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GROUND EQUIPMENT TO SUPPORT THE SATURN VEHICLE

by
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by

Georg von Tiesenhausen*

ABSTRACT

With the advent of the first large space vehicle, the SATURN, the ground support equipment and launch facility designer is faced with the necessity of conceiving and building an unprecedented launch system concurrent with the vehicle development. The paper intends to present a comprehensive picture of the problems involved and how they are solved. It follows the SATURN through the various modes of operation such as transportation over land and water, checkout, handling and erection, propellant loading, and describes the facilities at the launch site.

INTRODUCTION

Conceiving and developing launch equipment and facilities for space vehicles pose problems of a considerable magnitude, because many areas are without precedent. Time schedules do not allow for experimenting with various approaches, so the first approach has to be the right one or one runs into a dead end and large funds are wasted. This way of working without precedent has become a necessary habit of those involved in this business and requires a conceptual design based mainly upon a vast experience which was built up through several generations of missiles.

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However, facilities and GSE for space vehicles deviate in many respects from those familiar to many of us of IRBM's and ICBM's. The main difference is, that, where one could allow for possible failures in the initial phase of flight testing and thus depend on this ultimate means of proving the design, this approach cannot be afforded with a space vehicle worth many millions of dollars. Since there eventually will be failures, they cannot be considered in the design planning. In addition, failures due to malfunction of GSE in particular cannot be tolerated at all and are just out of the question. How can the GSE project engineer approach these problems and solve them under the heavy responsibility which rests upon him?

This paper intends to provide some information on the design philosophy for the SATURN space vehicle GSE. This presentation shall be devoted to problems of transportation, launch facilities and GSE for the SATURN vehicle in general.

A. LOGISTICAL CONSIDERATIONS

Logistical support of the launching of lunar mission SATURN vehicles from the Atlantic Missile Range will present major transportation problems. The four major vehicle components (booster, second and third stages, eventually a fourth stage, and payload) must be shipped to AMR* from different sections of the country, and most of these components have dimensions which exceed the maximum capabilities of conventional air, rail, or road carriers. Special equipment and special routing must be provided, and the over-all program schedule will not allow sufficient time for movement of these items at the most convenient times consistent with other transportation activities. Several requirements will be discussed in the following paragraphs to illustrate the problems involved.

The SATURN Booster to be transported from the George C. Marshall Space Flight Center, NASA, Huntsville, Alabama, to AMR in an assembled condition will be 256 inches in diameter and approximately 82 feet in length. Since the booster will be moved on its transporter, these dimensions will become even larger. Therefore, the only way to transport such a large, expensive, and vulnerable item from MSFC to AMR is by waterway. A rather detailed description of the facilities

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*AMR - Atlantic Missile Range

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and equipment for handling and transporting the booster over this route is given in paragraph B. 1. below. The barge transportation described will assure safe handling of the cargo, but will require between two and three weeks for the transportation phase alone. Handling of the booster after a successful landing and recovery also constitutes a major operation. The operation of spotting and water recovery of re-entry nose cones is well known. However, the water recovery of a small and compact nose cone is far more simple than that of the voluminous, delicate booster which is partially filled with propellant residuals and, therefore, presents a safety hazard to equipment and personnel. Details of the proposed water recovery scheme are presented in paragraph D. A Landing Ship Dock (LSD) is proposed as the main equipment. Flushing, inspection, preservation and disassembly of delicate parts will be done on board ship by a special crew during the return trip. Later, the vehicle will be transferred to a river barge for return to RSA dock.* A suitable harbor with proper crane facilities, such as New Orleans, will be used for this purpose. Preparation, recovery action and return to New Orleans will require an LSD for about one week and supporting ships for a portion of this time.

B. TRANSPORTATION TO LAUNCH SITE

1. Booster

a. Land Transportation (Figs. 1 and 2)

Transporter (Fig. 1). The booster transporter is a unique piece of equipment in that a part of the booster final assembly jig is used to make up the transporter assembly. The assembled booster, with its Support Cradles, Connecting Trusses and Assembly Rings, is jacked up as a unit and placed on two axle and wheel assemblies. Pertinent transporter dimensions and wheel and axle loads are shown on the silhouette representation of the vehicle-transporter combination (Fig. 2). Each wheel assembly consists basically of two pairs of two independently braked and hydraulically steered aircraft tandem wheels on an axle assembly. The Support Cradles are secured to the axle assemblies and a towbar on the forward assembly connects to the prime mover. The booster is carried on this composite vehicle through all phases of testing, checkout, and transportation from the Fabrication Plant to the launch site.

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* RSA - Redstone Arsenal

The maximum towed speed of the loaded transporter is between 3 and 5 mph. The maximum angle of approach and departure is 13° and 17°, respectively.

b. Dockside Facilities

(1) Redstone Arsenal Dock (Figs. 3 and 4). After all booster testing at MSFC is completed (Figs. 5 and 6), the booster-transporter combination is towed to the RSA Dock and is rolled on to a specially designed barge. The dockside facilities for this operation consist of a ramp to the water's edge and two electrically powered winches mounted at the top of the ramp to control movement of the transporter up and down the ramp. An undamaged booster returned to RSA Dock on a transporter will be off-loaded in a similar manner. However, if a heavily damaged booster is returned, it may not be supported on a transporter, and partial salvage operation may be necessary before off-loading is accomplished. In this case, lift facilities, such as a mobile crane, will be necessary for removing salvaged components from the barge. As the recovery program becomes more extensive and, if the return of heavily damaged boosters requires heavier off-loading facilities, the RSA Dock will have the capability for expansion to include construction of a 100-ton stiff-leg derrick with a reach of 85 feet to provide lifting facilities for a complete booster when it is returned in a damaged condition without its transporter.

(2) New Orleans Port. Existing heavy-lift facilities at the New Orleans Port are considered sufficient for transferring the recovered booster from the recovering LSD to the barge for return to RSA Dock.

(3) Atlantic Missile Range. Ramp facilities similar to those described for RSA Dock will be used for unloading the booster-transporter at Site C, AMR, approximately one mile from Complex 34 on the Banana River.

c. Water Transportation (Fig. 7)

Sea-Going Barge. With this type barge the loading at RSA Dock will be accomplished by the roll-on/roll-off method. At New Orleans the river tug (approximately 65 feet long) will be exchanged for a sea-going tug (approximately 100 feet long) which will then tow the barge to Fort Pierce, Florida. Here the sea-going tug will be exchanged for a river tug which will complete the trip to Site C barge basin. The obvious advantage of this method of transportation is that no

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LSD loading and unloading of the barge is required with the inherent possibility of damage to booster.

2. Payload

a. Transporter. The proposed transporter for a lunar payload of 10 feet diameter is essentially a modified version of a commercially available four-wheel transporter. The payload rests on a rear saddle, and is restrained and supported at the forward end by its lifting bolts. This is a proven system for missile transporters, and it effectively prevents torsional strains from being introduced into the payload.

b. Prime Mover. Any commercial type small tug tractor with pintle hook may be used as prime mover for the payload transporter since road movement will normally be limited and will be accomplished on first-class roads. However, road speeds must not exceed five miles per hour to prevent shock loading of the payload in excess of 4g's.

c. Transportation. Payload dimensions will permit transport by C-133 aircraft, and this will be the normal method of transportation to the launch site complex. Shipment of the payload will be made on the transporter to facilitate loading, unloading and tie-down in the aircraft. Either rail or road facilities may be used for return shipment of the reusable materials and equipment from the AMR to MSFC.

d. Packaging. The outer skin of the payload will constitute the external container in which the internal components will be living in a controlled environment. End covers and strippable coating will complete the sealing requirements. Desiccant breathers and appropriate venting will provide protection and prevent excessive differential pressures during air transport. Environmental protection will be provided by a waterproof tarpaulin or insulated blanket as required by ambient conditions.

C. LAUNCH SITE

1. Launch Site Complex (Fig. 8)

The SATURN Launch Complex contains all necessary facilities for handling, storing, servicing, checkout, erection and launching of the SATURN vehicle as well as the required administration and logistical facilities and special research laboratory facilities to support the various projects to be carried out during the SATURN Program.

Upon arrival at the barge basin, the booster and transporter are off-loaded from the barge and towed to the launch pad for erection. The upper stage assemblies pass through the assembly building where final assembly details and horizontal checkout are accomplished.

One launch pad facility is sufficient to support SATURN firings at approximately two-month intervals. However, the propellant storage and transfer facilities are designed with the capability of supporting two launch pads at alternate intervals when required. This will be a requirement when Lunar Payload Missions are superimposed on other SATURN program schedules.

2. Booster Erection (Figs. 9 and 10)

The SATURN Booster is erected on the launcher by utilizing the track mounted gantry type service structure. This structure has a bridge crane supporting two hooks at 40 and 60 tons capacity each. The hooks are approximately 12 feet apart horizontally and can be moved horizontally, longitudinally, and vertically. In preparation for erection, the service structure is positioned over the launcher, the booster transporter is towed into position parallel to the service structure base, and the booster is rotated 45^{o} from transporting plane to the erecting plane. The rear assembly ring is removed from the booster. The gantry crane is then moved into position and connected to the booster pickup points by means of erection slings and beams. The 60-ton hook is connected to the forward sling, and the 40-ton hook to the thrust frame sling. The booster is lifted from the transporter, rotated into vertical position, moved into the gantry structure and lowered onto the four preleveled launcher support and hold-down points with the assistance of removable guides attached to the launcher arms.

3. Booster Checkout (Figs. 11-16)

a. Leak and Function Checkout. After erection, a pneumatic leak and function check is made on the booster to determine if any components or subsystems were damaged during transportation and handling. Gaseous nitrogen (GN_2), used in performance of the checks, is routed to the checkout panels on the launcher through a pneumatic distribution station in the base of the umbilical tower. The GN_2 pressure is regulated at these panels and, in conjunction with electrical control panels in the blockhouse, serve to distribute the GN_2 to various checkpoints throughout the system where function

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checks of the valves, leakage of joints and fittings, and flow rate checks are performed. Pneumatic distribution lines also extend from the pneumatic distribution station to checkout panels on the service structure for checkout of the top part of the booster.

b. Engine Servicing. Following pneumatic checkout, an engine service operation is performed using the Engine Servicing Trailer. This operation includes flushing and purging of the critical portions of the engine such as the fuel jacket, LOX dome, gas generator, and the fuel igniter line to insure absolute cleanliness of these parts.

4. Vertical Engine Removal

Lack of working space in the booster tail section area makes it necessary to have a handling and hoisting system capable of operation in a restricted area for removal and replacement of a defective engine after the booster is in the vertical position.

Removal of an engine is accomplished by attaching a hoisting bar assembly to the engine "rabbit ears" and turbopump mounting frame. The engine is then lowered by a hoist and pulley system until it is clear of adjacent engines and the booster structures. Here the engine is secured to a sled or skid which has been raised to position on a service platform. Half of the platform is then detached, lowered to the base of the launcher and removed from the area on a monorail. The engine is then lowered on its skid along the face of the deflector by means of a cable and hoist arrangement to the base of the launcher where it is removed from the area on the monorail. Reversal of this procedure is used to install a replacement engine.

5. Upper Stage Assembly (Fig. 17)

Assembly of the upper stages is accomplished after booster checkout is completed. However, details on these operations are not yet available.

6. Launcher and Umbilical Tower

a. Launcher. (Figs. 18-19). The SATURN Launcher is a reinforced concrete and steel structure 42 feet square and 27 feet high. It has eight support arms. Four supports 90° apart (Fig. 20) are cantilevered at the outboard engines and are retracted horizontally after the valid commitment signal is given, to permit the engine shrouds to clear the vehicle during lift-off. The other four supports (Fig. 21) are dual purpose support and hold-down points located at 45 degrees between the outboard engines. Holddown is accomplished by a toggle linkage which is activated when the retractable arms are fully retracted. In event of malfunction of one or more of the retractable supports, all four supports may be returned to position under the missile thrust frame prior to engine cut-off.

b. Umbilical Tower (Figs. 22-23). The umbilical tower is used to support and service the umbilical arms as well as to house and support the various electrical cables, pneumatic and LOX replenishing lines, liquid nitrogen cooling tanks, mechanical refrigeration units, the ground hydraulic unit, and the pneumatic and electrical distribution station which are required to service the booster and upper stages prior to launching. The tower is 240 feet high and 24 feet square at the base. The bottom 27 feet of the tower is enclosed to provide for two air-conditioned equipment rooms. Above the 27-foot level the four-tower columns slope inward to a 10-foot square at the top. Tower facilities include safety ladders and service platforms at 20-foot intervals, a 2000-pound capacity personnel and small hardware elevator, and a 3000-pound capacity electric hoist at the top for handling lines, cables and the umbilical arms.

7. Propellant Storage and Loading

a. Liquid Oxygen (Figs. 24-26). The LOX facility for the SATURN complex consists of protective revetments, foundation, and partial weather protection for liquid oxygen storage and transfer system. The system has the capability of servicing two pads from one facility at different intervals. The storage facility consists of an insulated sphere of 125,000 gallon capacity. The 41-foot diameter storage tank is insulated, but not vacuum jacketed, to sustain an evaporation loss of LOX of 0.2%/24 hrs. The working pressure of the sphere is 40 psig which is maintained by a heat exchanger for self-pressurization. The booster transfer system consists basically of a 2500 gpm, 400-foot head pressure centrifugal cryogenic pump with associated valving necessary to transfer liquid through 750 feet of 8-inch uninsulated aluminum transfer line. Initial loading of oxidizer to the upper stages is facilitated by manifold lines connected to the Umbilical Tower and branching off at each stage servicing connection. The second stage initial filling is accomplished by using a 1000 gpm, 600-foot head pressure pump and a 6-inch

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aluminum transfer line. The third stage filling utilizes the same 1000 gpm pump, but is operated under throttled conditions.

Replenishing of the various stages is accomplished by using an additional 13,000 gallons, 200 psi working pressure, vacuum jacketed tank located in the storage facility confines. Replenishing of the booster and upper stages is accomplished by using a pneumatic actuated modulating valve controlled by a LOX tanking computer and level control associated with each of the stages to be replenished. The replenishing transfer lines for the booster, second, and third stages are 3-inch, 2-inch, and 1-inch insulated lines, respectively.

Replenishing LOX to the upper stages is controlled to exact level and maintained until umbilical separation during the launch countdown. The replenishing transfer lines for the upper stages are also routed through the umbilical tower.

The LOX transfer system is automated and is initiated and controlled from the blockhouse propellant loading panels during transfer sequence. Prior to propellant loading, the system component checkout can be accomplished at either the blockhouse or the LOX complex.

b. <u>Fuel</u> (Figs. 27-28). The RP-1 fuel facility for the SATURN consists of protective revetments, foundation, and partial weather protection for the storage and transfer system. The system can service two SATURN launch pads from one storage facility, but at different intervals. A retaining wall to contain 125% of the volume of the fuel tanks is provided with the reveted area to retain the fuel in case of tank rupture. The revetment wall is 15 feet high and is earth reveted on the pad side. Fuel storage is facilitated by using two 30,000-gallon capacity cylindrical insulated tanks. The transfer system and associated plumbing consist of a pad to support two 1000-gpm centrifugal pumps operating at 175 psi head pressure for fueling the booster, a 600-gpm recirculation pump, a 600-gpm filter-separator unit, an abductor system, miscellaneous valves, piping, and controls. The booster is serviced by two 1000-gpm pumps manifolded into 1000 feet of 8-inch diameter transfer line. Liquid level is controlled in the booster by a fuel tanking computer. The density of RP-1 fuel is monitored at all times by the fuel density indicator. The fuel is overfilled in order that the fuel computer can adjust fuel level to 100% by draining the fuel. The proper LOX-fuel weight ratio at take-off is accomplished by replenishing the LOX to proper level as dictated by the fuel.

Initial upper stage fuel filling is accomplished through the same system but by utilizing only one 1000-gpm pump and a 6-inch line attached to the Umbilical Tower structure. Once filled to the prescribed level, the fuel transfer lines are evacuated of RP-1 by a jet eductor operating on Bernoulli's Law of Continuity.

Initial charging of the storage tanks is through the filter-separator unit to insure proper filteration of fuel and to minimize the entrained water content of the RP-1. During long storage periods, periodic operation of the filter-separator unit is required to insure desired fuel cleanness prior to vehicle servicing.

The fuel transfer system is automated and is initiated and controlled from the blockhouse fuel loading panels. Prior to propellant loading, the fuel system component checkout is accomplished at the blockhouse by the fuel loading panels. Communications between blockhouse and fuel complex is required during this operation.

D. BOOSTER RECOVERY OPERATIONS (Fig. 29)

Recovering of the SATURN booster from the ocean is planned to be accomplished by the use of a fleet of surface vessels, including an LSD (Landing Ship Dock), four destroyer (or similar) escorts, two sea tugs, a PT (Patrol) boat, and a command-communications-helicopter-tender ship of a suitable type. Fixed-wing aircraft are employed in spotting the downed booster.

The recovery operation will consist of four phases:

1. Location and damage surveillance
2. Recovery of the booster from the ocean
3. Decontamination and preservation, and
4. Return shipment of the recovered components.

Immediately after impact, the helicopter and the PT boat seek out the booster and keep it under surveillance until the remainder of the recovery fleet arrives at the impact site. Upon arrival at the impact area, the recovery

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fleet deployed for the recovery operation.

With the aft deck of the LSD awash, the booster is floated into position on fixed supports in the LSD well. The well is then pumped dry, leaving the booster in a supported position for decontamination and preservation.

Decontamination consists of a dry air or LN_2 purge of the LOX system, an over-all washdown with hot fresh water, and disassembly and cleaning of critical and special components. After decontamination, the booster and components are thoroughly dried by purging with hot, dry air and preserved by the application of the desiccator breather assemblies.

The LSD then returns the booster to the appropriate dock (it is envisioned that this will be New Orleans) where it is barge-loaded for return shipment to RSA.

As stated previously, dependent upon the magnitude of damage to the booster during the recovery action, the booster would be put either on a transporter, or on supports used in the LSD. The recovered booster or salvaged components, deemed resuable by inspection specialists soon after recovery, are transported from New Orleans to RSA by barge. There, unloading is accomplished by roll-off of transporter, or when too heavily damaged, disassembly in barge and/or lifting the parts out of the barge by the available 20-ton crane.

APPENDIX (Table I-III)

Three tables are presented which summarize the general space vehicle launch site criteria, the launch site operations, and the relative cost of the main cost items of a SATURN launch system.

TABLE I

GENERAL LAUNCH SITE CRITERIA FOR A SPACE VEHICLE

1. Open water downrange to cover first and second stage fall-out range
2. Eastward launchings
3. Growth potential
4. Adequate azimuth traverse for various missions
5. Available land downrange for tracking facilities
6. Moderate climatic conditions
7. Modest sea traffic downrange
8. Soil characteristics, altitude, water supply, labor forces, local construction materials, personnel recruitment.

TABLE II

LAUNCH SITE OPERATIONS FOR A SPACE VEHICLE

1. Booster unloading from sea transport barge at dockside
2. Booster transport to launch pad
3. Upper stages unloading from sea transport barge at dockside
4. Upper stages checked horizontally in the staging building
5. Payload unloading and transporting to payload building for testing
6. Mating checks
7. Transfer of booster and stages to the launch pedestal
8. Vertical checkout (functional, over-all, pre-launch, calibration, alignment, simulated flight, flight safety).

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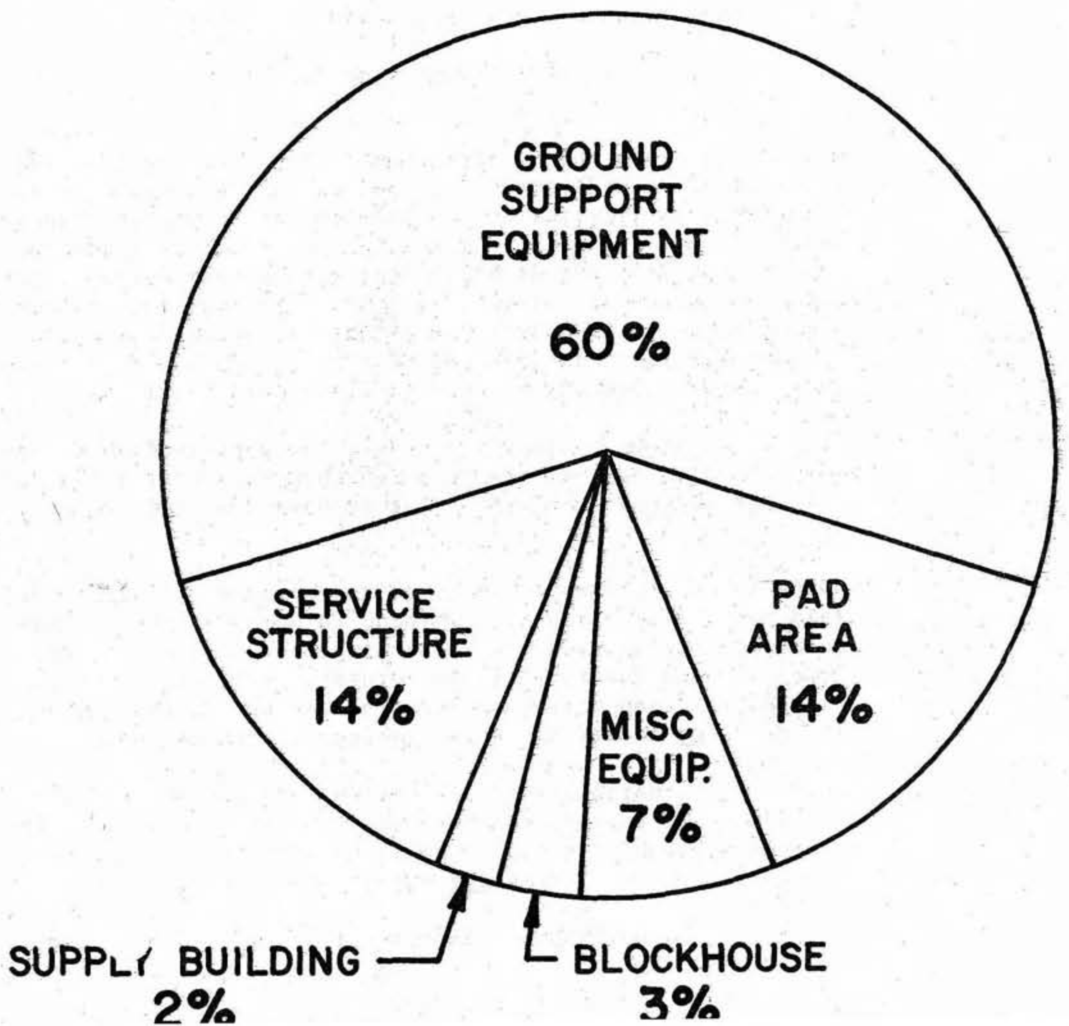
TABLE III
PROPORTIONATE COSTS OF A SATURN LAUNCH FACILITY



LIST OF ILLUSTRATIONS

Figure

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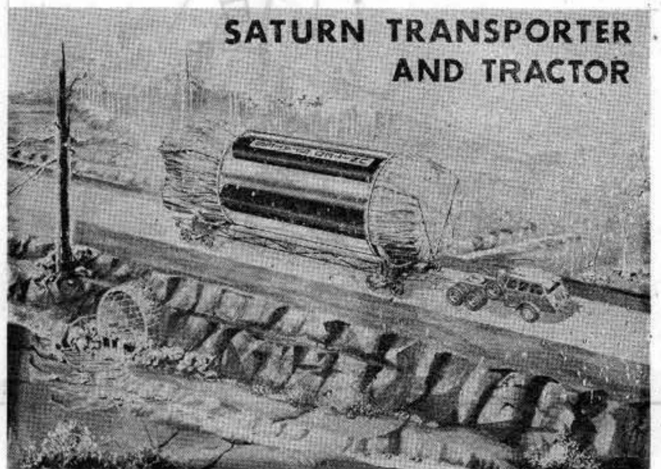


FIG 1

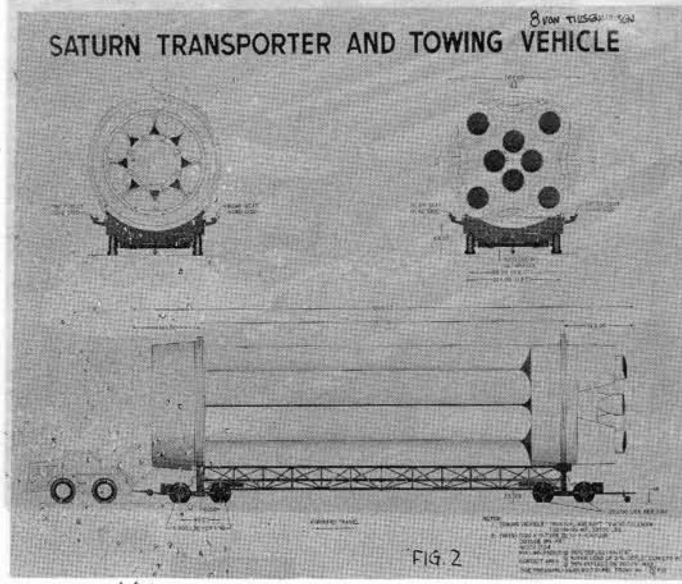


FIG. 2

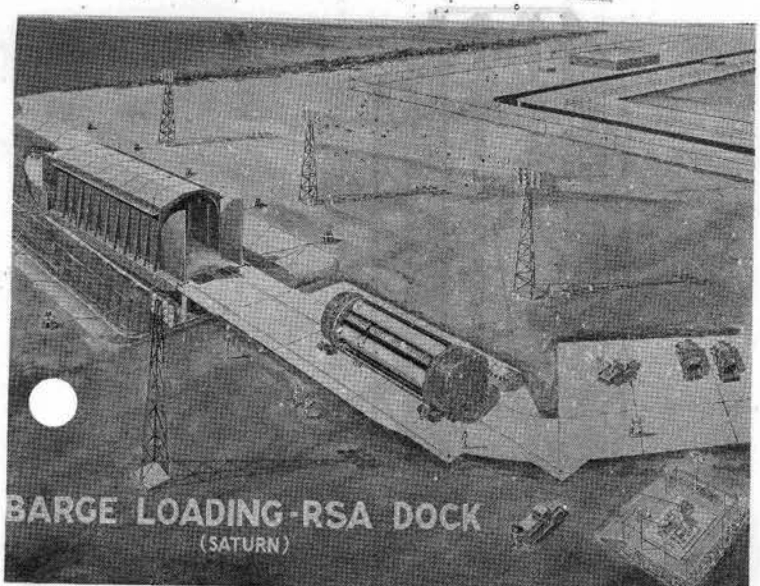


FIG. 3

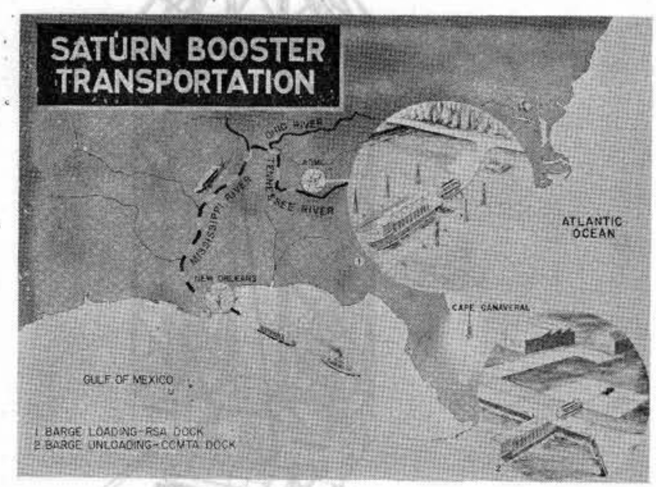


FIG 4

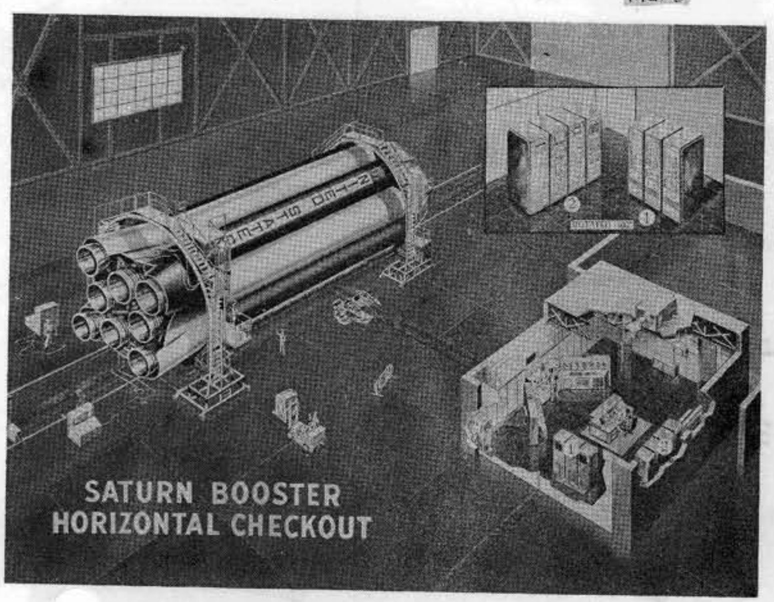


FIG. 6

FIG. 7

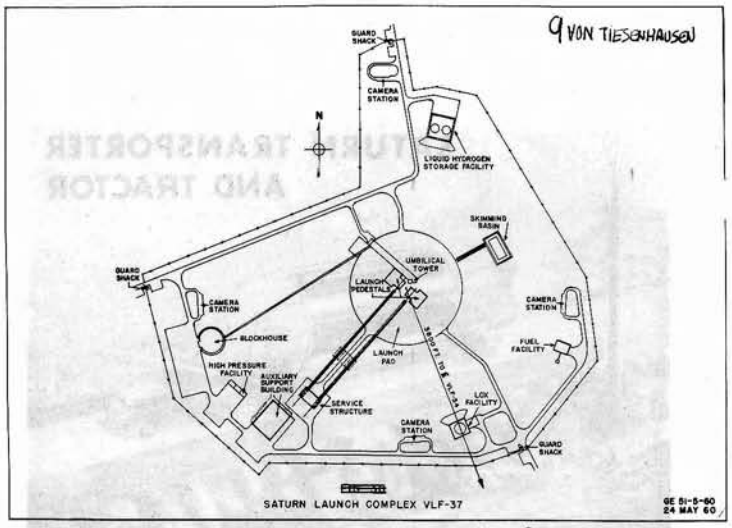
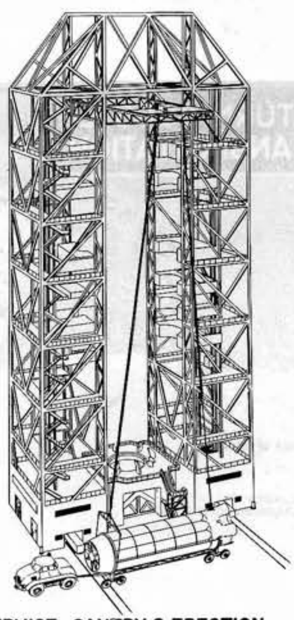
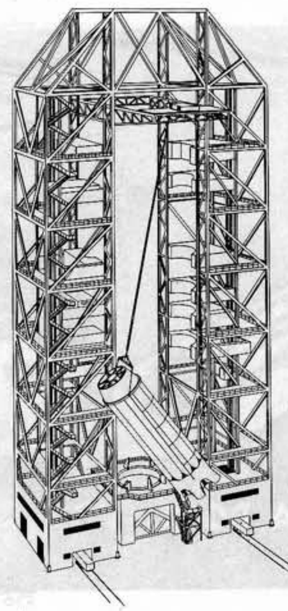


FIG. 8.



SERVICE GANTRY & ERECTION
(PHASE I)

Figure 9



SERVICE GANTRY & ERECTION
(PHASE II)

Figure 10

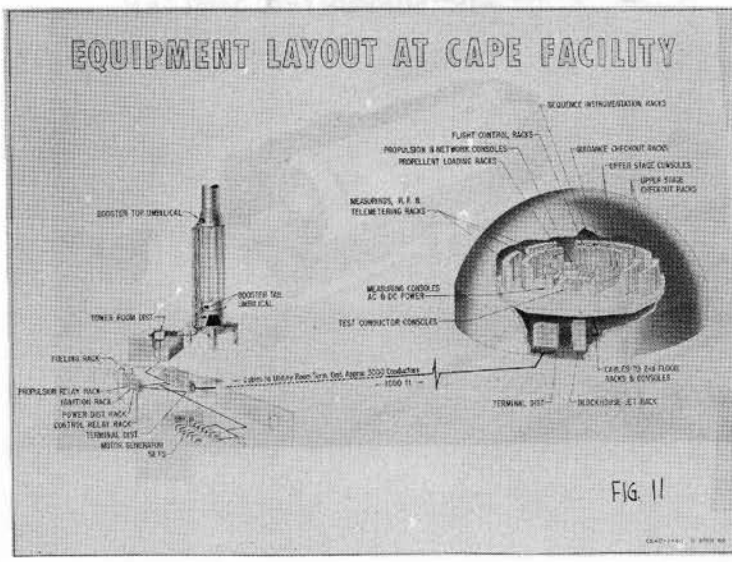


FIG. 11

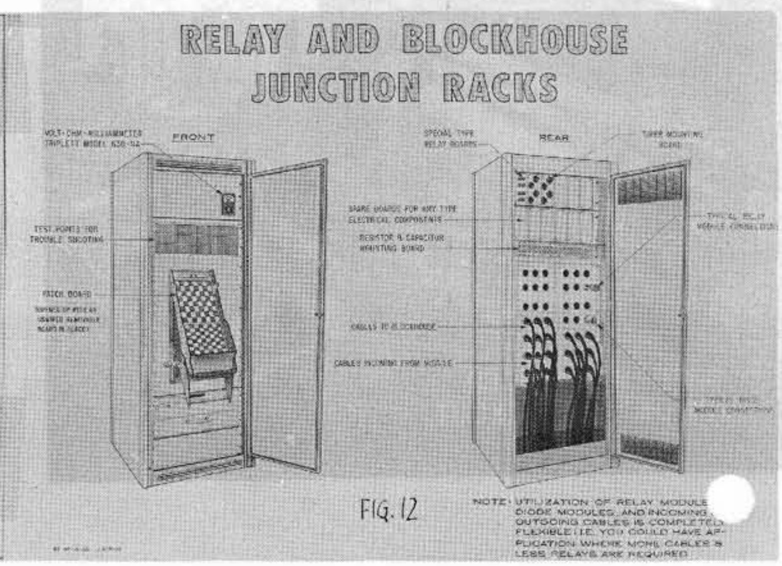


FIG. 12

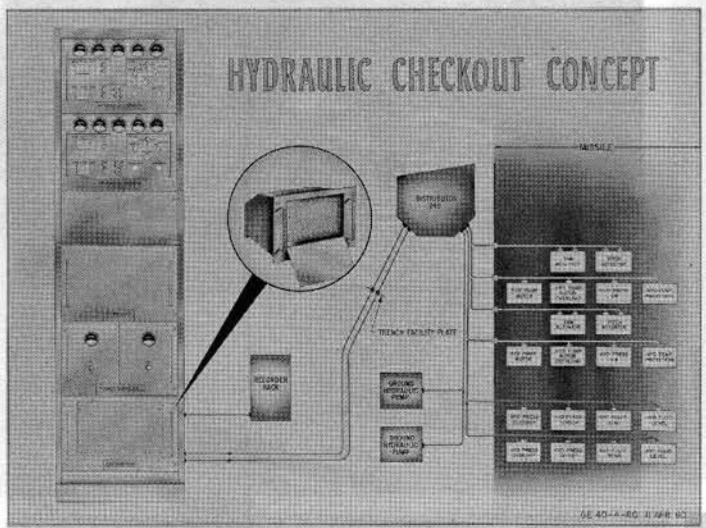


FIG. 13

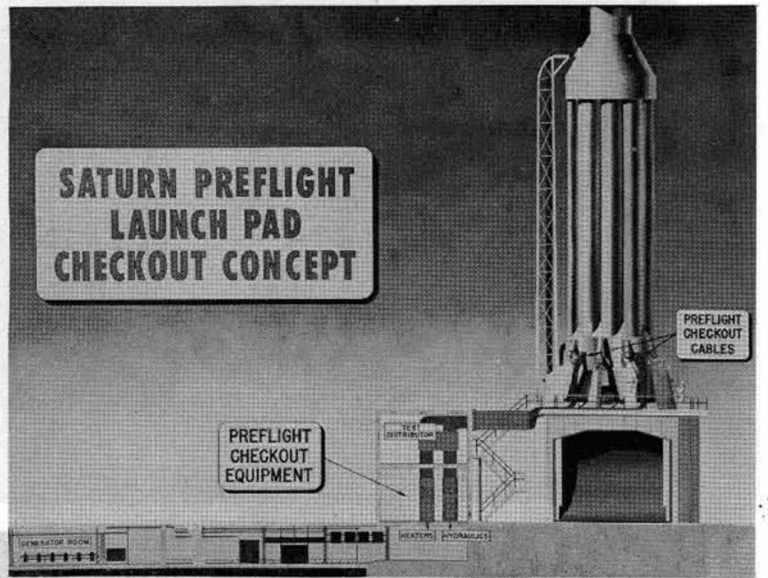


FIG. 14

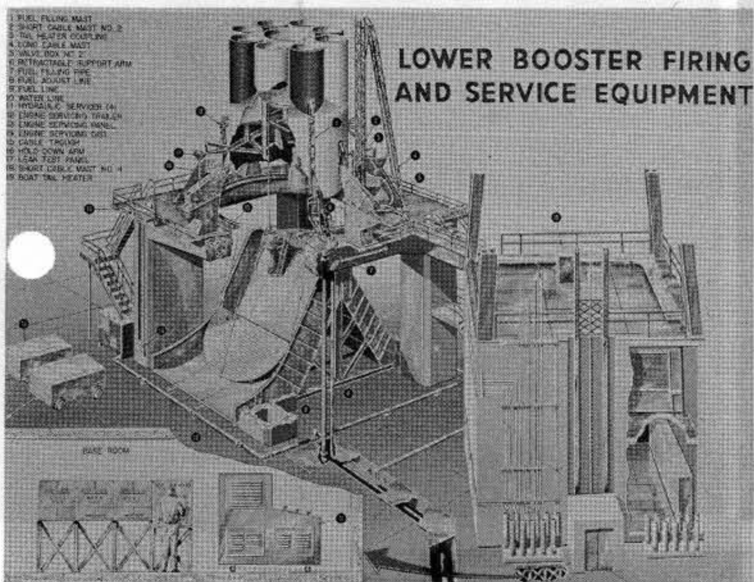


FIG. 15

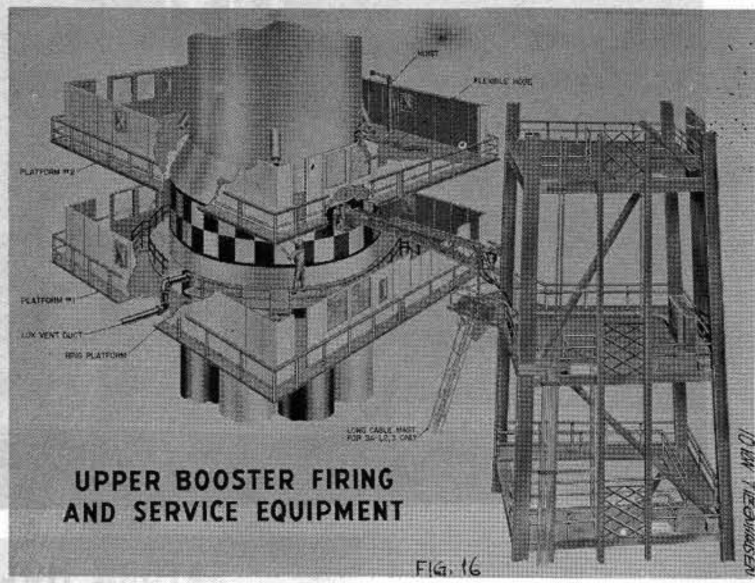


FIG. 16

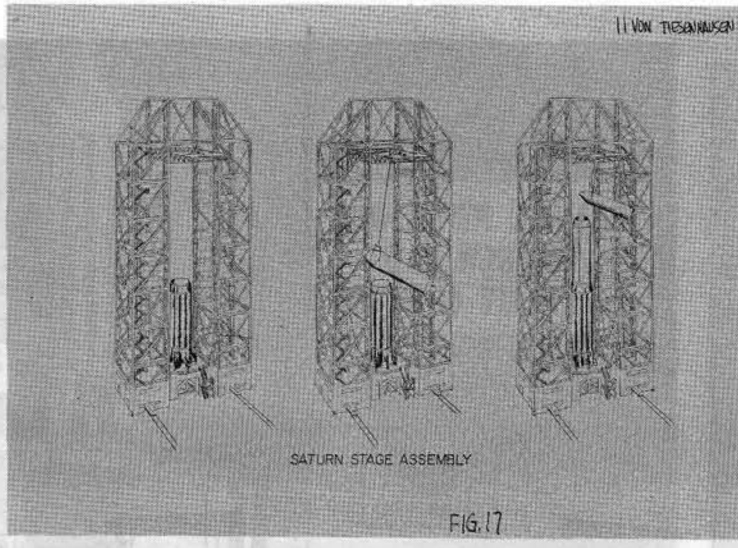


FIG. 17

FIG. 18

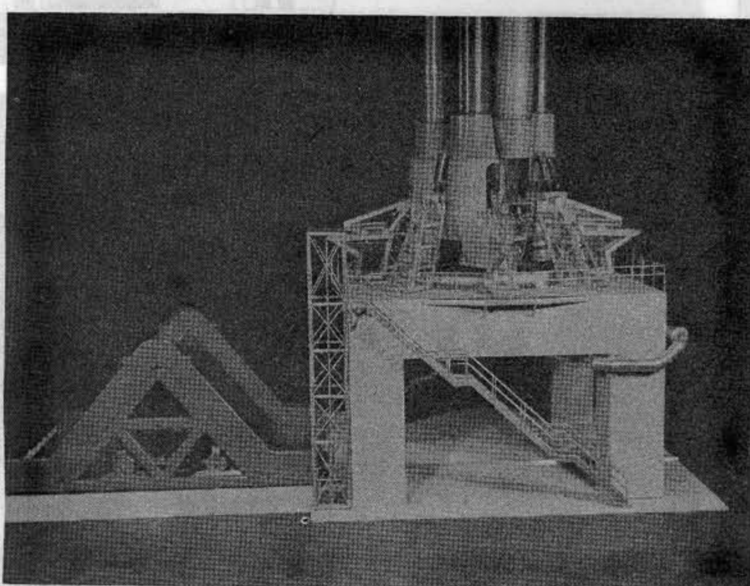


FIG. 19

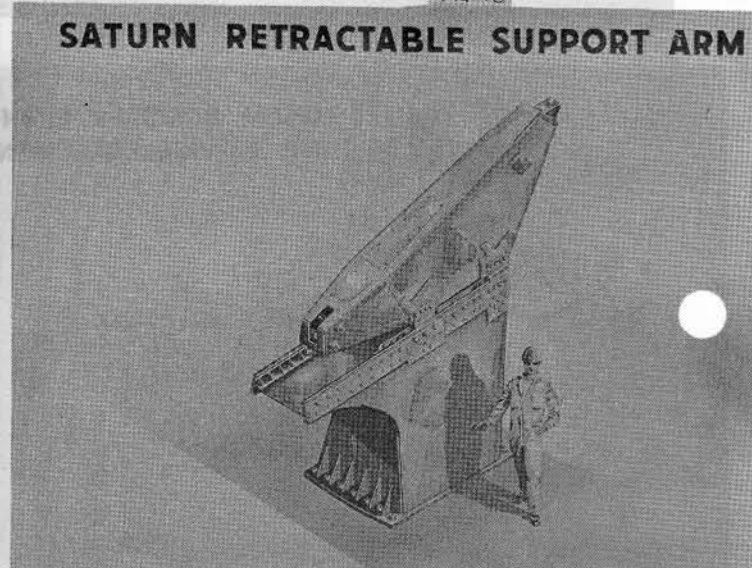


FIG. 20

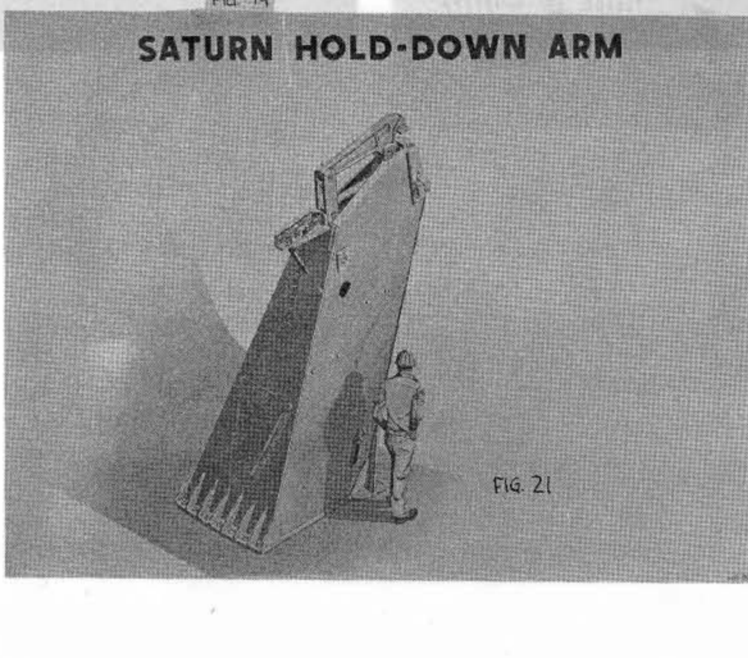


FIG. 21

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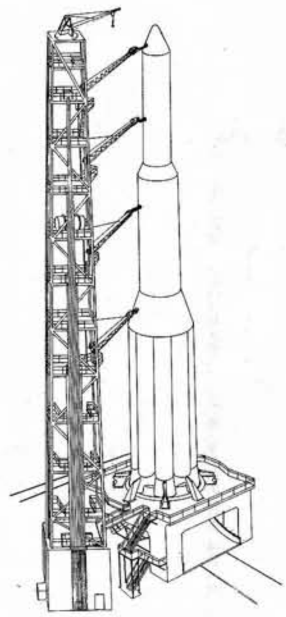


THREE STAGE SATURN
WITH UMBILICAL TOWER

FIG 22

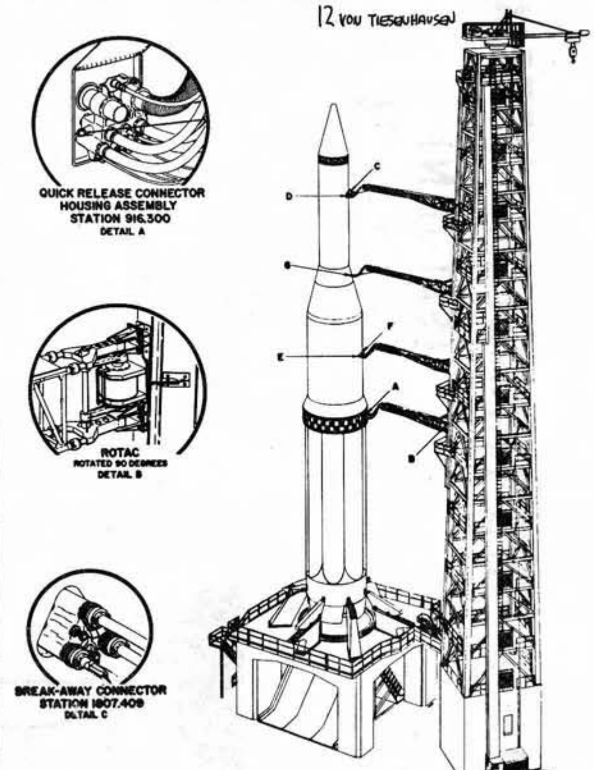


FIG. 23

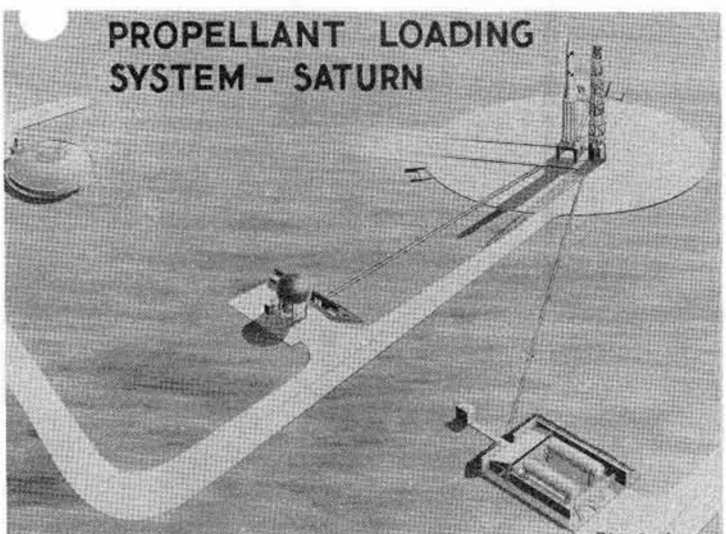
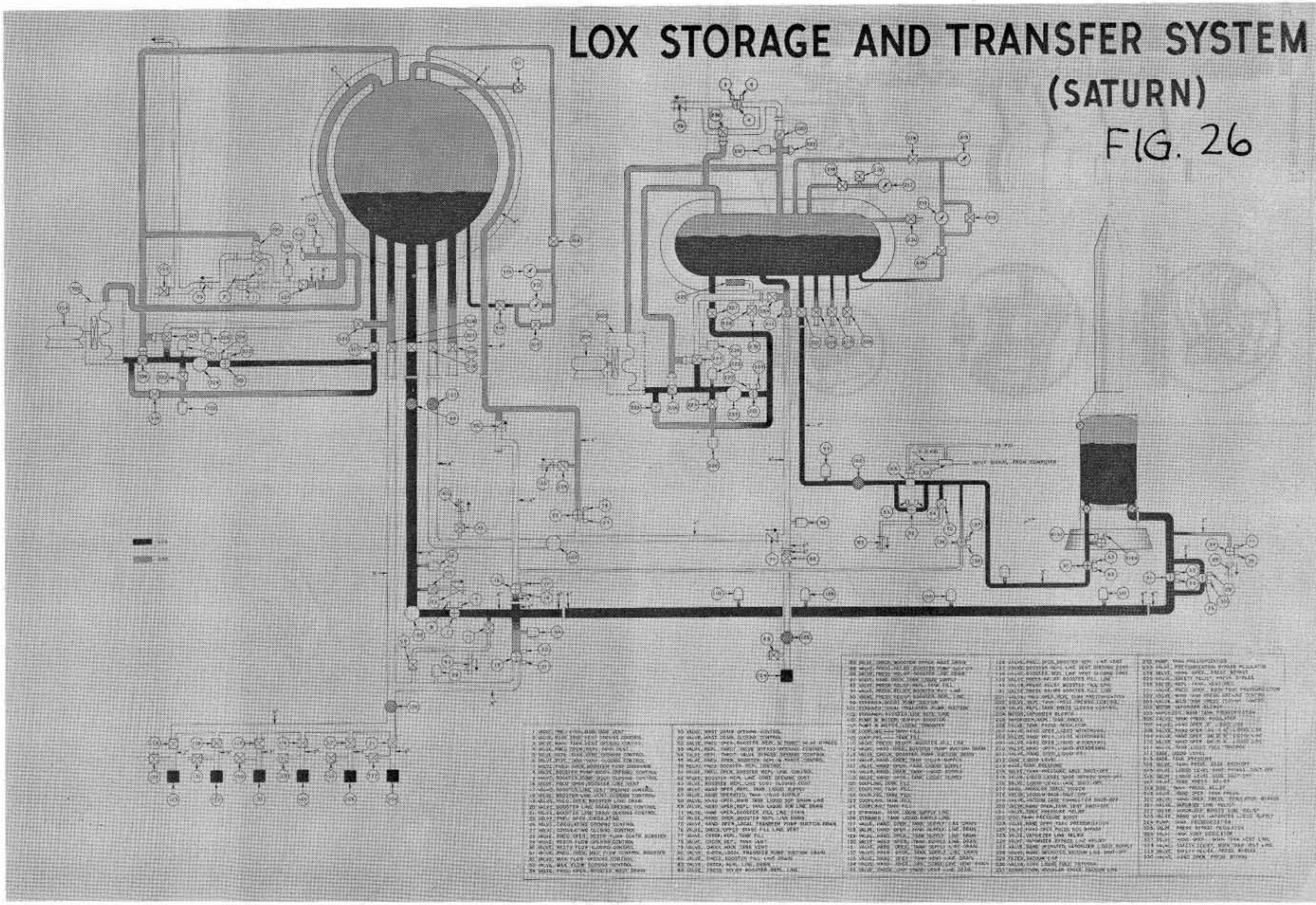


FIG. 24

FIG. 25

LOX STORAGE AND TRANSFER SYSTEM (SATURN)

FIG. 26



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FUEL SYSTEM SCHEMATIC (SATURN)

FIG. 28

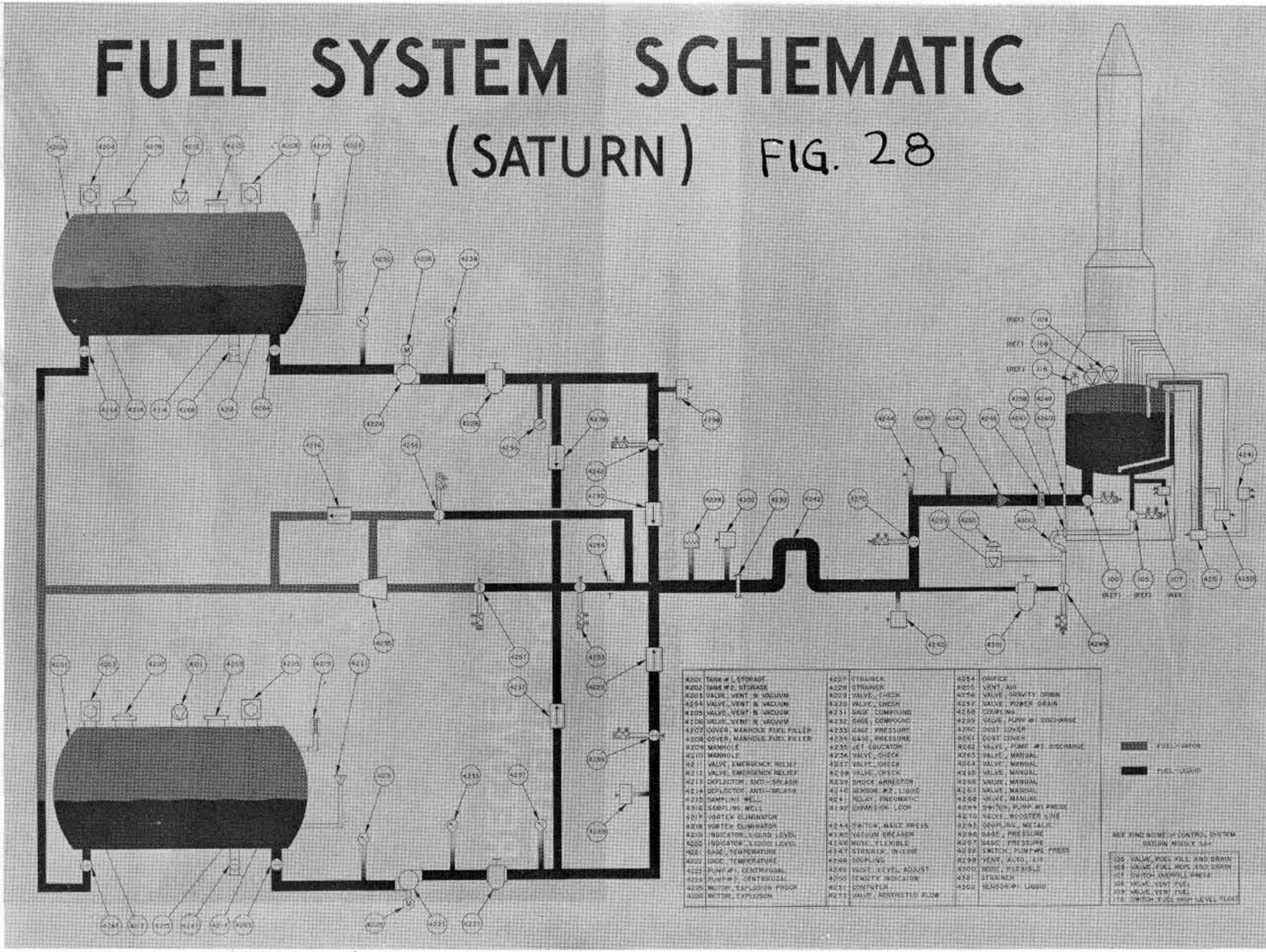

FIG. 27 APPEARS ON PAGE 15

14 VON TIESENHAUSEN

15 VON TIESENHAUSEN

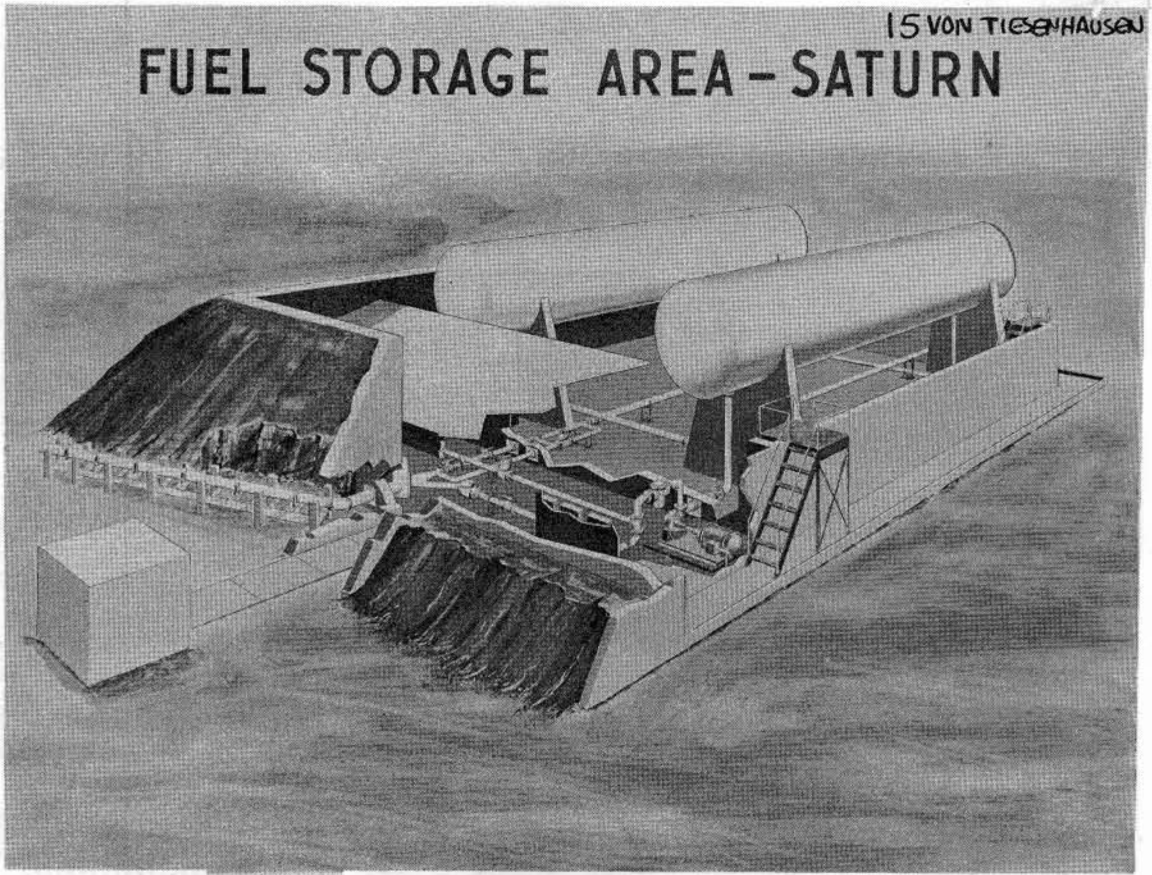

FIG. 27

FIG. 28 APPEARS ON PAGE 14

FIG. 29