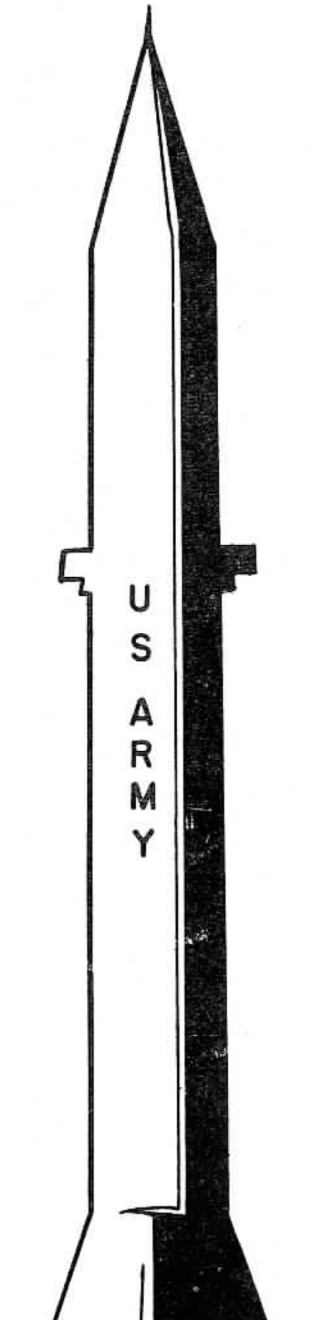
THE REDSTONE MISSILE SYSTEM



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Section I. INTRODUCTION

1. GENERAL

The Redstone is the U. S. Army's largest and longest range tactically operational weapon. This field artillery guided missile has a rocket type propulsion system which uses two liquid propellants, an alcohol-water solution and liquid oxygen, which are pump fed into the rocket engine by a hydrogen peroxide operated steam turbine. The guidance system is an inertial type, preset prior to firing, which automatically guides the missile to the target by correcting the trajectory as necessary for the missile to impact within an adequate circular probable error (CPE).

2. CHARACTERISTICS

The major characteristics and physical dimensions of the missile are as follows:

Length	21. 1 meters (69 feet 4 inches)
Diameter	1. 8 meters (70 inches)
Loaded weight	28, 000 kg (61, 700 pounds)
Empty weight	7, 420 kg (16, 300 pounds)
Range (maximum)	320 km (200 statute miles)
Propellants:	
Oxidizer	Liquid oxygen, 11, 370 kg (25, 000 pounds)
Fuel	75 percent alcohol +25 percent water, 8, 650 kg (19, 000 pounds)
Steam source	Hydrogen peroxide, 359 kg (854 pounds)
Thrust	35, 200 kg (78, 000 pounds) for 96 to 121 seconds
Guidance	Inertial
Warhead	Nuclear, 3, 590 kg (7, 900 pounds) total nose section weight
Mobility	100 percent and air transportable

3. MISSILE DESCRIPTION

The missile consists of three parts--the thrust, guidance, and warhead units (fig 1). The thrust unit includes the tail section which has four fixed stabilizers, four movable air rudders, and four carbon jet vanes which extend into the rocket exhaust to provide control of the missile until its speed is sufficient to cause the external air rudders to be effective. Inside the tail section is the rocket engine (fig 4) , which produces 78, 000 pounds of thrust, and a propellant pumping system operated by hydrogen peroxide, a chemical which readily decomposes into steam. Above the tail section is the oxidizer tank, which is loaded with approximately 25, 000 pounds of liquid oxygen. Above the oxidizer tank is the fuel tank into which is loaded approximately 19, 000 pounds of an alcohol-water solution. The guidance unit contains an inertial type guidance system (fig 3) that operates on information from accelerometers and potentiometers which measure the movements of the missile. The accelermeters are mounted on a stabilized platform which is kept in proper orientation by gyroscopes. The angular position of the missile about its center of gravity is measured by potentiometers which detect relative movements between the missile and the stabilized platform. A tape recorder contains part of the trajectory data with the remainder of the data being set into the guidance computers. The warhead unit, weighing 7, 900 pounds, contains the nuclear warhead. The guidance and warhead units, when mated, form the missile body, that portion of the missile which goes all the way to the target (fig 1). The thrust unit and missile body are joined by six bolts which contain internal explosive charges. After cutoff of the propulsion system, these bolts will detonate and the thrust unit and the missile body are pushed apart by two airloaded pistons. At the base of the guidance unit are four air vanes (fig 4) which provide maneuvering control for the missile body after separation. To keep the missile weight to a minimum, only the missile body is made strong enough to withstand the forces created when the missile reenters the dense atmosphere as it descends to the target.

4. FIRING DATA OPERATIONS

The missile is assembled and erected to the vertical position by using a lightweight erector-servicer (fig 9) which consists of a modified $2\frac{1}{2}$-ton truck, and H-frame, an A-frame, and cabling. The sections of the H- and A- frames, the cabling, and other accessories are carried on the bed of the $2\frac{1}{2}$-ton truck which also tows the launcher. The launcher is emplaced over a preselected and surveyed location, and the H- and A- frames are assembled between the launcher and the truck. All firing area operations take place in the vicinity of the launcher.

a. Assembly. The three missile units arrive at the firing area on their respective transporters. The missile body is assembled first by lifting the guidance unit from its transporter, removing the transporter, and positioning the warhead unit to permit the two units to be joined. The missile body can be assembled by using the erector-servicer or the M246 wrecker. The thrust unit transporter is backed into position, and the thrust unit is picked up by using the chain hoists suspended from the A-frame overhanging the launcher (fig 16). The transporter is removed, and the missile body is positioned for mating with the thrust unit. Six bolts containing internal explosive charges mate the body to the thrust unit. The assembled missile is then hinged to the launcher with the warhead unit resting on the warhead trailer (fig 16).

b. Horizontal Checkout. The missile is then given a horizontal checkout to assure proper operation of its guidance and propulsion systems.

c. Erection. To erect the missile, the winch on the bed of the erector truck is operated to pull the cable attached to the A-frame (fig 9). The A-frame rotates about pivot points on the launcher. Cables lead from the A-frame to the missile. The missile nose is lifted with the tail section rotating on pivots on the launcher. As the missile approaches the vertical position, hydraulically operated pistons, mounted on the launcher, engage the missile and slowly lower the missile to the erect position. This prevents the missile from tumbling over the launcher. Then the cables are released and the H-frame is repositioned to provide a servicing platform in case repairs or replacements are required in the guidance system (fig 9).

d. Laying. After erection, the missile is then oriented on the firing azimuth by rotating the rotating frame assembly on the launcher. Theodolites are used to provide the reference direction.

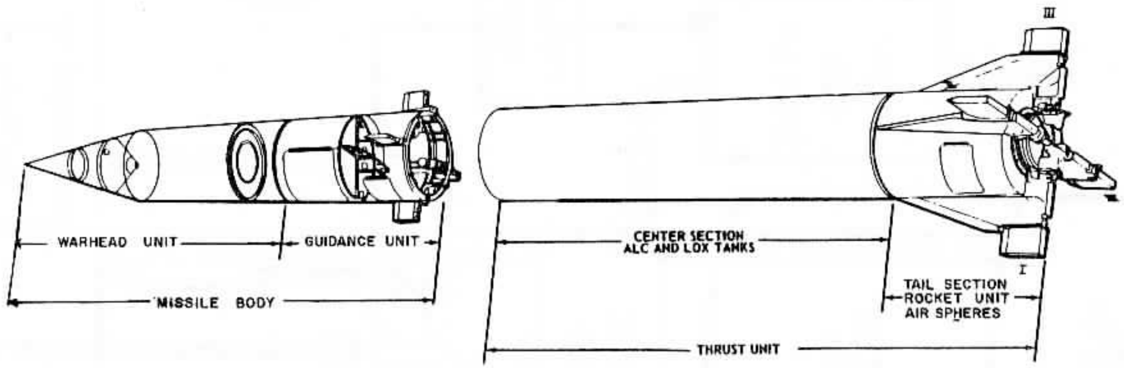

Figure 1. Missile component nomenclature.

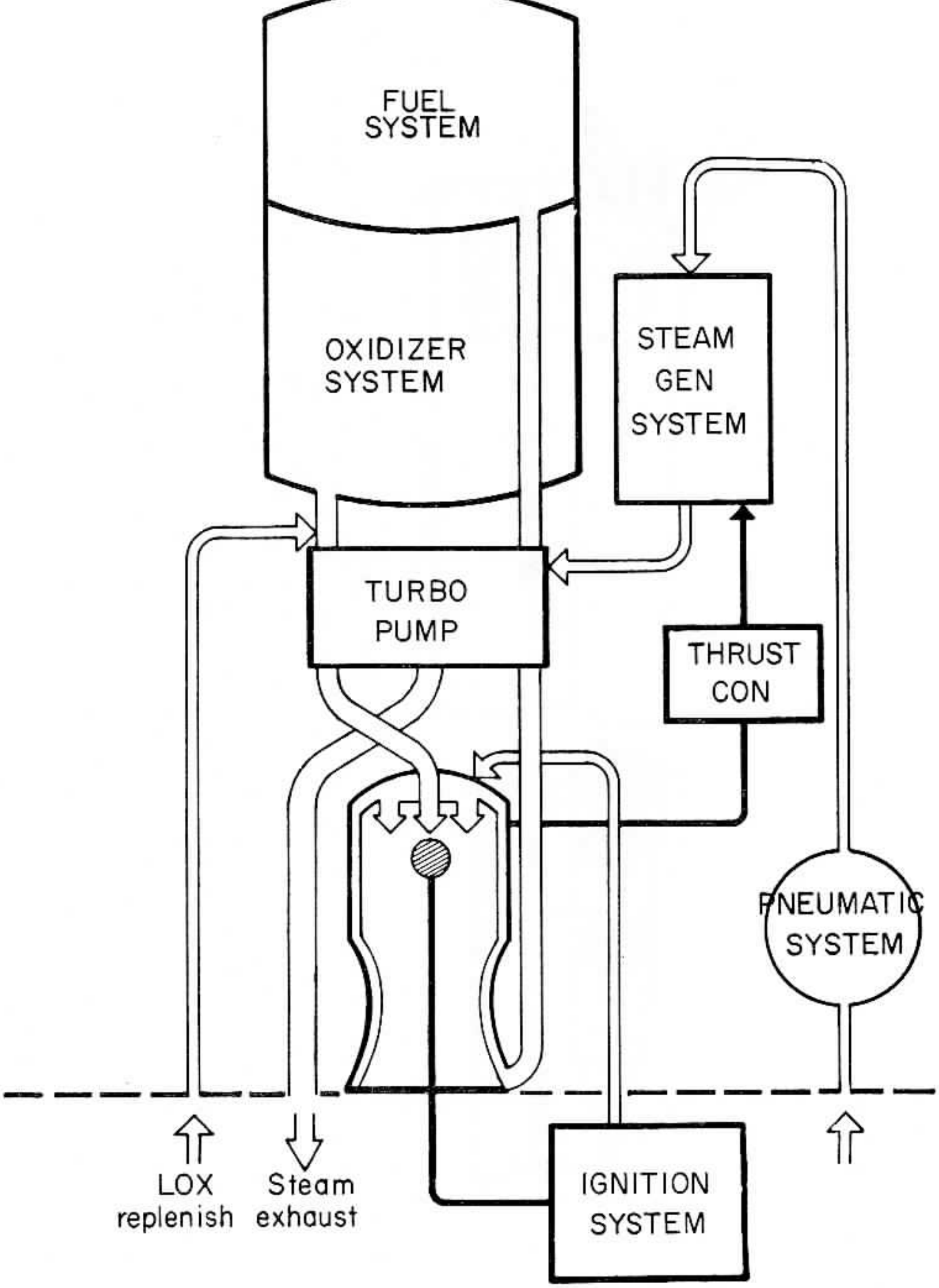

Figure 2. Propulsion system (block diagram).

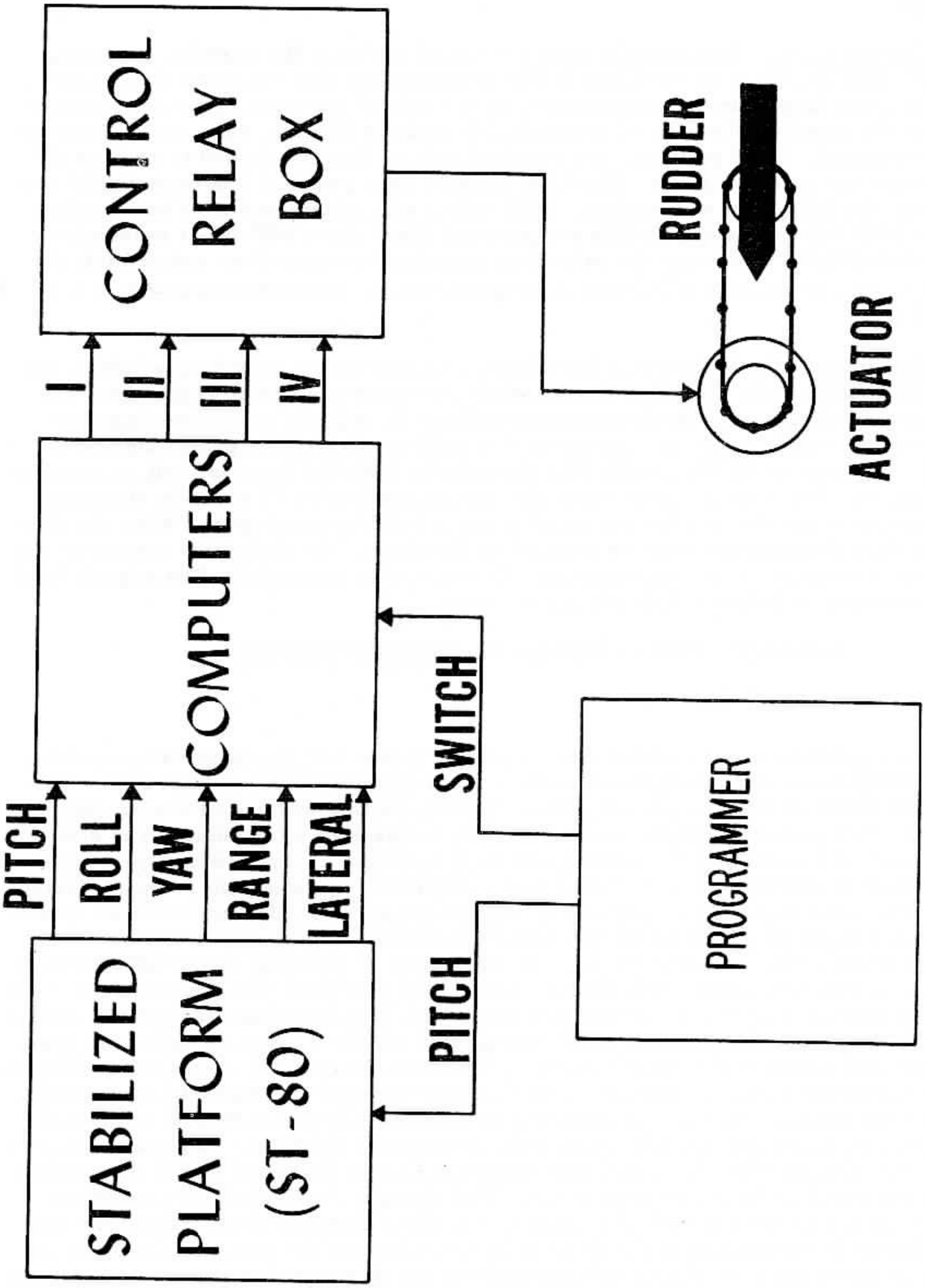

Figure 3. Guidance system (block diagram).

e. Vertical Checkout. The missile is then given a vertical checkout including fire mission presettings.

f. Propellant Loading. Immediately after the initial laying of the missile, propellant loading begins. The alcohol is carried in a 3, 000-gallon trailer (fig 10) resembling a gasoline trailer. A pump located in the compartment at the rear of the truck is used to transfer the alcohol into the missile. Two liquid oxygen (LOX) trailers (fig 11), each with a capacity of 9 tons (approximately 1, 800 gallons), are required to load the missile and to replace the LOX which evaporates prior to firing. The LOX trailers have a special Thermos bottle construction to keep the LOX from evaporating. LOX exists only at temperatures below minus 297° F. When LOX becomes warm and its temperature rises above 297° F, it evaporates. Hydrogen peroxide (H_2O_2) to operate the propellant pumping system is then pumped into the missile. The hydrogen peroxide is carried in 86-gallon drum, mounted on a modified 3/4-ton truck (fig 12).

g. Missile Firing. The Redstone is fired from a remote firing panel located about 180 meters from the launcher (fig 14). The firing switch starts the propulsion system(par 13). If initial ignition is satisfactory, the hydrogen peroxide is forced into a reaction chamber (steam generator) to create steam for operation of a turbine to which the propellant pumps are connected. A thrust of 78, 000 pounds lifts the missile from the launcher and accelerates it toward the target. The missile rises vertically for approximately 17 seconds; then the guidance system automatically pitches the missile into a ballistic trajectory. When the missile has attained the position and velocity to coast to the target, the propulsion system is cut off by the guidance system. A few seconds later the missile is separated. The missile body is guided as necessary to insure a high impact accuracy.

Section II. THE REDSTONE PROPULSION SYSTEM

5. GENERAL

The Redstone guided missile utilizes a bipropellant, pump-fed, liquid rocket propulsion system. The components of the propulsion system are located in the thrust unit of the missile (fig 4). The Redstone uses an alcohol-water solution for fuel with liquid oxygen (LOX) as the oxidizer. The propellant pumps are powered by a steam driven turbine. The steam is generated on board the missile by the decomposition of hydrogen peroxide into superheated steam. The steam is routed through turbine blades that drive the propellant pumps. Various valves of the propulsion system are operated by high pressure air. High pressure air is also used to maintain a slight pressure on the fuel tank; the oxidizer tank is self-pressurized by the evaporation of the LOX. Initial ignition is accomplished by injecting igniter alcohol from an external source into the combustion chamber where it is combined with liquid oxygen. This mixture is ignited by an electrically energized squib. With successful initial ignition, alcohol from the missile alcohol tank is applied to the combustion chamber. The design of the combustion chamber and nozzle of the rocket engine is such that the thermal energy of the burning propellants is converted to kinetic energy. The thrust or forward propulsive force is proportional to the kinetic energy. The thrust produced by the rocket engine is held at a constant value by maintaining a constant pressure within the combustion chamber. Any change in pressure in the combustion chamber is sensed and converted into an electrical signal that results in a change in the speed of the propellant pumps. This changes the quantity of propellants consumed each second to the value which creates the correct chamber pressure and the correct thrust. Thrust is terminated at the desired time by stopping the flow of propellants to the engine and stopping the flow of hydrogen peroxide to the steam generator. The propulsion system of the Redstone missile includes the following major components and systems:

a. Pneumatic system.

b. Electrical system.

c. Rocket engine.

d. Fuel system.

e. Oxidizer system.

f. Steam generating system.

g. Ignition system.

Note. In the following description of the propulsion system, all figures discussed are approximations. This has been done to help generalize the scope of discussion.

6. PNEUMATIC SYSTEM

A supply of high pressure air is carried in six spheres mounted in the missile tail section (fig 4). These spheres are charged prior to takeoff to 3, 000 pounds per square inch (psi). Air from these spheres, after passing through the heat exchanger, maintains a slight pressure in the alcohol tank. High pressure air is controlled by a regulator and distributed to pressurize the hydrogen peroxide (H_2O_2) system and operate various propellant control valves (fig 5).

7. ELECTRICAL SYSTEM

The electric power required by the propulsion system is derived from three sources.

a. Batteries. 28-volt, direct-current (DC) power is supplied by batteries located in the missile body guidance compartment. This power is routed to various relays and rocket engine controls which provide automatic sequencing of engine ignition and cutoff operations.

b. Ground Source. 120-volt, 60-cycle alternating-current (AC) power is supplied by a ground source prior to firing to operate various heaters in the propulsion system.

c. Generator. 115-volt, 400-cycle alternating-current power is supplied by an inverter in the missile body unit to operate the thrust controller. The inverter transforms the 28-volt direct current from one of the missile batteries to alternating current.

8. ROCKET ENGINE

The Redstone missile is powered by a liquid bipropellant rocket engine (fig 6) rated to provide a nominal thrust of 78, 000 pounds. The capacity of the missile propellant tanks limits burning time to a maximum of 121 seconds. Operation is by the continuous injection and combustion of fuel and oxidizer. The rocket engine is very simple in construction. It has a large, cylindrical, double-walled combustion chamber, open at one end for escape of the powerfully expanding gases and closed off at the forward end by a perforated injector plate. Alcohol and liquid oxygen are forced through the perforations under pressure and atomized, mixed, and ignited just behind the plate. Started electrically, ignition occurs along a broad flame front covering the full cross sectional area of the chamber. The burning gases expand violently and gain velocity, rushing to escape through the narrow throat of the chanber. Additional thrust is delivered when the gases surge into the flaring exhaust nozzle, expand still more, and emerge as a white-hot jet stream.

9. FUEL SYSTEM (FIG 5)

The alcohol tank is filled with 19, 000 pounds of an alcohol-water solution when the missile is in the firing position (fig 10). The 25 percent water content of the fuel reduces the flame temperature and adds to the weight and pressures of gases expelled, thus contributing to thrust. Prior to alcohol loading, 10 gallons of water or a lithium chloride solution (par 37) as an inert lead start are placed in the rocket engine manifold. During ignition, this inert lead start is forced into the combustion chamber ahead of the main alcohol flow to reduce the violence of mainstage ignition. The alcohol tank is pressurized to approximately 20 pounds per square inch by air from the high pressure air spheres. The turbopump draws 150 pounds of fuel per second from the tank and forces it through a single duct to a manifold encircling the rocket engine exhaust nozzle. The alcohol then flows forward between the double walls of the engine, cooling it effectively, and passes through the injector plate and into the combustion chamber.

10. OXIDIZER SYSTEM (FIG 5)

The LOX tank is filled when the missile is in the firing position with approximately 25, 000 pounds of LOX. The liquid oxygen, because of its low temperature (-297° F), evaporates rapidly. Because of this high evaporation rate, the tank must be replenished just before the missile is fired. Liquid oxygen is drawn from the LOX tank by a turbopump and delivered to a small reservoir or "LOX dome" above the injector plate of the engine. The normal flow is 200 pounds per second. The LOX tank is pressurized to approximately 30 psi to insure smooth flow through the turbopump. During the engine ~~starting~~ sequence, this pressure is provided by a ground source of compressed air. When the engine begins to operate, this pressure is continuously maintained by gaseous oxygen. For this purpose, a small amount is bled from the main LOX line and passed through coils in the exhaust duct (heat exchanger) of the steam system where heat converts it to gas (fig 5 and 6).

11. STEAM GENERATING SYSTEM (FIG 5)

Hydrogen peroxide (H_2O_2) produces steam to power the turbopumps that deliver the propellants to the engine. Located just forward of the engine, the 78-gallon hydrogen-peroxide tank is filled after the missile has been erected. The H_2O_2 tank is then pressurized by the pneumatic system. When a feed valve is opened, the hydrogen peroxide flows to a steam generator, strikes a bed of potassium permanganate pellets, and is instantaneously converted into superheated steam. The steam rotates the turbopumps and exits through an exhaust duct containing heat exchanger coils. Some of the heat is recovered here to maintain the pressure level in the pneumatic system and the LOX tank. Escaping steam contributes slightly to thrust. Thrust is maintained at a constant value by a servomechanism known as the thrust controller. The thrust controller measures pressure in the combustion chamber, compares this pressure with a desired value, and acts, according to the difference, to either increase or decrease the flow of hydrogen peroxide to the steam generator. Steam production is thus adjusted to alter the speed of the propellant pumps, thereby controlling the rate of propellant flow to the rocket engine.

12. IGNITION SYSTEM (FIG 5)

Once started, combustion is self-sustaining; but because alcohol and liquid oxygen do not ignite spontaneously when mixed, some method of initiating combustion must exist in the rocket engine. The engine ignition system consists of the following:

a. Igniter Alcohol. An igniter alcohol supply, consisting of a 3. 5-quart container mounted on the missile launcher, is pressurized during the missile preparation sequence.

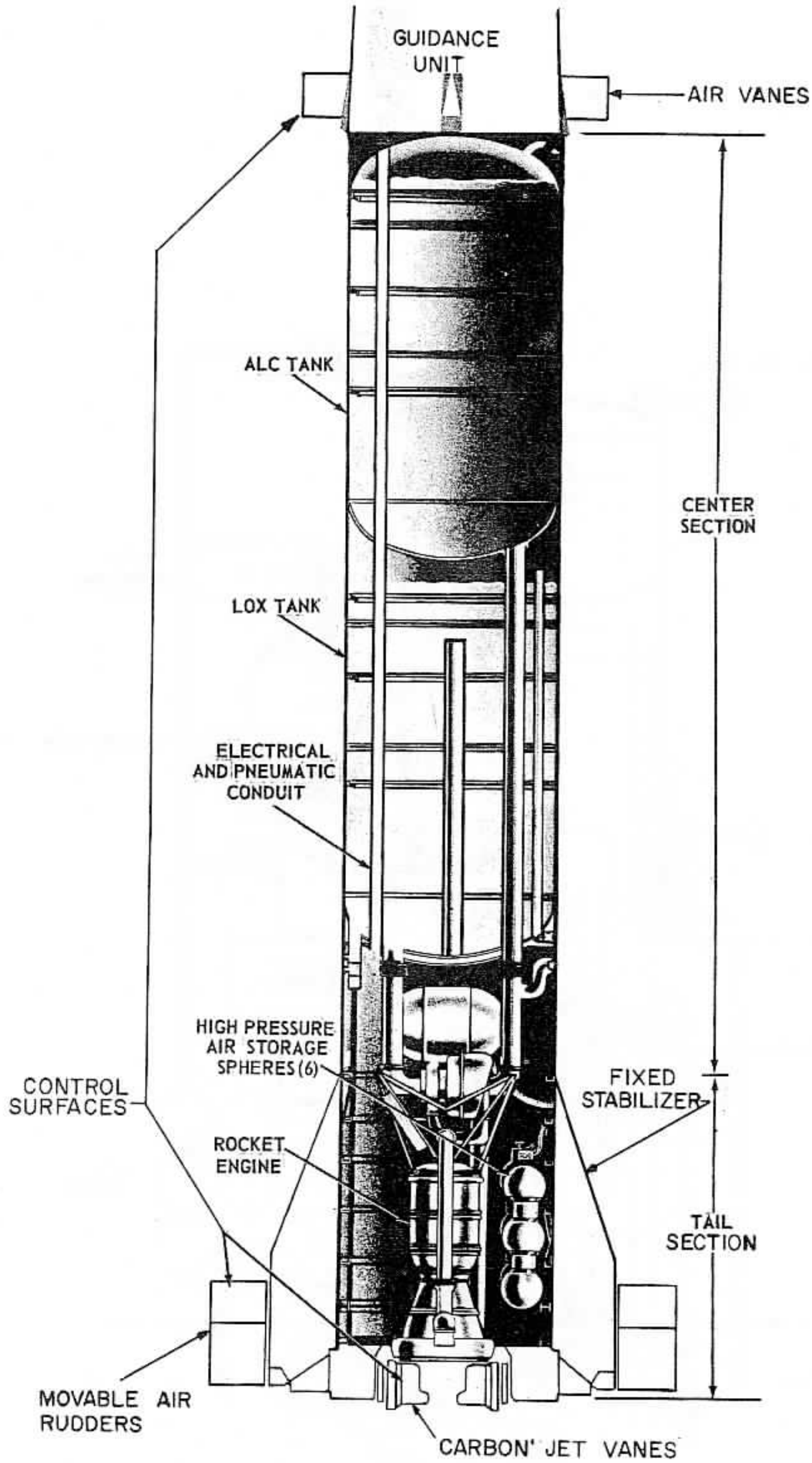

Figure 4. Thrust unit.

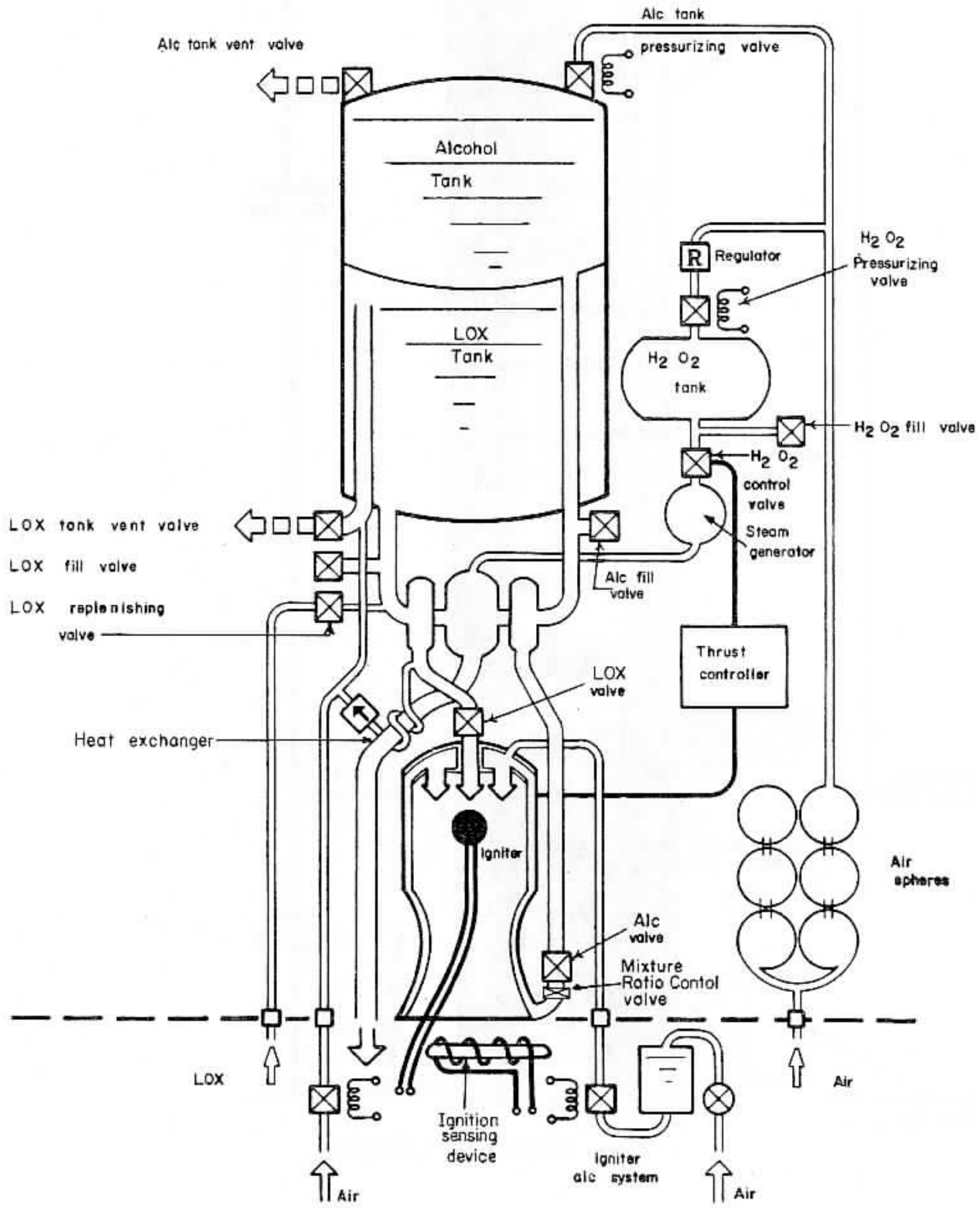

Figure 5. Propulsion system (functional schematic).

Alcohol from this container is forced at the proper time through the valve box and multiple coupling to the center ring of the rocket engine injector plate which functions much like a shower head.

b. Igniter Cartridge. An igniter cartridge assembly, consisting of four electrically fired squibs igniting a pyrotechnic with a burning time of 10 seconds, initiates combustion. This assembly is suspended beneath the injector plate by means of a thin plastic rod which screws into the injector head prior to firing.

c. Ignition Sensing Device. An ignition sensing device, commonly called the mainstage stick, is installed below the rocket engine nozzle. This device has a loop of wire which extends into the jet stream of the engine. With proper ignition, the wire will break, generating an electrical signal which causes the alcohol valve to open and the turbopump to activate.

13. ROCKET ENGINE OPERATION (FIG 5)

The following events (a through m below) occur automatically upon actuation of the firing circuit from the remote firing panel. Some of these events occur simultaneously.

a. Alcohol and hydrogen peroxide tanks pressurize.

b. When the alcohol tank is pressurized, LOX tank pressurization from the ground high pressure air supply begins. (It takes approximately 8 seconds from the time the fire switch is pressed for the LOX tank to pressurize.)

c. The igniter squibs are energized, and the cartridges begin to burn in the igniter assembly. The igniter link burns through.

d. The main LOX valve opens. LOX flow to the rocket engine is caused by gravity and tank pressurization (b above).

e. Alcohol from the igniter alcohol container is forced through the center ring of the injector head into the combustion chamber.

f. Combustion begins with excess oxygen.

g. The ignition sensing device (mainstage stick) senses the ignition and causes the alcohol valve to open, and alcohol flows into the manifold and up through the combustion chamber walls forcing the inert lead start into the chamber.

h. The hydrogen peroxide valve opens to admit this chemical to the steam generator.

i. Steam is produced to drive the turbine. The turbopump accelerates.

j. Thrust rises rapidly as the flow of liquid oxygen and alcohol increases.

k. Admission of gaseous oxygen from the heat exchanger into the LOX tank maintains a constant pressure.

l. The turbopump attains rated speed (4, 800 rpm).

m. Full thrust is developed. (When the thrust developed exceeds the weight of the missile, the missile leaves the launcher.)

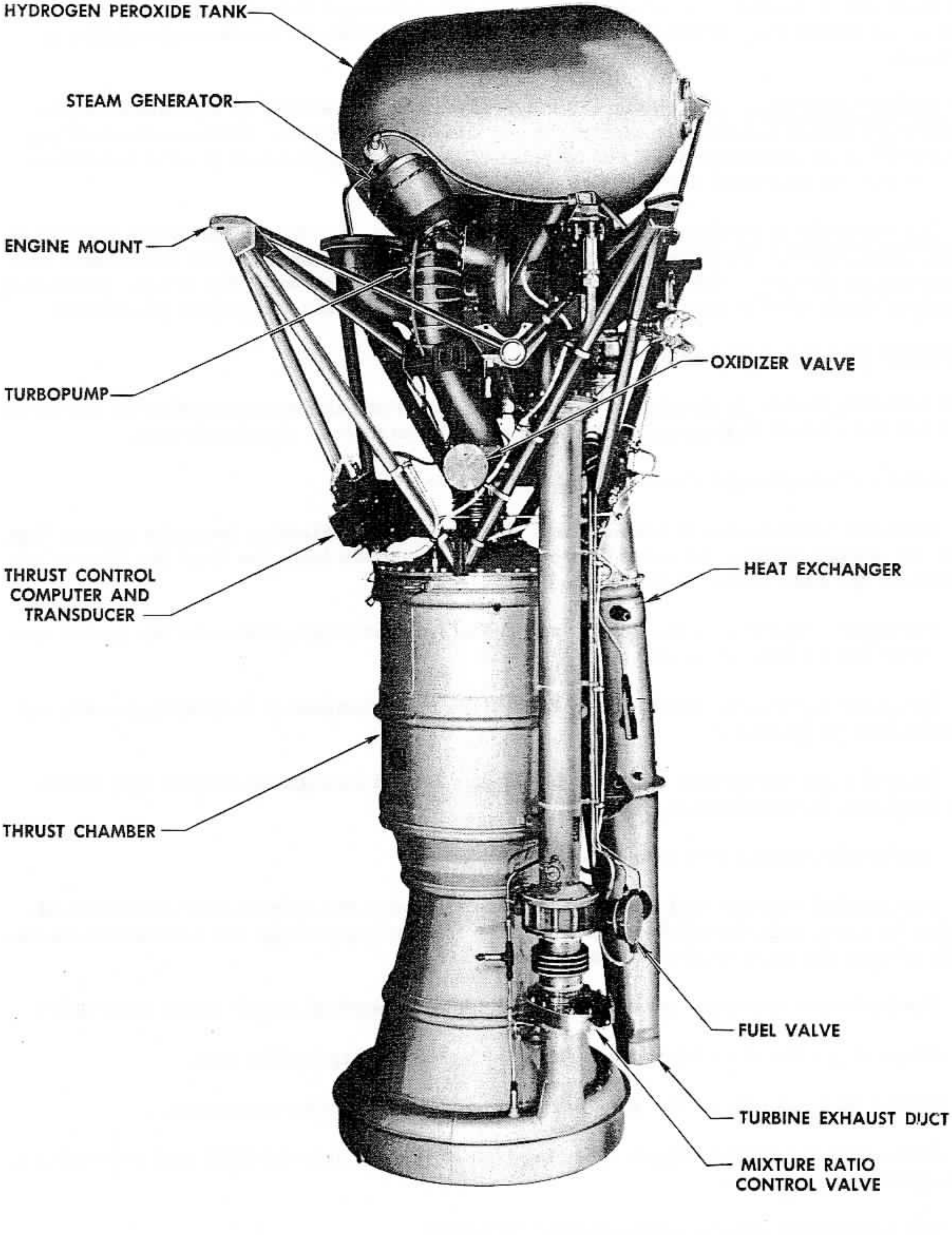

Figure 6. Rocket engine.

14. CUTOFF

At the proper time, depending on the range to the target, thrust is terminated by stopping the flow of propellants to the engine and by stopping the transmission of power to the turbine. After engine cutoff, the propulsion system serves no function.

Section III. THE REDSTONE GUIDANCE SYSTEM

15. GENERAL

The Redstone guidance system maintains proper angular orientation of the missile; senses, measures, and corrects deviations from the predetermined flight path; and determines the point at which thrust will be terminated. The guidance system is of the inertial type; that is, a system completely self-contained, depending on no other information other than errors generated as a result of positive or negative changes in velocity. These velocity changes can occur in either one of two measuring planes--a lateral plane or a range plane. The missile guidance system has two types of control--attitude control and path control.

a. Attitude Control. Attitude is the angular position of the missile with respect to its center of gravity. The terms used to define attitude are "roll," "pitch," and "yaw." Roll is the angular orientation of the missile about an axis drawn longitudinally through the center of the missile. With the missile in a horizontal position, yaw is the orientation of the missile about an axis perpendicular to the horizon and may be clockwise (to the right) or counterclockwise (to the left) of the desired orientation, as seen from above the missile. Pitch is the orientation as seen from the side and may be up or down.

b. Path Control. Guidance or path control is the determination and control of the position of the missile with respect to its references. Range guidance is in the direction of the target and, in the Redstone system, is measured along a line perpendicular to the tangent of the trajectory at impact (fig 7). The other reference direction is lateral--the displacement right or left of the line between the launcher and target.

c. Components. To satisfy the requirements for attitude and path control, self-contained equipment must measure the performance of the missile, determine the amount of deviation from the desired conditions, form corrective commands, and then reposition the missile as necessary. The Redstone guidance system consists of a stabilized platform as a reference, accelerometers to measure the performance, computers to determine corrective commands, a relay box to apply battery power to the motor actuators which position the control surfaces as required, and the necessary feedback circuits to provide additional stability and prevent overcontrol (fig 8). The heart of the guidance system is the ST-80, the stabilized platform. The stabilized platform is automatically leveled and alined before firing and maintains that orientation until impact. Three gyroscopes mounted on the platform maintain its proper orientation.

16. ATTITUDE CONTROL

a. General. One of the guidance requirements, that of attitude control, is accomplished by potentiometers (voltage measuring devices) mounted between the stabilized platform and the missile frame. If the missile develops a roll, yaw, or pitch error, the angle error between the stabilized platform and missile frame is electrically measured and the signals are fed into the control computer. The error signals are mixed in the control computer to produce outputs which are used to reposition the missile. During the powered-flight phase, the combined effects of the jet vanes in the exhaust stream of the rocket engine and air rudders (fig 4) on the thrust unit produce the necessary control torques. During travel through the midcourse portion of the trajectory (which is essentially out of the atmosphere), a system of air jet nozzles using high pressure air produces the necessary control forces. During the terminal portion of the trajectory, air vanes (fig 4) located on the rear end of the missile body produce the attitude control.

b. Pitch Programming. Since the missile is launched from the vertical position, the missile must be steered into a ballistic trajectory; therefore, a timed pitch program is introduced into the control system to cause the missile to assume the correct attitude which is approximately tangent to the desired trajectory. Timing for signal ratio changes and other functions along the missile trajectory is stored in the form of pulses on a magnetic tape. This tape is run through a missileborne playback unit. This unit feeds the pulses into the stabilized platform to initiate the action of a stepmotor which displaces the wiper arm of the pitch potentiometer on the stabilized platform. This action is sensed as an error and in correcting for this deliberate pitch wiper arm displacement, the missile is pitched so that the potentiometer wiper arm is brought back to the zero position, thus pitching the missile toward the target. Since the program is different for various trajectories, the proper program corresponding to the desired trajectory is imposed on the missile tape from a program recording system in the Programmer Test Station. Tapes for different trajectories are from a library of tapes carried by the firing battery.

c. Jet Nozzle System. Because the Redstone missile passes through areas in which there is little atmospheric air, there is essentially no control exercised through the use of moveable control surfaces. Consequently, attitude control must be accomplished in another manner. To accomplish attitude control at high at high altitudes, a jet nozzle system is used. Located at the base of each missile body air vane are two jets nozzles mounted opposite to each other, which create a small thrust by exhausting air. When the air vanes move to correct an attitude error, the respective air jet nozzles are activated to create a force which rotates the missile about its center of gravity to the proper attitude. For example, if a pitch-up error exists, air jets on opposite sides of the missile operate, exhausting air downward to create an upward reaction which rotates the missile to the proper attitude.

17. PATH CONTROL

The inertial system senses errors from a predetermined reference trajectory. The path of the missile is adjusted during the latter portion of flight so that the actual impact point will coincide with that of the reference trajectory. The adjustment is brought about by signals generated by two accelerometers mounted on the stabilized platform. These accelerometers are air-bearing gyroscopic devices with pendulous masses and are single integrating mechanisms which sense accelerations and convert these accelerations to velocity outputs which are fed to the range and lateral computers. To obtain displacement information, the velocity signals are again integrated, this time by a ball and disc integrator in the computers. Then the control signals from the range and lateral computers are fed into the control computer previously mentioned.

a. Range Control. The range accelerometer is oriented on the stabilized platform so that it measures in a direction perpendicular to the trajectory tangent (impact coordinate) (fig 7) and in the plane of trajectory. In this way, it can give velocity information pertaining to the location of the missile compared to the reference trajectory. Its output is fed to the range computer which performs the second integration for obtaining displacement, computes a corrected thrust termination time, and supplies arming signals for the warhead fuze. Any range error existing at cutoff, as well as deviations caused by various disturbances after cutoff, is measured, stored, and sent out as path corrections during the terminal guidance phase (phase IV).

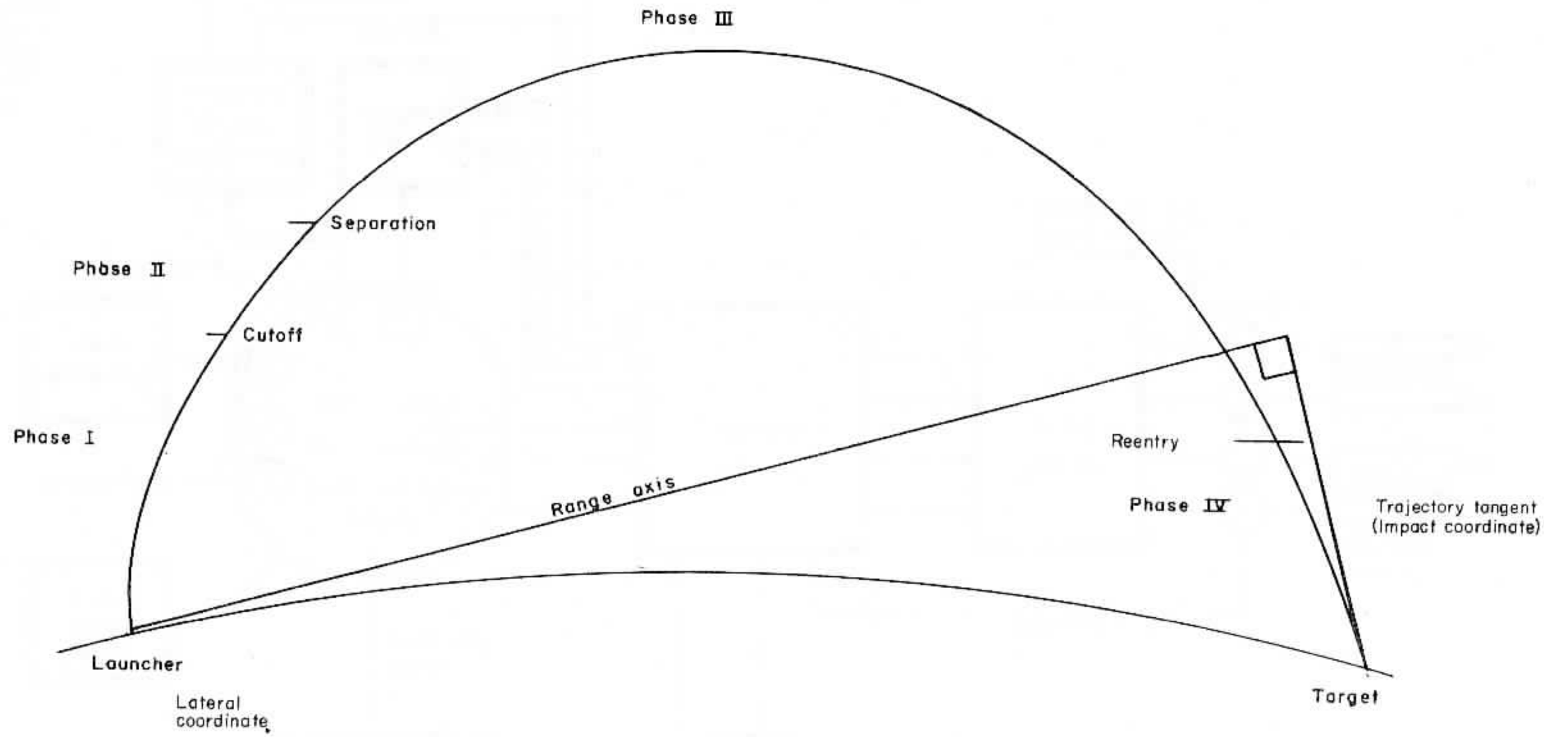

Figure 7. Redstone trajectory.

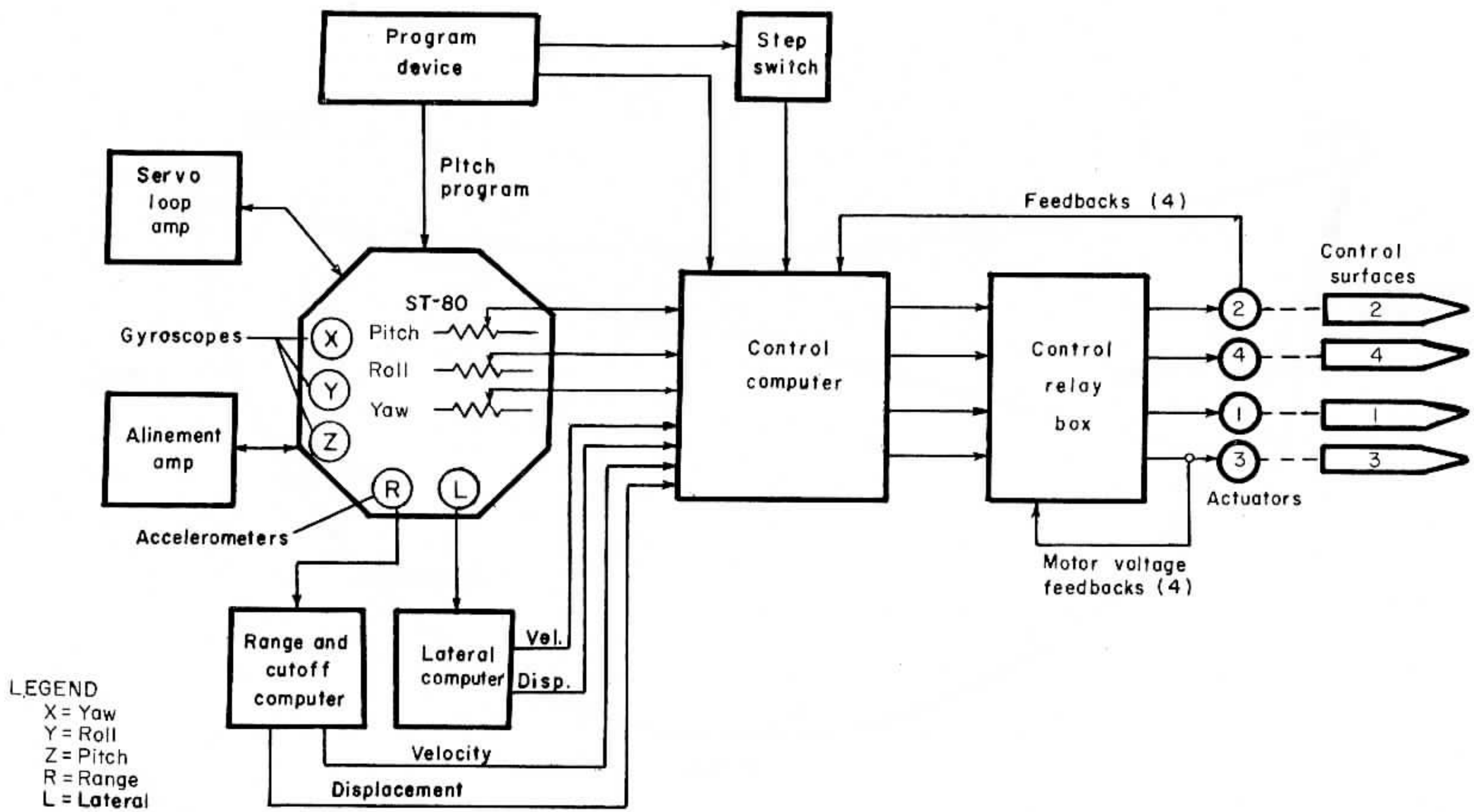

Figure 8. Redstone guidance system.

b. Lateral Control. The lateral accelerometer measures in a direction perpendicular to the plane of the trajectory and gives information as to the location of the missile compared to the plane of the reference trajectory. Deviations are measured along the entire trajectory and corrective signals are introduced into the control system of the missile during the initial (phase I) and terminal (phase IV) phases of the flight.

18. LAYING

Since all path control information is determined by devices within the missile, a precise degree of alinement of the stabilized platform on the firing azimuth is necessary. Stabilizer I of the missile is pointed toward the target. Two theodilites and a missile prism are used to establish the precise firing azimuth by referencing to a previously surveyed orienting line. The missile prism is a reflector mounted on the missile and is alined to the missile airframe, as is the stabilized platform. The firing angle is established, and, then the missile, in the vertical position, is rotated until the missile prism can be sighted from one of the theodolites. After final adjustments, such as leveling the launcher to within a close tolerance, final laying of the missile is achieved. Since the missile prism is mechanically alined to the stabilized platform and since the missile has been rotated as a result of sighting on the prism from the theodolite in reference to the firing azimuth, the range and lateral accelerometers of the stabilized platform are oriented with respect to the target.

19. SEPARATION

During the preliminary designing of the missile, it became apparent that it would be advantageous if the missile body and thrust unit were separated after thrust termination. It was obvious that the high dynamic pressure encountered during descent toward the target becomes an important consideration in the design of the missile from the structural, aerodynamic, and control concepts, especially if the missile maneuvers during terminal guidance (phase IV). It was determined that a large amount of structural weight in the thrust unit could be saved if it were constructed to meet only the conditions encountered during the ascending phase of flight when the speed of the missile is relatively slow. A separate reentry section offers a more favorable center of pressure location over the wide range of velocities encountered, thus improving stability. Control forces are less for the short and lighter body. For these reasons, provisions were made in the missile design for separation of the missile body and thrust unit after the powered flight phase is completed. The two units are connected until cutoff by six bolts, each containing an explosive charge in the head. Shortly after cutoff, the programmer supplies a signal which detonates the bolts. At the same time, two internally mounted expulsion cylinders operate to supply the force to separate the two parts of the missile. This expulsion device is a piston and cylinder mechanism powered by compressed air.

20. TEMPERATURE CONTROL

A single temperature maintenance system is used in the missile. The entire guidance compartment is heated or cooled as required to maintain a temperature of about 60° F prior to firing the missile. This is accomplished by a heater-cooler drop tank. The drop tank is attached to the outside of the guidance compartment and contains a heater, a blower, an outer tank, and an inner tank. The inner tank contains liquid nitrogen (par 38). Air is then routed through the heater for heating or circulated around the liquid nitrogen tank for cooling, thus maintaining temperature and humidity control in the guidance compartment. The drop tank is released and falls to the ground when the firing switch is operated. The stabilized platform contains heating elements which help preheat it; the heat generated when the stabilized platform is operating is sufficient to keep it at the required temperature throughout the entire trajectory.

21. POWER SUPPLIES

The Redstone missile requires four types of electrical power for its operation.

a. 28-Volt Direct Current. Power to operate the rudder actuators, the various relays, the valves, the ignition circuits, and a 400-cycle, alternating-current generator is obtained from two 28-volt, direct-current batteries.

b. 60-Volt Direct Current. Power used in the guidance measuring and feedback circuits is provided by a 60-volt converter, which operates from the output of the missile inverter.

c. 115-Volt, 400-Cycle Alternating Current. Power used in amplifier circuits and in the stabilized platform is provided by a 115-volt, 400-cycle inverter operated by one of the 28-volt, direct-current batteries.

d. 208- and 115-Volt, 60-Cycle Alternating Current. Power to operate the direct-current generators for use in testing and firing the missile and to operate the missile heaters is provided by a 60-kilowatt, 60-cycle, 208-volt, trailer-mounted diesel generator. This generator also supplies power to operate the propellant transfer equipment.

22. TRAJECTORY SEQUENCE

The Redstone follows a modified ballistic path which is divided into four phases (fig 7).

a. Phase I. The first phase of operation is the power phase during which the rocket engine is operating. During the early portion of flight, control of the missile is accomplished by carbon jet vanes extending into the jet exhaust. Pitch programming begins to gradually incline the missile toward the target. Attitude and lateral control of the missile are exercised. Range information is used to determine the cutoff point. When the velocity and displacement of the missile are such that the missile will coast on to the target, the guidance system initiates action to turn off the propulsion system.

b. Phase II. Phase II is the period during which the missile settles to a free-flight condition. Then a signal from the programmer causes the thrust unit and missile body to separate. Separation is accomplished by exploding six bolts which hold the units together and by the expulsion cylinders (two airloaded pistons) which push the units apart.

c. Phase III. During phase III, the missile is coasting to the target. Only attitude control is maintained, but range and lateral errors are determined and will be corrected just before impact. Since the missile is now in an atmosphere so rare that little or no control forces can be created by the air vanes, air jet nozzles are used to maintain the proper attitude. These nozzles are mounted perpendicular to each air vane. Two or more are turned on as required to reorient the missile. The resulting force is like that of a rocket engine creating thrust in the opposite direction of the flow.

d. Phase IV (Terminal Guidance Phase). The last phase of the trajectory begins at what is called reentry, the point about 20 miles high where the missile meets enough air resistance to cause it to slow down. This air resistance causes a switch to operate which allows the range and lateral errors to be corrected.

Section IV. THE REDSTONE HANDLING EQUIPMENT

23. MISSILE TRANSPORTERS

The packaging and transportation equipment permits the missile and ground equipment to be moved by road, rail, water, and air. The missile is shipped from the production plant to the firing position in the same container and is checked out by the Redstone Group Ordnance Company without having to be completely removed from the container. The stabilized platform is packaged separately and is shipped by the manufacturer through the prescribed routes to the Redstone Group Ordnance Company. After conducting various tests, the Redstone Group Ordnance Company returns the stabilized platform to the package and sends it to the firing battery which has facilities for installation. The missile transporters include the--

a. Warhead Unit Semitrailer. The warhead unit semitrailer, a single-axle, 2-wheel, special vehicle, provides storage protection and transportation for the warhead unit and also provides space for carrying the van cover jacks and casters. In addition, all explosive items are carried in this container.

b. Guidance Unit Trailer. The guidance unit trailer, a single-axle, 2-wheel, special trailer, provides storage protection and transportation for the guidance unit.

c. Thrust Unit Semitrailer. The thrust unit semitrailer, a single-axle, 2-wheel, special semitrailer, provides storage, protection, and transportation for the thrust unit and storage and transport space for the van cover jacks and missile components which are installed at the firing position.

24. STABILIZED PLATFORM TRUCK

The stabilized platform truck, a $2\frac{1}{2}$-ton, 6 x 6, M35 vehicle, provides transportation for the stabilized platform in its controlled temperature container. When necessary to heat the container, direct current is furnished by the truck.

25. CHECKOUT AND FIRING EQUIPMENT

The checkout and firing equipment is designed for the performance of functional tests and inspections of the missile to the extent necessary to insure the success of the mission. Artillery troubleshooting is limited to items which can indicate defective components which are easily replaced. Typical items in this category are amplifier boxes, solenoid valves, and the stabilized platform. These and certain other replaceable missile and ground equipment components are stored in spare parts vehicles which accompany the firing battery. The checkout and firing equipment includes the--

a. Programmer Test Station. The programmer test truck ($2\frac{1}{2}$-ton, 6 x 6, shop van) accommodates a number of equipment racks and test panels for prefiring tests of the missile at the firing position and for performing periodic checks of missile components and systems maintained on a standby basis. This vehicle also serves as the center of the firing position communications. In addition, the programmer test station is used by the Redstone Group Ordnance Company along with other equipment that enables Ordnance to carry out more thorough checkout and troubleshooting procedures.

b. Power Distribution Station. The power distribution station (3/4-ton, 2-wheel trailer) provides a means of converting 208-volt, 3-phase, 60-cycle, alternating-current electrical power required from the generator trailer to 28-volt direct-current, 60-volt direct-current, and 400-cycle electrical power for use in other items of ground equipment and in the missile during checkout.

c. Generator Trailer. The generator trailer ($2\frac{1}{2}$-ton, 2-wheel) provides a base for mounting of the Cummins diesel generator and accessory equipment. The generator provides 120-volt, single-phase, and 208-volt, 3-phase, 60-cycle electrical power to the power distribution station for conversion to required voltage, phase, and cycles for use in missile checkout procedures.

d. Air Servicer. The air servicer is mounted on a modified trailer chassis. It stores high pressure air (5,000 psi) from the air compressor truck and supplies regulated air pressure to the missile for checkout and in-flight operations. The air servicer carries four air bottles which have a combined capacity of 10 cubic feet of air.

e. Liquid Nitrogen Trailer. The liquid nitrogen necessary for cooling the guidance compartment is transported from the engineer company to the firing batteries in trailer-mounted containers with a capacity of 150 gallons. Since liquid nitrogen has a very low boiling point (-320.4° F), these containers have a thermos bottle type construction similar to the liquid oxygen trailers. The transfer of liquid nitrogen is effected by pressurizing this container and forcing the liquid nitrogen through the transfer hose up to the heater-cooler drop tank.

26. ACCESSORIES TRANSPORTATION TRUCKS

Two accessories transportation trucks ($2\frac{1}{2}$-ton, 6 x 6) serve as the prime storage and transport vehicles for loose items of equipment and accessories necessary for missile checkout and servicing at the firing position.

27. AIR COMPRESSOR TRUCK

The air compressor truck ($2\frac{1}{2}$-ton, 6 x 6) serves as a base for mounting the air compressor, regulating system, and accessory equipment. The compressor provides compressed air at a specified dewpoint to the missile for testing and pressurizing before firing.

28. FIRE TRUCK

The fire truck is used for emergency fire fighting. It provides a means of diluting or flushing away propellant spillage. This truck has an integral water tank storage capacity of 1,000 gallons and a pumping capacity of 1,500 gallons per minute (par 29). The fire truck is also the prime mover for the water tank trailer.

29. WATER TANK TRAILER

The water tank trailer (4-wheel) furnishes 2,000 gallons of reserve water to the fire truck. The fire truck supply together with that of the trailer permits pumping at maximum capacity for 2 minutes.

30. ERECTOR-SERVICER

The erector-servicer truck (fig 9) is a $2\frac{1}{2}$-ton, 6 x 6 truck which houses a 10-ton winch and a 1-ton electric hoist. In addition to the truck, the erector-servicer consists of an H-frame, H-frame spreader bars, jack-type support stands, an A-frame, a hydraulic cart with arresting cylinders, a winch, and erecting cables with associated pulleys and blocks. All of this equipment can be compactly stowed or mounted on the truck. This arrangement provides mobility, speed, and space and weight requirements for shipping as well as maneuverability in a tactical area. The purpose of the H-frame is to prevent the movement of the truck with respect to the launcher during assembly and erection of the missile. After the missile is erected, the H-frame is also used as a boom for positioning and supporting the service platform. The A-frame is employed as a boom for lifting and positioning the guidance unit to the warhead unit, for lifting and positioning the rotating frame assembly to the thrust unit, and for lifting and suspending the thrust unit for mating to the missile body. A rotating frame assembly is secured to the rear of the thrust unit and attached to the launcher. The rotating frame assembly serves as a hinge during missile erection. When the missile is prepared for erection, the A-frame, with the cables attached, is approximately vertical (fig 9). Winch power is then applied to the A-frame which erects the missile by functioning as a lever arm for the erection force transferred through the cables. The A-frame pivots on the launcher in the direction of the truck and raises the missile, and, when the A-frame is almost horizontal, the missile is erected. After the missile is erected, rollers on the rotating frame assembly permit rotation of the missile on the launcher to the correct firing azimuth.

31. LAUNCHER

The launcher, consisting of a base, deflector plate, and rotating frame assembly, is mounted at the outrigger support arms to a removable single axle. This arrangement provides mobile capability to the launcher base when the unit is towed behind the truck and furnishes a means for quickly disconnecting the wheel and axle assembly, when the launcher is emplaced at the firing position.

32. PROPELLANT VEHICLES

Propellant handling and transportation equipment has been designed and selected for long distance road travel and limited cross-country movement. The transfer equipment fills the missile tanks rapidly and conveniently. The regular electrical power source at the firing position is used to drive the propellant pumps. The propellants are alcohol, liquid oxygen, and hydrogen peroxide. The liquid oxygen is pumped from the generating plant, where it is produced, directly into the trailers which deliver it to the firing position, whereas the hydrogen peroxide is carried in the original container supplied by the manufacturer. The alcohol is normally shipped to Ordnance in 55-gallon drums; and, from the drums, it it transferred to a trailer in which the alcohol is mixed with water. The propellant vehicles include the--

a. Alcohol Tank Semitrailer. The alcohol tank semitrailer (2-wheel, 3, 000-gallon tank) provides storage, transport, and pumping facility for the 75 percent alcohol, 25 percent water fuel mixture. The fuel transfer equipment is mounted in a closed compartment at the rear of the trailer and provides means of metering, filtering, heating, and transferring the fuel to the missile at the firing position.

b. Liquid Oxygen Semitrailers. Two LOX semitrailers (2-wheel, 9-ton, tank, special) provide storage, transport, and pumping facilities for the LOX. This LOX transfer equipment is mounted in a closed compartment at the rear of each trailer. Initial filling of the missile tank at the firing position and final filling to replenish evaporation losses is accomplished from one of the LOX semitrailers.

c. Hydrogen Peroxide Servicer. The hydrogen peroxide servicer (a modified army 3/4-ton, 4 x 4 truck) provides transport and a means of handling the 86-gallon drum of concentrated hydrogen peroxide and maintaining it at a temperature of 75° F $\pm$ 10° F by using the heating and cooling kits included with the truck. The pumping equipment when connected to the alternating-current power source is used to transfer the hydrogen peroxide to the missile at the firing position.

Section V. PROPELLANT SUPPLY AND HANDING

33. GENERAL

a. Loading. Because of the size of the missile, the propellant weights, and structural considerations, the Redstone must be loaded with propellants only while in the vertical position. Normally, only one propellant at a time is pumped into the missile. The propellants are loaded in this sequence: alcohol, liquid oxygen, and hydrogen peroxide. Tests have demonstrated the feasibility of simultaneous loading of two propellants. When sufficient experience has been accumulated, simultaneous loading can probably be adoped as a standard procedure, thus reducing the total missile preparation time appreciably. All missile filling

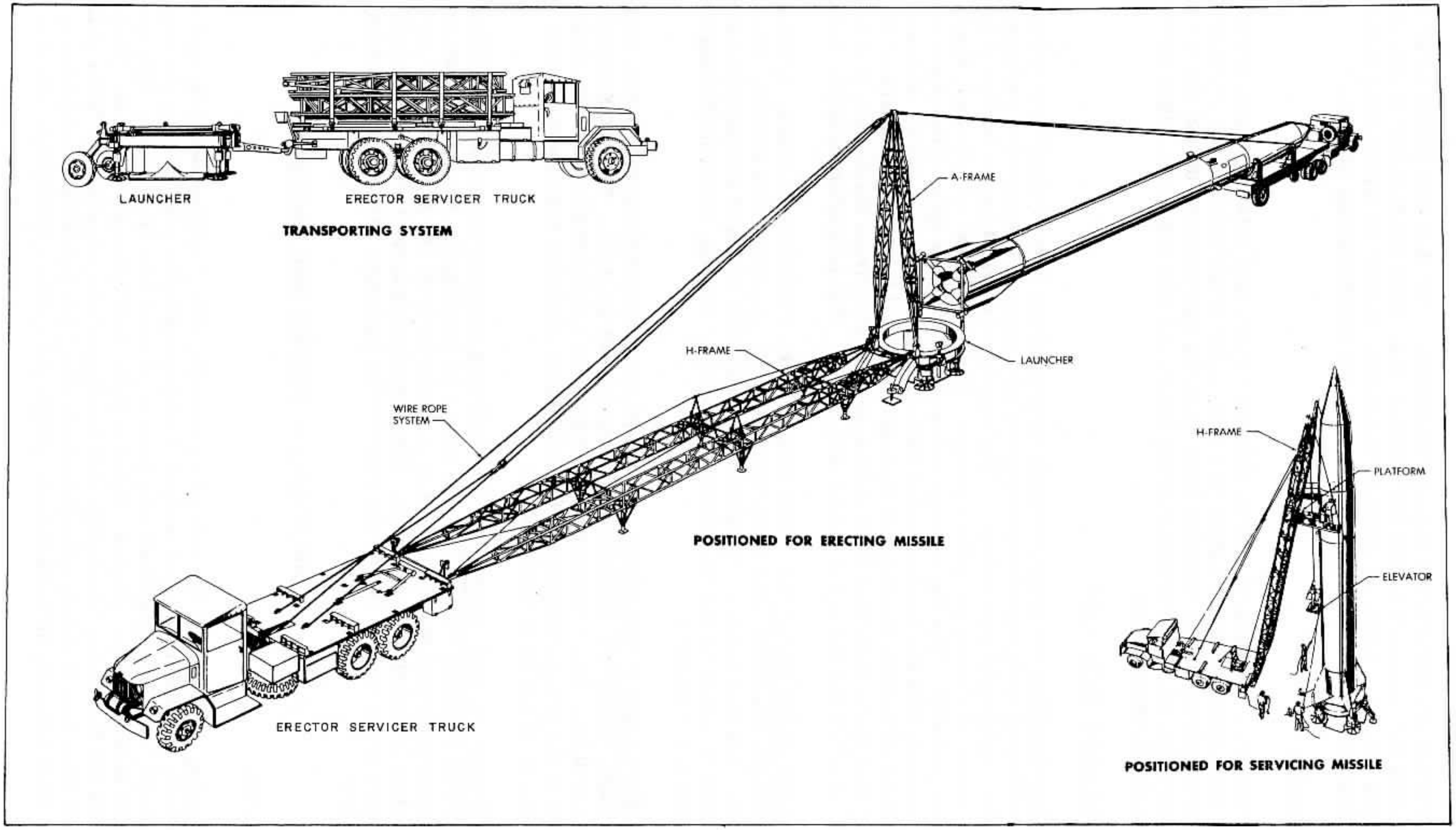

Figure 9. Erector servicer truck.

connections are located on one quadrant of the missile circumference and are at approximately the same level above the ground. In order to provide accessibility to these connections, a lightweight propellant loading ladder with a platform for the operator is provided (fig 10). This ladder, with the vertical standpipes for the oxygen and alcohol build into it, connects to the vehicle hose on the lower end and to short hoses to the missile filler valves on the upper end.

b. Draining. If the missile must be taken down after having been loaded with propellants, the alcohol is drained back into its transporter. Liquid oxygen is also salvaged. If the saving of time is a critical element, the oxygen may be dumped on the ground. The draining of the propellants requires approximately one-half hour for each propellant. Hydrogen peroxide is drained back into its drum, but, owing to the possibility of contamination during the handling process, it should be discarded by dumping in a ditch or other out-of-the-way place and then diluting it with water. The hydrogen peroxide should not be kept for reuse since a slight contamination makes the concentration extremely dangerous.

34. ALCOHOL

a. Logistics. Since adequate facilities for alcohol manufacturing are in existance and alcohol is a readily storable item, no special problems are involved in shipment and storage. The normal method for shipment is in ordinary 55-gallon drums. Alcohol stored in drums can be transported overseas in regular cargo ships. Rail or cargo trucks are used to forward it to the ammunition supply point. The concentration of alcohol shipped in the drum is the highest normally available, 95 percent by volume, although the missile only requires a 75 percent (by weight) mixture. The Ordnance Company has 3, 000-gallon, alcohol tank semi-trailers which are used to prepare and store the proper mixture until needed. The pumping equipment (fig 10) installed in the trailer is capable of siphoning the alcohol from the supply drums. As the alcohol is transferred, it is metered by the trailer equipment. As soon as the proper quantity of alcohol has been loaded, water is added for dilution to the proper concentration. The trailer pump is used to circulate the alcohol and water unitl it is thoroughly mixed. The mixture is then sampled with a hydrometer to determine the concentration, and any necessary small adjustments are made by adding either water or alcohol, as required. When the firing battery requires more alcohol, the semitrailers are sent to the ammunition supply point (ASP), and the alcohol is transferred from the Ordnance trailers into those of the firing battery.

b. Loading. At the firing position, the procedures for alcohol handling are relatively simple. For each fire mission, approximately 19, 000 pounds of alcohol are used; however, since the volume of alcohol varies over a wide range of temperature, its specific gravity changes. Using the temperature of the alcohol (obtained from a thermometer in the pumping compartment of the alcohol trailer) and the percent mixture of the alcohol water solution (furnished by the ordnance direct support unit) as entries to the Alc-O-Lator (a circular slide rule), firing battery personnel determine the specific gravity of the alcohol. These data are then used to convert the weight of the alcohol from pounds to gallons, since the metering device on the alcohol trailer is calibrated in gallons. The computations for the conversion are made with the Alc-O-Lator. Finally, the meter on the trailer is preset to the specified number of gallons that corresponds to the weight in pounds. The trailer delivery hose is connected to the fitting on the lower end of the propellant loading ladder. A short line is connected between the ladder top and the missile filler valve. The trailer is connected to a source of 208 volts electrical power through the alternating-current distribution box, and the trailer and missile are connected by a ground wire. The pump is switched on, and the missile filling commences. After the proper quantity has been pumped in the missile, the meter cuts off the flow and stops the pump. Residual quantities of liquid in the hose are drained by using the suction system in the trailer after the missile fill valve has been disconnected.

c. Preheating. Variations in the density of the alcohol will affect the performance of the missile propulsion system by shifting the mixture ratio from the ideal figure of 1.35 pounds of oxidizer for each pound of fuel. Since the density of the alcohol is inversely proportional to the temperature, a mixture ratio control valve is used to insure that the correct amount of alcohol is delivered to the combustion chamber regardless of temperature. This valve controls the opening of a variable orifice in the alcohol feed line and is manually set based on the temperature of the alcohol (fig 5). Preheating the alcohol normally is not necessary although each engine does have a minimum alcohol temperature limit based on range and specific impulse. Electrical heaters are furnished on the trailer if preheating is necessary. If, in the case of long standby of the missile after alcohol loading, reheating is needed, the alcohol must be drained back into the trailer.

d. Safety. Although alcohol is not a particular hazardous liquid to handle, fire precautions should be taken and accidental spillages should be diluted with water. Safety precautions similar to those observed in gasoline handling should be followed.

35. LIQUID OXYGEN

a. Losses. Liquid oxygen cannot be stored economically for extended periods because its normal boiling point under standard atmospheric pressure is -297° F. This means that the liquid oxygen must be produced in the Army area and that the vessels and transport vehicles which will contain the liquid must be insulated to prevent excessive losses. The two 9-ton transporters with each firing battery provide a total of 36,000 pounds of liquid oxygen; of this, approximately 25,000 pounds is the nominal missile capacity. The remainder of approximately 11,000 pounds is used to cool down the missile tank and to supply additional liquid for replenishing during final missile preparation or standby. Depending on wind and weather, the reserve could cover periods between oxygen filling and actual firing of from 2 to 6 hours. Losses occur in the following magnitudes:

(1) When stored in the transport trailers, approximately 1 percent evaporates per 24 hours while standing and 2 to 3 percent evaporates per 24 hours while traveling.

(2) During transfer, approximately 2.5 tons are required to cool down the missile tank, transfer lines, pumps, etc.

(3) During standby while the missile is loaded, approximately 30 pounds per minute are lost from the missile tank, dependent on environmental conditions.

b. Production. The supply and field production of liquid oxygen is the responsibility of the Engineer Company organic to the Redstone Group. The general scheme of production consists of compression of air, cooling it by refrigeration, and then passing it to an expander valve where it is cooled to liquefaction temperatures by expansion. The liquid air is then passed to a rectification column where separation of the oxygen and nitrogen takes place by fractional distillation.

c. Liquid Oxygen Semitrailer. For transportation of the liquid oxygen between the production plant and the firing position, a 9-ton capacity semitrailer is used. This unit was developed by the Corps of Engineers for this purpose. It includes a vacuum insulated container, a transfer system with an electrically driver pump, and other accessories. In order to prevent pump cavitation, the liquid container must be pressurized. This is done by allowing some liquid oxygen to flow into a finned tube coil exposed to the atmosphere, where the liquid evaporates. The resulting gas is fed back into the tank vapor space until the required pressure is reached. An automatic valve is also in the system to permit the pressurization to be remotely controlled for replenishing the missile tanks from the remote firing panel.

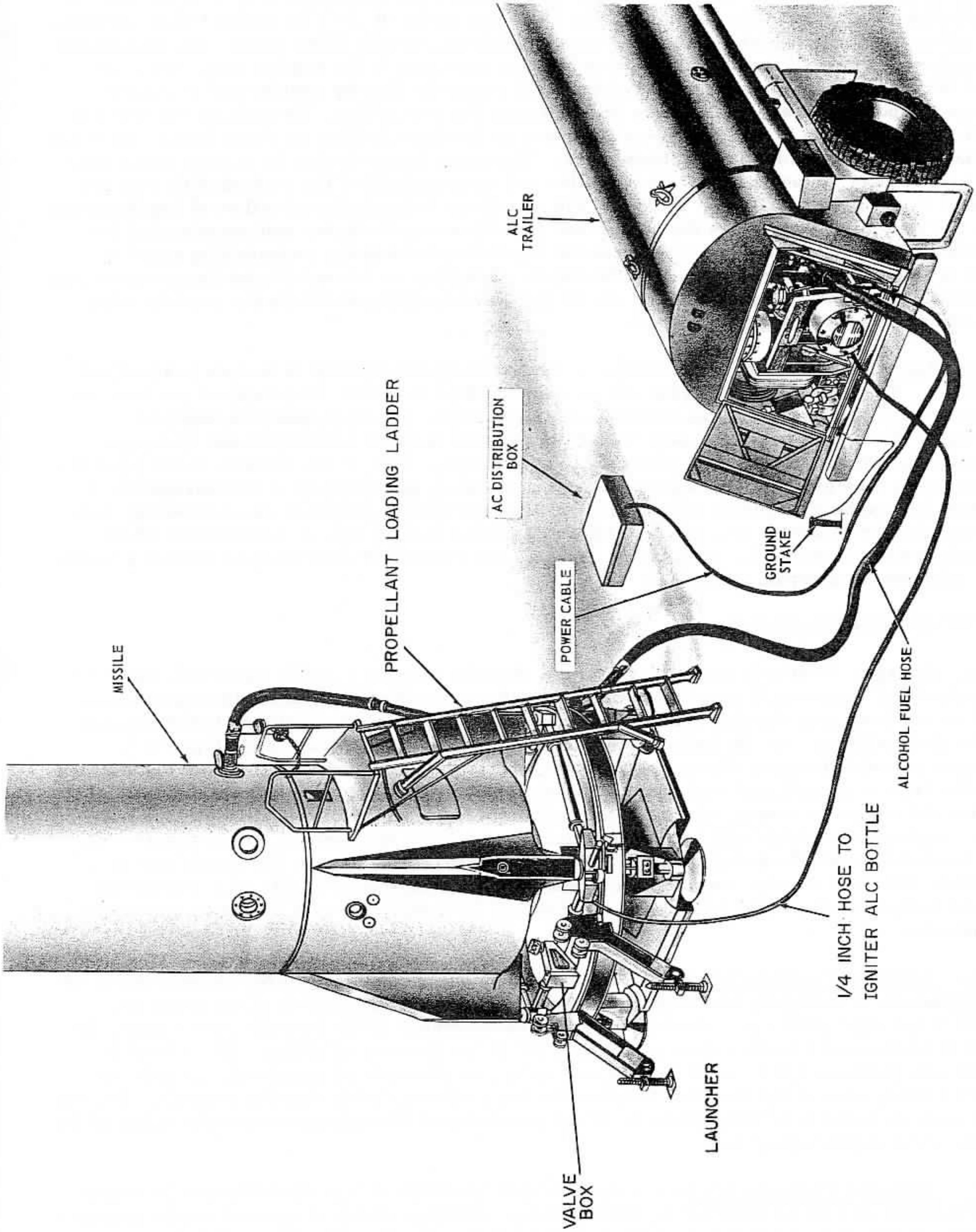

Figure 10. Alcohol loading.

d. Loading. At the firing position, the two trailers are connected to a Y-connection by metallic hoses supplied with the vehicle (fig 11). The outlet of the Y is connected to the loading ladder standpipe, which is, in turn, connected to the missile filler valve. As soon as the connections are made, the operator starts building pressure in the trailer tank. He also opens the tank discharge valve to allow the liquid oxygen to flow by gravity and pressure through the pump, hoses, and missile to commence the precooling. As soon as the precooling of lines and pump is well along, as indicated by the frost buildup on these items, the pump is started and the liquid transfer takes place. The pump in one trailer is started a few minutes earlier than the pump in the other trailer to insure that all of the replenishing reserve remains in one of the trailers. Filling of the missile is indicated by overflow of liquid oxygen from the vent pipe, whereupon the pumps are shut down and the hoses and accessories are removed. The trailer containing the reserve liquid is moved to the replenishing position, which is near the compressor truck. The replenishing line is connected and the pressure control line is installed. From this time on, oxygen can be replenished into the missile when required during the firing procedures.

e. Safety. Handling of liquid oxygen produces no undue hazards if certain precautions are taken. The vapors are nontoxic and noncombustible; however, they support combustion of a wide variety of materials at an extremely rapid rate. It is necessary to ventilate thoroughly clothing of personnel who have been exposed to large concentrations of oxygen gas before allowing smoking and contact with open flame. Five to ten minutes in the open air will serve to dissipate any gases permeating the clothing, particularly if the dissipation is assisted by brushing. Contact of the liquid with exposed flesh produces rapid freezing, and injuries similar to a burn will result. Asbestos gloves and goggles or a face mask should be worn by the personnel handling liquid oxygen. All equipment used must be free of grease, oils, solvents, and organic material.

36. HYDROGEN PEROXIDE

a. Storage. Hydrogen peroxide (H_2O_2) in the pure form is a stable chemical, but contamination can cause rapid decomposition. To reduce the possibility of contamination which could result from transferring the liquid it is shipped from the manufacturer to the missile in a single container. An 86-gallon aluminum drum is used for storage and shipment of hydrogen peroxide because this capacity is enough for one missile filling. The drum features a double head with a fill and vent opening. The design chosen has received the approval of government agencies responsible for road, rail, and overseas shipment of hazardous materials. Hydrogen peroxide will be received and stored at the ammunition supply point. The drums should not be stacked and should be spaced to allow easy access for inspection or removal. Periodic checks must be made, and any drum showing a steady increase above ambient temperature should be isolated and handled in accordance with the pertinent safety regulations.

b. Hydrogen Peroxide Servicer. The hydrogen peroxide drum will be transported to the firing position in a slightly modified 3/4-ton cargo truck (fig 12) capable of carrying two drums of hydrogen peroxide. To insure proper performance of the missile power plant, the peroxide must be at a temperature of 75° F $\pm$ 10° F, at the time of filling. The peroxide vehicle has provisions for either heating or cooling the peroxide as required. Locally installed heating pads in the missile maintain the temperature during standby periods. Cooling in the missile is not a problem because of the proximity of the hydrogen peroxide tank and the bottom of the liquid oxygen tank.

c. Hydrogen Peroxide Loading. The hydrogen peroxide is transferred from the drums to the missile tank by an electrically driven pump. Filling control is carried out by an overflow device with the overflow going into a container; the overflow should be diluted with water and dumped.

d. Safety. Personnel handling hydrogen peroxide are required to wear protective clothing consisting of boots, flame proof coveralls, face shield, and gloves. Like any high energy material, hydrogen peroxide requires careful handling. Given this care, it can be safely used. Cleanliness of equipment is the key to proper handling. Materials in direct contact with hydrogen peroxide require proper passivation.

37. INERT LEAD START

In temperatures above 35° F, water is used as the inert lead start. Below 35° F, a lithium chloride and water solution is used similar to antifreeze solution used in the cooling system of an automobile (lithium chloride freezes at -105° F). The purpose of the inert lead start is to insure a smooth buildup of thrust between ignition and mainstage. It is transported in a 20-gallon tank contained within the pumping compartment of the alcohol tank semitrailer. A motor-driven pump with hose attachments feeds the inert lead start into the regenerative jacket and manifold of the rocket engine.

38. LIQUID NITROGEN (LN_2)

a. Description. Liquid nitrogen (LN_2) is a byproduct in the manufacture of liquid oxygen. To all outward appearances, LN_2 physically resembles LOX; and, for this reason, in addition to its primary purpose of instrument compartment cooling, it is often used in training as a LOX substitute. The temperature at which LN_2 boils is -320° F. It will not support combustion.

b. LN_2 Trailer. To facilitate transportation of the LN_2, each firing battery has two small trailers. Mounted on each trailer is a small (150-gallon) insulated tank. Appropriate controls to transfer the LN_2 are located in an enclosed compartment at the rear of the trailer.

c. LN_2 Uses. One of the two uses of LN_2 is as a coolant in the missile temperature control system (par 20). Another use is as a coolant to help maintain the hydrogen peroxide at the proper temperature while stored on the hydrogen peroxide servicer (par 36b).

d. Safety. Personnel handling liquid nitrogen are required to wear face shields and asbestos gloves.

Section VI. THE REDSTONE TRAINER

39. GENERAL DESCRIPTION

The Redstone trainer (fig 13) provides realistic training of missile-firing battery personnel and includes means for testing their proficiency. The use of a tactical missile is not required. The five major components which comprise the trainer (training missile, trainer test station, two junction boxes, and dummy load box) are used in conjunction with the Redstone checkout equipment, and all of the Redstone missile handling, servicing, and launching equipment can be used with the training missile.

40. OPERATION

a. Simulation. In operation, command signals from the Redstone checkout equipment are intercepted in the two trainer junction boxes and sent to the trainer test station, where simulation signals are produced. The simulation signals are substituted for the output signals normally provided by the missile and sent to the checkout equipment in the programmer test station truck through the junction boxes. Missile operations are simulated fully by these

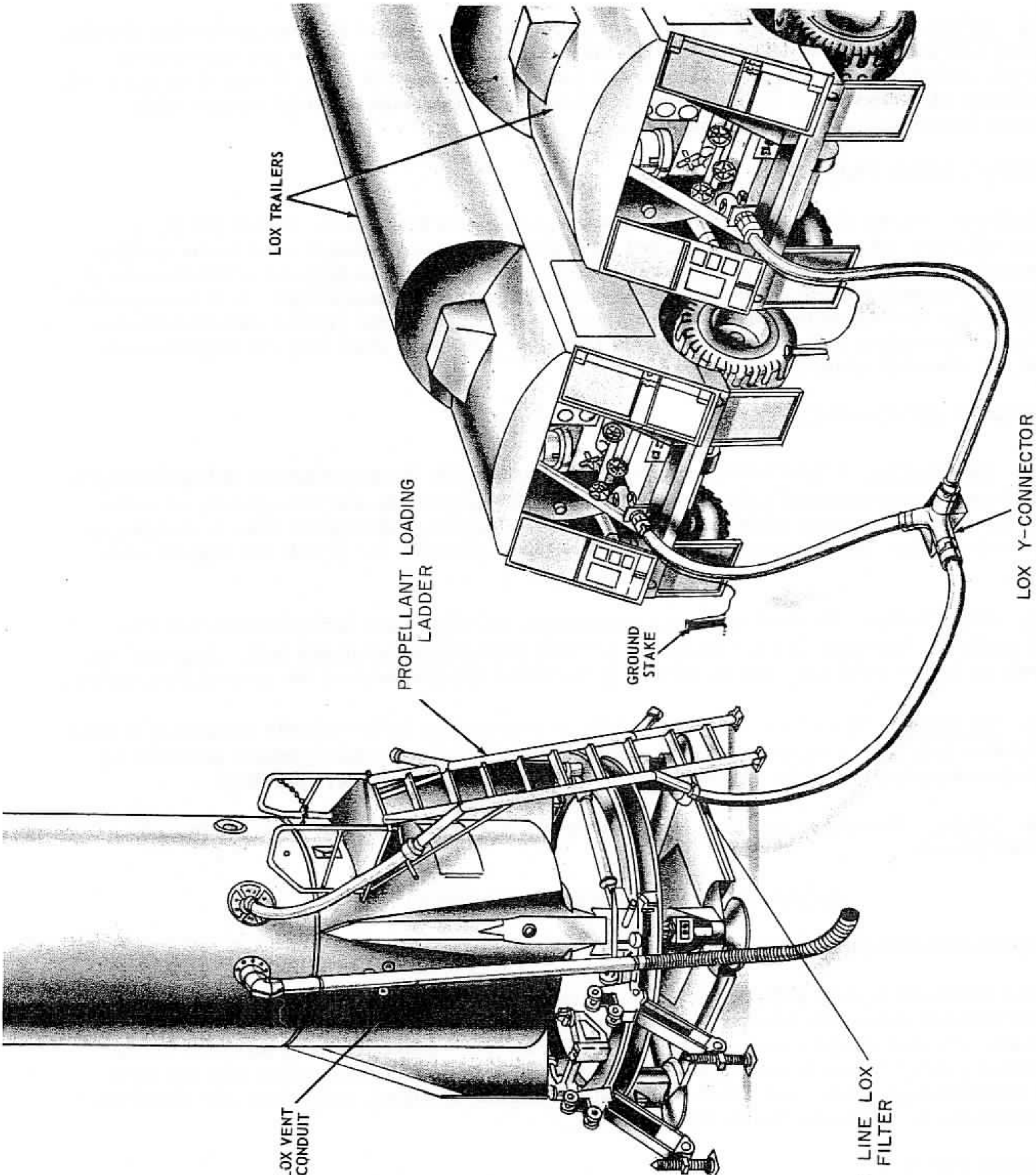

Figure 11. Liquid oxygen loading.

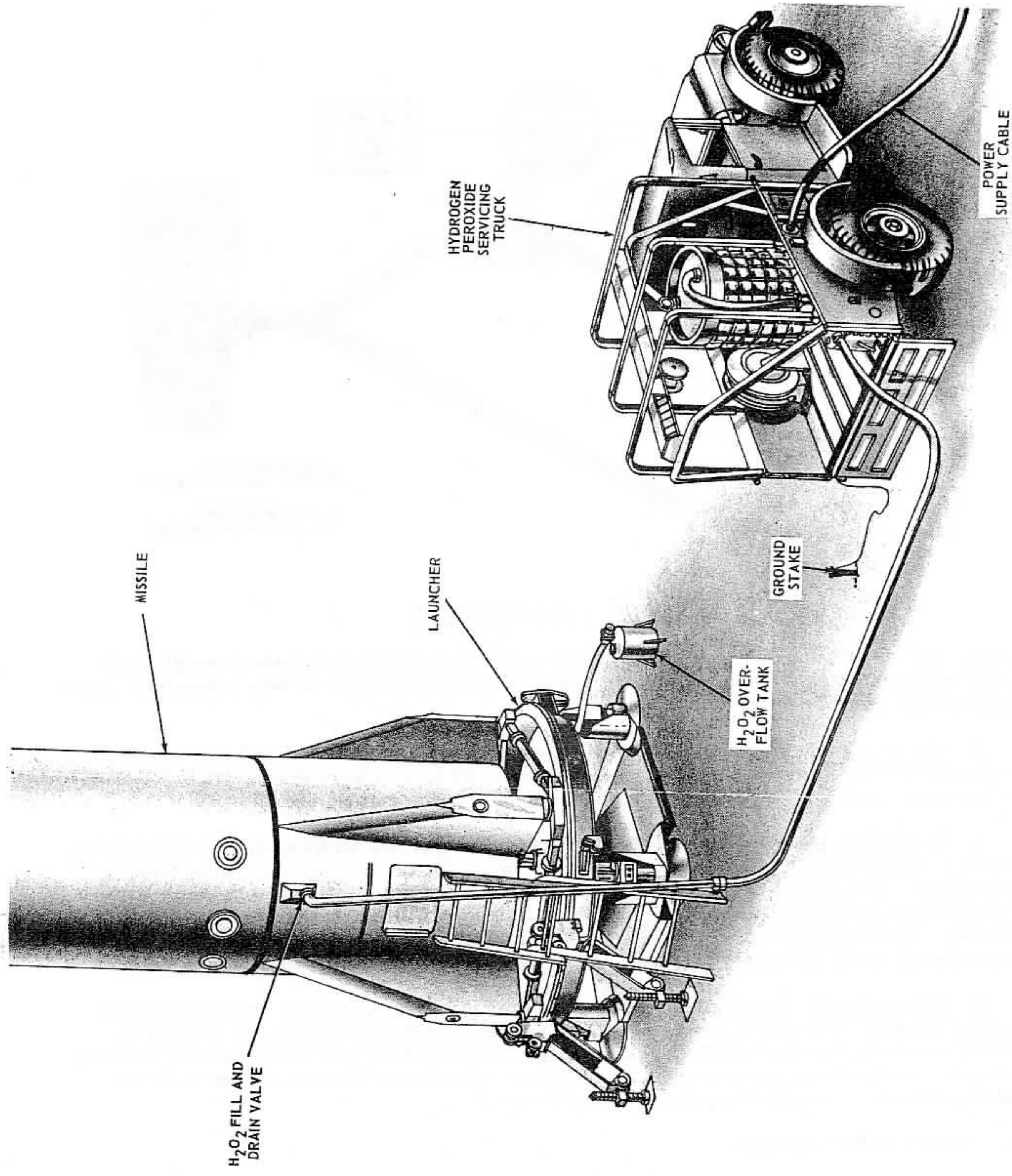

Figure 12. Hydrogen peroxide loading.

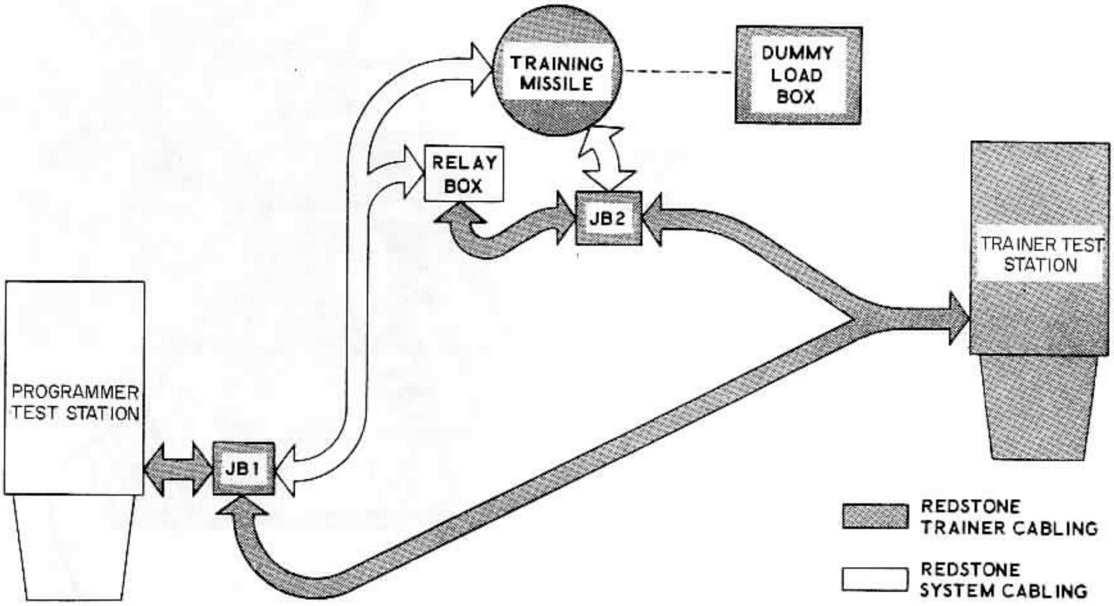

Figure 13. Redstone trainer.

means, and, in addition, simulation equipment in the training missile presents audible and visual representation of the operation of various missile components as they respond to command signals from the programmer test station.

b. Malfunctions. The trainer also provides simulation of indication and traceable malfunctions. These two types of malfunctions are initiated by operation of controls in the trainer test station and provide training in the detection and tracing of equipment malfunction.

c. Recording. A complete record of the operations performed by members of the firing battery is furnished by the automatic printer and the magnetic tape recorder in the trainer test station. The automatic printer records the use of all controls operated by firing battery personnel and the elapsed time during an operation, as well as out-of-sequence use of such controls. The magnetic tape recorder system employs handy-talkie radios (supplied with the trainer) and permits the recording of all conversations that occur during a training exercise.

d. Dummy Load. The dummy load box provides the same electrical responses as the training missile. Therefore, it can be substituted for the training missile for training in missile checkout, and the training missile can be used elsewhere for other phases of training (i. e., missile handling, erection, etc.). A dummy relay box is supplied for use with the training missile during handling and erection practice.

41. THE TRAINING MISSILE

The external appearance of the training missile, including movable air rudders and air vanes, closely resembles that of the tactical missile. Most of the interior details are duplicated, using inoperative or dummy components where operative components are not required for simulation purposes. Like the tactical missile, the training missile is constructed of three units (warhead, guidance, and thrust). The bolts by which the units are attached to each other are similar to the actual components. To provide training in missile assembly, the missile body unit and thrust unit can be separated from each other, and the missile body can be separated into the warhead and guidance units. Ballast has been built into the training missile to make its centers of gravity coincide with those of the tactical missile. With these structural characteristics, the training missile can be handled in the same manner as the tactical missile. All external propellant loading and pneumatic connections are duplicated on the training missile. Some of these connections are operative and other are dummies, but all are capable of receiving the connectors used to service the actual missile. Other components and systems duplicated on the training missile include all of the electrical tail plugs, all lifting and handling hardware, the intercommunication facilities, and many of the test outlets used during launching preparations. In addition, provisions exist for introducing traceable malfunctions into the equipment.

Section VII. MISSILE PREPARATION AND FIRING

42. GENERAL

This section contains a general discussion of the firing area operations in the typical sequence. Tactical considerations may dictate other sequences. After the launcher position is selected, the other equipment is located in positions near the launcher generally dictated by the lengths of cables and hoses. Generally, one side of the area is free of equipment so that the propellant servicing equipment may be readily brought into position to load the missile as rapidly as possible.

43. OCCUPATION OF POSITION

a. Launcher. A centerline is established by using a light rope for the intended position of the erector-servicer and missile unit trailers. This is done to facilitate missile assembly. The line is laid to cross the center of the launcher position stake. The erector-servicer truck tows the launcher into the firing position (fig 14). The launcher is emplaced directly over the stake so that the erector-servicer can be assembled easily without encountering alinement problems between the launcher and truck. The wheel and axle assembly is removed from the launcher. The support pads are seated, and jacks in the launcher legs are used to level the launcher. Three additional stabilizing pads are emplaced.

b. Erector-Servicer. The hydraulic cart, arresting cylinders, A-frame cables, hoists, and other equipment are unloaded near the launcher. The erector-servicer truck is then positioned on the opposite side of the launcher. The H-frame sections are unloaded, connected to the launcher, and assembled. The truck is driven forward along the centerline to the proper position so that the assembled H-frame can be fastened to the rear end of the truck. Prior to H-frame assembly, the A-frame and cabling systems are assembled.

c. Power Equipment. The generators and power distribution station are usually emplaced in one area ahead of the erector-servicer truck. The generators and power distribution station are required for missile firing; so the power equipment should be as far from the launcher as cable lengths permit (about 200 feet).

d. Air Equipment. The air compressor and air servicer are emplaced near each other and connected by a short length of air hose. The air servicer is connected to the valve box by 200 feet of air hose. The air servicer must remain in the firing position for missile pressurization.

e. Programmer Test Station (Fig 14). The programmer test station is emplaced near the launcher. The programmer test station is not required to fire the missile. Complete control of the missile is transferred to a remote firing panel after the missile is ready for firing. The programmer test station is then removed.

44. MISSILE ASSEMBLY

The missile unit trailer covers are removed by releasing the covers and raising them a few inches by using the jacks located at each corner of the trailers. The units are exposed for assembly when the trailers are pulled out from under the covers. The guidance unit is picked up from its trailer by two manually operated hoists which hang from the A-frame (fig 15). The trailer is then removed. The warhead unit is then backed into position to permit joining the warhead and guidance units to form the missile body. The hoists are released, and the missile body resting on the warhead trailer is pulled away from the immediate area. The thrust unit is then backed into position, and the launcher rotating frame assembly is attached to the thrust unit by the use of the hoists. The thrust unit is then picked up from its trailer by using the hoists, and the trailer is removed (fig 16). The missile body is then backed into position; the hoists are used to rotate or change the position of the thrust unit, and the missile body and thrust unit are joined with the explosive bolts. The tail of the assembled missile is hinged to the launcher with the warhead unit resting in the warhead trailer.

45. HORIZONTAL CHECKOUT

By the time missile assembly is complete, the electrical cables and air lines are laid out and connected. The compressor and generators are started. The missile is then given a horizontal checkout to insure proper operation of the guidance and propulsion systems. Upon completion of horizontal checkout, some of the cables connected to the missile are removed. Missile components are inspected for proper mounting. The compartment doors are closed, and the instrument compartment is leak tested. During flight, the instrument compartment is slightly pressurized to help prevent electric arcing in the near-vacuum trajectory. The drop tank is installed.

46. ERECTION

The 10-ton winch on the erector-servicer truck is used to pull the erector cables (fig 14). A cable leads from the winch to the A-frame. Two cables lead from the A-frame to the missile body. The rotating frame assembly attached to the rear end of the missile is mounted on its pivots after missile assembly. When the winch operates, the A-frame rotates on pivots on the launcher. The cables to the missile body lift the missile nose; the rear end of the missile rotates about the pivots on the launcher. Just before the missile center of gravity shifts past the pivots, the hydraulic arresting cylinder yokes engage the rotating frame assembly. When the missile weight shifts from one side of the pivots to the other, the arresting cylinders allow the missile to slowly rotate to the vertical position. The erection cabling is removed, and the rotating frame assembly is released from its pivots to permit rotation of the missile to the proper firing azimuth. The H-frame (fig 14) is positioned nearly vertical to form a servicing platform and elevator. The elevator, operated by an electrical hoist, is used to replace guidance system components in the event of malfunctions.

47. INITIAL LAYING

Two theodolites are used to lay the missile--one theodolite on the orienting line and the other sighted on a prism mounted on the missile.

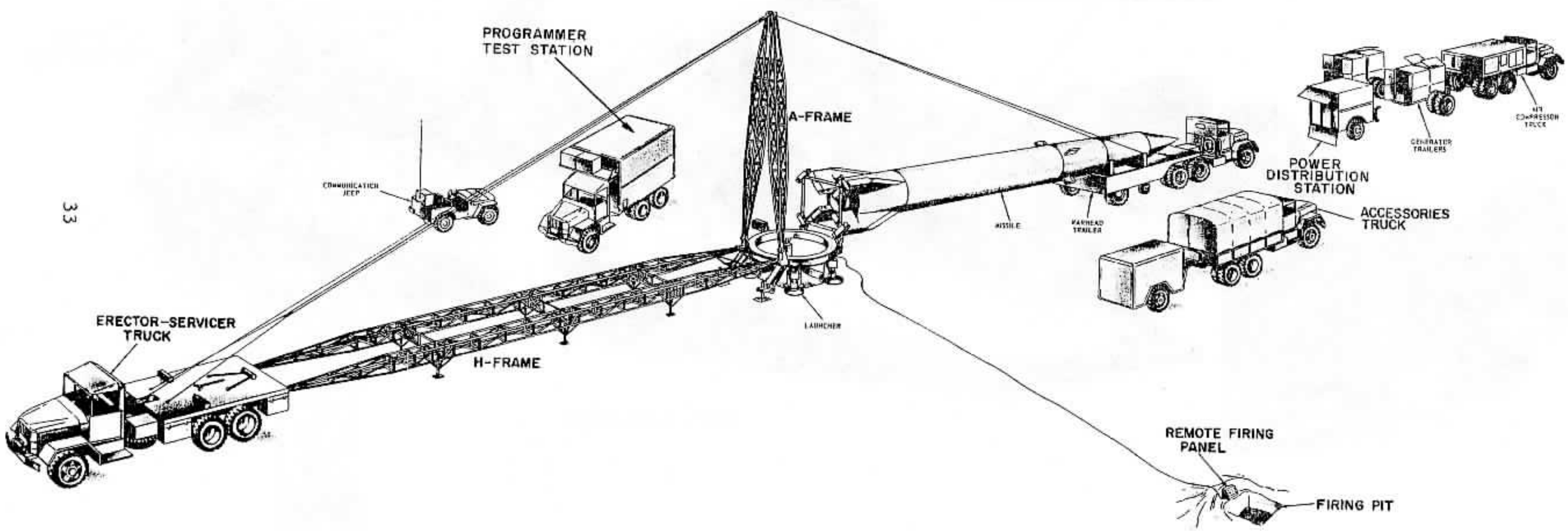

Figure 14. Firing position.

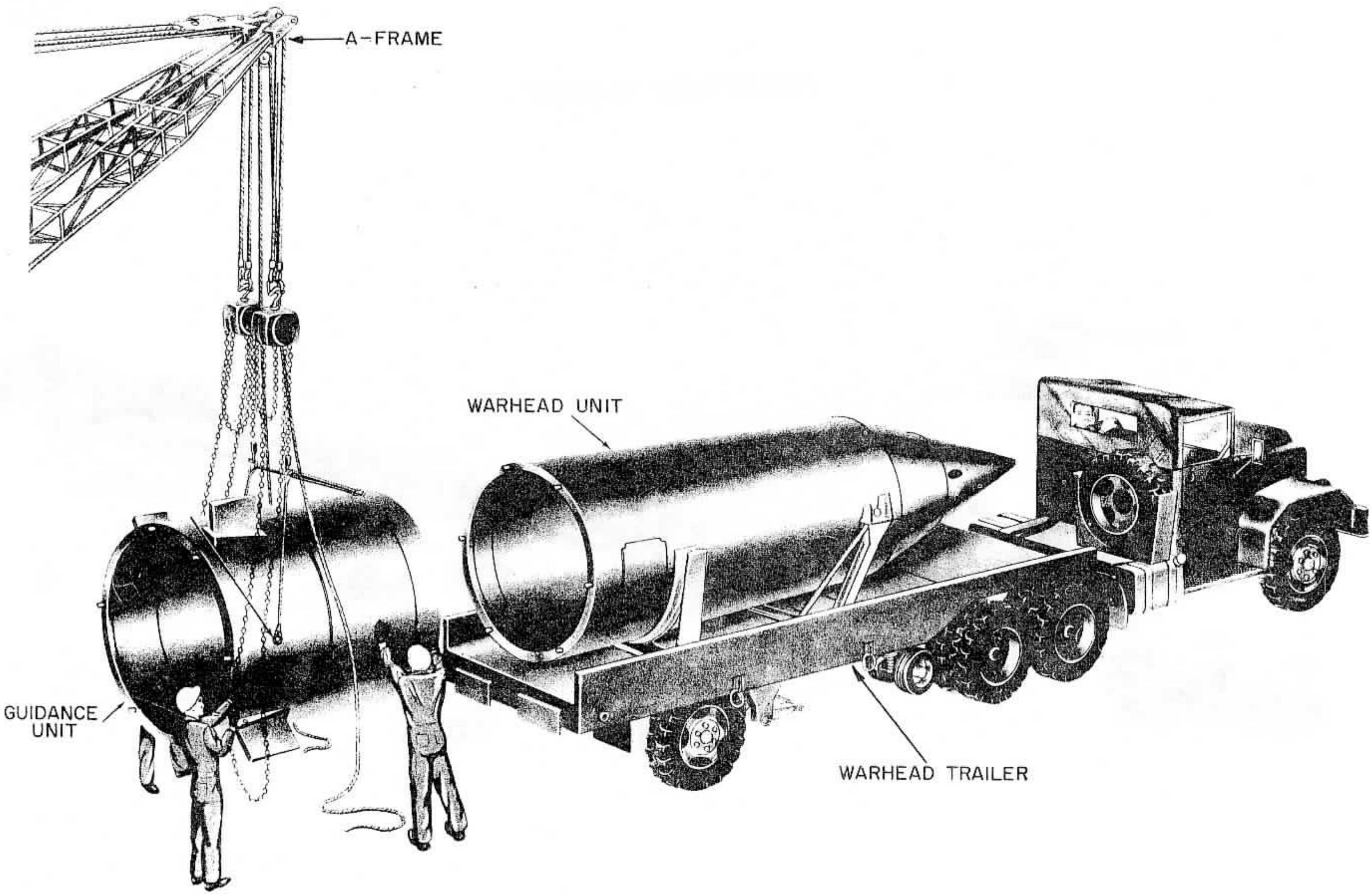

Figure 15. Attaching guidance unit to warhead unit.

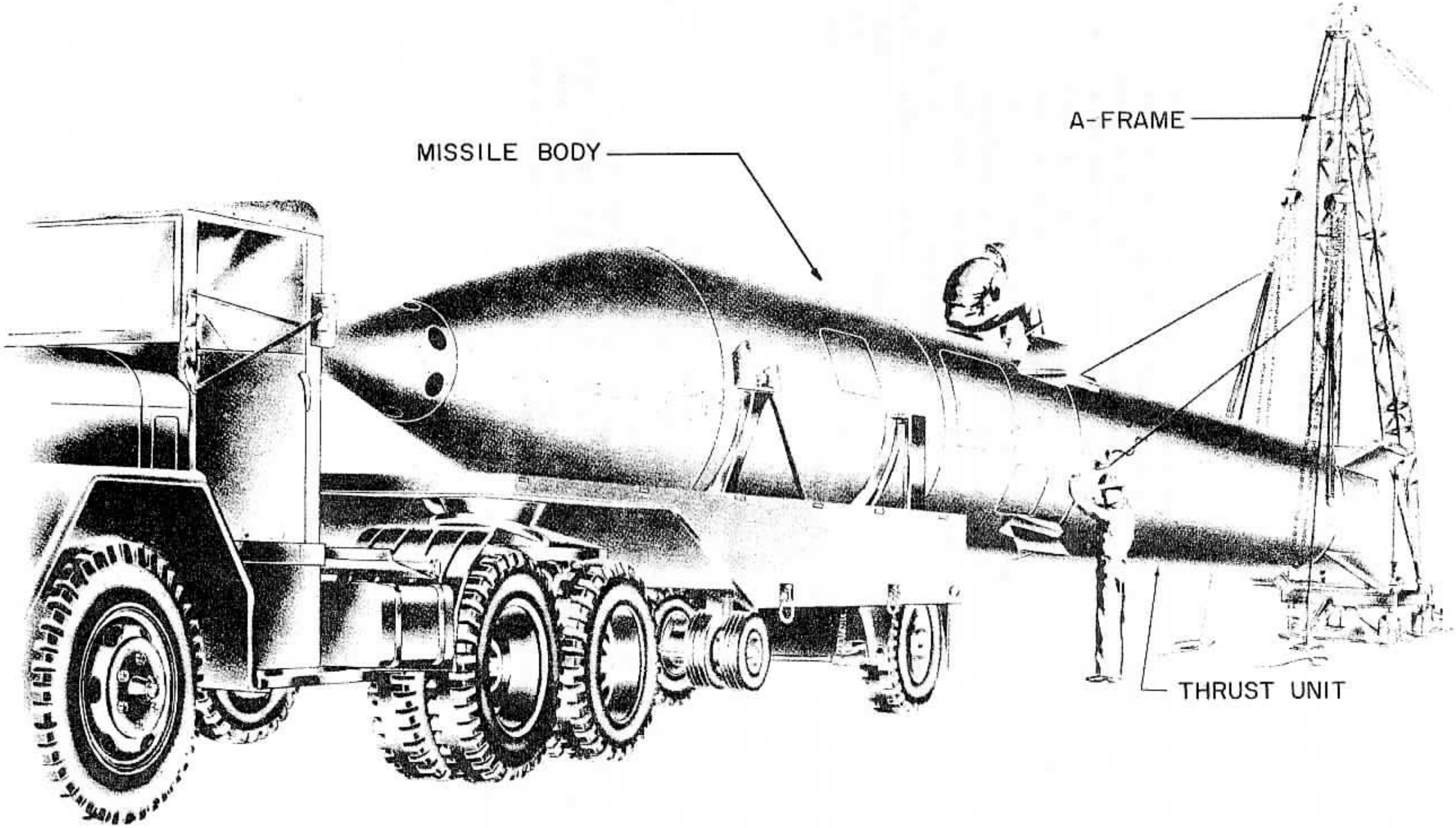

Figure 16. Attaching thrust unit to missile body.

48. VERTICAL CHECKOUT

The power cables are connected for vertical checkout. The carbon jet vanes and air rudders are installed. A vertical checkout consisting mainly of power tests and stabilized platform tests are conducted. The fire mission data are inserted into the computers and programmer.

49. PROPELLANT LOADING

Propellant loading is conducted concurrently with vertical checkout. However, the LOX overflow pipe, LOX replenishing pipe, and propellant loading ladder are installed as soon as the missile is initially laid. The hoses from the top of the ladder are connected to the missile fill valves. The alcohol is loaded first; the proper quantity in gallons is preset on a flow meter, located in the alcohol semitrailer, and the pump is started. The flow meter turns off the pump when the preset quantity has been transferred. The alcohol equipment is then removed from the area. Liquid oxygen is loaded from two 9-ton semitrailers. The proper quantity of LOX has been transferred when overflow occurs from a standpipe within the LOX tank. The standpipe is set at the proper level by a height adjustment mechanism. Liquid oxygen density is mainly a function of pressure so the standpipe is set to compensate for the nominal atmospheric pressure at the firing position altitude. After the liquid oxygen is transferred, one liquid oxygen semitrailer is positioned for replenishing which will occur at X-5 minutes. Hydrogen peroxide is pumped from the 86-gallon drum on the truck until overflow occurs from the hydrogen peroxide tank in the missile. No adjustments of quantity are required.

50. FINAL PREPARATION FOR FIRING

The missile is given a final laying to insure that it has not rotated or twisted during propellant loading. The igniter cartridge and ignition sensing device are installed. Control of the missile is transferred from the programmer test station to the remote firing panel, and the programmer test station is disconnected and removed from the area. The erector-servicer is removed from the area. The missile is pressurized, the liquid oxygen is replenished, and the fire switch is activated. If ignition is not satisfactory, the propulsion system is either automatically cut off by the ignition system or manually cut off from the remote firing panel if necessary.

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