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HELIUM UTILIZATION IN THE APOLLO/SATURN V VEHICLE

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By

J. R. Nunnelley — NASA MSFC 10/24/68

ABSTRACT

Helium is used extensively throughout the Apollo/Saturn V space vehicle for a number of applications. The welding use is not discussed since it is a special topic. In the first stage (S-IC), helium is used for liquid oxygen tank pressurization during vehicle checkout and launch.

The second stage (S-II) requires helium for liquid hydrogen tank sidewall insulation purge. The common bulkhead, between the liquid oxygen and liquid hydrogen propellant tanks, is purged with helium. Helium is used during checkout and static test of the stage for tank pressurization and as a purge gas.

The major use of helium in the third stage (S-IVB) is for fuel tank pressurization. Helium is used extensively for a number of other checkout and prelaunch pressurizations of the S-IVB. Other requirements are for operation checkout such as detanking and engine purge. Helium is used in pressurization of the fuel and oxidizer systems of the Auxiliary Propulsion System (APS).

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INTRODUCTION

The Apollo program is America's program to land man on the moon and return safely to earth. The Apollo program is directed by NASA's Office of Manned Space Flight. The Marshall Space Flight Center is providing the Saturn launch vehicles. The Manned Spacecraft Center at Houston is providing the three separate modules of the spacecraft, selecting and training the astronauts, and operating the Mission Control Center. The Kennedy Space Center in Florida will launch the astronauts on their flight.

The Saturn V is able to launch into orbit more than a quarter of a million pounds. The total earth-orbiting tonnage in the lunar mission will be about 280,000 pounds. This includes the weight of the third stage and the instrument unit section. The fully fueled and loaded Apollo spacecraft in its lunar mission configuration will weigh about 100,000 pounds.

The Saturn V, with its Apollo Payload (Figure 1) is 363 feet tall. Physical and performance characteristics of the stages, in a mission such as the lunar trip, are as follows:

First Stage

The first stage burns over 15 tons of propellants per second during its two and one-half minutes of operation to take the vehicle to a height of about 36 miles and to a speed of about 6,000 miles per hour. The stage is 138 feet long and 33 feet in diameter.

Second Stage

The second stage burns over one ton of propellants per second during about six and one-half minutes of operation to take the vehicle to an altitude of about 108 miles and to a speed of near orbital velocity, which in this case is about 17,400 miles per hour. This stage is also 33 feet in diameter and its length is 81-1/2 feet.

Third Stage

The third stage has two important operations during the Project Apollo lunar mission. After the second stage drops away, the third stage ignites and burns for about two minutes to place itself and the spacecraft into the desired earth orbit. At the proper time during this earth parking orbit, the third stage is re-ignited to speed the Apollo spacecraft to escape velocity of 24,900 miles per hour. In this second sequence, the stage burns for about six minutes. The stage is 58 feet long and 21.7 feet in diameter.

Instrument Unit

The instrument unit, located atop the third stage, between the stage and the payload, contains guidance and control equipment for the launch vehicle. It is 3 feet long and 21.7 feet in diameter.

Apollo Spacecraft

Command Module: 13 feet in diameter; weight, 11,000 pounds.

Service Module: 13 feet in diameter, 22 feet in height; weight, 52,000 pounds.

Lunar Module: Two stages; total weight 32,000 pounds. Descent engine's thrust can be varied from 1,050 to 10,500 pounds.

Figure 2 is a cut-away illustration of the Apollo/Saturn V. The liquid oxygen tanks of the three stages are shown. In the first stage, the fuel used is RP-1, a form of kerosene. The RP-1 tank is shown for this stage. In the second and third stages, liquid hydrogen is used as fuel. The liquid hydrogen tanks are shown for these two stages.

Propellants for the spacecraft are nitrogen tetroxide for the oxidizer and monomethylhydrazine for the fuel.

This has been a very brief overall description of the Apollo/Saturn V space vehicle. From some of the propellants mentioned, it is understandable that the utilization of helium is essential. These stages are made of various aluminum alloys, including many of the more recently developed high strength alloys. Based on the size of this vehicle, it is obvious that tremendous amounts of welding has to be accomplished by some technique. This is done with the inert process which uses helium as the inerting media. This process is a technical field of its own and much has been reported on the welding of aluminum alloys using helium as the inerting gas; therefore, any discussion at this time would be repetition.

GROUND SUUPORT EQUIPMENT

The launch vehicle requires a tremendous quantity of ground support equipment not only at the launch site but at the prime contractor's facilities for checkout and testing. These facilities supply all operation requirements up to launch. Included are power requirements and all necessary fluids such as fuels, oxidizers, and pressurants.

The helium pressurization gas is supplied to the vehicle interface at the required purity level. The gas is requested through normal supply channels from the Bureau of Mines, and is transported to the manufacturer's plant, the test site, or the launch site by the appropriate transportation containers. For some uses, the gas can be used from the containers as received; however, for others it is necessary to boost the pressure to a much higher pressure. This operation has been one area where problems have developed in handling and transfer and at the same time still maintain the required quality of gas at the vehicle interface. The ground support equipment for helium had some different problems from the media which the maintenance personnel had been familiar with handling. It was necessary to upgrade the hardware to meet the interface documents. Valve quality had to be improved over previous systems; line connections and weldments were required to be of a higher quality. High quality gas compressors have been used with the ground support equipment.

Filters and filter systems is a subject in itself throughout the space vehicle program and is not new in the helium ground support equipment. Filter systems in conjunction with other techniques such as freeze-out systems are used to assure that the helium at the vehicle interface is of the quality required for reliable vehicle performance.

S-IC, FIRST STAGE

The first stage of the Apollo/Saturn V launch vehicle (Figure 3) is a Boeing Company manufactured stage which uses the propellant combination of liquid oxygen for the oxidizer and RP-1 for the fuel. The high pressure helium cylinders are located in the liquid oxygen tank. Prior to liquid oxygen loading during prelaunch countdown, these containers are pressurized. Prior to launch during the launch preparation, the ground support equipment supplies helium for fuel and oxidizer tank pre-pressurization. Helium is also used for oxidizer suction line bubbling. This bubbling is continuous from start of oxidizer loading.

The utilization of helium for propellant tank pressurization of the first stage (S-IC) of the Saturn V affords a weight saving of approximately 1800 pounds. This is a considerable amount when applied to the spacecraft payload.

S-II, SECOND STAGE

The second stage (Figure 4) of the Saturn V is manufactured by North American Rockwell Corporation. This stage is powered by five J-2 engines which use liquid oxygen as the oxidizer and liquid hydrogen as the fuel. The fact that hydrogen is used indicates the necessity for some type of inerting media for which helium is an excellent candidate. This stage has an external insulation of polyurethane. The first of these were insulated with a honeycomb polyurethane which required a helium purge to maintain an adequate thermal conductivity. This system of insulation does have some disadvantages such as repair techniques after damage to handling. The purge system has been a continuing challenge. Through continued research and development, a new concept of spray foam insulation has advanced to the point that it is used on later vehicles. This also is a polyurethane material which is installed by a spray application. This spray foam will eliminate the helium purge and the associated problems.

The requirement for helium in this stage is very different from the first stage. Fuel and oxidizer tanks are pressurized with helium in similar manners as the first stage (Figure 5). In addition to the pressurization system, there is a number of purge operations in this stage; fuel tank and fuel feed lines are purged during testing and launch prior to engine ignition. There are many valves and actuators that require inerting by purge procedures. To discuss each component which requires an inert purge of this large complex stage would be a major task and will not be done since all purge systems have many commonalities.

The S-II does, however, have one unique purge requirement and that is the common bulkhead. This area is purged with helium to maintain it free of fuel and oxidizer which could enter the area by leakage from either propellant tank into this common bulkhead.

S-IVB, THIRD STAGE

The third Stage, S-IVB (Figure 6), manufactured by McDonnell Douglas Astronautics Company, is similar in some respect to the S-II stage. It has one J-2 engine which uses liquid hydrogen for fuel and liquid oxygen for the oxidizer. However, the insulation for the liquid hydrogen tank on this stage is internal and does not require the helium purging as in the case with the S-II stage. This stage does require helium inerting of tanks, fuel lines, valves, and regulators as any other system where hydrogen is used. This stage also has a common bulkhead which requires an inert purge. For flight, the high pressure helium spheres on this stage are located in the liquid hydrogen tank.

The S-IVB stage has an Auxiliary Propulsion System (APS) which uses helium in the pressurization system. The propellants for the APS are nitrogen tetroxide and monomethylhydrazine.

INSTRUMENT UNIT

The Instrument Unit, containing the stabilizing platform, telemetering equipment, and associated black boxes, is the section between the third stage and the Apollo spacecraft. This unit controls the vehicle during launch and staging. While the Instrument Unit does not require helium for purging or valve actuation this unit is considered as an integral part of the launch vehicle.

APOLLO SPACECRAFT

The Apollo Spacecraft (Figure 7) shows the various modules of the spacecraft; the Lunar Module, the Service Module, and the Command Module, then the uppermost segment - the Launch Escape System.

These modules and systems are manufactured by several prime contractors, then assembled for the overall spacecraft. The Lunar, Service, and Command Modules are manufactured by Grumman Aircraft, McDonnell Douglas Astronautics Company, and North American Rockwell Corporation, respectively. The propellants for these engines are nitrogen tetroxide and monomethylhydrazine. These propellant tanks as on the stages require a helium pressurant and is described herein as general information and subject continuity.

SUMMARY

In summary, it is very obvious that helium has contributed extensively to the Saturn program. The uses have been from the first weldment to the last engine cut-off. The purge systems for checkout, testing, and launch have maintained safe conditions throughout the program. The inerting welding techniques have assured sound structure with minimum weight. Without the utilization of helium, the design, manufacture, checkout, testing, and launch would be very much different from what is on the launch pad today.

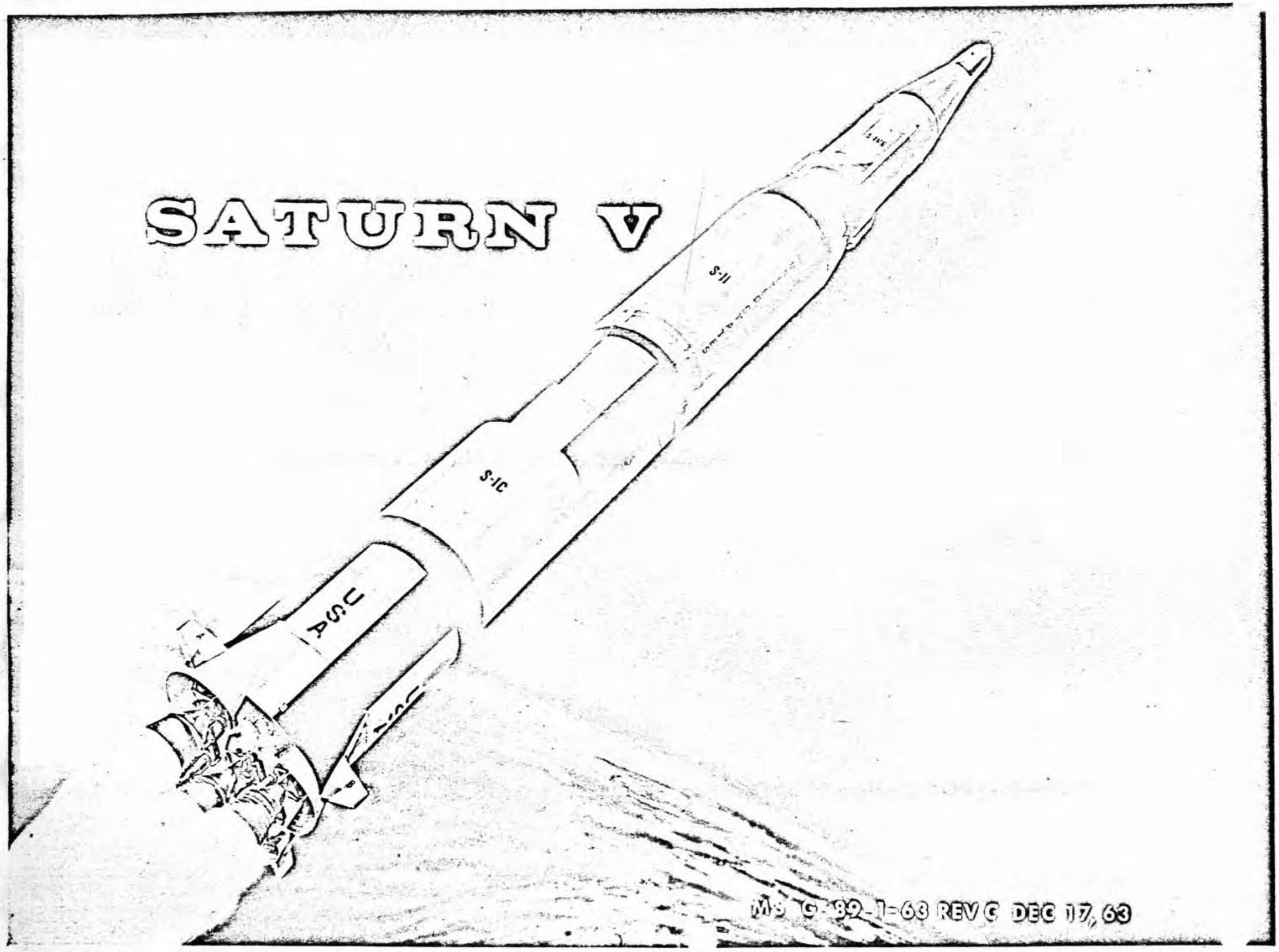


FIGURE 1

APOLLO SATURN V LAUNCH VEHICLE

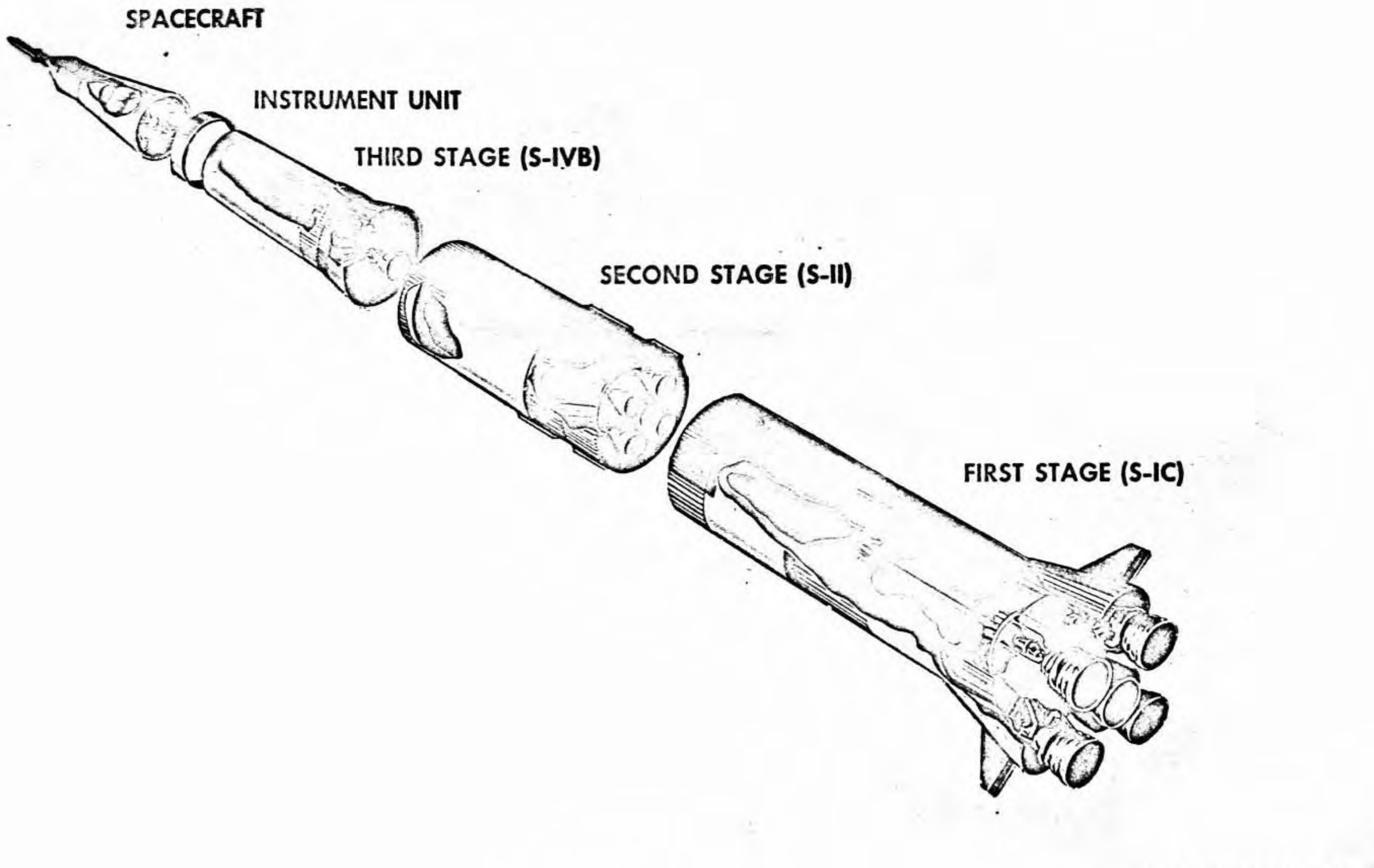


FIGURE 2

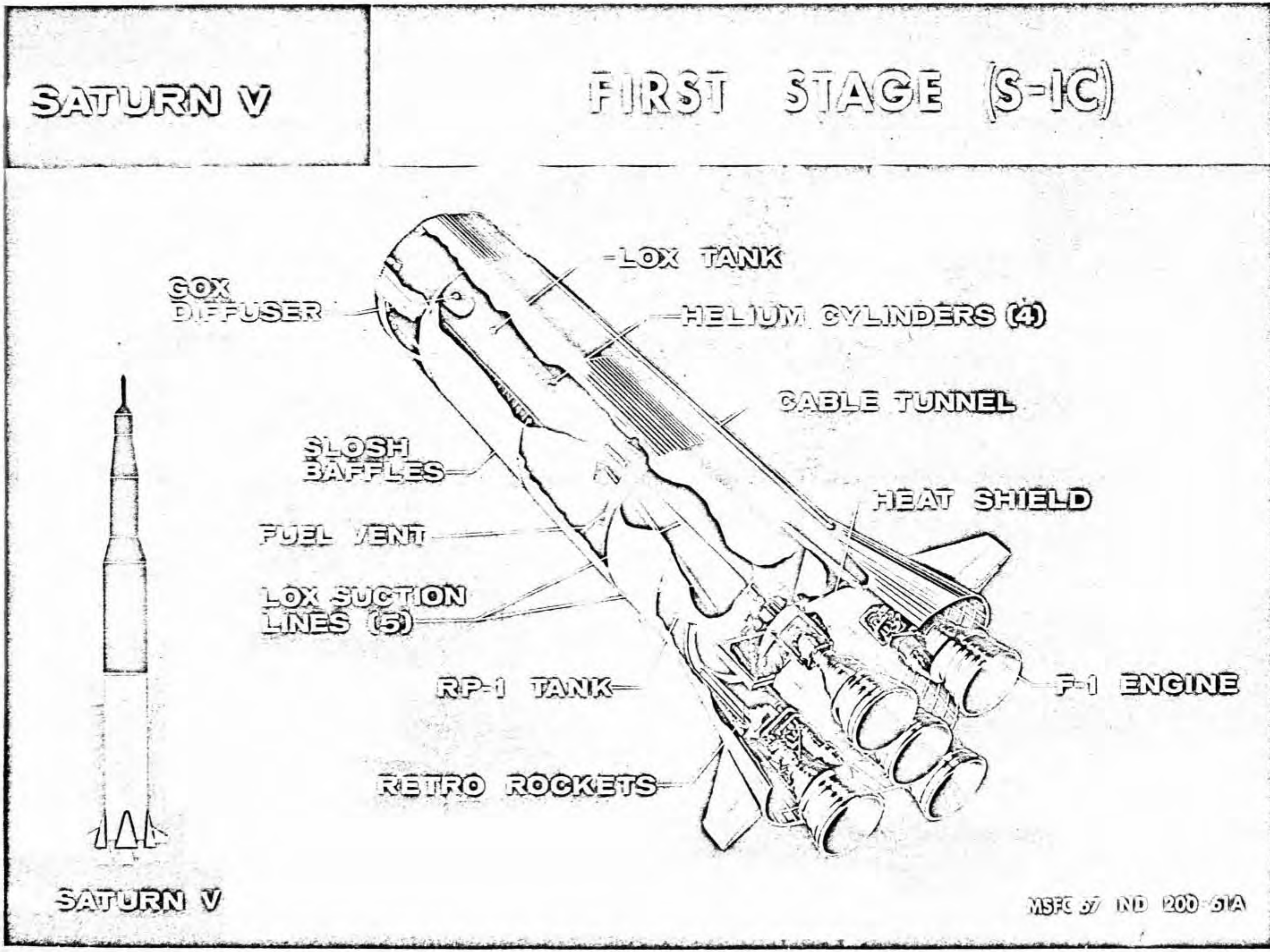

SATURN V
FIRST STAGE (S-IC)
LOX TANK
GOX DIFFUSER
HELIUM CYLINDERS (4)
CABLE TUNNEL
SLOSH BAFFLES
HEAT SHIELD
FUEL VENT
LOX SUCTION LINES (5)
RP-1 TANK
F-1 ENGINE
RETRO ROCKETS
SATURN V
MSFC 67 IND 200 61A

FIGURE 3

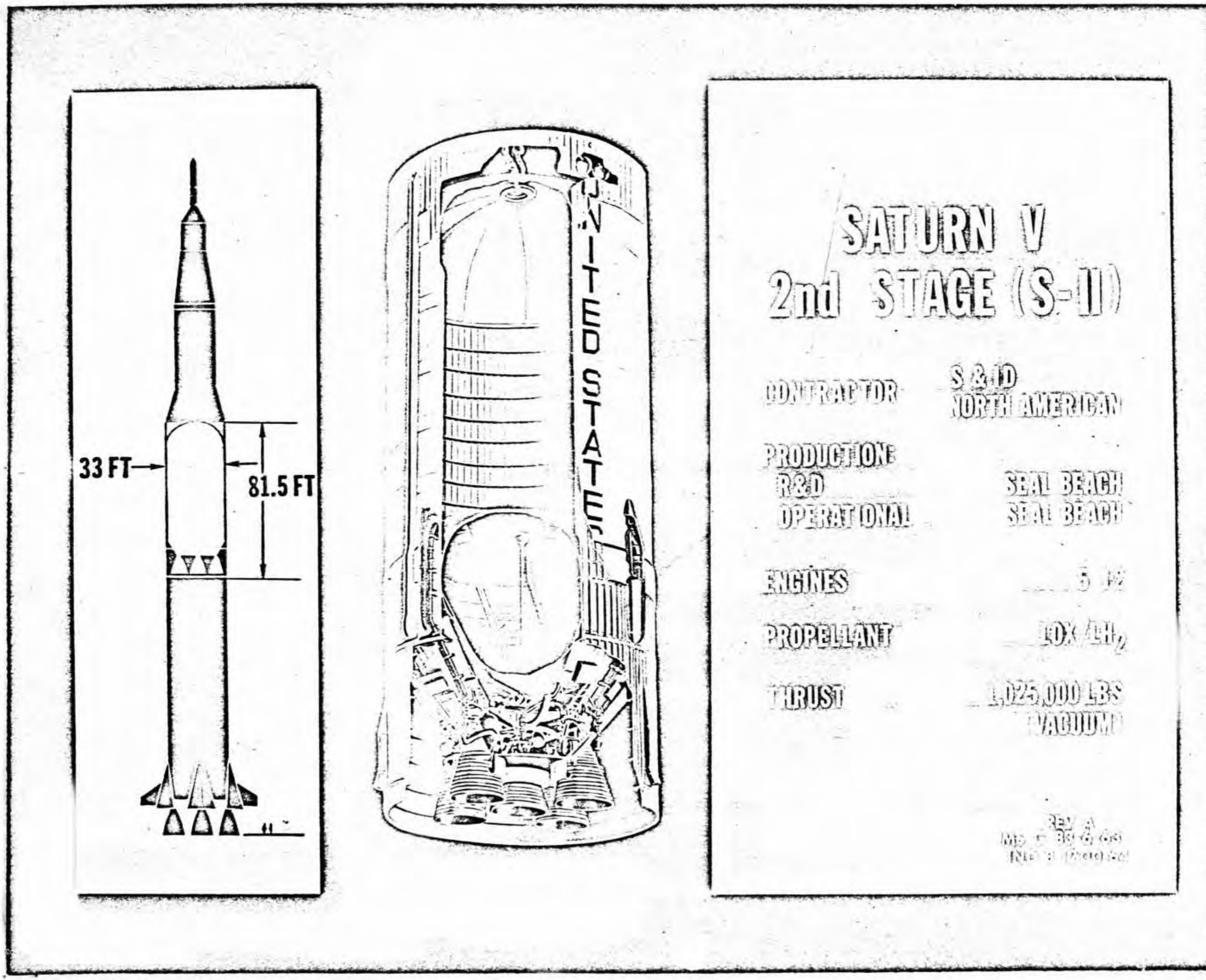

33 FT
81.5 FT
UNITED STATES
SATURN V
2nd STAGE (S-II)
CONTRACTOR
S & ID
NORTH AMERICAN
PRODUCTION:
R&D
SEAL BEACH
OPERATIONAL
SEAL BEACH
ENGINES
5
PROPELLANT
LOX/LH2
THRUST
1,025,000 LBS
(VACUUM)
REV A

FIGURE 4

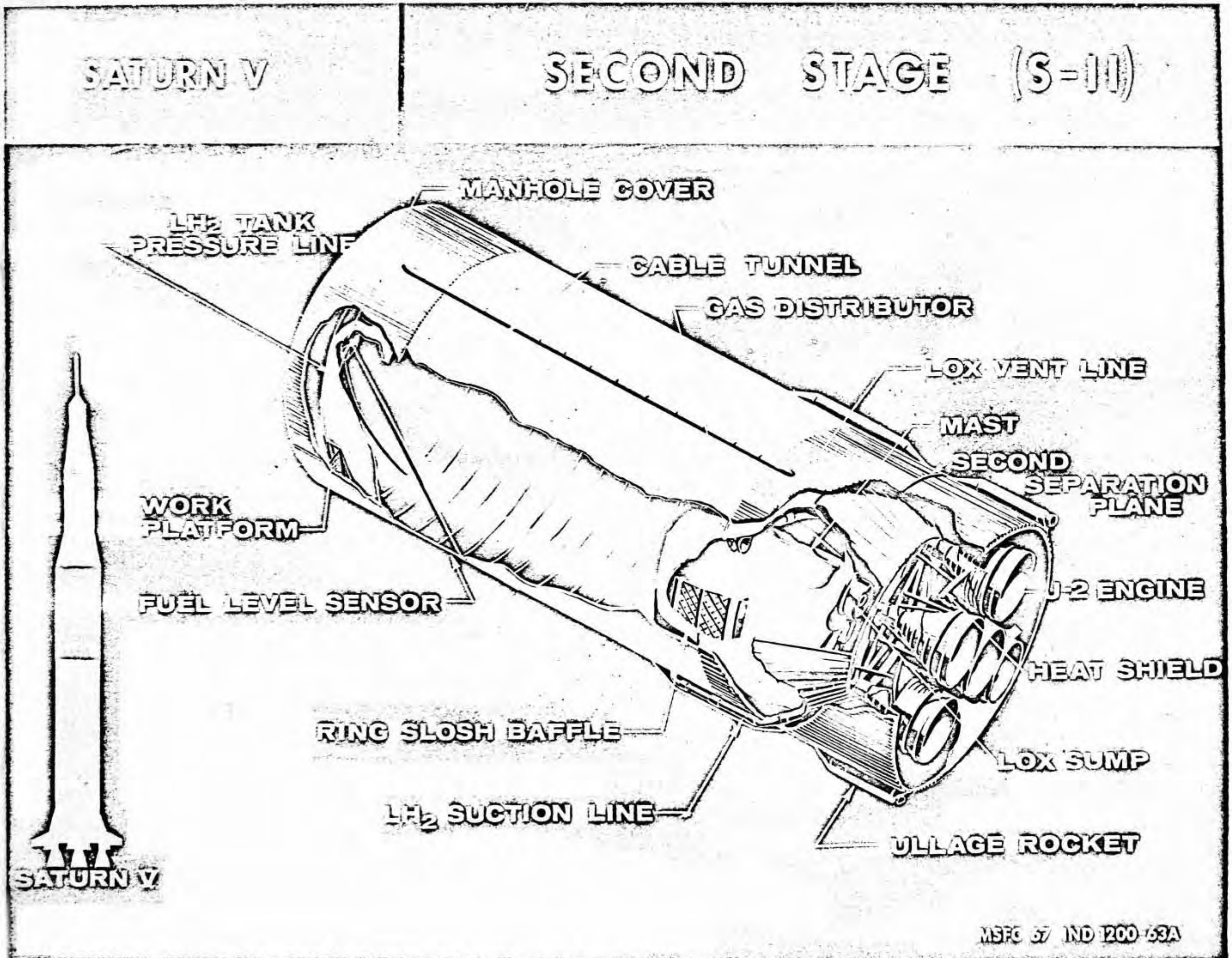
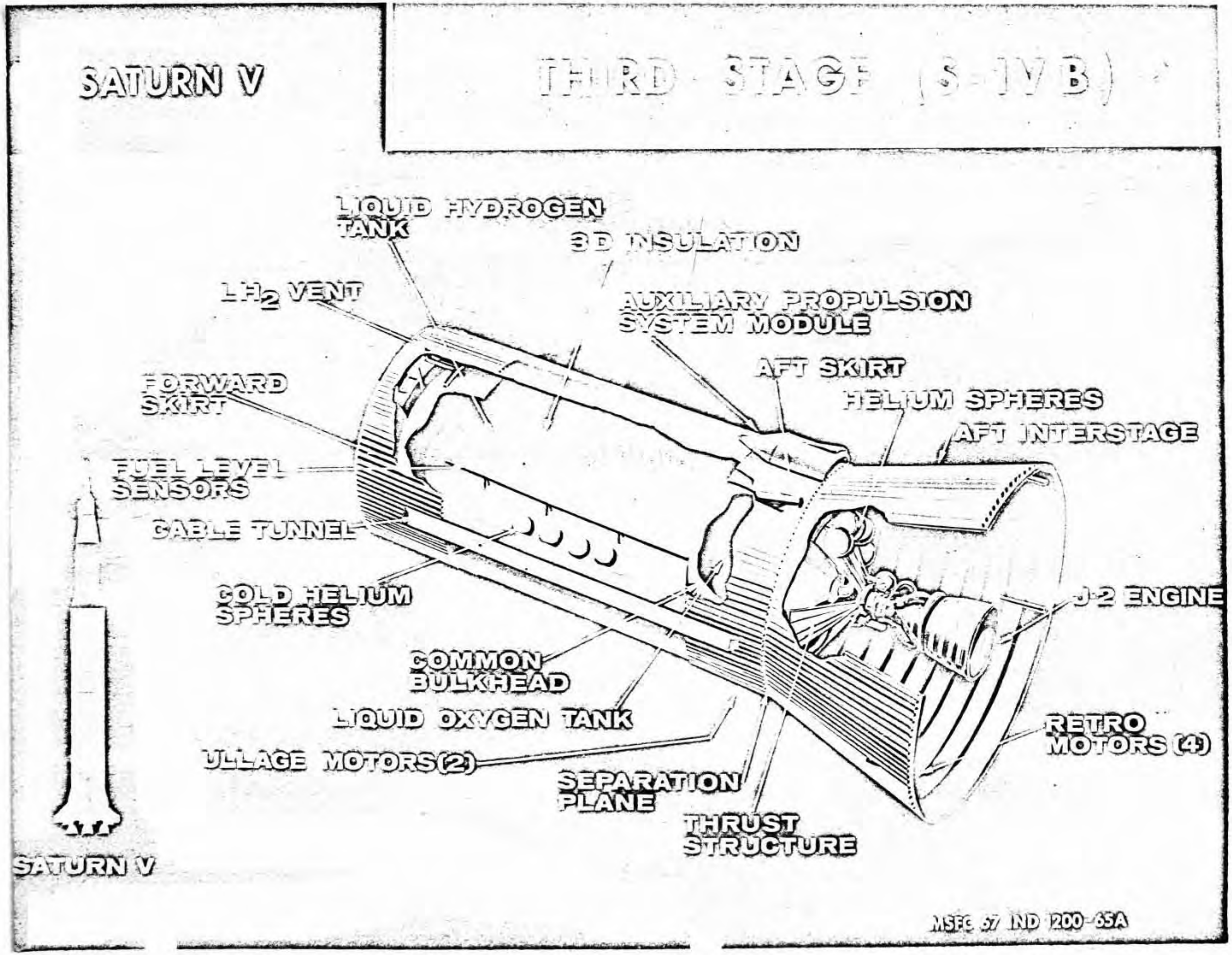

SATURN V
SECOND STAGE (S-II)
MANHOLE COVER
LH2 TANK PRESSURE LINE
CABLE TUNNEL
GAS DISTRIBUTOR
LOX VENT LINE
MAST
SECOND SEPARATION PLANE
WORK PLATFORM
J-2 ENGINE
FUEL LEVEL SENSOR
HEAT SHIELD
RING SLOSH BAFFLE
LOX SUMP
LH2 SUCTION LINE
ULLAGE ROCKET
SATURN V
MSFC 67 IND 1200 63A

FIGURE 5



SATURN V
THIRD STAGE (S-IVB)
LIQUID HYDROGEN TANK
3D INSULATION
LH2 VENT
AUXILIARY PROPULSION SYSTEM MODULE
AFT SKIRT
FORWARD SKIRT
HELIUM SPHERES
AFT INTERSTAGE
FUEL LEVEL SENSORS
CABLE TUNNEL
COLD HELIUM SPHERES
J-2 ENGINE
COMMON BULKHEAD
LIQUID OXYGEN TANK
RETRO MOTORS (4)
ULLAGE MOTORS (2)
SEPARATION PLANE
THRUST STRUCTURE
SATURN V
MSFC 67 IND 200-65A

FIGURE 6

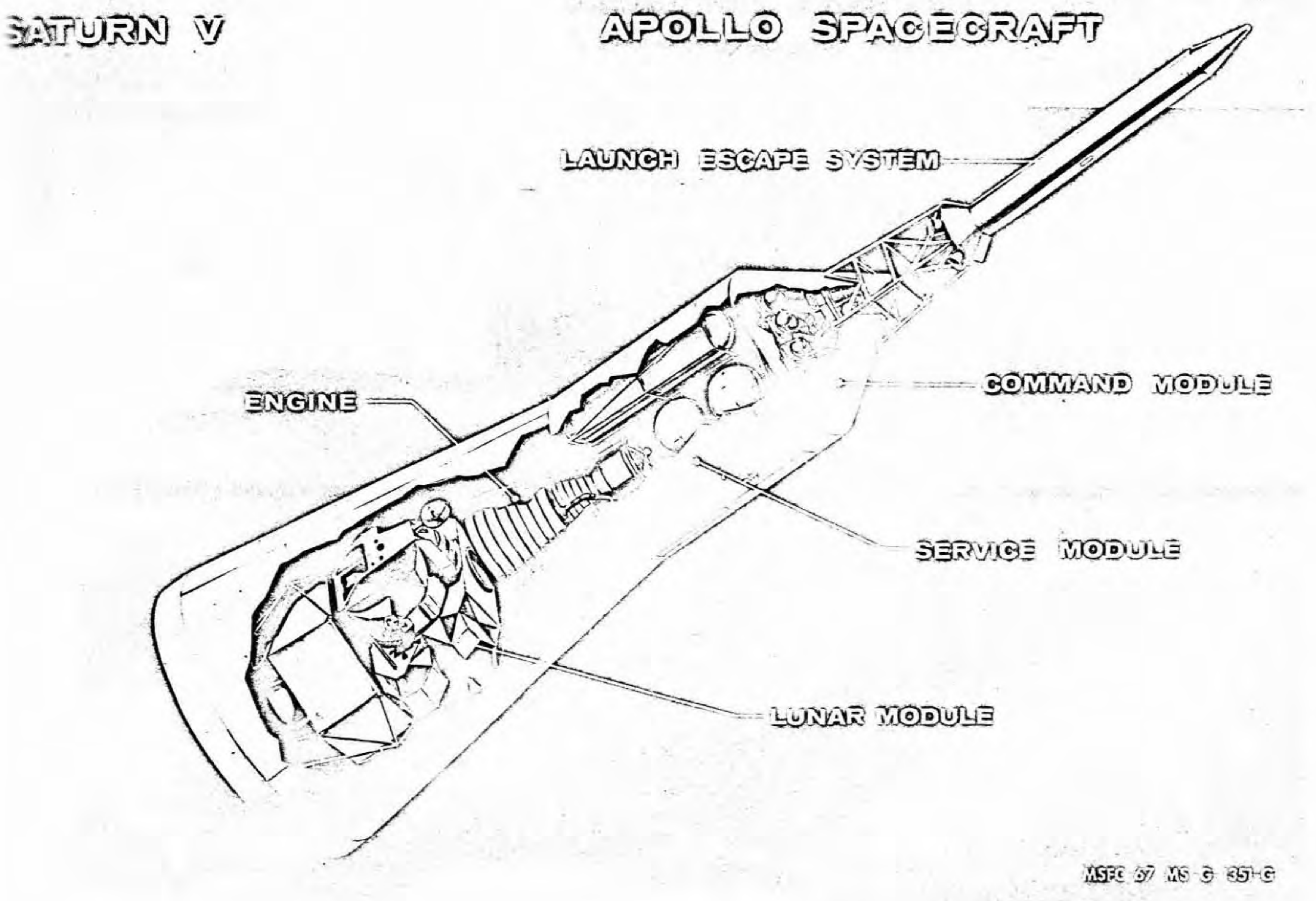

SATURN V
APOLLO SPACECRAFT
LAUNCH ESCAPE SYSTEM
COMMAND MODULE
ENGINE
SERVICE MODULE
LUNAR MODULE
MSFC 67 MS G 351-G

FIGURE 7