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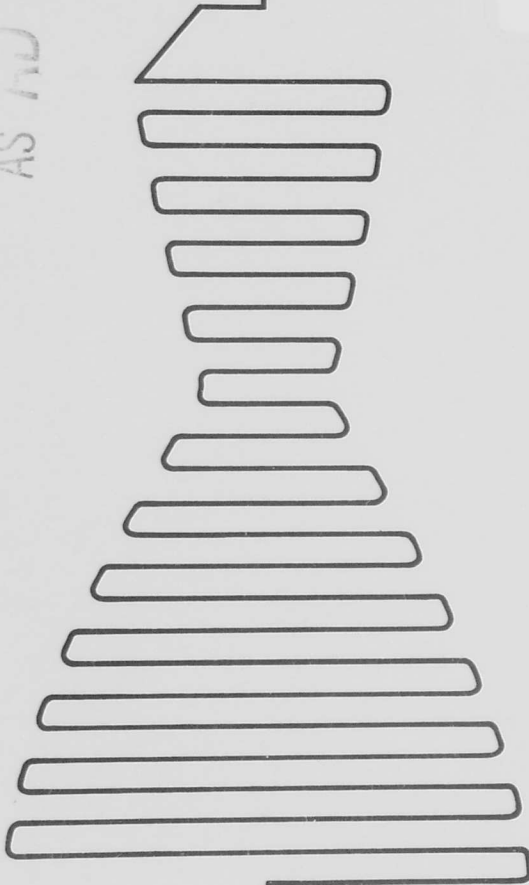


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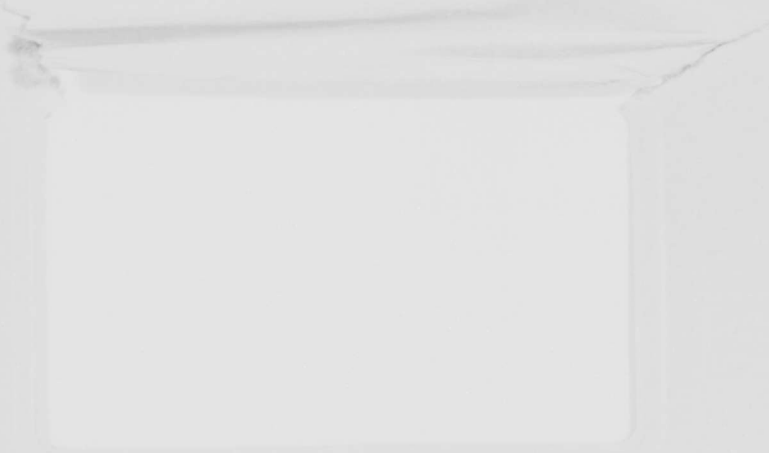
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ROCKETDYNE

A DIVISION OF NORTH AMERICAN AVIATION, INC.

CANOGA PARK, CALIFORNIA



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PERFORMANCE DATA FOR INDIVIDUAL
ATLAS MA-2 AND MA-5 ENGINES

ROCKETDYNE

A DIVISION OF NORTH AMERICAN AVIATION, INC.

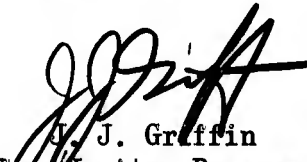
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10 Sept 1963	EAA/WNP	ALL	Updates report R-5108 dated 15 April 1963

FOREWORD

This report was prepared under G.O. 8466 and Contract AF04(695)-306 to provide information needed by the customer.

ABSTRACT

This report updates and supersedes Rocketdyne report R-5108, dated 15 April 1963, and presents specific performance data for individual MA-2 and MA-5 booster, sustainer, and vernier engines. These data can be used to optimize vehicle trajectories.

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INTRODUCTION AND SUMMARY

The values presented on the following pages may be used in a variety of situations, but are arranged to fulfill the customer's prime need for accurate information to be used when calculating flight trajectories for missiles powered by the Atlas MA-2 or MA-5 propulsion systems.

This report will be periodically updated to include new information for overhauled and later production engines. Data presented are valid for a given engine only if the final acceptance test date shown in the applicable table agrees with the date recorded in the engine log book. This acceptance test date will change if the engine has been overhauled.

DATA REDUCTION PROCEDURES

The over-all Atlas MA-2 and MA-5 data reduction procedures have not been radically changed since the start of MA-2 engine production. Improvements have been made in specific sustainer engine reduction procedure, but no data reduction procedural changes have been made in the determination of booster engine parameters, vernier engine parameters and sustainer LOX regulator reference pressure.

Originally, the average of all data slices corrected to rated thrust and mixture ratio for the engine acceptance tests (for engines up to and including sustainer engine NA225165) were used. The next change applied to engines NA225166 to NA225172; the engine parameters were determined for each acceptance test during which the sea level mixture was closest

to nominal. These parameters were then corrected to rated thrust and mixture ratio. An average value was determined and reported for each parameter. Parameters for engines acceptance tested after MA-5 sustainer engine NA225172 were determined by the data reduction procedures presented in this report.

DATA REDUCTION COMPUTER PROGRAMS

Several changes have been incorporated into the computer programs used for engine data reduction. PAST 210, 230, 251, 252, 254, and 255 incorporate significant advances in the state of the art over the original MA-2 programs. Improved methods of calculating LOX density, theoretical characteristic velocity, and theoretical thrust coefficient are included. Nominal pump constants have been built into the new programs and are not required as input items.

Booster

PAST 251 changes format to accept input data from earlier computer programs. PAST 252 simplifies the method of inputting data. PAST 254 is the unclassified version of PAST 252. PAST 255 involves a 330,000-pound-thrust version of PAST 254.

Sustainer

PAST 210 (MA-2 engine) differs from PAST 230 (MA-5 engine) concerning the type of mixture ratio controller installed on the engine.

PERFORMANCE DATA

All engine parameters in this report were determined through use of the most recent data reduction computer programs and procedures. The applicable data reduction computer program for each engine is shown in Table 1. The applicable procedures for each type of engine are outlined below. Variations between the engine log book and this report are attributable to changes in data reduction procedures and computer programs.

BOOSTER

The reported values for a booster engine were determined by averaging acceptance test values corrected to rated thrust and standard conditions. This was done for all applicable performance demonstration tests.

SUSTAINER

Except for LOX regulator reference pressure, the reported values for a sustainer engine were determined in the following manner:

1. Data slices were selected from all applicable demonstration tests which displayed an engine sea level mixture ratio of 2.2700 ± 0.1135 .
2. Engine performance parameters corrected to rated thrust and mixture ratio at standard conditions were selected for all above slices.
3. The mean value for engine parameters of each performance demonstration test was calculated from item 2.
4. Report values are the average of the mean value of applicable tests.

The value reported for LOX regulator reference pressure was determined as follows:

1. Data slices were selected from each applicable performance demonstration test which displayed an engine sea level mixture ratio closest to nominal (2.27).
2. LOX regulator reference pressure corrected to rated thrust and mixture ratio at standard conditions was selected for each of the above slices.
3. The corrected values selected for the above slices were averaged.

VERNIER

The reported values for a vernier engine were determined by averaging acceptance test values corrected to rated thrust and mixture ratio. This was done for all applicable performance demonstration tests.

MA-2 ENGINES

Table 2 presents engine serial number and final acceptance test date for MA-2 booster engines, plus values for engine thrust, mixture ratio, specific impulse, and LOX regulator reference pressure.

Table 3 presents engine serial number and final acceptance test date for MA-2 sustainer engines, plus values for engine thrust, specific impulse, and LOX regulator reference pressure. The nominal mixture ratio for a sustainer engine is defined as 2.27 by the model specification. Table 3 also includes the minimum LOX net positive suction head and estimated MA-2 sustainer engine duration capability; further discussion of these values is presented later in this report.

Data concerning MA-2 vernier engines are not included in this report.

MA-5 ENGINES

Table 4 presents engine serial number and final acceptance test date for MA-5 booster engines, plus values for

1. Thrust
2. Mixture Ratio
3. Specific Impulse
4. LOX Regulator Reference Pressure
5. No. 1 and No. 2 Thrust Chamber
 - a. LOX Flowrate
 - b. Fuel Flowrate
 - c. Injector End Pressure
6. Gas Generator
 - a. LOX Flowrate

- b. Fuel Flowrate
- c. Injector End Pressure
- 7. No. 1 and No. 2 Turbopump Speed

Table 5 presents engine serial number and final acceptance test date for MA-5 sustainer engines, plus values for

- 1. Thrust
- 2. Mixture Ratio
- 3. Specific Impulse
- 4. LOX Regulator Reference Pressure
- 5. Thrust Chamber
 - a. LOX Flowrate
 - b. Fuel Flowrate
 - c. Injector End Pressure
- 6. Gas Generator
 - a. LOX Flowrate
 - b. Fuel Flowrate
 - c. Injector End Pressure
- 7. Turbopump Speed
- 8. Minimum LOX Net Positive Suction Head
- 9. Estimated Engine Duration Capability

Table 6 presents engine serial number and final acceptance test date for MA-5 vernier engines, plus the tank-fed and pump-fed injector end chamber pressure.

TABLE 1
SEA LEVEL DATA REDUCTION COMPUTER PROGRAMS

Engine	Report Reduction Deck No.	Effective On Engine	Log Book Reduction Deck No.	Remarks
Booster	PAST 251	112032 through 112157	Original MA-2 Booster	All engines reduced with original program were reprocessed with PAST 251. Data reduction programs PAST 251, 252, and 254 produce equivalent performance results
	PAST 251	112501 through 112502		
	PAST 252	117001 through 117019	PAST 254	
	PAST 252	115101 through 115139	PAST 255	
	PAST 252	115501 through 115503		
			115140 through 115172 115173 and subsequent	
Sustainer	Original MA-2 Sustainer	222032 through 222157; 222501 through 222502; MA-2 overhauls prior to January 1961	Original MA-2 Sustainer	A bias was found in thrust system. Tables contain only nominal specific impulse and re-evaluated LOX regulator reference pressure
	PAST 210	MA-2 overhauls from January 1961 to present; 227001 through 227019; 225101 through 225125	PAST 202 PAST 202 PAST 202	These engines used MA-2 type mixture ratio controllers
	PAST 230	225126 through 225136; 225137 and subsequent; 225501 through 225503	PAST 202 PAST 230	PAST 210 and PAST 230 produce equivalent performance results
Vernier	All	All	All	All verniers reduced on same program

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TABLE 2

MA-2 BOOSTER PERFORMANCE DATA

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Remarks
112031	8-24-58	309,000	2.286	251.32	566.6	Expended
112032	10-2-58	309,000	2.265	253.10	567.0	Expended
112033	9-22-58	309,010	2.281	249.34	574.0	Expended
112034	9-9-58	308,990	2.267	253.30	563.6	Expended
112035	10-24-58	308,970	2.255	252.18	557.3	Expended
112036	9-12-61	308,910	2.268	249.89	571.3	Expended
112037	11-24-58	309,040	2.276	252.87	541.0	Expended
112038	9-23-61	309,020	2.273	250.74	541.4	Expended
112039	11-16-58	309,070	2.281	253.96	558.9	Expended
112040	1-1-59	309,000	2.262	250.51	572.4	
112041	11-15-58	308,990	2.272	252.24	566.9	Expended
112042	12-5-58	308,960	2.297	251.63	572.2	Expended
112043	11-28-58	309,030	2.275	251.02	576.2	
112044	12-15-58	309,020	2.269	251.44	566.8	Expended
112045	12-10-58	309,000	2.262	250.81	567.8	Expended
112046	12-4-58	308,980	2.281	250.82	550.4	Expended
112047	9-15-61	309,030	2.289	250.49	563.4	Expended
112048	12-13-58	309,030	2.253	249.53	574.7	Expended
112049	12-17-58	309,000	2.275	250.85	528.3	Expended
112050	12-30-58	308,950	2.286	251.50	545.7	
112051	12-23-58	308,990	2.271	249.50	570.2	Expended
112052	1-2-59	308,990	2.275	249.63	565.3	Expended
112053	1-6-59	309,030	2.280	249.95	561.5	
112054	1-9-59	308,990	2.271	250.14	544.8	Expended
112055	1-17-59	308,950	2.298	251.04	545.9	
112056	8-26-61	309,000	2.273	250.52	556.0	Expended
112057	5-24-62	309,000	2.288	249.90	565.0	
112058	2-2-59	308,950	2.276	250.95	555.6	Expended
112059	2-25-59	309,010	2.295	250.55	560.0	
112060	3-4-59	309,000	2.253	251.51	537.0	Expended
112061	2-20-59	309,020	2.265	249.69	552.6	Expended
112062	2-28-59	308,980	2.285	250.22	580.4	Expended
112063	3-25-59	308,980	2.256	251.70	560.4	

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TABLE 2
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Remarks
112064	3-30-59	309,000	2.291	251.38	558.6	Expended
112065	3-27-59	308,980	2.254	250.26	560.1	Expended
112066	3-18-59	308,970	2.273	251.38	547.0	Expended
112067	3-23-59	309,030	2.268	249.91	556.8	Expended
112068	3-27-59	309,030	2.279	250.44	554.9	Expended
112069	3-28-59	308,980	2.285	250.38	557.6	Expended
112070	3-24-59	308,990	2.277	250.29	551.7	Expended
112071	4-3-59	308,990	2.279	250.15	552.0	
112072	11-27-62	308,994	2.277	250.38	569.1	
112073	4-21-59	309,030	2.268	252.42	562.2	
112074	4-7-59	308,980	2.279	252.75	559.1	
112075	4-7-59	308,950	2.292	249.84	557.9	Expended
112076	4-27-59	309,010	2.269	252.49	559.0	Expended
112077	11-14-62	308,999	2.289	250.11	590.0	
112078	5-6-59	308,980	2.287	250.59	572.5	Expended
112079	5-20-59	308,960	2.280	250.89	571.9	Expended
112080	5-1-59	309,030	2.297	250.98	576.9	
112081	4-25-63	308,970	2.283	250.29	573.9	
112082	5-15-59	309,000	2.286	251.95	554.1	Expended
112083	5-21-59	309,000	2.273	251.40	567.4	
112084	7-2-59	309,000	2.276	252.06	567.2	Expended
112085	6-3-59	308,990	2.299	250.52	597.6	Expended
112086	6-4-59	309,000	2.270	251.74	579.6	Expended
112087	6-10-59	309,040	2.285	249.40	570.9	Expended
112088	6-15-59	309,010	2.292	250.19	569.5	Expended
112089	6-22-59	309,040	2.281	252.26	559.7	Expended
112090	6-12-59	309,000	2.269	249.80	590.9	Expended
112091	6-22-59	308,960	2.300	249.48	579.3	Expended
112092	6-25-59	308,980	2.300	251.69	562.6	Expended
112093	9-4-59	309,010	2.305	251.38	560.0	Expended
112094	7-7-59	309,020	2.274	250.28	560.1	Expended
112095	7-17-59	309,030	2.303	251.00	570.8	Expended
112096	7-22-59	309,000	2.284	251.13	558.2	
112097	7-15-59	309,000	2.304	250.48	564.5	Expended
112098	7-27-59	309,000	2.300	251.23	560.9	Expended
112099	7-28-59	309,020	2.298	250.70	548.1	

TABLE 2
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Remarks
112100	9-19-59	308,995	2.280	250.76	568.4	Expended
112101	7-30-59	308,999	2.273	250.79	562.6	Expended
112102	8-17-59	308,990	2.283	250.67	573.5	
112103	6-28-61	308,970	2.275	249.95	565.4	
112104	9-21-59	309,030	2.297	250.44	555.7	
112105	8-25-59	308,990	2.285	251.92	556.0	Expended
112106	8-27-59	308,757	2.291	250.67	567.4	Expended
112107	9-1-59	308,970	2.295	250.38	547.7	
112108	8-28-59	308,960	2.293	251.33	568.4	Expended
112109	9-2-59	309,010	2.295	251.11	556.6	Expended
112110	9-4-59	308,930	2.284	250.96	570.6	
112111	9-9-59	309,010	2.269	251.54	553.7	Expended
112112	9-14-59	309,000	2.308	251.33	558.3	
112113	9-21-59	308,910	2.264	252.12	544.4	Expended
112114	9-23-59	308,940	2.291	252.24	570.6	Expended
112115	9-25-59	308,970	2.286	251.75	562.7	
112116	9-29-59	309,000	2.272	251.02	562.2	
112117	10-5-59	308,980	2.297	251.19	551.0	
112118	12-17-62	308,953	2.263	249.60	583.2	
112119	10-14-59	309,020	2.296	251.37	545.0	Expended
112120	9-25-62	309,028	2.284	249.16	562.5	
112121	1-28-63	309,004	2.286	250.66	560.7	
112122	10-28-59	308,990	2.270	250.53	552.8	Expended
112123	11-17-59	309,010	2.278	250.64	553.6	Expended
112124	11-20-59	309,010	2.277	250.67	560.7	
112125	12-21-59	309,000	2.253	250.66	550.9	
112126	12-30-59	309,020	2.255	251.01	549.2	Expended
112127	1-4-60	309,000	2.262	251.38	566.2	
112128	1-7-60	309,020	2.284	251.37	569.2	
112129	1-11-60	308,990	2.284	251.68	545.2	Expended

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TABLE 2
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Remarks
112130	1-14-60	308,930	2.253	251.85	544.1	Expended
112131	2-18-60	308,990	2.296	252.06	552.4	Expended
112132	2-23-60	309,020	2.280	251.77	558.0	Expended
112133	2-25-60	308,980	2.269	251.00	568.7	Expended
112134	2-29-60	308,970	2.284	252.00	544.4	
112135	3-15-60	308,990	2.261	251.58	552.4	
112136	3-18-60	309,000	2.282	252.94	542.9	
112137	3-22-60	308,960	2.282	252.85	529.3	Expended
112138	3-24-60	308,990	2.284	253.30	554.6	
112139	3-29-60	309,020	2.273	252.81	560.0	Expended
112140	4-25-60	308,960	2.282	251.91	536.9	Expended
112141	4-27-60	309,010	2.254	251.48	548.9	Expended
112142	4-26-60	309,000	2.287	252.87	545.8	
112143	5-2-60	308,920	2.293	251.76	528.1	Expended
112144	5-10-60	309,000	2.284	252.13	533.0	Expended
112145	5-13-60	308,990	2.264	252.29	559.8	Expended
112146	6-28-60	309,000	2.279	253.22	550.3	Expended
112147	6-30-60	308,940	2.273	251.44	555.5	Expended
112148	7-5-60	308,960	2.278	252.15	555.2	Expended
112149	7-8-60	308,980	2.268	252.51	548.0	
112150	8-11-60	308,960	2.273	252.74	539.1	Expended
112151	8-16-60	309,000	2.282	251.34	555.4	
112152	8-23-60	309,040	2.302	252.32	530.4	Expended
112156	10-17-60	308,940	2.280	251.29	546.4	Expended
112157	10-31-60	309,050	2.270	252.53	542.4	Expended

TABLE 2
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Remarks
112501	12-2--59	308,960	2.290	250.52	549.4	Expended
112502	12-11-59	308,910	2.264	252.08	538.2	Expended
117001	3-7-61	308,980	2.264	251.32	542.0	Expended
117002	4-6-61	308,980	2.272	251.09	563.7	
117003	3-15-61	308,970	2.268	251.41	553.4	
117004	4-12-61	308,970	2.276	250.58	546.5	
117005	4-20-61	309,000	2.289	251.71	534.2	
117006	5-6-61	309,010	2.283	251.61	542.6	
117007	5-22-61	309,980	2.259	250.84	540.4	
117008	5-12-61	309,010	2.281	251.77	545.1	
117009	6-23-61	309,030	2.299	251.25	553.1	
117010	7-12-61	308,960	2.292	251.29	580.7	
117011	9-18-61	309,030	2.273	252.13	554.3	
117012	10-19-61	309,030	2.278	253.05	561.4	
117013	10-21-61	308,960	2.300	251.43	570.3	
117014	12-9-61	309,050	2.276	251.29	573.0	
117015	12-27-61	309,010	2.298	250.67	565.9	
117016	2-7-62	308,990	2.262	251.02	562.0	
117017	3-27-62	309,020	2.290	250.72	558.2	
117018	4-5-62	309,050	2.281	250.67	571.9	
117019	4-30-62	309,010	2.294	250.88	569.2	

TABLE 3

MA-2 SUSTAINER PERFORMANCE DATA

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
222031	8-24-58	57,000	214.9*				Expended
222032	9-9-58	57,000	214.9*			299	Expended
222033	10-3-58	57,000	214.9*				Expended
222034	5-6-62	57,000	214.7	823	27	297	Expended
222035	10-2-58	57,000	214.9*				Expended
222036	11-13-58	57,000	214.9*				Expended
222037	11-28-58	57,000	214.9*				Expended
222038	10-24-58	57,000	214.9*				Expended
222039	6-14-60	57,000	214.9*	800	23	297	
222040	9-13-60	57,000	214.9*			293	Expended
222041	11-15-58	57,000	214.9*				Expended
222042	3-8-60	57,000	214.9*			310	Expended
222043	3-4-60	57,000	214.9*			299	Expended
222044	12-4-59	57,000	214.9*				Expended
222045	12-15-58	57,000	214.9*				Expended
222046	12-18-58	57,000	214.9*	818	28	309	
222047	12-20-58	57,000	214.9*				Expended
222048	12-19-58	57,000	214.9*				Expended
222049	12-12-58	57,000	214.9*				Expended
222050	12-31-58	57,000	214.9*				Expended
222051	1-6-59	57,000	214.9*				Expended
222052	1-9-59	57,000	214.9*	797	25	312	
222053	1-16-59	57,000	214.9*	786	25	305	
222054	1-15-59	57,000	214.9*				Expended
222055	1-17-59	57,000	214.9*	784	24	316	
222056	8-19-61	57,000	214.6	799	28	302	Expended
222057	10-20-61	57,000	215.2	781	24	310	Expended
222058	3-7-59	57,000	214.9*				Expended
222059	2-10-59	57,000	214.9*				Expended

*Engine hot fired with thrust system bias. Nominal sea level specific impulse assumed.

TABLE 3
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
222060	2-11-59	57,000	214.9*	793	28	293	
222061	3-14-59	57,000	214.9*				Expended
222062	3-16-59	57,000	214.9*				Expended
222063	3-24-59	57,000	214.9*	826	13	302	
222064	3-21-59	57,000	214.9*	787	26	301	
222065	3-10-59	57,000	214.9*				Expended
222066	4-13-59	57,000	214.9*				Expended
222067	3-20-59	57,000	214.9*				Expended
222068	3-28-59	57,000	214.9*				Expended
222069	4-16-59	57,000	214.9*				Expended
222070	3-31-59	57,000	214.9*				Expended
222071	12-22-62	57,000	215.3	810	25	312	
222072	4-10-59	57,000	214.9*	794	27	305	Expended
222073	9-15-61	57,000	213.2	787	25	293	
222074	5-1-59	57,000	214.9*	794	13	317	
222075	4-23-59	57,000	214.9*				Expended
222076	4-14-59	57,000	214.9*				Expended
222077	10-18-62	57,000	214.7	836	29	298	
222078	4-22-59	57,000	214.9*	776	24		Expended
222079	4-24-59	57,000	214.9*				Expended
222080	4-30-59	57,000	214.9*			326	Expended
222081	5-25-59	57,000	214.9*	821	28	314	
222082	4-29-59	57,000	214.9*				Expended
222083	8-12-62	57,000	214.6	840	28	330	
222084	5-6-59	57,000	214.9*				Expended
222085	5-11-59	57,000	214.9*				Expended
222086	5-13-59	57,000	214.9*				Expended
222087	12-4-62	57,000	214.02	825	29	316	
222088	6-5-59	57,000	214.9*				Expended
222089	6-4-59	57,000	214.9*	844	27	335	Expended

*Engine hot fired with thrust system bias. Nominal sea level specific impulse assumed.

TABLE 3
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
222090	6-10-59	57,000	214.9*				Expended
222091	6-15-59	57,000	214.9*				Expended
222092	6-16-59	57,000	214.9*				Expended
222093	6-24-59	57,000	214.9*				Expended
222094	7-17-59	57,000	214.9*			340	Expended
222095	7-16-59	57,000	214.9*			313	Expended
222096	9-17-59	57,000	214.9*				Expended
222097	7-20-59	57,000	214.9*	830	25	322	
222098	7-23-59	57,000	214.9*				Expended
222099	8-24-62	57,000	214.9	850	25	300	
222100	7-27-59	57,000	214.9*			315	Expended
222101	7-29-59	57,000	214.9*			325	Expended
222102	9-22-59	57,000	214.9*	810	28	333	
222103	10-9-61	57,000	214.4	822	30	325	
222104	9-9-62	57,000	214.1	821	30	294	
222105	9-8-59	57,000	214.9*			327	Expended
222106	8-25-59	57,000	214.9*				Expended
222107	9-10-59	57,000	214.9*	814	25	299	
222108	9-15-59	57,000	214.9*				Expended
222109	10-2-59	57,000	214.9*				Expended
222110	10-30-59	57,000	214.9*	822	25	312	
222111	10-2-59	57,000	214.9*				Expended
222112	10-6-59	57,000	214.9*	844	25	325	
222113	10-14-59	57,000	214.9*	807	26	318	
222114	10-16-59	57,000	214.9*				Expended
222115	11-10-59	57,000	214.9*				Expended
222116	10-23-59	57,000	214.9*	818	25	294	
222117	10-28-59	57,000	214.9*	808	27	299	
222118	7-14-61	57,000	215.4	845	25	304	
222119	11-11-59	57,000	214.9*				Expended

*Engine hot fired with thrust system bias.
Nominal sea level specific impulse assumed.

TABLE 3
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
222120	11-2-62	57,000	215.9	830	13	309	
222121	10-17-59	57,000	214.9*				Expended
222122	12-16-59	57,000	214.9*	821	25	304	
222123	12-14-59	57,000	214.9*				Expended
222124	12-16-59	57,000	214.9*				Expended
222125	12-18-59	57,000	214.9*	842	27	309	
222126	1-6-60	57,000	214.9*				Expended
222127	1-7-60	57,000	214.9*	814	28	304	
222128	2-12-60	57,000	214.9*	822	30	298	
222129	1-28-60	57,000	214.9*				Expended
222130	2-16-60	57,000	214.9*				Expended
222131	11-21-62	57,000	213.6	869	29	295	
222132	1-29-63	57,000	212.9	856	28	288	
222133	3-11-60	57,000	214.9*				Expended
222134	3-7-60	57,000	214.9*	850	25	289	
222135	2-24-60	57,000	214.9*	838	26	295	
222136	3-17-60	57,000	214.9*	828	24	298	
222137	3-23-60	57,000	214.9*	843	26	304	
222138	3-25-60	57,000	214.9*	852	30	305	
222139	5-4-60	57,000	214.9*				Expended
222140	4-6-60	57,000	214.9*				Expended
222141	4-14-60	57,000	214.9*				Expended
222142	4-15-60	57,000	214.9*				Expended
222143	5-5-60	57,000	214.9*				Expended
222144	5-18-60	57,000	214.9*				Expended
222145	6-2-60	57,000	214.9*				Expended
222146	6-3-60	57,000	214.9*				Expended
222147	6-22-60	57,000	214.9*				Expended
222148	8-11-60	57,000	214.9*				Expended
222149	1-30-62	57,000	214.0	836	26	298	

*Engine hot fired with thrust system bias.
Nominal sea level specific impulse assumed.

TABLE 3
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
222150	8-3-60	57,000	214.9*				Expended
222151	8-9-60	57,000	214.9*	847	26	306	
222152	8-25-60	57,000	214.9*				Expended
222156	10-20-60	57,000	214.9*				Expended
222157	10-24-60	57,000	214.7	806	26	306	Expended
222501	11-13-59	57,000	214.9*				Expended
222502	12-8-59	57,000	214.9*	836	30	303	
227001	2-28-61	57,000	214.2	820	25	333	
227002	3-8-61	57,000	214.2	831	24	304	Expended
227003	4-10-61	57,000	214.7	829	26	320	Expended
227004	5-3-61	57,000	215.46	825	27	303	
227005	4-5-61	57,000	213.2	821	13	301	Expended
227006	4-27-61	57,000	214.7	834	13	314	Expended
227007	5-17-61	57,000	214.9	825	12	314	Expended
227008	5-19-61	57,000	215.58	829	11	304	Expended
227009	6-22-61	57,000	213.3	836	14	303	
227010	7-26-61	57,000	214.7	835	14	278	
227011	9-1-61	57,000	215.3	831	14	303	
227012	10-14-61	57,000	215.62	805	15	321	
227013	11-2-61	57,000	214.2	828	14	303	
227014	12-17-61	57,000	215.12	819	14	294	
227015	2-19-61	57,000	215.6	846	11	297	
227016	1-25-62	57,000	213.71	820	14	291	
227017	2-27-62	57,000	214.85	833	11	301	
227018	5-2-62	57,000	213.73	834	13	310	Expended
227019	5-21-62	57,000	214.71	815	14	305	

*Engine hot fired with thrust system bias.
Nominal sea level specific impulse assumed.

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	No. 1 Thrust Chamber		
						LOX Flow- rate, lb/sec	Fuel Flow- rate, lb/sec	Injecto End Pressur psia
112116*	10-23-59	309,004	2.272	251.02	562.2	426.7	179.3	542.4
112149*	7-8-60	308,986	2.267	252.51	548.0	417.65	175.1	540.7
112151*	8-16-60	309,014	2.283	251.34	553.1	421.3	176.1	537.0
112156*	10-17-60	309,017	2.280	251.29	546.4	422.9	178.4	544.2
115101	9-23-60	309,016	2.300	251.46	554.6	424.9	175.9	545.7
115102	9-22-60	308,970	2.278	251.26	539.0	426.7	176.5	540.8
115103	12-21-60	309,023	2.301	251.70	540.5	420.9	176.4	547.5
115104	11-30-60	309,020	2.265	251.69	541.8	420.6	177.2	544.4
115105	12-6-60	308,990	2.261	251.40	547.8	424.6	179.0	550.5
115106	1-4-61	309,021	2.275	251.50	551.5	424.3	179.4	547.4
115107	1-31-61	309,054	2.278	251.84	547.9	423.0	178.7	544.8
115108	2-6-61	309,020	2.267	251.56	555.6	424.9	179.7	546.2
115109	2-21-61	309,022	2.268	251.93	561.0	423.6	178.5	546.5
115110	2-27-61	308,998	2.280	251.60	561.6	423.9	177.9	541.3
115111	3-2-61	308,993	2.265	251.04	563.9	422.6	179.6	544.3
115112	4-23-61	308,972	2.260	251.86	547.7	417.3	177.4	535.5
115113	4-25-61	309,019	2.282	251.15	542.1	426.8	179.1	538.9
115114	5-27-61	309,039	2.267	251.18	554.1	422.0	179.1	544.6
115115	6-5-61	309,027	2.272	250.96	550.6	420.9	177.7	534.7
115116**								
115117**								
115118	7-21-61	309,050	2.302	252.29	563.9	422.4	174.6	541.3
115119**								
115120	8-22-61	309,045	2.297	251.61	561.7	427.5	175.8	542.4
115121	8-23-61	309,005	2.283	252.13	560.7	424.0	176.0	541.6
115122	9-5-61	308,993	2.285	251.22	584.8	422.4	175.7	543.7
115123	3-1-63	308,910	2.275	250.40	584.9	420.7	179.8	544.1
115124	2-14-63	309,028	2.289	250.54	589.0	433.9	180.5	553.3

R-5108-1

*MA-2 used for space application

**Error in input. New log to be released when completed.

2

TABLE 4

MA-5 BOOSTER PERFORMANCE DATA

1 Thrust Chamber			No. 2 Thrust Chamber			Gas Generator			No. 1 Turbopump Speed, rpm	No. 2 Turbopump Speed, rpm	Remarks
Fuel Flow-rate, lb/sec	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia				
179.3	542.4	421.6	178.1	539.6	6.41	18.91	471.9	5989	6108		
175.1	540.7	425.1	179.4	550.1	6.40	20.04	470.1	6037	6124		
176.1	537.0	427.4	179.6	550.2	6.23	18.91	460.6	6064	6226		
178.4	544.2	425.4	177.9	546.2	6.39	18.63	464.9	5995	6152		
175.9	545.7	425.1	177.9	546.4	6.39	18.86	465.0	6061	6509		
176.5	540.8	421.7	180.9	548.4	6.14	17.84	456.5	6034	5986	Expended	
176.4	547.5	428.6	177.2	551.3	6.24	18.36	463.2	6093	6133	Expended	
177.2	544.4	424.8	180.2	549.4	6.32	18.71	465.1	6072	6087	Expended	
179.0	550.5	421.6	179.5	547.9	6.19	18.53	467.6	5986	6095	Expended	
179.4	547.4	422.8	176.1	546.9	6.37	19.72	470.5	6024	6052	Expended	
178.7	544.8	423.4	176.8	545.6	6.44	18.88	466.4	6084	6015	Expended	
179.7	546.2	421.1	177.5	544.5	6.42	18.84	466.2	6185	6063	Expended	
178.5	546.5	421.2	177.8	545.9	6.48	19.13	476.1	6111	6070		
177.9	541.3	423.4	177.2	544.4	6.48	19.24	472.7	6108	6094	Expended	
179.6	544.3	424.7	178.3	547.9	6.47	19.20	477.9	6081	6128	Expended	
177.4	535.5	426.8	180.2	546.0	6.27	18.78	463.3	6090	6104	Expended	
179.1	538.9	422.4	177.3	537.8	6.30	18.62	464.7	6055	6029		
179.1	544.6	425.3	179.4	546.8	6.37	18.21	467.4	6102	6093		
177.7	534.7	427.8	180.5	550.3	6.31	18.11	462.0	6049	6120	Expended	
174.6	541.3	425.0	178.0	552.3	6.62	18.41	479.3	6050	6061	Expended	
175.8	542.4	421.6	178.3	545.0	6.58	18.49	480.6	6059	6085		
176.0	541.6	421.9	179.2	550.2	6.47	18.10	475.2	6036	6063	Expended	
175.7	543.7	426.7	181.0	552.0	6.47	17.81	499.4	6019	6134	Expended	
179.8	544.1	429.4	178.1	552.3	6.81	18.89	490.8	6102	6113		
180.5	553.3	417.7	176.1	539.2	6.80	18.07	494.4	6139	6061		

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TABLE 4
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	No. 1 Thrust Chamber			F r 1
						LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia	
115125	1-22-63	308,999	2.275	251.62	595.9	432.5	178.6	550.0	4
115126	2-4-63	308,970	2.267	250.66	585.7	424.3	178.2	545.4	4
115127	11-9-61	309,000	2.287	250.98	581.8	426.0	178.2	542.1	4
115128	2-25-63	308,988	2.279	250.29	579.2	426.3	176.3	544.1	4
115129**									
115130**									
115131	12-13-61	308,987	2.289	251.21	570.5	423.4	180.3	544.7	4
115132	1-4-62	308,976	2.294	251.45	572.0	428.1	177.4	549.1	4
115133	1-29-62	308,996	2.286	251.89	550.7	426.4	177.4	548.2	4
115134	2-2-62	308,960	2.282	252.01	573.3	422.8	177.8	548.2	4
115135	3-4-62	309,039	2.268	250.77	554.1	425.1	179.2	548.4	4
115136	3-13-62	309,022	2.261	250.31	566.1	423.8	178.9	545.0	4
115137	3-15-62	308,995	2.291	250.61	565.5	425.1	178.3	548.6	4
115138	3-20-62	308,965	2.279	250.95	573.1	420.2	176.9	544.6	4
115139	3-23-62	309,018	2.260	250.73	569.8	421.7	180.2	545.8	4
115140	3-27-62	309,018	2.295	250.41	570.9	431.4	179.6	553.7	4
115141	4-21-62	308,959	2.267	250.07	582.1	425.3	179.4	546.3	4
115142	4-25-62	308,954	2.272	250.10	570.2	426.5	178.8	547.2	4
115143	5-7-62	309,018	2.287	251.14	550.1	420.8	177.1	541.5	4
115144	5-25-62	308,971	2.268	250.50	565.3	422.1	178.5	541.4	4
115145	5-16-62	308,983	2.280	250.72	561.8	423.1	178.2	539.1	4
115146	5-22-62	308,995	2.277	250.78	564.4	423.7	177.7	543.7	4
115147	6-7-62	308,993	2.286	251.30	562.3	425.3	177.2	547.9	4
115148	6-12-62	309,004	2.274	249.88	564.9	424.0	178.2	539.8	4
115149	7-12-62	309,022	2.274	249.70	563.1	425.2	180.9	545.2	4
115150	7-14-62	308,989	2.286	250.57	560.6	425.2	179.3	542.0	4
115151	7-18-62	308,977	2.273	248.85	569.5	427.7	180.7	541.4	4
115152	8-2-62	309,000	2.278	250.80	559.9	423.2	179.1	542.8	4
115153	8-8-62	308,972	2.269	249.52	558.3	425.6	180.3	543.3	4
115154	9-8-62	308,983	2.291	249.91	564.5	426.2	179.7	541.5	4

TABLE 4
(Continued)

2

Chamber	No. 2 Thrust Chamber			Gas Generator			No. 1 Turbopump Speed, rpm	No. 2 Turbopump Speed, rpm	Remarks
	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec			
550.0	413.5	176.5	540.7	7.02	19.95	505.5	6145	6035	
545.4	424.3	180.4	551.7	6.81	18.67	493.7	6103	6155	
542.1	423.9	177.7	543.9	6.82	18.71	489.2	6059	6001	Expended
544.1	424.8	181.2	554.0	6.87	19.01	492.0	6074	6079	
544.7	426.1	175.6	550.2	6.45	18.11	473.6	6063	6029	Expended
549.1	421.1	176.5	544.7	6.63	19.12	479.2	6098	6023	Expended
548.2	420.4	176.8	545.7	6.57	19.14	475.8	6080	5992	Expended
548.2	423.0	176.4	544.7	6.64	19.34	482.0	6110	6043	Expended
548.4	423.7	179.7	547.0	6.43	18.67	476.9	6075	6087	Expended
545.0	425.6	181.1	551.1	6.63	18.74	481.1	6099	6130	Expended
548.6	426.7	177.8	546.1	6.42	18.64	475.6	6052	6051	
544.6	429.0	180.0	551.5	6.61	18.65	482.2	6067	6127	
545.8	426.2	178.9	549.2	6.57	18.94	486.7	6110	6113	
553.7	421.5	176.0	538.0	6.67	18.98	492.9	6126	6009	
546.3	425.3	179.1	546.2	6.66	19.7	491.3	6159	6129	Expended
547.2	424.7	179.2	545.4	6.56	19.54	486.4	6119	6074	
541.5	428.9	178.0	547.7	6.39	19.32	467.4	6048	6000	
541.4	427.3	179.8	548.4	6.53	19.19	477.9	6096	6075	Expended
539.1	427.1	178.3	545.7	6.47	19.32	473.2	6090	6030	
543.7	425.9	178.8	544.7	6.51	19.46	477.9	6075	6037	
547.9	423.6	177.9	543.1	6.46	19.17	474.4	6094	6006	
539.8	428.3	180.0	548.4	6.62	19.56	477.4	6108	6069	Expended
545.2	427.8	178.3	547.8	6.58	18.86	476.0	6107	6066	Expended
542.0	426.2	177.0	547.0	6.53	18.95	472.2	6077	6046	
541.4	428.0	179.5	549.4	6.63	19.08	482.0	6114	6015	Expended
542.8	426.5	177.8	550.2	6.53	18.93	475.2	6065	6038	
543.3	427.3	179.5	549.8	6.57	18.92	474.6	6073	6049	
541.5	428.0	176.8	551.6	6.55	19.12	477.7	6103	6030	Expended

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TABLE 4
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	No. 1 Thrust Chamber			Inlet Fuel Pressure, psia
						LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia	
115155	9-13-62	308,972	2.259	250.68	553.2	420.4	177.1	535.1	42
115156	9-15-62	308,992	2.297	251.21	553.5	422.4	176.6	539.6	42
115157	9-17-62	309,004	2.272	251.84	552.3	425.2	176.6	542.5	42
115158	9-28-62	308,998	2.269	249.57	570.6	430.4	180.9	548.4	42
115159	10-31-62	308,987	2.276	249.23	563.9	424.9	178.8	538.1	42
115160	11-13-62	308,994	2.267	250.55	570.3	427.7	180.5	543.9	42
115161	1-15-63	308,992	2.291	251.75	552.9	427.4	178.2	543.2	42
115162	12-10-62	308,954	2.292	250.12	566.6	428.9	175.8	544.2	42
115163**	1-18-63								
115164**	1-25-63								
115165**	2-6-63								
115166	11-19-62	308,957	2.269	249.74	568.7	428.1	179.9	544.7	42
115167	2-7-63	308,997	2.281	250.94	560.5	424.9	177.6	543.7	42
115168**	3-7-63								
115169**	4-1-63								
115170**	4-23-63								
115501	7-23-61	309,000	2.250	250.94	564.9	429.0	181.7	551.4	41
115502	7-25-61	309,017	2.303	250.52	564.1	425.7	177.9	541.5	42
115503	8-9-61	308,987	2.295	251.18	564.2	428.0	176.3	542.0	42

** Error in input. New log to be released when completed.

TABLE 4
(Continued)

2

No. 1 Thrust Chamber		No. 2 Thrust Chamber			Gas Generator			No. 1 Turbopump Speed, rpm	No. 2 Turbopump Speed, rpm	Remarks
Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia				
535.1	427.5	181.7	554.6	6.49	19.44	476.5	6022	6073		
539.6	428.1	177.0	553.2	6.49	19.46	476.1	6038	6028		
542.5	420.3	179.0	550.9	6.54	19.41	477.3	6073	5952		
548.4	422.3	177.5	549.6	6.67	20.32	491.8	6053	6126		
538.1	429.8	180.2	550.8	6.53	19.50	472.2	6056	6079		
543.9	421.4	178.0	543.2	6.67	19.00	476.6	6146	6079		
543.2	420.5	175.9	544.6	6.54	18.96	474.3	6048	6014		
544.2	424.5	179.8	548.6	6.66	19.70	481.7	6134	6096		
544.7	424.0	179.4	545.9	6.66	19.19	477.7	6060	6056		
543.7	424.6	179.3	547.2	6.50	18.51	470.9	6030	5905		
551.4	417.1	178.5	544.9	6.42	18.57	491.8	6065	6033		
541.5	427.9	176.9	547.1	6.59	18.56	477.7	6036	6018		
542.0	422.3	178.8	546.7	6.54	18.32	480.9	6065	6052		

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TABLE 5

MA-5 SUSTAINER PERFORMANCE

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Thrust Chamber		
						LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Inj. Pres. ps
222116*	10-23-59	57,000	2.270	214.9**	818.0			
222149*	1-30-62	57,000	2.270	213.96	835.8	183.3	73.0	70
222151*	8-9-60	57,000	2.270	214.9**	847.0			
222156*	10-20-60	57,000	2.270	214.65	794.9	182.9	73.9	70
225501	6-21-62	57,000	2.270	215.27	832.4	182.2	72.7	70
225502	8-11-62	57,000	2.270	214.9**	815.6			
225503	10-3-62	57,000	2.270	214.19	831.0	183.4	74.6	69
225101	2-8-61	57,000	2.270	215.45	831.4	182.1	72.7	70
225102	9-13-60	57,000	2.270	217.21	829.3	180.6	71.6	70
225103	12-21-60	57,000	2.270	216.03	827.4	181.7	72.4	70
225104	11-14-60	57,000	2.270	215.60	847.2	181.9	72.5	7
225105	11-18-60	57,000	2.270	216.20	833.7	181.4	72.3	70
225106	2-16-61	57,000	2.270	216.50	829.6	181.1	71.9	70
225107	2-9-61	57,000	2.270	215.56	823.0	182.0	72.5	69
225108	2-17-61	57,000	2.270	213.48	831.9	183.4	73.6	69
225109	1-24-61	57,000	2.270	214.65	826.6	182.7	73.3	7
225110	2-24-61	57,000	2.270	214.41	823.0	183.0	73.6	69
225111	3-9-61	57,000	2.270	213.97	827.0	182.6	73.4	69
225112	4-22-61	57,000	2.270	214.38	838.5	183.2	73.4	70
225113	4-28-61	57,000	2.270	216.59	822.0	181.1	72.7	69
225114	7-10-61	57,000	2.270	215.24	816.7	182.2	73.3	6
225115	6-20-61	57,000	2.270	215.04	831.2	182.5	73.3	70
225116	7-6-61	57,000	2.270	216.44	820.6	181.3	72.9	70
225117	7-18-61	57,000	2.270	215.06	829.3	182.5	73.4	7
225118	7-22-61	57,000	2.270	216.29	840.8	181.0	72.1	70
225119	8-4-61	57,000	2.270	213.29	833.3	183.7	73.5	69
225120	8-15-61	57,000	2.270	215.75	824.1	181.8	73.0	70

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*MA-2 used for space application

**Engine hot fired with thrust system bias. Nominal sea level specific impulse assumed

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TABLE 5

STAINER PERFORMANCE DATA

Thrust Chamber		Gas Generator			Turbopump Speed, rpm	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
Fuel Flow-rate, lb/sec	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia				
73.0	700.5	2.19	7.79	667.8	10176	24	300	
						26	298	
						24	302	
73.9	706.3	2.04	6.75	731.8	10078	29	314	Expended
72.7	700.7	2.13	7.70	766.9	10071	14	299	Expended
						13	294	
74.6	697.7	1.93	6.23	729.3	10186	12	302	
72.7	701.3	2.13	7.69	765.7	10023	24	299	
71.6	703.3	2.14	8.07	760.8	10104	24	291	Expended
72.4	700.6	2.18	7.60	768.5	10073	25		Expended
72.5	707.5	2.22	7.81	778.2	10122	26	299	Expended
72.3	706.0	2.20	7.80	769.2	10104	24	308	Expended
71.9	703.4	2.21	8.04	763.6	10114	28	306	Expended
72.5	697.9	2.12	7.85	758.5	10120	26		Expended
73.6	699.2	2.15	7.82	758.4	10147	30	303	Expended
73.3	706.9	2.08	7.53	764.1	10212	30	303	Expended
73.6	698.5	2.04	7.34	746.9	10064	28		Expended
73.4	698.7	2.15	7.54	761.7	10175	25	314	Expended
73.4	702.1	2.22	7.66	766.4	10125	16	302	Expended
72.7	699.6	2.10	7.23	758.8	10172	16	298	
73.3	697.8	2.11	7.25	750.1	10196	16	292	Expended
73.3	701.9	2.11	7.16	754.6	10224	15	323	Expended
72.9	700.5	2.06	7.16	749.6	10125	16	300	
73.4	708.3	2.12	7.29	752.1	10291	15	302	
72.1	700.8	2.30	8.07	779.6	10168	15	299	Expended
73.5	698.0	2.24	7.76	778.7	10268	16	296	
73.0	703.1	2.17	7.28	758.6	10248	14	296	Expended

else assumed

TABLE 5
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Thrust Chamber		
						LOX Flow- rate, lb/sec	Fuel Flow- rate, lb/sec	Inj Pre P
225121	8-23-61	57,000	2.270	214.27	819.6	183.1	73.6	7
225122	9-2-61	57,000	2.270	215.85	814.5	181.6	72.0	7
225123	4-10-61	57,000	2.270	214.22	822.0	183.1	73.4	7
225124	10-21-61	57,000	2.270	213.72	828.3	183.5	73.7	7
225125	11-15-61	57,000	2.270	215.01	827.2	182.4	72.9	7
225126	11-14-61	57,000	2.270	214.32	830.9	182.9	73.1	7
225127	11-21-61	57,000	2.270	214.11	842.0	183.1	73.6	7
225128	11-17-61	57,000	2.270	214.03	820.6	183.2	73.0	7
225129	12-18-61	57,000	2.270	215.35	799.5	182.1	72.9	7
225130	12-4-61	57,000	2.270	214.04	829.9	183.2	73.4	7
225131	2-17-62	57,000	2.270	215.61	815.4	182.1	73.3	7
225132	2-16-62	57,000	2.270	215.29	832.3	182.1	73.2	7
225133	1-20-62	57,000	2.270	214.26	820.9	183.0	73.3	7
225134	1-27-62	57,000	2.270	215.60	812.5	181.9	72.6	7
225135	2-13-62	57,000	2.270	215.81	826.1	181.7	72.6	7
225136	2-28-62	57,000	2.270	214.75	836.0	182.4	72.9	7
225137	3-8-62	57,000	2.270	213.97	808.6	183.4	73.5	7
225138	4-16-62	57,000	2.270	214.75	808.2	182.7	73.1	7
225139	4-5-62	57,000	2.270	213.85	821.8	183.5	73.4	7
225140	4-9-62	57,000	2.270	213.89	817.0	183.4	73.5	7
225141	4-12-62	57,000	2.270	214.12	838.7	183.0	72.9	7
225142	4-26-62	57,000	2.270	214.81	826.8	182.7	73.0	7
225143	5-21-62	57,000	2.270	214.43	811.4	183.0	73.3	7
225144	5-24-62	57,000	2.270	214.93	816.9	182.6	73.0	7
225145	5-17-62	57,000	2.270	212.89	836.6	184.3	73.7	7
225146	5-18-62	57,000	2.270	213.94	808.3	183.5	73.7	7
225147	6-18-62	57,000	2.270	212.91	815.2	184.4	74.1	7
225148	6-5-62	57,000	2.270	214.66	815.3	182.7	73.1	7

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TABLE 5
(Continued)

Thrust Chamber			Gas Generator			Turbopump Speed, rpm	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia				
83.1	73.6	712.6	2.13	7.54	739.2	10192	17	313	Expended
81.6	72.0	707.7	2.24	8.27	758.6	10067	14	310	Expended
83.1	73.4	711.6	2.13	7.53	749.3	10178	17	310	Expended
83.5	73.7	711.9	2.12	7.29	751.5	10207	15	312	
82.4	72.9	706.4	2.17	7.60	759.9	10203	12	315	Expended
82.9	73.1	708.8	2.22	7.74	760.7	10198	13		Expended
83.1	73.6	716.0	2.22	7.31	775.2	10293	14	308	
83.2	73.0	716.0	2.24	7.94	762.3	10101	18	308	
82.1	72.9	700.1	2.09	7.54	737.2	10041	14	290	
83.2	73.4	704.5	2.12	7.49	758.6	10073	13	306	
82.1	73.3	705.8	2.02	7.10	748.6	10116	14	295	
82.1	73.2	706.7	2.14	7.32	768.4	10171	17		Expended
83.0	73.3	702.9	2.09	7.41	752.5	10089	12		Expended
81.9	72.6	708.2	2.15	7.73	754.6	10141	13	303	Expended
81.7	72.6	709.3	2.18	7.74	769.7	10118	12	294	
82.4	72.9	722.0	2.09	7.39	742.5	10061	12	294	Expended
83.4	73.5	721.2	2.09	7.39	742.5	10080	14	293	
82.7	73.1	706.2	2.13	7.54	742.5	10113	14	301	
83.5	73.4	706.8	2.11	7.34	747.6	10058	14	305	
83.4	73.5	704.7	2.10	7.50	740.5	9991	11	311	
83.0	72.9	706.7	2.25	7.96	773.0	10104	14	307	Expended
82.7	73.0	710.0	2.11	7.57	754.5	10027	16	302	
83.0	73.3	707.8	2.07	7.42	757.7	9997	11	297	
82.6	73.0	716.3	2.10	7.58	751.4	9991	13	299	Expended
84.3	73.7	707.0	2.18	7.71	772.8	10171	12	298	
83.5	73.7	712.9	2.06	7.26	752.4	10026	17	298	
84.4	74.1	704.4	2.02	7.15	747.1	10091	16	305	
82.7	73.1	705.0	2.35	7.48	759.8	10045	12	309	Expended

TABLE 5
(Continued)

Engine S/N	Final Acceptance Test Date	Thrust, pounds	Mixture Ratio	Specific Impulse, seconds	LOX Regulator Reference Pressure, psig	Thrust Chamber	
						LOX Flow- rate, lb/sec	Fuel Flow- rate, lb/sec
225149	6-6-62	57,000	2.270	214.83	821.3	182.6	73.2
225150	7-23-62	57,000	2.270	214.86	822.8	182.5	73.3
225151	7-27-62	57,000	2.270	215.28	815.3	182.2	73.5
225152	12-10-62	57,000	2.270	214.09	812.1	183.4	73.9
225153	8-14-62	57,000	2.270	215.20	841.7	182.2	73.3
225154	8-17-62	57,000	2.270	214.88	827.3	182.8	73.4
225155	9-11-62	57,000	2.270	214.57	832.1	182.6	73.3
225156	11-7-62	57,000	2.270	213.65	823.5	183.7	73.8
225157	10-23-62	57,000	2.270	214.57	811.6	183.0	73.5
225158	1-18-63	57,000	2.270	213.44	812.2	184.0	74.0
225159	10-4-62	57,000	2.270	213.15	819.6	184.2	73.7
225160	1-14-63	57,000	2.270	214.08	822.1	183.1	73.5
225161	1-10-63	57,000	2.270	213.29	837.7	183.9	74.4
225162	11-19-62	57,000	2.270	212.94	812.4	184.5	74.7
225163	1-24-63	57,000	2.270	213.66	826.2	183.6	73.5
225164	2-6-63	57,000	2.270	213.94	821.2	183.5	73.9
225165	2-22-63	57,000	2.270	213.96	822.6	183.4	74.2
225166	2-4-63	57,000	2.270	214.92	828.3	182.6	73.4
225167	2-15-63	57,000	2.270	213.50	817.0	183.8	73.8
225168	3-28-63	57,000	2.270	213.57	826.9	183.7	74.2
225169	4-2-63	57,000	2.270	213.23	828.5	183.9	74.3
225170	4-12-63	57,000	2.270	213.76	825.8	183.5	74.8
225171	4-17-63	57,000	2.270	213.74	821.5	183.6	75.7
225172	5-29-63	57,000	2.270	215.02	814.6	182.5	73.8
225173							
225174	7-3-63	57,000	2.270	214.94	807.2	182.5	73.9

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TABLE 5
(Continued)

Thrust Chamber			Gas Generator			Turbopump Speed, rpm	Minimum LOX Net Positive Suction Head, feet	Estimated Engine Duration Capability, seconds	Remarks
Fuel Flow-rate, lb/sec	Injector End Pressure, psia	LOX Flow-rate, lb/sec	Fuel Flow-rate, lb/sec	Injector End Pressure, psia					
6	73.2	702.1	2.11	7.53	751.3	9986	13	298	Expended
5	73.3	706.4	2.09	7.43	762.1	10127	15	298	
2	73.5	708.0	2.04	7.05	749.7	10100	11	302	Expended
4	73.9	699.5	2.02	6.88	737.7	10162	12	299	
2	73.3	712.0	2.12	7.22	771.8	10169	10	300	
8	73.4	704.0	2.04	7.12	747.2	10173	13	306	
6	73.3	702.6	2.09	7.49	761.8	10207	15	306	Expended
7	73.8	706.6	2.06	7.29	746.5	9975	10	314	
0	73.5	699.6	2.04	7.13	736.1	10120	16	288	
0	74.0	704.4	2.02	7.04	740.5	10170	12	284	
2	73.7	703.5	2.12	7.40	747.3	10112	13	313	
1	73.5	700.9	2.14	7.51	762.1	10080	13	322	
9	74.4	702.3	2.07	6.87	753.6	10233	10	306	
5	74.7	704.6	1.95	6.58	733.2	10144	11	300	
6	73.5	703.3	2.13	7.57	750.7	10090	13	282	
5	73.9	705.1	2.02	7.01	737.2	10262	11	306	
4	74.2	703.4	1.99	6.82	738.8	10065	17	293	
6	73.4	709.4	2.07	7.23	751.1	10090	11	303	
8	73.8	707.3	2.06	7.25	738.2	10045	12	295	
7	74.2	706.1	2.07	7.09	758.1	10098	12	310	
9	74.3	704.2	2.08	7.10	762.3	10114	11	296	
5	74.8	702.2	2.02	6.41	743.4	10199	12	323	
6	75.7	705.2	2.00	6.58	747.4	10082		291	
2.5	73.8	708.0	1.97	6.80	735.8	10131		281	
2.5	73.9	700.2	1.99	6.73	731.9	10008		299	

TABLE 6

MA-5 VERNIER PERFORMANCE DATA

Engine S/N	Final Acceptance Test Date	Tank-Fed Injector End Pressure, psia	Pump-Fed Injector End Pressure, psia	Remarks
335201				Expended
335202				Expended
335203		307	358	
335204	5-18-62	305	355	Expended
335205	1-31-61	300	357	Expended
335206	4-19-62	304	355	
335207	5-4-62	304	360	
335208	5-17-62	303	355	
335209	1-10-61	304	354	
335210				Expended
335211	5-24-62	307	362	
335212	1-18-61	303	357	Expended
335213	1-19-61	302	356	
335214	1-26-61	303	358	Expended
335215	4-17-62	303	357	
335216	2-15-61	303	358	
335217	2-16-61	304	358	
335218	2-17-61	306	359	
335219	5-25-62	302	352	
335220	4-3-61	301	358	Expended
335221	3-31-61	301	355	Expended
335222	4-1-61	301	354	Expended
335223	4-7-61	302	356	Expended
335224	4-25-61	303	357	
335225	5-3-61	302	359	
335226	5-4-61	303	359	
335227	6-2-61	304	359	Expended
335228	6-6-61	304	359	Expended
335229	6-7-61	305	360	Expended

TABLE 6

(Continued)

Engine S/N	Final Acceptance Test Date	Tank-Fed Injector End Pressure, psia	Pump-Fed Injector End Pressure, psia	Remarks
335230	6-7-61	305	360	Expended
335231	6-15-61	303	356	Expended
335232	6-14-61	303	356	Expended
335233	7-6-61	303	356	
335234	7-6-61	302	356	
335235	7-13-61	302	357	Expended
335236	7-18-61	303	359	Expended
335237	7-18-61	299	352	Expended
335238	7-25-61	303	354	Expended
335239	7-26-61	302	353	Expended
335240	8-3-61	302	354	Expended
335241	8-7-61	299	350	Expended
335242	8-9-61	303	354	Expended
335243	8-10-61	302	355	Expended
335244	9-5-61	302	356	Expended
335245	9-14-61	303	358	
335246	9-14-61	306	358	
335247	10-10-61	300	353	
335248	10-14-61	303	356	
335249	10-13-61	309	353	
335250	10-14-61	307	358	Expended
335251	11-15-61	302	354	
335252	11-21-61	307	358	
335253	11-22-61	302	358	Expended
335254	11-22-61	305	361	
335255	12-5-61	305	358	
335256	12-12-61	305	360	Expended
335257	12-6-61	303	357	
335258	12-7-61	303	359	Expended
335259	12-8-61	302	359	Expended

TABLE 6
(Continued)

Engine S/N	Acceptance Test Date	Tank-Fed Injector End Pressure, psia	Pump-Fed Injector End Pressure, psia	Remarks
335260	12-18-61	303	359	Expended
335261	12-27-61	303	357	Expended
335262	1-8-62	304	357	Expended
335263	1-10-62	302	358	Expended
335264	2-6-62	304	360	Expended
335265	1-26-62	305	361	Expended
335266	1-26-62	306	357	Expended
335267	2-1-62	304	360	Expended
335268	2-2-62	305	358	
335269	3-7-62	305	356	Expended
335270	3-16-62	304	354	Expended
335271	3-23-62	300	355	
335272	3-22-62	305	359	Expended
335273	3-21-62	305	361	
335274	3-23-62	301	355	
335275	3-26-62	303	359	
335276	4-11-62	307	360	
335277	4-18-62	306	361	
335278	4-19-62	304	362	
335279	4-19-62	299	354	
335280	4-20-62	308	363	
335281	4-19-62	302	357	Expended
335282	4-19-62	306	359	Expended
335283	5-22-62	302	358	
335284	5-21-62	299	354	
335285	5-23-62	303	352	
335286	5-22-62	307	362	
335287	5-22-62	303	354	
335288	5-23-62	306	356	
335289	5-29-62	303	359	Expended

TABLE 6

(Continued)

Engine S/N	Final Acceptance Test Date	Tank-Fed Injector End Pressure, psia	Pump-Fed Injector End Pressure, psia	Remarks
335290	6-12-62	303	352	Expended
335291	6-15-62	305	353	
335292	6-22-62	304	358	
335293	7-10-62	304	357	Expended
335294	7-11-62	305	360	
335295	7-19-62	310	360	Expended
335296	7-13-62	307	357	
335297	7-26-62	305	354	Expended
335298	8-21-62	308	361	Expended
335299	9-6-62	306	360	
335300	8-23-62	309	359	
335301	8-24-62	305	357	
335302	9-6-62	306	354	Expended
335303	9-10-62	306	354	Expended
335304	9-14-62	308	357	
335305	9-24-62	306	358	
335306	10-2-62	310	360	
335307	10-2-62	309	359	
335308	10-2-62	306	358	
335309	10-3-62	307	358	
335310	10-9-62	307	355	Expended
335311	10-4-62	307	357	
335312	10-9-62	311	359	Expended
335313	10-29-62	308	355	
335314	10-29-62	305	359	
335315	11-2-62	309	359	
335316	11-14-62	307	358	
335317	12-4-62	306	357	
335318	12-5-62	306	359	
335319	12-31-62	309	358	

TABLE 6
(Continued)

Engine S/N	Final Acceptance Test Date	Tank-Fed Injector End Pressure, psia	Pump-Fed Injector End Pressure, psia	Remarks
335320	1-18-63	310	358	
335321	1-8-63	305	355	
335322	1-9-63	308	356	
335323	1-14-63	309	356	
335324	1-14-63	309	360	
335325	1-18-63	309	361	
335326	2-6-63	307	360	
335327	2-7-63	305	354	
335328	2-21-63	306	355	
335329	2-18-63	309	357	
335330	2-21-63	309	358	
335331	3-11-63	308	355	
335332	3-8-63	305	358	
335333	3-28-63	310	361	
335334	4-1-63	307	363	
335335	4-3-63	308	361	
335336	4-11-63	307	357	
335337	4-22-63	311	359	
335338	4-23-63	308	360	
335339	4-29-63	308	360	
335340	5-9-63	307	355	
335341	6-14-63	304	352	
335342	6-6-63	304	358	
335343	6-10-63	310	358	
335344	6-12-63	310	356	
335901	6-28-62	300	355	
335902	6-27-62	301	358	
335903	7-5-62	304	355	
335904	8-9-62	309	357	
335905	8-16-62	306	358	
335906	8-22-62	308	361	

MINIMUM SUSTAINER
LOX NPSH

MINIMUM SUSTAINER LOX NET POSITIVE SUCTION HEAD

Minimum required LOX net positive suction head (NPSH) values are tabulated in Tables 3 and 5 for individual MA-2 and MA-5 sustainer engines. The minimum required LOX NPSH is defined as that value of NPSH corresponding to 2% loss in head developed by the LOX pump at nominal flowrate. These values are derived from individual turbopump calibration data which were obtained by using water as a test fluid.

The water calibration NPSH is determined on the head vs NPSH curve derived from water calibration data. Figure 1 is a typical example showing curves at the three flowrates used during the calibration. The curve representing a flowrate approximating nominal flow is used. The mean head is determined at the most constant portion of the curve, i.e., between points A and B, then 2% of this mean value is subtracted from the mean head value. Point C on the curve, corresponding to the new head value, is then determined. The value of NPSH for point C is the minimum allowable NPSH for water.

Through the use of the pump affinity laws, this minimum NPSH is corrected to rated engine pump speed and flow obtained from IBM reduction of data from the engine acceptance test. An additional correction is made by subtracting 5 feet of the head from the NPSH value obtained. This compensates for the difference that will occur when changing from water to

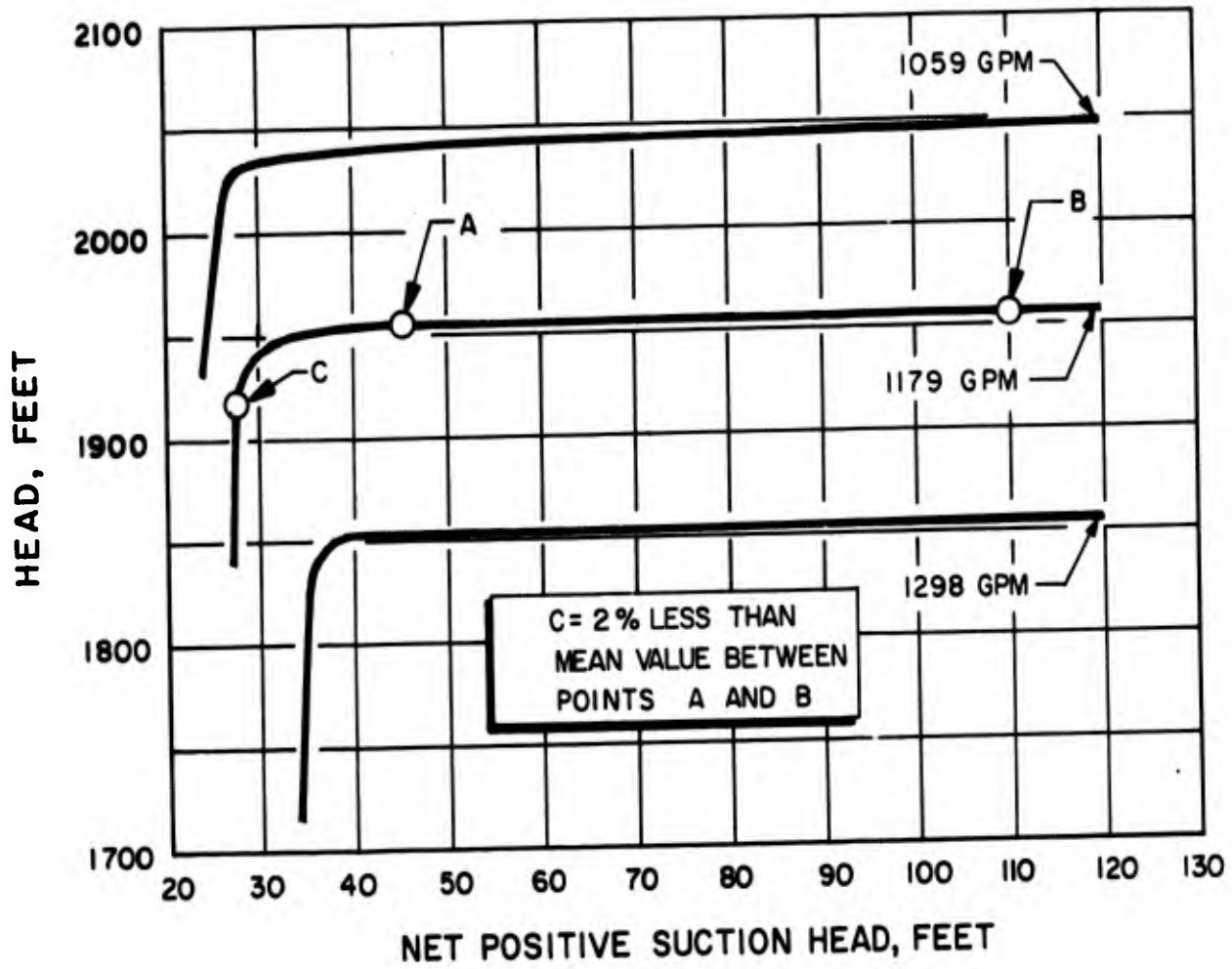


Figure 1. Typical Head vs NPSH From Water Calibration Data

liquid oxygen. The correction equation is then written as

$$\text{Minimum liquid oxygen NPSH} = \text{NPSH}_w \left[\frac{N_{s_l}}{N_{s_w}} \right]^2 \left[\frac{Q_l}{Q_w} \right]^2 - K$$

where

N_s = pump speed, rpm

Q = flow, gpm

K = constant for changing from water to liquid oxygen

Subscript l = engine test data

Subscript w = water calibration data

The value of K was found by running the P/N 451802-41 pump in liquid oxygen and in water. Data obtained from each of these liquids was reduced to 1200 gpm at 10,000 rpm, and it was found that the NPSH values differed by an average head value of 5 feet. No explanation can be found for the higher efficiency experienced with the use of liquid oxygen.

SUSTAINER LOX PUMP CONFIGURATION

Beginning with the MA-5 sustainer engine S/N NA225012, the configuration of the pump was changed by engineering change proposal MA5-68 (Modification No. 5). This pump, P/N 451802-51, uses a tapered hub inducer in place of the standard cylindrical inducer. The tapered hub inducer reduces the NPSH requirements of the turbopump, thus reducing the possibility of cavitation during flight and allowing the engine to operate efficiently with a lower NPSH. The value of K was again found to be 5.

The latest configuration pump, P/N 451802-61, uses a Kel-F liner in the LOX inlet. This replaces the steel wear ring beginning with production engine S/N NA225166. All existing MA-5 engines will be similarly modified. Required NPSH is equivalent to that of the P/N 451802-51 pump. The retrofit of all engines with the Kel-F liners will not affect the NPSH value from that already determined for the steel wear ring. Tests of 10 of these pumps show that the change in NPSH is negligible.

SUSTAINER ENGINE DURATION

A survey of engine requirements revealed that the capacity of the engine lube oil system was the critical factor influencing the duration capability of an engine. Basically, the lube oil system is a nonrecirculatory system which consists of a tank, pump, filter, and interconnecting lines and passages. The lube oil system supplies oil under pressure to lubricate and cool the bearings and gears of the turbopump.

Because the lube oil is not recirculated, the duration of the system is limited by the lube tank capacity and lube oil flowrate during engine operation. Lube oil consumption during start is negligible.

LUBE TANK CAPACITY

Based on a sample of 29 lube tanks, the mean and standard deviation of the tank volume are:

Mean = 6.902 gallons

Deviation = 0.1068 gallon

It was observed during measurement of lube tank volumes that a residual quantity of oil was retained in the tank. This residual oil is not available for lubrication purposes, so the effective volume within the lube oil tank is equal to the volume of the lube tank less the volume of the residual oil. The volume of residue was measured five times, and the largest volume was 0.022 gallon. This volume was adopted as the "normal" residual oil volume. An effective tank volume equal to 6.880 gallons was thus used to determine the maximum duration capabilities of the sustainer engine.

LUBE OIL FLOWRATES

The sustainer lube oil pump is a gear pump incorporating a bypass relief valve to maintain pump discharge pressure at a constant value. With this design, an increase in lube oil temperature results in an increase in lube oil flowrate. A temperature flow correction curve is used to adjust measured flowrates to 130 F. This is the maximum allowable lube oil temperature, and is used for comparison purposes.

$$\text{Flowrate at 130 F} = \frac{K_T \text{ (for measured oil temperature)}}{K_S \text{ (for standard 130 F oil temperature)}} \times \text{measured flowrate}$$

where K_T and K_S are derived from Fig. 2.

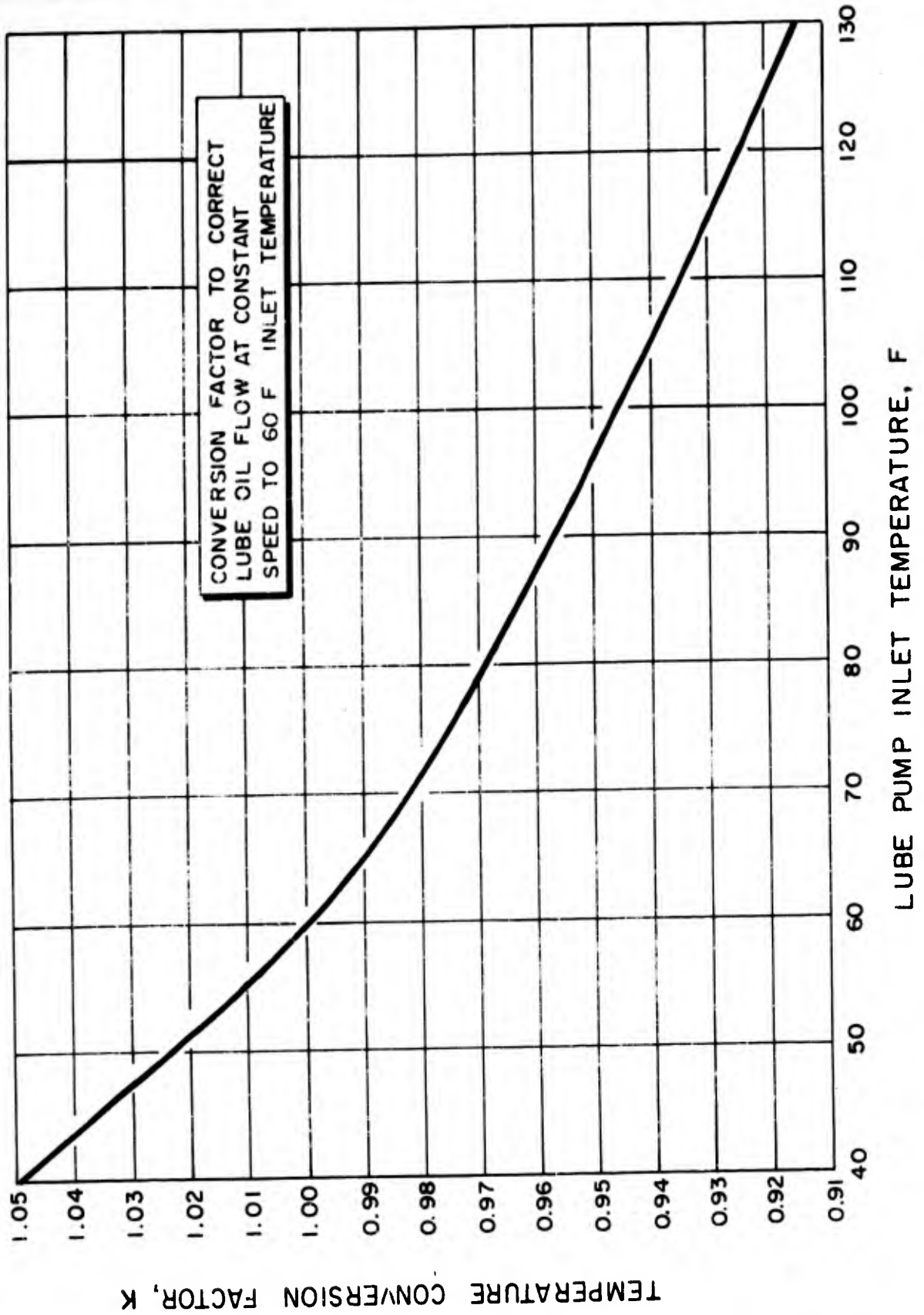


Figure 2. Temperature vs Flow Correction

The temperature flow correction curve was drawn from empirical test data which relates lube oil flow at constant turbopump speed to oil temperature. The value of the flow correction will be greater than 1 for all engines. To simulate the worst conditions, the maximum allowable lube oil temperature is used to calculate duration capability of the sustainer engine.

Using data obtained from nine R&D engines, a line of regression was used to correlate oil flowrates measured during component tests with oil flowrates measured during respective engine tests (Fig. 3). Because dimensional changes and internal leakages are not accurately predictable quantities, high correlation between component test and engine test flowrates cannot be expected. The equation of the line of regression for oil flowrates at 130 F is

$$Q_e = 0.5545 Q_c + 0.5101$$

where

Q_e = engine oil flowrate, gpm

Q_c = component oil flowrate, gpm

The standard error of estimate for Q_e is

$$S_e = 0.6341$$

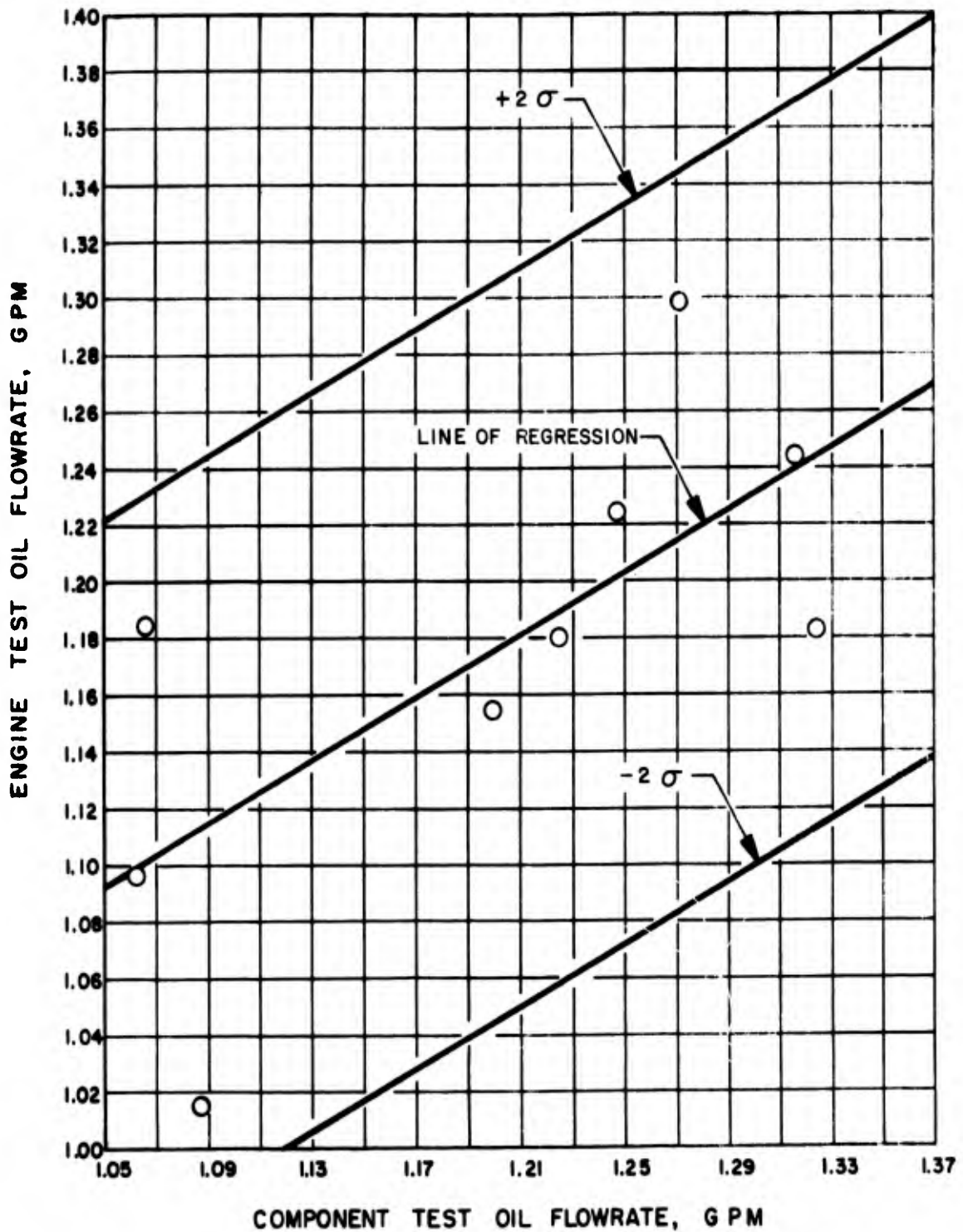


Figure 3. MA-2 Sustainer Engine Test Oil Flowrate vs Component Test Oil Flowrate at 130 F

INDIVIDUAL ENGINE DURATION CAPABILITIES

The determination of engine duration capability was accomplished in the following manner:

1. Oil flowrate was measured during turbopump component test (green run) and corrected to 130 F.
2. Engine lube oil flow was calculated from item 1 using the line of regression shown in Fig. 3.
3. An engine nominal duration was determined using item 2 and the nominal available lube tank capacity.
4. The nominal duration was reduced using the lower 95% confidence level of an rms summation of the standard error of estimate for the line of regression and the standard deviation of lube tank capacity. The resultant duration values are tabulated in Tables 3 and 5.

The above determination ensures that a 97.5% probability exists that the engine will be capable of the predicted duration. The relationship of predicted duration to nominal duration as a function of the probability of achieving the predicted duration is shown in Fig. 4.

Duration capabilities greater than those listed in Tables 3 and 5 can be achieved without a decrease in prediction accuracy by accepting the premise that a lube oil temperature of 130 F is probably beyond practical consideration. If the flowrate data are readjusted with Fig. 2 to achieve more realistic oil inlet temperature conditions, a 10-second minimum gain in engine duration capability is reasonable.

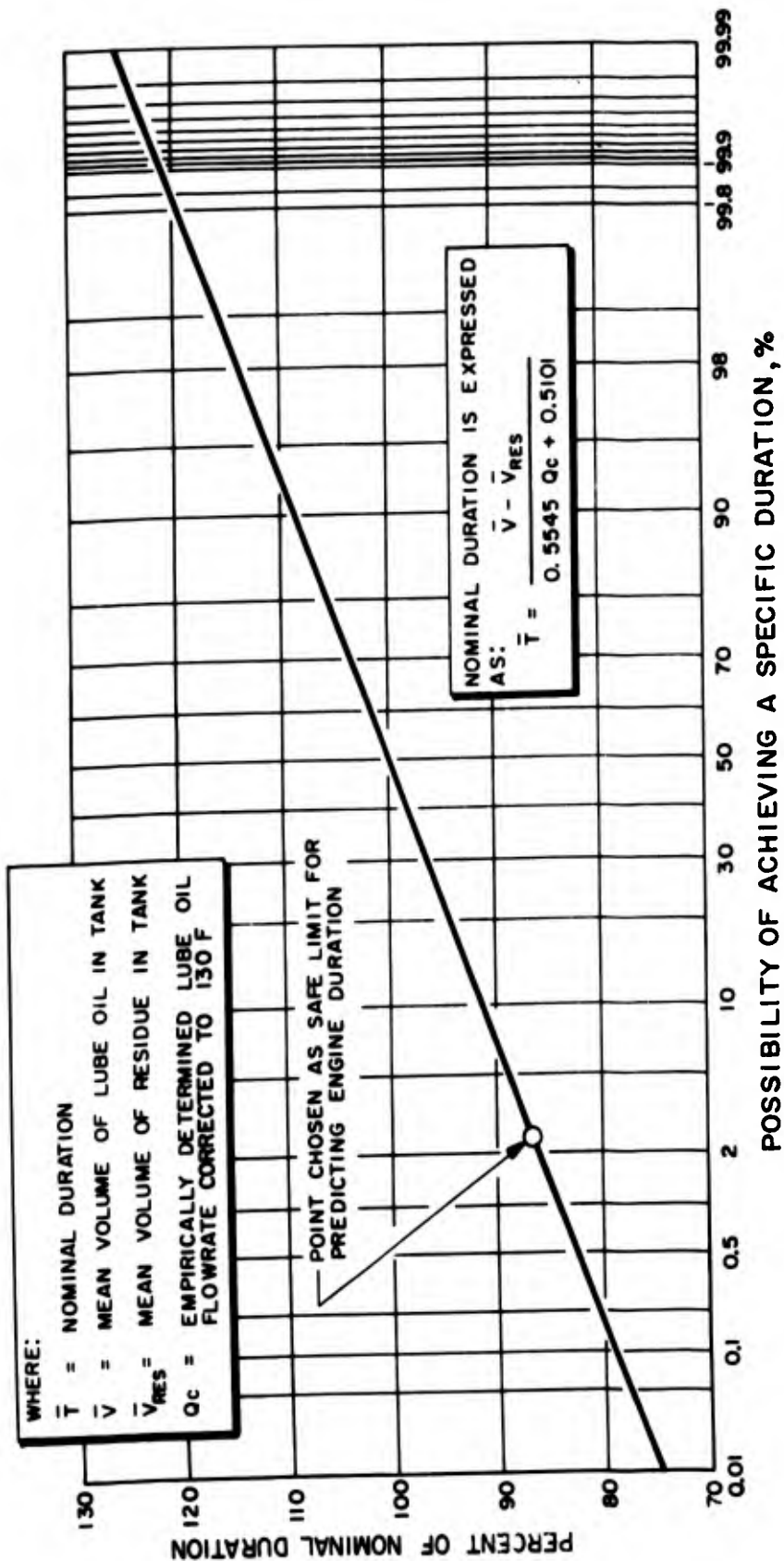


Figure 4. Engine Duration Probability

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