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C65-8064

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
EXHIBIT "E" Para. 5.1	13	LEM	NAS 9-1100	14 Jan 63

Type II Data

Primary No. 687

CLASSIFICATION CHANGE
To UNCLASSIFIED
By authority of GDS-EO 11652
Changed by L. Shirley Date 12/31/72
Classified Document Master Control Station, NASA
Scientific and Technical Information Facility

REPORT

No. LED-520-1D

DATE: 15 May 1963
Rev: 15 Nov. 1963
Rev: 15 March 1964
Rev: 15 May 1965

DESIGN CRITERIA AND ENVIRONMENTS

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000039

CODE 26512

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DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS
15 Aug 63	A.S.	Revisions on all pages except pages 3,4,7,9,21,22,24,30,37,39	Current information incorporated.
		Added pages 5.1, 17.1, 18.1, 46.1	
15 Nov 63	A.S.	Major Revision on all pages. Note Line in margin.	Current information incorporated.
15 Mar 64	A.S.	Revised Induced Radiation, Meteoroid Vacuum Values, LEM Mission Times.	Current information incorporated
		Little Joe II deleted. Revisions on all pages with lines in margins.	
15 May 65	A.S.	Major Revision on all pages. Note Line in Margin.	Current information incorporated.

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Group 4 Document Downgraded at 3 Year Intervals, DOD DIR 5200.10 Declassified After 12 Years

[redacted]

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

ENG 245

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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 LEM and its equipment.

DESIGN CRITERIA AND ENVIRONMENTS

1. General

1.1 Requirements - The LEM 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.

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 analyses 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 LEM 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 numerical 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.

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 apparant. 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 existance 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 LEM, the probability goal for accomplishing the mission objectives shall be 0.984. For the LEM, 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.

1.3 Advances 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 LEM 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 LEM shall be capable of receiving cabin repressurizations from the Command Module repressurization system. The LEM 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. Transportation is expected to be by truck, however, air transport will be considered to reduce shipping time. 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 AMR. Time for transportation by truck is expected to be on the order of one week to AMR and two weeks 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 C-13 flights. Assembly for C-5 flights will occur in the vertical assembly. Prior to prelaunch operations at AMR the LEM and its subsystems will undergo acceptance tests at Grumman. LEM subsystems 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 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 seconds or approx. 17 minutes.

2.3.3 Spacecraft - Immediately after translunar injection, the Command Module/Service Module is separated from the LEM shroud and the upper shroud is jettisoned. The CM/SM is then re-oriented to mate with the LEM at the upper LEM hatch. During this maneuver the CM/SM is the active member and the LEM remains attached to the empty S-IVB. 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 with the first correction occurring about 2 1/2 hours after injection. At about 65 hours the SM propulsion system establishes the spacecraft in a circular lunar orbit at 80 nautical miles altitude. The crew is transferred and after a system check, the LEM is separated at about 68 hours after launch. The LEM is the active member during Descent, Landing, Ascent, Rendezvous and Docking. After crew transfer to the Command Module the LEM is jettisoned and left in lunar orbit.

The summary of LEM 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.

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 LEM 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 will end in a hovering maneuver which may require translations up to 1000 ft. and may last for two minutes. Final touchdown horizontal velocity shall not exceed 4 ft/sec., and vertical velocity shall not exceed 10 ft/sec.

2.3.4.1 Lunar Ascent - The powered ascent of the LEM ascent stage to the 50,000 ft. altitude circular orbit shall take 7.1 minutes. A 9 hour orbital contingency at 50,000 ft. will be available to permit the insertion into a rendezvous trajectory at 80 nautical miles altitude. The total ascent time, including the 9 hour orbit contingency, shall take 13.5 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 LEM and its component subsystems shall be designed such that general modifications to the LEM module or its subsystems do not propogate through the other modules of the Apollo spacecraft.

3.2 Structural Requirements For LEM & LEM 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 limit loads, are conservatively selected to represent 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 limit 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.

Ultimate Factor - At limit load ** 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 to limit loads. This value may be reduced to 1.35 for special cases, not involving pressure vessels, upon rational analysis and with MSC approval.

Yield Factor - At limit load ** 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 limit 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 LEM.

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

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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.

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.* This factor may be reduced to 1.5 for special cases upon rational analysis and negotiation with MSC. (The main propellant tanks, RCS tanks, and Ambient Temperature Helium Pressurization Tanks are a special case and will have an ultimate factor of 1.50 on the worst combination of acceleration, pressure, vibrations, shock, etc) Ref. 18.

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. 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. 43.

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 factor for pre-launch packaged and unpackaged 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).

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 & Fog
d. Sand & Dust
e. Fungus
f. Hazardous Gases
g. Radiation
h. Temperature
i. Ozone
j. Hail
k. Lightning

3.3 Flight Loads

3.3.1 Launch Vehicle

3.3.1.1 Temperature

3.3.1.1.1 C-5 - Ambient sea level air temperature at AMR during launch time will vary between +15°F. and 100°F. The most likely range is between 56°F. and 83°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 C-5 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 LEM will vary between approximately -300°F to +370°F depending on the orientation of the spacecraft relative to the sun, due to space environment of -460°F. and solar radiation of 440 BTU/Ft^2 hr. The temperature will be between 0° to 160°F. in vacuum cabin and equipment bay, +40° to 100°F. in the propellant compartment, and +70° to +80° in the controlled (O_2) cabin. (Local spots in the cabin 50° to 90°F.)

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.)

3.3.2.3 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	±.037g	±2.82 Rad./sec.^{2}

3.3.2.4.2 Repositioning - The shock loads due to repositioning 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 LEM will vary between approximately -300° and +270° depending on the orientation of the sun. The space environment is -460° F. and solar radiation is 440 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. When pressurized the temperature of the cabin will be between 70° and 80° F. The temperature will be 0° to +160° F. in vacuum cabin and equipment bay and +40° to +100° F. in the propellant compartment. (Cabin local spots 90-100° F.) (The descent engine combustion chamber back face 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 LEM will be 5.0 psi ± .20 psi, with a relief valve setting of 5.6 psi ± .2 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	±.0378	±.192	±.091
Elliptic Orbit	+ .372	∓.0382	∓.193	∓.092
Start of Hover	+ .707	∓.0728	∓.448	∓.166
End of Hover	+ .815	∓.084	∓.645	∓.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 LEM attitude within 3° of local vertical and must hold the LEM motion within the following limits at impact on the lunar surface.

Local Vertical Velocity	Local Horizontal Velocity	Pitch/Roll Rate	Yaw Rate
≤ 10 f p s	≤ 4 f p s	≤ 3 deg./sec.	≤ 3 deg/sec.

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.

	Vertical Accel. Earth g's (X)	Lateral Accel. Earth g's (Y or Z)	Rad/Sec^2 about Y or Z
Initial Contact	8.0 (10-20 ms)	0	±14.0
Rock Back	0	±8.0. (10-20 ms)	∓14.0

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 g	X R/Sec^2	Y g	Y R/Sec^2	Z g	Z R/Sec^2
Maneuver	+.70	±.74	±.04	±.030	±.4	±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 LEM and/or individual item.

Criteria is presented for ground equipment during support of LEM 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 Proof Factor - After ground support equipment has been subjected to limit pressure times the proof factor, it shall be fully capable of performing its intended use. For hydraulic, fluid and pneumatic systems, GSE limit pressure shall be equal to the highest working pressure of the GSE system, except for servicing flight pressure systems it shall be no less than the proof pressure of the flight system. For hydraulic or fluid systems, the proof factor shall be 1.5. For pneumatic systems, the proof factor shall be 2.0.

3.4.1.2.4 Burst Factor - The burst factor for hydraulic or fluid systems shall be 2.5, applied to the GSE limit pressure. The burst factor for pneumatic systems shall be 4.[illegible], applied to the GSE limit pressure. There is to be no structural failure at these levels.

3.4.1.2.5 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.

3.4.1.2.6 Pressure Vessels - Pressure vessels used in GSE when designed in accordance with the ASME Unfired Pressure Vessel Code shall be tested to a proof pressure equal to 1.5 times the GSE limit pressure. Material allowable stresses and safety factors to be as specified in the ASME Code.

3.4.1.2.7 Shock - 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 LEM 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. 4 to obtain amplification factors for use with isolation material.

3.4.1.2.8 Acceleration

Load Environment		Load Factors (g) X	Y	Z
Hoisting		+2.67	±0.4	±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 (For Commercial aircraft, Case 5 should be +5.33)	Case 1	-1.67		
	Case 2	+3.0		
	Case 3		+1.0	
	Case 4	-1.0		
	Case 5			+4.0
Rolling Towing-Speeds not to exceed [illegible] on improved roads	Case 1	+1.25		
	Case 2	[illegible].0	+0.5	
	Case 3	+1.0		+1.0

3.4.1.2.9 Other Environments - For the following environments.(ref. 1)

1. Temperature
2. Humidity
3. Rain

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
13. Hail
14. Lightning

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 a lower 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.
	Unpackaged: -20 to 110°F air temperature plus 360 BTU/ft^2/hr. up to 6 hours per day

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 - For design purposes as simulated by Method 507, MIL-STD-810, June 14, 1962, except that the maximum test temperature shall be 110°F instead of 160°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 LEM 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 - 15 to 100 percent relative humidity including condensation.

3.4.4.4 Ozone - Same as 3.4.2.6

3.4.4.5 Rain - Same as paragraph 3.4.2.10 except no direct impingement.

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

3.4.4.7 Sand and Dust - Same as paragraph 3.4.2.3

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 LEM 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 LEM in the loaded condition, LEM 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. Shock for LEM Vehicle will be supplied.

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 LEM 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 magnitude field. The cut-off rigidity is given by:

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

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:

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

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:

$$T < 10 \text{ Mev}: \quad N(>T) = 22.3\, N(>239 \text{ MV})\, T^{-1.2}$$

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

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

where N (> 239 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 MV) particles/cm^2 in an 8.3-day mission plotted against N (> 239MV). 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 2 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 B_v for the entire event.

4.1.2. Thermal Radiation - The source of radiation presented below impinges on the exterior of the LEM 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	0°Rankine

(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 energy 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 [illegible] to [illegible] degrees F. This atmosphere will be 100% oxygen at a pressure of [illegible] to 5.[illegible] psi. The relative humidity will be between 40% and 70%.

4.1.5.3 [illegible] Exhaust Plume - [illegible] exhaust plume effects shall be [illegible] during Transluna, Descent, and Ascent. Plume heating effects shall [illegible] accordance with Fig. 3. Refer to Fig. [illegible] for location of [illegible] and [illegible] thrusters.

4.2.0 Meteoroid Considerations

4.2.1 Meteoroid Environment - The LEM mission environment is defined in Ref. 19

(a) Sporadic Meteoroids

(b) Shower Meteoroids

(c) Secondary Meteoroids (applies to lunar surface only)

The density for secondary meteoroids shall be 2.5 g/cc instead of 3.5 g/cc contained in Ref. 19.

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 440 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 5 (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 5 (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) Shallow depressions and low protuberances will be sufficiently numerous so that one or more of the landing pads of the LEM will be horizontally constrained after moving along the surface a variable distance. The coefficient of friction that may be expected during horizontal sliding will vary between 0.4 and 1.0. Topography in the touchdown area will produce both forms of surface resistance.

(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:

$$\text{Arc sin}\left[\frac{\text{height of protuberance} + \text{depth of depression}}{2(\text{overturn radius of the landing gear})}\right]$$

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 11 Ref. 16.

4.4.2 Cabin Temperature - The cabin temperature non-stressed limits shall be 70°F minimum and 80°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 12 Ref. 16.

4.4.6 Vibration - The vibration stressed, non-stressed and emergency limits are to be determined.

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 LEM Crew Compartment must be tested to LED-520-3 Revision A. The testing procedures include oxygen compatability, vacuum stability, toxicity limitations and flammability.

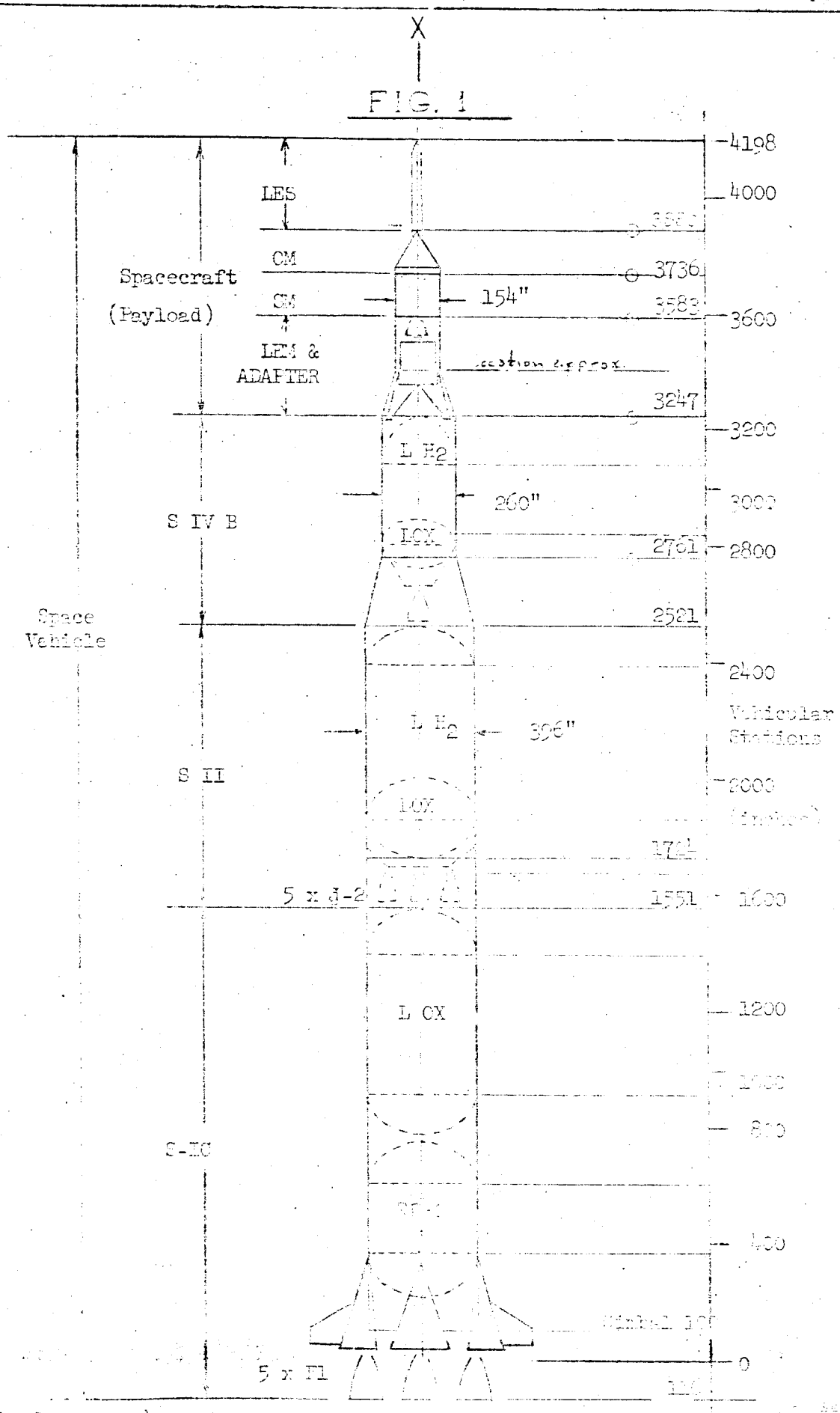
4.5.2 Outside the Crew Compartment - Materials used outside the crew compartment must be evaluated and approved by the LEM Materials Group. A list of approved materials is maintained by that group and an up-to-date list is circulated monthly by LEM Engineering Memorandum.

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

5.0 Summary of Simultaneous Conditions - Table II.

6.0 Weight and Balance - Table III.

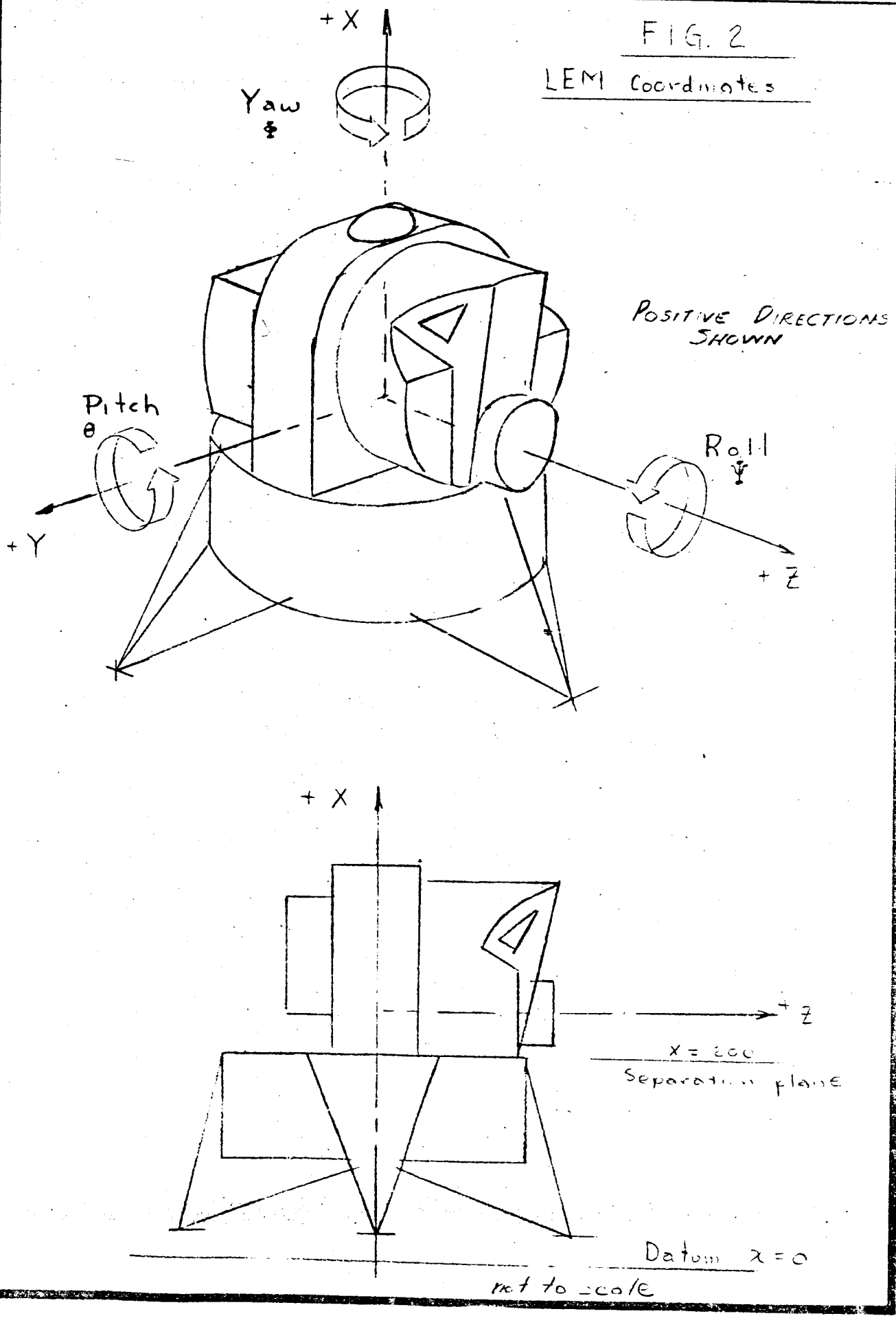
FIG. 1

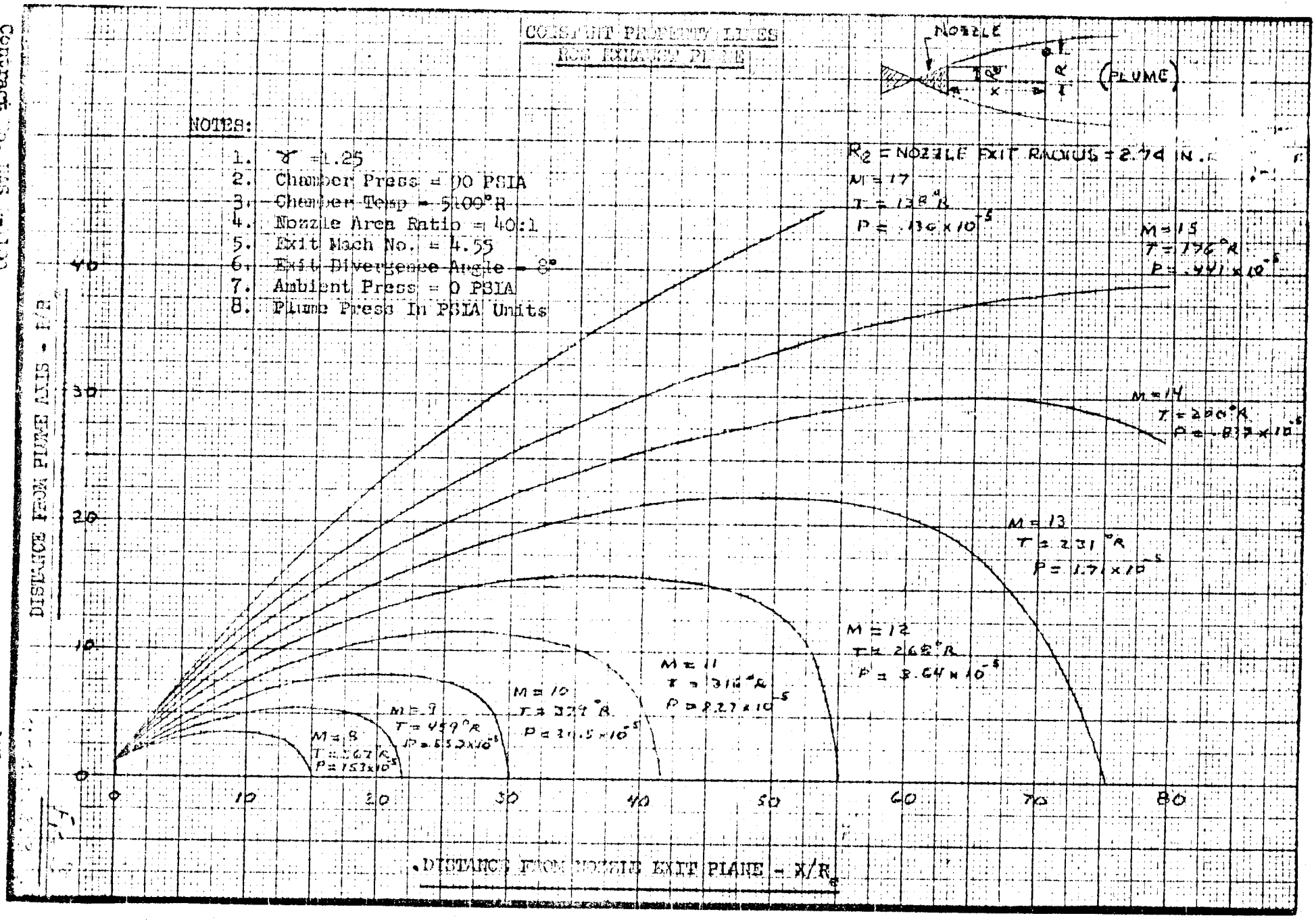


(Ref. Tech. Brief LEM) Apollo, Saturn C-5 Configuration

FIG. 2

LEM Coordinates




CONSTANT PROPERTY LINES
FOR EXHAUST PLUME
NOTES:
1. γ = 1.25
2. Chamber Press = 00 PSIA
3. Chamber Temp = 5400°R
4. Nozzle Area Ratio = 40:1
5. Exit Mach No. = 4.55
6. Exit Divergence Angle = 8°
7. Ambient Press = 0 PSIA
8. Plume Press In PSIA Units
NOZZLE
(PLUME)
R2 = NOZZLE EXIT RADIUS = 2.74 IN.
M = 17
T = 138°R
P = .136 x 10^-5
M = 15
T = 176°R
P = .441 x 10^-5
M = 14
T = 200°R
P = .837 x 10^-5
M = 13
T = 231°R
P = 1.71 x 10^-5
M = 12
T = 262°R
P = 3.64 x 10^-5
M = 11
T = 316°R
P = 8.27 x 10^-5
M = 10
T = 379°R
P = 31.5 x 10^-5
M = 9
T = 459°R
P = 53.2 x 10^-5
M = 8
T = 567°R
P = 153 x 10^-5
DISTANCE FROM PLUME AXIS - Y/R
DISTANCE FROM NOZZLE EXIT PLANE - X/R2
0
10
20
30
40
50
60
70
80

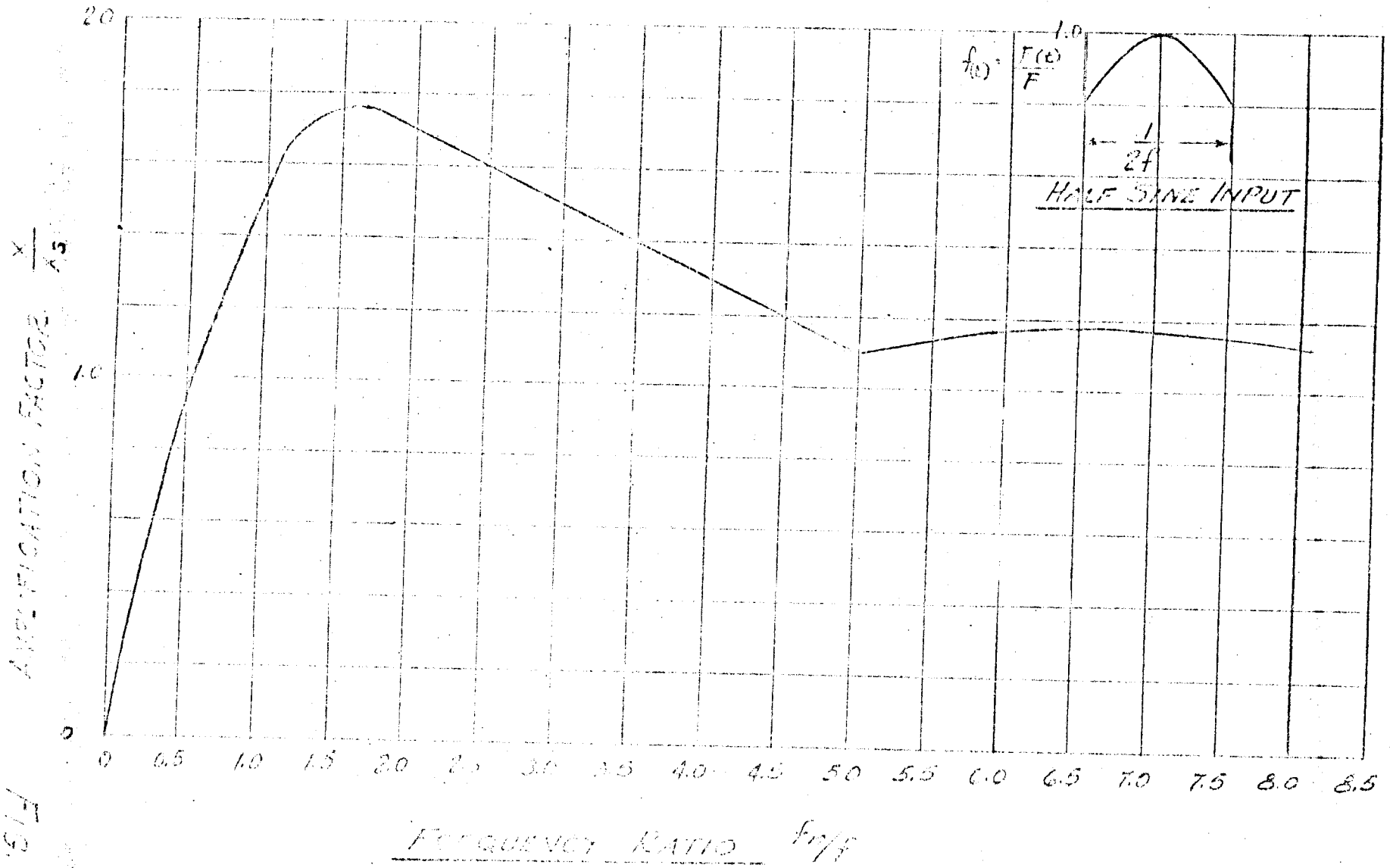

2.0
1.0
0
AMPLIFICATION FACTOR $\frac{X}{X_S}$
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5
FREQUENCY RATIO f_n/f
$f_{(t)} = \frac{F(t)}{F}$
1.0
$\frac{1}{2f}$
HALF SINE INPUT

Fig 4

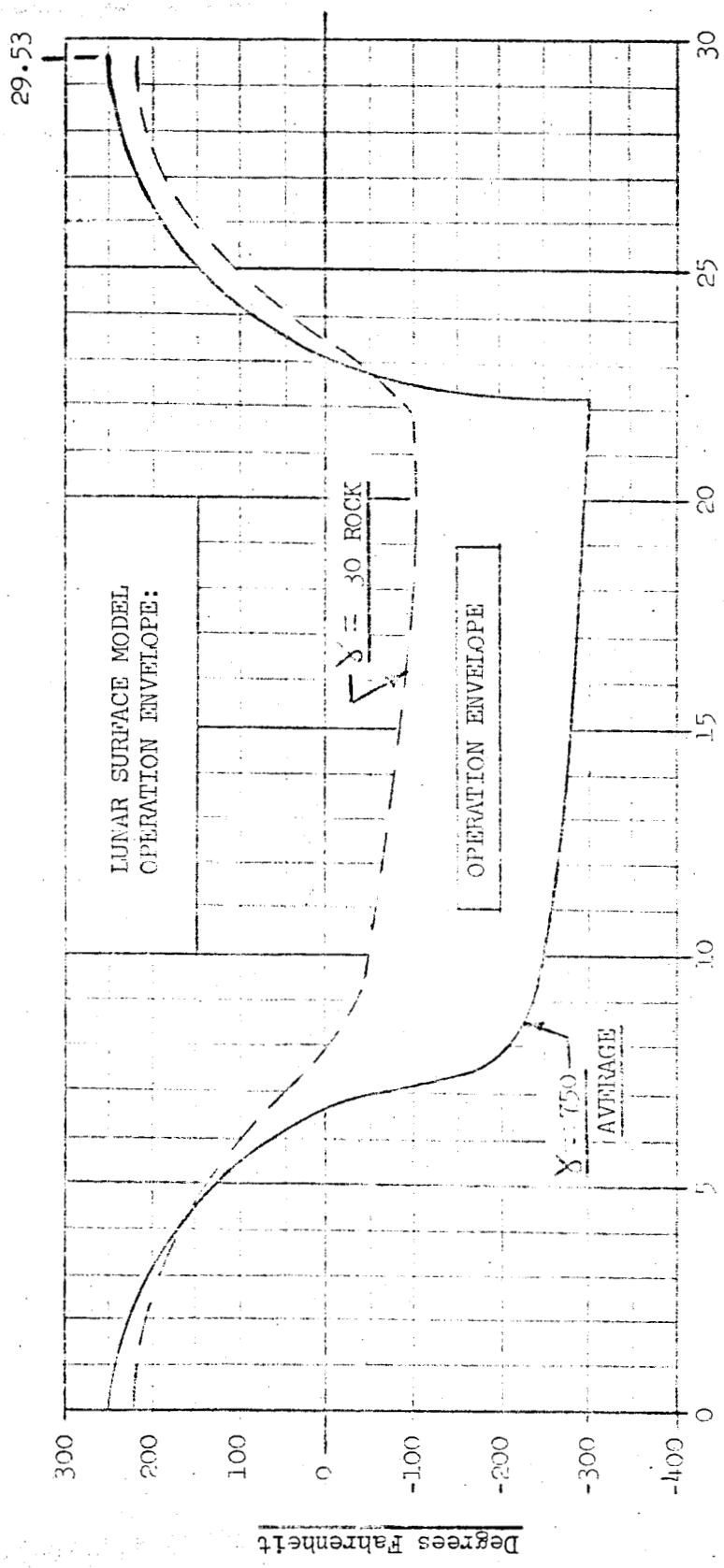


Figure 5 VARIATION OF LUNAR SURFACE TEMPERATURE DURING A COMPLETE LUNATION

See 4.3.3

LOCATION OF SM AND LEM R.C.S. THRUSTERS (REF. 4.1.2.3)

NOZZLE EXIT RADIUS FOR LEM & SM = 2.74"

FIG 6
SEE 4.1.2.3

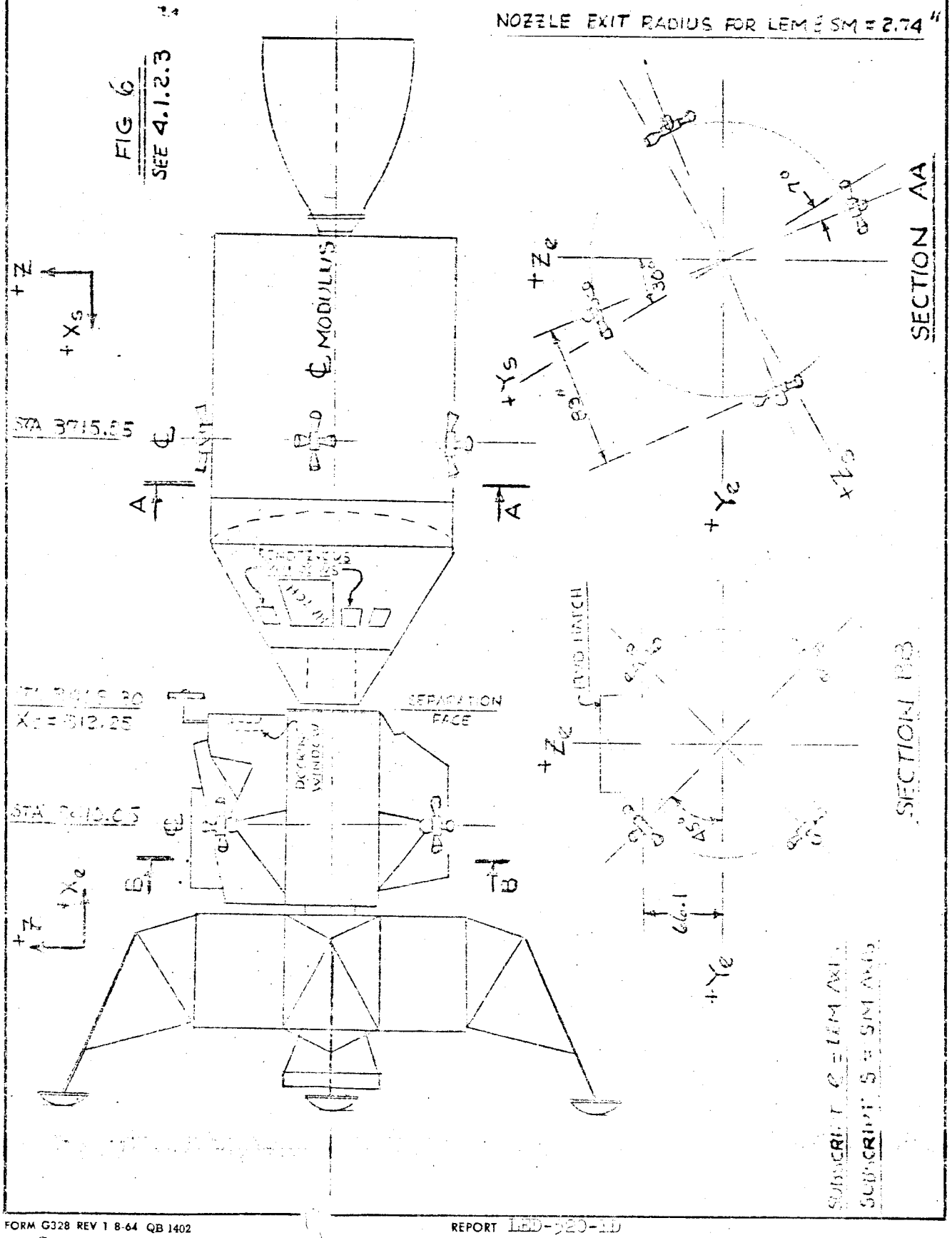


	Table I LEM Mission Time (L) Normal Mission and Min./Max. Missions	LEM Sys's. on	LEM Crew	Time Nominal (MP)	Min/Max. (Minutes)
1.1	Space Vehicle Prelaunch Positioning	-	-	480M	
1.2	Prelaunch Checkout	all	None	25,909M	
1.3	Launch Countdown			2,880M	
2.	Launch and Earth Ascent	"	"	12M	12/12
3.	Earth Orbit	"	"	180M	60/270
4.	Translunar Injection	"	"	5M	5/5
5.	Initial Coast - to transposition	"	"	15M	10/300
6.	Transposition, Dock & Jettison SIVB	"	"	30M	20/300
7.	Continue Translunar Trip to LOI	None	"	3613M	3600/6600
	2-7 (Launch and Translunar)			3855M 64.3H	
8.	Lunar Orbit Insertion	"	"	6M	6/6
9.	Lunar Orbit Coast	"	"	86M	60/200
10.	LEM Check Out and Alignment	all	Two	137M	60/150
	8-10 (Lunar Orbit)			229M 3.8H	
11.	LEM Separation and Prep. for Descent	"	"	20.0M	15/60
12.	Insert into Elliptical Orbit (Hohmann)	"	"	D. 0.6M	0.5/0.7
13.	Coast to 50,000 ft. Pericynthion	"	"	58.1M	55/60
14.	LEM Powered Descent to Hi Gate	"	"	D. 7.0M	6.75/7.25
15.	Hi Gate to Lo-Gate	"	"	D. 1.9M	1.3/2.0
16.	Lo Gate to Touchdown	"	"	D. 1.1M	1.0/3.6
17.	Postlanding Check Out	"	"	15M	10/15
	11-17 (Lunar Descent)			103.7M 1.73H	
18.	Lunar Exploration			33.5H	0/2580
19.	Prelaunch Preparation			61.8M	40/110
20.	Powered Ascent to Interceptor Park Orbit	"	"	A. 7.1M	7.0/7.2
21.	Insert into Intercept (If late launch) Orbit	"	"	A. 0.9M	0/0.1
22.	Coast in Transfer Orbit	"	"	46.8M	40/630
23.	Rendezvous from 5 N.M. to 500 ft.	"	"	11.3M	10/30
24.	Dock from 500 ft. to Contact (Soft Dock)	"	"	12.2M	5/20
25.	Hard Dock, Transfer Crew and Jettison LEM	"	None	41.5M	20/60
	19-25			180.5M 3.01H	
	2-25			106.34H	
D.	Descent Engine Operating Time (Including (90) seconds prelaunch check) (Duty cycle time in Engine Spec. = 1030 seconds)			17.2M	

(Continued Next Page)

(Table I Continued)

A.	Ascent Engine Operating Time (Including (60) seconds prelaunch check) (Duty cycle time in engine spec. = 525 sec.)	8.8M
(L.)	Approximate total LEM lifetime from launch = 170 hrs. (Including 10.5 hr orbit contingency)	7.1 Days
(M.P.)	Mission Phase M = Minutes H = Hours	

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

Notes:

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

   a. LEM/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 - will be specified

8. For launch and boost vibrations, that primary structure which is directly excited by the acoustics transmitted through the Spacecraft LEM 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.

9. The vibration levels from launch and boost through lunar ascent shall be as shown. Ref. 14.

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 LEM or LEM equipment and shall not increase weight of the LEM. The following design environment applies only to packaged LEM equipment and not to complete LEM 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 LEM 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, and 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 D.A.	26-52	.036 D.A.
52-500 (f)	±5.0 g	---- (f)	

(f) for 100 to 300 lbs - use figure 514-8 Method 514 MIL-STD 810 (USAF) 14 [illegible] 1962 for maximum frequency.

(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. (35000 ft. alt)

Temperature:

Ground Transportation:	-65°F to +160°F for 2 weeks
Air Transportation:	-45°F to +140°F for 8 hrs.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

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

* Humidity:	(nc)	In accordance with Method 507, MIL-STD810, 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 as 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 except test temp. shall be 90° ± 20°F instead of 160°F.
Fungus:		In accordance with Method 508, MIL-STD810 (USAF) 14 June 1962.
* Ozone:	(nc)	Three years exposure as follows: 72 hrs. 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.
	(v)	Earth gravity compensation is not required
	(ns)	Not simultaneous loading conditions at these levels.
	(nc)	Not simultaneous environment conditions at these levels.
	*	Ambient environment 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 LEM or LEM equipment and shall not increase weight of the LEM. The following design environment applies only to unpackaged LEM equipment and not to complete LEM stages, except where specified.
Acceleration:	2.67 g Vertical with 0.4 g Lateral applied simultaneously. This condition also applies to complete LEM stages
Shock: (v)	1.0 g vertical
(ns)	2.0 g in direction of hoisting
(ns)	Shock as in MIL-STD-810 (USAF) 14 June 1962 Method 516, Procedure I Modified. Modify shockpulse to sawtooth 15 g peak 10-12ms rise, 0-2ms 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/FT²HR up to 6 hr/day From the time of hypergolic loading (approx. T-112 hrs) to lift off (T-0): 40° to 110°F SLA cavity external to LEM 50° to 100°F SLA cavity internal to LEM

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(b) Pre-Launch Unpackaged (Cont'd)

Humidity	(nc)	15% to 100% relative humidity including condensation for ambient temperature range of 40°F to 110°F
Rain	(nc)	Same as prelaunch packaged but no direct impingement
Salt Fog	(nc)	Same as prelaunch packaged
Sand and Dust	(nc)	Same as Pre-Launch Packaged
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 Dwg. 10M01071. This condition also applies to complete LEM stages.
Electromagnetic Interference		Same as Pre-Launch Packaged

(v) See page 44

(ns) " " " "

(nc) " " " "

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(c) Launch and Boost C-5

Acceleration (2)	X g	X Rad/Sec^2	Y g	Y Rad/Sec^2	Z g	Z Rad/Sec^2
Lift Off Condition	+1.60	-	±.65	-	±.65	-
Max. q Condition(S-1C)	+2.07	-	±.30	-	±.30	-
Boost Condition (S-1C)	+4.90	-	±.10	-	±.10	-
Cut Off Condition (S-1C)	-1.70	-	±.10	-	±.10	-
Engine Hardover (S-11)	+2.15	-	±.40	-	-	-
Engine Hardover (S-11)	+2.15	-	-	-	±.40	-
Earth Orbit	0	0	0	0	0	0

Vibration:

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

INPUT TO EQUIPMENT SUPPORTS

(a) From Exterior Primary Structure

Random:

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

Sinusoidal:

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

(b) From Interior Primary Structure

Random:

10 to 23 cps	12 db/octave rise to
23 to 80 cps	.0148 g^2/cps
80 to 100 cps	12 db/octave rise to
100 to 1000 cps	.0355 g^2/cps
1000 to 1200 cps	12 db/octave decrease to
1200 to 2000 cps	.0148 g^2/cps

Sinusoidal:

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

(2) Para. 2.3.2: SIVB ignition prior to earth orbit and re-ignition for translunar boost.

(c) Launch and Boost (Cont'd)

For design purposes the above random spectrum applied for five min. along each of the three mutually perpend. 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 LEM 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 represented 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. For design purposes, the above random spectrum applied for 5 minutes along each of the three mutually perpendicular axis, X, Y, and Z, when applied in addition to the above sinusoidal vibration for 300 seconds exposure time will adequately represent the vibration environment.

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.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(c) Launch and Boost C-5 (Continued)

Acoustics:
(sound pressure levels in d. b. external to LEM)
(re .0002 dynes/cm^2)

Octave Band (cps)	C5 at max. q Level (db)
9 to 18.8	136
18.8 to 37.5	142
37.5 to 75	146
75 to 150	143
150 to 300	139
300 to 600	135
600 to 1200	130
1200 to 2400	125
2400 to 4800	119
4800 to 9600	113
overall	150

Pressure: Atmospheric pressure at sea level to 1 x 10-7 mm Hg (N_2)
except in cabin which is pure oxygen
29.5 psia to 5.5 psia (Decay time approx. 2 Mins.)

Temperature: 0° to 130°F uncontrolled cabin (unpressurized)
0° to 130°F equipment bay (ascent stage)
20° to 100°F equipment bay (descent stage)
40° to 100°F fuel and oxidizer compartment
15° to 100°F ambient sea level - AMR
-65° to 270°F LEM external surface
SLA internal surface - to be supplied

Humidity: "none"

Hazardous gases: Exterior to cabin: None
Inside Cabin: (O_2)

Electromagnetic Interference: Same as pre-launch packaged

Radiation: See Paragraph 4.1.

Meteoroids: For external items. Ref. 4.2.1

TABLE II

MISSION LEVELS"

ENVIRONMENTAL AND LOAD CONDITIONS

(d) Space Flight - Translunar	X		Y		Z	
Acceleration:	g	Rad/Sec^2	g	Rad/Sec^2	g	Rad/Sec^2
SM prop. system operating	-.36	-	±.062	±1.99	±.062	±1.99
SM prop. sys. not operating	0	0	0	0	0	0
Shock:						
condition transposition	-.037	-	±.065	±0.10	±.065	±0.10

Vibration:
SM prop. system operating — None

Plume Effects: — Due to engines to be supplied
Due to RCS in accordance with para. 4.1.23

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(d) Space Flight Translunar (Con'd)

Pressure:	1×10^{-14} mm Hg uncontrolled vacuum (space)
	5.3 to .1 psia uncontrolled cabin (O_2) About 66 hrs. non linear decay time.
	1×10^{-9} mm Hg uncontrolled vacuum (LEM Descent stage)
	1×10^{-10} mm Hg uncontrolled vacuum (LEM ascent stage)
Temperature: **	0° to 130°F uncontrolled cabin (unpressurized)
	0° to 130°F equipment bays (ascent stage)
	20° to 100°F equipment bays (descent stage)
	40° to 100°F fuel and oxidizer compartment
	-300° to +270°F LEM external surface
	-7.6°F Equivalent black body earth temp.
	For external items: Solar radiation = 440 BTU/ft^2/hr. Lunar surface -300° to +250°F. (depending on sun's position) Space = -460°F
Humidity:	None
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 hr. delay - outer belt 20) (See paragraph 4.1).
Meteoroids:	For external items. Paragraph 4.2.1

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

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

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

Accelerations:

	X		Y		Z	
	g	rad/sec^2	g	rad/sec^2	g	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 LEM For accelerations at any other point, see page 64						
Case 1	.798	±.036	±1.778	-.016	0	∓14.56
Case 2	.798	0	0	17.60	1.778	0
Case 3	.857	∓15.52	±.095	9.05	-.421	∓.573
Case 4	2.74	0	0	±28.1	±.514	0
Case 5	2.74	±.01	±.514	-.055	0	∓23.3
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	1.5 g Peak

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TABLE II

(e) Lunar Descent - (Cont'd)

Vibration:

(b) To Descent Stage Equip. Support

15 to 100 cps	.031 g^2/cps
100 to 175 cps	6 db/octave decrease to
175 to 2000 cps	.010 g^2/cps

Sinusoidal:

5 to 20 cps	0.10 in. D.A.
20 to 100 cps	1.92 g Peak

For design purposes the above random spectrum applied for 12½ min. along each of the three perpendicular axis x, y and z, when applied in addition to the corresponding sinusoidal spectrum acting for 12½ sec. at the natural frequency of the equipment being designed will adequately represent the environment.

Plume Effects:

Due to engines to be supplied
Due to RCS in accordance with para. 4.1.5.3

Pressure:

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

Temperature:**,*

70° to 80°F controlled cabin (O_2 - pressurized) average
50° to 90°F controlled cabin (O_2 - pressurized) local spots
0° to 130°F uncontrolled cabin (unpressurized)
0° to 130°F equipment bays (ascent stage)
20° to 100°F equipment bays (descent stage)
40° to 100°F fuel & oxidizer compartment
-300° to +270°F LEM external surface

400°F inside descent engine compartment or on descent engines (for 70 minutes)
> 1000°F after descent engine shutoff (soak back transient).

Areas affected by RCS engine firing - to be supplied.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(e) Lunar Descent (continued)

Temperature (continued) **, *	For external items: Solar radiation = 440 BTU/ft^2/hr. Lunar surface = -300° to +250°F (depending on sun's position) Space: -460°F
Humidity:	Controlled cabin (O_2), 40 to 70% r.h. Locally in cabin (O_2), 0 to 100% r.h.
Hazardous Gas:	Same as launch and boost
Electromagnetic Interference:	[illegible]
Meteoroids:	[illegible]
Sand and Dust:	This is to be specified by Grumman
Radiation:	See paragraph [illegible].

Equipment temperature due to combined [illegible] shall be determined for external items.

The backface temperature of the [illegible] Chamber is [illegible]°F. The [illegible] can be seen by the engine cavity walls. [illegible] is hidden by the heat shield.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

Formulae for determining linear and rotational accelerations at any point on the LEM. (Ref Page 54)

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

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

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

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

$\ddot{X}pt$, $\ddot{Y}pt$, $\ddot{Z}pt$ = Acceleration at any point on LEM 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 LEM C.G. [illegible]

g = 386 in/sec^2

See Fig. 2 for LEM axes

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 [illegible]

ENVIRONMENTAL AND [illegible]

(f) Lunar Stay (Con'd)

Pressure:	1 x [illegible] mm Hg uncontrolled vacuum (surface of moon)
	4.8 to [illegible] psia (O_2) controlled cabin
	1 x [illegible] mm Hg [illegible] (hatch open) Max open hatch time [illegible] linear decay.
	1 x [illegible] mm Hg vacuum (LEM Descent Stage)
	1 x [illegible] mm Hg vacuum (LEM Ascent Stage)
	5.8 psia [illegible] mm Hg uncontrolled cabin
Temperature:	70° [illegible] (hatch open) preliminary
	70° to [illegible] controlled cabin (O_2-pressurized) [illegible]
	50° to [illegible] controlled cabin (O_2-pressurized) [illegible]
	0° to [illegible] controlled cabin (unpressurized)
	0° to [illegible] Bays (Ascent Stage)
	0° to [illegible] bays (descent stage)
	40° to [illegible] fuel and oxidizer compartments
	-300° to [illegible]°F LEM external surface
	0° to [illegible]°F [illegible] compartment
	For [illegible]:
	Solar [illegible] = [illegible] BTU/ft²/hr.
	Lunar surface [illegible] to +[illegible]°F (depending on sun's position)
	Space = -4[illegible]°F
Humidity:	Controlled cabin (O_2) [illegible] rel. hum. [illegible]. locally [illegible] (O_2) [illegible] - 100% rel. [illegible].
Hazardous Gas:	Same as launch and boost
Radiation:	Solar [illegible] to be defined [illegible]. See [illegible]
Electromagnetic Interference:	[illegible] pre-launch.
Meteoroids:	For external items. Ref. 4.2.1
Sand and Dust:	This is to be [illegible] 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

Shock: To Be Supplied by Grumman

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	[illegible] db/octave rise to
20-100	[illegible] g^2/cps
100-120	12 db/octave decrease to
120-2000	[illegible] g^2/cps

Sinusoidal

5-17 cps	0.10 in D.A.
17-100	1.5 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 Engines to be Supplied.
Due to RCS in accordance with paragraph 4.1.5.3.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(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 (LEM Ascent Stage) 5.8 psia to 10^{-9} mm Hg uncontrolled cabin
Temperature: **,	70° to 80°F controlled cabin (O_2 pressurized) average. 50° to 90°F controlled cabin (O_2 pressurized) local spots 0 to 130°F uncontrolled cabin (unpressurized) 0° to 160°F equipment bays (ascent stage) 40° to 100°F fuel & oxidizer compartments -300° to +270°F LEM external surface 400°F - external separation surface (for 5 mins.) 450°F - on injector plate of ascent engine. 300°F on combustion chamber (engine mount and nozzle extension above 6:1) of ascent engine. 550°F on ascent engine nozzle surface (below 6:1 area ratio) 250°F ascent engine compartment (for 137 minutes) Areas affected by RCS engine firing - to be supplied. For external items: Solar radiation = 440 BTU/ft^2/hr. Lunar surface = -300° to +250°F (depending on sun's position) Space = -460°F.
Humidity:	Controlled cabin (O_2), 40 to 70% r.h. Locally in cabin (O_2), 0 to 100% r.h.
Hazardous Gas:	Same as launch and boost
Electromagnetic Interference:	Same as pre-launch packaged.
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

	Weight lb's	C. G. Inches Vehicle Stations	Iy slug - ft^2
S-IC Lift off t = 0	6,000,000	1249	758×10^6*
S-IC, Max. q t = 65 sec.	3,391,600	1377*	737×10^6*
S-IC, Burnout t = 130 sec.	1,759,000	1918*	279×10^6*
S-II, Ignition t = 130	1,376,000	2220*	91.9×10^6*
S-II, Burnout t = 531 sec.	453,150	2834*	32.2×10^6*
S-IV B, Ignition (initial - prior to orbit)	353,630	3004*	9,980,000*
S-IV B, Burnout (after translunar injection) 480 sec. burning time	122,130	3375*	3,850,000*
S-IV B, Initial docking (prior) - Transpositioning	(to be supplied)		
S-IV B Initial Docking (docked)			
Space Craft			
C/M and S/M			

* GAEC Approximations only.

TABLE III (CONT'D)

LEM MASS PROPERTY HISTORY - DESIGN WEIGHT - PRELIMINARY

MISSION EVENT	WEIGHT (EARTH LBS)	CENTER OF GRAVITY STA (In) X	Dist. From Thrust Axis Y	Dist. From Thrust Axis Z	MOMENT OF INERTIA (SLUG-FT^2) I_{xx}	I_{yy}	I_{zz}
TRANSLUNAR INJECTION	32000	187	0	1	21400	23350	23450
LEM/CSM SEPARATION	32500	188	0	0	22500	24600	24500
[illegible] INSERTION TO HORIZONT - DESCENT	32113	188	0	0	22300	24300	24250
[illegible] HOVER	16047	210	0	0	12350	14500	16500
[illegible] -MINIMUM	14650	218	0	0	10850	11250	13500
[illegible] -NOMINAL	15003	218	0	0	11100	11500	13800
-MAXIMUM	16[illegible]	218	0	0	12000	12300	15150
LUNAR [illegible]	10800	[illegible]	0	0	[illegible]	3300	5650
[illegible] INSERTION TO HORIZONT - ASCENT	5516	[illegible]	0	0	2900	2700	1650
[illegible] (LOCKED)	5322	[illegible]	0	0	2800	2650	1500
[illegible] OF CREW TRANSFER	4605	[illegible]	-1	-5	2500	2400	1400

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

TABLE IV

Sign convention positive directions as on page 34

ACCELERATION DUE TO BOOSTER LIMIT LOADS

Booster		Note	Weight - lbs. Ignition	Weight - lbs. Cut-Off	Thrust - lbs. Ignition	Thrust - lbs. Cut-Off	Accelerations: Longitudinal g's Minimum	Longitudinal g's Maximum	Lateral g's Y	Lateral g's Z	Rad/Sec² Y	Rad/Sec² Z
C-1B	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	---	---	--	
C-5	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)	---	---	--	
C-5 (Engine Hard-Over)	S-IC b/o		--	1,758,700	--	8,630,000	--	--	---	---	--	
	S-II b/o(2)		1,376,050	447,850		1,000,000	.8	2.15	±.40	--	--	
	S-IVB b/o		--	128,850	--	200,000	--	1.87(1)	±.23	±.23	±.70	±.70
	S-II 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

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