Coast Artillery Power Plants

Bolling W. Smith

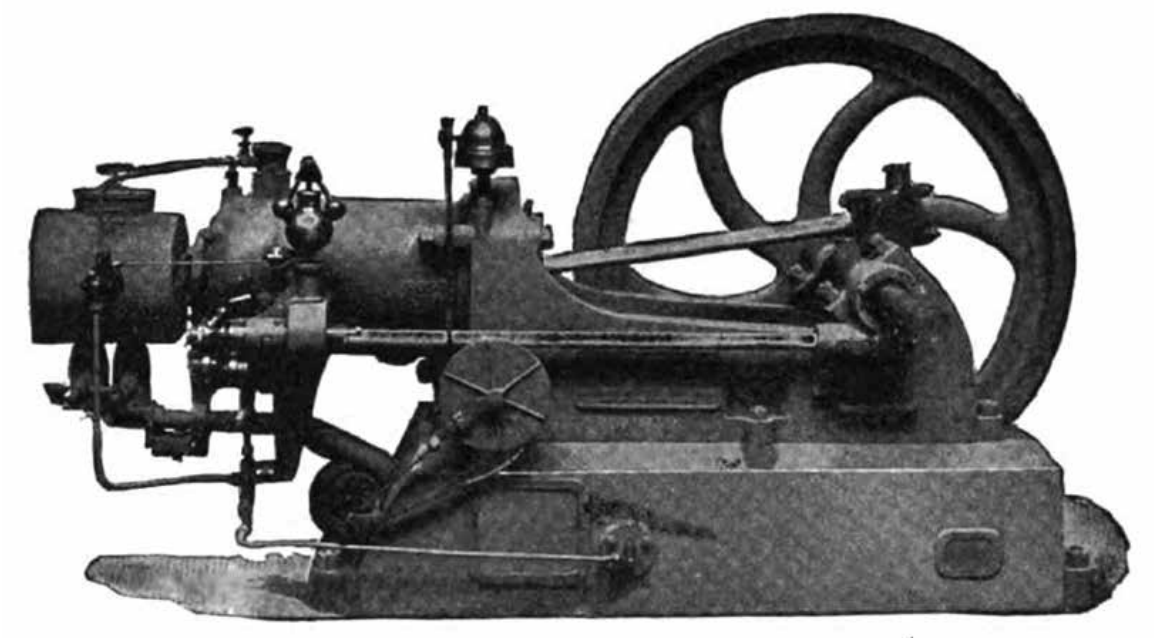
This article is a revised, illustrated version of Bolling Smith's "Emplacement Powerplants," article originally published in the *Coast Defense Study Group Journal* Vol. 7, Issue 3, August 1993, pp. 45-50. Several illustrations are from Lorimer D. Miller, "The 25 Kw Gasoline Driven Generating Set Used in the Coast Defenses of the United States", *The Journal of the United States Artillery,* Vol. 48 No.1, July-August, 1917, pp. 54-79.

By 1900, electricity had become a vital necessity for the Coast Artillery. It was used to traverse and elevate some of the large guns, to light emplacements, to operate ammunition hoists, to power searchlights, to control submarine mines, and for communications, in addition to standard garrison uses. Even when the power came from storage batteries, these had to be charged from generators. The requirement that coast defenses be self-contained resulted in power rooms being included in most batteries and mining casemates, and separate searchlight powerhouses were constructed.

Because direct current (D.C.) technology developed faster than alternating current (A.C.), and because D.C. was necessary to charge storage batteries and operate searchlights, the Engineers preferred D.C. power until the final batteries of the Taft era were built, when the ability to utilize commercial A.C. power in Los Angeles led to the first A.C. powered emplacements. Even in WW-II, D.C. plants were installed to power searchlights.

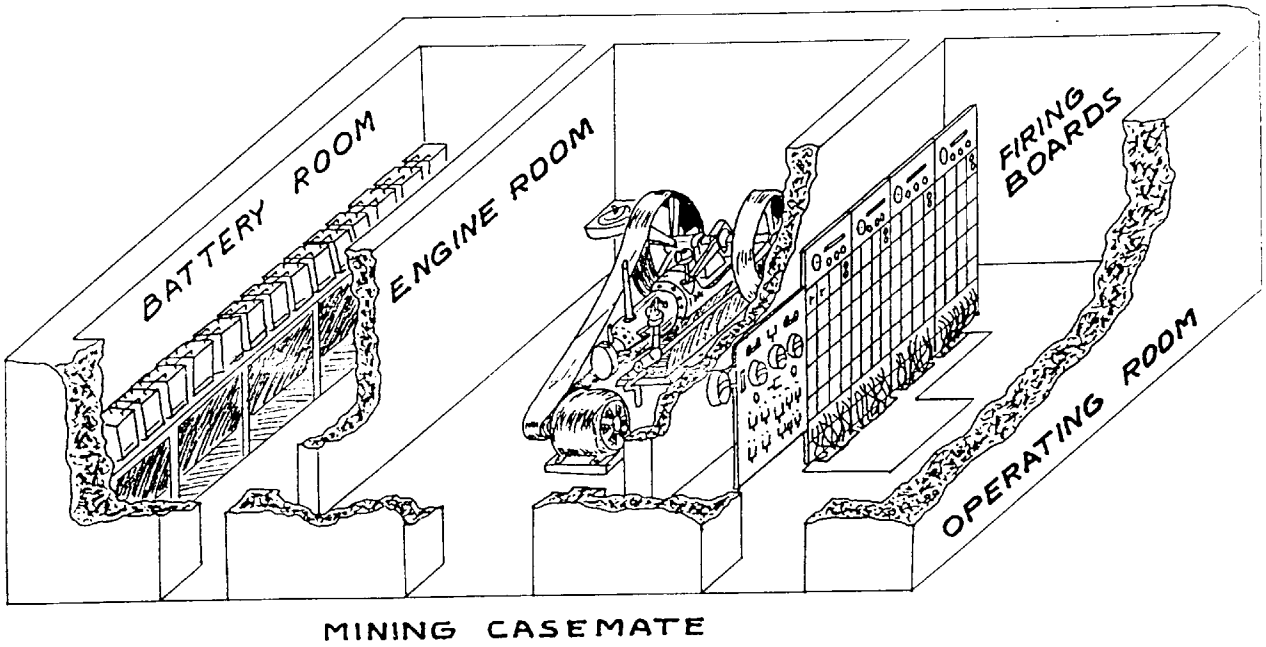
Since power plants were less than totally reliable, and were at any rate subject to hostile fire, it was deemed essential that any system have a separate reserve, in the event the primary source was disabled. Initially, steam generating plants were generally used in the emplacements, but the Hornsby-Akroyd oil engine was also extensively purchased, especially during the Spanish-American War, when a wide variety of power plants, steam and kerosene, were hastily purchased and installed, often in small powerhouses quickly constructed behind the emplacements rather than inside them. Kerosene engines were particularly well suited to locations where abundant supplies of good water for steam plants were not readily available. Banks of storage batteries were used as reserves, periodically charged from the primary plant, and used for short periods, when it was uneconomical to operate the engine and generator. Since both steam and kerosene engines required some time to start up, this was an important factor. Although these power plants were hardly standardized, they generally were of small capacity, in the range of 5 kilowatts (kW), and were usually intended only to provide power for lighting, and that at a level that a decade later would be considered totally inadequate.

The Hornsby-Akroyd oil engine was a four-cycle kerosene-fueled engine built by the De La Vergne Refrigerating Machine Company, New York, N.Y. It was manufactured in a wide range of sizes, from 1 $^1/_4$ to 125 horsepower (HP). It featured large flywheels to help maintain speed regularity. In 1911, 28 Hornsby-Akroyd engines remained in place in the coast defenses, with an average rating of 16 HP., producing approximately 10 kW of electric power, usually through a belt driven D.C. generator. Al`though figures are not available as to how many engines were purchased, it is reasonable to assume that many of the smaller engines, over a dozen years old, would have been replaced by 1911. This engine was well suited for small applications, where a steam plant would not have been practical, especially in mining casemates. The kerosene engine could be started up more quickly than a steam engine, but still had a startup time of 8 to 18 minutes, depending on the size of the engine.



The Hornsby-Akroyd oil engine. http://vintagemachinery.org/mfgindex/imagedetail.aspx?id=5986

In the early emplacements, the power room and storage battery rooms were well protected, in the interior of the emplacement; so much so that their location, coupled with the poor ventilation of the early emplacements, resulted in so much condensation that the electrical equipment deteriorated rapidly. The solution seemed to be to bring the plants out into temporary structures outside of the emplacements, where adequate ventilation was possible, and to replace the plants in their protected locations in the event of hostilities. In the inevitable nature of things, however, the old power rooms quickly became utilized for other functions, and had a hasty return been decided on, there would have been no place to return them to. This problem was finally resolved around 1903, when it became the policy to design all new emplacements with power rooms which were both well ventilated and well protected.



A Hornsby-Akroyd oil engine used for the water pumping system at Fort St. Phillip near Buras, Louisiana

In 1906, a sub-committee of the Taft Board recommended central, steam powered, D.C. power plants for coast defenses. Smaller D.C. oil or gasoline power plants were recommended as reserves for individual or close groupings of searchlights or emplacements, depending on local conditions, replacing the storage batteries whose expense and maintenance had finally proven too great. Realizing Congress would be slow to appropriate the funds for the central plants, Col. Fredrick V. Abbot, an assistant to the Chief of Engineers, determined to install the reserves first, and assigned two officers to find a satisfactory internal combustion engine to power these generators. The two fuels available were gasoline and kerosene, frequently referred to as gas and oil. Kerosene was the preferred fuel, as there was less danger of fire, a not inconsiderable advantage in combat. Additionally, the Coast Artillery had experience with the Hornsby-Akroyd oil engines, which were already in service. Offsetting this advantage, however, were significant disadvantages. Kerosene engines required considerable preheating before starting, and even then were often difficult to start. Any kerosene engine adopted, then, must be quick starting. Gasoline engines, on the other hand, also had drawbacks, in addition to their more volatile fuel. In particular, speed regulation was a problem with early gasoline engines. Diesel engines had not progressed sufficiently at this date to even be considered.

Two oil engines were evaluated, the Mietz and Weiss 10 kW engine, and the De La Vergne 25 kW engine. The Mietz and Weiss was a two cylinder, hot chamber engine, requiring ten minutes preheating before starting. Even then, despite the use of compressed air, it could never be started without great difficulty. On one occasion, a steam line was run into one cylinder in an unsuccessful attempt to start the engine, presenting the interesting picture of an internal combustion engine operated from a steam boiler. This engine was installed in Fort Banks, Mass., but was never really satisfactory. The second oil engine tested was ordered from the De La Vergne Machine Company, maker of the Hornsby-Akroyd engine. The four cylinder engine was under construction for over a year, and when completed was sent to Fort Monroe for testing. It had several unique features, including placing the generator between the two pairs of cylinders, so that it could be run at half capacity by using only two of the cylinders,

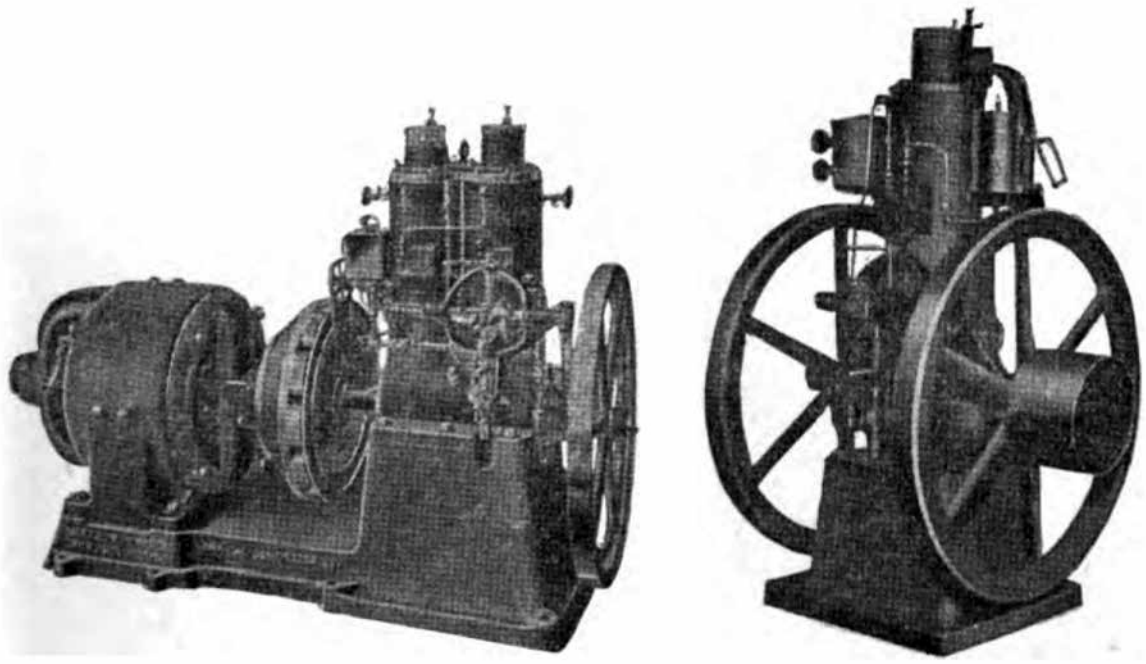


FIG. 3. 10 KW. KEROSENE SET 2096
(MIETZ & WEISS, NEW YORK CITY)

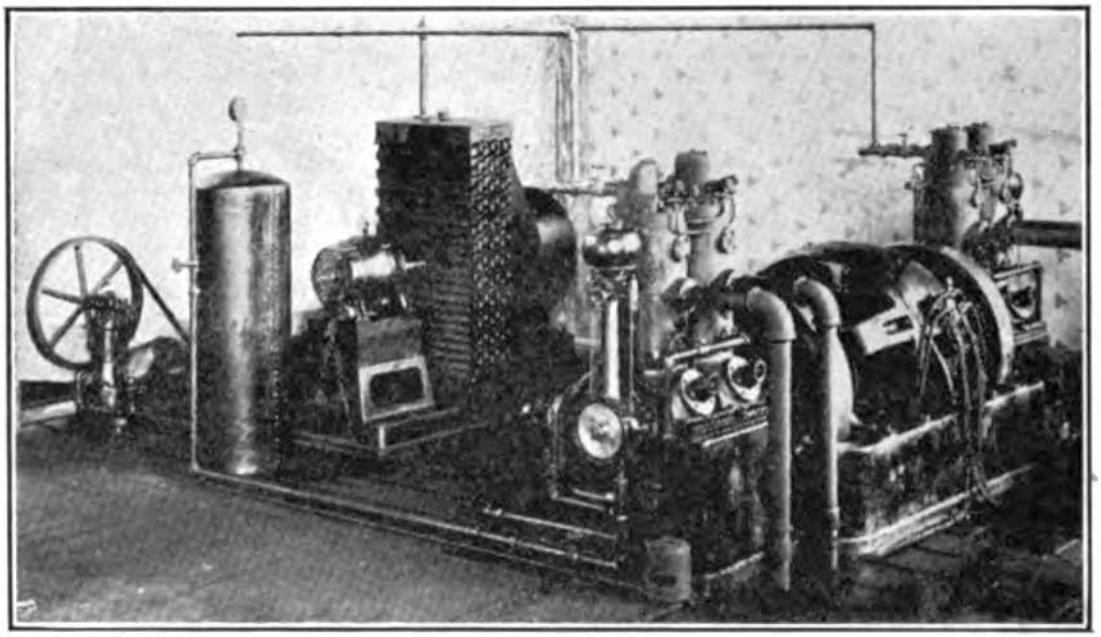


FIG. 4. 25 KW. KEROSENE SET 2097
(DE LA VERGNE MACHINE COMPANY, NEW YORK CITY)

thereby saving fuel. By the time it was finished, however, an improved gasoline engine had been developed, and proved so satisfactory that oil engines were no longer seriously considered.

The first gasoline engine evaluated was built in 1906 by the Westinghouse Company of Schenectady, N.Y., an experienced firm. The General Electric Company (G.E.), which did not build engines at this date, supplied the generator. One of these models had already been installed in Fort Wool, Va., during the 1905 maneuvers. The three-cylinder engine was comparatively crude, and several changes were made, including replacing the single throttle with a throttle for each cylinder in an effort to improve regulation. An unusual system of cooling the water was used; the fresh water was in an sealed loop, and flowed from the engine to an inner tank, surrounded by an outer jacket, through which flowed salt or other impure water. This improved model was installed at Fort Standish, Mass., but it had several insurmountable defects. The poor regulation obtained with three cylinders showed that four cylinders were necessary, and the need for twice as many water pumps was a major drawback. About the same time, a 25 set was purchased from the Westinghouse Machine Company, East Pittsburgh, Pa. This engine was installed in Fort Revere, Mass., where it proved an excellent engine, but unsuited to the particular conditions of coast defense, since it required ten feet of headroom to remove the cylinders and the normal height in the emplacements was only seven feet. The floor at Fort Revere was excavated two feet to allow the installation, but in too many emplacements the water table was too close to floor level to allow this solution.

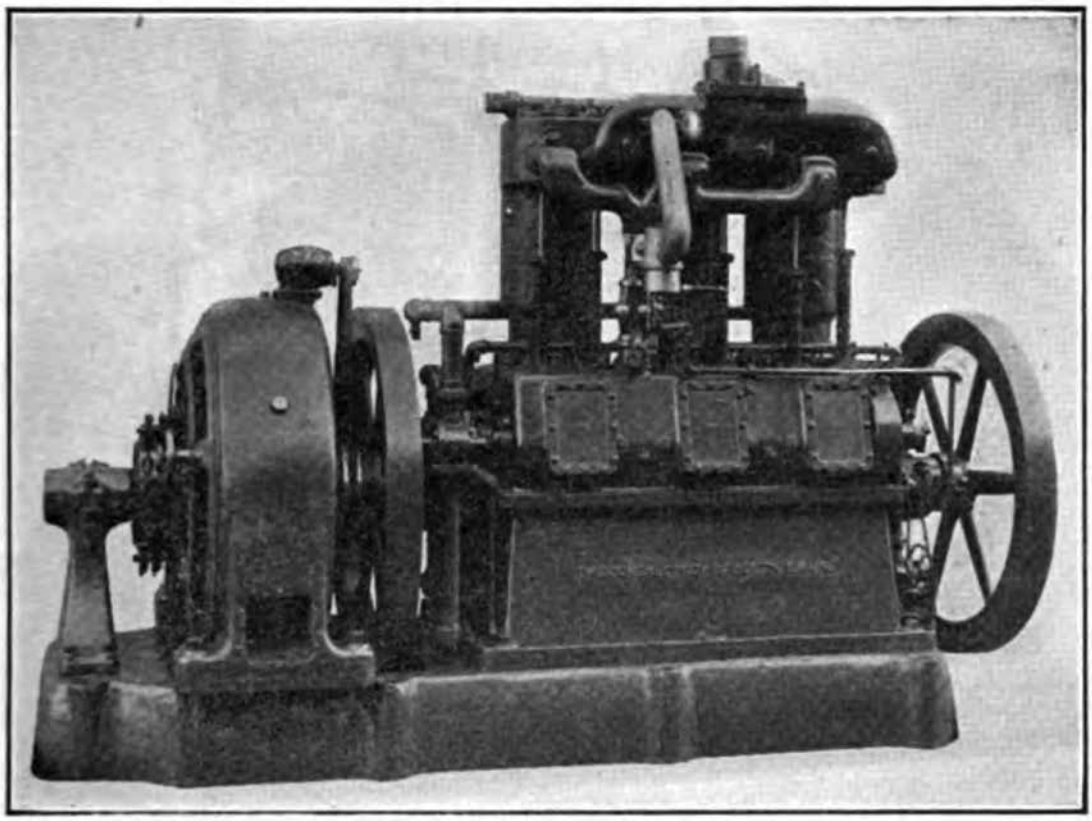


FIG. 1. 25 KW. GASOLINE SET 2094
(WESTINGHOUSE COMPANY, SCHNECTADY, N. Y.)

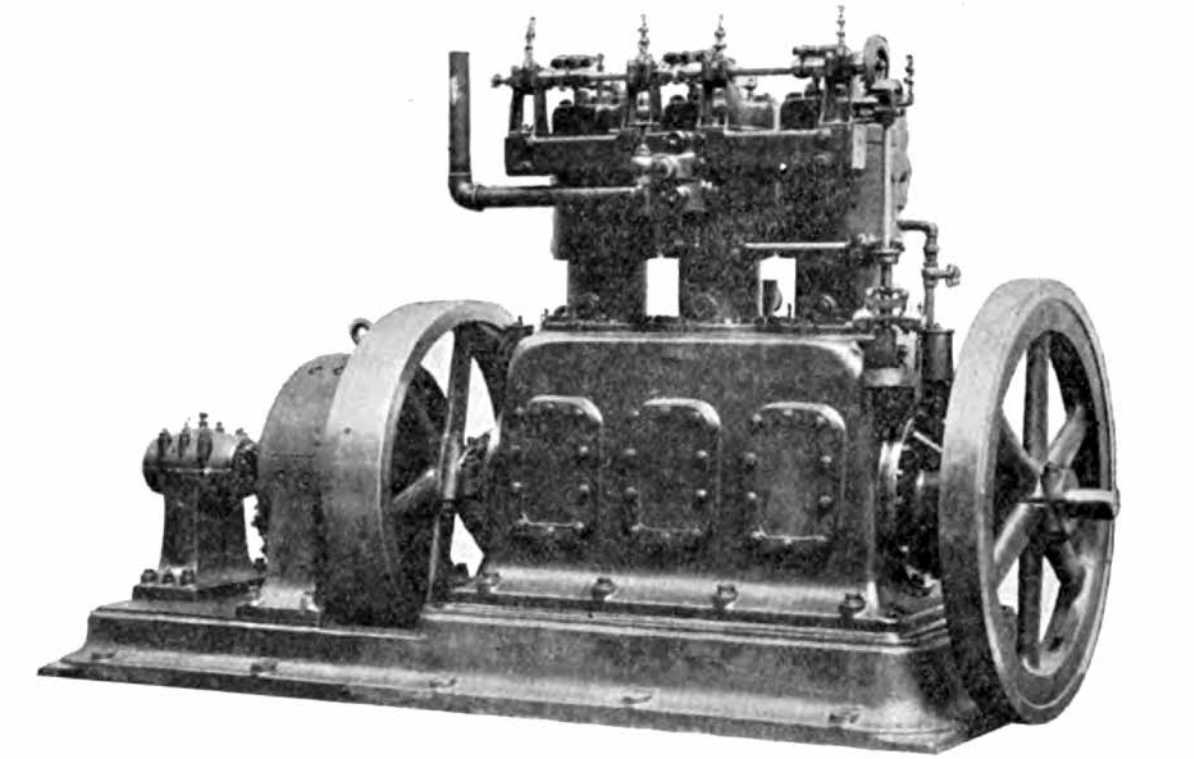


FIG. 2. 25 KW. GASOLINE SET
(WESTINGHOUSE MACHINE COMPANY, EAST PITTSBURGH, PENN.)

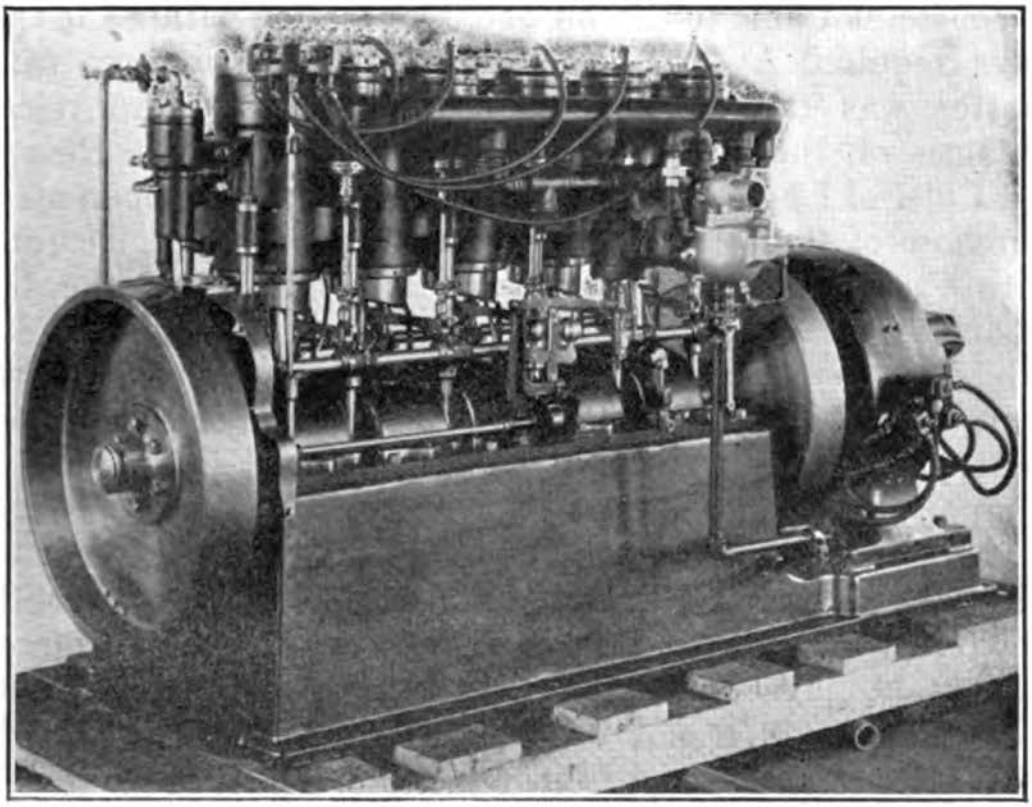


FIG. 5. 25 KW. "DOCK" GASOLINE SET 2098
(NEW YORK SAFETY STEAM POWER COMPANY, HOPE VALLEY, R. I.)

In June 1907, a new engine appeared which seemed to be the answer. The five-cylinder "Dock" engine, invented by Mr. H. Dock and manufactured by the New York Safety Steam Power Company, Hope Valley, R.I., seemed ideal. Light and compact, it offered excellent regulation, and promised durability and efficiency. The search seemed over, and specifications for bids on sixty engines were issued, tailored to the Dock engine. Everything seemed settled until the General Electric Company submitted a bid for an engine exactly like the five cylinder Dock engine, but 20 per cent cheaper, and in addition, offered a four-cylinder version at a further ten per cent reduction. The problem was that the makers of the Dock engine had produced a working prototype, while G.E. had never built a four or five cylinder engine, and certainly could not submit one in operation within the thirty days required by the specifications.

Now, however, events took an unexpected turn. The Chief of Engineers decided to give General Electric an order for ten four cylinder engines, despite their failure to win the contract. The makers of the Dock engine, in the meanwhile, despite the success of their prototype, were unable to build an acceptable second engine. Six engines were built and found unsatisfactory before the factory was destroyed by fire and the company went bankrupt. Ironically, all the rejected models were the product of established manufacturers, while in the end, the four cylinder by unproven G.E. was adopted as the standard, and between 1908 and 1917, 270 of these sets were installed in coast defenses.

As issued, the G.E 25 kW generating set consisted of a gasoline engine, direct coupled to a D.C. generator, and a radiator. Both engine and radiator could fit through a standard three-foot emplacement doorway, and the cylinders could be removed within a seven foot headroom. The first fifteen engines were required to be semi-transportable, and the weight limit of 4000 pounds meant that the base had to be made of bronze, but subsequent engines had cast iron bases. These sets proved to be durable, virtually foolproof, and suitable to a wide range of climates. The only complaint was their noise level, and several minor changes were made to make them quieter. The gasoline engine, designated Type GM-12, was a vertical cylinder, four cycle model, with maximum output of 54 HP at the two

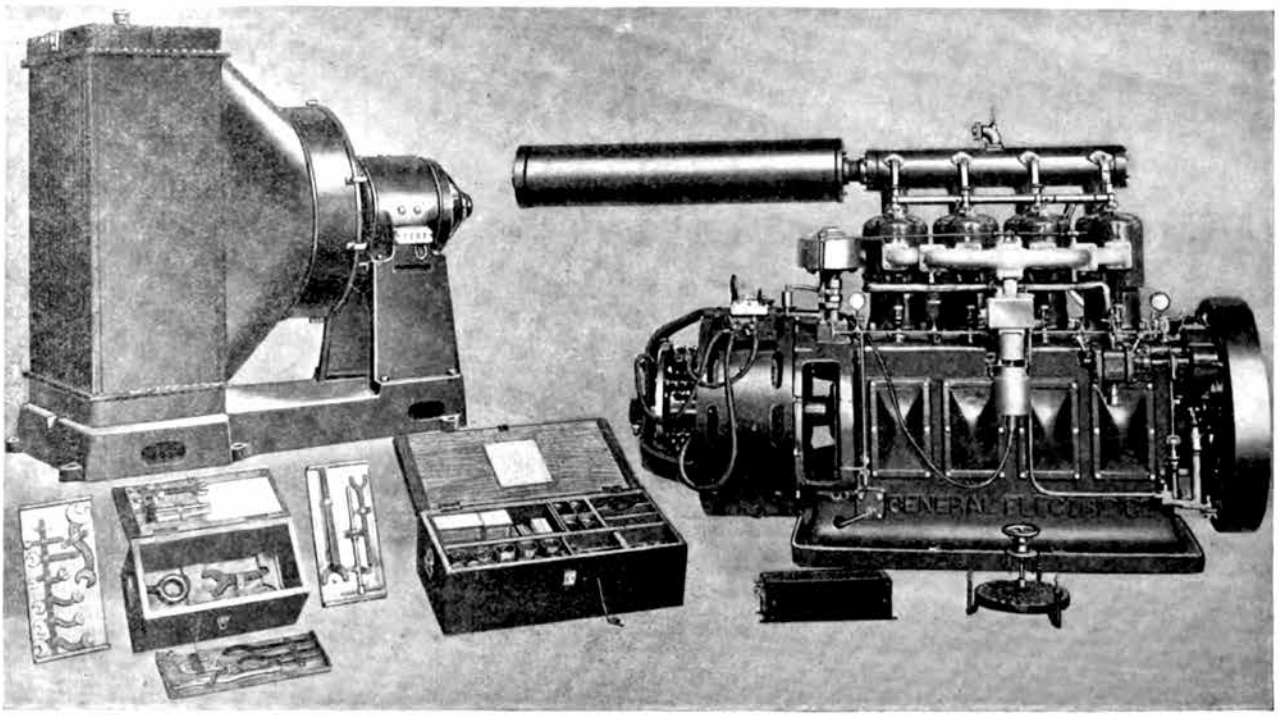


Fig. 7 Accessories to the General Electric Company's 25 Kw. Gasoline Set

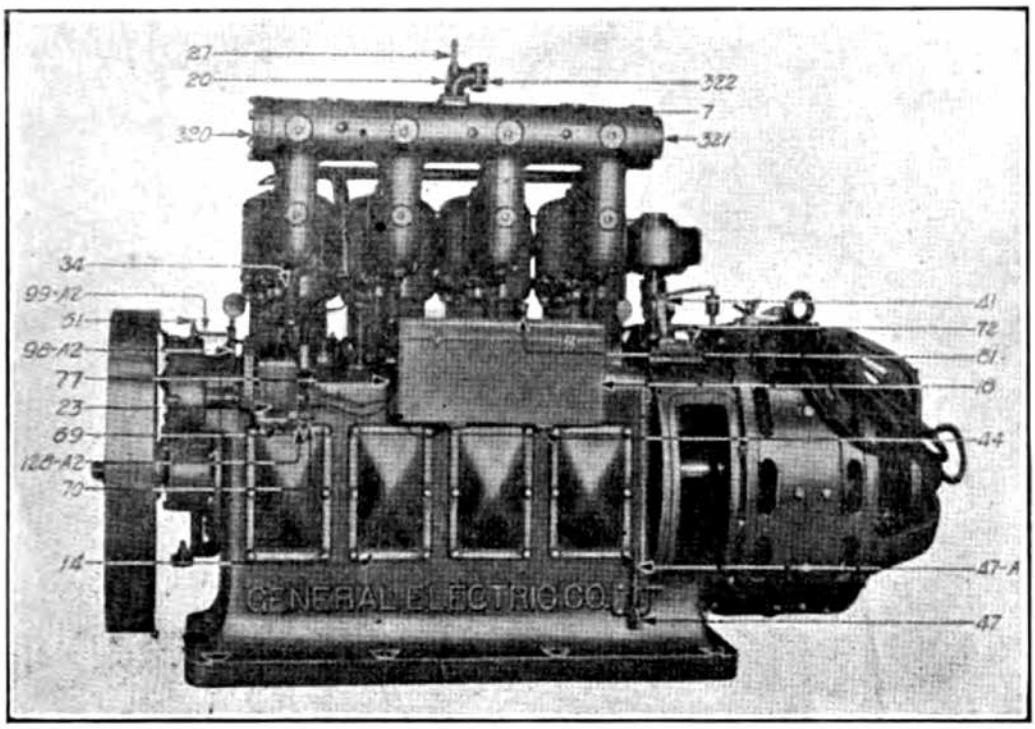


Fig. 6. 25 Kw. Gasoline Set—Ignition Side 2000
(General Electric Company, Schnectady, N. Y.)

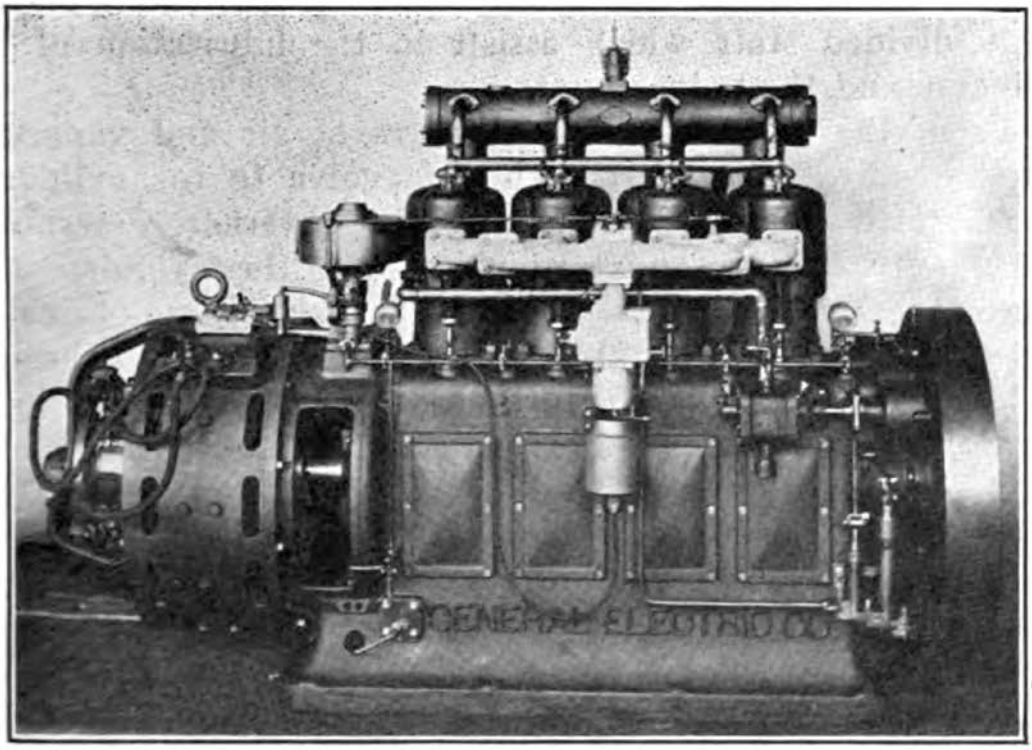


Fig. 10. Carburetor Side 2103

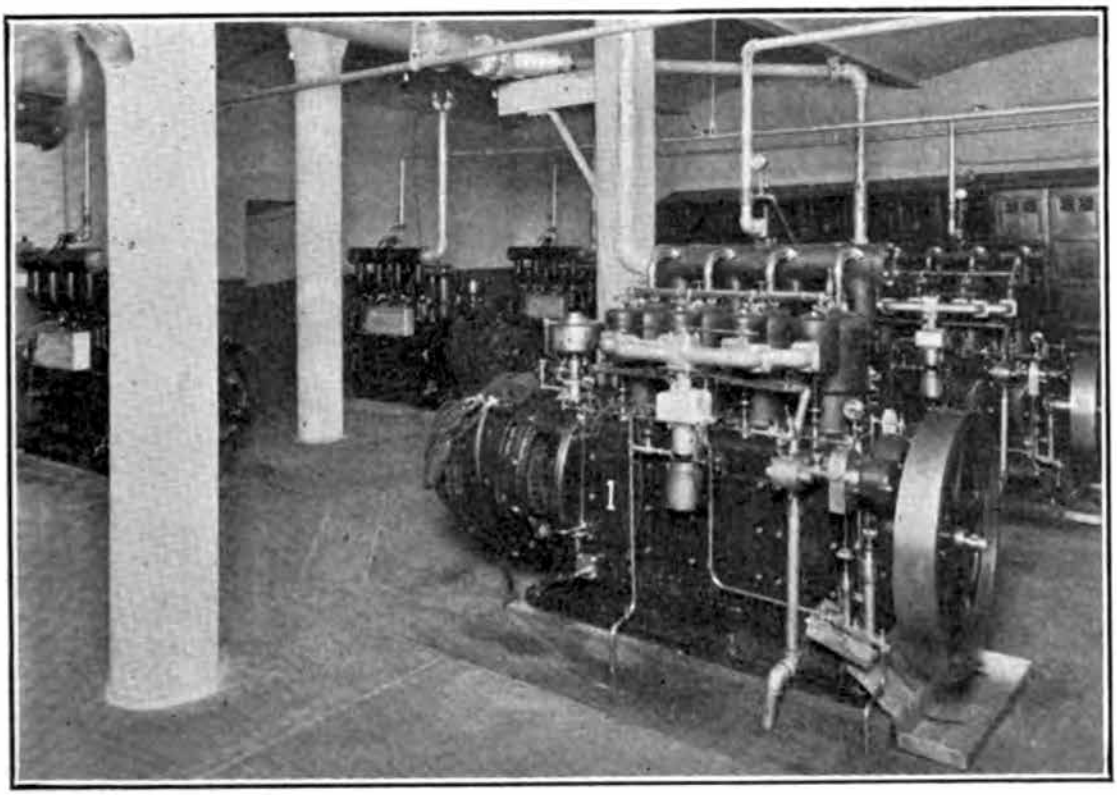


FIG. 16. CENTRAL POWER PLANT, FORT H. G. WRIGHT, NEW YORK 2109

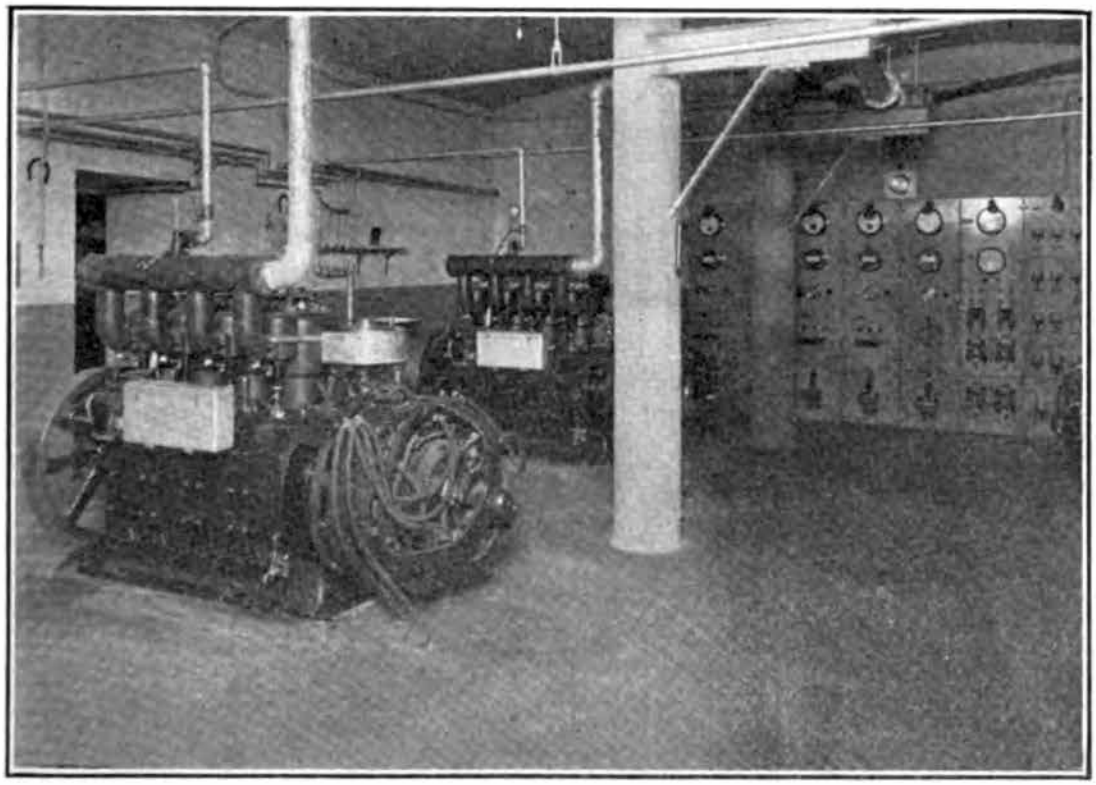


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FIG. 17. CENTRAL POWER PLANT, FORT H. G. WRIGHT, NEW YORK, SHOWING SWITCHBOARD

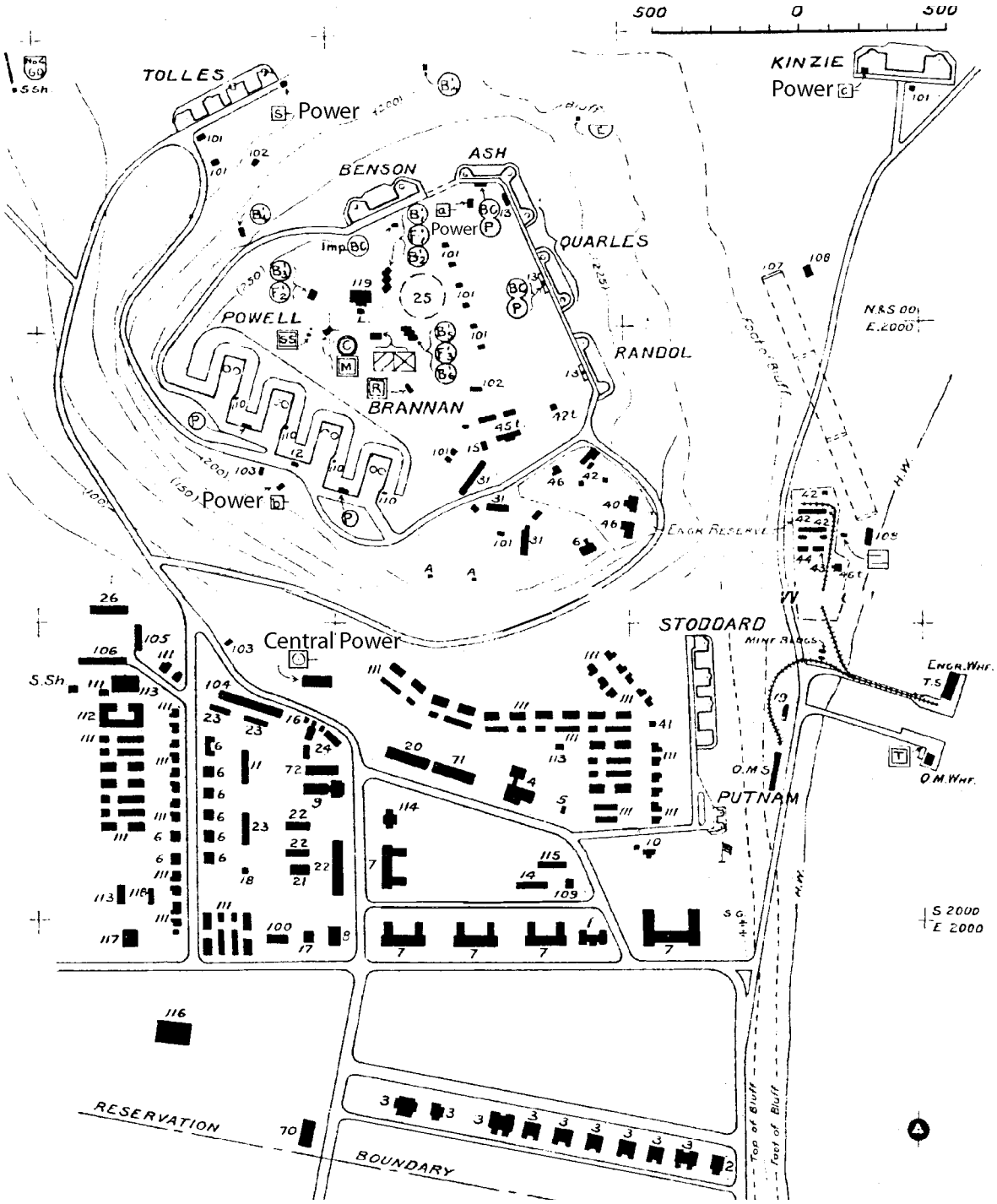
hour overload rate and a continuous rating of 43 HP. The speed varied from 560 rpm at no load to 575 rpm at full load. The cylinders were 7 1/4 inch diameter x 7 1/2 inch stroke. Fuel was supplied from a 370 gallon tank buried about two feet below ground level, outside of the emplacement. The use of a fuel pump avoided the fire hazard of a gravity feed system; as soon as the engine stopped, the gasoline would run back down into the outside tank. A hand pump was used for starting the engine. The carburetor was equipped with a resistance heating unit to prevent carburetor icing when starting in cold weather, and with a valve to draw preheated air from the crankcase, thereby also passing the products of combustion out through the cylinders and the exhaust, so that they would not leak out into the power room. The throttle, located between the carburetor and the "T" cylinder heads, was controlled by the fly-ball governor. These parts were responsible for the excellent regulation of the engine, which proved better than previously thought possible from a gasoline engine.

The ignition utilized a low voltage A.C. magneto, a make-and-break mechanism, a step-up transformer, and a high voltage distributor. Since the magneto would not produce enough current to operate the spark plugs until the magneto was up to speed, dry cells were supplied, along with a switch to cut them in for starting. The recommended method of starting involved the operator turning the engine over by means of a crank attached to the flywheel. An alternate method of instantaneous starting was supplied, whereby a blank black powder cartridge was exploded in one cylinder. This was not only effective, even if the dry cells were discharged, but required less effort than hand starting, so much so that some operators got into the habit of using this method normally, at least until orders were issued to restrict its use to emergencies.

Radiators were not usually installed in stationary engines; the hot water being normally allowed to run off. In fortification power plants, however, radiators were necessary to allow the reuse of the cooling water, often a scarce commodity. The radiators were not installed in the same room as the engines, due to their noise, and to the 10,000 cubic feet per minute of air delivered by the fan, powered by a 3 HP electric motor. One modification to reduce the noise level involved a cut in resistor to reduce the speed of the fan from 1150 rpm to 950 rpm when maximum cooling capacity was not needed. The water pump was one problems area, and several different designs were tried to improve longevity and reduce noise. The normal coolant was water, and if the local water was too impure, rainwater or distilled water could be used. For colder locations, instructions for an alcohol-water antifreeze mixture were issued, but this mixture was not recommended for general use and seemed to be little used, as artillery drills were not normally held when the temperature was below freezing.

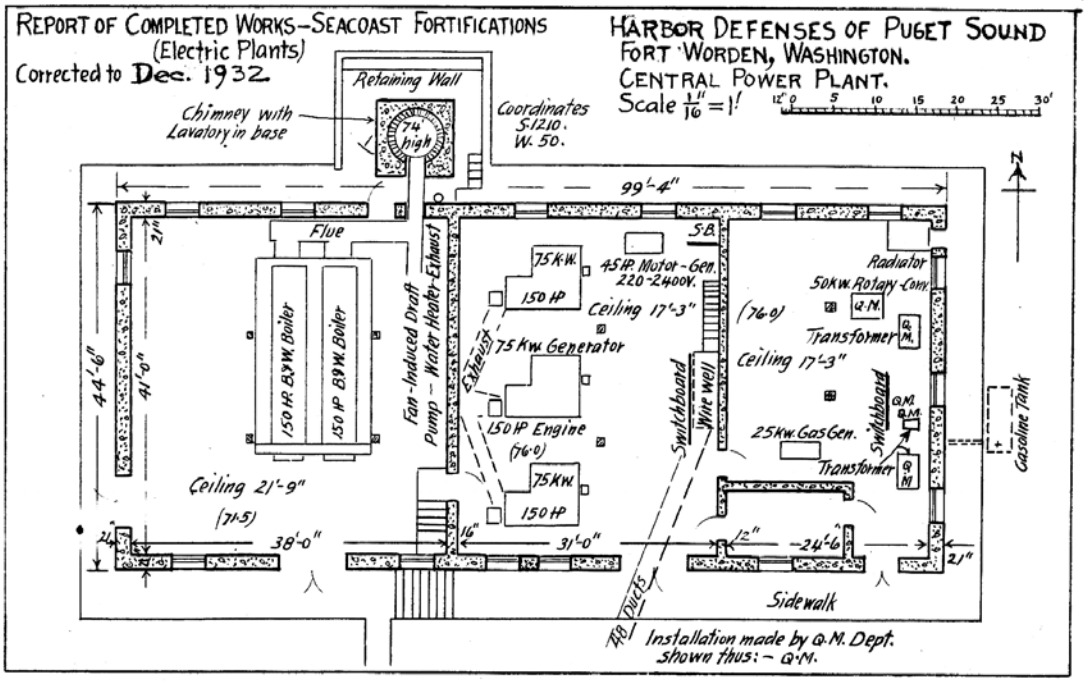
The engine was direct coupled to the General Electric MPC Type D.C. generator. With the exception of a few 220 volt units, all the generators were rated 115 volts at 560 rpm. They were compound wound to give the same voltage at either full or no load, and had a two-hour overload capacity of 33.3 kW. The continuous rating was 27 kW at 43 HP, of which 2 kW was needed for the radiator fan, giving the usable output of 25 kW. The engine and generator were mounted on a rectangular concrete foundation, at least two feet thick, and approximately 59 inches x 26 inches, with eight mounting bolts. The fan and radiator foundation, at least six-inches thick, was approximately 60 1/2 inches x 34 inches and narrower at the fan motor end, with six mounting bolts. The G.E. 25 kW Gasoline Generating Set remained in use until after the passing of the Coast Artillery, but due to larger power requirements and improvements in diesel engines, the primary source of emplacement power in the WW-II generation of fortifications was the diesel engine and A.C. generator. The G.E. 25 kW set, however, remained in service in large numbers through WW-II, and the number of foundations for engines and radiators remaining today is proof of the vital role they played for over forty years.

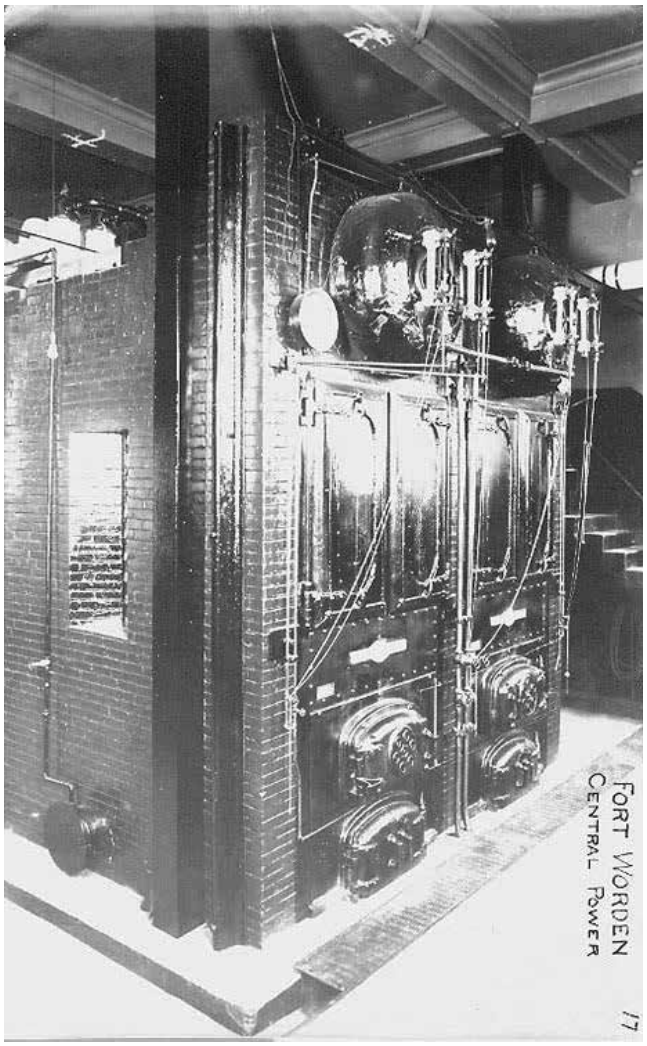
Most of the larger coast artillery posts received a central power plant which had coal fueled steam boilers to drive electrical generators. In general all coast artillery posts were connected to commercial electrical grids for lighting and general electrical uses by 1917. The cental power plant was a back up to commercial power, and to the various emplacement and searchlight power plants on the post.

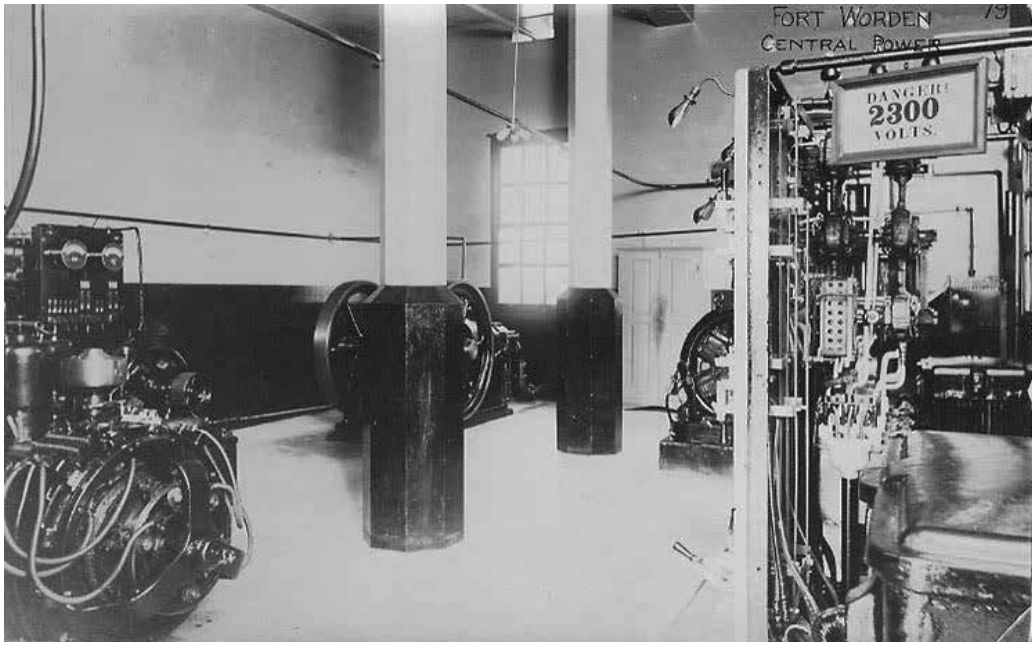


Detail map of part of the Fort Worden Reservation, Harbor Defenses of Puget Sound, showing the locations of five of the six power plants on the site (square symbols with a "o" or a letter inside and a dash on the outside)—the Central Power Plant, the "a" power plant at Battery Ash, the "b" power plant at Batteries Brannon and Powell, the "c" power plant at Battery Kinzie and the "s" power plant at Battery Tolles.

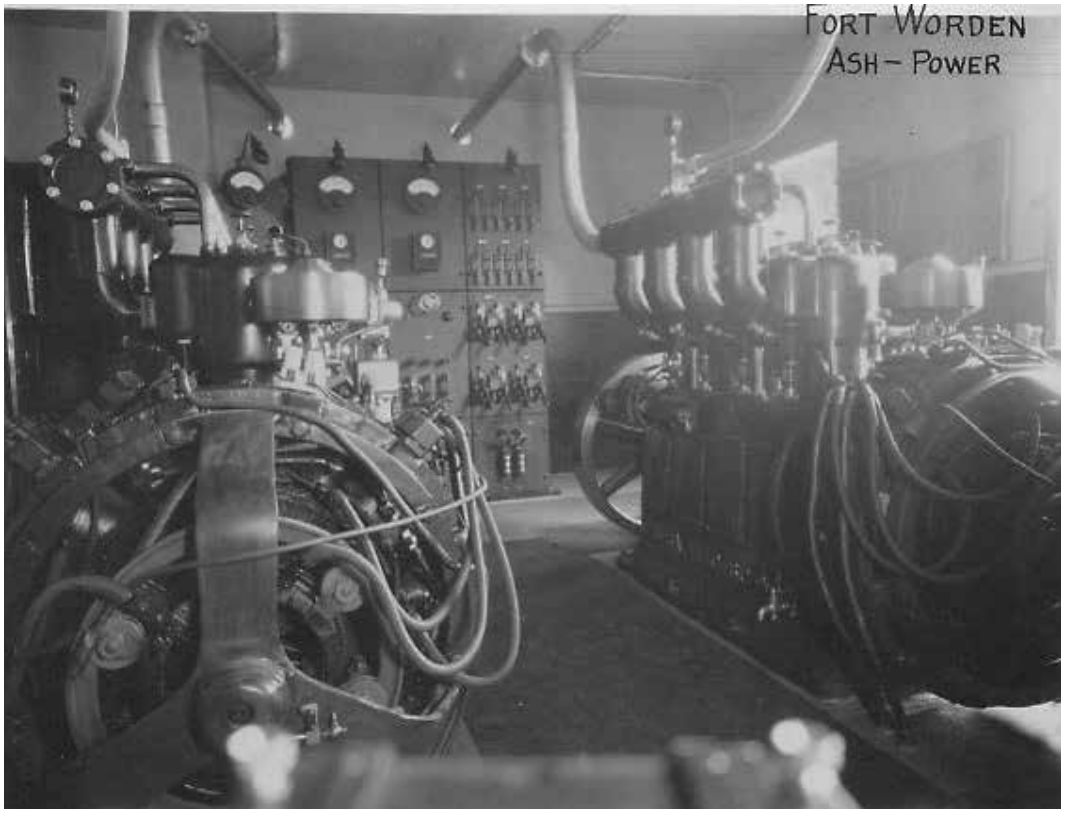
Central power plant at Fort Worden, Harbor Defenses of the Puget Sound (NARA)



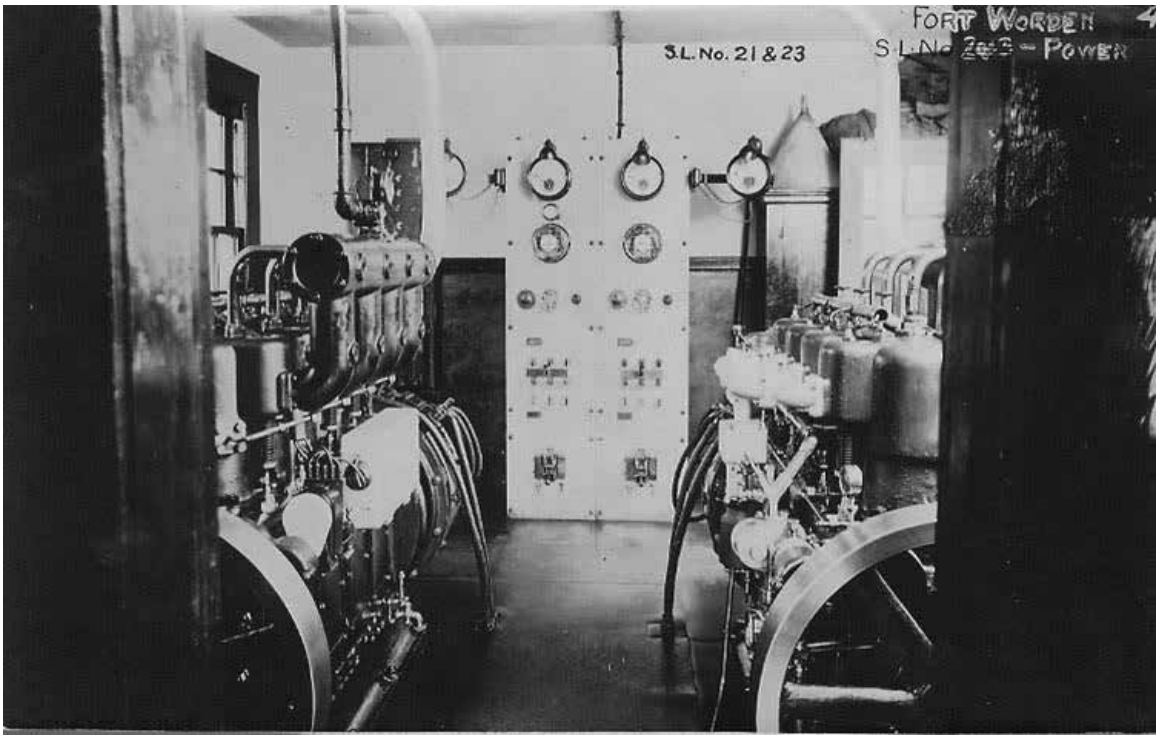




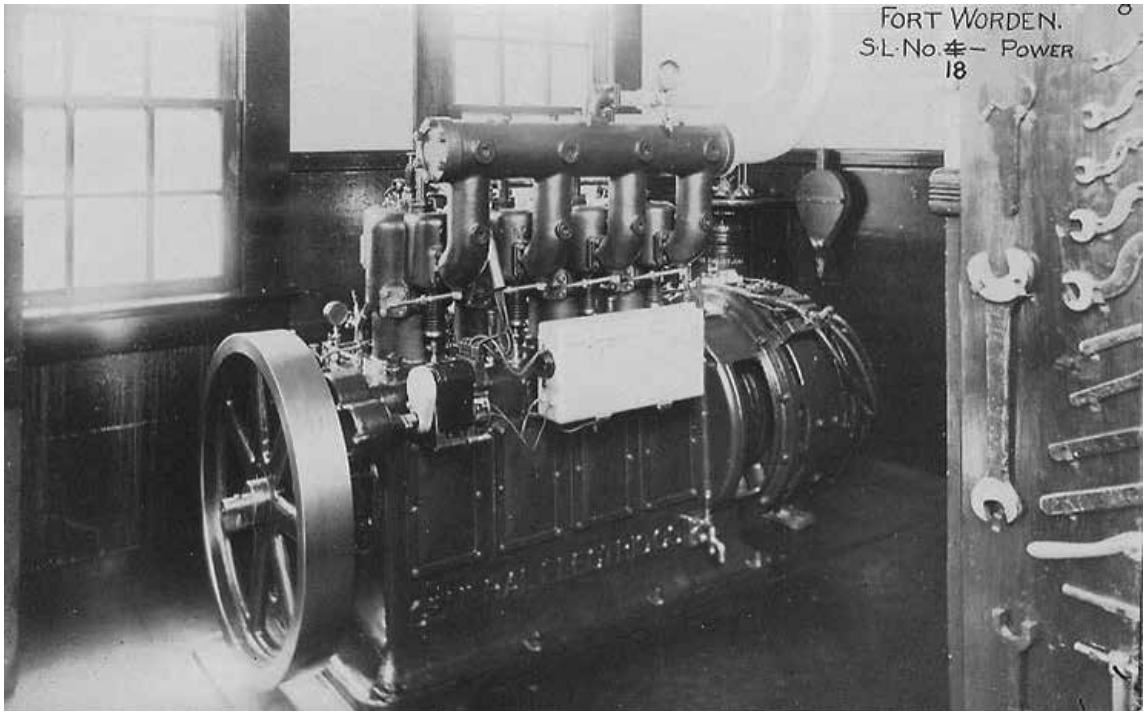
Interior views central power plant at Fort Worden (NARA)



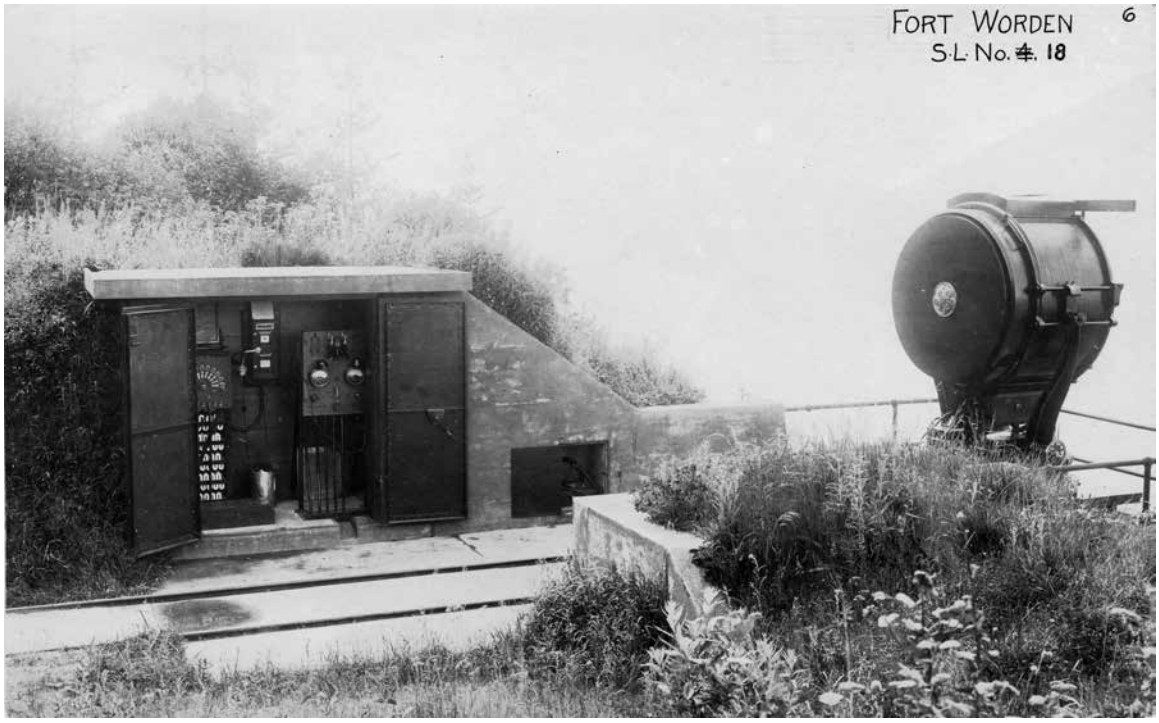
Battery Ash powerplant at Fort Worden (NARA)



Power plant for searchlights No. 21 & 23 (old SL No. 2 & 3) at Fort Worden (NARA)



The powerplant for searchlight 18 (old SL No. 4) at Fort Worden (NARA)



Power control for searchlight No. 18 (old SL No. 4) at Fort Worden (NARA)

Restored power plant, Battery Osgood-Farley, Fort MacArthur Museum, San Pedro, CA 2016
(Mark Berhow)

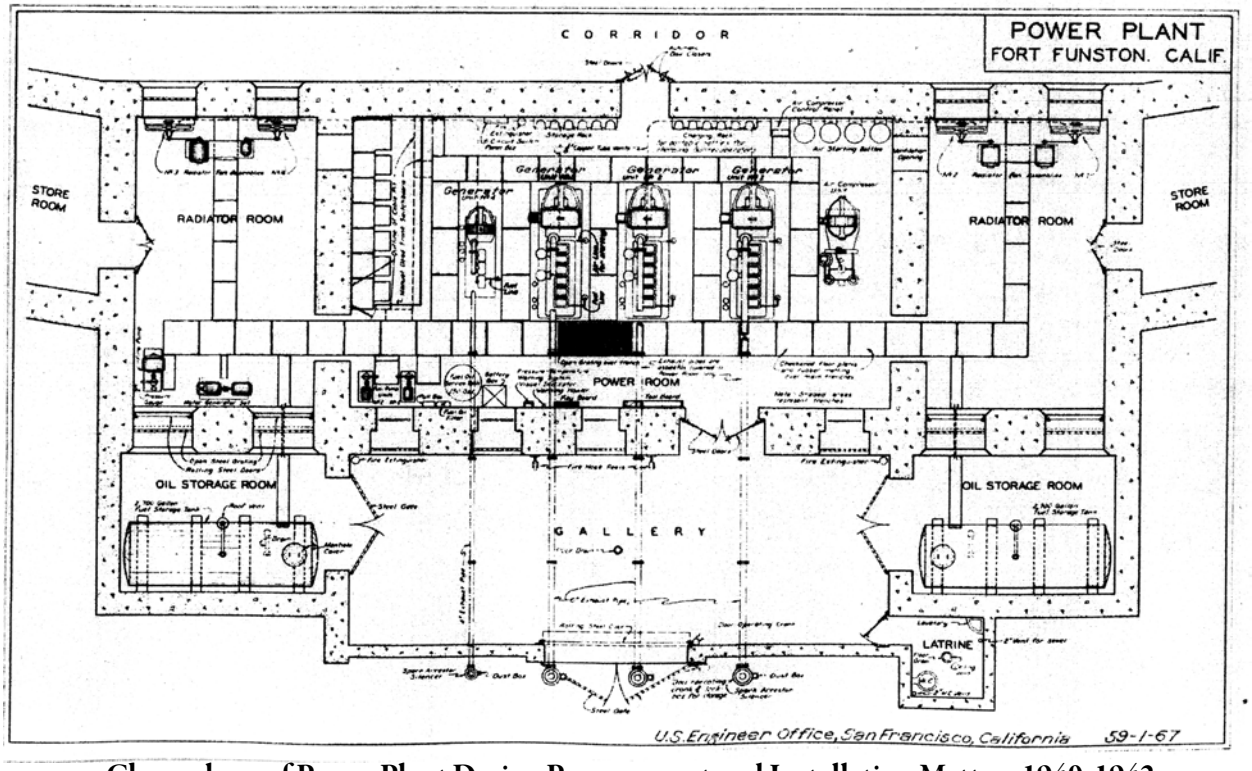
Fuse boxes for the electrical system at Battery Osgood-Farley, 2016 (Mark Berhow)

Interior lighting for shell magazine at Battery Osgood-Farley 2016 (Mark Berhow)

Portable 60-inch searchlight and generator, Fort MacArthur Museum, 2016 (Mark Berhow)

Power in Seacoast Fortification Modernization Program of 1940-45

The standard 200 Series 6-inch batteries built during WW-II contained three 150 HP Worthington diesel engines, each driving a Westinghouse 460 Volt 125 kW 3 phase A.C. generator, while the larger, 100 Series 16-inch batteries each contained three 340 HP Worthington Model CC-6 diesel engines and three Westinghouse 460 Volt 375 kW 3 phase A.C. generators. There were several 100 Series batteries, however, which had non-standard power plants, including Battery Gray (#107), Fort Church, R.I., which used diesel engines to drive D.C. generators. The previously built 16-inch batteries had significantly smaller power plants. The plan for the power facility of Battery Richmond C. Davis at Fort Funston, CA, the first casemated 16-inch battery built in 1938-40, is shown below.



Chronology of Power Plant Design Procurement and Installation Matters 1940-1942.

This document was found in Archives II, RG 77, Entry 1006, D.F. 662, Box 14. No source was given, but the context and the presence in RG 77 seem to make it clear that it was from the office of the chief of engineers.

July 21, 1942

Item No. 1: September 11, 1940

The modernization program was authorized by the secretary of war in a letter to the chief of engineers, July 27, 1940, with amendments. This provided for construction of 19 new and extensive modification of 17 existing major-caliber batteries, and 26 secondary-caliber batteries, to include necessary fire control elements in the continental United States and overseas bases.

Responsibility for battery power plant design, procurement, and installation was assigned to the chief of engineers by AR 100-20, February 10, 1936, as it had been previously. The basic plan was to use available designs and minimize development to allow expeditious accomplishment. DC power

plants were being procured by the district engineer, Philadelphia, when it was learned that the Ordnance Department was trying to procure AC motors for seacoast guns. Procurement by the engineers was stopped pending necessary data from the Ordnance Department to redesign the power equipment.

Item No. 2: 1941-1942

The chief of ordnance recommended an increase in power with conversion to AC to increase the speed of operations and fire power of the batteries. The chief of coast artillery concurred, with the general understanding that the changes would not materially delay the modernization program.

Earlier 16-inch batteries had 90-100 kW diesel generators, but now new estimates ran as high as 1000 kVA per gun. This required larger power rooms. The chief of engineers was unable to obtain definite data on the type of power equipment required until sufficient progress was made by the Ordnance Department, and the construction program suffered from the inability to complete power room designs.

Item No. 3: January 21, 1942

Circular No. 17, January 21, 1942, assigned the design, procurement, and installation of power equipment to the chief of ordnance, pending revision of AR 100-20, February 10, 1936.

Engineer requirements for lighting, etc., of major-caliber batteries were approximately 50 kVA, a minor amount compared with the requirements under consideration by the Ordnance Department for gun operation.

Item No. 4: 1940-1942

The construction program was progressed by engineer field forces as much as possible in the absence of complete data on the structural requirement to accommodate the new power equipment.

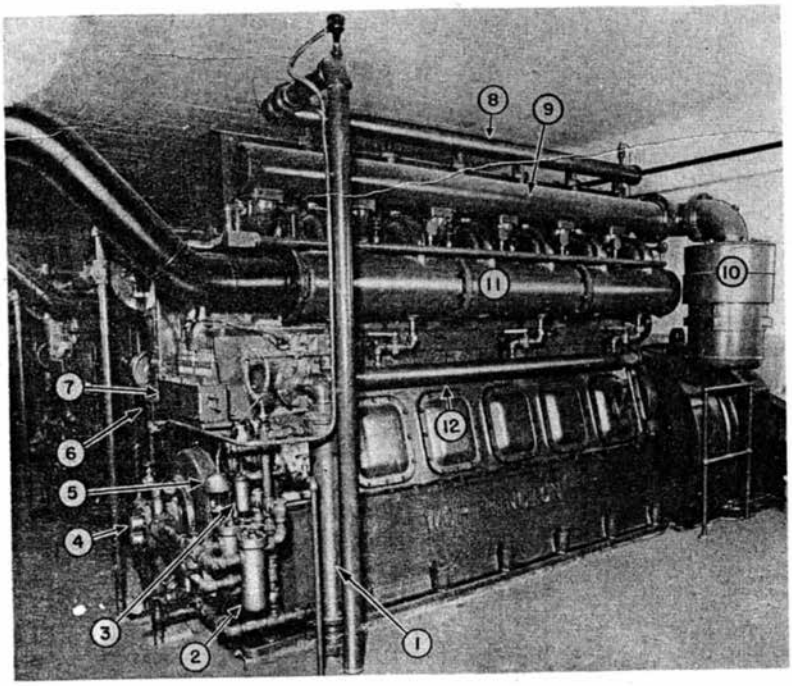
Because many construction contracts were already in force, it became increasingly difficult to avoid costly delays or even terminations of contracts. The Ordnance Department issued various sketch drawings on the basis of which, with supplementary consultations, it was possible to issue enough instruction to engineer field forces to continue construction at a reduced rate. These instructions were generally type plans approved by the representatives of the chief of ordnance. Resources resorted to keep field construction progressing were:

a. Temporary omission of entire areas of construction, principally power room areas.
b. Temporary omission of floor slabs, manholes, trenches, engine bases, etc.

As the ordnance development program progressed, structural changes to accommodate revisions in power plants, gun mounts, and ammunition service were requested. Sometimes, as many as three conflicting requests for one item were received. The chief of engineers cooperated as much as possible, consistent with minimizing confusion on the part of field construction forces and maintaining maximum progress. The 1942 policy as related to the chief of ordnance was in the 3rd indorsement, July 17, 1942, "CE 662 SPEEF, Subject: 16" barbette carriages arrangement of power equipment in fortifications," paragraph 1, which stated it had become increasingly clear that Ordnance Department power plant development and procurement difficulties would make minor structural changes unavoidable. There followed a summary of the general procedure which was to be followed to achieve the desired results in the field:

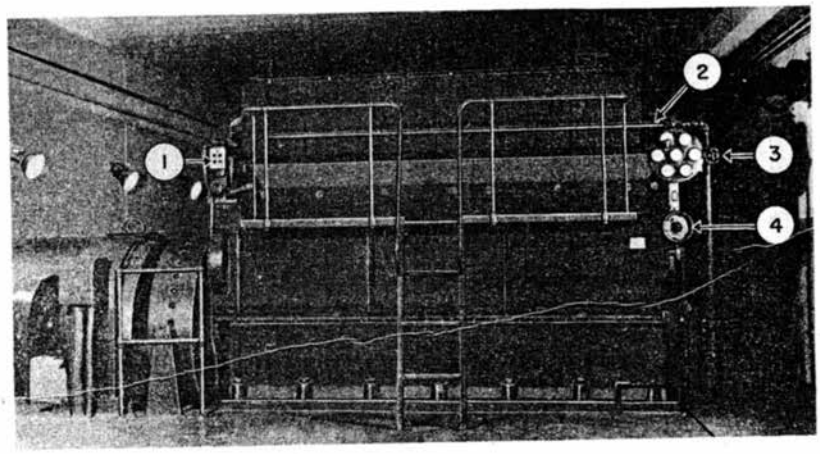
Radical structural changes in approved designs issued as the basis for construction contract documents could not be undertaken.

Minor structural changes required to accommodate changes in power, armament, or communications equipment were practicable for uncompleted construction and, when requested, would be incorporated in type plans from time to time with the understanding on the part of all concerned that the changes were not applicable to completed construction.



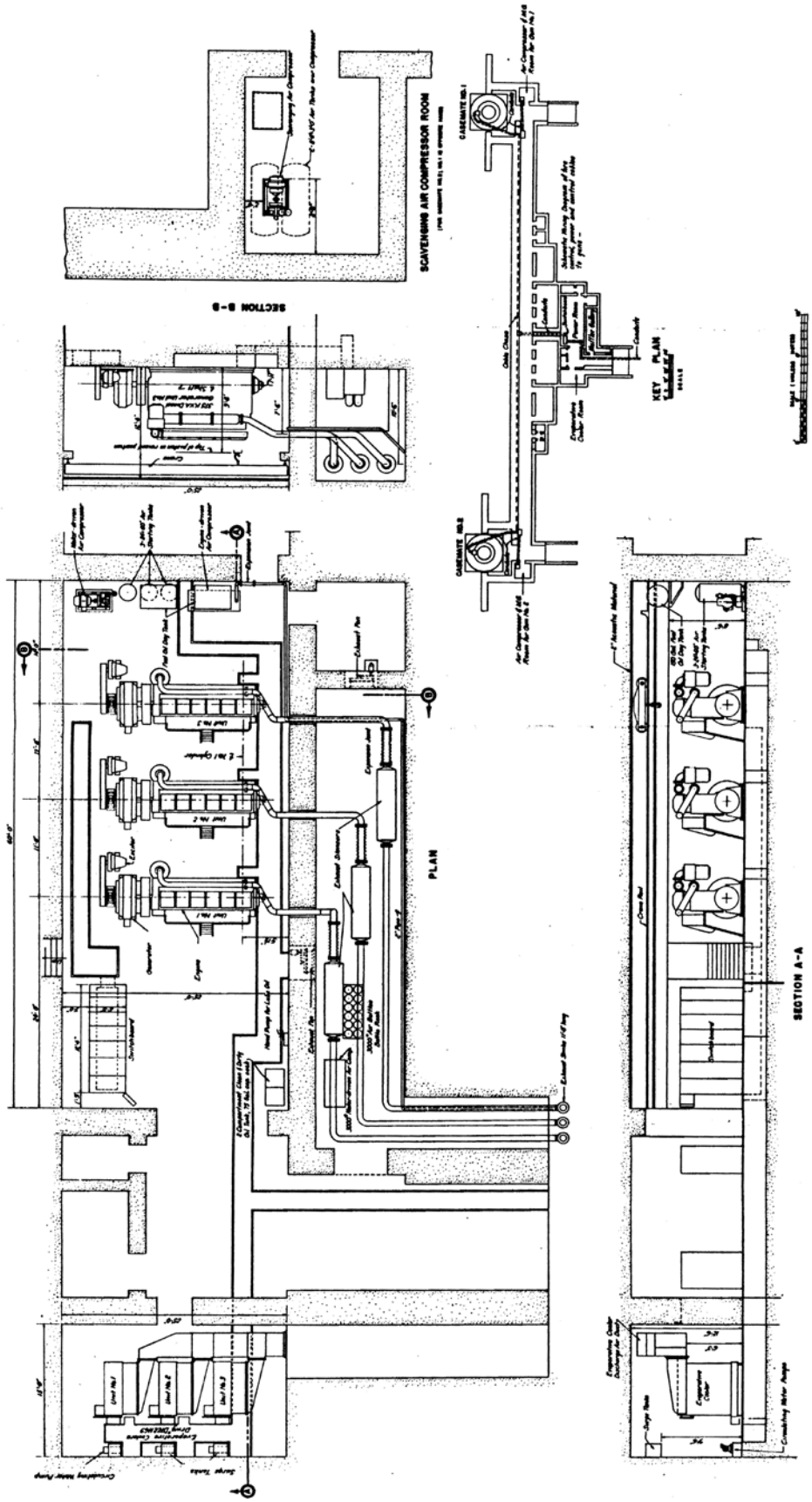
1. Lubricating oil cooler.
2. Lubricating oil filter.
3. Fuel oil filter.
4. Lubricating oil pump.
5. By-pass valve.
6. Safety control unit.
7. Force feed lubricator.
8. Outlet water manifold.
9. Air intake manifold.
10. Air cleaner.
11. Exhaust manifold.
12. Inlet water manifold.

FIGURE 4. Left side, Diesel engine for a 16-inch gun battery.



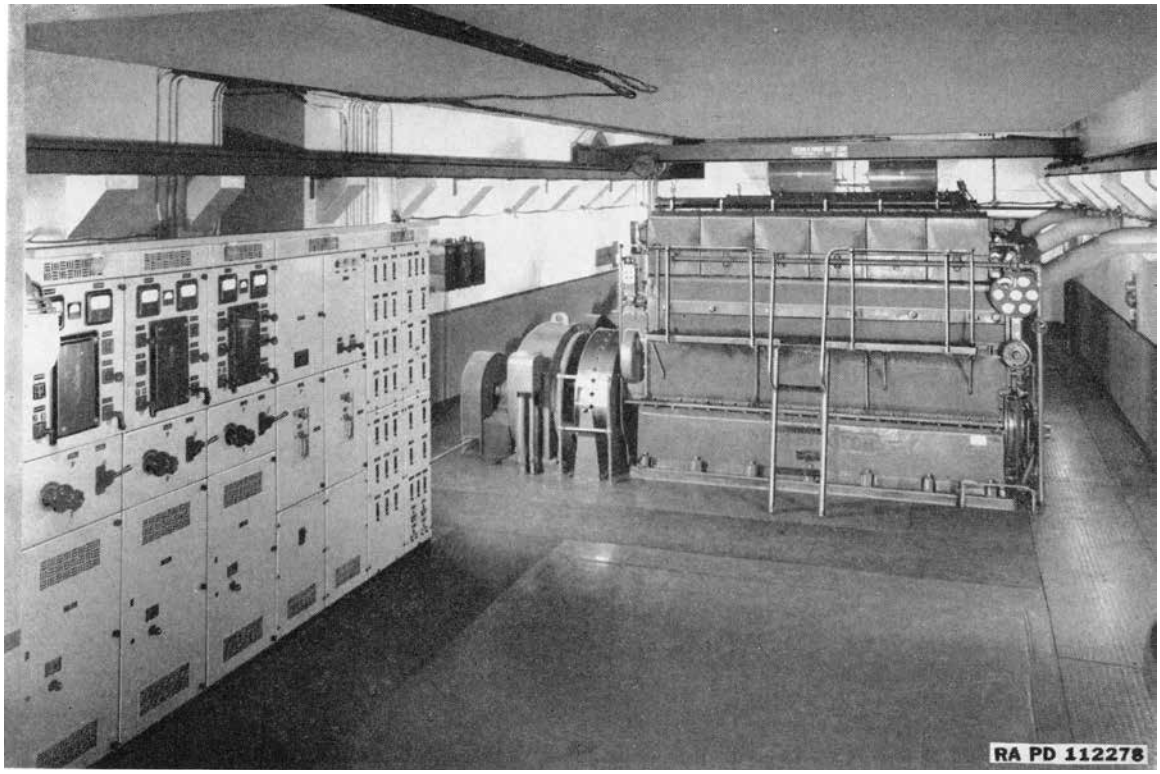
1. Governor.
2. Air starting manifold.
3. Master air valve.
4. Control wheel.

FIGURE 3. Right side, Diesel engine for a 16-inch gun battery.

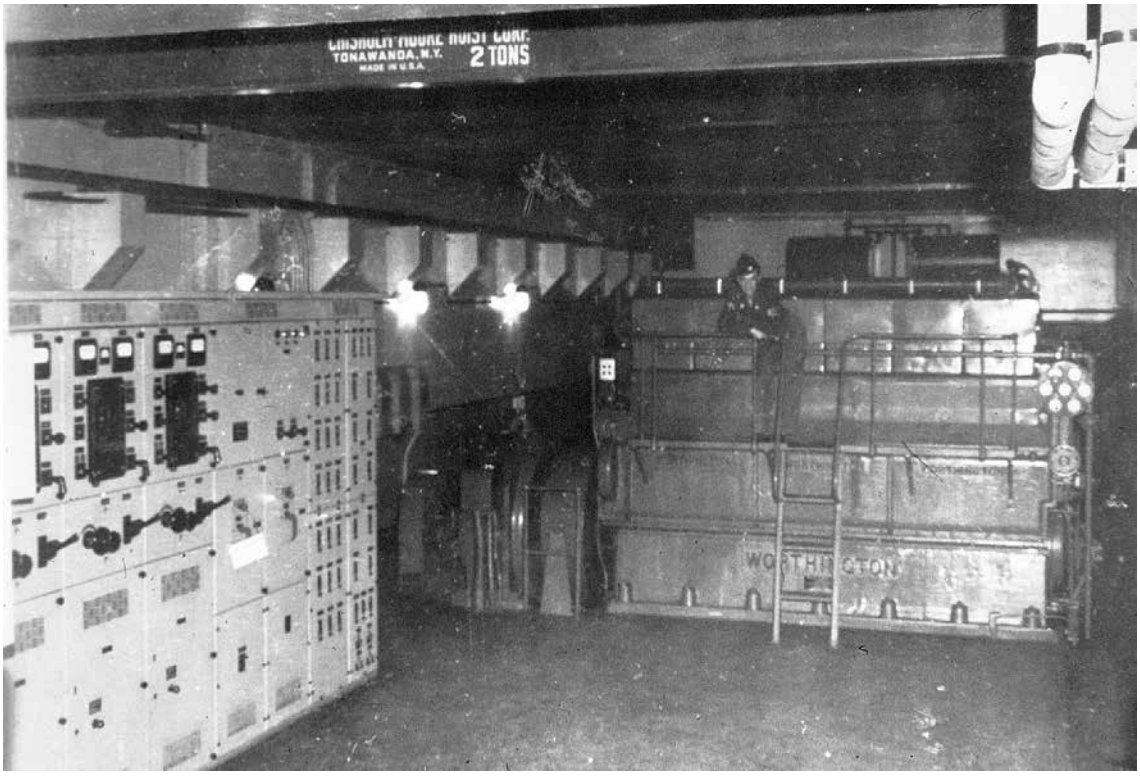


Equipment layout, M1 power plant for 16-inch gun battery.

Diesel electric plants for 6-, 12-, and 16-inch Gun Emplacements, Coast Artillery Training Bulletin, Vol. 4, No. 7, July 1945.



M1 power plant for 16-inch battery. *War Department, SNL 20, 1943.*



Power plant for Battery Steele, Harbor Defenses of Portland, Maine (NARA)

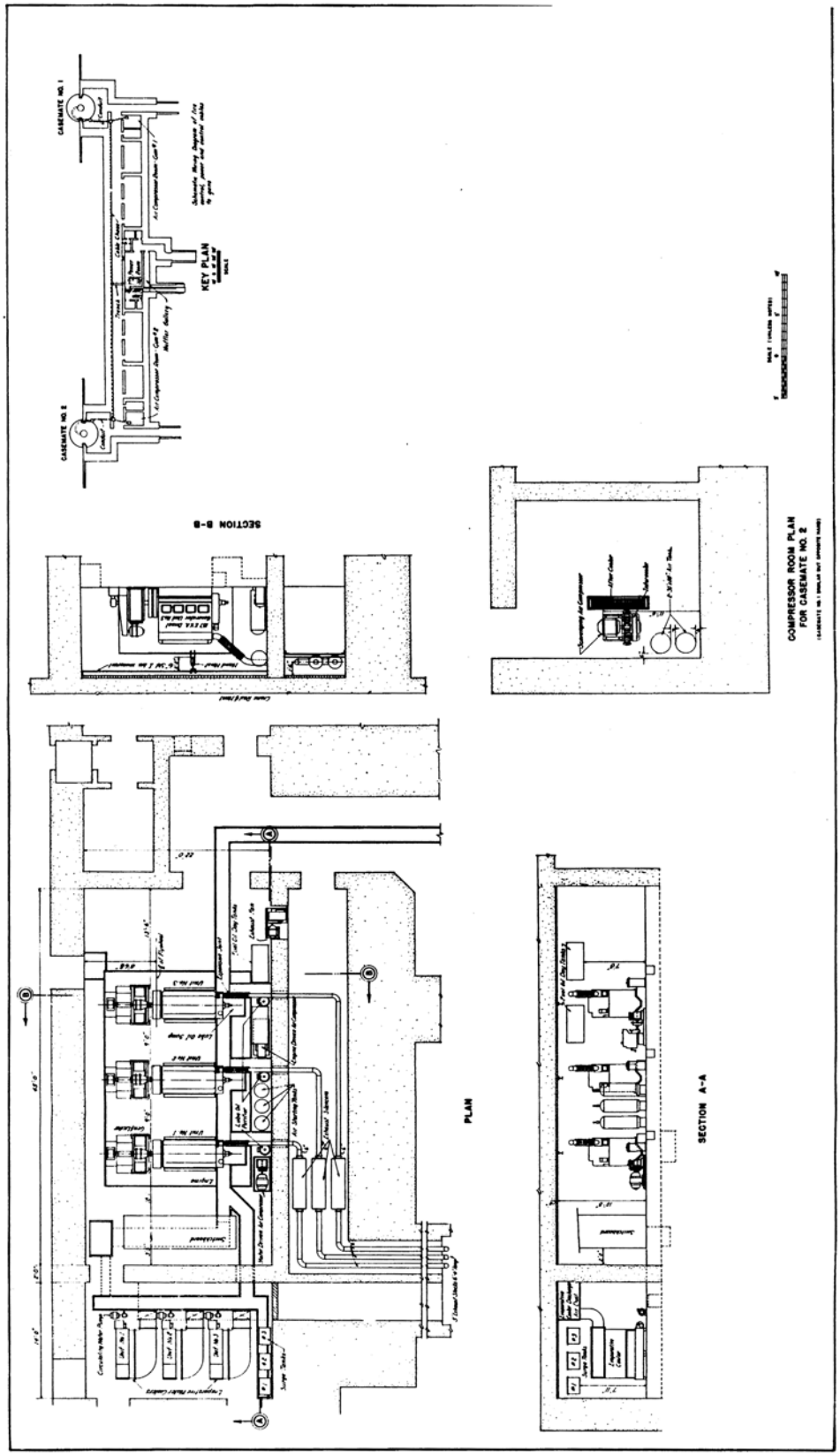
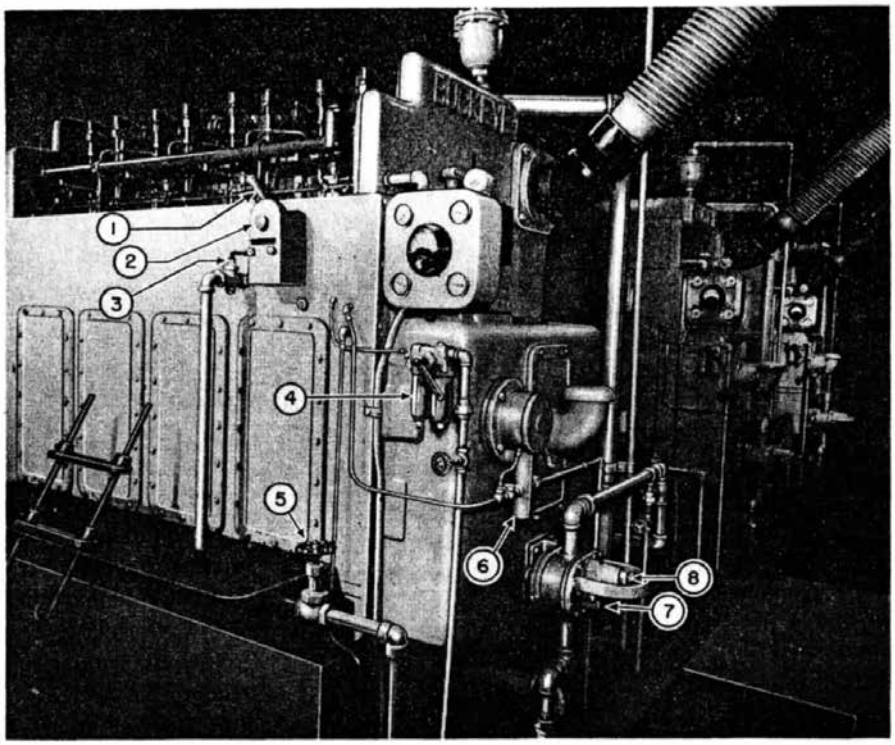


FIGURE 28. Equipment lay-out, power plant M2 for a 12-inch gun emplacement.

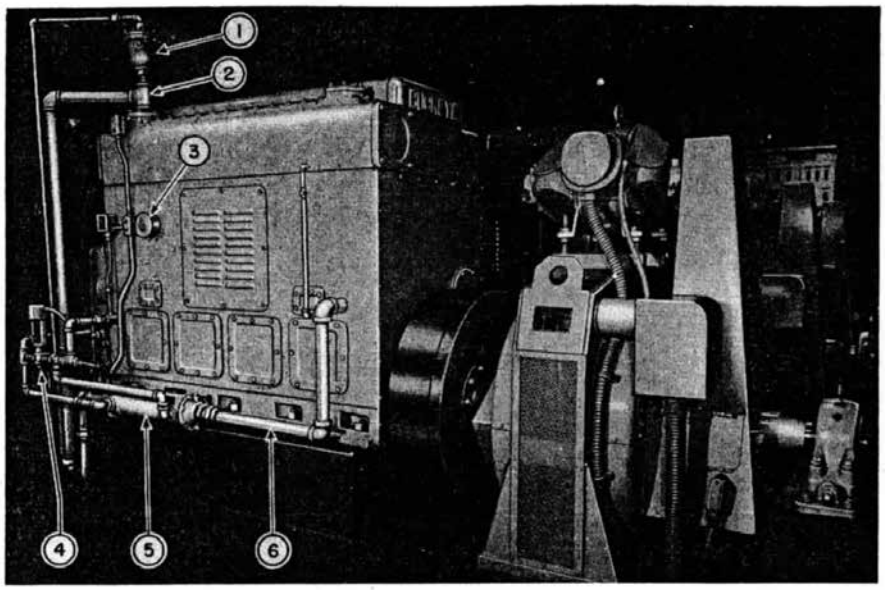
Equipment layout, M2 power plant for 12-inch gun battery.

Diesel electric plants for 6-, 12-, and 16-inch Gun Emplacements, Coast Artillery Training Bulletin, Vol. 4, No. 7, July 1945.



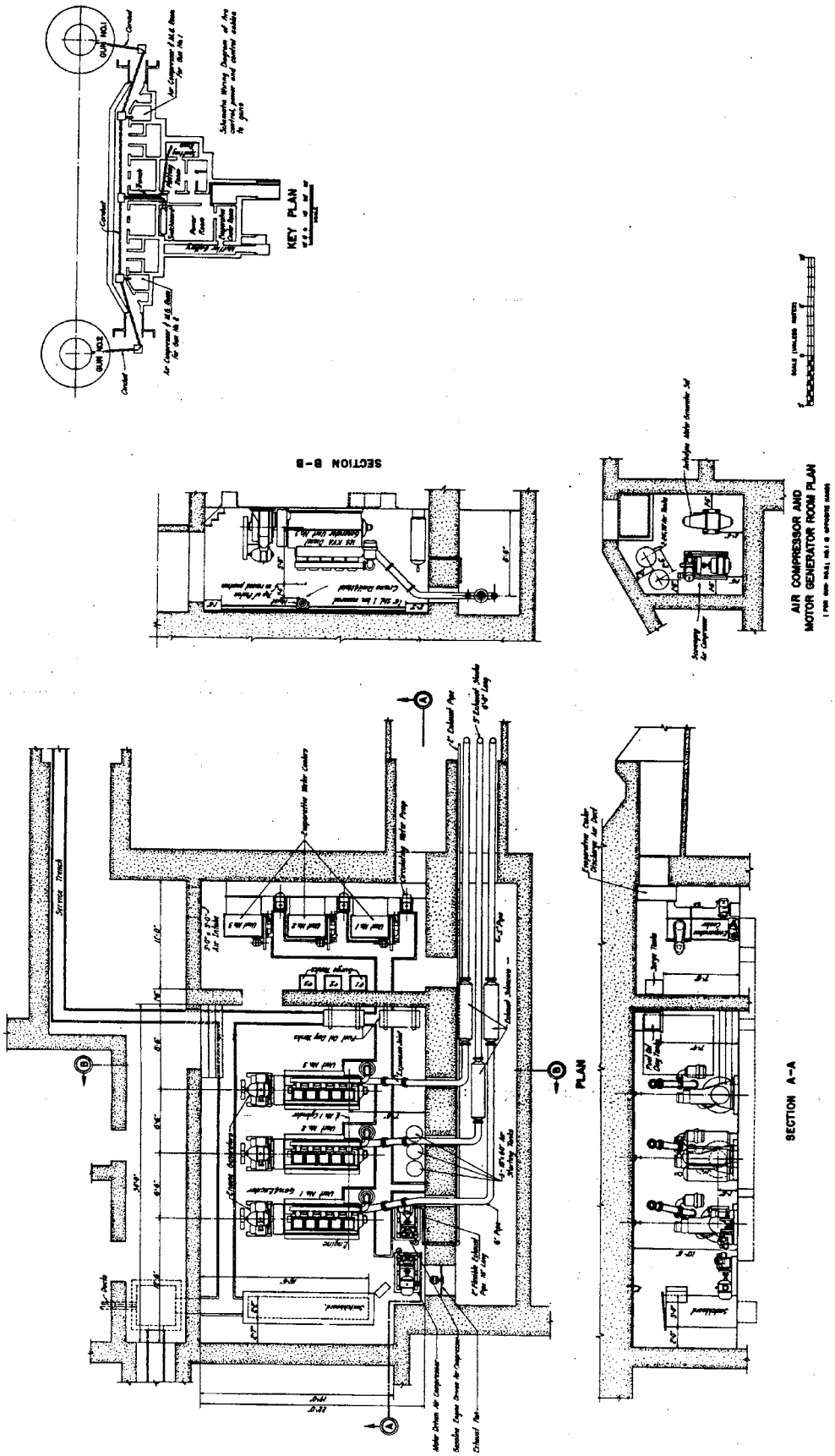
1. Control lever.
2. "Stop" push button.
3. Air cock.
4. Fuel oil filter.
5. Air valve.
6. Fuel oil plunger pump.
7. Lubricating oil pump.
8. Pressure adjustment screw.

FIGURE 8. Right side, Diesel engine for a 12-inch gun battery.



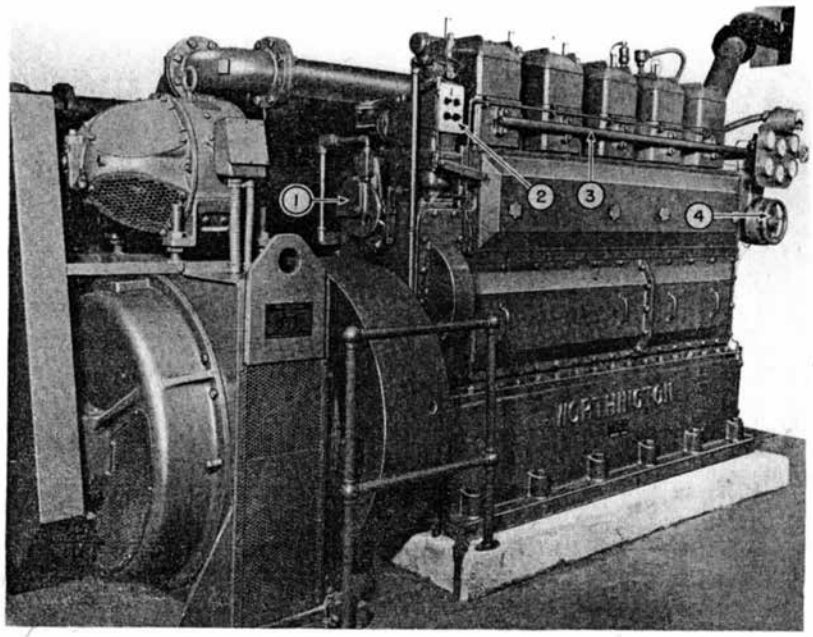
1. Air trap.
2. Water outlet pipe.
3. Safety alarm.
4. By-pass valve.
5. Lubricating oil cooler.
6. Water inlet pipe.

FIGURE 9. Left side, Diesel engine for a 12-inch gun battery.



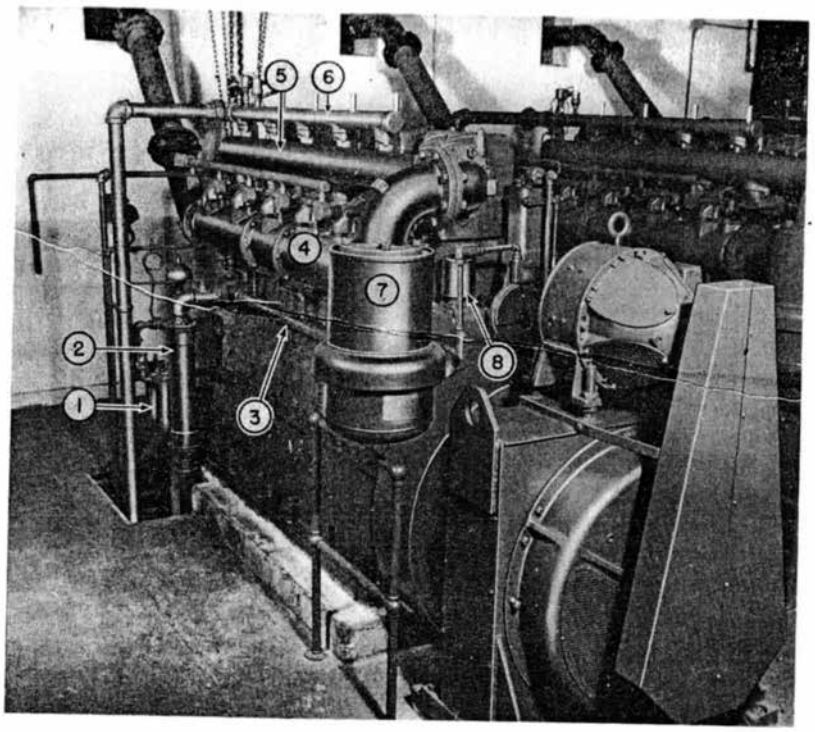
Equipment layout for standard 6-inch gun battery.

Diesel electric plants for 6-, 12-, and 16-inch Gun Emplacements, Coast Artillery Training Bulletin, Vol. 4, No. 7, July 1945.



1. Overspeed linkage.
2. Governor.
3. Air starting manifold.
4. Control wheel.

FIGURE 1. Right side, Diesel engine for a 6-inch gun battery.



1. Lubricating oil filter.
2. Lubricating oil cooler.
3. Inlet water manifold.
4. Exhaust manifold.
5. Air intake manifold.
6. Outlet water manifold.
7. Air cleaner.
8. Crankcase breather.

FIGURE 2. Left side, Diesel engine for a 6-inch gun battery.

Power plant for Battery 241, San Pedro, CA 2016 (Mark Berhow)

Power plant for Battery 241, San Pedro, CA 2016 (Mark Berhow)

Obviously, the frequency of such revisions had to be kept to a minimum to avoid confusion in field operations. The field offices were permitted to make minor changes or to meet local conditions with the understanding that none of these changes would interfere with machinery arrangements shown in approved type plans. When minor field office changes were approved, the Ordnance Department was furnished copies of the field drawings.

The exisiting 12-inch and 16-inch batteries that were casemated during the WW II years generally received a new power plant system as part of the casemating process.

As a final note, since almost all batteries built before the 1930s utilized D.C. power, it was not possible to use transformers to change the generated voltage to meet specific requirements. As a result, emplacements commonly contained motor-generators, direct coupled sets with a D.C. motor driving a D.C. generator, which would generate power at the desired voltage. They were also common in switchboard rooms. In some instances, motor-generators were used to convert A.C. power to D.C., such as when the commercially available power was A.C. and the battery required D.C. Before the development of semiconductor rectifiers, this was a standard technique. In summary, emplacement power plants evolved from steam to kerosene to gasoline to diesel, although not always in a steady progression in individual emplacements.

Power plants constituted a major element in the coast defenses, and they are today one of the most common remains of our Coast Artillery history. Some sites, like Fort MacArthur, Fort Moultrie, Fort Stevens and Fort Columbia even offer historic power plants for inspection.

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