Double-Compound Steam Engine, (Ferryboat) Sierra Nevada
Vicinity of Seaplane Anchorage
Terminal Island
Los Angeles County
California

HAER No. CA-24

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Western Region
Department of the Interior
San Francisco, California 94102

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HISTORIC AMERICAN ENGINEERING RECORD

Double Compound Steam Engine, Ferryboat Sierra Nevada
(formerly Ferryboat Feather River and Ferryboat Edward T. Jeffrey)

HAER No. CA-24

Location:	In the vicinity of the seaplane anchorage Terminal Island, Los Angeles County, California
Date of Construction:	1913
Builder/Designer:	Moore & Scott Iron Works Oakland, California
Present Owner:	Los Angeles District U. S. Army Corps of Engineers P. O. Box 2711 Los Angeles, California 90053-2325
Present Use:	Unrestored artifact in storage
Significance:	A presently rare example of an engine representing, in general, an important stage in steam engineering and, specifically, a form of engine once widely used for ferryboat propulsion.
Historian:	Larry Gilmore (acting as an independent consultant) Curator Columbia River Maritime Museum
Date:	August 1, 1985

Historical Background

The engine under consideration is the original one installed in the ferryboat Edward T. Jeffrey. This vessel was built for the Western Pacific Railroad Company by the Moore & Scott Iron Works at Oakland, California. She was the first vessel built by that company, which previously had only done repair work. Her launching took place on July 19, 1913. The Edward T. Jeffrey was named after the president of the Western Pacific and the Denver & Rio Grande Railroads.

The Edward T. Jeffrey, as depicted in surviving plans and historic photographs, was a double-ended ferry of steel construction and had one deck and five watertight bulkheads. A sizeable vessel, her registered dimensions of 218 feet in length, 42 feet in molded breadth, and 16.6 feet in depth, produced a gross tonnage of 1,578 or a net tonnage of 1,025. Her overall length was 230 feet and the width across the guards was 62-1/2 feet. A crew of twenty was required. She had a single screw (propeller) at each end, permitting her to steam in either direction with equal efficiency, thereby eliminating wastage of time in turning around after leaving dock.

The ferry was renamed the Feather River about 1931 and became the Sierra Nevada in 1933, but remained the property of the Western Pacific Railroad. In 1939 the Southern Pacific Railroad became her registered owner. She was taken over by the U. S. Maritime Commission during World War II, afterwards passing to the Richmond & San Rafael Ferry & Transportation Company (about 1948), then to the Moore Dry Dock Company (1958). She operated as a ferry until 1956, but during her last years, the Sierra Nevada served as a floating shopping center at Ports-o'Call Village in San Pedro, California. She became a derelict and was wrecked on the breakwater of the restricted Pier 21 area on the south side of Terminal Island in 1978. Planned harbor development called for clearance of her wreck, but the engine was salvaged.

Physical Description

Preserved components of the Sierra Nevada's machinery include the main engine, condenser, lubricating oil tanks, telegraphs, gauges, pumps, hardware, and auxiliary equipment. Not included are: boilers, furnaces (fireboxes), boiler feed tanks, piping between the boilers and engine, propeller shafts, or propellers. The machinery is constructed primarily of steel, iron, brass, and copper. It is somewhat deteriorated from its period of immersion in seawater, but is, nonetheless, in a tolerable state of preservation and fairly complete. The main engine weighs about 100 tons and is approximately 35 feet long, 15 feet broad, and 20 feet tall. Records show that its indicated horsepower (I.H.P.) was 2,500. It has four cylinders with a stroke of 28 inches; the bore of the two high-pressure cylinders is 20 inches, and that of the low-pressure cylinders is 42 inches. Although the boilers have not been preserved, it may be of interest to record that steam was provided by four oil-fired, water-tube boilers at a working pressure of 200 pounds per square inch.

The Sierra Nevada's main engine can be fully, if verbosely, characterized as a marine, inverted-vertical, double-compound, reversing, direct-acting, condensing, double-acting, reciprocating steam engine. It is a reciprocating engine because its basic action was accomplished by the back-and-forth (reciprocating) movement of pistons. The engine is classified as double-acting because the pistons were driven by steam alternately admitted to either side of the piston. It is a condensing engine, in that steam exhausted from the engine passed into a condenser for cooling back into liquid water. The engine is considered direct-acting because the piston and rods were coupled to the crankshaft to drive it directly, rather than indirectly, through some other mechanism (such as that of a beam engine). It is a reversing engine because it is fitted with mechanisms for reversing the direction of the crankshaft's rotation (in order to steam astern). The engine belongs to the compound class because a given quantity of steam was used first to drive a piston in a high-pressure cylinder, then passed into a low-pressure cylinder of larger diameter to drive another piston before being exhausted from the engine (note that "simple" steam engines could have more than one cylinder, but any given quantity of steam was used in only one cylinder before passing into the exhaust.) It is a double-compound engine in that it consists essentially of a pair of compound engines, inextricably joined together by a common bedplate, crankshaft, steam supply, and reversing gear. The physical arrangement of the cylinders above the crankshaft, placing the latter in the low position required for screw propulsion, makes it an inverted-vertical engine (early steam engines for paddle-wheelers had engines placed either vertically below the crankshaft, or horizontally.) Finally, the Sierra Nevada's engine is a marine type simply because its design incorporated a combination of features suitabe for vessel propulsion.

The general features, operating principles, and nomenclature of reciprocating steam engines are sufficiently well documented in published works as to require little elaboration here. Therefore, the following general review will concentrate more attention on features relating specifically to the particular use the Sierra Nevada engine was designed for.

The cylinders are supported on massive columns above the crankshaft and bedplate. The latter is a foundation for the engine in the form of a hollow box made from heavy girders; it was firmly bolted to the Sierra Nevada's frames. Steam was carried from the boilers to the engine through a large steam pipe, passing through a throttle valve, just before forking to supply each of the two high-pressure cylinders, located nearest the center of the engine. After a quantity of steam was expanded in one of these cylinders to drive a piston, it passed into the corresponding low-pressure cylinder for further expansion before exhausting into the condenser.

The cycle of steam admission, cut-off, and exhaust in each cylinder was controlled by a slide valve for that cylinder. The operation of the valve was kept in proper sequence by a mechanical linkage to the crankshaft via rods and eccentrics. The latter were keyed onto the crankshaft in a position at an angle relative to that of their respective corresponding cranks. The action of the valve gear was critical to the efficient operation of the engine and had, therefore, to be carefully set and periodically adjusted to compensate for wear.

The slide valves worked by alternately covering and uncovering steam ports and exhaust ports in the cylinder wsalls and exhaust ducts. The cycle inside each cylinder was identical, though not synchronous. On top center the piston had reached the end of its upward stroke and began its downward stroke; the slide valve was momentarily also moving downwards; the exhaust port was open for the escape of the steam that had just driven the piston up, while steam was already entering for the down stroke. As the piston moved down slightly, it reached the full port position, at which both the exhaust and appropriate steam ports were fully uncovered by the side valve. Next, the slide valve reached the limit of its movement and reversed direction, commencing the closure of the steam port (point of cut-off), leaving the steam just admitted to the cylinder to continue driving the piston by force of expansion. Next, the point of exhaust closure was reached, so that some steam remained at the opposite end of the cylinder to cushion the piston at the end of its stroke. At the point of exhaust opening, the piston was nearing the end of its stroke and the valve again uncovered the exhaust port to begin venting the steam. Just after that, the point of admission was reached and steam began to flow in from a different steam port, in preparation for another upward stroke. Last, the piston reached bottom center, at the end of its stroke, having driven its crank 180 degrees. The cycle was then repeated in the opposite direction to complete one full revolution of the crank.

The steam used for one stroke of a high-pressure piston exhausted into a low-pressure cylinder to propel that cylinder's piston on another stroke. The larger bore of the low-pressure cylinder was calculated to accomplish equivalent work through further expansion of the steam at a lower pressure; this permitted the stroke of pistons in both high- and low-pressure cylinders to be equal length. After its second use in a low-pressure cylinder, the steam exhausted into the condenser to be cooled back into liquid water.

The up-and-down motion of the pistons was converted to rotary motion of the crankshaft by means of the piston rods, crossheads, connecting rods, and cranks. The piston rods projected vertically through the bottoms of the cylinders and were connected at the crossheads to the connecting rods. The crossheads acted as guides, running up and down slides fixed to the engine columns, to keep the piston rods in vertical alighnment and prevent excessive wear of the piston rings and cylinder walls. The upper ends of the connecting rods were forked to receive the crossheads, which rested on the ends of the forks and were secured to them by adjustable brasses, which allowed the connecting rods to pivot laterally. The crossheads of the Sierra Nevada's engines are presently disconnected from the connecting rods. The lower end of each connecting rod was pinned between the outer edges of a pair of cranks, in the form of heavy disks keyed eccentrically onto the crankshaft. The radius from the center of the shaft to the center of the pins was calculated to convert the length of one piston stroke to a half revolution of the cranks.

At each end of the engine, the crankshaft connected to the propeller shafts via a thrust bearing. The function of these thrust bearings was to take up the thrust of the propellers against the water and transmit it to the hull, rather than into the engine, where the strain would throw working parts out of alignment, causing excessive wear and breakage. A section of shaft ran through each bearing and was fitted with a number of collars that turned with it and acted against the faces of a corresponding series of fixed collars. The latter fitted around the shaft and were positioned alternately between rotating collars on the shaft, receiving the thrust from them. The fixed collars were mounted on a trough-shaped pedestal, which was partially filled with lubricating oil for the collars. The pedestal was fastened securely to the engine's bedplate and that, in turn, passed the strain to the hull's framing. Ordinary vessels would have required only one thrust bearing, at the aft end of the engine. However, because the Sierra Nevada was a double-ended ferry, she had shafts running to propellers at both bow and stern (to permit efficient steaming in either direction, for the reason previously discussed); therefore, she required a thrust bearing at each end of her engine.

Virtually all power vessels, and certainly ferries, require some means of reversing the thrust of their propulsion for backing, especially when maneuvering to dock or undock It was possible to accomplish this directly in reciprocating steam engines by reversing the direction in which the crankshaft turned, eliminating any need for clutches and gearing or other arrangements for backing. The Sierra Nevada's engine is fitted with the double-bar form of the so-called Stephenson's link-motion reversing gear (which was actually invented by a man named Howe at Robert Stephenson & Sons' locomotive works in Newcastle, England in 1842).

The bottom of each of the engine's slide valve stems terminated in a link block which projected from above between two bars in the form of arcs of a circle. Protuberances from the link block gripped the top and bottom edges of the bars, yet left them (the links) free to slide back and forth through the block. At each end of the links, they passed between the forked upper ends of a pair of eccentric rods. Link pins projecting from the bars were attached to the forks of the eccentric rods by adjustable brasses (the link blocks of the engine are presently disconnected). The arch of the links is equal to that of a circle having a radius of the same length as that of the eccentric rods. The lower end of each eccentric rod was strapped to an eccentric keyed onto the crankshaft. There were two eccentrics and rods for each slide valve, one for going ahead and the other for backing. If the links were slid in one direction or the other, they would carry the upper ends of the pair of eccentric rods with them. When the top of the ahead eccentric rod was placed directly under the valve's link block, the shaft's rotation was converted to reciprocating motion by the eccentric acting as a crank in reverse; the up-and-down motion of the eccentric rod was transmitted to the slide valve through the links and link block to control its action. In this position, the engine was in full gear for steaming ahead. If the links were slid all the way over to bring the top of the reverse eccentric rod under the link block, then its motion controlled the slide valve and reversed its direction of travel and, therefore, that of the piston and rotation of the crankshaft. But if the link was positioned to place the eccentric rods equidistant from the link block, their motion was pivoting from the point of the link block and cased negligibe movement of the side valve; consequently, the engine would stop. Intermediate settings of the links were possible, which resulted in operation of the engine with an altered degree of steam expansion in the cylinders and permitted a very fine degree of control over engine speed.

The links for all the engine's slide valves were controlled simultaneously. Each link was connected by a pair of suspension rods to a reversing arm (this is presently disconnected) that projected from a rocker shaft. The latter is mounted horizontally along one side of the engine at the level of the cylinders. The rocker shaft was actuated by a special auxiliary steam engine, mounted vertically on the side of the main engine below the rocker shaft. The connecting rod of this small, single-cylinder engine is attached to another reversing arm projecting from the rocker shaft; therefore, movement of the reversing engine's piston would turn the rocker shaft and, through it and the suspension rods, cause all the links to slide in the same direction simultaneously. A special arrangement of the reversing engine's valves allowed it to be stopped at any desired point immediately and held there.

To permit independent adjustment of the action of each separate slide valve, a linking-in gear was incorporated into the reversing arms, in the form of a block which could be moved by a screw. The ends of the suspension rods were actually attached to these adjustable blocks.

This method of reversing constituted a major advantage of reciprocating steam engines, in general, for maneuvering in close quarters, in that full power was available for backing and the engine could be reversed almost immediately. Occasionally, however, when an engine was stopped, it would come to rest at dead center and then refuse to restart in either direction until the pistons were manually cranked over a bit. This phenomenon, though rare, would become a statistical certainty in the number of stops and starts required by a ferry during its many dockings. It might prove not only disconcerting, but downright hazardous, if it occurred at a critical moment. The double-compound engine could be made immune to this possibility, however, by merely having one set of high- and low-pressure cranks placed on the crankshaft at an angle to the other pair, so that all of them could never be on center at once.

It has already been mentioned that steam from the low-pressure cylinders exhausted into the condenser for cooling. Condensing was done for two reasons--to increase fuel economy and to conserve a supply of pure feedwater for the boilers. The first purpose was accomplished in part mechanically and in part through greater thermal efficiency. Creation of a partial vaccuum on the exhaust side of the pistons minimized any back pressure tending to retard the pistons and transformed more of the steam's heat into motion by encouraging a more thorough expansion of steam in the cylinders. Another enhancement of thermal efficiency was accomplished through providing the boilers with water that was already hot, by virtue of recycling the condensed steam. Some inland vessels, where feedwater supply was no problem, dispensed with condensers, exhausting ujsed steam directly into the atmosphere, accepting greater fuel consumption in return for lower initial cost of machinery and simpler operation. Early seagoing steamers used jet condensers, which saved fuel, but cooled the steam by a direct spray of seawater, thereby causing a progressive contamination of the feedwater with salt. This caused corrosion problems that became unacceptable after tubular boilers became common and working boiler pressures climbed.

The surface condenser was pioneered by Samuel Hall (British, 1781-1863) and appeared at sea in 1834; however, it did not come into general use until after 1860. This was the type used by the Sierra Nevada. It consisted of a cylindrical sheel containing a series of tinned brass tubes. Cold seawater was pumped continuously through the shell by an independent circulating pump to chill the steam flowing through the tubes. The condensed water, still quite hot, and any air or residual steam vapor, was evacuated from the condenser and into the hot well by the air pump, creating a partial vaccuum. The feedwater pump was another independent piece of machinery that drew feedwater for the boilers from the hot well and feedwater tanks as required.

Besides the main engine and auxiliary equipment already discussed, the Sierra Nevada's machinery included the usual complement of auxiiary steam engines driving bilge pumps, electrical generators, blowers, etc.

Mention must also be made of the turning (or jacking) gear incorporated into the main engine. This consisted of a toothed gearwheel mounted on the crankshaft and meshing with a worm gear which could be turned manually with a lever to slowly crank the engine over without the use of steam. This was necessary to keep working parts free and in good condition during extended dockings and for maintenance work on the engine.

Significance

The engine of the ferry Sierra Nevada is not of historic significance due to any particular distinction of the vessel; the Sierra Nevada performed long and faithful service, but took part in no great events and marked no milestone of marine progress. But in itself, the engine represents, in a general way, a very significant stage in the progress of steam engineering: tbe compound engine. More specifically, it is a presently rare example of the marine double-compound engine.

Hero of Alexandria wrote of the motive power of steam in 130 B.C., but the ancients made no practical use of steam power, nor did modern Europeans until 1698, when Thomas Savery developed a steam pumping apparatus (which operated without moving parts through alternating pressure and vaccuum). Denis Papin had, meanwhile, suggested the use of a piston in 1690, but his own design proved impractical. Thomas Newcomen gained the honor of introducing the first useful reciprocating steam engine in 1705. This was a single-acting engine that used steam only to raise a piston, depending on atmospheric pressure to push it down after the steam below it condensed inside the cylinder. This was adequate for pumping out mines, but too slow, weak, and wasteful of fuel for much else. It remained for James Watt to perfect a really versatile engine. In 1782, he patented a double-acting design, in which steam was alternately applied above and below a piston to actively drive it in both directions. Watt was also responsible for the introduction of a condenser separate from the engine and for the use of steam expansively, rather thanm admitting it during the entire length of a piston stroke. The combination of these improvements resulte in the first engines powerful and economical enough for marine use (and much else).

Meanwhile, proposals for propulsion of a vessel by steam had been set forth by the French physicist Denis Papin and various others subsequently. A number of experiments took place, and there are conflicting claims for the first steam vessel to actually work, but the best ones seems to be that of the Marquis Claude de Jouffroy d'Abbans' Pyroscaphe of 1783. John Fitch and James Rumsey had working steamboats on American rivers in 1786 and 1787, respectively. But it is generally conceded that William Symington's Charlotte Dundas, built for towing on a Scottish canal in 1802, was the first mechanically practical steamer. Commercial success was first achieved by a steamboat with Robert Fulton's Clermont on the Hudson River in 1807, using a Watt engine.

Steam quickly took hold on inland waters and short coastal routes in passenger service and for carriage of compact, high-value cargo. Early steamers were, however, handicapped in competition with sail on long ocean routes by considerations both of economics and range. All the early marine engines were simple engines, in that a given quantity of steam was used but once before being exhausted, although some had more than one cylinder. This, in combination with the low-pressure boilers then available, required very large, heavy machinery to develop even a modest horsepower; and prodigious quantities of fuel were consumed by these inefficient engines. Steamers could not hope to supplant sailing ships on the high seas until better engines appeared.

The answer lay in the compound engine, expanding steam successively in two separate cylinders. Increasing the horsepower of simple steam engines could only be done by increasing the size of bore and/or stroke, thereby also increasing stresses and requiring heavier parts. The compound engine held a mechanical advantage because, by dividing the work into stages, the range of stresses was held down through its use of relatively smaller working parts and its smoother, steadier motion; this, in turn, permitted a relatively lighter construction. However, the greater part of a compound engine's superiority was due to greater thermal efficiency. In very large cylinders, considerable energy was wasted by condensation of steam within the cylinder, due to the large range of internal pressure and temperature during a stroke. Division of the steam's expansion into stages in two smaller cylinders reduced this range of temperature and pressure, permitting more efficient expansion of the steam. Compund engines, therefore, tended to save a certain amount of space and weight and a great deal of fuel. Their introduction at sea reduced average fuel consumption on long voyages by half or more, compared to that required by a simple engine of similar horsepower in a ship of similar size.

The use of compound engines at sea was pioneered by John Elder, the founder of what later became the Fairfield Shipbuilding and Engineering Company, near Glasgow, Scotland. Jonathan Hornblower had developed a compound engine as early as 1781, but had been crushed by suits for infringement on some of Watts patents. His idea was periodically revived by others, and some compound engines were used on land from 1804 onwards; their superiority was, however, obscured by the low working pressures then in use. By the middle of the 19th century, improved boilers permitted considerably higher pressures, and the compound engine's time had come. In 1853, John Elder took out a patent, in conjunction with Charles Randolph, and, in 1854, built the Brandon, the first vessel fitted with a compound engine. Acceptance came somewhat slowly, until the French Navy adopted a compound engine in 1863. By 1871, compound engines were almost universally chosen for marine use (as well as on land). Meanwahile, the screw propeller had been patented in 1836, and proved superior in efficiency to paddle-wheels for most applications. Propeller shafts had to be placed low in the hull, so James Nasmyth introduced the inverted-vertical steam engine in 1850, conveniently placing the cylinders above the shaft.

The advantages of the compound engine could be applied in the direction of greater speed or lower fuel cost and greater range. It is not coincidental that the period which saw the acceptance of the marine compound engine is also that during which steamers replaced sailing vessels for all but trades involving low-value bulk cargo on the longest routes. The compound engine may be said to have fully ushered in the modern age of international marine transportation.

Progress in marine engineering did not, of course, stop with the compound engine. The triple-expansion engine, which extended the principle of the compound engine by expanding steam in yet another stage, had been discussed as early as 1823, and such an engine was built in 1861-62. Frenchman Benjamin Normand (1830-1888) tried one in a boat in 1871 and installed one in a ship in 1873. These engines soon proved themselves even more efficient than the compound engine and largely supplanted it in new construction during the 1880s. Many existing compound engines were converted by the addition of another cylinder. Quadruple-expansion engines appeared, beginning in 1884, but their degree of advantage was too slight to justify their installation in any but the largest ships.

Englishman Charles Parsons patented the first successful steam turbine in 1884. He also was first to install one in a vessel, the Turbinia of 1897, which achieved spectacular results in speed, leading to the general displacement of reciprocating engines by turbines for fast ships. The direction of development in marine engineering split with the introduction of diesel internal-combustion engines, patented in 1892 by Rudolf Diesel of Germany. The first large ship to receive one was the Selandia in 1912. Turbines were superior for high speed, but diesels held the advantages of compactness, a reduced personnel requirement, and fuel costs about half that of a comparable steamer.

An explanation must be made of the selection of a compound engine for the Edward T. Jeffrey in 1913, forty years after the first triple-expansion engine was placed in a ship and several years after turbine vessels began appearing in numbers. The turbine can be dismissed immediately as unsuitable for any harbor or coastal craft that required only moderate speed. It had to frequently slow, stop, and back up while maneuvering. The turbine was more efficient than any other existing type at sustained high speed, but at low and moderate speeds, its fuel consumption was higher than that of a reciprocating engine, while the high speed rotation of the turbine required expensive reduction gearing to obtain satisfactory propeller speeds. Furthermore, turbines offered poor maneuvering capabilities, in that reversing could not be done directly. A small, separate stern turbine was required for that, but it did not provide full power for backing. Reciprocating steam engines, by contrast, could be reversed directly and almost immediately, while providing full power for steaming astern.

The choice of a compound engine over triple-expansion machinery is a bit more complex to explain, but was in no way unusual. Compound machinery was very often the choice for tugboats, ferries, and other types of coastal and harbor craft, right up until the general acceptance of diesel propulsion for these types. The degree of advantage of triple-expansion engines over compound ones was not nearly so great as that of the latter had been over simple steam engines. Furthermore, the triple-expansion engine's advantage was confined to the area of fuel efficiency, as a compound engine of a given horsepower was actually more compact, within the range required by the craft that employed them. The question of fuel economy was very important to ocean-going ships on grounds of steaming range, as much as cost. But tugboats, ferries, and the like, were almost always within easy range of fuel supplies, while compound engines offered advantages of compactness, lower initial cost, and simplicity (fewer working parts to maintain). The double-compound engine is a special case, however. Although they existed in fair numbers, they never represented more than a fraction of the total marine steam engines in use. They actually had more working parts than a triple-expansion engine, but may, for a ferry, have offered a small advantage in reliability of restarting during maneuvering (as previously discussed). Generally, however, it would seem that a double-compound engine was chosen for coastal vessels of fair size, where achieving a fairly high horsepower as compactly as possible was considered more important than maximum fuel economy, a combination of factors which probably was found more frequently in large ferries than anywhere else. Double-compound engines were, however, not universally chosen, even for screw ferries, much less for paddle-wheel ferries (where other factors also applied).

The Sierra Nevada's engine represents, in a general way, the compound marine engine. As such, it holds a degree of significance, as surviving examples of any form of reciprocating marine engine are scarce, due to the length of time that they have been obsolescent; most were scrapped long before the maritime preservaton movement attained form. And the compound engine probably was the greatest single advance in steam engineering between Watt's invention of the double-acting engine and Parson's introduction of the steam turbine. Furthermore, compound engines remained an important form of propulsion for numerous coastal craft well into this century until finally supplanted by diesels.

More particularly, the engine under consideration is significant as a very rare example of a double-compound engine. We have seen that this type was employed in significant numbers, but was never a predominant form of marine propulsion. It was, rather, a successful adaptation to a very specific set of requirements, notably those of large ferries. Ferries were once a much more important component of the nation's transportation system than presently, due to construction of highway bridges and tunnels. The general attrition of the ferryboats themselves, combined with the adoption of diesel propulsion for most of the remaining ones, has led to the scrapping of nearly all the double-compound engines that once existed. Only one other surviving example is known to this writer (although there may be more), that of the ferryboat Major General William H. Hart (ex-John A. Lynch, ex-Harlem), built in 1925 and presently owned by the South Street Seaport Museum of New York City. It is not open to the public, but a staff member responded to a telephone inquiry with the opinion that the Major General William H. Hart's engine was essentially complete and could be restored to working order, although it has not been restored to working order, although it has not been operated for a number of years. Specific documentation on the double-compound engine is scarce. None of the works cited in the following bibliography contain a set of plans for an engine of this particular type.

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