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DESIGN CRITERIA AND ENVIRONMENTS

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INTRODUCTION

This report is presented in partial fulfillment of the requirements of paragraph 5.1 of Exhibit E of Contract No. NAS 9-1100 and contains the natural and induced environments to be used for the design of the LM and its equipment.

DESIGN CRITERIA AND ENVIRONMENTS

1. General

1.1 Requirements - The LM and its subsystems shall be designed to meet the general criteria and environmental conditions herein as well as the particular mission requirements as set forth in the detail specifications.

Modifications of the Lunar Module providing an increase in mission capability, shall be designed to meet the general criteria and environmental conditions herein as well as the particular mission requirements as set forth in the detail specification.

Design procedures shall be conducted in accordance with recognized rational principles within the following framework.

1.1.1 Design - The purpose of the entire design and test effort is to produce reliable equipment for the lunar landing mission. This purpose is accomplished by analysis and test of the failure modes for each item of equipment during the design development. The objective of this failure analysis is the ability to predict, accurately, not only the type, or mode, of failure but the stress level at which it occurs. The design and failure analysis must go hand-in-hand so that the effect of changing design features on the failure modes will be part of the design trade-off evaluations and the reliability assessment.

Stress level, as used here, means the intensity of any parameter, such as pressure, voltage, temperature, etc. which affects the ability of the equipment to perform its design function. These parameters consist of both the environmental conditions imposed on the equipment and the self-induced conditions due to operating the equipment for the design mission time. Operating time (or number of cycles) should also be considered as a criteria variable. The natural and induced environments given in this report are the maximum levels that can be expected to occur in any LM mission. Rational combinations of these environmental and self-induced conditions must be considered in the design of each item of equipment.

The factor of safety, that is, the ratio of the allowable stress to the design stress, must be selected so that the likelihood of failure under the maximum mission level stresses is acceptably remote. The likelihood of failure is due, in part to the range of distribution of strength available; this range being due to material and constructional variations from one part to another. This likelihood, expressed as a probability, leads to the numberical reliability of the item of equipment under consideration.

1.1.2 Tests - The development test program supports the design effort by providing design data, aiding in material, component and part selection, verifying design concepts and safety factors, substantiating design assumptions from breadboard to design freeze, evaluating environmental effects and determining failure modes and operating characteristics under off-design conditions. These tests should locate such critical features as vibratory resonances, intermittent operation and other non-linear anomalies indicative of potential weakness or malfunction as well as the effects of interaction between environmental and operational parameters.

As an integral part of the development test program, overstress tests will be employed to obtain failure modes and/or safety margins which exist in the flight weight design. These tests, in combination with background data, must provide information which gives us a measure of the unit to unit variability of strength.

The significance of the overstress tests will be increased by stressing the equipment to failure after exposing it to selected mission environments of the operating cycle. These selected mission environments will include all critical environments and loads due to ground and flight operation.

These tests are a logical extension of the design verification portion of the development tests in that they provide useful information early in the program as well as check on the ability of the equipment to pass qualification tests.

The information from the overstress tests as well as other development tests combined with the design analysis, should result in such a complete understanding of the equipment characteristics that the accurate prediction of failure modes can be made. Based on this information the requirements for qualification testing can be firmly established.

For testing purposes certain environments may be modified and combined in order to simulate a more realistic environment. For example, humidity and salt fog may be combined into a single test (sea-air humidity) which simulates the environment that is prevalent at KSC. (Reference 25)

1.1.3 Acceptance Tests - The planning for the acceptance tests should begin during the design analysis when the critical characteristics of the equipment becomes apparent. Thought should be given at this early stage, to non-destructive tests, inspections or operational procedures which will give meaningful information on the presence or lack of adequate strength or operational capability. These concepts should be checked during the foregoing testing to provide the necessary assurance that the objectives of the acceptance tests will be attained. This preliminary set of acceptance test requirements must be complete before equipment qualification since equipment must be "accepted" before it can be "qualified".

The eventual purpose of the acceptance tests is to show that the equipment is representative of and the performance is equivalent to the equipment used in qualification tests.

1.1.4 Qualification Tests - The qualification tests should be planned to demonstrate that the equipment will meet the design requirements and has the design safety factor.

The qualification equipment, therefore, will go through the following test phases:

1. The first phase will consist of the acceptance tests derived from the development effort mentioned above.

2. The second phase will be made up of two parts:

   a. The first part will consist of tests to demonstrate the existence of safety factors, as required by the failure analysis, for all critical modes. These tests, of necessity, will be run at stress levels higher than maximum mission level. No failure will be permitted at these levels which are called design limit.

   b. The second part will consist of an endurance test performed with mission level environments using operating time rather than stress as the critical parameter to affect the equipment function. The test duration will be equal to an operational cycle plus one additional flight simulation. (An operational cycle is defined as ground operating time plus flight time). No failure will be permitted during this test.

If during qualification a failure should occur a complete evaluation of the failure and the failure analysis shall be made. Pending the results of this evaluation the equipment is not considered qualified and the acceptance tests are invalidated.

1.1.4.1 Post Qualification Tests - The post qualification tests should be planned to follow the qualification tests and serve to increase confidence in equipment design life and strength. The qualification test units will therefore go through two test phases:

1. The post qualification testing of the design limit test unit shall consist of overstress tests.
2. The post qualification testing of the endurance test unit shall consist of two additional flight simulation tests.

1.2 Reliability - The nature of the lunar landing mission requires that crew safety be achieved through overall reliability rather than through the use of escape systems. Therefore, attainment of the maximum mission reliability and crew safety shall be the most important single consideration in the design, construction, handling and operation of the LEM.

For the LM, the probability goal for accomplishing the mission objectives shall be 0.984. For the LM, the probability goal that none of the crewmen shall have been subjected to conditions more severe than the emergency limits set forth in the crew requirements section shall be 0.9995.

These reliability goals are to be met including the effects of launch vehicle and spacecraft environments as well as ground complex reliability but excluding consideration of radiation, meteoroid impact and launch vehicle or Command and Service Module operational reliability.

The LM shall also be designed for a probability of at least 0.995 of not aborting the mission due to meteoroid penetration. (See 4.2)

1.3 Advance in Technology - Flexibility shall be incorporated into the design such that advantage can be taken of advances in technology.

2. Performance

2.1 Margins - Rational margins shall be used for systems and components so that the greatest overall design efficiency is achieved within the general criteria stated herein. The specific margins stated below are derived from rational consideration of past and anticipated operational experience. They are to be used as design criteria until experience justifies modification.

2.1.1 Design Margin - All LM systems shall be designed to positive margins of safety. No system shall be designed incapable of functioning at limit load conditions.

2.2 Criteria

2.2.1 Repressurization Requirements - The LM shall be capable of receiving cabin repressurizations from the Command Module repressurization system. The repressurization system shall be designed for a continuous leak rate as high as 0.2 lbs. per hour.

2.2.2 Vacuum Operation of Cabin Equipment - Equipment which is normally operated in the pressurized cabin environment shall be designed to function for a minimum of two days in vacuum without failure. Time period in vacuum prior to operation shall be a minimum of 5 days.

2.2.3 Mission Abort - Provisions shall be made for crew initiation of all mission aborts. All aborts during lunar excursion shall provide for return to, rendezvous and docking with the Command and Service Modules.

2.3 Mission Profile -

2.3.1 Ground Handling and Pre-Flight Operations

2.3.1.1 Packaged - Transportation of test and flight modules will be from GAEC to point of use. Air transportation will be the primary mode. Ground test modules will be shipped to Huntsville, Alabama; Houston, Texas; White Sands, New Mexico; and NAA Downey, California. Flight modules will be delivered directly to ETR. Flight times are expected to be 5 hours to ETR, 10 hours to MSC and 10 hours to WSMR. The total elapsed time, including stopovers and refueling, is expected to be 8 hours to ETR, 2 days to MSC and 2 days to WSMR.

2.3.1.2 Unpackaged - For flight modules, an acceptance checkout and assembly will be performed at the launch sites. Assembly into the Launch Vehicle will occur on the launch pad for Saturn IB flights. Assembly for Saturn V flights will occur in the Vert. Assy. Bldg. Prior to prelaunch operations at ETR the LM and its subsystems will undergo acceptance tests at Grumman. LM sub-systems will undergo vendor acceptance tests prior to being delivered to Grumman.

2.3.2 Launch Vehicle - First stage thrust time from hold-down release to burnout is about 135 seconds, maximum q occurs at about 65 seconds. Second stage burning time is approximately 400 seconds. The Launch Escape System will be jettisoned shortly after ignition of second stage. Third stage burning time will be about 160 seconds to place spacecraft in parking orbit. The third stage is restartable and after re-ignition will have a burning time of 320 seconds for translunar injection. Dynamic loads to be encountered are due to thrust changes, maneuvering, gusts and engine induced vibration. Total thrust time is (135 + 400 + 160 + 320) = 1015 second or approx.17 minutes.

2.3.3 Spacecraft - Immediately after translunar injection, the Command Module/Service Module is separated from the LM shroud and the upper shroud is deployed. The CM/SM is then re-oriented to mate with the LEM at the upper LM hatch. During this maneuver the CM/SM is the active member and the LM remains attached to the empty SIVB. After transpositioning, the S-IVB and lower shroud is separated from the spacecraft and translunar attitude is established for the lunar trip. Trajectory corrections are applied periodically by the Service Propulsion System. At about 75 hours the SM propulsion system establishes the spacecraft in a circular lunar orbit at 60 nautical miles altitude. The crew is transferred and after a system check, the LM is separated at about 95 hours after launch. The LM is the active member during Descent, Landing, Ascent, Rendezvous and Docking. After crew transfer to the Command Module the LM is jettisoned.

The summary of LM Mission Times (Table I) for a nominal mission is not to be used for major subsystems but rather as a guide for determining duty cycles of lower level assemblies. It should be noted that no single mission can contain all of the time contingencies and probably no mission will occur which contains none. In determining the duty cycle of a particular item of equipment the maximum range of each mission phase should be considered in the light of the subsystem total mission profile within which the item must perform. 26, 27, 28, 29, 30, 31, 32

2.3.4 Lunar Excursion - The Lunar Excursion Module shall have the capability of performing the separation, lunar descent, landing, ascent, rendezvous and docking independent of the spacecraft. All LM systems shall be capable of performing at their nominal design performance level for a mission of two days without resupply. Lunar descent will be by elliptical orbit ending at a lunar altitude of 50,000 ft. after which a powered descent may end in a hovering maneuver prior to touchdown. Final touchdown horizontal velocity shall not exceed 4 ft/sec., and vertical velocity shall not exceed 10 ft/sec. (See 3.3.3.4.2)

2.3.4.1 Lunar Ascent - The powered ascent of the LM ascent stage to the 10 X 45 N Mi. orbit shall take 7.1 minutes. A 12 hour orbital contingency at 50,000 ft. will be available to permit the insertion into a rendezvous trajectory at 60 nautical miles altitude. The total ascent time, including the 12 hour orbit contingency, shall take 15 hours, during which time all ascent stage systems shall be capable of performing at their nominal design performance level.

3. Design Criteria

3.1 General

3.1.1 Isolation of Modifications - The LM and its component subsystems shall be designed such that general modifications to the LM module or its subsystems do not propogate through the other modules of the Apollo spacecraft.

3.2 Structural Requirements For LM & LM Items *

3.2.1 Design Factors

3.2.1.1 Purpose and Definition of Safety Factors - The level of structural strength and stiffness is established by the conditions of 3.3, 3.4 and 4.0 in addition to specific loadings applicable to particular subsystems. Such loads, called Design Mission loads, are conservatively selected to rep. the maximum range of severity expected on the lunar mission. Rational allowance shall be made and incorporated in these loads for stress concentrations, fatigue, thermal stresses and dynamic response. Factors of safety are multiplied by these Design mission loads to provide precautions against unknown deficiencies in strength as well as against excessively severe loadings, in order to keep the probability of failure within the necessary limits. See Table V for summary of LM Factors of Safety.

Ultimate Factor - At mission level** times the ultimate factor of safety there shall be no failure of structural members. The ultimate factor shall be not less than 1.5 applied mission level. This value may be reduced to 1.35 for special cases, not involving pressure vessels, upon rational analysis and with MSC approval. The LM landing gear shall use 1.35 on all mechanical moving parts.

Yield Factor - At mission level** times the yield factor of safety there shall be no permanent deformation or total deformation which would prevent performance of the mission. The yield factor, applied to mission level loads is nominally 1.35, but may be as low as 1.0 for ductile materials and not involving pressure vessels and need not exceed 1.5.

3.2.1.2 Pressure Vessel Factors - The design of pressure vessels shall be based on two analytical considerations. When external loads are applied in combination with pressure, the factors of 3.2.1.1 above, will apply. When pressure is applied as a singular load, the factors of 3.2.1.2.1 and 3.2.1.2.2 below, will apply.

* See 3.4.1.2 for equipment when in ground support of LM..

** Combined loadings, acceleration, pressure, vibrations etc, shall be considered.

3.2.1.2.1 Pressure Vessel Proof Factor - All pressure vessels will be subjected to a pressure proof test during acceptance testing. After exposure to proof pressure, the pressure vessel shall be fully capable of performing the mission. The proof factor shall be 1.33 times limit pressure.* This factor may be reduced for special cases upon rational analysis and negotiation with MSC. The descent stage propellant storage tanks shall use a factor of 1.30, based on the maximum relief valve setting and 1.15, based on the maximum burst disc strength.

3.2.1.2.2 Pressure Vessel Ultimate Factor - At limit load times the ultimate factor of safety there shall be no failure of the pressure vessel. The ultimate factor shall be 2.00 applied to limit loads.* The ascent stage main propellant tanks, RCS tanks, and Ambient Temperature Helium Pressurization Tanks will have an ultimate factor of 1.50 on the worst combination of acceleration, pressure, vibrations, shock, etc. Ref. 18. The descent stage propellant storage tanks shall use a factor of 1.47, based on the maximum relief valve setting and 1.30, based on the maximum burst disc strength.

3.2.1.2.3 Pressure Vessel Limit Loads - Limit loads shall be obtained with limit pressures. Limit pressure shall be no lower than the maximum relief valve pressure for the system. For cases which do not include a relief valve, the limit pressure is the maximum due to the maximum temperature after pressurization. When pressure effects are relieving, pressure shall not be used.

3.2.2 Pressure Stabilized Structures - No primary structures shall require pressure stabilization.

* For Propulsion and Reaction Control System pressurized components downstream of the helium pressure regulators.

Proof press. shall be 2.0 times the maximum expected line pressure (use relief valve maximum) or the combined surge plus nominal maximum pressure, whichever is greater.

Ultimate pressure shall be 3.0 times the maximum expected line pressure (use relief valve maximum) or 1.5 times the combined surge plus nominal maximum pressures, whichever is greater.

3.2.3 Vibration - The applied vibrational environment for launch and boost, translunar, descent and ascent phases of the mission consists of random excitation up to 2000 cps. The test requirements include separate sinusoidal vibrations to account for this low frequency portion of the spectrum as well as to determine the design adequacy in individual vibration modes. Test requirements should be considered as part of the vibration design. Separate launch and boost vibration are given in Table II for exterior and interior primary structure. Definitions of exterior and interior primary structure are in Note 8, Table II, PP. 41.

3.2.3.1 Vibration Factors - The vibrational amplitudes given in Table II are estimated envelopes of the highest levels that will occur during a mission. Satisfactory operation must be attained with these amplitudes increased by a factor in combination with other appropriate environments. In cases where mission success or the safe return of the crew is not a consideration and where operational characteristics are to be evaluated, lower vibration requirements associated with specific locations may be used. The value of this design limit factor involving electronic assemblies and fatigue critical structure for pre-launch packaged of Table II, part (a) is 1.0 and the value for all other conditions is 1.3 applied to the g and D. A. and $(1.3)^2$ applied to random vibration (g^2/cps).

In cases involving strength-critical structure, the value of this factor for all flight conditions is 1.5 applied to g and D.A., and $(1.5)^2$ applied to random vibration (g^2/cps). For pre-launch packaged the factor is 1.0.

3.2.4 Other Environmental Factors of Safety - The limit proof and ultimate factors of safety shall be 1.0 for the following environments:

a. Humidity
b. Rain
c. Salt Spray and Fog
d. Sand and Dust
e. Fungus
f. Hazardous Gases
g. Radiation
h. Temperature
i. Ozone
j. Corrosive Contaminants.

3.3 Flight Loads

3.3.1 Launch Vehicle

3.3.1.1 Temperature

3.3.1.1.1 Saturn V - Ambient sea level air temperature at ETR during launch time will vary between +15°F. and 100°F. The most likely range is between 56°F. and 88°F.

3.3.1.1.2 Boosted Flight - The temperature/altitude relationship will be according to the U.S. standard atmosphere 1962 (Ref. 10).

3.3.1.2 Pressure - The pressure/altitude relationship will be according to the U.S. standard atmosphere 1962 (Ref. 10).

3.3.1.3 Vibration - For vibration due to Saturn V launch vehicle operation see Table II (d).

3.3.1.4 Dynamic Loading - Acceleration loads due to booster thrust are as shown in Table IV and Table II.

3.3.1.4.1 Staging - Dynamic loads due to thrust changes are covered by the following: Hold-down release produces ±1.25g superimposed on 1.25g static thrust. Thrust drop off at 1st stage burnout produces -1.7g.

3.3.2 Spacecraft -

3.3.2.1 Temperature - The external surface temperature of the LM will vary between approximately -300°F to +270°F (depending on the orientation of the spacecraft relative to the sun), due to space environment of -460°F and solar radiation of 442 BTU/ft^2 hr. The overall structural temperature of the ascent stage is 0° to +160°F and descent stage is 20° to +200°F. The oxygen temperature in the pressurized cabin ranges from 60° to 90°F (includes local spots).

3.3.2.2. Pressure - The atmospheric pressure in cislunar space will be on the order of 10^{-14} mm of Hg. The controlled cabin pressure is 5 psia (O_2 nominal.) The uncontrolled pressure is 5 psia to .1 psia (O_2 nominal.)

3.3.2.2.1 Corrosive Contaminants - (Applies to the LM cabin interior) Salt atmosphere, the effect of which is simulated by exposure to a one (1) percent salt solution by weight, for 48 hours. (Reference 24). The exposure time for LM-10 through 14 shall be between 54 and 78 hours.

3.3.2.3 Vibration - Vibration due to Service Propulsion System are of negligible design significance.

3.3.2.4. Dynamic Loading

3.3.2.4.1. Space Maneuvers - Maneuver accelerations due to Service Propulsion System & Stabilization and Control systems are as follows:

X	Lateral	Pitch
-.36 g	±.087g	±2.82 Rad./sec.^{2}

3.3.2.4.2 Transpositioning - The shock loads due to transpositioning after S-IVB burnout are:

X	Lateral	Pitch
-.052g	±.092g	±.14 Rad./sec.^{2}

3.3.3 Lunar Excursion

3.3.3.1. Temperature - The external surface temperature of the LM will vary between approximately -300° and +270° depending on the orientation of the sun. The space environment is -460° F. and solar radiation is 442 BTU/Ft.^{2} hr. The lunar surface temperature will be +250° to -300° F. depending on the position of the sun and the location of LEM on the moon. The oxygen temp. in the pressurized cabin ranges from 60° to 90°F (includes local spots). The structural temperature will be 30° to +160°F. in vacuum cabin for cabin equip. and equip. bay. +40° to +100°F. in the propellant compartment (the descent engine combustion chamber backface is 400°F.)

3.3.3.2 Pressure - The ambient pressure on the lunar surface will not exceed 10^{-12} mm of Hg. When pressurized the cabin pressure of the LM will be 5.0 psi ± .20 psi, with a relief valve setting of 5.6 psi ± .20 psi. The cabin atmosphere will consist of pure oxygen.

3.3.3.3. Vibration - Vibration due to descent or ascent engines are as follows:

Descent - Reference Table II (e)

Ascent - Reference Table II (g)

3.3.3.4. Dynamic Loading

3.3.3.4.1 Descent Maneuvers - Dynamic loads during descent are due to the operation of the main descent engine and the Reaction Control System. Significant loads calculated occur at separation, in elliptical orbit, at start of hover and just prior to touchdown. Accelerations are calculated assuming maximum thrust at any time during the 1030 second engine duty time.

Phase	Vertical Accel. earth g's X	Lateral Accel. earth g's Y and Z	Rad/Sec^2 about Y and Z	Rad/Sec^2 about X
At Separation	+ .368	$\pm$.0378	$\pm$.192	$\pm$.091
Elliptic Orbit	+ .372	$\mp$.0383	$\mp$.193	$\mp$.092
Start of Hover	+ .707	$\mp$.0728	$\mp$.448	$\mp$.166
End of Hover	+ .815	$\mp$.084	$\mp$.645	$\mp$.189
Transfer Orbit	0	0	0	0

3.3.3.4.2 Lunar Landing - At touchdown the propulsion and Reaction Control systems are capable of producing the accelerations given in 3.3.3.4.1 above. In addition the Reaction Control System combined with the Descent Engine must bring the LM attitude within 6° of local vertical and must hold the LM motion within the following limits at impact on the lunar surface.

Local Vertical Velocity	Local Horizontal Velocity	Pitch/Roll Rate	Yaw Rate
$\leq$ 10 f p s	$\leq$ 4 f p s	$\leq$ 2 deg./sec.	$\leq$ 2 deg/sec.

$V_H = 4/3\ (10 - V_V)$ for $10 \geq V_V \geq 7$

Critical impact loads during lunar landing, resulting from the limiting rates given above, occur for the initial leg impact and for the "rock back" or secondary impact. Design values are given in Table II (e), Pg. 59.

3.3.3.4.3 Ascent and Rendezvous - Loads due to ascent engine thrust and Reaction Control System are critical at minimum weight just before docking. The permissible closing velocities for docking do not exceed the following: Reference 11.

Closing Velocity Z	Side Velocity X or Y	Angular Velocity Any Axis
.1 to 1 ft/sec.	.5 ft/sec.	1 Degree/Sec.

Docking loads are estimated.

	X		Y		Z	
	g	R/Sec^2	g	R/Sec^2	g	R/Sec^2
Maneuver	+.70	±.74	±.04	±.830	±.04	±1.47
Docking	-4.0	0	0	0	0	0

3.3.4 Leakage Rates For Hermetically Sealed Instruments -

3.3.4.1 The following leakage rate shall apply to assemblies and instruments which are hermetically sealed:

"The leakage rate shall be not more than 1×10^{-4} STD CC/sec/cu. ft. of enclosed volume."

3.4 Transportation, Ground Handling, and Storage - This criteria presents the natural and induced environments associated with transportation, ground handling and storage for LM and/or individual item.

Criteria is presented for ground equipment during support of LM and/or individual items, and when subjected to induced accelerations, shocks and vibrations.

3.4.1 General

3.4.1.1 Definition - For the purpose of this section, a package is defined as follows: The package is the complete ready-for-shipment outer container loaded with its item, and including insulation and other special internal supports.

3.4.1.2 Structural Factors of Safety For Ground Equipment

3.4.1.2.1 Limit Load - Limit loads are service level loads. There shall be no permanent deformation at limit load.

3.4.1.2.2 Ultimate Factor - For ground support equipment and shipping containers the ultimate factor is to be 1.5 applied to limit loads. At limit loads times the ultimate load factor of safety there is to be no failure of structural members.

3.4.1.2.3 Hydraulic and Pneumatic Fluid System Factors

Component	Proof Factor	Burst Factor
Lines	2 times oper. press.	4 times oper. press.
Fittings	2 times oper. press.	4 times oper. press.
Hose	2 times oper. press.	4 times oper. press.
*Pressure Vessel	2 times oper. press.	4 times oper. press.
Actuating Cylinder	1.5times oper. press.	2.5times oper. press.
All other components	1.5times oper. press.	2.5times oper. press.

* and/or ASME Unfired Pressure Vessel Code.

3.4.1.2.3.1 Safety of Pressurized Systems - Pressure relief of GSE fluid and pneumatic systems shall be provided to ensure safety to operating personnel by limiting any pressure rise to GSE design limit pressure. In addition, for those systems used to service LM flight pressure systems, the GSE pressure relief shall provide protection against exceeding the design limit pressure of the flight system.

3.4.1.2.4 Proof Tests-Slings - All slings will be subjected to a proof load acceptance test. After exposure to proof load the sling shall be fully capable of performing its intended service. The proof factor shall be 2.67 times the weight of the article being lifted.

3.4.1.2.5 Pressure Vessels - The strength of all pressure vessels shall be substantiated by rational analysis and proof test of each delivered vessel. Pressure vessels shall not require pressure stabilization. Pressure vessels may be designed in accordance with the ASME Unfired Pressure Vessel Code, in which case they shall be tested to the GSE proof pressure. Since the ASME proof pressure is equal to 1.5 times the ASME working pressure, the ASME working pressure and GSE limit pressure are equal only when the GSE proof factor is 1.5. When the GSE proof factor is 2.0, the ASME working pressure is 1 1/3 times the GSE limit pressure.

3.4.1.2.7 <u>Shock</u> - The following table presents shock loads induced during handling and transportation.

Equipment Weight	Shock Level	Time	
Less than 250 lbs.	30 g	11 ± 1 ms	Half Sine Pulse
251 lbs. to 500 lbs.	24 g	11 ± 1 ms	
501 lbs. to 1000 lbs.	21 g	11 ± 1 ms	
Over 1000 lbs.	18 g	11 ± 1 ms	

When a severe cost or weight penalty is imposed by this shock criterion upon the design of LM GSE (end items), or if the fragility level of one or more components as installed in the end item is not compatible with the shock criterion, a deviation from this criterion shall be requested from Grumman and after approval incorporated into the contractor prepared specifications for that GSE. Packaging equipment containing shock isolating material or special handling instructions shall be employed to insure that the shocks imposed on the end-item during transportation do not exceed the level specified in the deviation. Refer to Fig. 5 to obtain amplification factors for use with isolation material.

3.4.1.2.8 <u>Acceleration</u>

(g)

Environment		X	Y	Z
		+2.67		±0.4
Hoisting		+2.67	±0.4	
Railroad	Case 1	±1.0		±15.0
	Case 2	±1.0	±2.0	
	Case 3	±5.0		
Highway and Secondary Road Transit	Case 1	+3.5		
	Case 2	±1.0	+2.0	
	Case 3	±1.0		+1.5
Airplane B377 PG Emergency Landing Conditions	Case 1	-1.67		
	Case 2	+3.0		
	Case 3		±1.0	
(For Commercial aircraft,	Case 4	-1.0		
Case 5 should be +6.0)	Case 5			+4.0
Dolly Towing-Speeds not to exceed 8MPH on improved roads	Case 1	+1.25		
	Case 2	+1.0	+0.5	
	Case 3	+1.0		+1.0

3.4.1.2.9 <u>Other Environments</u> - For the following environments,(see Ref. 1)

1. Temperature
2. Humidity
3. Rain

Code 26512 Eng-23A

3.4.1.2.9 (Cont.)

4. Sand and Dust
5. Fungus
6. Salt Spray
7. Ozone
8. Vibration
9. Acoustics
10. Hazardous Gases
11. EMI
12. Pressure Environment

Vibration and acoustical levels are dependent on the location of the GSE item, such as in the Launch Umbilical Tower (LUT). Shock and/or vibration isolation is required when the load environment exceeds the fragility level of the GSE item.

3.4.1.2.10 Work Platforms, Work Stands, and Floor Loads

The live load applied to work platforms, work stands, and floors is 60 lbs/sq. ft. uniformly distributed, or a 400 lb. concentrated load applied anywhere, whichever produces higher stresses.

The horizontal loading applied to work platforms, work stands, and floors shall be 20% of the live load, applied at the C.G. of the live load. Stairs shall support a uniformly distributed live load of 100 lbs/sq. ft., or concentrated loads of 300 lbs. spaced 3 ft. on centers, whichever produces higher stresses.

Railings shall be designed to resist a horizontal thrust of 50 lbs/ft. applied at the top of the railing.

For columns, ultimate load factor times applied load shall not exceed column allowable load. For design of other members, stress due to ultimate load factor times applied load shall not exceed 1.5 times the yield stress of the material, or shall not exceed the ultimate stress of the material, whichever is lower.

3.4.1.3 Other Environmental Factors - Use the factors of 3.2.4.

3.4.2 * Package Natural Environments

3.4.2.1 Temperature

Air transportation:	-45 to 140°F for 8 hours.
Ground transportation:	Packaged: -65 to +160°F for 2 weeks.

3.4.2.2 Pressure

Air Transportation:	Minimum of 3.45 psia for 8 hours (35,000 ft. altitude)
Ground Transportation and Storage:	Minimum of 11.78 psia.

3.4.2.3 Sand and Dust - As in MIL-STD-810, June 14, 1962, Method 510 with exception test will be conducted at a temperature of 90 ± 20°F instead of 160°F.

3.4.2.4 Fungi - Exposure as defined in MIL-STD-810, Method 508, June 14, 1962.

3.4.2.5 Ozone - 3 years exposure, including 72 hours at 0.5 PPM, 3 months at 0.25 PPM, and the remainder at 0.05 PPM concentration.

3.4.2.6 Salt Spray - As simulated in laboratory tests by Method 509 in MIL-STD-810. (No direct impingement on flight hardware).

3.4.2.7 Humidity - In accordance with Method 507, MIL-STD-810, 14 June 1962, except that the maximum test temperature shall be 110°F instead of 160°F and the minimum test temperature shall be 40°F instead of 68°F to 100°F.

3.4.2.8 Rain - For design purposes, this environment will be represented by Method 506, MIL-STD-810, June 14, 1962.

*Ambient environments external to package.

3.4.3 Package Induced Environments

3.4.3.1 Sustained Acceleration. - 2.67g vertical (X-axis) with 0.4g lateral (Y, Z axes).

3.4.3.2 Hoisting Acceleration. - Two separate conditions:

a) 2.0 g in direction of hoisting
b) 2.67 g Vertical (X-axis) with 0.40 g Lateral (normal to X-axis)

3.4.3.2.1 Hoisting with Lift Rings. - The 2.0 g hoisting shall be considered to be applied on any one ring or any combination of rings, whichever is critical.

3.4.3.3 Shock. - As in MIL-STD-810 (USAF) 14 June 1962 Method 516 - procedure III. See Table II (a). Shock on engine in special container see (Ref. 12).

Shock on LM Vehicle is to be supplied (preliminary 8 g 10-20 ms).

3.4.3.4 Vibration. - As in MIL-STD-810 (USAF) 14 June 1962 Method 514-6 see Table II (a).

3.4.3.5 Hazardous Gases. - Explosion proofing requirements defined in MIL-STD-810 (USAF) 14 June 1962, Method 511 to protect against fuel leakage.

3.4.3.6 Electro-magnetic Interference. - In accordance with LSP-530-001.

3.4.4 Unpackaged Equipment Item Natural Environments

3.4.4.1 Pressure - Atmospheric pressure corresponding to sea level (Hermetically sealed units installed in the crew compartment will be subjected to a limit pressure of 20.5 psi absolute during preflight checkout).

3.4.4.2 Temperature - -20°F to 110°F ambient air temperature plus 360 B.T.U./ft.^{2} hr. solar radiation up to 6 hours per day.

3.4.4.3 Humidity - In accordance with Method 507, MIL-STD-810, 14 June 1962 except that the maximum test temperature shall be 110°F instead of 160°F and the minimum test temperature shall be 40°F instead of 68°F to 100°F.

3.4.4.4 Ozone - Same as 3.4.2.5

3.4.4.5 Rain - Same as paragraph 3.4.2.8 except no direct impingement.

3.4.4.6 Salt Fog - As in MIL-STD-810 (U SAF) 14 June 1962 Method 509.

3.4.5 Unpackaged Equipment Item Induced Environments

3.4.5.1 Sustained Acceleration - 2.67 g vertical (X-axis) with 0.4 g lateral (Y, Z axes).

3.4.5.2 Hoisting Acceleration - Hoisting of the LM vehicle stages is permitted in the empty condition only; that is, with no fuel or other consumables on board. Hoisting from the ascent stage will be only through a GSE adapter attached to the docking structure. The empty descent stage may be attached. Hoisting of the descent stage will be through the interstage fittings or the landing gear outrigger trusses. If it should become necessary to hoist the LM in the loaded condition, LM Structural Analysis, and Vehicle Design and Integration must be consulted:

a) 2.0 g in direction of hoisting
b) 2.67 g vertical (X-axis) with 0.40 g lateral (normal to X-axis)

3.4.5.2.1 Hoisting With Lift Rings - The 2.0 g hoisting shall be considered to be applied on any one ring or any combination of rings whichever is critical.

3.4.5.3 Shock - Will not exceed MIL-STD-810 Method 516 procedure I, 15 g peak but modify shock pulse to a saw tooth 11 ± 1 ms rise, 1 ± 1 ms decay. Suitably padded work bench surfaces will be available for the equipment item.

3.4.5.4 Hazardous Gases (Exposed Equipment Only)- Explosion proofing requirement defined in MIL-STD-810 (USAF) 14 June 1962 Method 511 to protect against fuel leakage.

3.4.5.5 Electro-Magnetic Interference - In accordance with LSP-530-001.

4.0 General Environmental Conditions

4.1.0 Radiation Considerations

4.1.1 Nuclear Radiation - The nuclear radiation environments for near earth, cislunar and near-lunar space shall be as presented below.(Ref. 16) Charged particle radiation shall not be investigated by subcontractors for effects on LM equipment design.

a. Trapped Radiation - Radiation levels in the Van Allen and artificial belts will use protons and electron fluxes obtained from the Goddard Orbital Flux Code.

b. Galactic Cosmic Rays - Galactic cosmic ray doses range from 0.1 rad per week for solar activity maximum to 0.3 rad per week for solar activity minimum.

c. Solar Particle Events - The solar particle events described below are for rigidities above the cut-off rigidity for solar particle events in the earth's magnetic field. The cut-off rigidity is given by:

$$N = \frac{2.49 \times 10^9}{(6371 + h)^2} \left[\frac{2 + \cos^3\lambda \quad -2(1 + \cos^3\lambda)^{\frac{1}{2}}}{\cos^2\lambda} \right]$$

where:

N = particle's cut-off rigidity, BV

h = Altitude, KM

λ = Geomagnetic latitude

Solar particle events will be considered to contain solar produced alphas and protons with equal rigidity spectra.

(1) Time Integrated Spectra - The time-integrated spectrum for alphas and protons with rigidities greater than 137 MV (10 Mev) will be considered to be of the form

$$N(>P) = N_o \exp\left[-P/P_o\right] \quad \text{where } P > 137 \text{ MV}$$

where $N(>P)$ = time integrated flux with rigidities greater than P, particles/cm^2

N_o = total intensity of event, particles/cm^2

P = particle rigidity, million volts

P_o = characteristic rigidity, million volts

The rigidity of a particle is given by:

$$P = \frac{-1}{Z_e} \left(T^2 + 2\, TM_o\, C^2\right)^{\frac{1}{2}}$$

Where Z_e = particle's charge in units of electron charge e i.e., Z_e = -1 for protons and Z_e = -2 for alphas

T = particle kinetic energy, Mev

M_oC^2 = particle's rest mass energy, Mev
M_oC^2 = 938.2 Mev for protons;
M_oC^2 = 3727.1 for alphas

P_o is evaluated in the energy ranges:

$10 \text{ Mev} \leq T \leq 30 \text{ Mev}$ and $30 \text{ Mev} \leq T \leq 100 \text{ Mev}$

Below 10 Mev the spectrum is given by:

$$N(>T) = N_o T^{-n}$$

A model spectrum is described by the following expressions:

$T < 10$ Mev: $N(>T) = 72.9\, N(>239 \text{ MV})\, T^{-1.2}$

$137 \text{ MV} \leq P < 239$ MV: $N(>P) = 35.5\, N(>239 \text{ MV})\, e^{-P/67}$

$P \geq 239$ MV: $N(>P) = 10.9\, N(>239 \text{ MV})\, e^{-P/100}$

where $N(>239 \text{ MV})$ is the number of particles/cm^2 with rigidities greater than 239 MV (30 Mev) encountered during the mission. Figure 1 of Ref. 16 shows the probability of encountering greater than $N(>239 \text{ MV})$ particles/cm^2 in an 8.3-day mission plotted against $N(>239\text{MV})$. The values obtained for N_o shall be considered to hold for both alphas and protons.

(2) Time Dependent Spectrum - The model time dependent integral spectrum is shown in Figure 5 of Ref. 16 for several rigidities. The spectrum will be considered to hold for both alphas and protons. Note that the spectrum is normalized to one particle/cm^2 with rigidities greater than 0.239 BV for the entire event.

4.1.2. Thermal Radiation - The source of radiation presented below impinges on the exterior of the LM in logical combination:

Solar Flux	442 BTU/ft^2/hr
Earth Emission	73 BTU/ft^2/hr
Lunar Emission (sub-solar point)	419 BTU/ft^2/hr
Lunar Emission (Dark Side)	2.2 BTU/ft^2/hr
Earth Albedo (over entire solar spectrum)	0.35
Earth Albedo (over visible spectrum)	0.40
Lunar Normal Albedo (over entire solar spectrum)	0.047
Lunar Normal Albedo (over visible spectrum)	0.098
Lunar Spherical Albedo (over visible spectrum)	0.073
Space Sink Temperature	-460°F

(Thermal emitted energy distribution to be interpreted according to cosine law).

4.1.3 Protection Criteria

4.1.3.1 Radiation Exposure Limit - The nominal biological dose, emergency dose and single acute emergency dose are to be determined.

4.1.3.2 Materials - The effects of exposure to the Solar Event of paragraph 4.1.1 shall be evaluated and materials selected wherever possible which are unaffected. Where materials must be used which deteriorate or malfunction due to radiation exposure, an evaluation must accompany the request to MSC for approval of the material.

4.1.4 Natural Radiation Mission Environment - The charged particle fluxes in the Van Allen radiation belts plus all of the sources of electromagnetic radiation enumerated in Section 4.1.1, shall be considered.

4.1.5 Induced Radiation Considerations

4/1/5.1 Radio Frequency - The following radio frequency engergy will be present due to the operation of spacecraft equipment. The output power is effective at the antennae.

ITEM	FREQUENCY	POWER
DSIF	2100-2300 mc/sec	20 Watts
Voice Communication	250-300 mc/sec	10 Watts
Tracking Radar	X - Band	300 Milliwatts
Landing Radar	X - Band	300 Milliwatts

4.1.5.2 Thermal - When the environmental control system is operating, the cabin atmosphere will be at a temperature of 70 to 80 degrees F. This atmosphere will be 100% oxygen at a pressure of 3.5 to 5.8 psi. The relative humidity will be between 40% and 70%.

4.1.5.3 RCS Exhaust Plume - LM RCS exhaust plume effects shall be considered during Descent and Ascent. SM exhaust plume effect shall be considered during Translunar Coast and Lunar Orbit. The undisturbed RCS exhaust plume is presented in Figure 3. For determination of plume heating effects, Figure 3 applies to all SM RCS, and LM up-firing and horizontal firing RCS engines. LM down firing RCS have plume deflectors which disturb exhaust flow. Heating effects from LM down firing RCS must be determined for specific relationship of heated surface to plume deflector. Figure 7 presents location of CSM and LM RCS thrusters.

4.1.5.4 Descent Engine Exhaust Plume - Descent engine exhaust plume effects shall be considered during powered descent only. Undisturbed exhaust plume is presented in Figure 4, and applies for LM altitudes greater than 20 feet above lunar surface. Below 20 feet altitude, ground effects generate complex flow fields which are functions of altitude.

4.1.5.5 Ascent Engine Exhaust Plume - Ascent engine exhaust plume effects shall be considered during powered ascent only. Undisturbed exhaust plume is presented in Figure 11 and applies for ascent and descent stage separations greater than 10 feet. Below 10 feet separation, ground effects generate complex flow fields which are functions of altitude.

4.2.0 Meteoroid Protection - The meteoroid protection required by the LM vehicle to meet the meteoroid reliability goals is defined by the following criteria.

4.2.1 Failure Modes

4.2.1.1 Mission Success - In estimating the mission success probabilities, it should be assumed that the following criteria determine an aborted mission:

(a) Meteoroid penetration and/or spallation greater than 25% of the thickness of a pressurized tank wall.

(b) Meteoroid penetration and/or spallation of the inner or container wall of a cryogenic tank.

(c) Meteoroid penetration of the cabin area during any period of time during the mission.

4.2.1.2 Crew Safety - In estimating the crew safety probability it should be assumed that the following criteria would result in a crew fatality:

(a) Meteoroid penetration and/or spallation greater than 25% of the thickness of a pressurized tank of the descent stage in such a manner that a hazard would exist.

(b) Meteoroid penetration and/or spallation greater than 25% of the thickness of a pressurized tank of the ascent stage.

(c) Meteoroid penetration of the cabin while pressurized.

4.2.2 Overall Structural Reliability - The overall structural reliability is given by the equations:

$$P_o = (1 - \sum^{\eta} \Delta Q - \sum^{\gamma} p \cdot \Delta Qs)$$

where

$$\gamma = \frac{\Delta Ts \cdot \Delta e}{Ts \cdot Ae}$$

$$\eta = \frac{\Delta T \cdot \Delta Ae}{T \cdot Ae}$$

Ae = total effective area

$= \eta \cdot A$

η = shielding factor

T = total time in primary environment

Ts = total time in secondary environment

ΔT = time in primary environment for an elemental area

ΔTs = time in secondary environment for an elemental area

ΔQ = probability of penetration for an elemental area - time product in the primary environment

ΔQs = probability of penetration for an elemental area - time product in the secondary environment

P = probability of encounter of a secondary velocity class

4.2.3 Shielding Factor - The planetary shielding factor is determined by the equation:

$$\eta = \frac{1 + \cos \theta}{2}$$

where $\theta = \arc\sin \left(\frac{\text{lunar radius}}{\text{lunar radius + LEM orbit altitude}} \right)$

4.2.4 The Design Meteoroid - The design meteoroid for the primary environment and the secondary (lunar ejecta) environment are defined as follows:

The Primary Design Meteoroid - For the combined sporadic and stream environment the primary design meteoroid is established by the LM mission success probability, a 95% confidence level in the penetrating flux, and the sporadic meteoroid model specified in the following equation.

$$\log N = \log_{10} \alpha - \beta \log_{10} m$$

where N = impact per ft^2 - day units

$\alpha = 3.776 \times 10^{-11}$ (ft^2 - day units)

$\beta = 1.34$

m = meteoroid mass in grams

The design mass is given by the equation:

$$m = \left[\frac{1.4 \alpha \cdot \Delta A_e \cdot \Delta T}{\Delta Q} \right]^{1/\beta}$$

Primary mass density $\rho = .5$ gm/cm^3

Primary design velocity V = 30 km/sec.

The Secondary Design Meteoroid - The secondary design meteoroid is established by the LM mission success reliability, a 50% confidence level in the penetrating flux and the secondary flux model specified in the following equation.

$$\log_{10} N = \log_{10} \alpha_s - \beta \log_{10} m_s$$

where $\alpha_s = 2.57 \times 10^{-7}$ (ft^2 - day units)

$\beta = 1.34$

m_s = meteoroid mass in grams

The design mass is given by the equation:

$$m_s = \left[\frac{1.0 \alpha_s \cdot \Delta A_e - \Delta T_s}{\Delta Q_s} \right]^{1/\beta}$$

Secondary mass density $\rho_s = 2.5$ gm/cm^3

The secondary flux velocity has an average value of 200 meters/sec. In evaluating the secondary flux the following velocity distribution shall be used:

For Vs = 0.1 km/sec. probability of encounter p = 0.9785
Vs = 0.25 km/sec. probability of encounter p = 0.0214
Vs = 1.5 km/sec. probability of encounter p = 0.0001

4.2.5 Shielding Design Criteria - The penetration resistance of each elemental area shall be determined on the basis of the following criteria:

4.2.5.1 Finite Thickness Single Skin Areas - The thickness of a metallic shield required to resist penetration by a meteoroid of diameter d is shown in Figure 8 for impact velocities > 10 km/sec. Similarly Figure 9 covers the velocity range 0 to 1.5 km/sec.

4.2.5.2 Finite Thickness Double-Skin Areas (V > 10 km/sec) - The thickness of a metallic shield, t_s, required for complete melting or vaporization of a meteoroid of diameter d is:

$$0.08 < \frac{t_s}{d} < 0.25$$

The thickness of a metallic sheet t_b behind the shield defined above is given by the empirical expression:

$$t_b = \frac{42\ m \cdot V}{s^2} \cdot \left[\frac{70{,}000}{\sigma_{0.7}}\right]^{\frac{1}{2}}$$

where m = primary meteoroid design mass, gms

V = primary meteoroid impact velocity, km/sec

s = spacing between t_s and t_b, cms

$\sigma_{0.7}$ = compressive yield stress equivalent to 0.7% strain, psi

The expression is directly applicable to aluminum 7075-T6.

For the case when the sheet behind the meteoroid shield t_s is either a stressed tank wall or a non-stressed tank wall in direct contact with the contents, then the tank wall thickness t_t, is given by the formula:

$$t_t = \frac{168\ m \cdot V}{s^2} \left[\frac{70{,}000}{\sigma_{0.7}}\right]^{\frac{1}{2}}$$

The above criterion will satisfy the condition of no spall off the inner face of the tank wall.

4.2.5.3 Finite Thickness Double-Skin Areas (V_s 1.5 km/sec) - The thickness of the combined metallic shield t_s and back-up, t_b, required to prevent penetration by a secondary (lunar ejecta) particle d_s is given by the empirical expression:

$$\frac{t_s + t_b}{d_s} = A$$

where A is a function of the impact velocity and is obtained from Figure 10. For the case when the second sheet t_b is either a stressed tank wall, or a non-stressed tank wall in direct contact with the contents, the combined thickness to prevent penetration is:

$$\frac{(t_s + 0.25\ t_t)}{d_s} = A$$

4.3 Lunar Surface Model

4.3.1 Gravity - The mean acceleration due to the moon's gravity at the surface of the moon is 162.29 cm/sec^2 (5.3245 ft/sec^2). This is equivalent to 1/6.0426 times the standard surface gravity of the earth.

4.3.2 Pressure - The atmospheric pressure of the moon does not exceed 10^{-12} mm of Hg.

4.3.3 Thermal - The surface temperature varies between +120°C (250°F) on the bright side to -185°C (-300°F) on the dark side of the moon. The solar radiation is 442 BTU/sq. ft./hr. The variation of the surface temperature of a point on the lunar equator during a complete lunation (29.53 days) is shown in Figure 6 (solid line). During the lunar day, the temperatures of local surface areas may be up to 30°C higher than the averaged temperatures shown on this plot. This effect is due to local variations in albedo and topography, which cannot be taken into consideration on such a plot.

For a point at some higher latitude, the temperature decreases approximately as the cosine of the latitude to the 1/4 power, as compared to the temperature of an equatorial point at the same brightness longitude.

The calculated temperature variation for a lunar equatorial point having the thermal characteristics of a normal terrestrial rock is also shown in Figure 6 (dashed line).

Average Model - The measured surface temperatures are best fit by a theoretical survey of temperature versus time based on a lunar surface thermal inertia $\gamma \approx 750$ (cgs units). The thermal inertia $\gamma = (k\rho c)$ where

k (thermal conductivity) $\approx 1.0 \times 10^{-5}$ cal/cm/sec/°C

ρ (density) ≈ 0.9 gm/cm^3

c (specific heat) ≈ 0.2 cal/gm/°C

Model for Local Variation - Although most, if not all, of the lunar surface is covered with material having the above properties, there may be local patches of material whose thermal properties approach those of normal terrestrial rocks. Such material would have approximately the following characteristics:

$K \approx 2.2 \times 10^{-3}$ cal/cm/sec/°C

$\rho \approx 2.5$ gm/cm^3

$c \approx 0.2$ cal/gm/°C

$\gamma = (K\rho c)^{-\frac{1}{2}} \sim 30$ cgs units

4.3.4 Landing Site Engineering Design Model - Since the lunar surface varies considerably the following engineering design model will be used in configuring the landing gear: Ref. 16

(a) The touchdown point at the landing site is considered to be a circle having a radius of 10 meters. The landing site is considered to be an area of about 10 sq. kilometers.

(b) The surface consists both of high porosity material (either a cohesive or noncohesive aggregate) of variable thickness and a structurally competent material. A combination of these materials, whose essential properties are described in step (c) and (d), may produce a heterogeneous surface which does not exceed the specifications listed in steps (a) through (g).

(c) The minimum bearing strength of the high porosity material is such that a static load of 7×10^4 dynes/cm^2 (1 lb/in^2) will penetrate no more than 10 cm (4 in) and/or a dynamic load of 8.3×10^5 dynes/cm^2 (12 lb/in^2) will penetrate no more than 60 cm (24 in) below the surface.

(d) The effective rigidity and strength of the structurally competent material is infinite.

(e) The coefficient of friction that may be expected during horizontal sliding will be between 0.4 and 1.0 and will be constant for any given landing.

(f) The "effective protuberances" at the touchdown point will be less than 60 cm (24 in). Effective protuberances may result from single protuberances such as blocks, or from various combinations of heights, depressions, and surface sinkage within a horizontal distance of approximately 10 meters (11 yards).

(g) The "effective slope" at the touchdown point will not exceed 12 degrees. The effective slope consists of the general surface slope of the touchdown area plus or minus the combined effects of protuberances, depressions and surface sinkage. The increment of the "effective slope" due to protuberances and depressions (after accounting for erosion and soils mechanics effects) may be calculated from the formula:

$$\text{Arc sin} \left[\frac{\text{height of protuberance + depth of depression}}{2D} \right]$$

D = Minimum distance between the line connecting the adjacent pad centers and the vehicle x axis.

4.4 Human Tolerance Limits

4.4.1 Carbon Dioxide - The carbon dioxide partial pressure nominal limit shall be 7.6 mm of Hg maximum. The emergency limits shall be as indicated in Figure 14 Ref. 16.

4.4.2 Cabin Temperature - The cabin temperature non-stressed limits shall be 60°F minimum and 90°F maximum. The stressed and emergency limits are presented in Figures 15 and 16 respectively Ref. 16.

4.4.3 Cabin Relative Humidity - The cabin relative humidity non-stressed limits shall be 40 percent minimum and 70 percent maximum. The stressed and emergency limits shall be as indicated in Figures 15 and 16 respectively of Ref. 16.

4.4.4 Radiation Limits - The radiation limits are to be determined.

4.4.5 Noise - The noise non-stressed limit shall be 80 db overall and 55 db in the 600 cps to 4800 cps range. The stressed limit shall be the maximum noise level which will permit communications with the ground and between crew members at all times. The emergency limit is presented in Figure 17 Ref. 16.

4.4.6 Vibration - The vibration stressed, non-stressed and emergency limits are to be found in Figure 18 of Reference 16.

4.4.7 Sustained Acceleration - The sustained acceleration limits are to be determined. The sustained acceleration performance limits are defined as the maximum sustained acceleration to which the crew shall be subjected and still be required to make decisions, perform hand controller tasks requiring visual acuity, etc.

4.4.8 Impact Acceleration - The impact acceleration nominal and emergency limits are to be determined.

4.5 Materials

4.5.1 Crew Compartment - Materials used in the LM Crew Compartment must be tested to LED-520-3 Revision A. The testing procedures include oxygen compatability, vacuum stability, toxicity limitations and flammability.

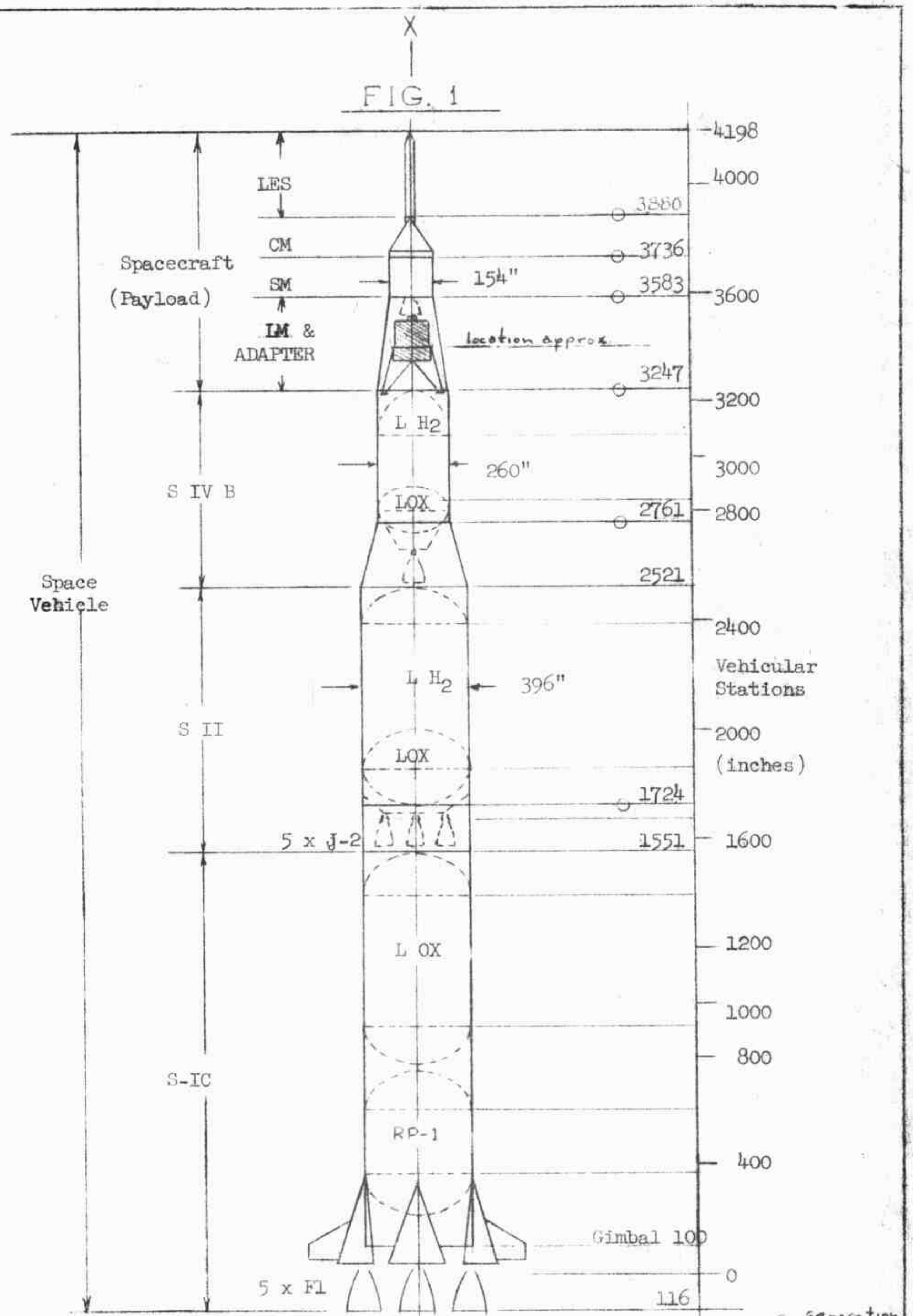
4.5.2 Outside the Crew Compartment - Materials used outside the crew compartment must be evaluated and approved by the LM Materials Group. A list of approved materials is maintained by that group and an up-to-date list is circulated monthly by LM Engineering Memorandum.

4.5.3 Processes - Processes used in the fabrication of LM equipment, including application of finishes, must be evaluated and approved by the LM Materials Group. Approved processes are published as the LSP-14-xxx series of Grumman Standard Specifications.

5.0 Summary of Simultaneous Conditions - Tables II & III

6.0 Weight and Balance - Tables IV & V

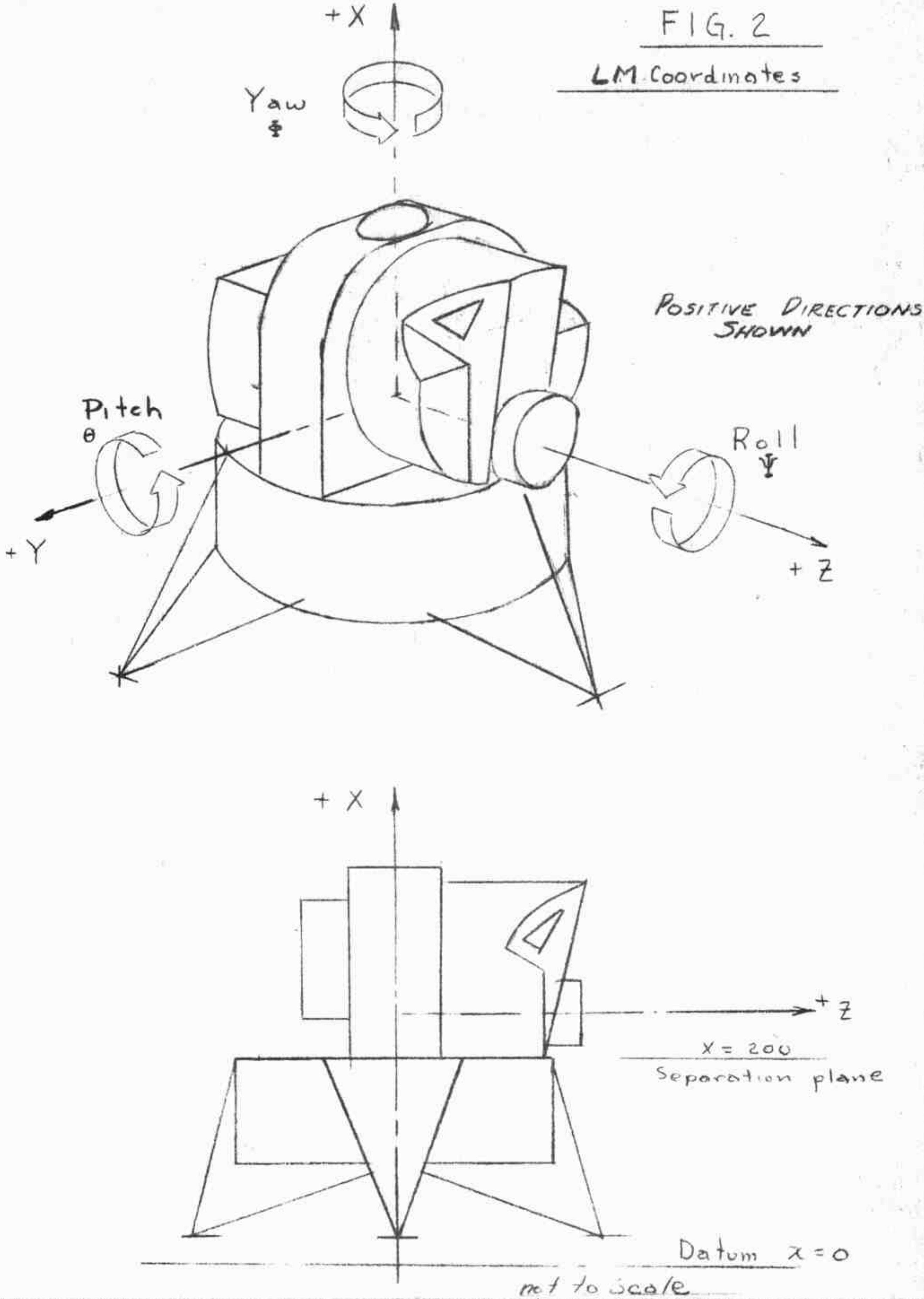
FIG. 1



(Ref. Tech. Brief LM) Apollo, Saturn V Configuration

FIG. 2

LM Coordinates



Constant Property Lines RCS Exhaust Plume

Notes: Exit Mach. No. and $\bar{\gamma}$ are mass flow average values
Exit Mach. No. = 4.54
$\bar{\gamma}$ = 1.323

M = Mach. No.
T = Plume Temperature (°R)
P = Plume Pressure (psia)
Ambient Pressure = 0 (psia)

Curve	M	T	$P \times 10^{-5}$
A	8	541	280
B	9	435	120
C	10	357	52.3
D	11	298	25.0
E	12	252	12.6
F	13	216	6.73
G	14	187	3.74
H	15	164	2.16
I	17	128	.794
J	20	93	.215
K	25	60	.0353

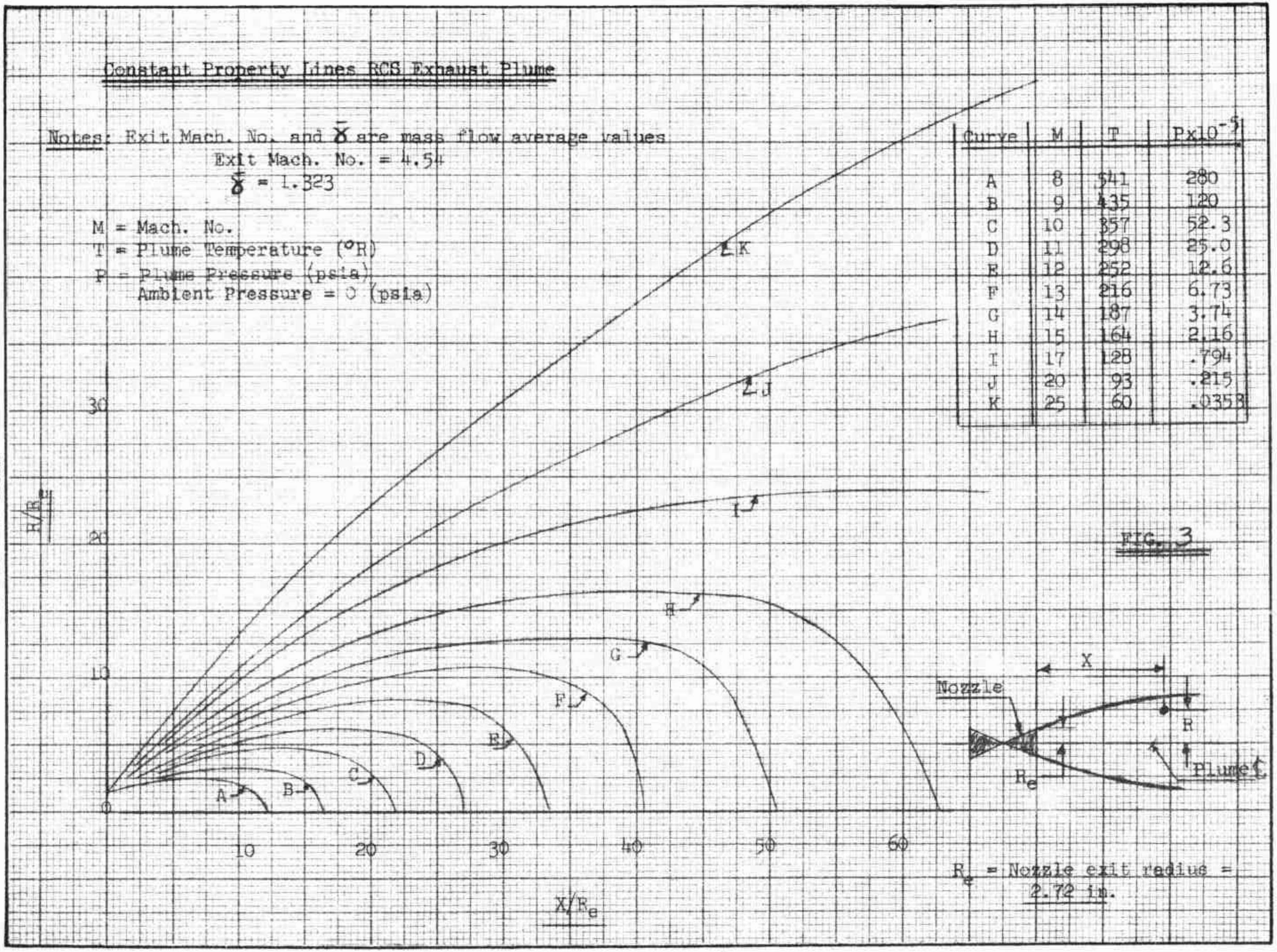


FIG. 3

R_e = Nozzle exit radius = 2.72 in.

Constant Property Lines Descent Engine Exhaust Plume (at 100% Thrust)

Notes:

R_e = Nozzle Exit Radius = 28.8 in.

Exit Mach. No. and $\bar{\gamma}$ are mass flow average values.

Exit Mach. No. = 4.8

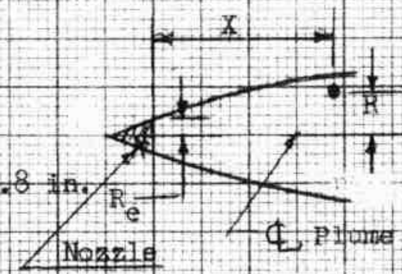
$\bar{\gamma}$ = 1.348

M = Mach. No.

T = Plume Temp. (°R)

P = Plume Pressure (psia)

Ambient Pressure = 0 (psia)



Curve	M	T	$P \times 10^{-2}$
A	6	902	3760
B	8	541	518
C	10	350	96.8
D	12	250	26.2
E	14	186	8.34
F	16	144	3.06
G	18	114	1.24
H	20	92.2	.547
I	25	59.0	.102

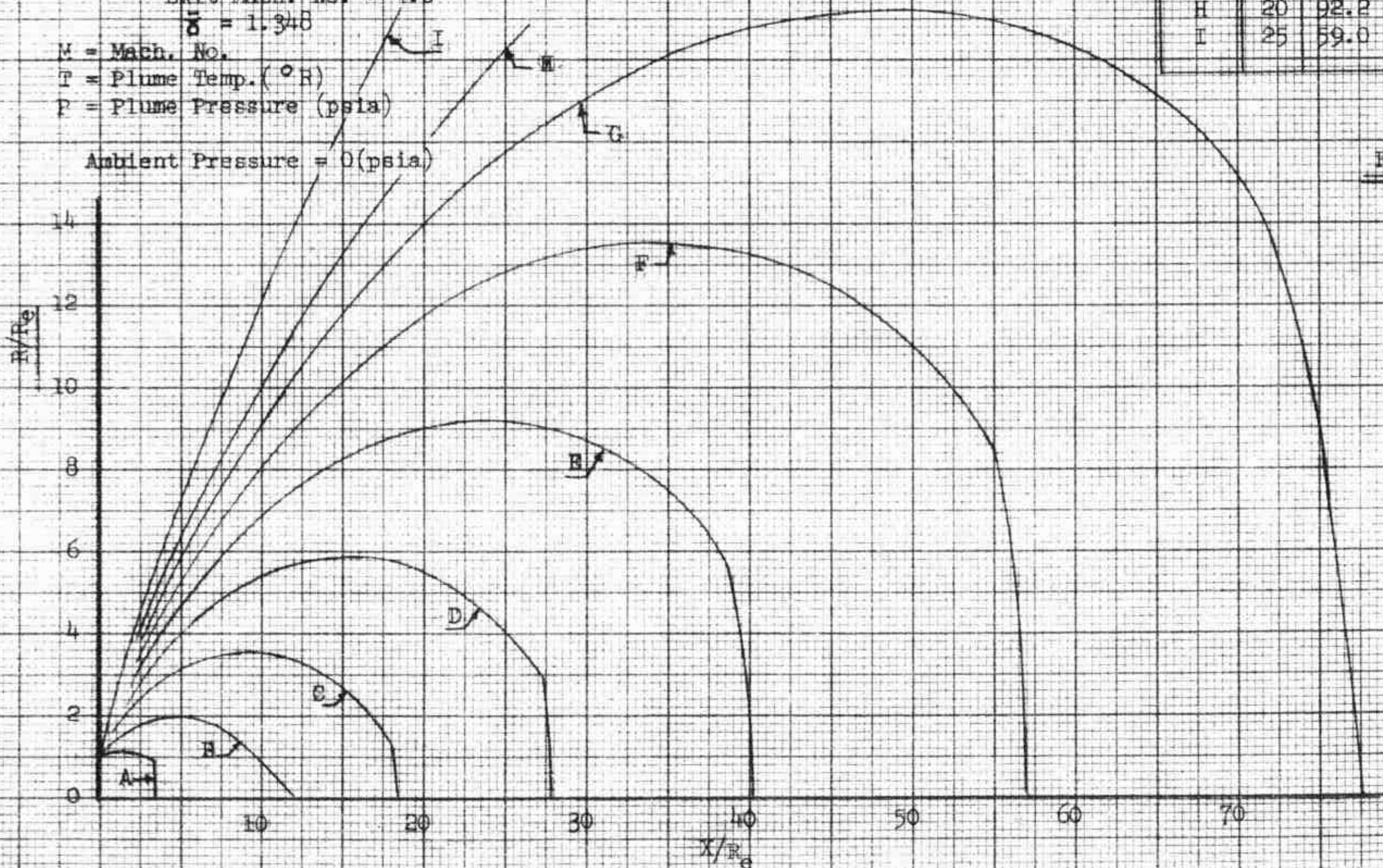


FIG. 4

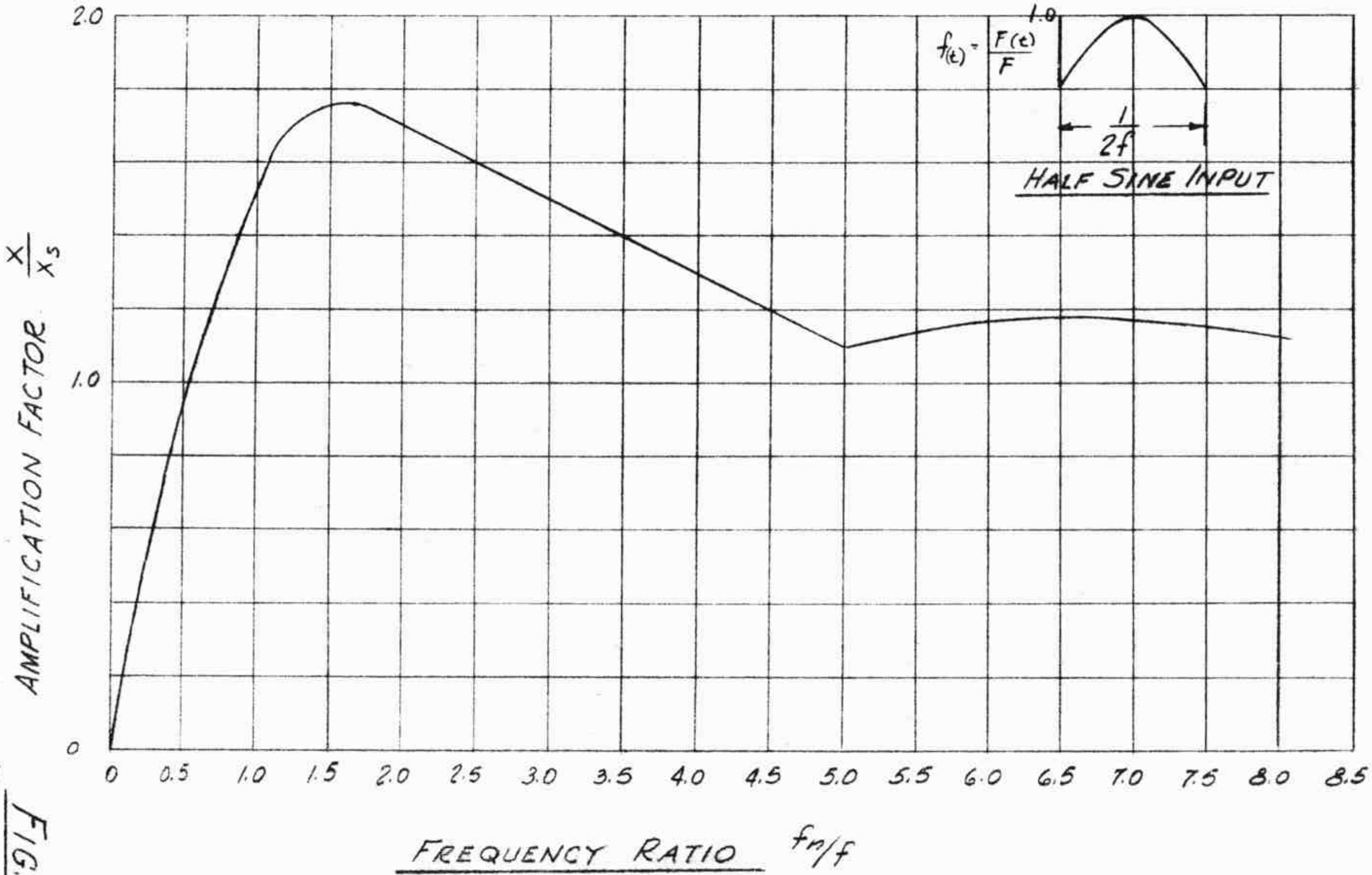


FIG. 5
(REF. 3.4.1.2.7)

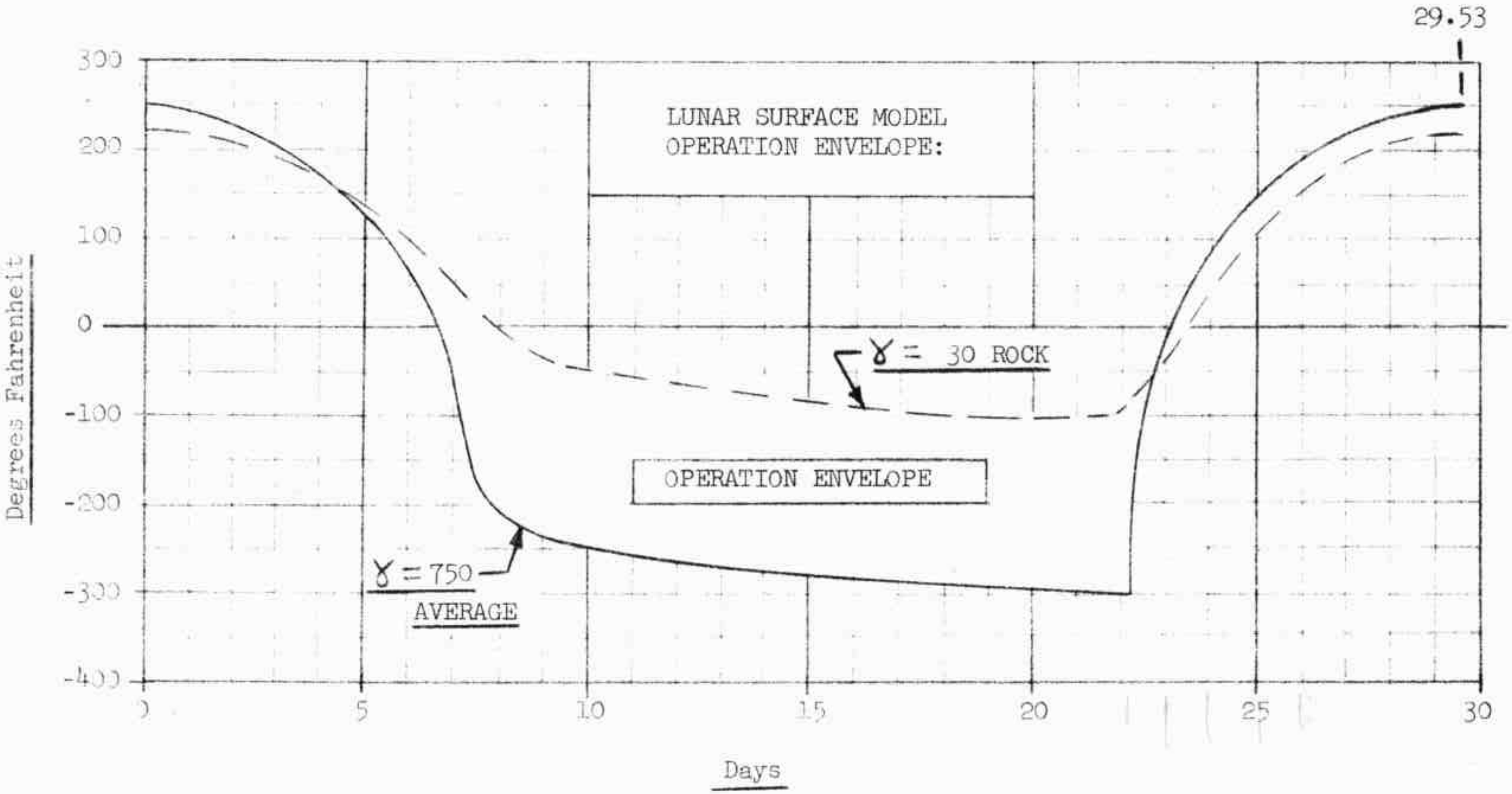
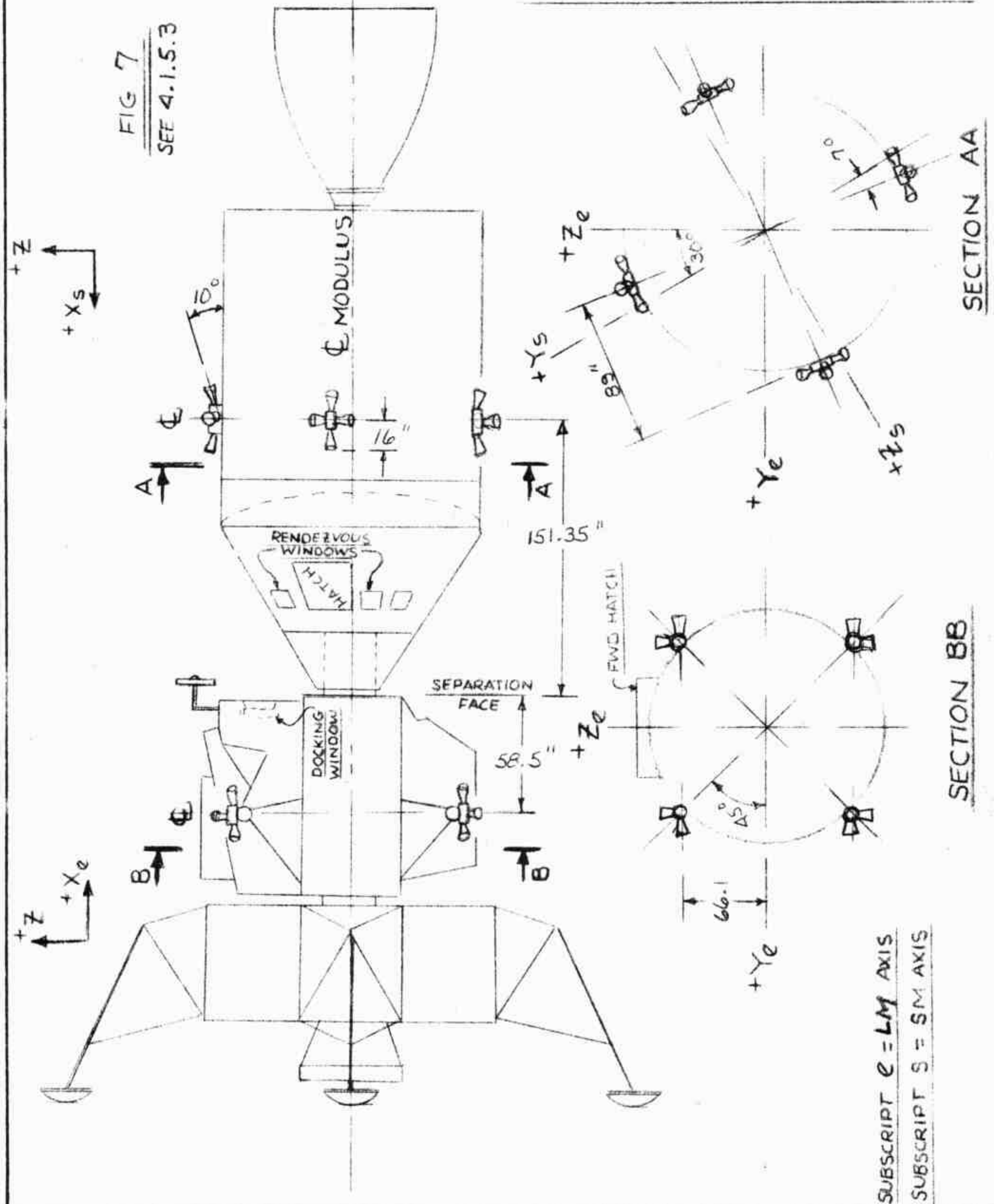


Figure 6 VARIATION OF LUNAR SURFACE TEMPERATURE DURING A COMPLETE LUNATION

See 4.3.3

LOCATION OF SM AND LM R.C.S. THRUSTERS

NOZZLE EXIT RADIUS FOR LEM & SM = 2.74"



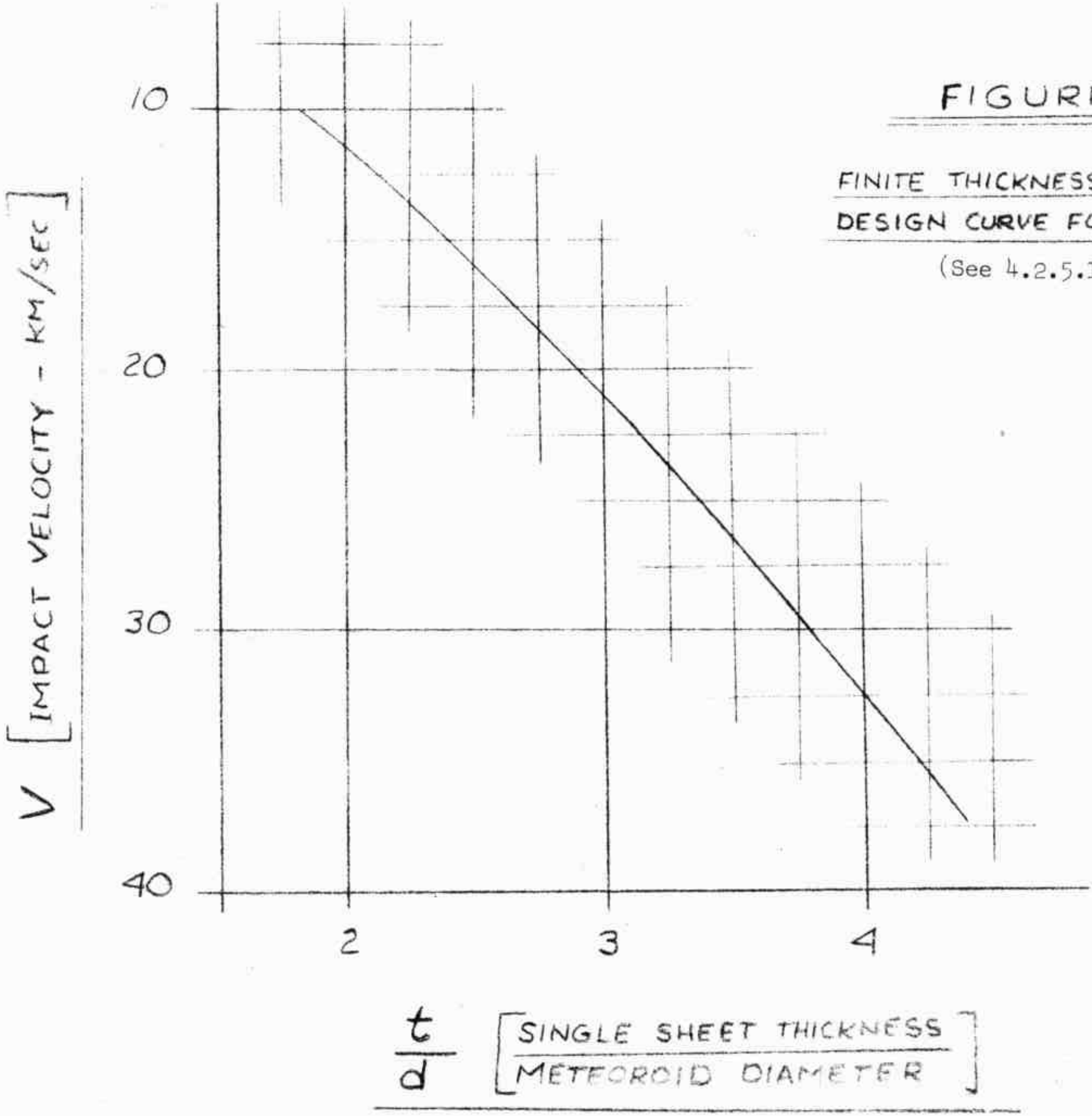


FIGURE 8

FINITE THICKNESS SINGLE SHEET DESIGN CURVE FOR $V \geq 10$ KM/SEC

(See 4.2.5.1)

FIGURE 9

FINITE THICKNESS SINGLE SHEET
DESIGN CURVE FOR V ≥ 1.5 KM/SEC
(See 4.2.5.1)

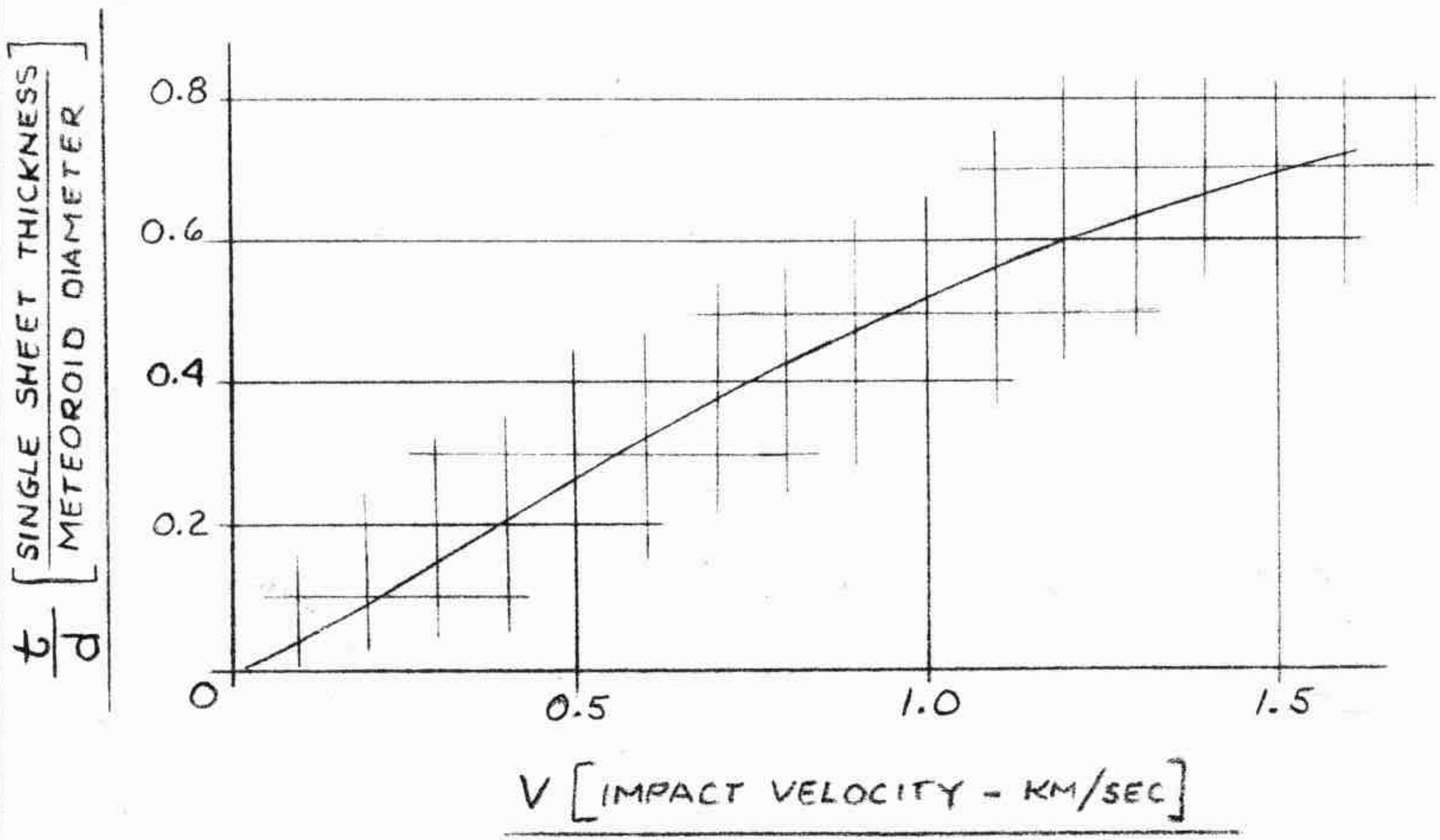


FIGURE 10

FINITE THICKNESS MULTI-SHEET
DESIGN CURVE FOR V ≥ 1.5 KM/SEC
(see 4.2.5.3)

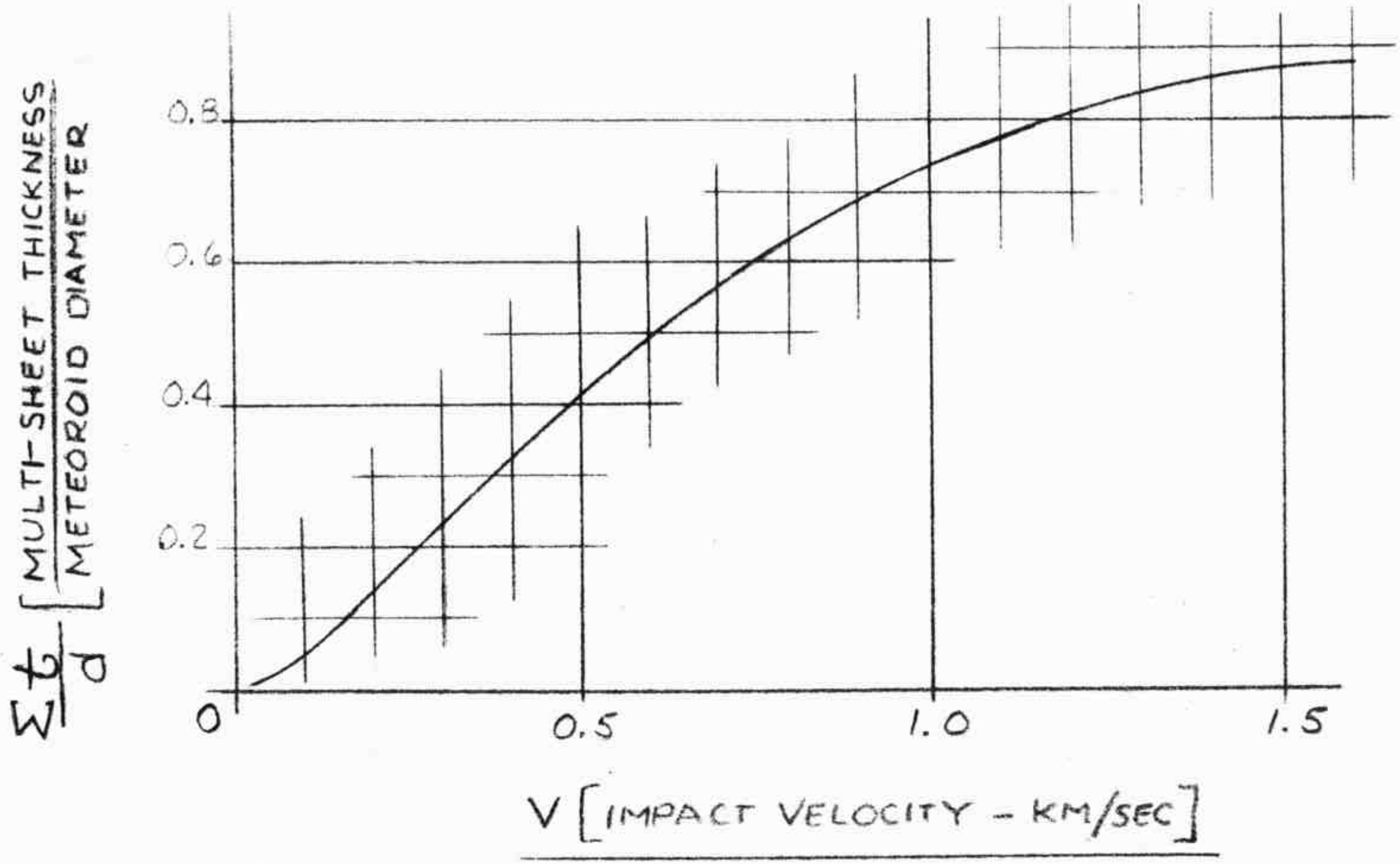


FIGURE 11

Constant Property Lines Ascent Engine Exhaust Plume

NOTES:

Exit mach. No. and $\bar{\bar{\gamma}}$ are mass flow average values

Exit Mach. No. = 4.76

γ = 1.36

Area Ratio = 45.5/1

M = Mach Number

T = Plume Tem. (°R)

P = Plume Pressure (psia)

Ambient Pressure = 0 psia

Curve	M	T	P x 10^{-5}
A	6	970	3300
B	8	581	500
C	10	378	100
D	12	271	28
E	14	201	9.1
F	16	155	3.4
G	18	122	1.46
H	20	98.8	.62
I	25	64	.115

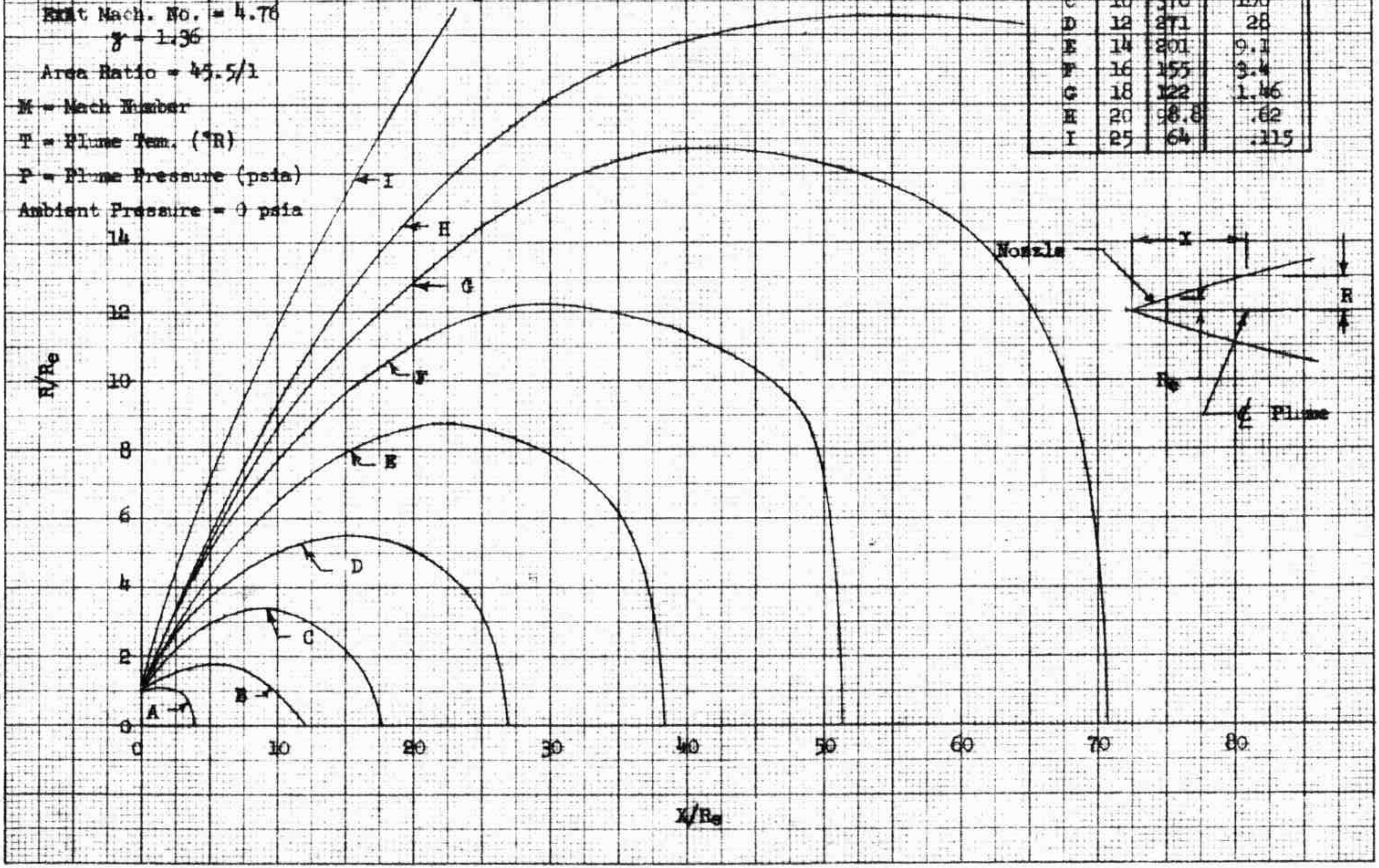


	Table I LM and LMMP Mission Time Normal Mission and Min./Max. Missions Mission Phase	LM Sys's. on	LM Crew	Time Nominal (MP)	Min/Max. (Minutes)
1.1	Space Vehicle Prelaunch Positioning.	-	-	480M	
1.2	Prelaunch Checkout	all	None	25,909M	
1.3	Launch Countdown			2,880M	
2.	Launch and Earth Ascent		"	12M	12/12
3.	Earth Orbit		"	180M	60/270
4.	Translunar Injection		"	5M	5/5
5.	Initial Coast - to transposition		"	15M	10/300
6.	Transposition, Dock and Jettison SIVB		"	30M	20/300
7.	Continue Translunar Trip to LOI		"	4080M	3600/6600
	2-7 (launch and translunar)			4307M	
8.	Lunar Orbit Insertion	all	"	6M	6/6
9.	Lunar Orbit Coast	"	"	240M	240/360
10.	DOI	"	two	.3M	.3M
11.	Lunar Orbit Coast	"	"	15M	15/-
12.	LM Housekeeping	"	"	90M	30/120
13.	Lunar Orbit Coast	"	"	780M	660/900
	(Lunar Orbit)				
14.	LM Checkout and Activation	"	"	137M	60/150
15.	LM Separation and Prep. for Descent	"	"	260M	260/260
16.	LM Powered Descent to Hi Gate	"	"	8.5M	8.5M
17.	Hi Gate to Low Gate	all	two	2.4M	2.4M
18.	Lo Gate to Touchdown	"	"	1.1M	1.1M
19.	Postlanding Checkout	"	"	15M	9M/75M
	(Lunar Descent)				
18.0	Lunar Exploration				
18.1	LM-7 to LM-9 (LM)			33.5H	
18.2	LM-10 to LM-13 (LMMP)			54H	
19.	Prelaunch Preparation			61.8M	40/110
20.	Powered Ascent	all	two	7.1M	7.1
21.	Rendezvous from 9X45 mi orbit to soft docking	"	"	150M	50/660
22.	Hard Dock, Transfer Crew to LM Jettison	"	None	300M	601

	(Lunar Ascent)	
D.	Descent Engine Operating Time (Including (90) seconds pre-launch check) (Duty cycle time in Engine Spec. = 1030 seconds)	17.2M
A.	Ascent Engine Operating Time (Including (60) seconds pre-launch check) (Duty cycle time in engine spec. = 525 sec.)	8.8M

(L.) Approximate total LM lifetime from launch = 170 hrs. (Including 112 hrs. orbit contingency) Days

(M.P.) Mission Phase M = Minutes
H = Hours

(Ref. 26, 27, 28, 29, 30, 31, 32)

TABLE II

IM MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

Notes: 1. Factors of safety are not included in the levels specified herein.

a. LM/or individual items ref. 3.2

b. Ground Equipment ref. 3.4

2. All accelerations are "earth g's". Multiply by earth weight or use 32.2 ft/sec.^{2} as appropriate. (sign conv. - Page 37)

3. Vibrational spectra shown gives straight lines on a log-log plot.

4. Packaged and unpackaged - The word "packaged" in this table refers to containers used for transportation, handling and storage.

5. Radiation - applied to external and internal items. Ref. para. 4.0 and 4.1.

6. Meteroids - applies to external items only. Ref. para. 4.2, and 4.2.1.

7. Plume induced environments

a. RCS - as per paragraph 4.1.5.3

b. Engines - as per paragraph 4.1.5.4

8. For launch and boost vibrations, that primary structure which is directly excited by the acoustics transmitted through the Spacecraft LM Adapter (SLA) is designated exterior primary structure; that primary structure which either does not face the adapter or is shielded from it by another piece of structure is designated interior primary structure.

TABLE II
MISSION LEVELS
ENVIRONMENTAL AND LOAD CONDITIONS

(a) Pre-Launch - Packaged

Transportation, handling and storage in shipping container shall not produce critical design loads on the LM or LM equipment and shall not increase weight of the LM. The following design environment applies only to packaged LM equipment and not to complete LM stages, except where specified.

Acceleration:

(ns) 2.67 g vertical with 0.4 g lateral, applied simultaneously to the package. This condition also applies to complete LM stages.

(v) 1.0 g vertical

(ns) 2.0 g in direction of hoisting (when rings are used, consider applied to any one or any combination of rings).

Shock:

(ns) Shock as in MIL-STD-810 (USAF) 14 June 1962 Method 516 Procedure III.

Vibration:

(ns) The following vibration levels are specified during transportation, handling and storage. Vibration to be applied, along three mutually perpendicular axes, x, y, z to the package.

(Time: 1/2 Octave per minute, three times per axis from 5 cps to max. cps and back to 5 cps).

For 100 lb. or Less		For 300 lb. or More	
cps	g or D.A.	cps	g or D. A.
5-7.2	.5 in D. A.	5-7.2	.5 in D.A.
7.2-26	±1.3 g	7.2-26	±1.3 g
26-52	.036 in. D.A.	26-52	.036 D.A.
52-500	±5.0 g	-----	
(f)		(f)	

(f) for 100 to 300 lbs. - use Figure 514-8 Method 514 MIL-STD-810 (USAF) 14 June 1962 for maximum frequency.

(v) Earth gravity compensation is not required

(ns) Not simultaneous loading conditions at these levels

(nc) Not simultaneous environment conditions at these levels

(a) Pre-Launch - Packaged (cont'd)

Pressure:

Ground transportation and storage: min. of 11.78 psia

Air Transportation: min. of 3.45 psia for 8 hrs. (35000ft. alt)

Temperature:

Ground transportation: -65°F to +160°F for 2 weeks

Air Transportation: -45°F to +140°F for 8 hrs.

Storage Temperature: -20°F to +110F ambient air temperature. plus 360 BTU/ft^2/hr. up to 6 hrs/day for 3 years.

*Humidity:

(nc) In accordance with Method 507, MIL-STD-810, 14 June 1962, except that the maximum test temperature shall be 110°F instead of 160°F and the minimum test temperature shall be 40°F instead of 68°F to 100°F.

*Rain:

(nc) Rain defined in Method 506 MIL-STD-810 (USAF) 14 June 1962.

*Salt Spray:

(nc) Per Method 509, MIL-STD-810; (No direct impingement)

*Sand and Dust:

(nc) Per Method 510, MIL-STD-810 except test. temp. shall be 90° ± 20°F instead of 160°F.

Fungus:

In accordance with Method 508, MIL-STD-810 (USAF) 14 June 1962.

*Ozone:

(nc) Three years exposure as follows: 72 hours. at 0.5 PPM, 3 months at 0.25 PPM and remainder at 0.05 PPM concentration.

*Hazardous Gases:

Explosion exposure as defined in Method 511, MIL-STD-810 (USAF) 14 June 1962.

*Electromagnetic Interference:

In accordance with LSP-530-001.

*Ambient environments on outside of package

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(b) Pre-Launch - Unpackaged

Ground handling shall not produce critical design loads on the LM or LM equipment and shall not increase weight of the LM. The following design environment applies only to unpackaged LM equipment and not to complete LM stages, except where specified.

Acceleration:

2.67 g Vertical with 0.4 g lateral applied simultaneously. This condition also applied to complete LM stages.

(ns) 2.0 g in direction of hoisting

Shock:

(ns) Shock as in MIL-STD-810 (USAF) 14 June 1962 Method 516, Procedure I modified. Modify shockpulse to sawtooth 15 g peak 10-12 ms rise, 0-2 ms decay.

Pressure:

Ambient ground level pressure. (Hermetically sealed units installed in the crew compartment will be subjected to a limit pressure of 20.5 psi absolute during preflight checkout).

Temperature:

-20°F to 110°F Ambient Air Temperature plus 360 BTU/FT^2/hr up to 6 hr/day.
From the time of hypergolic loading (approx. T-112 hrs) to lift off (T-0):
40°F to 110°F SLA cavity external to LM
50°F to 100°F SLA cavity internal to LM

Humidity:

(nc) In accordance with Method 507, MIL-STD-810, 14 June 1962, except that the maximum test temperature shall be 110°F instead of 160°F and the minimum test temperature shall be 40°F instead of 68°F to 100°F.

Rain:

(nc) Same as prelaunch packaged but no direct impingement

Salt Fog:

(nc) Same as prelaunch packaged

Sand & Dust:

(nc) Same as prelaunch packaged (not required for hermetically sealed cabin equip).

(b) Pre-Launch Unpackaged (cont)

Fungus:

Same as pre-launch packaged

Ozone: (nc)

Same as pre-launch packaged

Hazardous Gases:

MIL-STD-810, Method 511, 14 June 1962 and MSFC Dw. 10M01071. This condition also applied to complete LM stages.

Electromagnetic Interference:

Same as pre-launch packaged

(v) See Page 42

(ns) " " "

(nc) " " "

TABLE II

LM MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(b') Pre-Launch Sheltered Environment for complete LM Stages:

Ground handling shall not produce critical design loads on the LM or LM equipment and shall not increase weight of the LM. . The following design environment applies only to complete LM stages.*

Pressure:

Ambient ground level pressure. (hermetically sealed units installed in the crew compartment will be subjected to a limit pressure of 20.5 psia during preflight checkouts).

Temperature:

+60°F to 80°F for up to 3 years. +52°F to +105°F for 1 hour maximum with environmental equipment out of commission.

Humidity:

30 to 70% for up to 3 years. 100% rel. humidity up to 10 days.

Sand and Dust: (nc)

External to the LM the particle count shall not exceed level 1,000,000 of LSP-14-006 (Ref. 21). Internal to the LM cabin the particle count shall not exceed level 100,000 of LSP-14-006 (Ref. 21).

Ozone: (nc)

Same as pre-launch packaged

Hazardous Gases:

MIL-STD-810 (USAF), 14 June 1962, Method No. 511 and MSFC Drawing 10M01071. This condition applies to complete LM stages.

Electromagnetic Interference:

Same as pre-launch packaged.

*Grumman cold flow facility conditions to be supplied

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(c) Launch and Boost SATURN V

Acceleration (2)	g	Rad/Sec^2	g	Rad/Sec^2	g	Rad/Sec^2
Lift Off Condition	+2	-	±.65	-	±.65	-
Max q Condition (S-1C)	+2.3	-	±.30	-	±.30	-
Boost Condition (S-1C)	+4.4	-	±.20	-	±.20	-
Cut off Condition (S-1C)	-1.70	-	±.10	-	±.10	-
Outboard Engine Cut-Off	+3.0	-	-1.0	-	-1.0	-
Outboard Engine Cut-Off	-1.0	-	+1.0	-	+1.0	-
Cut-Off Condition (S-1C)	-1.70	-	±.10	-	±.10	-
Engine Hardover (S-II)	+2.10	-	±.40	-	-	-
Engine Hardover (S-II)	+2.10	-	-	-	±.40	-
Engine Hardover (S-IVB)	+1.60	-	±.23	±.70	±.23	±.70
Earth Orbit	0	0	0	0	0	0

Vibration

Themission vibration environment is represented by the following random and sinusoidal envelopes considered separately: (appropriate account must be taken for transmissibility of secondary structure).

INPUT TO EQUIPMENT SUPPORTS

(a) From Exterior Primary Structure

Random

10-23	12 db/oct. rise to
23-80 cps	.0148 g^2/cps
80-105cps	12 db/oct. rise to
105-950 cps	.0444 g^2/cps
950-1250 cps	12 db/oct decrease to
1250-2000 cps	.0148 g^2/cps

Sinusoidal

5-18.5 cps	0.154 in D.A.
18.5-100 cps	2.69 g peak

(b) From Interior Primary Structure

Random

10-23 cps	12 db/oct rise to
23-80 cps	.0148 g^2/cps
80-100 cps	12 db/oct rise to
100-1000 cps	.0355 g^2/cps
1000-1200 cps	12 db/oct decr. to
1200-2000 cps	.0148 g^2/cps

Sinusoidal

5-16 cps	0.154 in.D.A.
16-100 cps	1.92 g peak

(2) Paragraph 2.3.2: S-IVB ignition prior to earth orbit and reignition for translunar boost.

(c) Launch and Boost (continued)

For design purposes the above random spectrum applied for five min. along each of the three mutually perpendicular axis X, Y and Z when applied in addition to the corresponding sinusoidal spectrum acting for five seconds at the natural frequency of the equipment being designed will adequately represent the environment.

During the launch and boost phase of flight, the LM is exposed to random vibration of varied levels and spectra for 17 minutes. During all but approximately 2.5 minutes of this period, the intensity of the random vibration is of such a low level that it is considered to be of negligible design significance. In addition, the launch and boost environment is considered to include peak vibration levels which are presented by the above sinusoidal vibration envelopes. The number of sinusoidal peaks for design can be considered to be 1 percent of the natural frequency of the equipment being designed times the number of seconds of exposure.

Vibration levels may be lower at specific equipment locations due to the reaction of equipment on primary structure. Therefore, a rationally demonstrated reduction in these levels may be used for LEM equipment design and test.

Acoustics: (sound pressure levels in d.b. external to LEM) (re. .0002 dynes/cm^2)	Octave Band (CPS)	C-5 at max q Level (db)
	9 to 18.8	127
	18.8 to 37.5	133
	37.5 to 75	136
	75 to 150	134
	150 to 300	129
	300 to 600	125
	600 to 1200	120
	1200 to 2400	116
	2400 to 4800	112
	4800 to 9600	107
	Overall	141

Pressure:

Atmospheric pressure at sea level to $1x10^{-8}$ mm Hg except in cabin which is initially 60% pure oxygen at one (1) atmos. to $1x10^{-8}$ mm Hg (Decay time approx. 2 min.)

Temperature:

65° to 75 °F cabin structure.

(c) Launch and Boost --- cont'd.

Temperature: (cont'd)

65° to 75°F equipment bay (ascent stage) including NAVBASE equipment area
65° to 75°F equipment bay (descent stage)
65° to 75°F fuel and oxidizer compartment (adjacent to ascent and descent stage main propulsion tanks only.)
15° to 100°F ambient sea level - AMR
60° to 80°F LM external surface, L & B
65° to 75°F RCS propellant compartment structure. Fuel and oxidizer tank 65° to 75°. -200°F to 270°F LM external surface, orbit

Humidity:

"none"

Hazardous Gases:

Exterior to cabin: - None ; Inside cabin: - (O_2)

Electromagnetic Interference:

Same as pre-launch packaged

Radiation:

See Paragraph 4.1

Meteoroid:

For external items. Ref. 4.2.1

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(d) Space Flight - Translunar

Acceleration:	X g	X Rad/Sec^2	Y g	Y Rad/Sec^2	Z g	Z Rad/Sec^2
SM prop. system operating	-.36	-	±.062	±1.99	±.062	±1.99
SM prop. system not operating	0	0	0	0	0	0
Shock: (Cond. Transposition)	-.052	-	±.065	±.10	±.065	±.10

Vibration: None

SM prop. system operating

Plume Effects:

Due to Engine: To be Supplied
Due to RCS: In accordance with para. 4.1.2.3

Pressure:

1×10^{-14} mm Hg uncontrolled vacuum (space)
5.8 to .1 psia uncontrolled cabin (O_2) about 66 hrs. non linear decay time.
1×10^{-9} mm Hg uncontrolled vacuum (LM descent stage)
1×10^{-10} mm Hg uncontrolled vacuum (LM ascent stage)

**Temperature:

32° to 100°F Descent Engine Compartment (LM Structure)
32° to 100°F cabin structure
32° to 100°F equipment bays (ascent stage)
32° to 100°F equipment bays (descent stage)
50° to 90°F fuel and oxidizer compartment (adjacent to ascent and descent stage main propulsion tanks only.)
-300° to +270°F LM external surface*
32° to 110°F for navigation base equipment
-7.6°F Equivalent black body earth temp.
32° to 130°F RCS propellant compartment structure. Fuel and tank 40° to 100°F.
-14°F to 350°F inner panel cabin window (unpressurized cabin)
0°F to 350°F inner panel cabin window (pressurized cabin)
-87°F to +275°F outer panel cabin window (unpressurized cabin)
-70°F to +275°F outer panel cabin window (pressurized cabin)
**Equipment temperature due to combined exposure shall be determined for external items.
*Top surface of ascent stage can reach 1400°F due to Service Module RCS plume impingement during transposition, docking and separation.

(d) Space Flight Translunar (cont'd)

For External Items:

Solar radiation = 442 BTU/ft^2/hr
Lunar surface -300° to +250°F
(depending on sun's position)
Space = 0° Rankine (-460°F)

Hazardous Gas:

Same as launch and boost

Electromagnetic Interference:

Same as pre-launch packaged

Radiation:

Van Allen, Solar Flare and Space background.
To be defined as needed (inner belt 10 minutes followed by 1/2 hr. delay - outer belt 20) (See paragraph 4.1).

Meteoroids:

For external items. Paragraph 4.2.1

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(e) Lunar Descent - Including separation, descent, hover and touchdown

Accelerations:	X g	X rad/sec^2	Y g	Y rad/sec^2	Z g	Z rad/sec^2
Descent engine operating	+.82	±.19	±.08	±.65	±.08	±.65
Transfer Orbit	0	0	0	0	0	0
Landing: Steady state at C.G. of LM For accelerations at any other point, see page 55						
Case 1	.674	∓.125	±1.356	0	0	∓10.913
Case 2	.674	0	0	±13.121	±1.356	0
Case 3	.703	±11.468	∓.033	6.714	-.345	±.304
Case 4	2.375	0	0	±22.044	±.337	0
Case 5	2.375	±.210	±.337	0	0	∓18.334
Shock: Landing: 20 ms Rise Time 200 ms Dwell Time - 40 ms Decay						
Case 1	8.0			±14.0		
Case 2			±8.0			±14.0
Case 3				±14.0	±8.0	
Case 4	8.0					±14.0

Vibration: The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

INPUT FROM PRIMARY STRUCTURE

(Appropriate Account Must be Taken for Transmissibility of Secondary Struct.)

(a) To Ascent Stage Equip. Support

Random:

10 to 20 cps	12 db/octave rise to
20 to 100 cps	.02 g^2/cps
100 to 120 cps	12 db/octave decrease to
120 to 2000 cps	.01 g^2/cps

Sinusoidal:

5 to 17 cps	0.10 in. D.A.
17 to 100 cps	1.54 g Peak

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TABLE II

(e) Lunar Descent (Cont'd)

Vibration:

(b) To Descent Stage Equip. Support

Random:		Sinusoidal:	
15 to 100 cps	.031 g^2/cps	5 to 20 cps	0.10 in. D.A.
100 to 175 cps	6 db/oct. dec. to	20 to 100 cps	1.92 g Peak
175 to 2000 cps	.010 g^2/cps		

(c) To Descent Stage Equip. Support

Note: The following random and sinusoidal vibration levels shall apply to procurements made after January, 1965 (ref. 20).

Random:		Sinusoidal:	
10 to 30 cps	6 db/oct rise	5 to 23 cps	0.1 in. D.A.
30 to 60 cps	.085 g^2/cps	23 to 100 cps	2.77 g Peak
60 to 175 cps	6 db/oct dec. to		
175 to 2000 cps	.010 g^2/cps		

For design purposes the above random spectrum applied for 12 1/2 min. along each of the three perpendicular axes x, y and z, when applied in addition to the corresponding sinusoidal spectrum acting for 12 1/2 sec. at the natural frequency of the equipment being designed will adequately represent the environment.

Plume Effects:

Due to Descent Engine See Figure 4
Due to RCS in accordance with para. 4.1.5.3

Pressure:

1×10^{-12} mm Hg vacuum (space)
4.6 to 5.8 psia controlled cabin
1×10^{-9} mm Hg vacuum (LM descent stage)
1×10^{-10} mm Hg vacuum (LM ascent stage)
5.8 psia to 10^{-9} mm Hg uncontrolled cabin

Temperature:**,*

32° to 100°F Cabin Atmosphere ECS operating
32° to 100°F cabin structure
32° to 160°F environment for instrument panel equip. (rad. cooled) uncontrolled cabin (unpress).
32° to 130°F equipment bays (ascent stage) including NAVBASE equipment.
32° to 100°F equipment bays (descent stage)
50° to 90°F fuel and oxidizer compartment structure (adjacent to ascent and descent stage main propulsion tanks only).
-300° to +270°F LM external surface*
-14°F to 350°F inner panel cabin window (unpressurized cabin)
0°F to 350°F inner panel cabin window (press. cabin) (heaters to maintain LOW temp.
-87°F to +275°F outer panel cabin window (unpressurized cabin) (above dew pt.)
-70°F to +275°F outer panel cabin window (pressurized cabin)
32°F to 130°F RCS propellant compartment structure. Fuel and tank 40° to 100°F.
*Top side surfaces of descent stage can reach 1600°F during LM RCS plume impingement. A/S areas can reach 1400°F during plume impingement.

TABLE II

(e) Lunar Descent (cont'd)

Temperature:*** (cont'd)

32°F to 120°F on engine compartment walls

500°F to 1200°F - During Engine Operation - Descent Engine Case (Titanium)

For external items;

Solar radiation = 442 BTU/ft^2/hr
Lunar surface = -300° to +250°F
(depending on sun's position)
Space: 0° Rankine (-460°F)

Humidity:	Controlled cabin (O_2), 40 to 70% r.h. Locally in cabin (O_2), 0 to 100% r.h. (including 1% by weight, salt solution)
Hazardous Gas:	Same as launch and boost
Electromagnetic Interference:	Same as pre-launch packaged.
Meteoroids:	Use distribution for sporadic meteoroids as specified in Table V (for external items) (paragraph 4.2.3)
Sand and Dust:	This is to be specified by Grumman
Radiation:	See paragraph 4.1.

** Equipment temperature due to combined exposure shall be determined for external items.

*** The backface temperature of the Descent Engine Combustion Chamber is ~700°F (max). The back face of the Descent Combustion Chamber can be seen by the engine cavity walls. Only the radiation skirt is hidden by the heat shield.

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TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

Formulae for determining linear and rotational accelerations at any point on the

$$\ddot{X}pt = \ddot{X}cg - \ddot{\theta}_z \frac{\Delta y}{g} + \ddot{\theta}_y \frac{\Delta z}{g}$$

$$\ddot{Y}pt = \ddot{Y}cg + \ddot{\theta}_z \frac{\Delta x}{g} - \ddot{\theta}_x \frac{\Delta z}{g}$$

$$\ddot{Z}pt = \ddot{Z}cg - \ddot{\theta}_y \frac{\Delta x}{g} + \ddot{\theta}_x \frac{\Delta y}{g}$$

Where $\ddot{X}cg$, $\ddot{Y}cg$, $\ddot{Z}cg$ = Acceleration at LM c.g. in X, Y, Z directions.

$\ddot{X}pt$, $\ddot{Y}pt$, $\ddot{Z}pt$ = Acceleration at any point on LM in X, Y, Z direction.

$\ddot{\theta}x$, $\ddot{\theta}y$, $\ddot{\theta}z$ = Rotational Acceleration about respective axes.

Δx, Δy, Δz = Distance from specific point to LM C.G. along respective axis (X = 218, Y = 0, Z = 0 = LM CG)

g = 386 in/sec^2

See Fig. 2 for LM axes

Code 26512 Eng-23A

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Stay

Accelerations:	X
cond. - at rest	1/6 g
Shock:	Not critical

NOTES: Ascent and descent engines not operating. Vibration due to other sources to be supplied.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Stay (cont'd)

Pressures:

1×10^{-12} mm Hg uncontrolled vacuum (surface of moon)
4.8 to 5.8 psia (O_2) controlled cabin
1×10^{-9} mm Hg cabin (hatch open) max. open hatch time = 20 mins. non-linear decay.
1×10^{-9} mm Hg vacuum (LM descent stage)
1×10^{-10} mm Hg vacuum (LM ascent stage)
5.8 psia to 10-9 mm Hg uncontrolled cabin

Temperature:
32° to 130°F (O_2 temp) pressurized controlled cabin
32° to 100°F ** Cabin structure at touchdown
32° to 130°F ** Cabin structure at lift-off
32° to 160°F environment for instrument panel (rad. cooled) uncont. cabin (unpress.) equip.
32° to 130°F equipment bays (ascent stage) including NAVBASE equipment
32° to 160°F equipment bays (descent stage)
40° to 100°F fuel and oxidizer compartments (adjacent to a/s main prop. tanks only)
32° to 200°F fuel and oxidizer compartments (adjacent to d/s main prop. tanks only)
-300° to +270°F LEM external surface
0° to 300°F descent engine compartment
-14°F to 350°F inner pane cabin window (unpressurized cabin)
0°F to 350°F inner pane cabin window (press. cabin) (heaters to maint. low temp. above dew pt.)
-87°F to +275°F outer panel cabin window (unpressurized cabin).
-70°F to +275°F outer panel cabin window (pressurized cabin)
32° to 130°F RCS propellant compartment (40° to 100°F - RCS Fuel & Ox. Tanks)
32° to 160°F Aft Bay Equipment
**ECS Oxygen Design Mission, the maximum cabin structure temp. increases linearly from 100°F to 130°F during the lunar stay period.

For external items:

Solar radiation = 442 BTU/ft^2/hr
Lunar surface = -300° to +250°F (depending on sun's position)
Space = 0° Rankine (-460°F)

Humidity: (cabin only)

Controlled cabin (O_2) 40-70% rel. hum. avg.
locally in cabin (O_2) 0-100% rel. hum.
(including 1% weight, salt solution)

Hazardous Gas:

Same as launch and boost

Radiation:

Solar flare and space background to be defined as needed. See para. 4.1

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Stay (cont'd)

Electromagnetic Interference:

Same as packaged pre-launch

Meteoroids:

For external items. Ref. 4.2.1

Sand and Dust:

This is to be specified by Grumman

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Ascent - Including ascent rendezvous and docking

Acceleration:	X		Y		Z	
	g	rad/sec^2	g	rad/sec^2	g	rad/sec^2
engine operating	+.70	±.74	±.04	±.83	±.04	±1.47
docking condition	-4.0	0	0	0	0	0
transfer orbit	0	0	0	0	0	0

Vibration: The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately.

INPUT FROM PRIMARY STRUCTURE
(Appropriate Account Must be Taken for Transmissibility of Secondary Structure)

(A) to Ascent Stage Equipment Supp't

Random

10-20 cps	12 db/octave rise to
20-100	.02 g^2/cps
100-120	12 db/octave decrease to
120-2000	.010 g^2/cps

Sinusoidal

5-17 cps	0.10 in D.A.
17-100	1.54 g peak

For design purposes the above random spectrum applied for 8 1/2 min. along each of the three mutually perpendicular axis x, y, and z, when applied in addition to the sinusoidal spectrum acting for 8 1/2 sec. at the natural frequency of the equipment being designed will adequately represent the environment.

Plume Effects: Due to Ascent Engine See Figure 11
Due to RCS in accordance with paragraph 4.1.5.3.

TABLE II

MISSION LEVELS

(g) Lunar Ascent

Pressure:

1×10^{-12} mm Hg vacuum (Space)
4.8 to 5.8 psia controlled cabin
1×10^{-10} mm Hg vacuum (LM Ascent Stage)
5.8 psia to 10^{-9} mm Hg uncontrolled cabin

During the course of the Fire-in-the-Hole (FITH) staging pressures are created in the interstage area as a function of separation distance, tilt angle, and sideslip. Pressure transients arise as a result of the interstage configuration, separation distance and the resulting flow field. The maximum equivalent steady state pressures occur at zero stage separation (starting transient). Tests to date indicate that on the ascent stage a pressure of approximately 0.79 psia is developed in the separated flow region adjacent to the nozzle in the ascent engine compartment and pressures as high as 3.14 psia occur in the regions of minimum clearance between stages due to the reattached flow. The peak pressure on the descent stage deflector is 6.0 psia due to the direct flow impingement. Maximum equivalent steady state pressures are built up on the descent stage in the first 0.10 seconds of the starting transient decaying to 50% of the steady state value 0.30 seconds after ignition.(Ref. 26)

Temperature:**

32° to 130°F (O_2 temp) pressurized cabin
32° to 130°F* cabin structure
32° to 130°F equipment bays (ascent stage), including NAVBASE equipment
40° to 100°F fuel and oxidizer compartments (adjacent to a/s main prop. tanks only)
-300° to +270°F LM external surface*
-14°F to 350°F inner pane cabin window (unpressurized cabin)
0°F to 350°F inner pane cabin window (press. cabin)(heaters to maintain low temp. above dew pt.)
-87°F to +275°F outer pane cabin window (unpress. cabin).
-70°F to +275°F outer pane cabin window (pressurized cabin)
32° to 130°F RCS propellant compartment (40° to 100°F RCS Fuel & Ox, Tanks)
225°F max. on engine cover
400°F - external separation surface (for 30 mins) - Temp transient during FITH, 270°F at peak load & 710°F at zero load on A/S base heat shield
470°F - on injector plate of ascent engine
32° to 160°F environ. for instrument panel (rad. cooled) uncont. cabin (unpress) equip.
250°F max. on engine mount brackets
650°F on ascent engine nozzle surface (below 6:1 area ratio)
40° to 250°F ascent engine compartment structure (max. temp. is reached 1 - 3 hours after engine shutdown).

For external items:

Solar radiation = 442 BTU/ft²/hr
Lunar surface = -300° to +250°F (depending on sun's position)
Space = 0° Rankine (-460°F)

Humidity: (cabin only)

Controlled cabin (O_2), 40 to 70% r.h.
locally in cabin (O_2), 0 to 100% r.h. (including 1% by weight, salt solution)

Hazardous Gas:

Same as launch and boost

Electromagnetic Interference:

Same as pre-launch packaged

*Will reach 1600°F on certain skins during service module RCS plume impingement.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Ascent (cont'd)

Meteoroids:

For external items. Paragraph 4.2.1

Sand and Dust:

This is to be specified by Grumman

Radiation:

See paragraph 4.1

**Equipment temperature due to combined exposure shall be determined for external items.

TABLE III

LMMP MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

Notes: 1. Factors of safety are not included in the levels specified herein.

a. LMMP/or individual items ref. 3.2

b. Ground Equipment ref. 3.4

2. All accelerations are "earth g's". Multiply by earth weight or use 32.2 ft/sec.^{2} as appropriate. (sign conv. - Page 37)

3. Vibrational spectra shown gives straight lines on a log-log plot.

4. Packaged and unpackaged - The work "packaged" in this table refers to containers used for transportation, handling and storage.

5. Radiation - applied to external and internal items. Ref. para. 4.0 and 4.1.

6. Meteroids - applies to external items only. Ref. para. 4.2 and 4.2.1.

7. Plume induced environments.

a. RCS - as per paragraph 4.1.5.3

b. Engines - as per paragraph 4.1.5.4

8. For launch and boost vibrations, that primary structure which is directly excited by the acoustics transmitted through the Spacecraft LMMP Adapter (SLA) is designated exterior primary structure; that primary structure which either does not face the adapter or is shielded from it by another piece of structure is designated interior primary structure.

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(a) Pre-Launch - Packaged

Transportation, handling and storage in shipping container shall not produce critical design loads on the LM or LM equipment and shall not increase weight of the LM. The following design environment applies only to packaged LM equipment and not to complete LM stages, except where specified.

Acceleration:

(ns) 2.67 g vertical with 0.4 g lateral, applied simultaneously to the package. This condition also applies to complete LM stages.

(v) 1.0 g vertical

(ns) 2.0 g in direction of hoisting (when rings are use, consider applied to any one or any combination of rings).

Shock:

(ns) Shock as in MIL-STD-810 (USAF) 14 June 1962 Method 516 Procedure III.

Vibration:

(ns) The following vibration levels are specified during transportation, handling and storage. Vibration to be applied, along three mutually perpindicular exes, x, y, z to the package.

(Time: ½ Octave per minute, three times per axis from 5 cps to max. cps and back to 5 cps).

For 100 lb. or Less		For 300 lb. or More	
cps	g or D.A.	cps	g or D.A.
5-7.2	.5 in D.A.	5-7.2	.5 in D.A.
7.2-26	±1.3 g	7.2-26	±1.3 g
26-52	.036 in D.A.	26-52	.036 D.A.
52-500	±5.0 g	-----	
(f)		(f)	

(f) for 100 to 300 lbs. - use Figure 514-8 Method 514 MIL-STD-810 (USAF) 14 June 1962 for maximum frequency.

(v) Earth gravity compensation is not required

(ns) Not simultaneous loading conditions at these levels

(nc) Not simultaneous environment conditions at these levels

(a) Pre-Launch - Packaged (continued)

Pressure:

Ground transportation and storage: min. of 11.78 psia

Air Transportation: min. of 3.45 psia for 8 hrs. (35000 ft. alt)

Temperature:

Ground Transportation: -65°F to +160°F for 2 weeks

Air Transportation: -45°F to _140°F for 8 hrs.

Storage Temperature: -20°F to +110°F ambient air temperature. plus 360 BTU/ft^2/hr. up to 6 hrs/day for 3 years.

*Humidity:

(nc) In accordance with Method 507, MIL-STD-810, 14 June 1962, except that the maximum test temperature shall be 110°F instead of 160°F and the minimum test temperature shall be 40°F instead of 68°F to 100°F.

*Rain:

(nc) Rain defined in Method 506 MIL-STD-810 (USAF) 14 June 1962.

*Salt Spray:

(nc) Per Method 509, MIL-STD-810; (No direct impingement)

*Sand and Dust:

(nc) Per Method 510, MIL-STD-810 except test. temp. shall be 90° ± 20°F instead of 160°F.

Fungus:

In accordance with Method 508, MIL-STD-810 (USAF) 14 June 1962.

*Ozone:

(nc) Three years exposure as follows: 72 hours, at 0.5 PPM, 3 months at 0.25 PPM and remainder at 0.05 PPM concentration.

*Hazardous Gases:

Explosion exposure as defined in Method 511, MIL-STD-810 (USAF) 14 June 1962.

*Electromagnetic Interference:

In accordance with LSP-530-001.

*Ambient environments on outside of package

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(b) Pre-Launch - Unpackaged

Ground handling shall not produce critical design loads on the LM or LM equipment and shall not increase weight of the LM. The following design environment applies only to unpackaged LM equipment and not to complete LM stages, except where specified.

Acceleration:

2.67 g Vertical with 0.4 g lateral applied simultaneously. This condition also applied to complete LM stages.

(ns) 2.0 g in direction of hoisting

Shock:

(ns) Shock as in MIL-STD-810 (USAF) 14 June 1962 Method 516, Procedure I modified. Modify shock pulse to sawtooth 15 g peak 10-12 ms rise, 0-2 ms decay.

Pressure:

Ambient ground level pressure. (hermetically sealed units installed in the crew compartment will be subjected to a limit pressure of 20.5 psi absolute during preflight checkout).

Temperature:

-20°F to 110°F Ambient Air Temperature plus 360 BTU/FT^2/hr up to 6/hr/day.
From the time of hypergolic loading (approx. T-112 hrs) to lift off (T-0):
40°F to 110°F SLA cavity external to LM
50°F to 100°F SLA cavity internal to LM

Humidity:

(nc) In accordance with Method 507, MIL-STD-810, 14 June 1962, except that the maximum test temperature shall be 110°F instead of 160°F and the minimum test temperature shall be 40°F instead of 68°F to 100°F.

Rain:

(nc) Same as prelaunch packaged but no direct impingement

Salt Fog:

(nc) Same as prelaunch packaged

Sand & Dust:

(nc) Same as prelaunch packaged (not required for hermetically sealed cabin equip).

(b) Pre-Launch Unpackaged (cont)

Fungus:

Same as pre-launch packaged

Ozone: (nc)

Same as pre-launch packaged

Hazardous Gases:

MIL-STD-810, Method 511, 14 June 1962 and MSFC Dw. 10M01071. This condition also applied to complete LM stages.

Electromagnetic Interference:

Same as pre-launch packaged

(v) See Page 42

(ns) See Page 42

(nc) See Page 42

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(b^1) Pre-launch Sheltered Environment for complete LM Stages:

Ground handling shall not produce critical design loads on the LM or LM equipment and shall not increase weight of the LM. The following design environment applies only to complete LM stages .*

Pressure:

Ambient ground level pressure (hermetically sealed units installed in the crew compartment will be subjected to a limit pressure of 20.5 psia during preflight checkouts).

Temperature:

+60°F to 80°F for up to 3 years. +52°F to 105°F for 1 hour maximum with environmental equipment out of commission.

Humidity:

30 to 70% for up to 3 years. 100% rel. humidity up to 10 days.

Sand and Dust: (nc)

External to the LM the particle count shall not exceed level 1,000,000 of LSP-14-007 (Ref. 21). Internal to the LM cabin and partical count shall not exceed level 100,000 of LSP-14-006 (Ref. 21).

Ozone: (nc)

Same as pre-launch packaged

Hazardous Gases:

MIL-STD-810 (USAF). 14 June 1962, Method No. 511 and MSFC Drawing 10M01071. This condition applies to complete LM stages.

Electromagnetic Interference:

Same as pre-launch packaged.

* Grumman cold flow facility conditions to be supplied

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(c) Launch and Boost SATURN V

Acceleration (2)	X g	X Rad/Sec^2	g	Rad/Sec^2	g	Rad/Sec^2
Lift Off Condition	+2	-	±.65	-	±.65	-
Max q Condition (S-1C)	+2.3	-	±.30	-	±.30	-
Boost Condition (S-1C)	+4.4	-	±.20	-	±.20	-
Outboard Engine Cut-Off	+3.0	-	-1.0	-	-1.0	-
Outboard Engine Cut-Off	-1.0	-	+1.0	-	+1.0	-
Cut Off Condition (S-1C)	-1.70	-	±.10	-	±.10	-
Engine Hardover (S-II)	+2.10	-	±.40	-	-	-
Engine Hardover (S-II)	+2.10	-	-	-	±.40	-
Engine Hardover (S-IVB)	+1.60	-	±.23	±.70	±.23	±.70
Earth Orbit	0	0	0	0	0	0

Vibration:

The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

1. General Primary Structure

Since these vibration levels are input to equipment support, appropriate account must be taken for transmissibility of the secondary structure.

1.1 To Ascent Stage Equipment Support

Random: 2.5 min/axis

20 -	69 Hz	.015 g^2/Hz
69 -	100	+12db/oct
100 -	145	.065 g^2/Hz
145 -	200	+12db/oct
200 -	300	.25 g^2/Hz
300 -	620	-6 db/oct
620 -	1500	.50 g^2/Hz
1500 -	2000	-12db/oct

Sinusoidal: 3 oct/min/axis 5-100-5 Hz

5 - 20 Hz	.154 inch D.A.
20 - 100	3.1g

1.2 To Descent Stage Equipment Support

Random: 2.5 min/axis

20 -	35 Hz	+15db/oct
35 -	60	.083 g^2/Hz
60 -	100	+6db/oct
100 -	350	.24 g^2/Hz
350 -	580	-6db/oct
580 -	2000	.089 g^2/Hz

Sinusoidal: 3 oct/min/axis 5-100-5 Hz

5 - 27 Hz	.154 inch D.A.
27 - 100	5.8 g

2.0 General Secondary Structure

These vibration levels are input to equipment from secondary structure and shall be considered as input to "hard mounted" equipment.

2.1 To Ascent Stage Equipment

Random: 2.5 min/axis

20	-	200Hz	+3db/oct
200	-	250	.36 g^2/Hz
250	-	2000	-db/oct

Sinusoidal: 3 oct/min/axis 5-100-5 Hz

5	-	25Hz	.154 inch D.A.
25	-	100	5g

2.2 To Descent Stage Equipment

Random: 2.5 min/axis

20	-	200Hz	+3db/oct
200	-	250	.36 g^2/Hz
250	-	2000	-3db/oct

Sinusoidal: 3 oct/min/axis 5-100-5 Hz

5	-	25Hz	.154 inch D.A.
25	-	100	5g

3.0 Specific Equipment Vibration Levels

The vibration levels for individual components on the Lunar Module are specified in LSP-520-001B dated August 4, 1967.

(c) Launch and Boost (cont'd)

Acoustic:

Sound pressure levels in d.b. (reference 0.0002 dynes/Cm^2 external to the LM with the Saturn V at lift-off and max g levels are as follows:

Octave Band Center Frequency Hz	Sound Pressure Level d.b.
16	106
32	125
63	135
125	139
250	134
500	126
1000	122
2000	117
4000	112
8000	108
Overall	141

Pressure:

Atmospheric pressure at sea level to 1x 10^{-8} mm Hg (N_2) except in cabin which is 82% pure oxygen at one (1) atmos. to 5.8 psia (Decay time approx. 2 mins.)

Temperature:

65° to 75°F cabin structure.
65° to 75°F equipment bay (ascent stage) including NAVBASE equipment area
65° to 75°F equipment bay (descent stage)
65° to 75°F fuel and oxidizer compartment (adjacent to ascent and descent stage main propulsion tanks only).
15° to 100°F ambient sea level - AMR
60° to 80°F LM external surface Launch & Boost, -200°F to 270°F during orbit*
65° to 75°F RCS propellant compartment structure. Fuel and tank 65° to 75°F SIA internal surface - to be supplied

* The LM skins can reach 1400°F during SM/RCS plume impingement

(c) Launch and Boost - (Cont'd)

Humidity:

"none"

Hazardous Gases:

Exterior to cabin: - None; Inside cabin: - (O_2)

Electromagnetic Interference:

Same as pre-launch packaged

Radiation:

See paragraph 4.1

Meteoroid:

For external items. Reference 4.2.1

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(d) Space Flight - Translunar

Acceleration:	X g	X Rad/Sec²	Y g	Y Rad/Sec²	Z g	Z Rad/Sec²
SM prop. system operating	-.36	-	±.062	±1.99	±.062	±1.99
SM prop. system not operating	0	0	0	0	0	0
Shock: (Cond. Transposition)	-.052	-	±.065	±.10	±.065	±.10

Vibration: None

SM prop. system operating

Plume Effects:

Due to Engine: To be supplied
Due to RCS: In accordance with para. 4.1.2.3

Pressure:

1×10^{-14} mm Hg uncontrolled vacuum (space)
5.8 to .1 psia uncontrolled cabin (O_2) about 66 hrs. non linear decay time.
1×10^{-9} mm Hg uncontrolled vacuum (LM descent stage)
1×10^{-10} mm Hg uncontrolled vacuum (LM ascent stage)

Temperature:

32° to 100°F cabin structure
32° to 130°F equipment bays (ascent stage)
32° to 100°F equipment bays (descent stage)
50° to 90°F fuel and oxidizer compartment (adjacent to ascent and descent stage main propulsion tanks only).
-300° to +270°F LM external surface*
32° to 110°F for navigation base equipment
32° to 100°F D/S engine compartment (LM Structure)
32° to 130°F RCS propellant compartment structure. Fuel and tank 40° to 100°F.
-14 to 350°F inner panel cabin window (unpressurized cabin)
0°F to 20°F inner panel cabin window (pressurized cabin)
-87°F to 275°F outer panel cabin window (unpressurized cabin)
-70°F to 275°F outer panel cabin window (pressurized cabin)

* LM external surface can reach 1400°F due to Service Module RCS plume impingement during transposition, docking and separation.

(d) Space Flight Translunar (cont'd)

For External Items:

Solar radiation = 442 BTU/ft^2/hr
Lunar surface -300° to +250°F
(depending on sun's position"
Space = 0° Rankine (-460°F)

Hazardous Gas:

Same as launch and boost

Electromagnetic Interference:

Same as pre-launch packaged

Radiation:

Van Allen, Solar Flare and Space background.
To be defined as needed (inner belt 10 minutes followed by ½ hour delay-outer belt 20) (See paragraph 4.1).

Meteoroids:

For external items. Paragraph 4.2.1

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(e) Lunar Descent - Including separation, descent, hover and touchdown

Accelerations:	X g	X rad/sec²	Y g	Y rad/sec²	Z g	Z rad/sec²
Descent engine operating	+.82	±.19	±.08	±.65	±.08	±.65
Transfer Orbit	0	0	0	0	0	0
Landing: S.S. at C.G. of LM for accelerations at any other point, see P.55						

Case No.	X g	X rad/sec²	Y g	Y rad/sec²	Z g	Z rad/sec²
1	+.545	±.037	±1.096	-.016	0	∓6.957
2	+.545	±.072	0	+7.344	+1.096	-.030
3	+.570	±8.584	∓.026	+4.923	-.280	±.112
4	+1.917	±.018	0	±14.507	±.273	-.104
5	1.917	0	±.273	-.057	0	∓13.742
Shock:						
Landing: 20 ms Rise Time 200 ms Dwell Time - 40 ms Decay						
Case 1	8.0			±14.0		
Case 2			±8.0			±14.0
Case 3				±14.0	±8.0	
Case 4	8.0					±14.0

Vibration:

The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

1. General Primary Structure

Since these vibration levels are input to equipment supports, appropriate account must be taken for transmissibility of the secondary structure.

1.1 To Ascent Stage Equipment Support

Random: 12.5 min/axis

10 - 34 Hz	.003 g^2/Hz
34 - 40	+12 db/oct
40 - 400	.0059 g^2/Hz
400 - 480	-12 db/oct
480 - 2000	.003 g^2/Hz

Sinusoidal: 1 oct/min/axis 5-100-5Hz

5 - 30Hz	.023 inch D.S.
30 - 100	1.1g

(e) Lunar Descent - Including Separation, Descent, hover and touchdown (cont'd)

1.2 To Descent Stage Equipment Support

Random: 12.5 min/axis

10	- 60Hz	.018 g^2/Hz
60	- 67	-12 db/oct
67	- 300	.012 g^2/Hz
300	- 430	-12 db/oct
430	- 2000	.003 g^2/Hz

Sinusoidal: 1 oct/min/axis 5-100-5Hz

5	- 30Hz	.023 inch D.A.
30	- 100	1.1g

2.0 General Secondary Structure

These vibration levels are input to equipment from secondary structure and shall be considered as input to "hard mounted" equipment.

2.1 To Ascent Stage Equipment

Random: 2 min/axis

10	- 38Hz	.018 g^2/Hz
38	- 50	+24 db/oct
50	- 70	.15 g^2/Hz
70	- 600	-3 db/oct to .018 g^2/Hz
600	- 750	-24 db/oct
750	-2000	.003 g^2/Hz

Sinusoidal: 1 oct/min/axis 5-100-5Hz

5	- 30 Hz	.023 inch D.A.
30	- 100	1.1 g

Random: 10.5 min/axis

10	- 38Hz	.018 g^2/Hz
38	- 44	+24 db/oct
44	- 120	.059 g^2/Hz
120	- 140	-24 db/oct
140	- 600	.018 g^2/Hz
600	- 750	-24 db/oct
750	-2000	.003 g^2/Hz

2.2 To Descent Stage Equipment

Random: 12.5 min/axis

10	- 50Hz	+12 db/oct
50	- 100	.015 g^2/Hz
100	- 500	-3 db/oct
500	-2000	.003 g^2/oct

Sinusoidal: 1 oct/min/axis 5-100-5Hz

5	- 30Hz	.023 inch D.A.
30	- 100	1.1g

3.0 Specific Equipment Vibration Levels

The vibration levels for individual components on the Lunar Module are specified in LSP-520-001B, dated August 14, 1967.

(e) Lunar Descent (Cont'd)

Plume Effects:

Due to Descent Engine See figure 4
Due to RCS in accordance with para. 4.1.5.3

Pressure:

1×10^{-12} mm Hg vacuum (space)
4.6 to 5.8 psia controlled cabin
1×10^{-9} mm Hg vacuum (LM descent stage)
1×10^{-10} mm Hg vacuum (LM ascent stage)
5.8 psia to 10^{-9} mm Hg uncontrolled cabin

Temperature:

32° to 100°F pressurized cabin (oxygen atmosphere)
32° to 100°F cabin structure
32° to 160°F environment for instrument panel equip. (rad. cooled) uncontrolled cabin (unpress).
32° to 130°F equipment bays (ascent stage) including NAVBASE equipment.
32° to 100°F equipment bays (descent stage
50° to 90°F fuel and oxidizer compartment structure (adjacent to ascent and descent stage main propulsion tanks only).
-300° to +270°F LM external surface*
-14°F to 350°F inner panel cabin window (unpressurized cabin)
0°F to 350°F inner panel cabin window (press. cabin)(heaters to maintain LOW temp.
-87°F to 275°F outer panel cabin window (unpressurized cabin
-70°F to 275°F outer panel cabin window (pressurized cabin)
32°F to 130°F RCS propellant compartment structure. Fuel and tank 40° to 100°F.

* Some surfaces of descent stage can reach 1600°F during LM RCS plume impingement. A.S areas can reach 1400°F during plume impingement.

32° to 120°F on engine compartment walls (LM structure)
500° to 1200°F on D/S engine case (titanium) during engine operation
1000°F on titanium backface of base heat shield.

For external items:

Solar radiation = 442 BTU/ft^2/hr
Lunar surface = 300° to +250°F
(depending on sun's position)
Space: - 0° Rankine (-460°F)

(e) Lunar Descent (cont'd)

Humidity:	Controlled cabin (O_2), 40 to 70% r.h. Locally in cabin (O_2), 0 to 100% r.h. (including 1% by weight, salt solution)
Hazardous Gas:	Same as launch and boost
Electromagnetic Interference:	Same as pre-launch packaged.
Meteoroids:	Use distribution for sporadic meteoroids as specified in Table V (for external items) (paragraph 4.2.3)
Sand and Dust:	This is to be specified by Grumman
Radiation:	See paragraph 4.1

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

Formulae for determining linear and rotational accelerations at any point of the LEM.

$$\ddot{X}pt = \ddot{X}cg - \ddot{\theta}z \frac{\Delta y}{g} + \ddot{\theta}y \frac{\Delta z}{g}$$

$$\ddot{Y}pt = \ddot{Y}cg + \ddot{\theta}z \frac{\Delta x}{g} - \ddot{\theta}x \frac{\Delta z}{g}$$

$$\ddot{Z}pt = \ddot{Z}cg - \ddot{\theta}y \frac{\Delta x}{g} + \ddot{\theta}x \frac{\Delta y}{g}$$

Where $\ddot{X}cg$, $\ddot{Y}cg$, $\ddot{Z}cg$ = Acceleration at LM c.g. in X, Y, Z directions.

$\ddot{X}pt$, $\ddot{Y}pt$, $\ddot{Z}pt$ = Acceleration at any point on LM in X, Y, Z direction.

$\ddot{\theta}x$, $\ddot{\theta}y$, $\ddot{\theta}z$ = Rotational Acceleration about respective axes.

Δx, Δy, Δz = Distance from specific point to LM C.G. along respective axis (X = 207, Y = 0, Z = 0 = LMMP CG) See Table V

g = 386 in/sec^2

See Figure 2 for LMMP axes

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Stay

Accelerations	X
cond. - at rest	1/6 g
Shock:	Not critical

NOTES: Ascent and descent engines not operating. Vibration due to other sources to be supplied.

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Stay (cont'd)

Pressures:

1×10^{-12} mm Hg uncontrolled vacuum (surface of moon)
4.8 to 5.8 psia (O_2) controlled cabin
1×10^{-9} mm Hg cabin (hatch open) max. open hatch time = 20 mins. non-linear decay.
1×10^{-9} mm Hg vacuum (LM descent stage)
1×10^{-10} mm Hg vacuum (LM ascent stage)
5.8 psia to 10^{-9} mm Hg uncontrolled cabin

Temperature:

32° to 130°F (O_2 temp) pressurized controlled cabin
32° to 100°F cabin structure at touchdown
32° to 130°F cabin structure at lift-off
32° to 160°F environment for instrument panel (rad. cooled) uncont. cabin (unpress. equip.)
32° to 130°F equipment bays (ascent stage including NAVBASE equipment
32° to 160°F equipment bays (descent stage)
40° to 100°F fuel and oxidizer compartments (adjacent to a/s main prop. tanks only)
32° to 200°F fuel and oxidizer compartments (adjacent to d/s main prop. tanks only)
-300° to +270°F LEM external surface
32° to 300°F descent engine compartment structure; 40° to 100°F RCS fuel and oxidizer tanks
-14° to 350°F inner pane cabin window (unpressurized cabin)
0° to 350°F inner pane cabin window (press. cabin)(heaters to maint. low temp. above dew pt.)
-87° to 275°F outer pane cabin window (unpressurized cabin).
-70° to 275°F outer pane cabin window (pressurized cabin).
32° to 130°F RCS propellant compartment structure.
32° to 160°F Aft Bay Equipment.

For External Items:

Solar radiation = 442 BTU/ft^2/hr
Lunar surface = -300° to +250°F (depending on sun's position)
Space = 0° Rankine (-460°F)

Humidity: (cabin only)

Controlled cabin (O_2) 40-70% rel. hum. avg.
Locally in cabin (O_2) 0-100% rel. hum.
(including 1% weight, salt solution)

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Stay (cont'd)

Hazardous Gas:

Same as launch and boost

Radiation:

Solar flare and space background to be defined as needed. See para. 4.1

Electromagnetic Interference:

Same as packaged pre-launch

Meteoroids:

For external items. Ref. 4.2.1

Sand and Dust:

This is to be specified by Grumman

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Ascent - Including ascent rendezvous and docking

Acceleration:	X		Y		Z	
	g	rad/sec^2	g	rad/sec^2	g	rad/sec^2
engine operating	+.70	±.74	±.04	±.83	±.04	±1.47
docking condition	-4.0	0	0	0	0	0
transfer orbit	0	0	0	0	0	0

Vibration:

The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

1. General Primary Structure

Since these vibration levels are input to equipment supports, appropriate account must be taken for transmissibility of the secondary structure.

1.1 To Ascent Stage Equipment Support

Random: 8.5 min/axis

10 - 34 Hz	.003 g^2/Hz
34 - 40	+.2 db/oct
40 - 400	.0059 g^2/Hz
400 - 480	-12 db/oct
480 -2000	.003 g^2/Hz

Sinusoidal: 1½ oct/min/axis 5-100-5Hz

5 - 30 Hz	.023 inch D.A.
30 - 100	1.1 g

2.0 General Secondary Structure

These vibration levels are input to equipment from secondary structure and shall be considered as input to "hard mounted" equipment.

2.1 To Ascent Stage Equipment

Random: 5 min/axis

10 - 34Hz	.003 g^2/Hz
34 - 40	+12 db/oct
40 - 400	.0059 g^2/Hz
400 - 480	-12 db/oct
480 - 2000	.003 g^2/Hz

Sinusoidal: 1½ oct/min/axis 5-100-5Hz

5- 30Hz	.023 inch D.A.
30-100	1.1 g

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Ascent - (cont'd)

Random: 3.5 min/axis

10 - 38Hz	.018 g^2/Hz
38 - 44	+24 db/oct
44 - 120	.059 g^2/Hz
120 - 140	-24 db/oct
140 - 600	.018 g^2/Hz
600 - 750	-24 db/oct
750 - 2000	.003 g^2/Hz

3.0 Specific Equipment Vibration Levels

The vibration levels for individual components on the Lunar Module are specified in LSP-520-001B, dated August 14, 1967.

Plume Effects: Due to Ascent Engine See Figure 11
Due to RCS in accordance with paragraph 4.1.5.3.

Pressure:

1×10^{-12} mm Hg vacuum (Space)
4.8 to 5.8 psia controlled cabin
1×10^{-10} mm Hg vacuum (LM Ascent Stage)
5.8 psia to 10^{-9} mm Hg uncontrolled cabin

During the course of the Fire-in-th Hole (FITH) staging pressures are created in the interstage area as a function of separation distance, tilt angle, and sideslip. Pressure transients arise as a result of the interstage configuration, separation distance and the resulting flow field. The maximum equivalent steady state pressures occur at zero stage separation (starting transient). Tests to date indicate that on the ascent stage a pressure of approximately 0.79 psia is developed in the separated flow region adjacent to the nozzle in the ascent engine compartment and pressures as high as 3.14 psia occur in the regions of minimum clearance between stages due to the reattached flow. The peak pressure on the descent stage deflector is 6.0 psia due to the direct flow impingement. Maximum equivalent steady state pressures are built up on the descent stage in the first 0.10 seconds of the starting transient decaying to 50% of the steady state value 0.30 seconds after ignition. (Ref. 26).

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Ascent (cont'd)

Temperature:**

32° to 130°F (O_2) temp) pressurized cabin
32° to 130°F cabin structure
32° to 130°F equipment bays (ascent stage), including NAVBASE equipment
40° to 100°F fuel and oxidizer compartments (adjacent to a/s main prop. tanks only)
-300° to +270°F LM external surface*
-14° to 350°F inner panel cabin window (unpressurized cabin)
0° to 350°F inner panel cabin window (press. cabin)(heaters to maintain low temp.
-87° to 275°F outer panel cabin window (unpress. cabin).
-70° to 275°F outer panel cabin window (pressurized cabin)
32° to 130°F RCS propellant compartment structure; 40 to 100°F RCS fuel and oxidizer tanks
225°F max. on engine cover 120 min. after engine shutdown
400°F external A/S base heat shield (30 mins) Temp. transient during FITH, 270°F at peak load & 710°F at zero load on A/S base heat shield during firing
470°F on injector plate of ascent engine
32° to 160°F environ. for instrument panel (rad. cooled) uncont. cabin (unpress) equip.
250°F max. on engine mount brackets
650°F on ascent engine nozzle surface
40° to 250°F ascent engine compartment structure **

For External Items:

Solar radiation = 442 BTU/ft^2/hr
Lunar surface = -300° to +250°F (depending on sun's position)
Space = 0° Rankine (-460°F)

Humidity: (cabin only)

Controlled cabin (O_2), 40 to 70% r.h.
locally in cabin (O_2), 0 to 100% r.h. (including 1% by weight, salt solution)

Hazardus Gas:

Same as launch and boost

TABLE III

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Ascent (cont'd)

Electromagnetic Interference:

Same as pre-launch packaged

* Temp. can reach 1600°F on certain skins due to RCS plume impingement.

** Max. temperature of structure is reached 1 - 3 hours after engine shutdown.

Meteoroids:

For external items. Paragraph 4.2.1

Sand and Dust:

This is to be specified by Grumman

Radiation:

See paragraph 4.1

** Equipment temperature due to combined exposure shall be determined for external items.

TABLE IV

LM MASS PROPERTY HISTORY - DESIGN WEIGHT - PRELIMINARY

MISSION EVENT	WEIGHT (EARTH LBS)	CENTER OF GRAVITY			MOMENT OF INERTIA (SLUG-FT^2)		
		STA (In)	Dist. From Thrust Axis		I_{xx}	I_{yy}	I_{zz}
		X	Y	Z			
TRANSLUNAR INJECTION	32000	187	0	1	21400	23350	23450
LEM/CSM SEPARATION	32500	188	0	0	22500	24600	24500
END INSERTION TO HOHMANN - DESCENT	32113	188	0	0	22300	24300	24250
BEGIN HOVER	16947	210	0	0	12350	14500	16500
LUNAR TOUCHDOWN -MINIMUM	14650	218	0	0	10850	11250	13500
LUNAR TOUCHDOWN -NOMINAL	15021	218	0	0	11100	11500	13800
LUNAR TOUCHDOWN -MAXIMUM	16200	213	0	0	12000	12800	15150
LUNAR LAUNCH	10820	244	0	0	6500	3300	5650
END INSERTION TO HOHMANN -ASCENT	5516	254	0	0	2900	2700	1650
BURNOUT (DOCKED)	5322	254	0	0	2800	2650	1500
COMPLETION OF CREW TRANSFER	4695	254	-1	-5	2500	2400	1400

NOTE - THE NUMBERS GIVEN ABOVE ARE NOT EXACT. THEY REPRESENT ESTIMATED VARIATION OF LM WEIGHTS AT VARIOUS STAGES OF THE MISSION STARTING WITH THE SEPARATION WEIGHT OF 32500#. FIRM NUMBERS WILL BE PROVIDED AS SOON AS POSSIBLE.

TABLE V

LM-10 MASS PROPERTY HISTORY - DESIGN WEIGHT

MISSION EVENT	Weight (Earth lbs.)	Center of Gravity			MOMENT OF INERTIA (SLUG-FT^2)					
		STA (In)	Dist. From Thrust Axis							
37000# Case		X	Y	Z	I_{xx}	I_{yy}	I_{zz}	I_{yz}	I_{xz}	I_{xy}
TLI	37000	182.2	.17	-.71	26522	28558	27132	248	305	50
SEPARATION	37426	183.2	.17	-.25	27972	29821	28267	237	616	57
PDI	37381	183.1	.17	-.25	27947	29730	28163	234	614	59
LUNAR TOUCHDOWN										
Minimum (19361 DPS + 130 consum)	17890	207.2	.36	-.52	15714	17545	18753	239	663	26
Nominal (18953 + 130)	18298	205.9	.35	-.51	15971	17990	19138	239	660	28
Maximum (17970 + 130)	19281	203.0	.33	-.49	16589	19011	20016	239	654	31
LUNAR LAUNCH	10931	244.0	-.04	2.83	6738	3499	5985	-20	180	60
CONCENTRIC SEQUENCE INIT. MANEUVER	5915	258.1	-.04	5.24	3300	2910	1992	-21	86	74
FINAL HARD DOCK	5674	257.2	-.04	5.47	3191	2868	1867	-13	92	74
COMPLETION OF CREW TRANSFER	4949	257.1	.74	2.53	2952	2641	1726	-16	120	75

TABLE VI

Sign convention positive directions as on page 34

ACCELERATION DUE TO BOOSTER LIMIT LOADS

Booster		NOTE	Weight - lbs.		Thrust - lbs.		Accelerations					
							Longitudinal g's		Lateral g's		Rad/Sec^2	
			Ignition	Cut-Off	Ignition	Cut-Off	Minimum	Maximum	Y	Z	Y	Z
SATURN IB	S-IA		1,199,080	381,210	1,504,000	1,730,000	1.25	4.5	---	---	--	
	S-IVB		256,100	51,900(5)	--	200,000	.78	3.85	---	---	--	
SATURN V	S-IC							1.6	±.65	±.65	--	
	S-IC	(2)	6,000,000	1,758,700	7,500,000	8,630,000	--	4.9	±.1	±.1	--	
	S-IC(max.q)(2)		--	--	--	--	--	2.07	±.3	±.3	--	
	S-IC(c/o)(7)(2)		--	--	--	--	--	-1.7	±.1	±.1	--	
	S-IVB		360,050	128,850(6)	--	200,000	.56	1.87(1)	---	---	--	
SATURN V	S-IC b/o		--	1,758,700	--	8,630,000	--	--	---	---	--	
(Engine	S-11 b/o(2)		1,376,050	447,850		1,000,000	.8	2.15	±40	- -	--	
Hard-Over)	S-IVB b/o		--	128,850	--	200,000	--	1.87(1)	±.23	[illegible].23	±.70	±.70
	S-11 b/o(2)		1,376,050	447,850		1,000,000	.8	2.15	- -	±.40		

Notes:
(1) Includes 1.2 dynamic amplification.
(2) NASA Ltr. PS5/L1665 1-64-675 7 December 1964

(5) Second stage jettison weight = 25,180, Payload weight = 26,720.
(6) Third stage jettison weight = 36,500, Payload weight = 92,350 including adapter
(7) At end of first stage thrust, longitudinal springback.

b/o Burn out   c/o Cut Off

TABLE VII - SUMMARY - LM FACTORS OF SAFETY

Environment	Location	Mission Level	Acceptance	Design Mission	Design Limit[1] (Qualification)	Ultimate
Loads		1.0	1.0	1.0	1.5[6]	1.5[6]
Acceleration		1.0	1.0	1.0	1.5	1.5
Shock		1.0	1.0	1.0	1.5[7]	1.5[7]
Vibration	Elect. Assy. or Fatigue crit. Struct.	1.0	1.0	$(1.3)^2$	$(1.3)^2$	$(1.3)^2$
(Random PSP)	Strength Crit. Struct.				$(1.5)^2$	$(1.5)^2$
Vibration	Elect. Assy. or Fatigue crit. struct.	1.0	1.0	1.3[7]	1.3[7]	1.3[7]
(Sine G or DA)	Strength Crit. Struct				1.5[7]	1.5[7]
Pressure	Cabin	1.0[2]	1.33	1.0[2]	2.0[5]	2.0[5]
	Prop. Storage Tanks	1.0[2]	1.33	1.0[2]	1.5[8]	1.5[8]
	Helium Storage Tanks	1.0[2]	1.33	1.0[2]	1.5[8]	1.5[8]
	Super Critical He. Tanks	1.0[2]	1.33	1.0[2]	2.0[5]	2.0[5]
	Water Tanks	1.0[2]	1.33	1.0[2]	2.0[5]	2.0[5]
	Pneumatic (High Pressure)	1.0[2]	1.33	1.0[2]	2.0	2.0
	Prop./RCS (Low Pressure)	1.0[2]	2[3]	1.0[2]	3.0[4]	3.0[4]
Temperature		~~1.0~~	~~1.0~~	~~1.0~~	~~1.0~~	~~1.0~~
Accoustics		1.0	1.0	1.0	1.0	1.0

NOTES:

(1) Qualification shall consist of two parts (a) design limit level tests as noted herein (b) endurance tests to consist of one complete operational cycle plus one additional flight simulation at mission level (Ref. Para. 1.1.4).

(2) Factor applied to max. relief valve setting or max. thermally developed pressure.

(3) Proof pressure = 2 x max. relief valve setting or combined surge plus nominal pressure whichever is greater (not applicable to propellant storage tanks).

(4) Burst Pressure = 3 x max. relief valve setting or 1.5 x combined surge plus nominal pressure whichever is greater (not applicable to propellant storage tanks).

(5) For pressure combined load conditions use 1.5, where pressure is a singular load use 2.0.

(6) For all mechanical moving parts of LM landing gear use 1.35.

(7) For packaged or unpackaged prelaunch conditions use 1.0.

(8) For pressure combined with load.

REFERENCES

1. Apollo Ground Support Equipment - General Environmental Criteria and Test Specification. MSC-GSE-1B, Rev. 1, June 23, 1964.

2. NASA Project Apollo - LEM Technical Briefing

3. MSFC Drawing No. 10M01071

4. Grumman LSP-530-001

5. ARDC - 1956 Standard Atmosphere

6. MIL-STD-810 (USAF) 14 June 62

7. NASA TWX058 to GAEC dated 6 May 1963

8. GAEC Telecon LTM-520-16 dated 16 May 1963

9. Grumman - LPL-540-1 dated 15 July 1963 - Mission Analysis

10. NASA Letter SSS/LM - 63-48 1 April 63

11. NASA Telegraphic Message - SCE-T356/63-62, 7 June 1963

12. Engine Container Spec. LSP-420-001

13. NASA LTR PS5/L1665 -164-675 7 December 1964

14. Grumman Letter - LLR-520-27 dated 8 March 1965

15. NASA Letter SLE-13-63-427, dated October 16, 1963

16. Grumman LSP-470-1A dated 7 June 1965

17. ASME Unfired Pressure Vessel Code

18. MSC Letter ES2-1-65-3 dated 18 Jan. 1965 (for ambient temp. helium press. tanks)

19. Grumman LSP-470-1A, SCN 5A dated 3-21-66

20. Grumman LMO-520-246 dated 25 June 1965

21. Grumman LSP-14-006, 1 July 1964

22. Grumman LED-520-3 Revision A, dated May 24, 1965

23. NASA Ltr. PS5/L145/13/65-837 Oct. 1, 1965

24. NASA Ltr. BG54 66-199, April 7, 1966

25. NASA Ltr. PR23-66-125, February 15, 1966

26. Grumman LED 611-2, LM-1 Operating Equipment vs Mission Time.
27. Grumman LED 540-47, Modular Mission Data (LM-2)
28. Grumman LED 540-59, LM3 T-Cup
29. Grumman LMO 540-1441, LM-4 T-Cup
30. Grumman LMO 540-1481, LM-5 T-Cup
31. Grumman LMO 540-1527, LM-6 T-Cup
32. Grumman LAV 540-1275, LM-10 Thru 14 T-Cup (Timeline & Consumable Usuage Program)