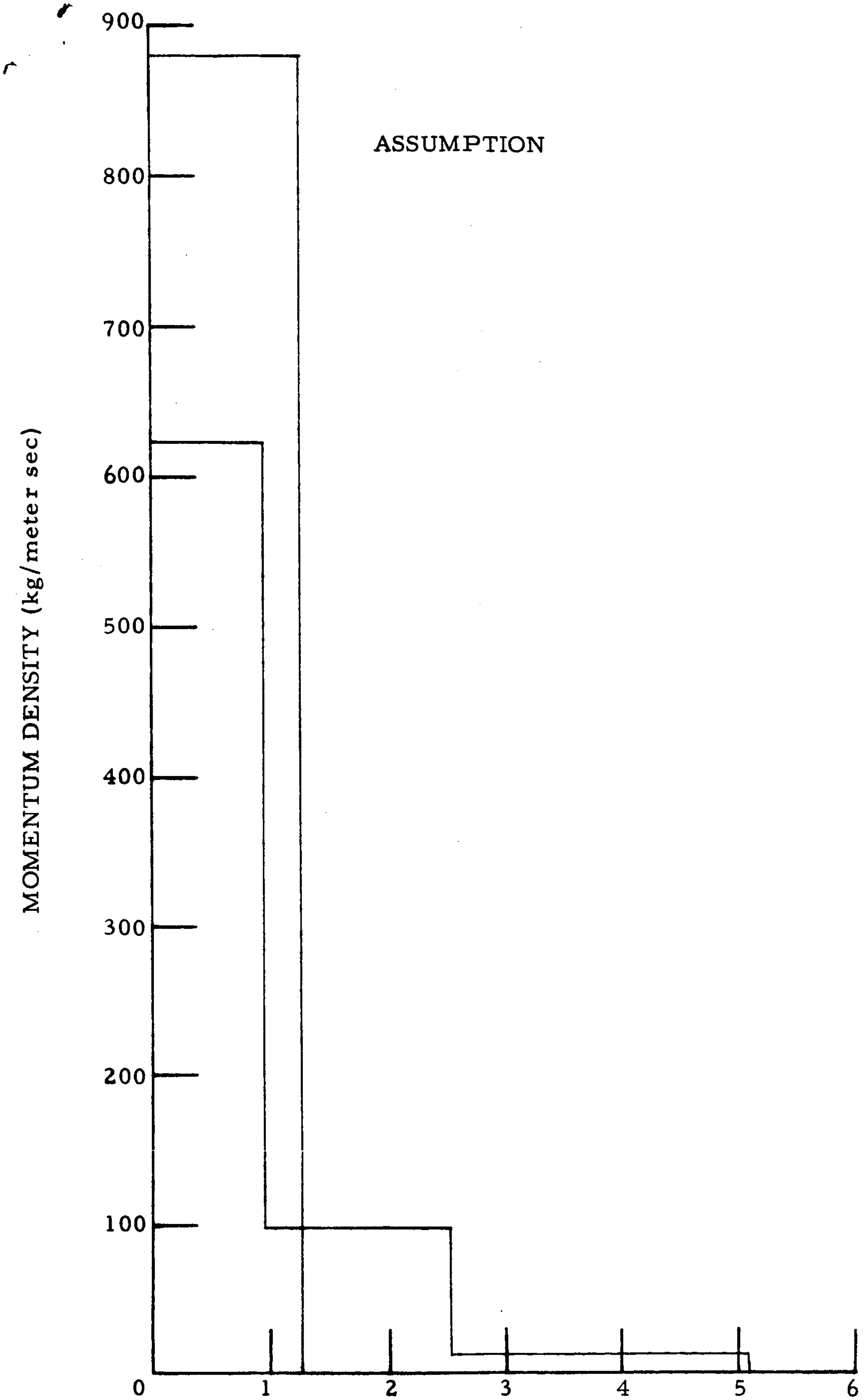
The measured distribution is shown in Figure 1 and compared with the assumed distribution used in the shell analysis calculations.

Proposed Program for the Next Reporting Period

During the period from 1 February 1965 through 31 March 1965, calculations of the necessary backup thickness requirements for the 3.18

millimeter aluminum, 1.59 millimeter and Apollo particle will be calculated using the circular plate calculations and will be compared to the results obtained using the "strip approximation" program.

Experiments will be undertaken to examine the effects of projectile porosity and further tests to determine momentum distribution on the backup will be performed. As these distributions are determined, they will be utilized in the circular plate calculations to determine the effect of distribution upon the results.



RADIUS OF MEASUREMENT FROM CENTER OF IMPACT (cm)

FIGURE 1

SHOT NO.	PROJECTILE MATERIAL	DIAMETER (mm)	SHIELD MATERIAL	THICKNESS (mm)	SPACING (cm)	BACKUP MATERIAL	THICKNESS (mm)	VELOCITY (km/sec)	TOTAL PENETRATION (mm)	HOLE SIZE (mm)	SPRAY DIAMETER (mm)	SPRAY ANGLE	MV/mv	REMARKS
D-1153	Cd	2.56	Cd	0.635	5.08	7075-T6 Al	1.60	3.84	0.76	6.1	102	90		
1154		3.18		.330			12.7	3.69	.69	4.8	89	82		
1155				.635				5.12	.89	5.2	89	82		
1156				.330				3.87	.74	4.8	76	74		
1157	Al		1100-0 Al	1.02			6.35	6.89	1.19	8.1	102	90	1.34	
1222	Cd		Cd	.330				3.55	1.04	4.85	86	81		
1223				.635				5.12	.81	7.22	89	82		
1224	PYREX		1100-0 Al				6.35	4.92	1.65	5.68	89	82	1.23	
1225	Al			1.02	2.54		12.7	5.88	1.65	7.87	43	81	1.42	
1226			Cd	.330	1.27			6.10	1.09	5.89	36	109	1.40	
1227	Cd				5.08			—	—	—	—	—		NO LAUNCH
1228								—	—	—	—	—		NO LAUNCH
1229	1100-0 Al	4.12 x 4.14 CYLINDER	1100-0 Al	.635				5.61	2.13	7.97	109	94	1.28	
1230	Cd	3.18	Cd	.330				3.60	.66	4.62	99	89	1.26	
1231	Al	1.59	1100-0 Al	.305				4.36	1.04	2.8	61	62		
1232							3.18	6.16	.43	3.2	91	84		PISTON HIT
1233				.152				4.69	1.02	2.5	61	62		
1234								6.59	.89	—	84	79		PISTON HIT
1235				.305				6.50	.46	3.0	99	89	1.18	
1236		3.18		.635			12.7	6.61	1.19	6.50	99	89	1.25	
1237								7.10	1.14	6.63	98	87		SABOT HIT
1238								7.19	.97	6.60	99	89		
1239								7.19	1.14	6.65	98	87	1.32	
1240								—	—	—	—	—		NO LAUNCH
1241								7.38	1.25	6.63	94	86		SABOT HIT
1242								7.26	.89	6.63	94	86		PISTON HIT