RESTRICTED

FM 4-193

WAR DEPARTMENT

ANTIAIRCRAFT ARTILLERY FIELD MANUAL

BARRAGE BALLOON

GAS GENERATION, USE, PURIFICATION, AND SERVICE OF HYDROGEN GENERATOR

12 August 1943

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(For explanation of symbols see FM 21–6.)

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ANTIAIRCRAFT ARTILLERY FIELD MANUAL

BARRAGE BALLOON

GAS GENERATION, USE, PURIFICATION, AND SERVICE OF HYDROGEN GENERATOR

(This manual supersedes part III, FM 4-117, 1 June 1942.)

CHAPTER 1

BARRAGE BALLOON GASES

■ 1. GENERAL.—*a*. The efficiency of a gas for inflating barrage balloons is determined primarily by the lift of that gas. The lift of a gas is equal to the difference in weight between a given volume of the gas and an equal volume of air. The two lightest known gases are hydrogen and helium, hydrogen being the lighter of the two.

b. Requirements other than lightness governing the selection of a gas for balloon inflation are:

(1) It should have no detrimental effect on the balloon fabric.

(2) It must be readily available in large quantities.

(3) It should be noninflammable.

c. Hydrogen fulfills all the requirements listed in *b* above except that of noninflammability. However, since its inflammability is controllable, it may be used for inflating balloons. Helium satisfies all the requirements but that of availability. Since a large amount of gas is required for inflating barrage balloons, helium can be used only rarely, principally for training purposes.

■ 2. CHARACTERISTICS OF HYDROGEN.—*a*. Hydrogen, in addition to being the lightest gas known, is relatively inexpensive and has little detrimental effect on the balloon fabric. It is a comparatively common gas, and is manufactured commercially in almost every section of the United States.

b. Hydrogen is colorless, odorless, and tasteless.

c. (1) Hydrogen is *inflammable* under all conditions met in practice, and is easily ignited when mixed with air or oxygen. Ignition may be caused by flame, sparks, or intense heat. The hydrogen flame is intensely hot. When burning at moderate pressure, it is pale blue or colorless and difficult to see, especially in sunlight. When the gas burns at relatively high pressure, the flame becomes yellow as a result of the heating of particles of sodium always present in the air.

(2) When the purity of hydrogen in air falls below 74.2 percent, the mixture is *explosive* when ignited.

■ 3. **Sources of Supply.**—*a.* Large quantities of inflation gas must be made available to a balloon barrage in the field. Initial inflation of one barrage of 54 D–8 balloons will require approximately 1,100,000 cubic feet of gas. To keep the barrage flying 30 days will require about 1,000,000 additional cubic feet of gas.

b. In the field, hydrogen is obtained from one of the following sources:

(1) Commercial hydrogen plants.

(2) Mobile gas generators supplied to the antiaircraft balloon unit.

■ 4. **Helium.**—Helium, the second lightest gas known, has about 92 percent the lift of hydrogen. It has the advantage of being completely inert, and will not burn or explode under any condition.

CHAPTER 2

FERROSILICON PROCESS OF HYDROGEN GENERATION

■ 5. **General.**—The ferrosilicon process of hydrogen generation has been adopted as the standard method for field generation of hydrogen for barrage balloons.

■ 6. **Materials Used.**—A discussion of the materials used in the generation of hydrogen follows.

a. Ferrosilicon.—Ferrosilicon is an alloy of iron and silicon. Various impurities appear in ferrosilicon as carbides, which will react with water to produce substances inflammable in air. If ferrosilicon is stored in a damp place, the amount of inflammable substances formed from the carbides may become dangerous. Therefore, ferrosilicon should be kept in tightly closed containers and stored in a dry place. Ferrosilicon, which is normally packed in 100-pound containers, should be shipped in a dry, well-ventilated compartment. Ferrosilicon and caustic soda react violently in the presence of moisture, and should never be stored together where there is any possibility of their becoming mixed through the breakage of one or more containers.

b. Caustic soda.—(1) Caustic soda (sodium hydroxide), the chief constituent of the lye in everyday use, is a white solid prepared and sold in a variety of forms. The flake form is used in the ferrosilicon process. It is highly soluble in water, and on dissolving generates a large amount of heat. Caustic soda has a strong tendency to absorb water, and if allowed to remain in contact with the air will absorb enough moisture to dissolve itself. It also will absorb carbon dioxide from the air and form sodium carbonate, which is insoluble and will interfere with the generation of hydrogen.

(2) Caustic soda, either in solid form or in solution, is an extremely corrosive material. It severely irritates the skin and may cause blindness if allowed to come in contact with the eyes.

(3) Caustic soda is supplied in airtight iron drums of from 100 to 400 pounds capacity. The drums should be opened

only as the material is needed. Caustic soda must always be stored under cover in a dry place.

■ 7. REACTION.—*a. General.*—The production of hydrogen by the ferrosilicon process is based on the reaction of ferrosilicon, caustic soda, and water.

b. Rate of hydrogen production.—The controllable factors affecting the rate of hydrogen production by the M1 hydrogen generator are the concentration of caustic solution, the amount and size of ferrosilicon lumps, the percentage of silicon in the ferrosilicon, and the exhausting of sludge.

(1) *Concentration of caustic solution.*—Increasing the concentration of caustic solution increases the temperature of the reaction and the rate of hydrogen production. However, a solution containing more than 40 percent caustic should not be used, since it forms a sludge that is extremely viscous, or even solid, and very difficult to remove from the generator.

(2) *Amount and size of ferrosilicon.*—Since the reaction occurs at the surface of the particles of ferrosilicon, the reaction rate can be increased by increasing the surface exposed to the caustic solution. The smaller the lumps of ferrosilicon, the greater will be the rate of reaction. It is not practical to use powdered ferrosilicon because this material will mix with the sodium silicate formed and create a hard concretelike mass which is almost impossible to remove from the generator. Furthermore, the rate of reaction with powdered ferrosilicon is so rapid that the liquids in the generator foam, resulting in the danger of plugging the hydrogen outlet with sludge. The ferrosilicon lumps used in the M1 hydrogen generator should be small enough to pass through a 4-inch screen, but large enough not to pass through a ½-inch screen.

(3) *Percentage of silicon in ferrosilicon.*—The iron present in the ferrosilicon takes no part in the reaction. Below 75 percent silicon, the rate of hydrogen production is quite slow. Above 75 percent silicon, the rate of production rises sharply, approaching a maximum between 85 and 90 percent silicon. The ferrosilicon used in the M1 hydrogen generator should contain between 80 and 90 percent silicon.

(4) *Exhausting sludge.*—The waste product made in the reaction chamber is called sludge. It consists of sodium silicate, water, caustic soda, iron, and whatever impurities are

present. If the sludge is allowed to accumulate in the reaction chamber, the reaction will be retarded materially or stopped completely. To prevent this occurrence, the sludge is exhausted from the reaction chamber from time to time.

c. Production.—Actual production figures from the M1 hydrogen generator indicate that about 50 pounds of ferrosilicon and 95 pounds of caustic soda are required to produce 1,000 cubic feet of hydrogen.

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CHAPTER 3

ALUMINUM PROCESS

■ 8. **Process.**—Aluminum may be substituted for ferrosilicon in the M1 hydrogen generator. The reaction proceeds more rapidly than the reaction with ferrosilicon and develops 40 percent more heat. For this reason it requires more careful control. The sludge formed by the reaction of caustic soda and aluminum is fluid and does not solidify.

■ 9. **Use.**—Use of the aluminum process depends on availability of scrap aluminum. The aluminum is used in the form of lumps about 2 by 1 by 1 inches in size. It can be stored anywhere (except with the caustic), and no special precautions are necessary. Actual production figures from the M1 hydrogen generator indicate that the aluminum method requires about 55 pounds of aluminum and 109 pounds of caustic soda per 1,000 cubic feet of hydrogen generated.

CHAPTER 4

M1 HYDROGEN GENERATOR

■ 10. **General.**—*a.* The M1 mobile hydrogen generator is designed to generate hydrogen gas of very high purity, at high pressure, in the field. It is a completely self-contained unit, requiring only a supply of caustic soda, ferrosilicon, and water for continuous operation. The unit can generate hydrogen gas at the rate of approximately 5,000 cubic feet per hour, at pressures up to 2,500 pounds per square inch. Nomenclature of the M1 generator is shown in figures 1 to 4, inclusive.

b. The M1 mobile hydrogen generator is mounted on a drawbar type trailer, which has a rigid, welded framework and a hard maple floor. Since there are no springs on the trailer, the maximum speed on surfaced roads is 20 miles per hour; on rough terrain the speed should not exceed 5 miles per hour.

■ 11. **Dimensions.**—*a.* The dimensions of the M1 hydrogen generator are—

Width	8 feet.
Length	18 feet 6 inches.
Height	11 feet 7 inches (crane in traveling position).
Height	17 feet 2 inches (crane in operating position).
Weight	29,000 pounds.

b. When crated for shipment, the dimensions are—

Width	9 feet 3 inches.
Length	25 feet 3 inches.
Height	10 feet 9 inches (crane removed).
Weight	30,700 pounds.
Displacement	2,465.5 cubic feet.

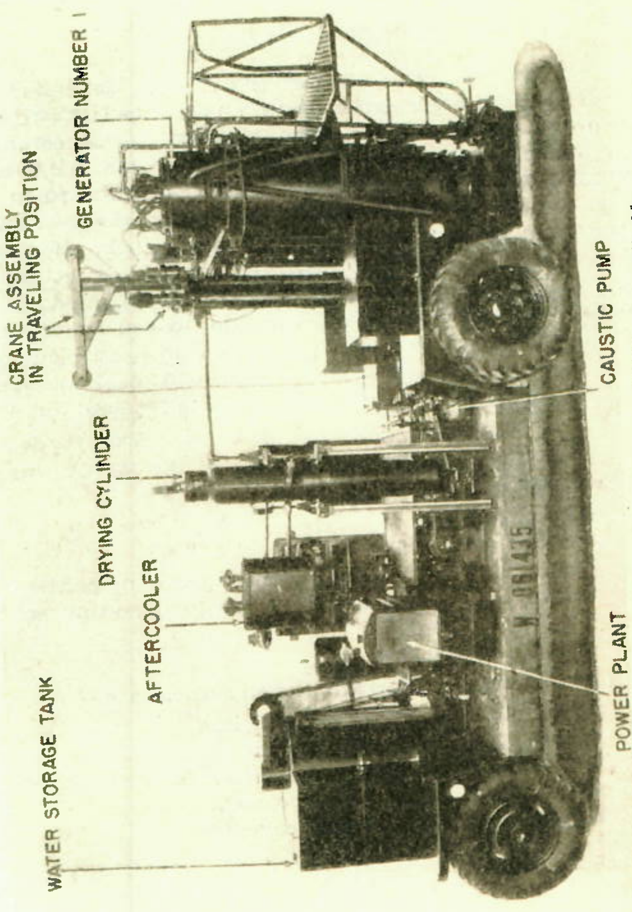

FIGURE 1.—Generator, mobile, hydrogen, M1—left side.

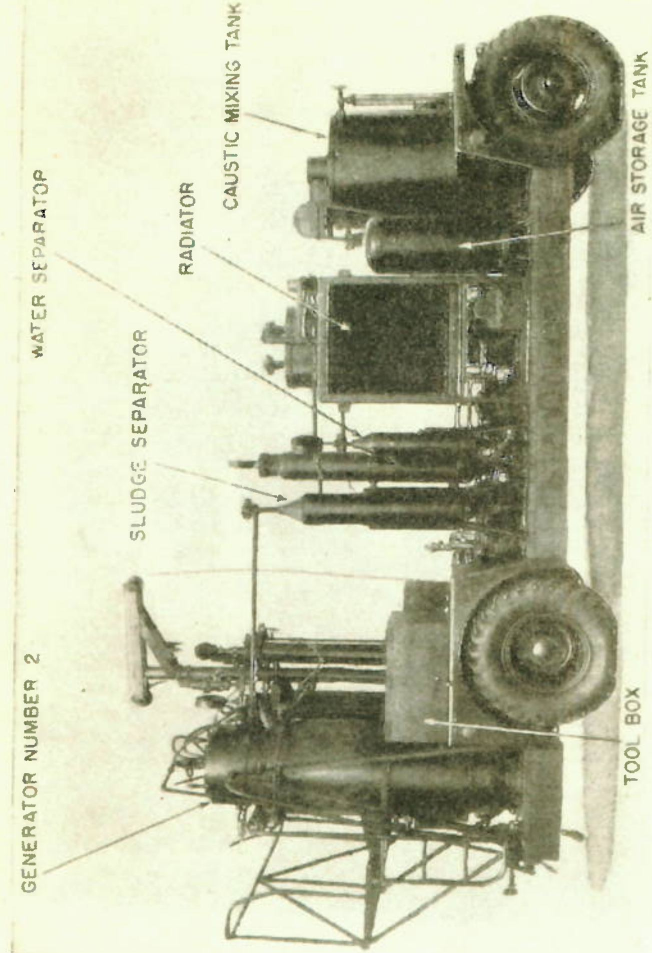

FIGURE 2.—Generator, mobile, hydrogen, M1—right side.

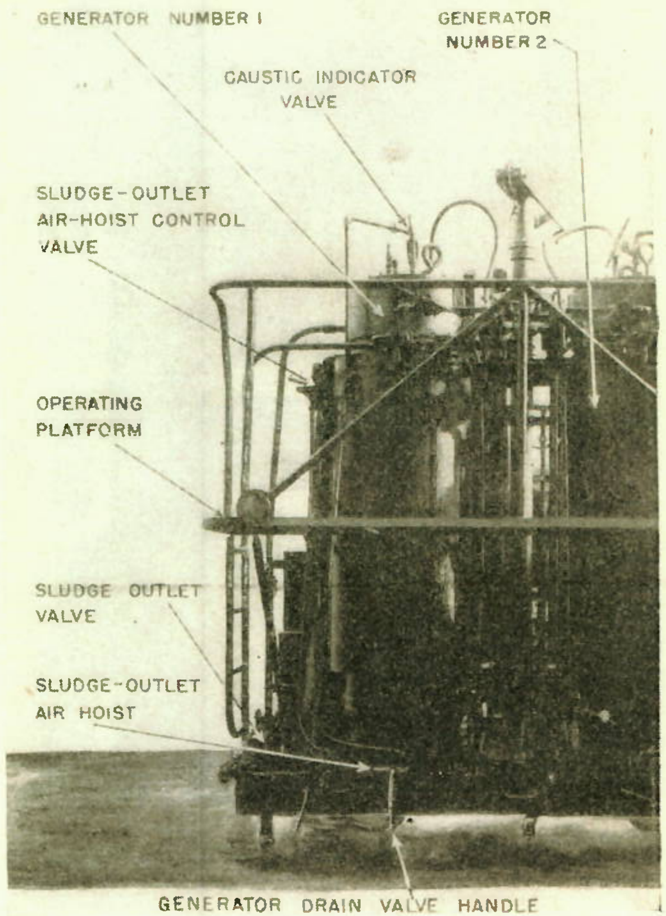

FIGURE 3.—Generator, mobile, hydrogen, M1—rear view.

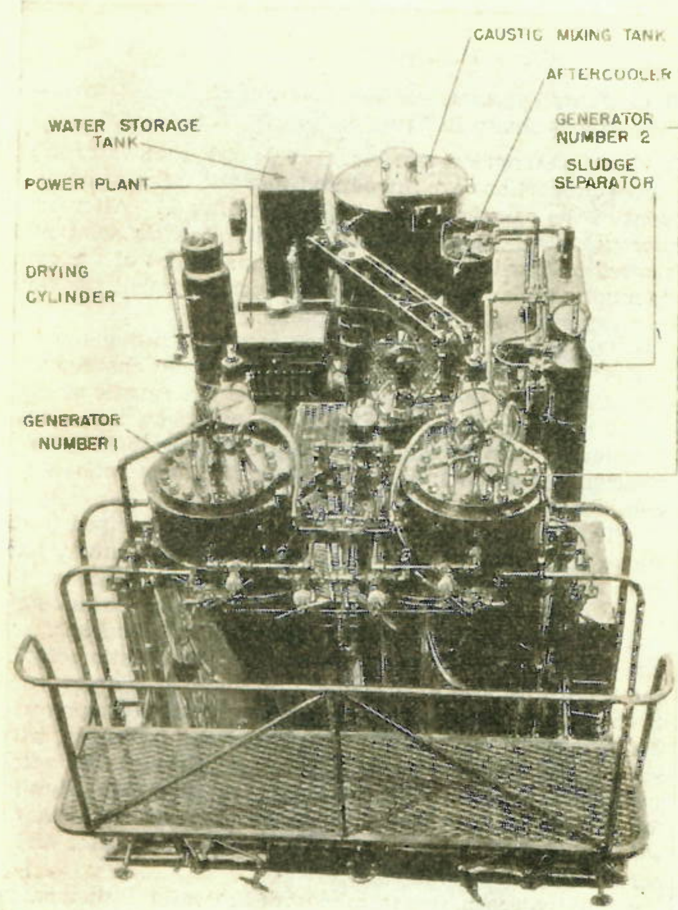

FIGURE 4.—Generator, mobile, hydrogen, M1—top view.

CHAPTER 5

FUNCTIONING OF M1 GENERATOR

■ 12. Flow Diagram.—A flow diagram of the M1 hydrogen generator is shown in figure 5.

■ 13. Generating Process.—*a.* Caustic soda and water in the proper proportions are introduced into the mixing compartment of the caustic mixing tank. (See fig. 6.) After being thoroughly mixed by the agitator, the caustic solution is allowed to flow into the reservoir compartment of the caustic mixing tank. From the reservoir compartment the caustic solution flows to the caustic pump.

b. The caustic pump forces the caustic solution into the generator chamber, which has previously been charged with ferrosilicon. In the generator chamber the caustic solution reacts with the ferrosilicon to form hydrogen and sludge. The sludge settles to the bottom of the silicon container and is blown out through the sludge outlet line at intervals of from 1 to 2 minutes. (See fig. 8.)

c. The hydrogen generated by the reaction is piped to the sludge separator which traps any sludge that might have been carried along with the hydrogen. On entering the sludge separator, any sludge in the hydrogen settles to the bottom of the separator and is periodically blown out.

d. The heat of the reaction between the caustic solution and the ferrosilicon in the generator chamber converts some of the water present into steam, which is carried along with the hydrogen. To remove this water, the hydrogen, after leaving the sludge separator, is passed through the aftercooler and then into the water separator. In passing through the aftercooler, the steam condenses and, on entering the water separator, falls to the bottom of the separator and is periodically blown out.

e. The hydrogen, free from most of the water, is then passed through a drying cylinder filled with potassium hydroxide, which absorbs any remaining moisture.

f. Emerging from the drying cylinder, the pure, dry hydrogen passes to the manifold and is stored in cylinders.

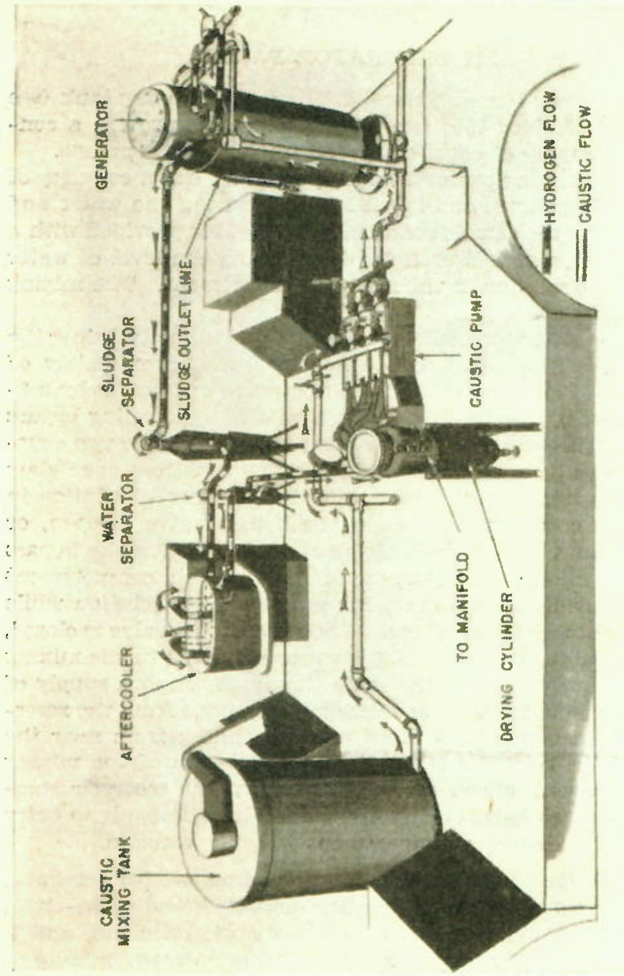

Figure 5.—Flow diagram, M1 hydrogen generator.

CHAPTER 6

M1 GENERATOR PARTS

■ 14. CAUSTIC MIXING TANK.—*a*. The caustic mixing tank (see fig. 6) is divided into two compartments to provide a continuous supply of caustic solution to the caustic pumps.

b. The mixing compartment of the tank has a capacity of about **150** gallons, and is used for measuring the water and for mixing the caustic soda and water. It is provided with a gage glass, which is used for determining the level of water or caustic solution in the mixing compartment. The mixing is done by the agitator.

c. The reservoir compartment, located directly below the mixing compartment, has a capacity of approximately 47 gallons. It is connected to the mixing compartment by a 2-inch pipe bypass in which is located a quick-opening bypass valve. This compartment also is connected to the two caustic pumps by a 1½-inch line. A caustic solution gage glass provides a means of determining the amount of solution in the two compartments when the bypass valve is open, or the amount in the reservoir compartment when the bypass valve is closed. The purpose of the reservoir compartment is to provide storage space for mixed caustic solution while a new batch is being mixed. When the bypass valve is closed, a new batch of caustic solution may be mixed in the mixing compartment, and at the same time a continuous supply of solution may be furnished the caustic pumps from the reservoir compartment. A bleed pipe, extending from near the top of the reservoir compartment to the top of the mixing compartment, allows air to escape from the reservoir compartment while it is being filled, and also allows air to enter when the reservoir compartment is being emptied.

■ 15. CAUSTIC PUMPS.—The caustic pumps, two per generator plant, are single-acting, eccentric-actuated, and roller-chain driven (see fig. 7). Each pump has three cylinders, and is designed to deliver approximately 2.6 gallons per minute at 3,500 pounds per square inch pressure. The outlets of the two pumps are connected so that either or both pumps can

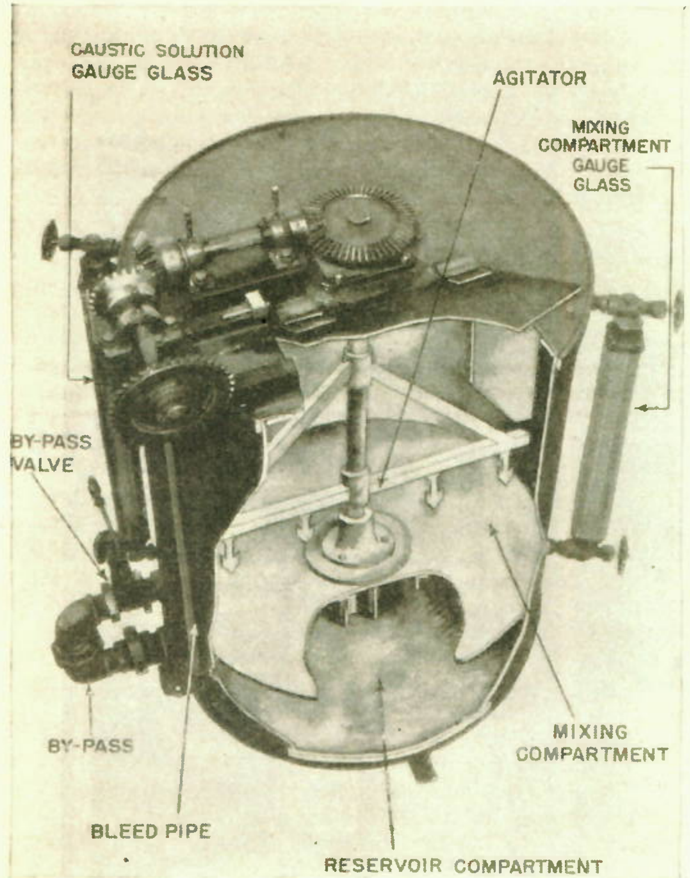

FIGURE 6.—Caustic mixing tank.

force caustic solution to either or both generator chambers. Connections also are provided so that water may be pumped into the generator chambers. Quick-opening inlet valves are provided on the pumps to facilitate the change from caustic solution to water. The pumps normally operate at

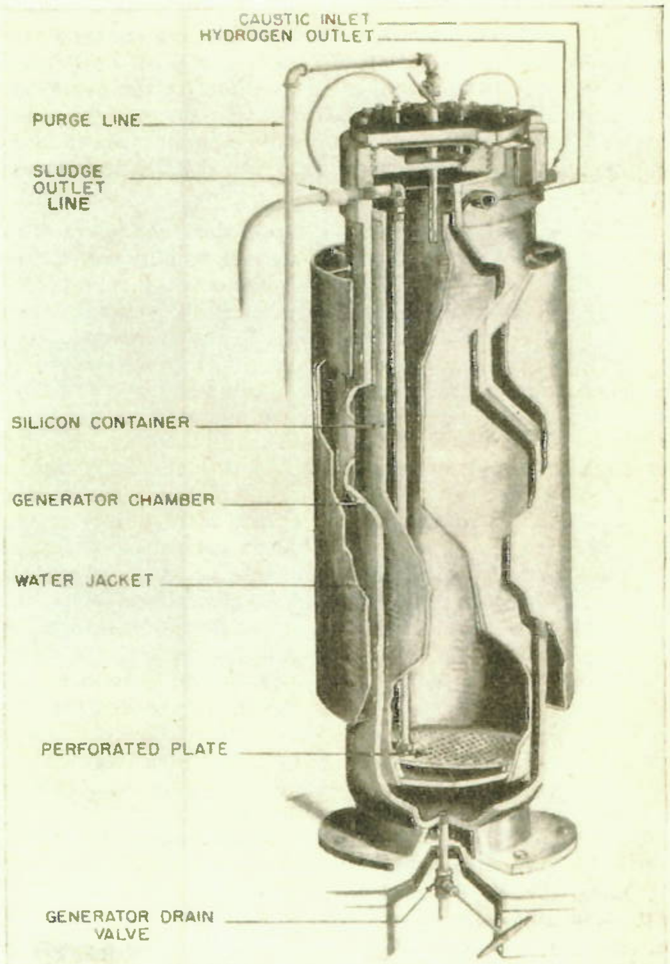

FIGURE 8.—Diagram of generator chamber.

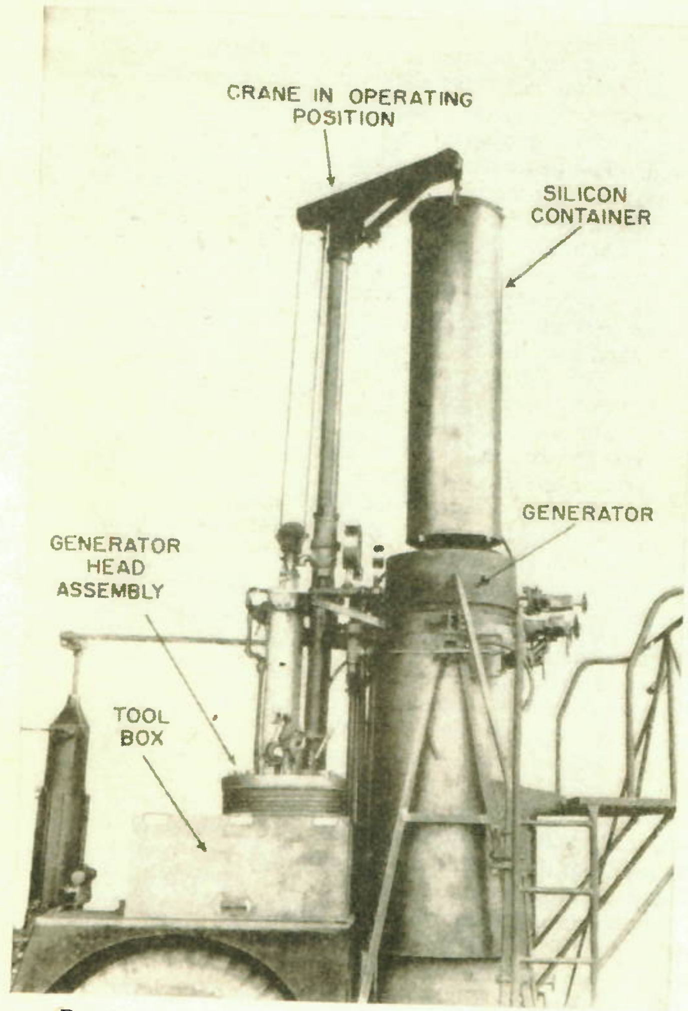

FIGURE 9.—Removing silicon container from generator.

the generator, is a 1-inch sludge outlet line through which sludge is exhausted. The bottom of the container is sloped to aid in draining the sludge toward the sludge outlet line.

d. Generator head assembly.—The generator head assembly (see fig. 10) is removable to allow the generator to be charged with ferrosilicon or the silicon container to be removed. The generator head assembly consists of two main parts: the generator head, threaded with coarse, square threads for screwing into the generator; and the compression head, attached to the generator head by 18 bolts. Between the compression head and the generator head is a head gasket. Cooling water may be circulated in the head assembly. Extending downward from the head assembly is a dip pipe, perforated near its lower end. The lower end of the dip pipe is at the operating level of the caustic solution. The upper end of the dip pipe is connected to the purge line. The caustic indicator valve, located in the purge line, is used to purge the generator of air and to determine if the caustic solution has reached the proper level. Chisel marks on the head assembly and the generator chamber are used to mark the proper position for replacing the head assembly. Correct position of the head assembly is necessary to assure alinement of the purge line and a flat surface for the head gasket.

■ 17. SLUDGE OUTLET VALVE.—*a.* The sludge outlet valve, located in the sludge outlet line, releases sludge from the generator. It is a lubricated plug valve operated by an air hoist. Operation of the air hoist is controlled by a sludge outlet air-hoist control valve. The valve is opened momentarily at frequent intervals during operation to exhaust accumulated sludge. (See figs. 11 and 12.)

b. To operate the sludge outlet valve, the hand lever of the sludge outlet air-hoist control valve is moved from neutral to open position. This allows compressed air to flow through a line leading to one end of the air-hoist cylinder, pushing a piston through the cylinder. This movement of the piston rod opens wide the sludge outlet valve. (See fig 12.) The hand lever is then returned to neutral position.

c. To close the sludge outlet valve, the hand lever is moved from neutral to closed position. Compressed air flows through a second line from the air-hoist control valve to the

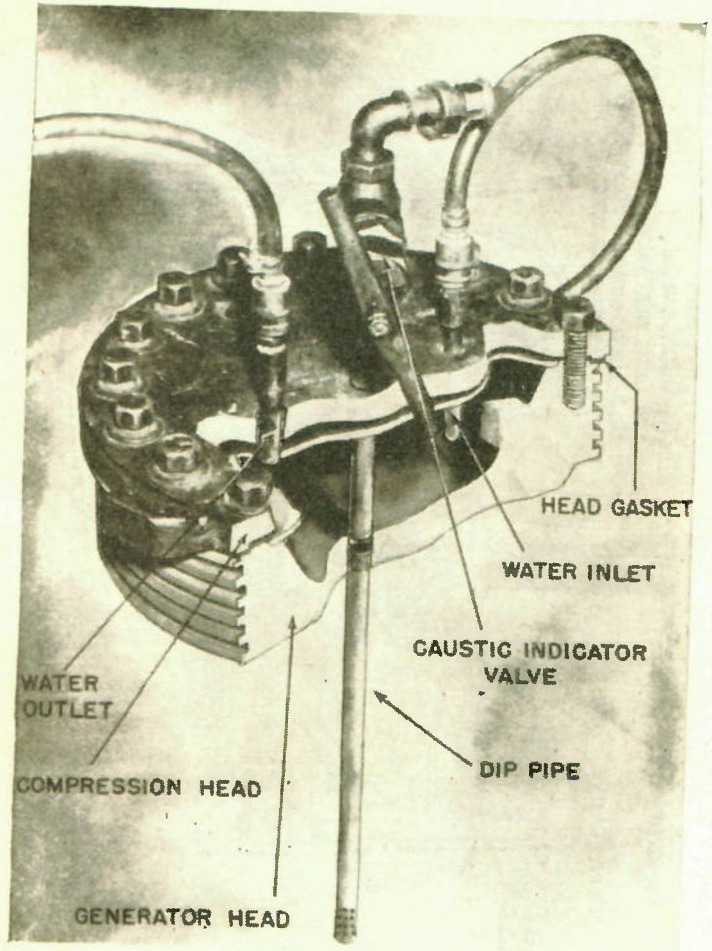

FIGURE 10.—Generator head assembly.

opposite end of the air-hoist cylinder, pushing the piston back to its original position, and closing the sludge outlet valve. The hand lever is then returned to neutral position.

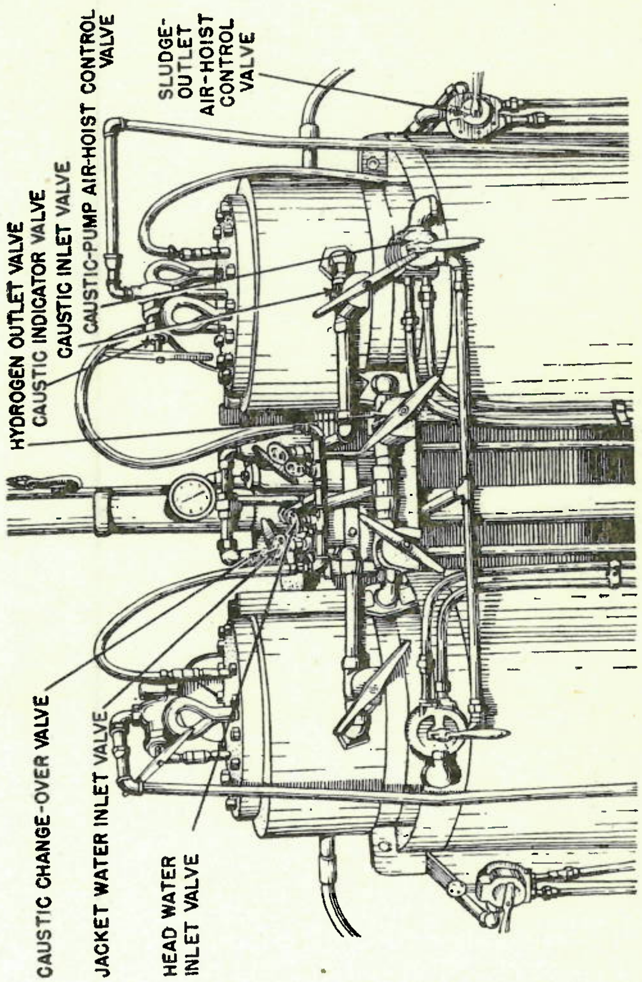

FIGURE 11.—Control valves.

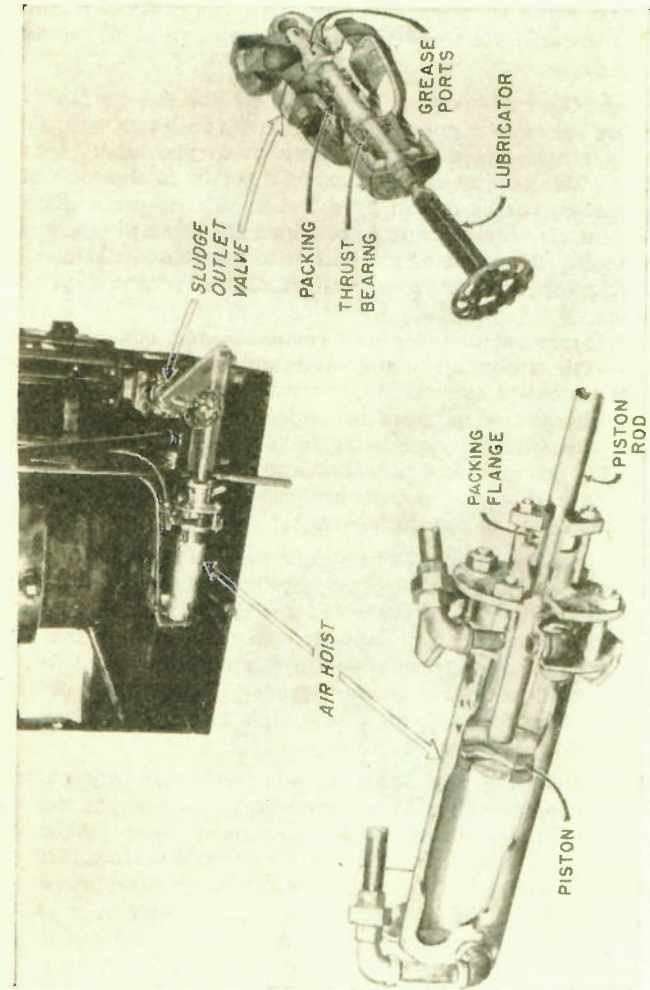

FIGURE 12.—Sludge outlet valve and air hoist.

■ 18. **Crane Assembly.**—The crane assembly consists of the crane and crane air hoist. (See fig. 1.) The purpose of the crane is to facilitate removing the generator head assembly and the silicon container. (See fig. 9.)

■ 19. **Air Compressor.**—*a.* To supply air for the air hoists operating the caustic pump clutches, sludge outlet valves, and crane, a single-cylinder air compressor is provided. (See fig. 13.) The compressor is located directly to the side of the radiator, and is driven by a V-belt off the main drive shaft. An air storage tank is provided for storage of compressed air. There being no clutch to disengage the compressor, it operates whenever the main drive shaft is in operation.

b. Air-pressure unloader and regulator and vacuum unloader.—The air-pressure unloader and regulator and the vacuum unloader (see fig. 13) operate together to prevent the compressor from starting under compression and to prevent excessive pressure being built up in the air storage tank. The air-pressure unloader and regulator can be set to maintain the desired pressure (usually 150 pounds per square inch) in the air storage tank.

■ 20. **Sludge Separator.**—The sludge separator removes any sludge carried from the generator by the hydrogen. Hydrogen from the generator enters at the top of the separator and leaves through an opening in the side about 9 inches from the top. As a result of the change in velocity and direction of flow of the hydrogen, most of the sludge drops to the bottom of the separator and is blown out through the drain valve. (See fig. 2.)

■ 21. **Aftercooler and Radiator.**—To condense any water that is carried along from the generator in the form of steam and to cool the gas for storage, the gas is passed through an aftercooler (a series of coils immersed in a cooling tank). (See figs. 1 and 4.) The cooling water is pumped through an opening near the bottom of the cooling tank by a centrifugal pump driven off the main drive shaft. The cooling water flows up past the coils, out through an overflow pipe, and into the top of a sectional core, blower type radiator, where it is cooled by air blown through the radiator by a fan.

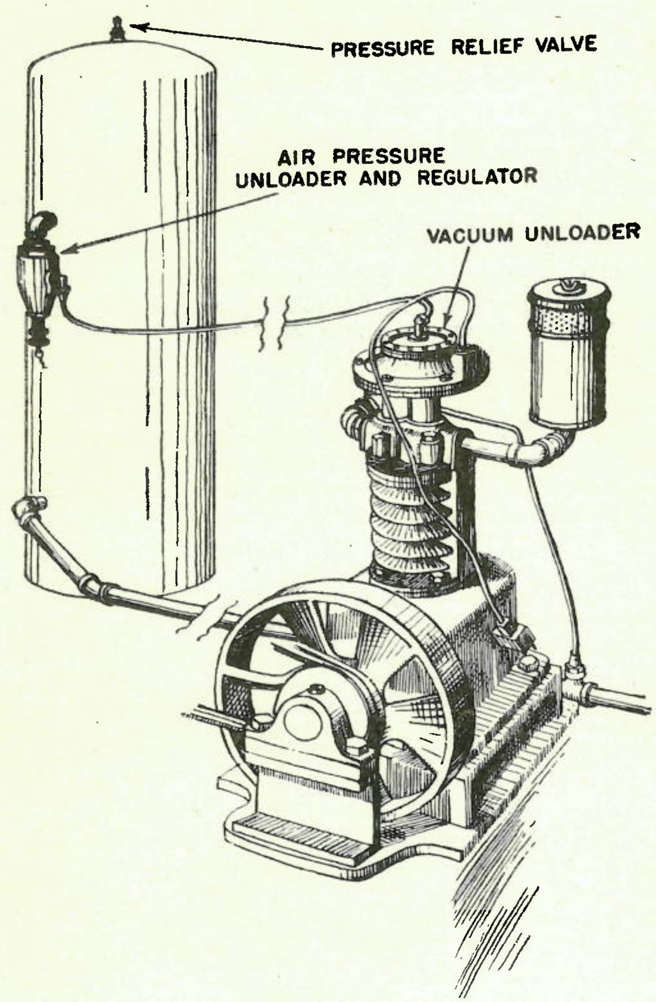

Figure 13.—Air compressor.

■ 22. Water Separator.—Gas from the aftercooler enters the water separator through the top and leaves through an opening in the side located approximately 7 inches from the top. As a result of the change in velocity and direction of flow of the hydrogen, any liquids carried along drop to the bottom of the separator and are blown out through the drain valve. (See fig. 2.)

■ 23. Power Unit.—The power unit is a 3¼ by 4-inch, four-cylinder, inclosed, internal combustion gasoline engine. The normal operating speed of the engine is approximately 1,500 rpm. Operating through a gear reduction of 5 to 1, it gives an operating speed of 300 rpm to the main drive shaft. (See fig. 1.) The unit supplies power for the caustic mixing tank agitator, cooling fan and water pump, caustic pumps, and the air compressor. Sufficient power is generated to run the plant and accessories continuously under maximum load conditions. The clutch controlling the power take-off is of the friction disk type and is hand-controlled. A gasoline tank of about 15-gallon capacity is mounted directly beneath the power unit and under the flooring.

■ 24. Auxiliary Water Pump.—For field use a small, gasoline engine-driven water pump is provided. (See fig. 14.) This

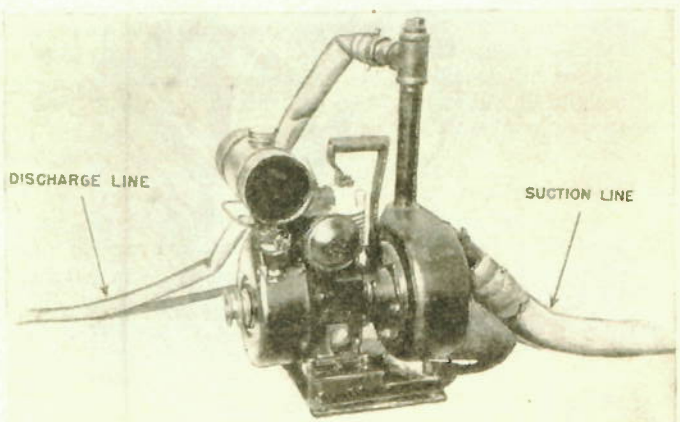

Figure 14.—Auxiliary water pump.

pump is a completely self-contained unit weighing approximately 65 pounds. It is carried on the floor of the trailer behind the left front wheel housing and is easily removed. The pump is provided with a 25-foot length of suction line and a 25-foot length of discharge line. It is used for pumping water from the source of water supply to the caustic mixing and water tanks.

■ 25. Water Storage Tank.—To provide a means for storing water, a water storage tank is mounted on the left front fender of the M1 generator. (See fig. 1.) The tank has a capacity of approximately 65 gallons. The tank is connected to the inlet line of the caustic pumps. A water-level gage glass provides a means of determining the amount of water in the tank when it is less than half full. A clean-out plate located in the front of the tank makes it possible to clean out any sediment.

■ 26. Drying Cylinder.—To remove any moisture remaining in the hydrogen after it has passed through the water separator, the gas is passed through a drying cylinder filled with lump potassium hydroxide. The gas enters near the bottom of the cylinder and flows up through the potassium hydroxide, which removes the moisture from the gas. The accumulated liquid is periodically blown out through a drain valve located in the bottom of the cylinder. For ease of cleaning, the cylinder is mounted so that when the gas lines are disconnected it may be tilted so that the top is lower than the bottom. In this position the potassium hydroxide may be easily removed. When the head of the cylinder is removed, an opening the full size of the cylinder is available for charging or cleaning the cylinder. (See fig. 1.)

■ 27. Manifold.—A 20-cylinder manifold is provided for transferring the hydrogen generated by the plant into cylinders. (See fig. 15.) This manifold is made of ¾-inch heavy pipe and is divided into two banks. Each bank has an inlet valve, 10 outlet valves, and a pressure gage. Attached to each of the outlet valves is a 5-foot, copper tubing "pigtail" to provide connection between the manifold and the cylinder. Hydrogen from the plant enters at the center of the manifold, and its flow can be directed to either bank of the manifold by the inlet valves.

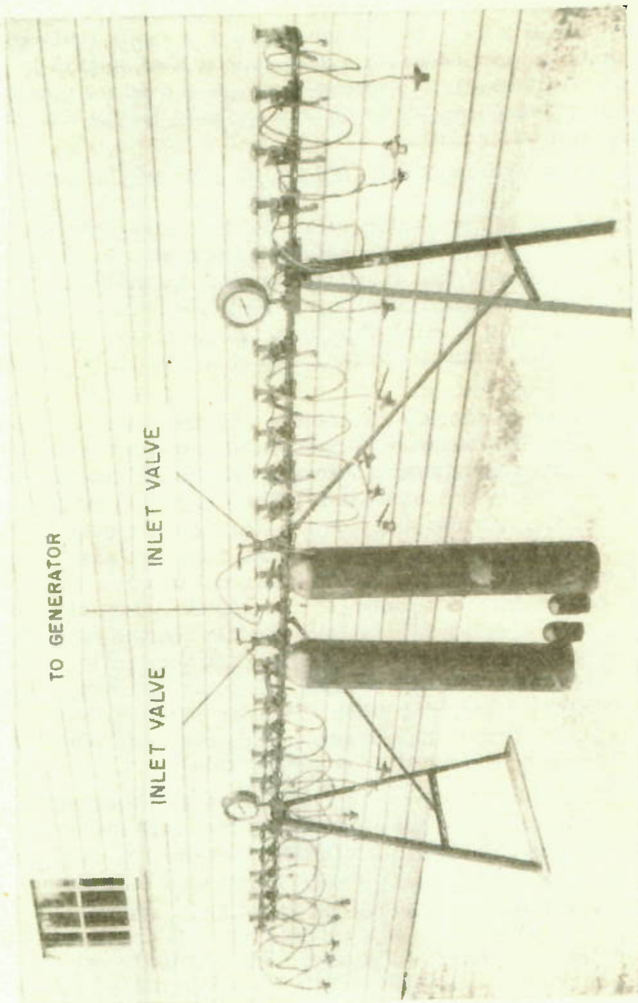

FIGURE 15.—Manifold.

CHAPTER 7

HYDROGEN GENERATOR SITE

■ 28. LOCATION.—A desirable site for the M1 hydrogen generator should have the following characteristics:

a. Level space for generator.
b. Nearby source of water.
c. Good transportation facilities.

■ 29. SITE LAY-OUT.—Figure 16 shows a typical lay-out of a site for two hydrogen generators, including cylinder storage shed, toolroom, ferrosilicon and caustic storage sheds, sheds for sheltering the generators, and sludge pits and tunnels to prevent the sludge from damaging nearby buildings and equipment.

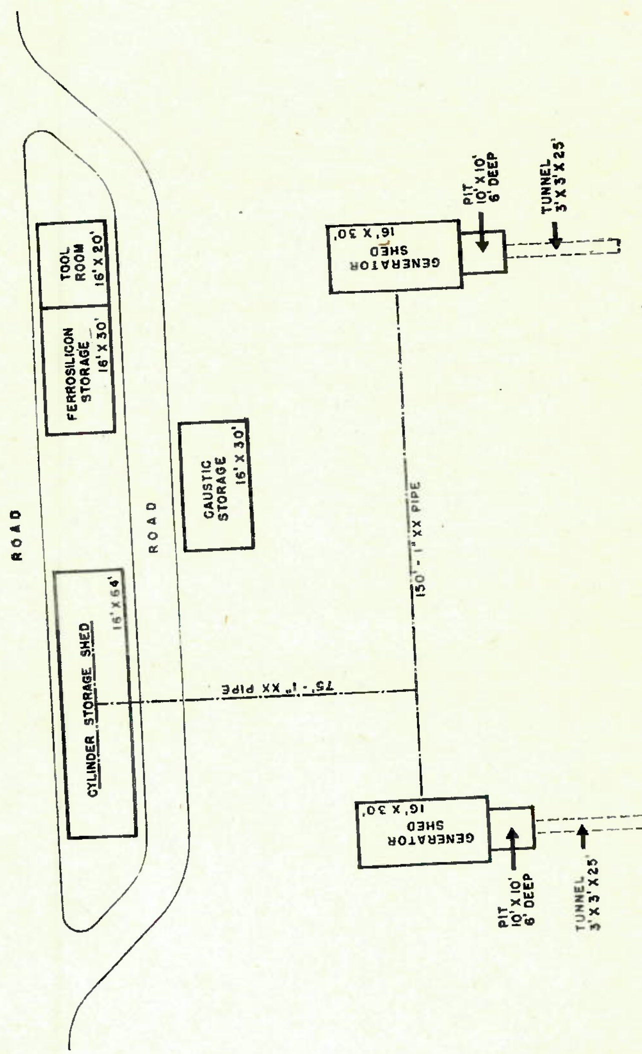

FIGURE 16.—Typical lay-out of generator site.

CHAPTER 8

OPERATING PERSONNEL AND THEIR DUTIES

■ 30. SELECTION.—Men to operate the high pressure hydrogen generator should be carefully chosen. Those selected should be familiar with the handling of tools and should be technically inclined. They should not be afraid of working around high pressure and high temperature apparatus, but should respect the danger that may result if the equipment is improperly handled.

■ 31. SIZE OF CREW.—The M1 generator can be operated by a crew of eight men, consisting of a plant chief, a maintenance man, two generator operators, two caustic operators, and two manifold operators. However, it is desirable to have two utility men with each crew, making a total of ten men to a crew.

■ 32. DUTIES OF CREW MEMBERS.—*a. Plant chief.*—The plant chief is in charge of the generator and generator crew. He is responsible to the gas officer for—

(1) Training and efficiency of his crew.

(2) Condition, care, and operation of the generator.

(3) Observance of all safety precautions pertaining to operation of the generator.

(4) Police of the generator position.

(5) Records of materials used and amount of gas produced.

(6) Records of all maintenance and repairs to generator.

b. Maintenance man.—The maintenance man is in charge of the mechanical parts of the generator. He is responsible for—

(1) Condition, care, and maintenance of all moving parts of the generator.

(2) Proper lubrication of all moving parts.

(3) Testing all joints and valves in hydrogen lines for leaks.

(4) Completing Daily Inspection and Lubrication Record (See app.)

c. Generator operators.—The generator operators are responsible for maintaining, charging, operating, and cleaning the generators.

d. Caustic operators.—The caustic operators are responsible for—

(1) Maintaining a supply of properly mixed caustic solution.

(2) Draining the generators, sludge separator, water separator, and drying cylinder at the proper times.

e. Manifold operators.—The manifold operators are responsible for charging the cylinders from the manifold, and for testing the cylinder valves for leaks after the cylinders have been filled.

f. Utility men.—The utility men should be able to take over the duties of any member of the crew. For the most part, however, they will perform the duties incidental to the operation of the generator. They will help in handling cylinders, will keep the operators supplied with materials, will police the plant, and will do any other similar tasks as directed by the plant chief.

■ 33. SPECIAL CLOTHING FOR CREW MEMBERS.—*a.* All crewmen will wear nonwoolen coveralls or a similar garment.

b. All crewmen will wear rubber footgear, preferably rubber overshoes or boots.

c. Caustic operators will wear rubber gloves long enough to protect their wrists and lower forearms.

d. Generator operators will wear extra-heavy canvas gloves.

e. All crewmen except generator and caustic operators will wear canvas gloves.

f. All crewmen will wear close-fitting hats or caps to eliminate scalp irritation from caustic fumes.

g. All crewmen, except manifold operators, will be provided with goggles, which must be worn whenever the plant is in operation. *This rule will be followed at all times.*

CHAPTER 9

OPERATING M1 HYDROGEN GENERATOR

SECTION I

GENERAL

■ 34. GENERAL.—*a.* This chapter includes the standard drill for operating the M1 hydrogen generator.

b. It is essential that the correct sequence of each operation be followed closely at all times. The purpose of a standard drill is to train personnel to perform their duties quickly, coolly, and efficiently under adverse conditions. Thorough training with standard drills improves morale, reduces danger to personnel and equipment, and increases efficiency.

SECTION II

FORMATION OF CREW

■ 35. FORMATION OF CREW.—*a.* At the command 1. GENERATOR CREW, 2. FALL IN, given by the plant chief, the crew members take positions as shown in figure 17.

b. At the command CALL OFF, the crew members call off from right to left as follows: generator operator No. 1, generator operator No. 2, maintenance man, caustic operator No. 1, caustic operator No. 2, manifold operator No. 1, manifold operator No. 2, utility man.

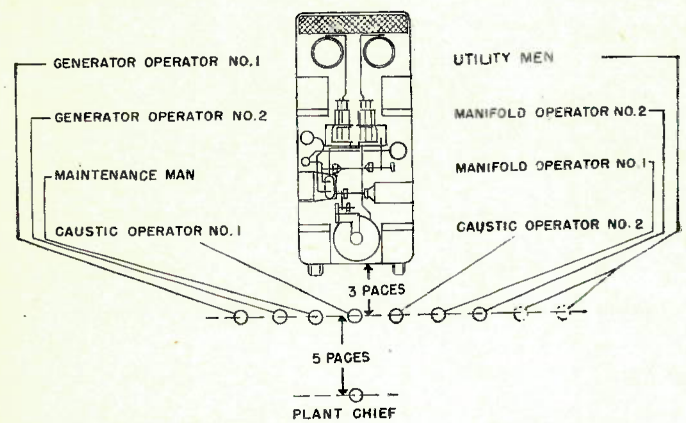

FIGURE 17.—Formation of generator crew.

SECTION III

DRILL TABLE

■ 36. **DRILL FOR OPERATING GENERATOR.**—The following table outlines the drill procedure for training personnel to operate the M1 hydrogen generator:

DRILL TABLE

Details	DETAILS, POSTS:	PREPARE FOR OPERATION:	COMMENCE OPERATION:	CEASE OPERATION:
Plant chief.	Gives command.	Gives command and supervises preparation.	Gives command and supervises operation.	Gives command and supervises stopping of operation.
Maintenance man.	Takes post at power plant.	Checks power plant, clutches, air compressor, and caustic pump; checks lubrication of all moving parts; starts power plant; engages clutches on order.	Inspects and maintains power plant, caustic pumps, air compressor, and all operating parts of plant; checks for and repairs leaks; maintains proper lubrication of all moving parts.	Continues operational duties; when directed by plant chief, disengages fan and power take-off clutches; shuts off cross-head oilers on caustic pumps; stops power plant; inspects plant and makes any necessary repairs; cleans plant and prepares it for further operation.
Generator operator No. 1.	Takes post at generator No. 1.	Closes hydrogen outlet valve of drying cylinder; opens drying cylinder drain valve; opens caustic pump No. 1 drain valve; closes generator water jacket drain valve; checks to see that change-over valve in caustic inlet line is closed; closes hydrogen outlet valve on generator; closes caustic inlet valve on generator; closes sludge outlet valve; removes head assembly, charges generator, and replaces head assembly; closes caustic indicator valve; reports "Generator No. 1 in order."	Starts caustic pump No. 1; opens caustic inlet valve to generator No. 1; opens water inlet valve to generator head; opens water inlet valve to generator water jacket; checks level of caustic solution in generator and shuts down caustic pump when caustic solution reaches proper level; purges generator through caustic indicator valve; has caustic operator No. 1 purge generator through drain valve; operates sludge outlet valve; maintains proper level of caustic solution in the generator; regulates flow of hydrogen from the generator.	Pumps water into generator; continues to operate sludge outlet valve and regulate the flow of hydrogen as it is generated; pumps water into generator up to level of dip pipe after rate of generation has slowed to such an extent that no more gas is being stored; closes hydrogen outlet valve at proper time; operates sludge outlet valve to remove remaining sludge; pumps in water for about 2 minutes and operates sludge outlet valve until all pressure is gone; refills generator with water and blows water out through sludge outlet valve; directs caustic operator No. 1 to open generator drain valve; closes water inlet valve to water jacket and generator head assembly; removes generator head assembly; if necessary, removes silicon container and empties and cleans container; replaces silicon container; if operations are to be continued, recharges generator and replaces head assembly; otherwise replaces head assembly without charging the generator.

Details	DETAILS, POSTS:	PREPARE FOR OPERATION:	COMMENCE OPERATION:	CEASE OPERATION:
Generator operator No. 2.	Takes post at generator No. 2.	Opens water separator drain valve; opens sludge separator drain valve; opens caustic pump No. 2 drain valve; closes generator No. 2 drain valve; closes generator water jacket drain valve; closes hydrogen outlet valve on generator; closes caustic inlet valve on generator; checks to see that change-over valve in caustic inlet line is closed; closes sludge outlet valve; removes head assembly, charges generator, and replaces head assembly; closes caustic indicator valve; reports "Generator No. 2 in order."	Performs same duties as generator operator No. 1, operating generator No. 2.	Performs same duties as generator operator No. 1, operating generator No. 2.
Caustic operator No. 1.	Takes post at caustic mixing tank.	Closes caustic inlet and water inlet valves of caustic pump No. 1; closes drain valve of caustic mixing tank; closes bypass valve; turns on water to generator water system; fills mixing compartment of caustic mixing tank with proper amount of water; directs maintenance man to start agitator; adds correct amount of caustic to mixing compartment; drains mixed caustic solution into reservoir compartment; reports "Caustic mixer in order."	Opens caustic inlet valve of caustic pump No. 1; closes caustic pump drain valve after pump has been purged; opens generator No. 1 drain valve to purge generator when directed to do so by generator operator No. 1; then closes valve; closes drying cylinder drain valve after sludge separator and water separator drain valves have been closed by caustic operator No. 2; opens drying cylinder hydrogen outlet valve; maintains a supply of caustic solution; opens drying cylinder drain valve every 20 minutes; sees that a supply of caustic is brought to generator.	Closes caustic inlet valve to caustic pump No. 1, and opens water inlet valve; closes water inlet valve to caustic pump No. 1 when directed to do so by generator operator No. 1; opens drain valve to caustic pump No. 1, and drains water from caustic pump and lines; closes hydrogen outlet valve from drying cylinder when no more gas is being generated by either generator; opens generator No. 1 drain valve as directed by generator operator No. 1; assists generator operator No. 1 in removing the generator head assembly and silicon container; if the generator is to be shut down for some time, opens drain valve of generator water jacket and drains water from jacket, closes water inlet valve to pump line, and opens caustic drain valve of caustic mixing tank; opens drain valve of drying cylinder to remove any accumulated moisture and relieve pressure from plant; then closes valve; cleans up around plant.

Details	DETAILS, POSTS:	PREPARE FOR OPERATION:	COMMENCE OPERATION:	CEASE OPERATION:
Caustic operator No. 2.	Takes post at caustic mixing tank.	Closes caustic inlet valve and water inlet valve to caustic pump No. 2; closes cooling tank and radiator drain valve; fills cooling tank to proper level; assists caustic operator No. 1 to mix caustic solution.	Opens caustic inlet valve of caustic pump No. 2; closes caustic pump drain valve after pump has been purged; opens generator No. 2 drain valve to purge generator when directed to do so by generator operator No. 2; then closes valve; closes sludge separator and water separator drain valves after the sludge separator and water separator have been purged; assists caustic operator No. 1 in mixing additional caustic solution; every 20 minutes opens water and sludge separator drain valves to blow out accumulated water and sludge, then closes valves; assists caustic operator No. 1 in bringing supply of caustic to generator.	Closes caustic inlet valve to caustic pump No. 2 and opens water inlet valve; closes water inlet valve to caustic pump No. 2 when directed to do so by generator operator No. 2; opens drain valve to caustic pump No. 2 and drains water from caustic pump and line; opens generator No. 2 drain valve as directed by generator operator No. 2; assists generator operator No. 2 in removing the generator head assembly and silicon container; if the generator is to be shut down for some time, opens drain valve of generator No. 2 water jacket and drains water from jacket; opens sludge and water separator drain valves to drain any sludge and water; then closes valves; cleans up around plant.
Manifold operator No. 1.	Takes post at manifold.	Places CO_2 fire extinguishers at generator No. 1 and manifold; connects cylinders to right bank of manifold; closes inlet valve to right bank of manifold; opens manifold and cylinder valves; records pressure in cylinders; checks valves and connections for leaks; opens inlet valve to right bank of manifold; reports "Manifold in order."	Closes inlet valve to right bank of manifold when pressure in cylinders reaches desired amount; closes cylinder valves; bleeds down pressure of gas trapped in manifold and tubing connections; disconnects tubing from filled cylinders; connects tubing to empty cylinders; checks cylinder valves for leaks; records number of cylinders filled and the pressure to which filled assists manifold operator No. 2 whenever possible.	Records pressure in cylinders and number of cylinders when no more gas comes over from the generator; closes cylinder valves; closes manifold inlet valve; bleeds down pressure of gas trapped in manifold and tubing connections; replaces fire extinguishers and first-aid kit; assists in cleaning up around plant.

Details	DETAILS, POSTS	PREPARE EOR OPERATION:	COMMENCE OPERATION:	CEASE OPERATION:
Manifold operator No. 2.	Takes post at manifold.	Places CO_2 fire extinguisher at generator No. 2; checks contents of first-aid kit and places it in vicinity of generator; connects cylinders to left bank of manifold; closes inlet valve to left bank of manifold; opens manifold and cylinder valves; has manifold operator No. 1 record pressure in cylinders; checks valves and connections for leaks.	When inlet valve to right bank of manifold is closed, opens inlet valve to left bank and stores hydrogen; closes inlet valve to left bank of manifold when pressure in cylinders reaches desired amount; closes cylinder valves; bleeds down pressure of gas trapped in manifold and tubing connections; disconnects tubing from filled cylinders; connects tubing to empty cylinders; checks cylinder valves for leaks; has manifold operator No. 1 record number of cylinders filled and pressure to which filled; assists manifold operator No. 1 whenever possible.	Assists manifold operator No. 1.

SECTION IV

NOTES ON OPERATING M1 HYDROGEN GENERATOR

■ 37. GENERATORS.—*a. Failure to generate.*—If during operation, there is any question as to whether a generator is generating gas, it is only necessary to shut off the hydrogen outlet valve of the generator for a few moments and note whether the pressure in the generator rises. If the pressure does not rise, the generator is not generating gas. If it is not generating gas, it will be because of one of the following reasons:

(1) The ferrosilicon charge has been consumed.

(2) There is insufficient caustic solution in the generator.

(3) The sludge has not been removed properly.

b. Ferrosilicon charge consumed.—If the ferrosilicon has been consumed, it is necessary to charge the generator with ferrosilicon to correct the trouble. This will not normally occur in less than 3 hours, if the usual charge of 600 pounds of ferrosilicon is used. The operator should be able to determine from the length of time the generator has been in operation whether this is the cause of the trouble.

c. Insufficient caustic solution.—If no liquid is blown from the purge line when the caustic indicator valve is opened, there is insufficient caustic solution in the generator. This can be corrected by pumping more caustic solution into the generator with the caustic pump.

d. Improper removal of sludge.—If the sludge has not been removed properly, the trouble may be corrected in some cases by blowing out as much of the sludge as possible through the sludge outlet valve and pumping in fresh caustic solution. If it is impossible to blow out the sludge because it has solidified in the silicon container, or if the sludge outlet line has been clogged, it is necessary to shut down the generator, remove the silicon container, and clean out the solidified mass. In normal operation, because of the difficulty of removing all the sludge from the bottom of the silicon container by exhausting through the sludge outlet valve, it is necessary to remove the container from the generator after every second charge and thoroughly clean the perforated plate and bottom of the container. If this is not done, the sludge will gradually collect on the perforated plate and eventually plug the openings, preventing it from settling to the bottom.

■ 38. **Cold Weather Operation.**—*a. Starting generator.*—In cold weather considerable time may be saved in attaining operating pressure by using 200 pounds of caustic to 66 gallons of water in mixing the first batch of caustic solution. When operating pressure has been reached, the usual mixture of 200 pounds of caustic to 88 gallons of water may be used satisfactorily.

b. Shutting down generator.—In case the generator is to be shut down for some time and there is danger from freezing, precautions must be taken to remove all water from the generator. Points to check are power plant, aftercooler system, generator head assembly, generator water jackets, caustic pump, caustic mixing tank and lines, and water storage tank and lines. Antifreeze solution may be used in the power plant and aftercooler system.

■ 39. **Storage Pressure of Gas.**—Each group of hydrogen cylinders connected to the manifold should be filled to a pressure greater than the final desired pressure, since subsequent cooling of the gas will reduce the pressure in the cylinders. Under normal operating conditions, cylinders filled to approximately 2,150 psi gage pressure will have approximately 2,000 psi gage pressure when the gas has cooled to 68° F., which is the final desired pressure.

Section V

DESTRUCTION OF MATÉRIEL

■ 40. **General.**—For instructions concerning the destruction of matériel, see FM 4–187.

CHAPTER 10

MAINTENANCE OF M1 HYDROGEN GENERATOR AND EQUIPMENT

■ 41. **General.**—Frequent inspections of the plant should be made to locate points of excessive wear or material deterioration and to make appropriate corrections or changes before break-downs occur. This chapter deals with the most common maintenance problems found in the M1 hydrogen generator and the recommended solutions.

■ 42. **Caustic Pump.**—The principal items requiring attention on the caustic pump are packing, pistons, packing flanges, check valve gaskets, cross-head slide plates, and connecting rods. (See fig. 18.)

a. Replacing worn packing.—To replace worn packing in the caustic pump, proceed as follows:

(1) Shut off oil and remove oil line from cross-head slide.

(2) Rotate pump until cross head is as far forward as it will go.

(3) Remove cross-head slide.

(4) Loosen packing flange from cylinder.

(5) Rotate pump until cross head is as far back as it will go.

(6) Slide packing flange along piston to cross head.

(7) Examine piston and packing flange for signs of wear or presence of burs. If in bad condition, these parts should be repaired or replaced.

(8) With the aid of an ice pick, provided in the tool kit for this purpose, remove worn packing, being very careful that all is removed. If the generator is connected to a high pressure water system, turning on the water may help to blow out the worn packing.

(9) Put in new packing, following steps below:

(*a*) Place the rings of packing on the piston in the order in which they come in the package, being sure that the ring marked "bottom ring" is next to the cylinder. Place packing rings around the piston by spreading each ring at the cut and slipping it over the piston. Be sure that after each

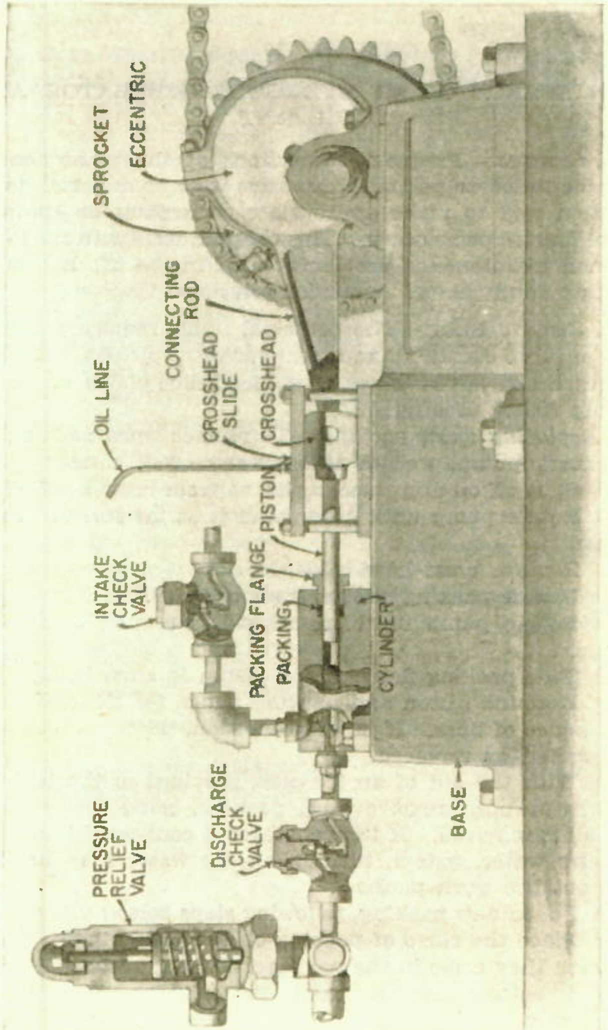

FIGURE 18.—Diagram of caustic pump.

ring is on the piston, it is adjusted so that the ends of the cut fit back into place properly.

(*b*) Force the rings into position, one at a time, being sure that the cuts in adjoining rings are not opposite each other. Cuts should be staggered 90°.

(10) Replace packing flange. Special precautions must be taken that the flange is tightened so that it is centered and alined with the piston. If one side of the flange is tightened too much, excessive wear will result. The end of the packing flange should be at least ¼ inch inside the end of the cylinder.

(11) Replace cross-head slide, taking care not to tighten the slide too tight.

(12) Replace oil line.

(13) Start pump and make further adjustments if necessary.

b. Replacing piston and packing flange.—To replace a piston and packing flange, proceed as described in *a*(1) to (7) above; then proceed as follows:

(1) Remove wrist pin from cross head and raise connecting rod back out of the way.
(2) Withdraw piston from cylinder.
(3) Slide packing flange off piston.
(4) Remove taper pin from cross head.
(5) Remove piston from cross head.
(6) Insert new piston in cross head.
(7) Insert taper pin and drive it into place.
(8) Slip new packing flange on piston.
(9) Slide piston into cylinder.
(10) Lower connecting rod into position.
(11) Replace wrist pin.
(12) Proceed as outlined in (*a*) (8) to (13) above.

c. Replacing check valve gasket.—To replace a check valve gasket, proceed as follows:

(1) Remove head from check valve.
(2) Remove ball guide from body of valve.
(3) Remove old gasket and carefully clean gasket seats.
(4) Insert new gasket and reassemble, taking care that the gasket is properly seated and the head securely tightened.

(5) After the check valve has warmed up from use, again tighten the head. All check valves should be examined frequently to see that the heads are tight. Proper tightening will result in fewer gasket failures.

d. Adjusting connecting rods.—To adjust connecting rods that become loose as a result of wear, proceed as follows:

(1) Rotate pump until the eccentric is in the best position for removing the nuts that hold the bearing parts of the connecting rod together, and remove these nuts.

(2) To take up the bearing, either remove some of the shims or grind down the spacer. In grinding the spacer, use a flat piece of glass and valve grinding compound.

(3) When proper adjustment of shims or spacer has been made, reassemble the connecting rod.

■ 43. AIR COMPRESSOR.—*a. Vacuum unloader.*—(1) *Breather holes.*—Failure of vacuum unloader to function properly is usually caused by clogging of the breather holes in the side of the vacuum chamber. *Be sure these holes are open at all times.* (See fig. 20.)

(2) *Regulating loading time.*—The time interval before the air compressor will load (start pumping) after the compressor is started can be regulated by the viscosity of the oil

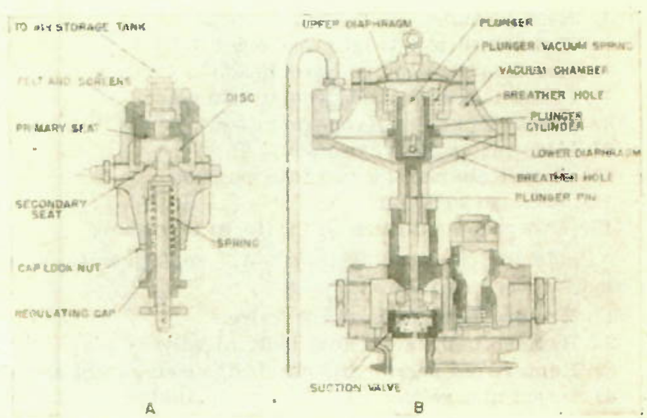

FIGURE 19.—Air-pressure unloader and regulator (A) and vacuum unloader (B).

in the plunger cylinder of the vacuum unloader. Heavy oil will slow the movement of the plunger, and light oil will permit it to move faster. If the compressor loads too soon, heavier oil should be used. Loading too soon will throw too heavy a load on the crankshaft of the compressor and is likely to break it. If the compressor requires too much time to load, lighter oil should be used. To change oil in the plunger cylinder, proceed as follows:

(*a*) Remove upper diaphragm cap and diaphragm.

(*b*) Remove plunger slowly so that oil is not carried out of plunger cylinder.

(*c*) Remove vacuum chamber and plunger vacuum springs.

(*d*) Remove, clean, and replace plunger cylinder, plunger pin, and lower diaphragm.

(*e*) Replace vacuum chamber and plunger vacuum springs.

(*f*) Fill plunger cylinder to within ¾ inch of the top with oil of the proper viscosity.

(*g*) Very slowly push plunger into plunger cylinder until plunger strikes bottom.

(*h*) Replace upper diaphragm and upper diaphragm cap.

(3) *Replacing diaphragms.*—If the vacuum unloader and air-pressure unloader fail to operate properly, remove and examine the diaphragms of the vacuum unloader. Replace if they are cracked or broken.

b. Air-pressure unloader and regulator.—(1) *Failure to function.*—Failure of the air-pressure unloader and regulator to function is usually caused by dirt. If it does not function properly, take it apart and wash the parts in gasoline. (See fig. 19.) If the cleaning does not correct the failure, check the diaphragms of the vacuum unloader as directed in *a*(3) above.

(2) *Regulating pressure in air storage tank.*—To regulate the pressure in the air storage tank, loosen cap lock nut. To increase pressure, screw the regulating cap *in;* to decrease pressure, screw the regulating cap *out.* When the desired pressure regulation is obtained, tighten the cap lock nut.

■ 44. CLUTCHES.—*a. General.*—The M1 hydrogen generator is equipped with four friction clutches: one 4-inch clutch on the caustic mixing tank countershaft for controlling the caustic agitator; one 7-inch clutch on the main drive shaft for operating the radiator fan and centrifugal water pump of the cooling system; and two 8-inch clutches for operating the caustic pumps. (See fig. 20.)

b. Adjusting.—To adjust a clutch to prevent slipping under load or for wear, proceed as follows:

(1) Loosen setscrew in toggle fulcrum ring.

(2) Turn adjusting ring clockwise until proper adjustment is secured.

(3) Tighten setscrew in toggle fulcrum ring.

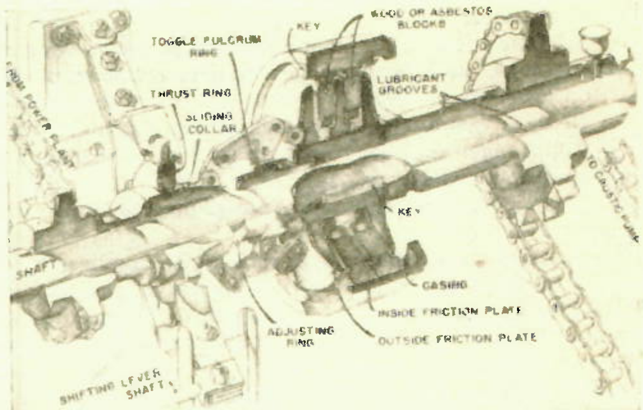

FIGURE 20.—Caustic pump clutch.

■ 45. SLUDGE OUTLET VALVE.—*a. Frequent replacement.*—The sludge outlet valve, which receives extremely hard wear, must be replaced frequently. The hard wear is due to tremendous drop in pressure through the valve as the valve is opened and closed. This wears away both the plug and the body of the valve.

b. Installation.—Install the valve so that the two drilled holes in the plug shank will be on the low pressure side of the valve when the valve is closed. Fill the lubricator with special sludge valve lubricant, and screw it into the plug shank. Open the valve, turn the lubricant screw five turns to lubricate the valve. and operate the valve.

■ 46. OTHER HIGH PRESSURE VALVES.—*a. General.*—As a result of high pressure, heat, frequency of use, and the adverse conditions under which they are used, the various valves on the plant require frequent replacement of gaskets, valve seats, and valve stems.

b. Replacing valve seat and stem.—When a valve seat or stem becomes worn and replacement is necessary, proceed as follows:

(1) Relieve all pressure from the line and open valve.

(2) Unscrew bonnet from body of valve and remove seat with special valve seat removing tool.

(3) Replace worn seat with new seat, being careful to tighten it securely. The threads of the seat should be well oiled before it is screwed into the body.

(4) Turn handle of valve stem clockwise in the bonnet until the threads of the stem are free from the body of the bonnet.

(5) Take off valve handle retaining nut and remove handle.

(6) Pull stem out of bonnet.

(7) Check condition of packing and replace if necessary.

(8) Insert new stem through bonnet, and attach handle and handle retaining nut.

(9) Turn the handle counterclockwise as far as it will go. If this is not done, the valve will be damaged when the bonnet is replaced.

(10) Check condition of gasket and replace if necessary.

(11) Replace bonnet and tighten, being careful that the gasket is seating properly.

c. Replacing gasket.—To replace the gasket between the bonnet and body of a valve, proceed as follows:

(1) *Relieve all pressure from the line and open valve.*

(2) Unscrew bonnet from body of valve.

(3) Remove old gasket and carefully clean gasket seats.

(4) Insert new gasket.

(5) Turn valve stem counterclockwise as far as it will go.

(6) Replace bonnet and tighten, being careful that the gasket is seating properly.

(7) As soon as the valve becomes hot from use, check the bonnet for tightness.

d. Inspecting valves.—All valves should be checked frequently to insure that the bonnets are kept tight. Proper inspection and maintenance of valves will result in fewer gasket failures and plant shut-downs.

■ 47. **Lubrication.**—*a. Power unit.*—Lubricate according to instructions in the manual provided with each unit.

b. Caustic pump.—(1) *Cross heads and slides.*—The cross heads and slides of the caustic pump are lubricated from the caustic pump oil reservoir. Use the same oil as used in the power unit. Adjust rate of flow by means of sight feed valve.

(2) *Eccentrics.*—The eccentrics are lubricated by means of grease cups. Use No. 3 sodium soap (fiber) grease. Turn grease cups about two turns every hour of operation. Do not use too much grease, since an excessive amount of grease will result in the eccentrics running hot until the excess is used up.

(3) *Pillow block bearings.*—The pillow block bearings are packed with the proper lubricant at the factory and need to be lubricated only after every 50 million revolutions. Use grease, Specification NLGI 2–110.

c. Air compressor.—Use good grade motor oil; SAE No. 30 for summer and SAE No. 10 for winter. Add oil as needed. Change after every 200 hours of operation. Do not oil compressor anywhere but through gage. Keep oil gage cap tight.

d. Caustic mixing tank.—Four oilholes are located on top of the tank. Oil daily with same grade of motor oil as used in power unit.

e. Cooling system.—One grease cup is located on the shaft turning the radiator fan and water circulating pump. Turn cup about one turn every 8 hours of operation. Use No. 3 grease.

f. Clutches.—(1) *Casing with sleeve.*—The casing with sleeve and sprocket must be well lubricated at all times. One grease cup is provided in sleeve. Use No. 3 grease.

(2) *Sliding collar.*—Oil sliding collar frequently with motor oil in places where it runs on the shaft and where it carries the thrust collar.

g. Air hoists.—Keep piston rods clean and well oiled while in operation. Use same grade oil as for power unit. If plant is to be shut down for some time, clean piston rods and give them a coating of grease. Keep guides for air hoist piston rod on sludge outlet valves clean and well oiled with motor oil at all times.

h. Chain drives.—Keep chains clean and well oiled with motor oil at all times.

i. Sludge outlet valves.—(1) When in service, lubricate valves by giving lubricant screw one full turn after every 5 minutes of operation.

(2) After operation, give lubricant screw 20 full turns. The valves must be open when this is done.

(3) Should a packing leak develop, remove the packing screw at the side of the valve, insert one stick of No. 611 plastic packing, and slowly turn the packing screw until the leak stops.

j. Crane assembly.—Turn grease cups down as needed. Use No. 3 grease. Keep piston rod of air hoist clean and well oiled with motor oil at all times. Oil pulleys as needed.

k. Line shaft bearings.—All line shaft pillow block bearings are prepacked antifriction bearings and need to be repacked only after every 50 million revolutions under ordinary conditions. If operating in windy, dusty country, bearings should be repacked more often. Use grease, Specification NLGI 2–110.

CHAPTER 11

SAFETY PRECAUTIONS AGAINST FIRE

■ 48. PRECAUTIONS AGAINST IGNITION.—All sources of ignition must be kept a safe distance from any volume of hydrogen. The precautions for the prevention of fire discussed in FM 4–187 will be observed at all times.

■ 49. ACTION IN CASE OF FIRE.—In case of fire at the generator or the hydrogen cylinder stacks, the action prescribed in FM 4–187 in case of fire at a balloon site will be followed at the hydrogen generator. In the event of fire at the generator, the generators should not be blown down to relieve the pressure in them. Blowing down the generators would release a large amount of hydrogen into the atmosphere, which would create a very dangerous condition and might result in a serious explosion.

■ 50. COMBATING HYDROGEN FIRE.—The most effective way to combat a hydrogen fire is to shut off the hydrogen at the source. The only fire extinguisher which can be used effectively against a hydrogen fire is a CO_2 extinguisher.

CHAPTER 12

SAFETY PRECAUTIONS IN MANUFACTURING HYDROGEN

■ 51. PRECAUTIONS.—The following precautions should be observed in operating the high-pressure hydrogen generating plant, and in handling materials and equipment used in hydrogen generation:

a. Air should be flushed from the generator and lines at the start of operation and before any gas is stored, by opening the drain valves beneath the generator, sludge separator, water separator, and drying cylinder.

b. Care must be exercised to keep all joints and connections gastight.

c. A careful periodic check must be made for leaks in all lines by applying a soapy water solution with a brush. A match should *never* be used to test for leaks.

d. Special clothing for crew members discussed in paragraph 33 will be worn.

e. Any materials containing linseed oil should not be used in making repairs to the generator. The special thread compound furnished with the generator should be used.

f. Ferrosilicon should be shipped in airtight drums and stored in dry, well-ventilated compartments.

g. Ferrosilicon and caustic should not be stored together in such a way that a mixture may result from damaged or broken containers.

h. Tests for the purity of the hydrogen produced should be made at least once every 8 hours.

i. If generation is carried on indoors, the building should be well ventilated. The engine should be provided with a flame arrester on the exhaust system and rubber caps on the spark plugs and ignition system to avoid the possibility of igniting any hydrogen-air mixture which may exist within the building. To avoid producing sparks, all personnel using tools or metal equipment should be warned not to strike metal to metal.

j. A first-aid kit containing plenty of absorbent cotton, boric acid ointment, and a saturated solution of boric acid should be kept near the generator. Vinegar or acetic acid also may be supplied. This kit should be inspected each day and the contents replenished if necessary. A bucket of clean water should be kept on hand.

k. Caustic that gets on the skin or clothing of individuals operating the hydrogen generating plant should be removed immediately with clean water, either by submerging the affected area in water or dousing it with water. The skin and eyes should then be treated with boric acid solution. Vinegar or acetic acid may be used on the skin, but will not be used in the eyes. The affected area should not be rubbed. Persons with eye burns or any serious skin burns will be taken to the hospital immediately for treatment.

l. In case repairs of any kind are to be made, all pressure must be released from the part to be repaired.

m. If repairs are to be made to a caustic pump while the engine is running, the caustic pump clutch will be blocked in such a manner that it will be impossible for the pump to start accidentally.

■ 52. HANDLING, STORING, AND TRANSPORTING CYLINDERS.—The instructions contained in FM 4–187 concerning the identification of cylinders, handling of cylinders, defective valves, damaged cylinders, and shipment and storage of cylinders are applicable to the hydrogen generator, and will be observed at all times.

CHAPTER 13

HELIUM PURIFICATION

■ 53. GENERAL.—Since the supply of helium is limited, it will not ordinarily be used to inflate balloons in a barrage. However, it is used to inflate balloons used for training purposes. Diffusion of air through the balloon fabric reduces the purity of helium in a balloon, thereby decreasing the lift. When it becomes necessary to deflate a helium-filled balloon, because of low gas purity, insufficient lift, or other reasons, the helium is purified and reclaimed through the use of a helium purification plant. Hydrogen-filled balloons of low gas purity are deflated by allowing the gas to escape into the atmosphere, and no attempt is made to reclaim the hydrogen.

■ 54. PRINCIPLES OF HELIUM PURIFICATION.—The principal impurities likely to be found in helium gas are oxygen and nitrogen. Oxygen, nitrogen, and helium will liquefy at —182°, —196°, and —268° C., respectively, at the pressures developed in the helium purification plant. Therefore, the oxygen and nitrogen may be liquified and drained off, leaving the purified helium. The helium purification plant contains an air cycle and a helium cycle. The purpose of the air cycle is to produce liquid air which in turn produces a sufficiently low temperature to liquefy the oxygen and nitrogen impurities. The purpose of the helium cycle is to provide means for separating the impure helium into liquid impurities and gaseous purified helium, and for removing the impurities.

CHAPTER 14

HELIUM PURIFICATION PLANTS

■ 55. TYPES.—Two types of helium purification plants are now in use. One type is mounted on a railway car and is referred to as helium purification plant, car No. ( ). Car No. 1, now in use, is capable of purifying 5,000 cubic feet of helium per hour. The other type is mounted on a trailer and is referred to as a mobile helium purification laboratory, type B–1 (originally type A–3). This laboratory is capable of purifying 1,500 cubic feet of helium per hour. An explanation of the principles of operation of these plants and instructions for operation may be found in A. C. Technical Order No. 16–1–5, 1 December 1941.

■ 56. PERSONNEL.—*a. Helium purification plant, car No. 1.*—The recommended size of the crew for operating this plant is six enlisted men, including the noncommissioned officer, who is in charge of the operation. The other five men are employed as follows: one man to operate the air compressor; one man to operate the helium compressor; one man to operate the control panel; and two men to attach the source of impure helium to the helium compressor, and to attach the manifold to cylinders for collecting the purified helium. Due to the heat in the air compressor room, the air compressor operator may alternate with the helium compressor operator, or may be relieved by the noncommissioned officer in charge.

b. Mobile helium purification laboratory, type B–1.—The recommended size of the crew for operating this laboratory is seven enlisted men, including a noncommissioned officer, who is in charge of the operation. The other six men are employed as follows: one man in the compressor room to operate the air and helium compressors; one man to operate the control panel; two men to attach the source of impure helium to the helium compressor, and to attach the manifold to cylinders for collecting the purified helium; and two men to handle the helium cylinders. Owing to the heat in the compressor room, the compressor operator may alternate with the control panel operator, and may also be relieved by the noncommissioned officer in charge.

APPENDIX

DAILY INSPECTION AND LUBRICATION RECORD, M1 HYDROGEN GENERATOR

Plant serial No. W–____________ Date________________194__ AM PM

POWER PLANT

Time started	----	----	Total running time to date	---- hr ---- min
Time stopped	----	----	Total running time today	---- hr ---- min
Running time (hr and min)	----	----	Total running time end of day	---- hr ---- min

Gasoline		*Oil*	
Beginning of day	---- gal	Level, start	----
Amount added	---- gal	Pressure—warm	----
Total in tank	---- gal	Oil added	---- qt
Amount end of day	---- gal	Total hr run since last change	---- hr ---- min
Amount used today	---- gal		

Battery

Charging rate ---- amp
Water level ----

LUBRICATION

Grease cups		*Oil*	
Caustic pump No. 1 clutch	----	Agitator drive shaft bearings	----
Caustic pump No. 2 clutch	----	Cross head oilers	----
Agitator clutch	----	Air hoist piston rods	----
Cooling pump and fan clutch	----	Clutch thrust and sliding collars	----
Cooling pump and fan shaft	----	Drive chains	----
Caustic pump connecting rods	----		
Crane bands, air-hoist slip	----		

Other parts

Sludge valves	----
Power take-off clutch	----
Date pillow block bearings greased	----

INSPECTION

Vacuum unloader breather holes	----	Gear case oil level	----
Power plant radiator water level	----	Air compressor oil level	----
V-belt drives	----	Pump connecting rods	----
		Clutch thrust collars	----

REMARKS: ______________________________

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(Maintenance man) (Officer in charge)

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