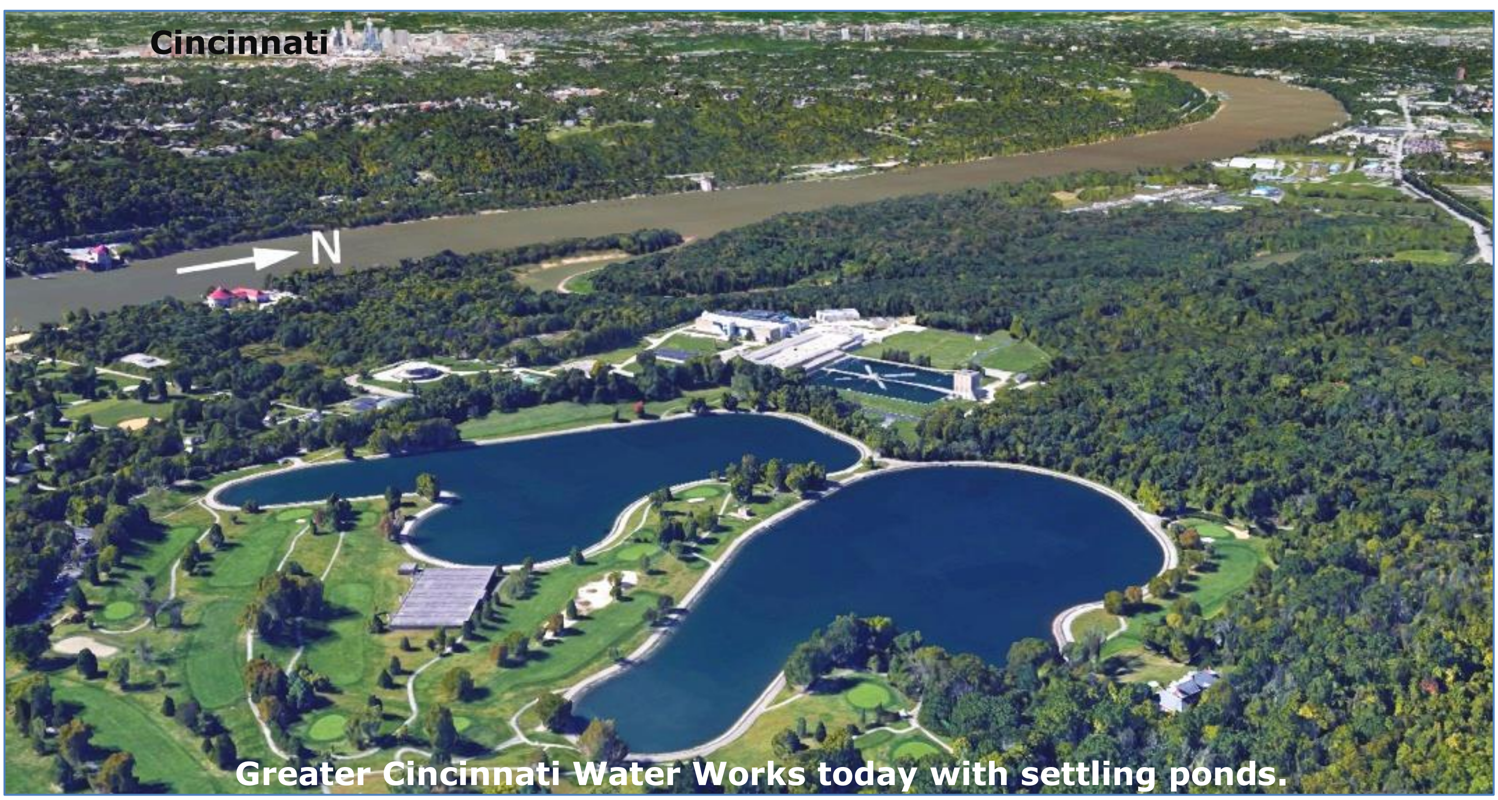
A Pocket Guide to Old River Station

Featuring four of the World's Largest Steam Engines
Located at the Greater Cincinnati Water Works
By Leland L. Hite – CincinnatiTripleSteam.org

Typical high-water level at Cincinnati Water Works-1907 view.



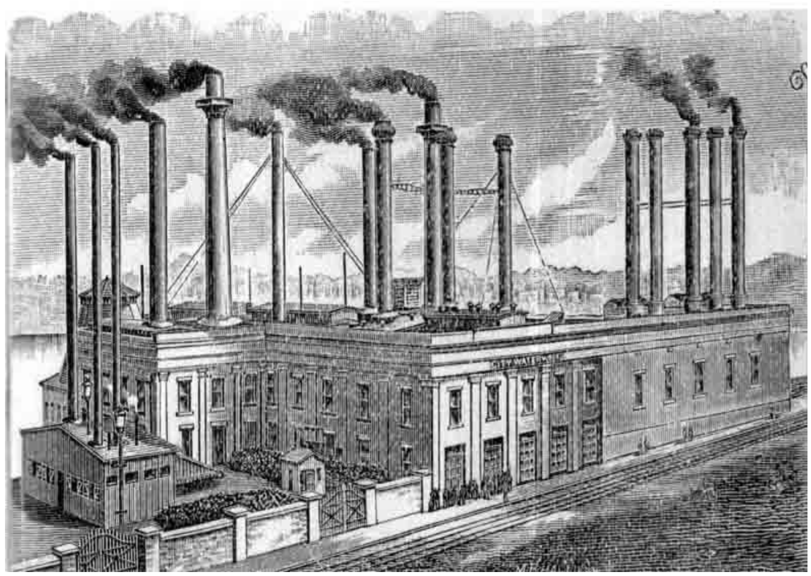
Greater Cincinnati Water Works today with settling ponds.

Content

Introduction: A unique period in Cincinnati history began in 1898 when four of the world's largest vertical, triple expansion, crank and flywheel, water pumping steam engines were incorporated into an equally amazing pump house for the Cincinnati Water Works, CWW. Resting deep in the ground the engines pumped Cincinnati's water from the Ohio River for 57 years, 1906 to 1963. Designed using the same space age technology employed for the Apollo missions, the slide rule with three digit calculation accuracy, Old River Station was built using human labor, draft horses, steam engines and a large dose of innovativeness.

Astronauts like Neil Armstrong, Jerry Ross, Roy Bridges, Eugene Cernan, Richard Covey and Guy Gardner were Purdue students using slide rules for their engineering, mathematics and statistics courses. Neil Armstrong carried a slide rule with him when he went to the Moon

For the first time in the history of CWW, an entire pumping system was purchased and installed from an outside vendor. Prior to this decision, the water works had the reputation of being a *curiosity shop* for the design of water pumping steam engines. As new pumping requirements emerged, the accepted culture had been for the Chief Engineer of the water works to design the pump and associated steam engine. Previous design experience with steam powered pumping systems was not a job requirement. As a result, many newly designed pumping systems at Front Street Station were abandoned after one or two years, because of poor reliability. 57 years of reliable operation from the outside purchase steam pumps at Old River Station was a testament to the advisability of this concept.



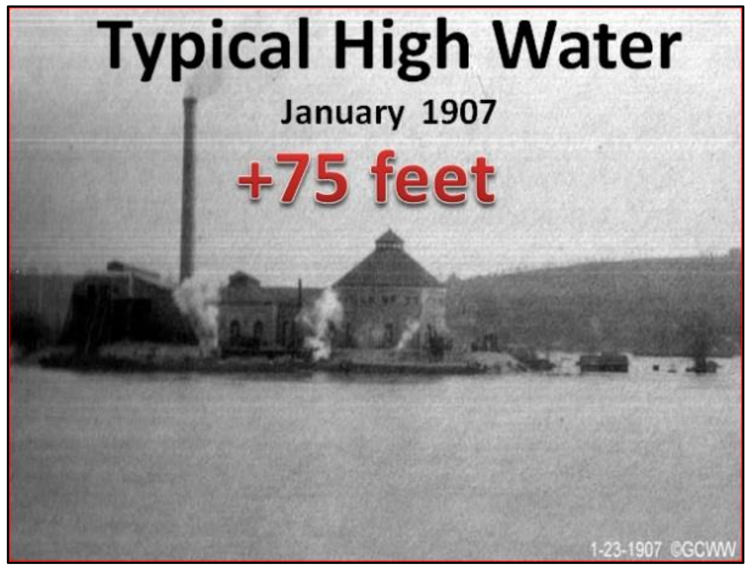
Front Street Station, now Eastern Ave., aka Riverside Drive

Also known as the Eastern Pumping Station for the New Water Works, Old River Station was built between 1898 and 1907 under contract to the F. H. Kirchner & Company of Cincinnati. This would appear to be a contradiction to the 1908 date on the nameplates for each of the engines, but it isn't. 1908 is the year final tests were performed on the engines and the Water Works accepted and paid the invoice.

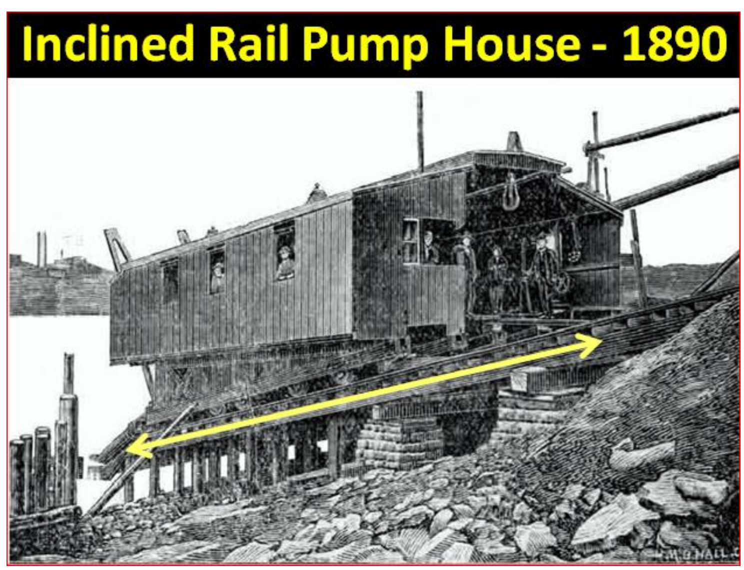
The facility included a circular pump house, a boiler room, auxiliary building, elevated coal storage building, coal hoisting house, deaerating plant and a water-softening plant. Four vertical triple expansion, crank and flywheel water-pumping engines set on the pump room floor 85 feet below grade, and extend to 18 feet above ground. The engines, boilers and overhead radial crane were under contract to the R. D. Wood Company of Philadelphia, PA, and built by the Camden Iron Works of Camden, NJ.

Prior to navigation control locks and dams on the Ohio River in 1929, when navigation depth was increased to a minimum depth of nine feet, the draft required by a coal barge tow, the Ohio River level often changed from under two feet, shown right, to over 75 feet in the fall and spring. When the New Water Works project began construction in California, Ohio during 1898, this large dynamic range caused a challenging set of design considerations for pumping water to the City of Cincinnati.

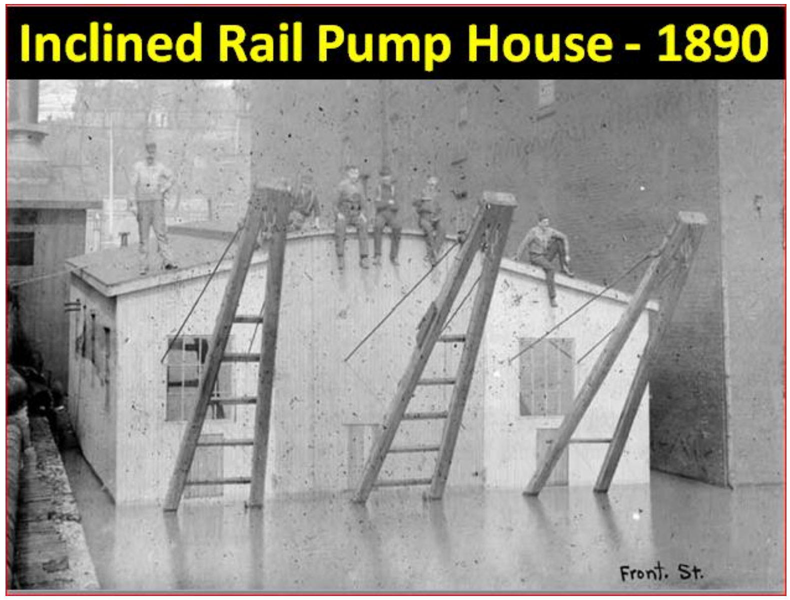
A major concern for the Chief Engineer of CWW, George H. Benzenberg and Architect, Gustave W. Drach, was how to safely pump water at low water stage and at flood stage. Because the Ohio River level Cincinnati was often at a level of two feet deep or less, existing pumps at Front Street Station often caveated caused by air entering the suction line. With air in the pump chamber a dangerous condition of no-load can cause the engine to over rev and quickly break apart. At high water, the station would flood causing boilers to extinguish and the engines to be submerged. This river condition is unique to the Cincinnati Water Works and not found at other river pumping stations. The Ohio River at Louisville, KY is about one mile wide and they experience less change in level during periods of high water compared to Cincinnati, where the river is narrow at 1/5th mile wide and a minimum depth of 26 feet.



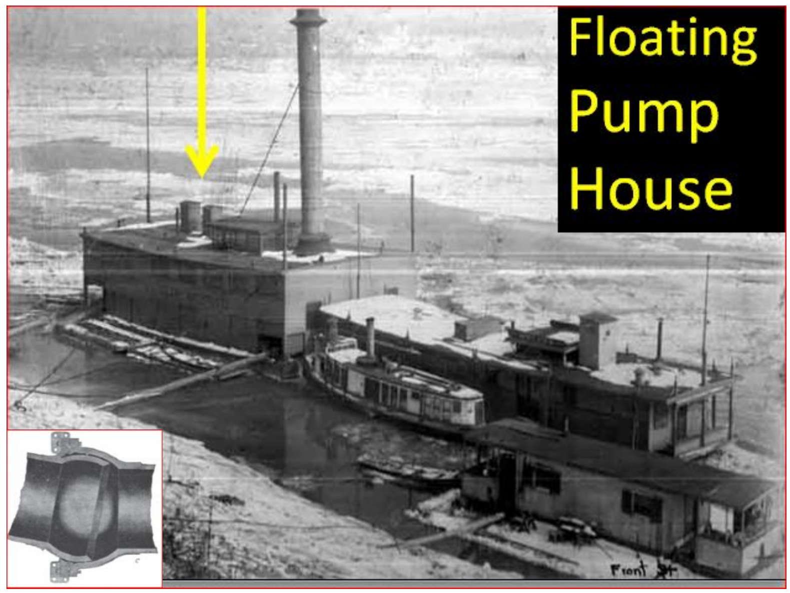
Twice Cincinnati attempted to solve pumping issues associates with this wide dynamic range. In 1890 an inclined rail pump house was installed. Three pumps, boilers and an onboard coal supply allowed the pumping station to follow the river level to pool stage. Hoisting booms for each of the three suction lines lowered the pipes to water level as cables from the hoisting house moved the station toward the river.



While this design worked extremely well, in part because the pumps were well designed and operated efficiently, they could not prevent the boilers from flooding at high water level as shown right.



To solve the high water issue, a second attempt to deal with this 75 foot dynamic range was installed. A completely self-contained pump house (yellow arrow) was moved into position using tow boats and moored using cables anchored shore side. Two flexible cast iron pipes, stretching shore-side, allowed the station to move water efficiently.

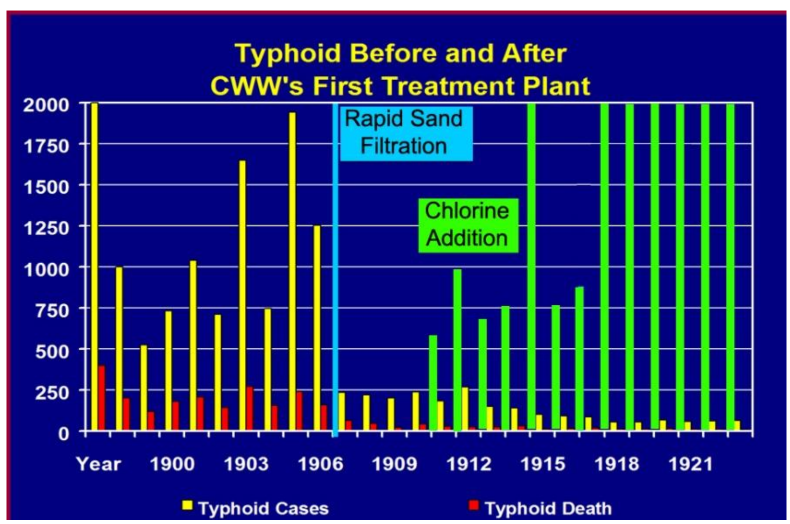


Again this design proved to be very successful, except for one unforeseen issue causing discontinuance after a bad winter.

Difficulty keeping the station accurately moored in place, to prevent delivery pipe damage, was caused by heavy ice flow as shown in the picture to the right.

All too often the cables would break from the extreme ice flow pressure, causing panic among the tow boat captains, as they struggled to recover the runaway station.

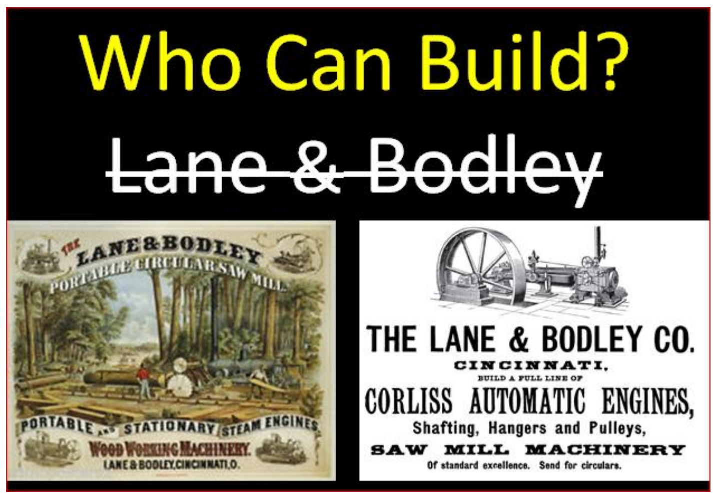
Because typhoid was already rampant, the city population was expanding from the success of steamboat traffic, and the failure of both the inclined rail pump house and the floating station, now was the time to consider a completely new approach to supplying clean and safe water to the City of Cincinnati. From the beginning of mechanized pumping for the city, raw river water was delivered to the distribution system that supplied water to people's homes. The picture to the right shows the reduction in typhoid after the New Water Works went on line in 1906 and the further reduction in 1916 from the addition of chlorine.



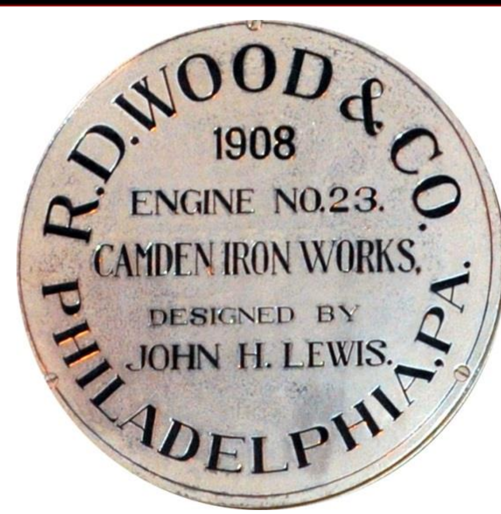
While the design of triple expansion water pumping engines was relatively new in the late 1800s, no one had ever built an engine the size required by Old River Station. When the New Water Works was designed, engineers specified the pump suction line to be below the floor of the Ohio River, allowing for an air-free gravity feed. This small inlet head pressure allowed water to naturally fill the pump intake chamber and prevent cavitation. Likewise, the top of the engine was to remain dry during periods of extreme flooding. This requirement caused the engine to be 104 feet high with the base resting six feet under the river floor, and was clearly unique to Cincinnati because of the large dynamic range for the river.

Fifteen bids from eight manufacturers in December of 1897 resulted in a contract to the Lane & Bodley Co. of Cincinnati, Ohio. Three of the biding companies were already building triple expansion engines (E. P. Allis, Milwaukee, WI; Holly Mfg., Lockport, NY; R. D. Wood & Co, Philadelphia, PA) but not the size required by CWW.

On the other hand, Lane & Bodley had never built a triple expansion engine, but enjoyed an outstanding reputation in the stationary steam engine business. The task for L&B was to furnish and erect four vertical, triple expansion pumping engines, each of thirty million gallons daily capacity with the necessary boiler equipment and a thirty ton circular traveling overhead electric crane.



While Lane & Bodley Co. was a highly respected builder of stationary steam engines in the USA, they failed to make progress on this contract, with only a couple of wood patterns completed after two years. Because no plans or drawings, acceptable to the City, were ever submitted, the city attempted to cancel the contract. Law suits against L&B by the City of Cincinnati eventually arrived at the Ohio Supreme Court. In January 1900, by a Supreme Court order, the contract for $514,000 was officially cancelled for failure to comply. Subsequently, in June of 1903, after a long legal battle, Lane & Bodley was required to pay back $65,000 of the $303,000 paid to them from their failed efforts to design and build these engines.

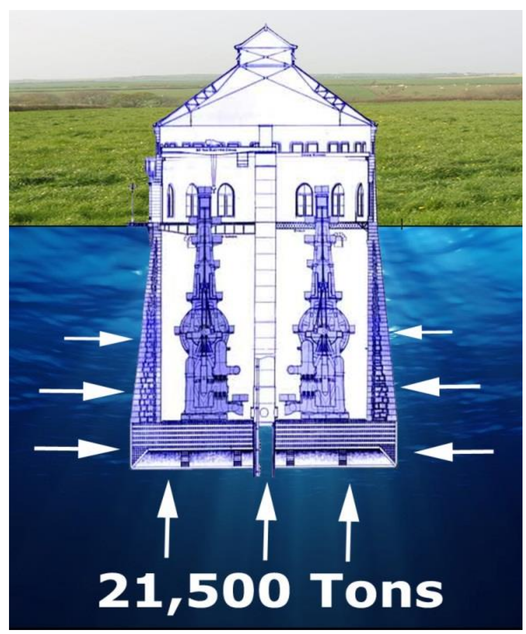


Proving to be a larger challenge than anticipated, the Cincinnati Water Works remained diligent in their quest for a successful design. Two successive attempts to acquire a successful proposal produced 14 responses from four companies, all rejected as unsatisfactory, causing considerable anxiety about the feasibility for the project.

Finally, in 1901, reviewing 11 proposals from four companies revealed several bids that were close to meeting requirements. Most agreeable to making design changes in real time, at no additional cost, The Camden Iron Works from Camden, New Jersey was happy to be the selected builder. Contracted to supply four engines, each of thirty million gallons daily capacity with the

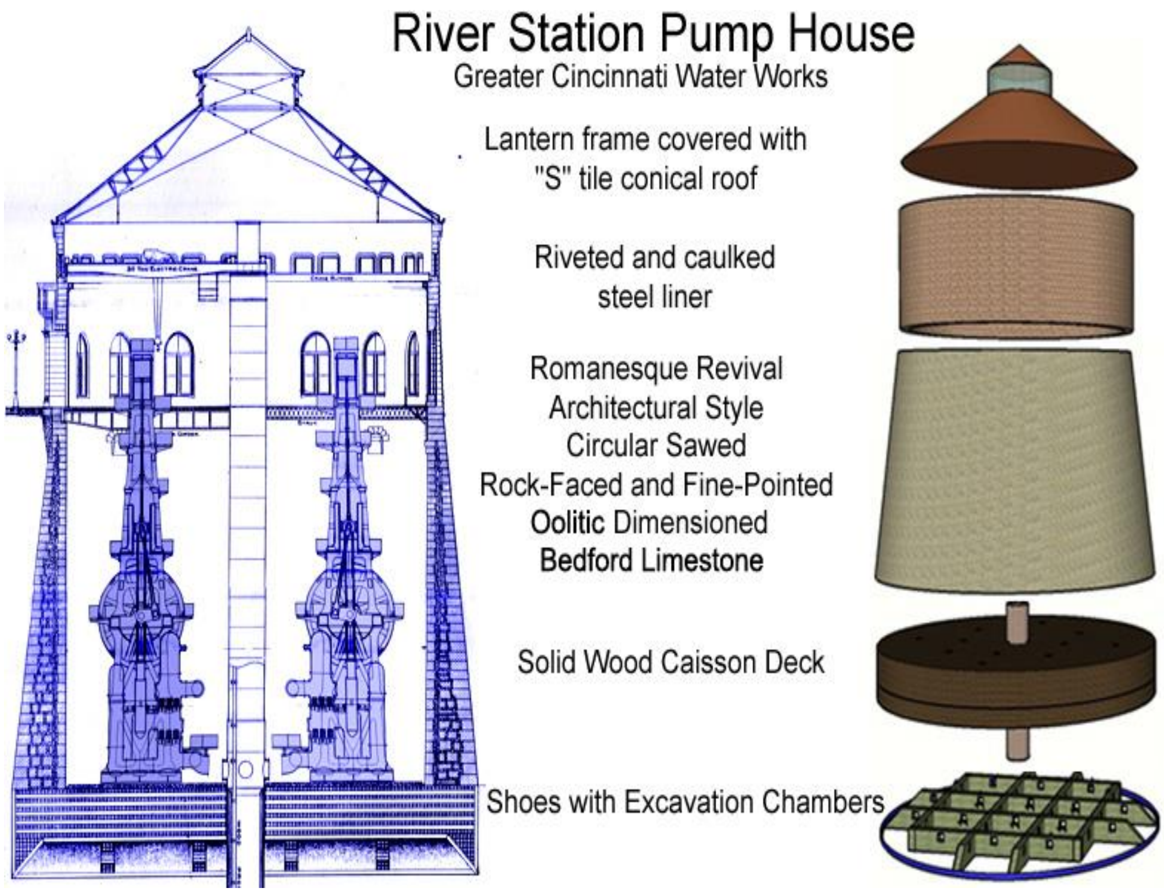
necessary boiler equipment, and a thirty ton circular traveling overhead electric crane (pictured above), the bid price was $807,500. Foundry began work in January 1901. Work proceeded quickly. Two and a half years later, with most of the foundry work finished, two-thirds of the castings were machined and half of each engine WAS constructed on site in Camden. Ultimately, each engine was erected and hand rotated at the Iron Works to assure moving parts functioned as designed, but never rolled from steam.

Hydraulics: At high water, when the river level rises to the height of the engine operating floor, the hydraulic pressure from ground water causes a buoyance pressure of about 21,500 tons pushing up on the building. Designed to push down on the pit floor was about 25,800 tons, the weight of the wall, steel liner, engines, crane, ballast, and ancillary equipment. At the time, this was considered more than adequate to hold the building firmly in the ground. In the mid-1960s, when the engines were taken out of service, about 4,000 tons of ancillary equipment was removed, but 4,200 tons of ballast had been installed late in construction, leaving a near perfect balance between buoyancy pressures and building weight,



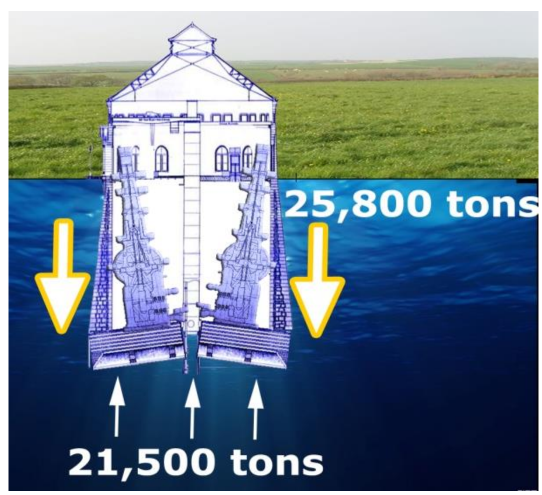
To withstand the extreme hydraulic pressure, the building was configured with a circular tapered wall, 15 feet thick at bottom decreasing to 4 feet thick at grade. Circular cut Bedford Limestone, 6 feet x 2 feet x 2 feet weighting 3,800 lb. each, were transported from the stone mason yard west of the station using draft horses, with a steam tractor assist when the soil was muddy.

Pump pit construction featured knife edge caisson shoes, seven feet high x 3 feet wide under a 12-foot thick crisscrossed white oak timber deck. The caisson was built at ground level and simultaneously lowered to a depth of 105 feet in six months ending on October 12, 1899, as above ground construction of the tapered wall continued.



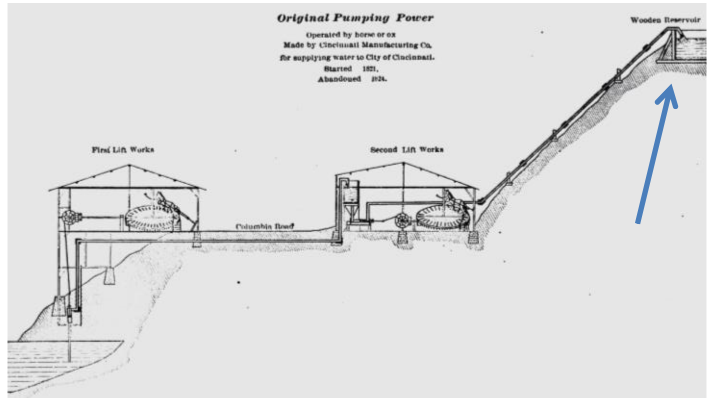
At high river level nine months later, June 1900, the center of the caisson deck rose up almost 5 inches while the outer-most edge fell one and a half inches, making the floor uneven and not level. This was an unacceptable floor deformation for the precision placement of the engines.

This was a catastrophic surprise to the engineers and builder. Since the caisson tipped upwards toward the center, the logical solution was to push down at the center. To assure the deck would not move in the future during periods of high water 4,200 tons of cast iron ballast was ad hoc designed to circle the standpipe. Trapezoid shaped segments were supplied by the Bollman-Wilson Foundry Company of Cincinnati because they were the lowest bidder at $17.35 per ton. The ballast segments, each 6 ton, was cast in 30 days and installed in another 60. Fortunately space was available between the stand pipe and the engines to place this unplanned ballast, but the spiral staircase had to be relocated from the front of the engine to the rear.



Deformation of the twelve foot thick wood deck was caused by the three forces. Because the engines were not in place immediately following the sinking of the building, 100% of the wall weight (about 15,000 tons) rested on the outer most 25% of the deck, thereby providing an unbalancing force sufficient to tip the floor upward at the center. Moisture expansion of the dry white oak timbers provided considerable radial pressure toward the center stand pipe casing, causing further upward force, and the hydraulic pressure from the high ground water provided the final nudge upward.

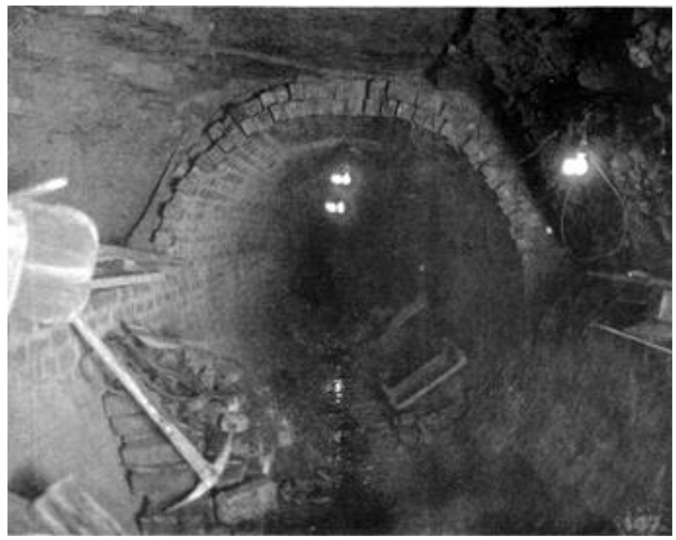
CWW had a long and successful history constructing wooden reservoirs using white oak timbers. White oak is a perfect choice for a watertight container. Its high expansion rate from dry to wet, radial 5.6 % and tangential 10.0 %, would be a perfect choice for a whiskey barrel, a wooden reservoir or a steam locomotive track-side water supply tank, but not a good choice for a closely spaced and bolted pump house caisson, 105 feet in the ground.



Wooden Reservoir used at Front Street Station

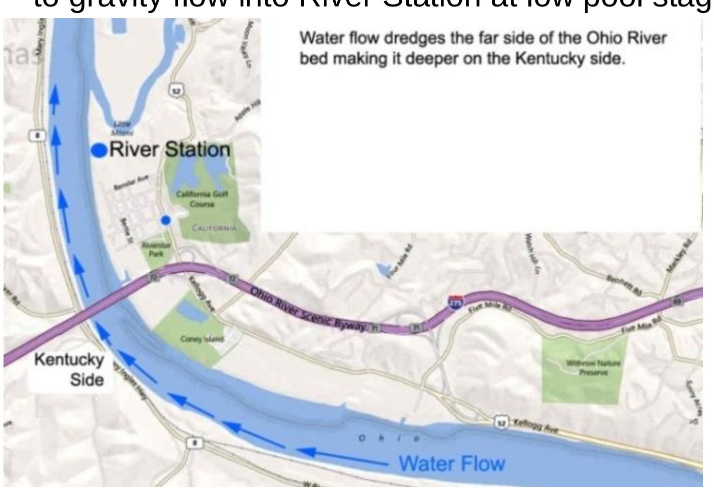
An example for the proper use of this closely spaced construction was the nearby wood reservoir at front street station. Measuring 30' x 40' x 6' with sides and bottom lined with closely spaced and bolted white oak timbers, the wood expanded nicely to seal joints and provide an outstanding reservoir.

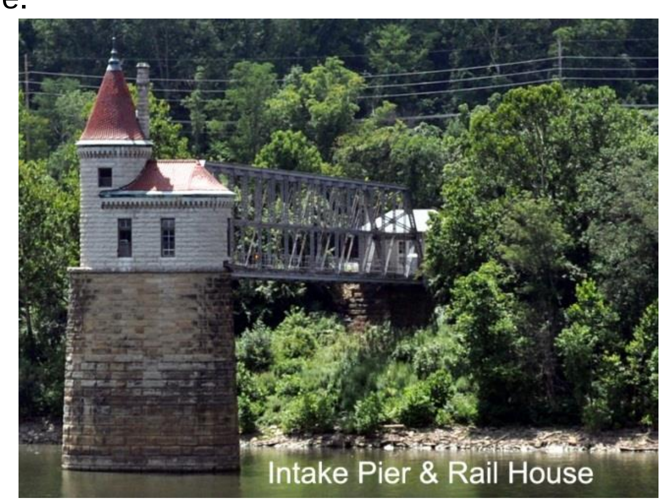
Sixty feet below the caisson floor the 10 foot diameter riveted and caulked standpipe connects to the 1,400 foot horizontal brick lined circular intake tunnel, seven feet in diameter, shown right. The tunnel was dug by hand using mules to move the excavated rock and dirt to the hoisting bucket in the standpipe.



The tunnel was dug by hand using mules to remove the excavated rock and dirt to the hoisting bucket in the standpipe.

Caused by the bend in the river near River Station, shown below, scrubbing or dredging the far side of the riverbed, the thalweg is 20 feet deeper on the Kentucky side. Therefore, CWW intake pier rest on the KY side of the river because the extra depth allowed water to gravity flow into River Station at low pool stage.





Station Design: Construction lasted eight years from 1898 -1906. The head for the intermediate pressure cylinder on engine #2 cracked at initial startup in 1906. After that, the four engines ran with no major failures from 1906 -1963 (57 years) and supplied water to the Greater Cincinnati area. Pulled by a narrow-gauge steam locomotive, engine components were delivered by rail using the Cincinnati Georgetown & Portsmouth (CG&P) dual gauge line. A narrow gauge engine (19 inch) pushed standard gauge (56 ½ inch) cars inside the station on tracks resting on a plate girder riveted to the standpipe.

Spiral Stair Cases: Dual spiral staircases, supplied by the Camden Iron Works, were to extend from the pit floor up to the engine operating deck. Originally designed to be located between the engines and the standpipe, they were redesigned to be anchored to the outside wall, because the unplanned 4,200-ton ballast occupied its space. This location prevented the staircase from extending to the main engine operating floor because it would have blocked passage around the outer walkway of the operating deck. So, they terminated the staircase at the eccentric deck. A railed staircase extends from the main engine floor to the eccentric deck. Railing for all stairs and elevated walkways was bright work polished brass. It was common practice during plant operations when a worker walked long the brass railing, they would carry a polishing rag in each hand and rub both the left and right rails as they traveled. On the return trip they would reach to the lower rails and polish as they walked.

From the Morgan Engineering Company, Alliance Ohio, the dual hook (5 ton and 30 ton) crane was initially the only circular traveling crane in the USA and featured a span of 49 feet 6 inches with a 110-foot lift. The three 230 Vdc electric motors used Morgan rheostat controllers with adjustable speed and direction controls. All three motors are still powered today by 230 Vdc from an in-house motor-generator set, and included a 30 HP hoisting motor, a 25 HP a bridge motor and a 5 HP trolley motor. Ordered on April 26, 1901 by the Camden Iron works, the crane shipped to the California, Ohio facility on November 18, 1903.

Design of the engine and its pumps allowed every principal part to be reached and removed by the overhead hoisting crane without disturbing any other part of the machinery.

Station Staffing was 36 employees for day time operations. Each eight-hour shift maintained a minimum staffing of one licensed stationary engineer, four oilers, one licensed fireman, two coal-passers, and an assistant Chief Engineer. Daily staffing include a station chief, clerk, one machinist and helper, one boiler cleaner, one locomotive operator, a janitor, and three or four grounds keepers.

Each engine contained its own air compressor (diameter 3 3/8 inch), boiler feed water pump (diameter 2 ¾ inch), and its own bilge pump (3 inch diameter), all with a 96 inch stroke. All three pumps were driven from an attachment to the lower crosshead on the low-pressure cylinder.

The large gear for the bevel gear set that transfers power from main crank shaft to the eccentric shaft features hard maple cogs. Wood is more forgiving than cast iron to a sudden jerk in rotation, caused by either accidental air in the pump chamber or a steam valve failure. Individual wood cogs made repair easy work and allowed the bevel gear set to run quieter than the traditional whirling sound of metal against metal.

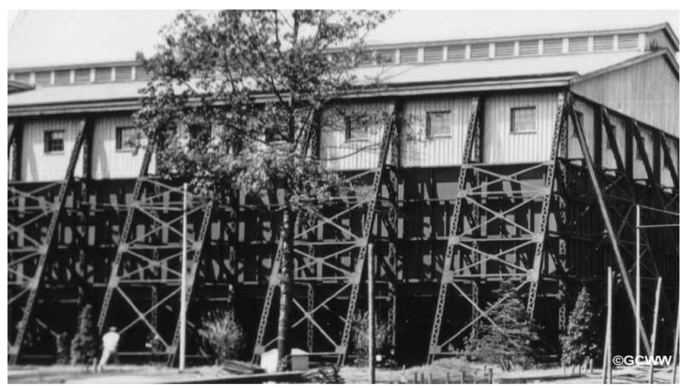
The attached surface condenser is in line with the 48-inch discharge header allowing the entire water discharge to pass through. A 48-inch check valve on the discharge side prevented backflow through the condenser.

Annex, Boiler House, Coal Storage, Coal Intake and Intake Pier

Annex: Electrical Supply: Three units, each consisting of a DeLaval steam turbine driving two 75 KW, 4- pole Crocker and Wheeler, 230 volt direct current generators provided electricity to both river station and the filtration/treatment plant.

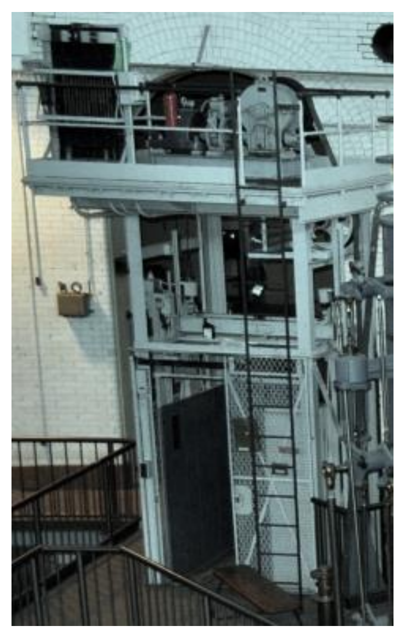
Machine Shop: overhead crane, two metal lathes, two drill presses, grinders, vertical milling and horizontal milling.

Boiler House: was rated at 4,500 HP and housed nine Sterling water tube boilers producing 150 p.s.i.g. dry steam (2.2% at engine, 2% at boiler) at 366°. Supplied with coal by an American underfeed stoker, the boilers were eventually converted to forced draught Riley Stokers. The 175 foot stack with an ID of eight feet, used a dual set of 85-inch Buffalo Forge draught fans with direct drive Buffalo Forge engines. Between 1920 and 1921 the boilers were replaced.



Two Wheeler surface condensers, each equipped with a Mullan air pump, were in the boiler room to accept the exhaust steam from the ancillary engines.

Coal: Pittsburg nut & slack coal, 1½" and ¾" respectively, provided 13,000 BTU per pound of coal. Storage featured a 310 day elevated supply, 8,000 tons, stored in 114 pocket-hoppers elevated six feet from the ground. Average daily usage was 26 tons.



Coal Intake from river's edge was via an elevated narrow gauge (19 inch) rail system, that supported 2-ton coal dump cars, pulled by a steam powered dual-cable hoisting engine.

Coal was supplied to the boilers by this narrow gauge system using an Edison battery powered locomotive called the Dinky. Coal was dumped on the floor in front of each stoker and shoveled into the hopper by a coal passer. The stoker coal feed was later converted to a Lorry overhead delivery system.

Elevator: Warner Elevator Manufacturing Company on Spring Grove Avenue, Cincinnati, Ohio provided a 2,500 lb. capacity, 230 Vdc motor driven elevator. Traveling between the engine operating floor level and the pump pit floor level, the elevator stopped at five additional levels. Usage was restricted to management while workers used the spiral staircase to move up and down the engine operating levels.

Warner Elevator, one of six elevator manufactures in Cincinnati, was the third largest elevator company in the country and was proud to have the largest elevator factory in the USA, pictured right. They were the first to supply water driven hydraulic elevators to the local area (1860) and the oldest hydraulic elevator builder in the nation. Every type of elevator, from the high-speed passenger and freight elevator to the dumbwaiter was made at the Spring Grove Ave. factory. An exclusive product was their electrically driven, plunger type elevator for residential use.

Partial View of Machine Assembling Department

Warner Elevator Co. assembly floor

Warner Elevator Company was acquired by the Shepard Elevator Company of Cincinnati around 1921, and became the Shepard Warner Elevator Company. Eventually purchased by the Dover Corp around 1959, the home elevator division of Dover Corporation was acquired by the ThyssenKrupp Access Elevator Division around 1990.

This Stair Lift was originally designed and sold by Warner Elevator Co., and remains a product today with the original flip-up seat

Water Pumps: Three displacement type pumps, one for each steam cylinder, uses an outside packed nickel-iron plunger measuring 37½" inches in diameter. Moving 460 gallons/revolution/pump, with 1,380 gallons per revolution per engine, the 14 foot long, 96 inch plunger, moved two tons of water /revolution/engine. Eight tons of water was move into and out of the station for every revolution of the flywheel. One revolution was every 4 seconds (15 RPM).

One-way valves, aka check valves, are the poppet valve design. Both the suction side and the discharge side used 280 valves/assembly, requiring 560 valves/pump. Seven valve cages per assembly contained 40 valves each. 6,720 valves/station.

There are 30% more valves per assembly than required for the volume from the pump plunger, providing a comfortable safety margin.

Railroad System: It was important that a railroad connection be established between the New Water Works and the Cincinnati, Georgetown & Portsmouth Railroad. This connection enabled contractors to deliver their tools and supplies as well as the construction materials and machinery with the least amount of haul by teams. The railroad, along with the viaduct, was built by the Fort Pit Bridge Works, from Canonsburg, PA.

Pictured are the standard gauge and narrow gauge (19 inch) tracks at Old River Station sometime after 1963 when the station was taken out of service

4,850 feet of dual gauge railroad track on a 2% graded roadbed was laid from the main CG&P line to the New Water Works. The CG&P was a narrow gauge steam line constructed by the Cincinnati & Portsmouth Railroad company between 1876-1886, and converted to Standard Gauge and Electrified in 1902. While the line never made it to Portsmouth because funding ended when they reached Georgetown, it was the first steam railroad in the country to convert to electricity. The branch to the California water works was built with dual gauge tracks to allow standard gauge freight cars from the Little Miami Railroad to be hauled to the water works with the CG&P narrow gauge locomotives. CWW purchased this rail addition in the 1930s when CG&P was liquidated.

Shown are standard gauge tracks leading to the inside of Old River Station

At the water works, the tracks divide with the standard gauge tracks ending at the center of the pump house supported by a plate girder, and the narrow gauge continuing to the coal storage building. The track consists of three 60-pound rails for a 19 inch and 4 feet 8 ½ inch gauge track ballasted with gravel. The tracks were able to carry a live load of two locomotives coupled and followed or preceded by a uniform load of 3,000

Shown is the CWW Whitcomb D-500, 20-ton gasoline powered Critter Locomotive pounds per lineal foot, moving at the rate of thirty miles per hour. Rail cars were switched at the station using a Whitcomb D-500; 20-ton gasoline powered Critter Locomotive.

The Cincinnati-Georgetown Railroad Co. reorganized in 1927. Service was cut back and they eventually abandoned the entire line. The remaining route between Carrell Street and the New Water Works was sold to the City of Cincinnati. The City Water Works use was suspended in 1943.

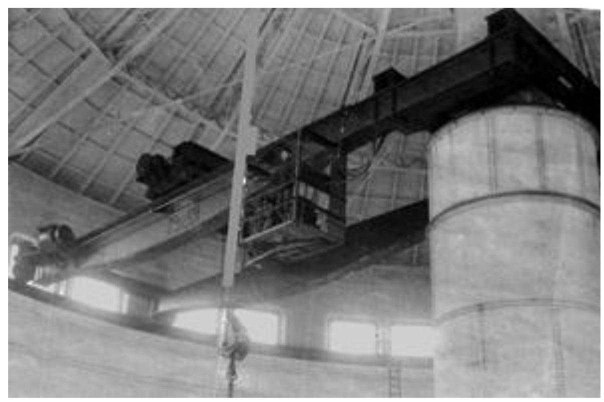
Station Staffing:

Three engines could be run at rated capacity without increasing the regular daily staffing of 36 employees. The Station Chief was in charge of the entire operation and the stationary engineer was in charge of the engines. Each eight-hour shift maintained a minimum staffing of one stationary engineer, four oilers, one licensed fireman, two coal-passers, and an assistant Chief Engineer. In the day time, the assistant Chief Engineer was in charge of the four oilers, one fireman, one clerk, and one machinist with helper, one boiler cleaner, one locomotive operator, a janitor, and three or four laborers to take care of the grounds.

Circular Traveling Radial Crane

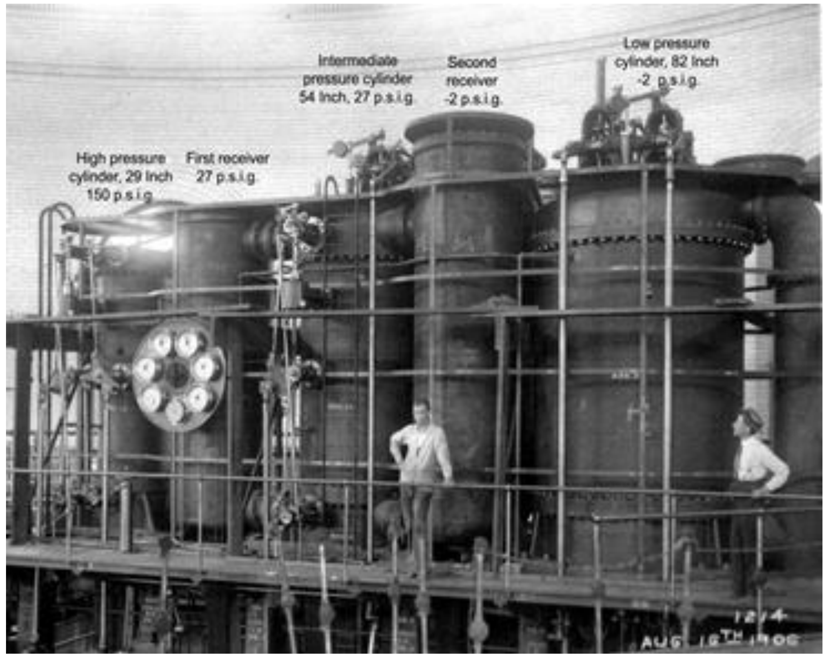
Supplied from the Morgan Engineering Company (formerly the Morgan Crane Company) in Alliance, Ohio, the crane has a span of 49 feet 6 inches and a 30-ton lift of 110 feet and a 5-ton lift hook. The three electric motors use Morgan controllers with adjustable speed and direction controls. All motors are 230 Vdc and include a 30 HP hoisting motor, a 25 HP bridge motor and a 5 HP trolley motor.

On a projection in the above grade wall is placed a steel track girder for the rail of a circular radial traveling 30 ton 230 Volts dc electric crane. The inner end of the crane revolves on a track placed on the top of the standpipe rising from the center of the caisson.



Shown is the original overhead crane with the control platform anchored to the movable support truss between the standpipe and outside wall.

Design of the engine and its pumps allowed every principle part to be accessed and removed by the overhead crane without disturbing any other part of the machinery. However, when the head for the intermediate pressure cylinder cracked at the initial startup for engine two and required replacement, some steam piping was removed to access the engine. BTW, that was the only major engine failure in 57 years of operation.



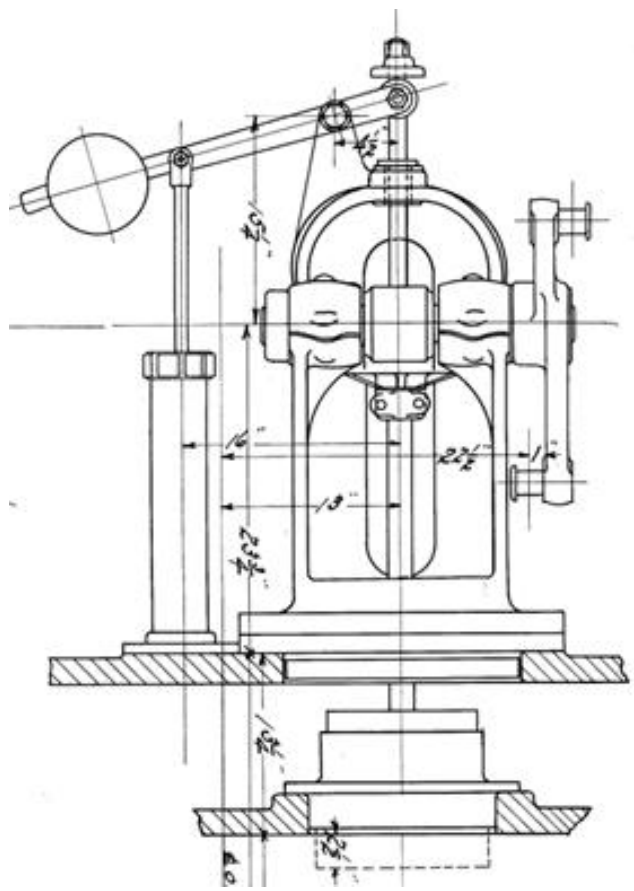
Shown are the steam cylinders with their associated receivers, valving and the gauge panel

Triple Expansion Steam Engines
High-pressure cylinder:
Dry process steam at a gauge pressure of 150 p.s.i.g. and a temperature of 366°F entered the 29-inch high-pressure dual-acting cylinder.

Steam entered the cylinder through a dual set of rotary cylinder Corliss valves equipped with knockoff cams controlled by the governor. The Corliss valve was selected because it requires little operating force in the presence of high-pressure steam.

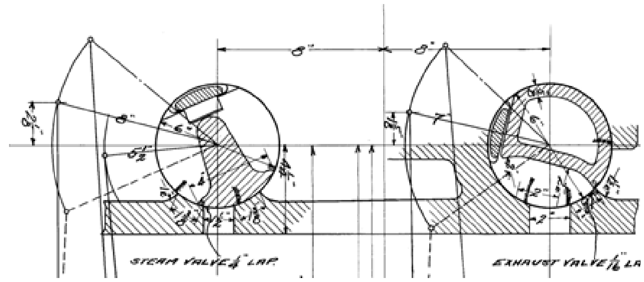
Corliss & Poppet Valving System
Balanced Poppet Valve: (American) original name *Puppe*t valve invented around 1800 by Jonathan Hornblower, a British pioneer of steam power, who also invented the compound engine in 1781, but litigation with James Watt prevented its application until 1804.

The balanced poppet valve was invented and patented by the F. E. Sickels, New York in 1842, #2631 and improved on by the Frisbie Engine and Machine Co., Cincinnati, Ohio. Patent issued on July 29, 1884 as patent #302,835. The "poppet" was originally "puppet", a word that implies working a device from a distance, as a puppeteer works a marionette with strings.


Shown is a typical balanced poppet valve using a spring and weight to balance the force from steam pressure

Shown right is the spring and weight balanced poppet valve use on the R. D. Wood engines at Old River Station.

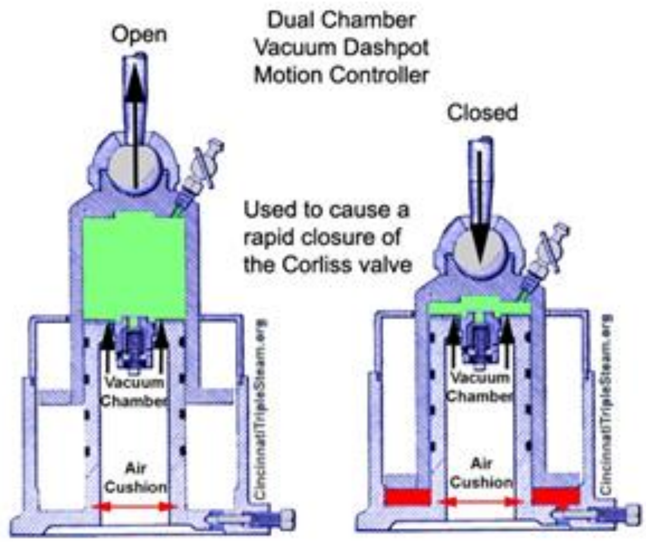
The Corliss Valve was invented by and named after the American engineer George Henry Corliss in 1849, Providence, Rhode Island, who also made the gun turret ring for the USS Monitor and invented a heavy-duty sewing machine for boots, shoes and heavy leather.



Shown is the Corliss valve for both the steam side and the exhaust side.

As a side note: The engines at the Eden Pumping Station were built by H. R. Worthington, NY, who invented the duplex pump, built the engines for the U.S.S. Monitor and designed the steam powered canal boat.

The dual cylinder vacuum dashpot:
The Corliss valve opens with a sinusoidal motion from the eccentric shaft but requires a rapid closure to cut off steam early in the cycle for the HP and IP cylinder. Rapid closure is accomplished using a dual cylinder vacuum dashpot. As the piston moves upward a vacuum is drawn in the green chamber and upon release rapidly returns to the bottom position. Near the bottom of the cylinder is a second air chamber colored red that compresses the air and acts to cushion the dashpot stroke.



Showing are both cylinders for the dashpot

First receiver: A second set of Corliss valves released expanded exhaust steam from the high-pressure cylinder into the first receiver for temporary storage.

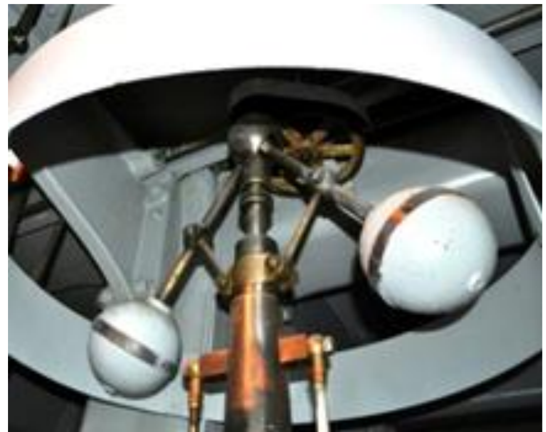
Intermediate pressure cylinder: Steam, at a gauge pressure of 27 p.s.i.g., from the first receiver enters the 54-inch dual-acting intermediate pressure cylinder through a third set of Corliss valves. The valves are equipped with knockoff cams controlled by a hand operated adjustment on the engine operating floor.

Second receiver: A dual set of balanced poppet valves releases exhaust steam from the intermediate pressure cylinder into the second receiver for temporary storage.

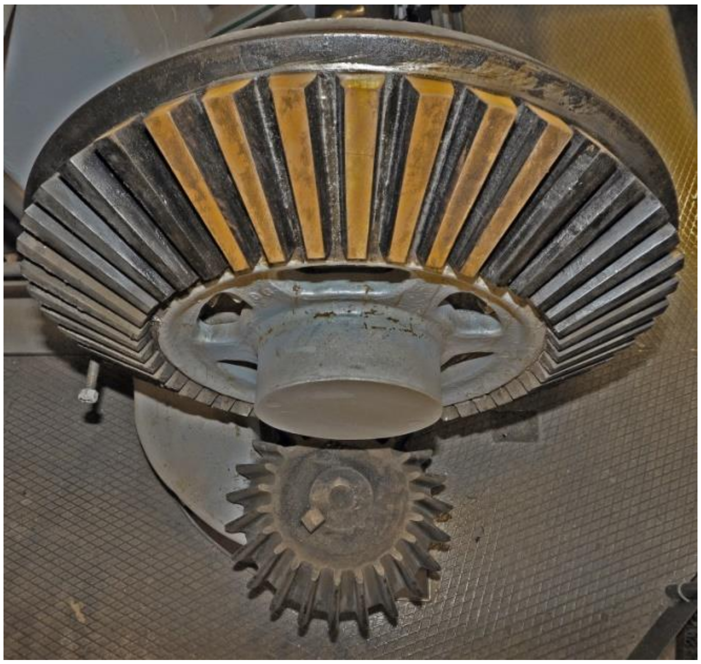
The poppet valve was selected because of its ability to control large volumes steam; however, the normal poppet valve would require considerable operating force in the presence of considerable steam pressure. That problem is solved by using a spring and weight balanced poppet valve that requires little force to open, but maintains its ability handle a large volume steam flow.

Low-pressure cylinder: Steam, with a gauge pressure of -2 p.s.i.g., from the second receiver enters the 82-inch double-acting low-pressure cylinder through a second set of double balanced poppet valves. A third set of double balanced poppet valves releases exhaust steam from the low-pressure cylinder headed toward the exhaust heater and surface condenser.

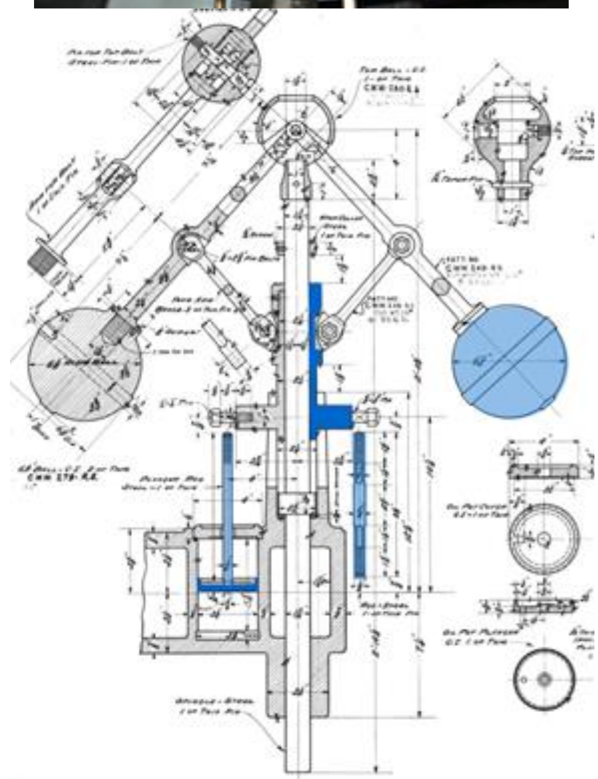
Speed Control: A centrifugal flyball governor regulated engine speed by adjusting the cut-off position for the rotary cylinder Corliss intake valves located on both the HP and the IP cylinders. Typical operational speed was adjusted between 11 and 15 ½ RPM. Highlighted in blue are a few of the moving parts.



Beveled Wood Cog Gears:

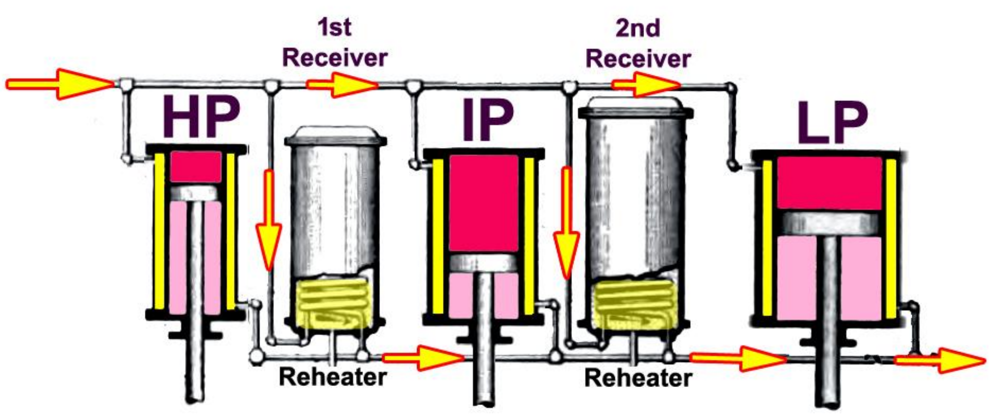


Two beveled sets of hard maple beveled cog gears transfer power from the flywheel shaft to the eccentric shaft. A third set of metal teeth beveled gears transfers power from the eccentric shaft to the flyball governor. Wood cog gears were selected rather than the traditional cast iron cogs to facilitate a small amount of shock absorption should the engine experience a sudden rotational jerk. In addition, wood cog gears run quietly compared to cast iron and are easy to replace.

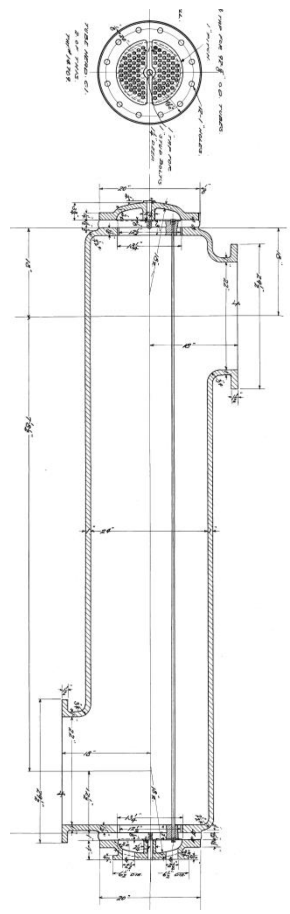


Colored blue are a few of the moving components for the centrifugal flyball governor

High Coal to Water Efficiency about 22% - 24%, resulted from a number of enhancements. Steam circulated through the steam jackets for all three cylinders to minimize condensation inside the cylinder and to increase operating efficiency as shown on the right-hand side of the page.

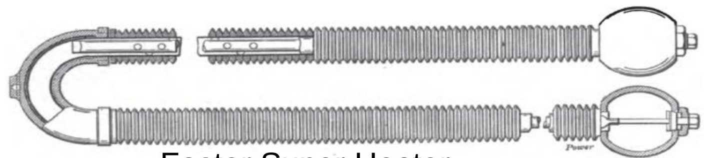


In both the first receiver and the second receiver process steam passed through reheating coils to add additional heat to the expanded steam.



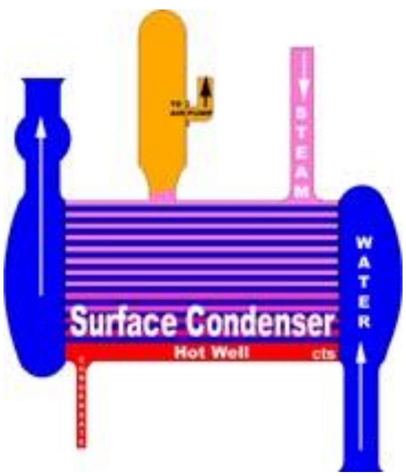
In addition, exhaust steam from the low-pressure cylinder was circulated through the 150 square foot exhaust heater (shown right) to preheat boiler feed water from 92° up to 142°.

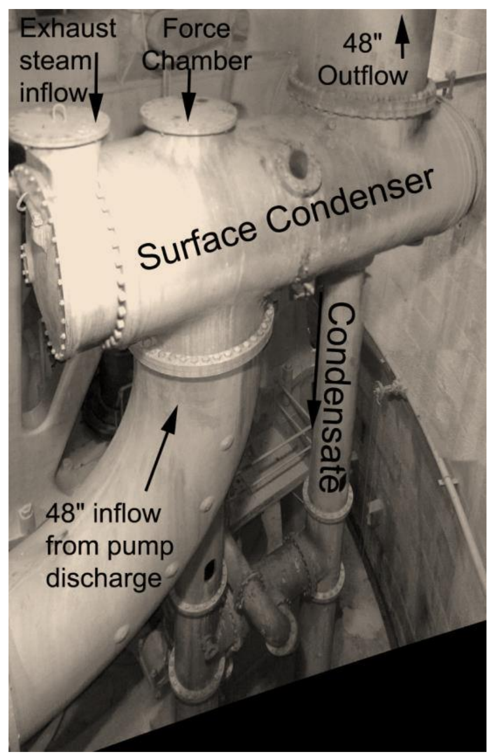
A Green Economizer captured boiler gases prior to entering the stack while a Foster Super Heater, inside the boiler firebox, added additional heat to the process steam.



Foster Super Heater

Surface Condenser, shown below and to the right, it is in line with the discharge header and allows the entire 48-inch discharge from the three water pumps to flow over the steel condensing tubes. Condensate falls to the hot well with at a typical temperature of 100° F.





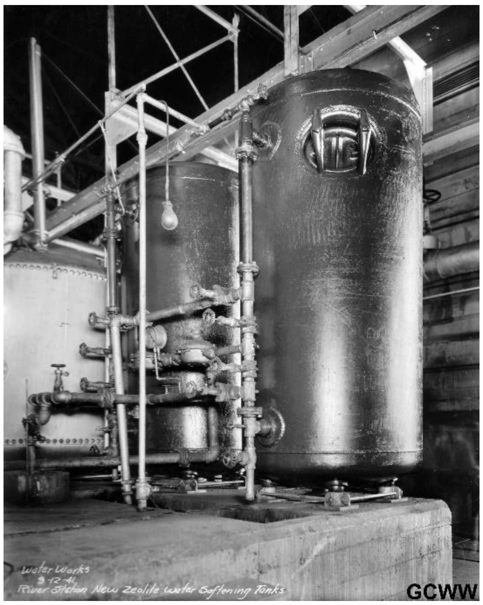
Boiler Feed Water Pump: The condensate water from the hot well of the surface condenser is pumped to the boiler house by an attached boiler feed water pump (aka doctor pump) with a stroke of 96" and a plunger diameter of 2¾".

Air Compressor: the attached air compressor with a 96-inch stroke supplied process air for ancillary equipment.

Bilge Pump: An attached bilge pump with a piston diameter of 3 inches x 96-inch stroke removed excess water collected at the bottom of the pump pit.

Wet Air Pump: The attached wet air pump, shown right, with a stroke of 30 inches and a piston diameter of 28 inches, removed oxygen; CO_2 and uncondensed moisture from the surface condenser chamber, while maintaining a gauge pressure of -13.8 p.s.i.g. Fifty-seven marine poppet valves are inside each wet air pump. Eighteen 4½ inch valves are in both the suction valve plate and the bucket valve plate, with 21- 4 ½" valves in the delivery valve plate gland.

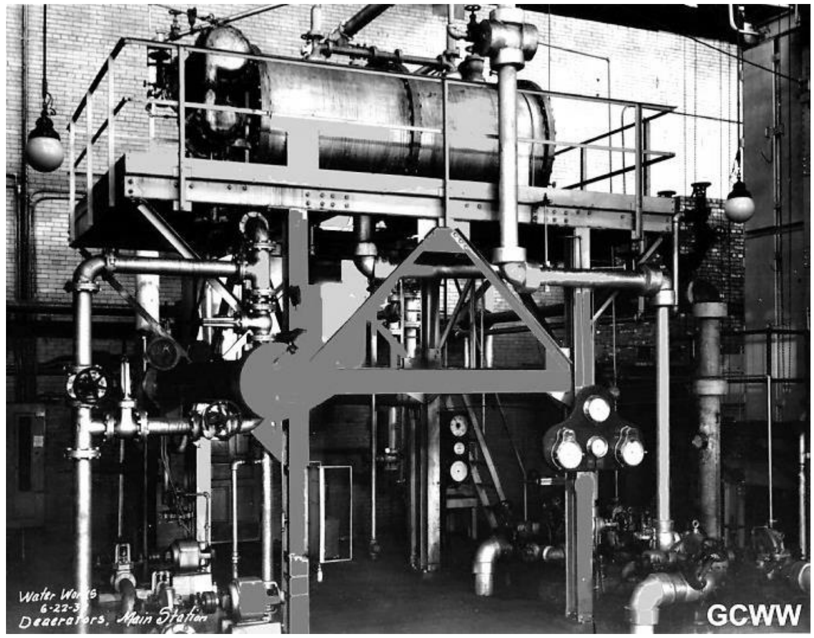
Water softener: Boiler feed water was preconditioned using the Zeolite process, shown below, to soften water and proved to be very efficient in the elimination of boiler scale.



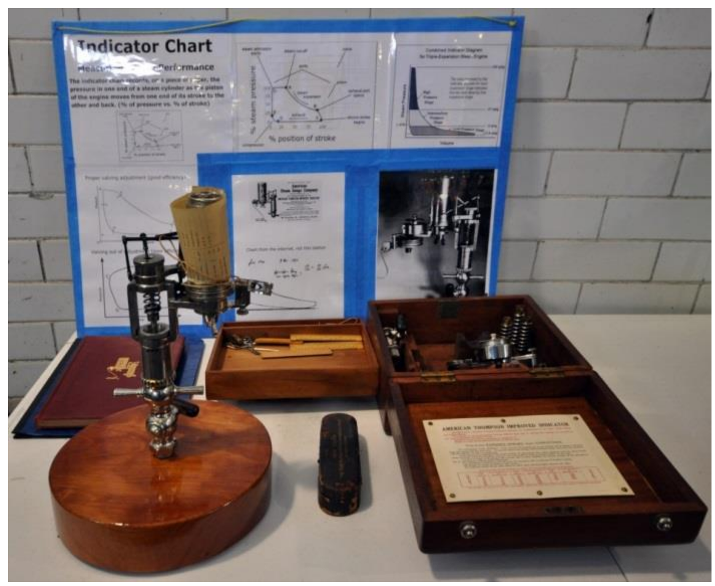
The Condensate Tanks, shown right and located on the pit room floor, collected water from the hot well of the surface condenser.

The Deaerating Plant purified condensate by removing scale and dissolved gases such as oxygen, carbon dioxide and other harmful chemicals prior to becoming boiler feed water. Condensate entered at 100° F and was discharged at 92° F.

How a Deaerating plant works

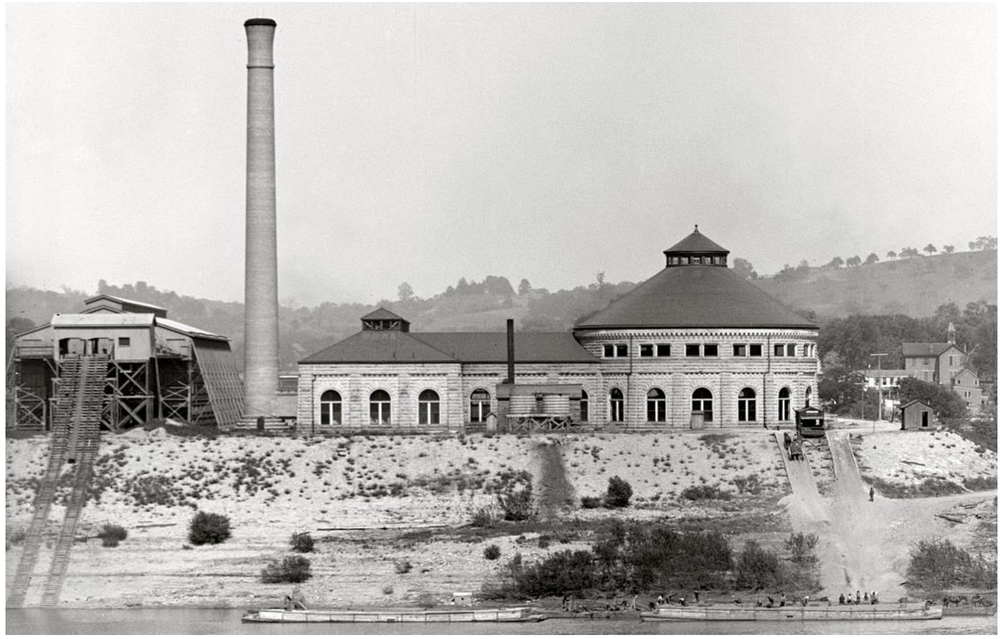


The Indicator: The American Thompson indicator, shown below, was donated by Bruce Babcock and is believed to be the exact model used at Old River Station.

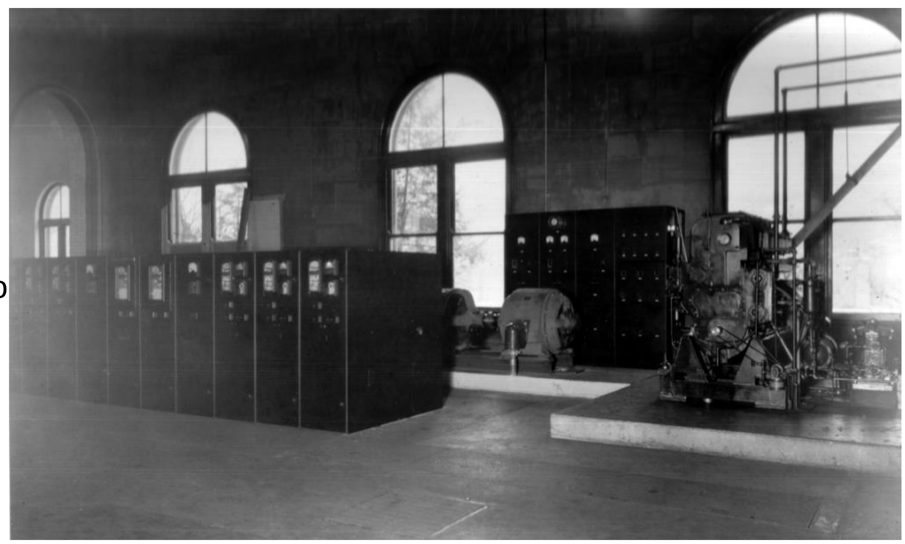


Annex, Boiler Room, Coal Storage, Coal Intake and Intake Pier

Annex: A 55-foot by 54-foot annex building connects the pump house with the boiler house. Individual lockers for all employees, toilet rooms with showers and other conveniences were provided.

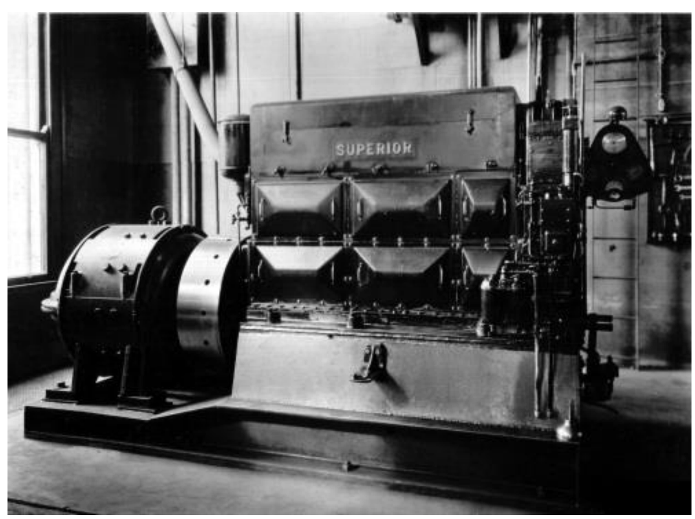


Electric Supply: The electric generating plant, located in the Annex was supplied by Dravo, Doyle & Co., of Pittsburg, Pa, and consisted of three units of two 75-kilowatt, 4-pole Crocker-Wheeler 230 Volt direct current generators. They were directly connected to two gear wheels, which were driven by a DeLaval steam turbine, fitted to operate either condensing or non-condensing.



These generators were used when the current required by the station was greater than could be supplied by the power generated from the water wheels at the Filtration Plant.

In addition, a direct electrical connection was made to a diesel fueled Russell engine (later converted to a Superior engine) driving a 60-kilowatt Northern Electric 230 Vdc generator. The generator supplied current to the electric motor operating the tunnel pump and was used as emergency backup to the steam driven generators.

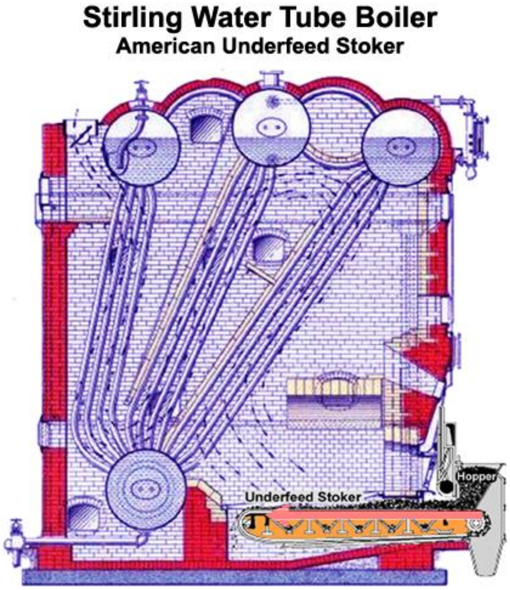


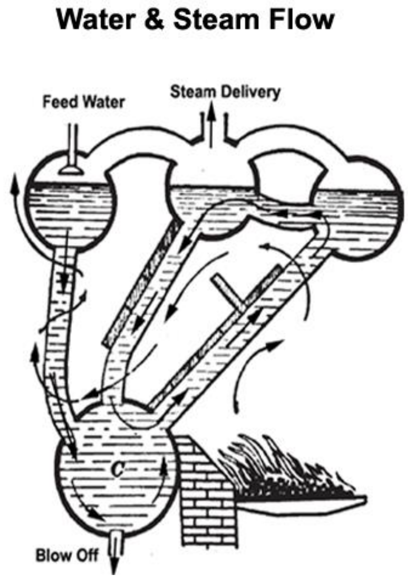
A seven-panel highly polished black enameled switchboard, on which all the various instruments are mounted, was also located in the Annex to be within observation from any point near the generators

Machine Shop: Contained an overhead crane, two metal lathes, two drill presses, grinders, vertical milling, and horizontal milling.

Steam and the Boiler Plant

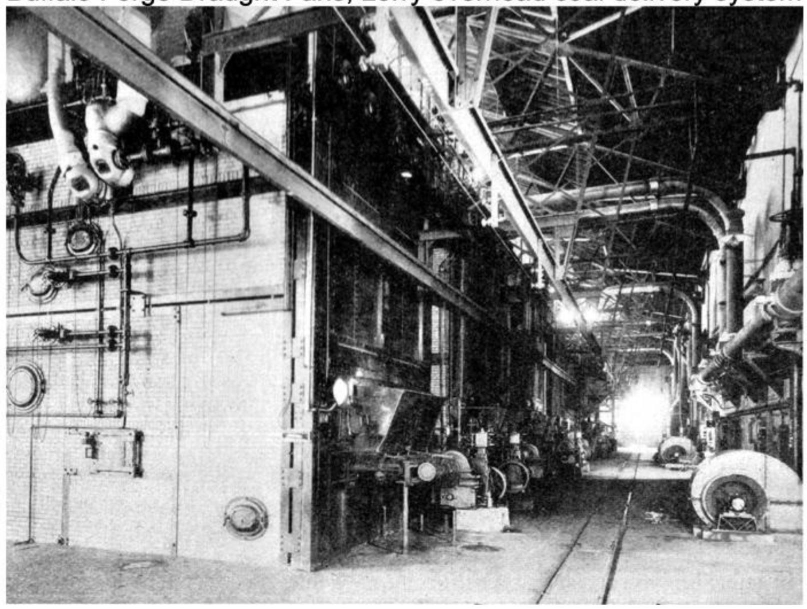
Boiler House: A stone walled building measuring 60 feet X 180 feet was constructed from oolitic-dimensioned Bedford limestone, with the exterior being rock-faced and fine pointed, and the inside sawed smooth and rubbed. The boiler room floor is concrete; the toilet room from red American tile, and the office and storeroom included matched yellow pine flooring.





Boiler: The boiler plant, rated at 4,500 HP used Sterling water tube boilers, eight at 424 HP and one at 529 HP and was the 4-drum version with three steam drums and one mud drum. Process steam left the boiler at 150 p.s.i.g. at 366 °F through a 14-inch delivery pipe.

Stirling Water Tube Boilers, Riley Forced Draught Stokers
Buffalo Forge Draught Fans, Lorry overhead coal delivery system



The piping was arranged to use either saturated steam or superheated steam and branched into two lines inside the engine room and with two engines taking steam from each branch.

The boilers were fired using a daily average of 26 tons of Pittsburgh nut and slack coal that produced 13,000 BTU per pound of coal. The coal work duty tested at 152,875,648 ft. lb. for every 100 lb. of coal, while the steam duty tested at 172,925,997 ft. lb. per 1,000 lb. of dry steam, weir measurement.

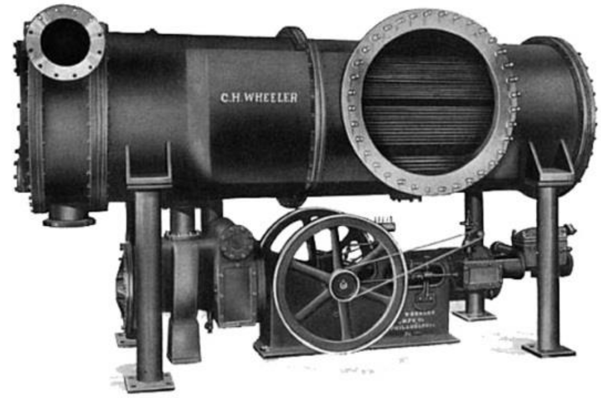
Coal entered the boiler using an American underfeed stoker, and later thru a forced draught Riley Stoker. Through a series of baffles, heat from the coal fire passed over 176 steel tubes 3¼" in diameter. A Buffalo Forge fan engine using a Buffalo Forge fan supplied air to all the boilers. The exposed surfaces of the boiler settings, flues and economizers was faced with Hanover red pressed brick, laid and pointed in red colored mortar.

Boiler feed water was preheated prior to entering the mud drum to a temperature of 200°F using a Green economizer and was heated to its boiling point as it circulated upward to the three steam drums. A Foster cast-iron superheater located after the final battle in the boiler added additional heat to the steam. Both systems contributed an additional temperature of 100 °F to the 150 p.s.i.g. dry steam with a typical moisture content less than 2%.

The boilers also furnished steam necessary for operating the electric generators and all auxiliary machinery, and for heating the building consisting of radiators and coils distributed throughout the buildings.

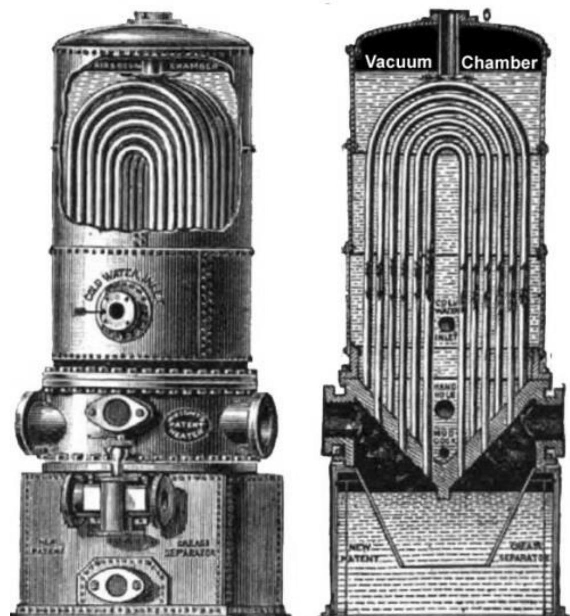
Ancillary Condenser & Wet Air Pump: Exhaust steam from the ancillary engines used throughout River Station, was converted to condensate using two C. H. Wheeler surface condensers with an attached Mullan Valveless Wet Air Pump.

A special eight-inch water line from the filter plant supplied the boilers and toilet rooms with filtered water. Boiler feed water was preconditioned using a Zeolite water softener and the feed water from the condenser hotwell was purified using a deaerating plant.



C. H. Wheeler Surface Condenser with Mullan Wet Air Pump used to support all the condensing type ancillary steam engines used throughout River Station.

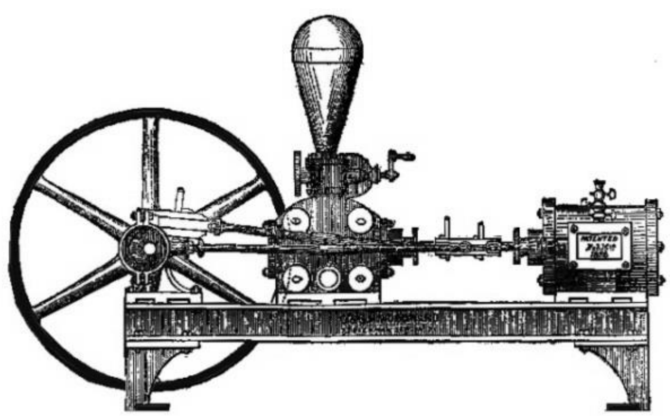
Ancillary Feed Water Heater & Grease Separator: Condensate from the C. H. Wheeler surface condenser was used to preheat boiler feed water using a Berryman Feed Water Heater and Grease Separator, located in the boiler house



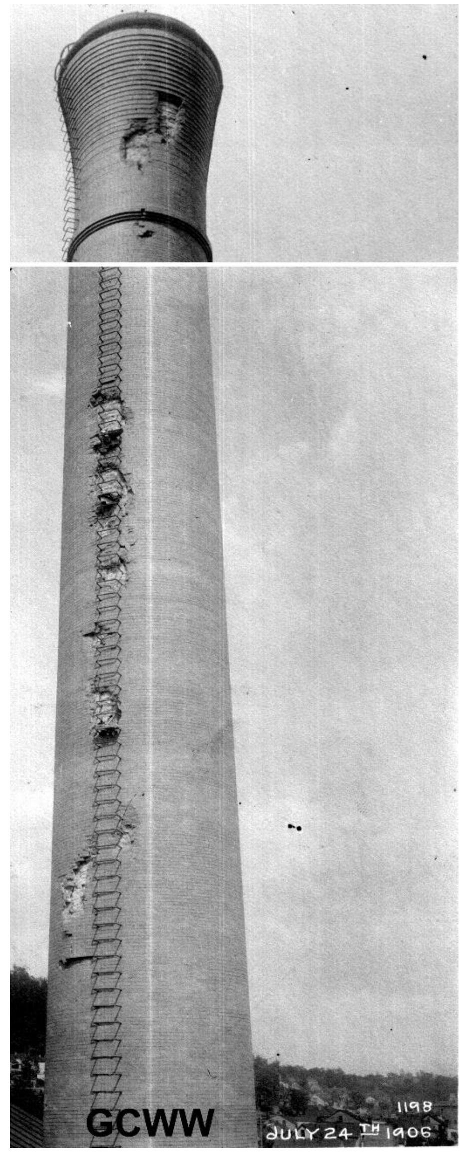
Berryman Feed Water Heater & Grease Separator used to process the return steam from the ancillary engines used throughout River Station

Ancillary Feed Water Pump
(Aka Doctor Pump)
Condensate from the ancillary engines was returned to the boiler using a H. R. Worthington Feed Water Pump, located in the boiler house.

H. R. Worthington Feed Water Pump
used to pump condensate back to the boiler from the ancillary engines

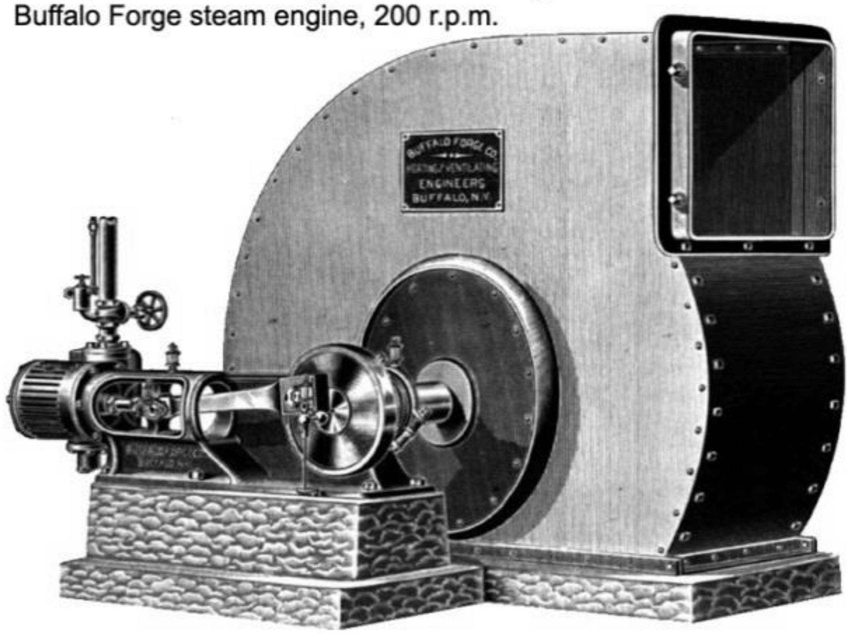


Stack Boiler plant gases were exhausted into the 175-foot high, 8 feet inside diameter stack fitted with a cast iron top, using two 82 inch Buffalo Forge forced draught fans, each driven by a Buffalo Forge steam engine. Lightning protection was not initially provided for the stack and as a result considerable surface damage occurred close to the steel ladder used to climb the stack.

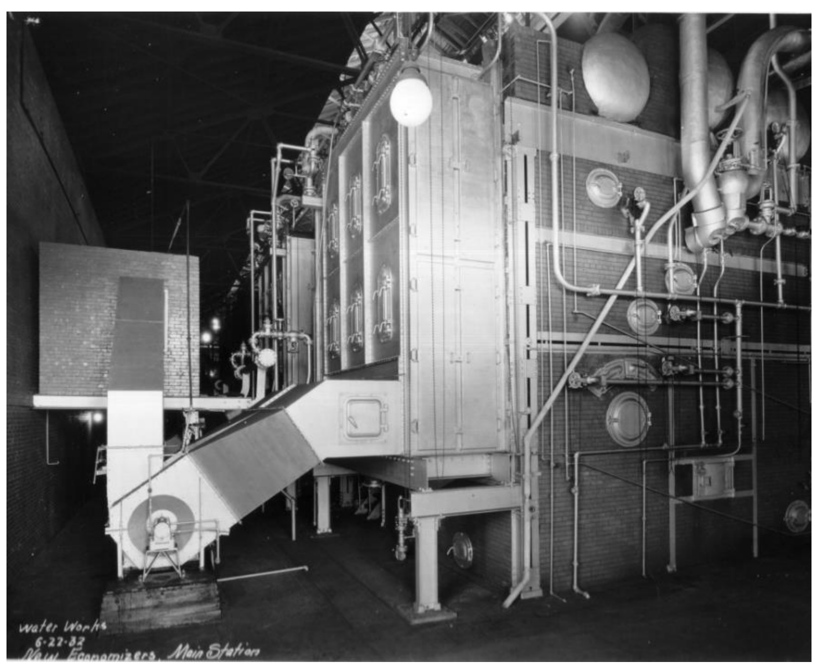


Forced Draught to the Riley Stoker's was supplied by two 85-inch fans from Buffalo Forge equipped with direct drive Buffalo forge steam engines.

Dual 85 inch Buffalo Forge Co. stack draught fans with direct drive Buffalo Forge steam engine, 200 r.p.m.



Green Economizer: 437°F exhaust gases from the boiler passed through a preheater prior to entering the stack and was used to heat boiler feed water. The Green Economizer increased feed water from 142°F to 200°F.



Coal: Coal was originally delivered by Ohio River barge and on occasion by truck. 8,000 tons of coal (310-day supply) was stored in 114 elevated pocket hoppers shown right. The coal was dry during periods of high river level, and provided sufficient capacity for periods of low river level. The elevated 69-foot X 225-foot coal storage building, with a superstructure of steel supported on steel columns and covered with a roof from eight-inch plain boards, was designed and constructed by Chas. L. Strobel, of Chicago.

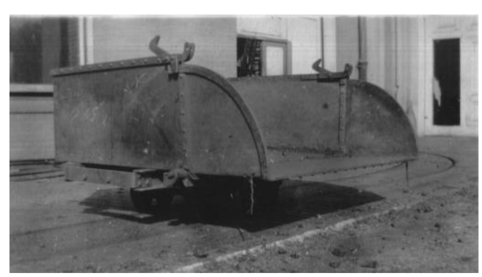
Supplying coal during periods of high river lever was assured by an elevated coal storage building holding 8,000 tons of Pittsburg Nut & Slack coal that was stored in 114 elevated pocket hoppers each holding 70 tons. Average daily use was 26 tons.

Coal was elevated from the river barge by a narrow gauge rail system (19 inch) installed from the river level to the top of the hoisting house using a dual cable-car system, one car traveling up while the other traveled down. Steam hoisting engines in the hoisting house used a dual cable hoisting drum to lower one car as the other car was being pulled up the incline. Steel trestle bents were used for the elevated section.

The two-ton outside flanged coal dump cars deposited coal onto a cross a belt conveyor that fed shuttle belt conveyors to the 114 pocket hoppers, each holding 70 tons of coal.

Each pocket hopper was equipped with a coal spout valve leaving 6 1/2 feet of headroom above a narrow gauge rail system.

Steel aprons were provided to span the distance between the tracks on the incline and the tracks on the unloading barge at any stage of the river water above elevation 16. During the delivery of coal by barge, it was found later that the distance between the center of tracks on the inclines did not always agree with the spacing of the tracks under the coal hoppers for the unloading barge, and some changes had to be made on the steel aprons to permit adjustment to the tracks on the barge.



Coal was switched to the boiler house from the coal storage building by a continuous loop narrow gauge rail system. The boiler charging cars were pulled by an electric automotive engine called the Dinky powered by Edison batteries. Boiler ash was moved to the ash pit using the same narrow gauge rail system.

A rail suspended hopper system called the "Lorry", eventually replaced the coal shovelers and delivered coal to each stoker hopper. The Lorry was supplied by a coal hoist in a new three story poured concrete lifting house at the front of the boiler house. The railroad siding had been extended to the coalbunkers and a new river-side incline built, so that coal could be received either by rail or by river. However, rail delivery was never required.

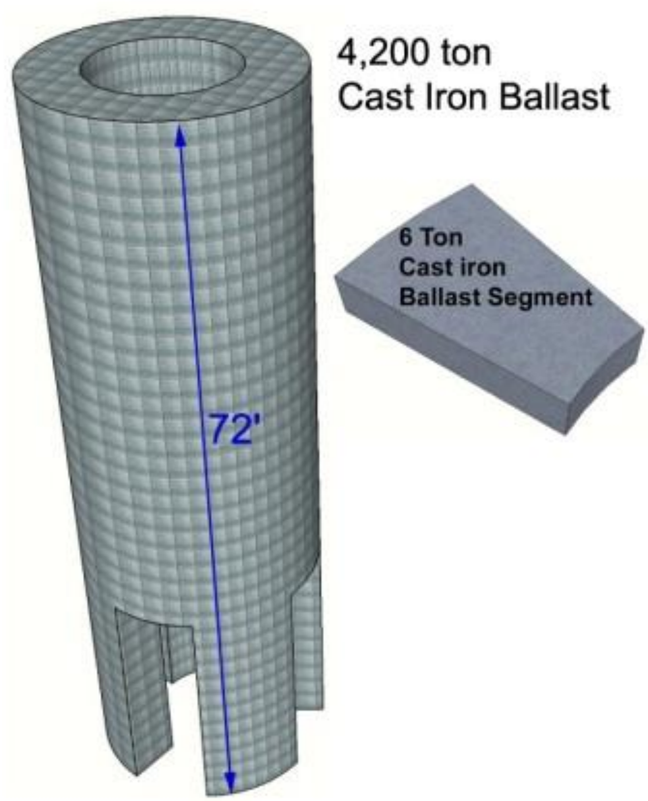
Pump Pit Floor

Warner Elevator:
Between pumping engines one and two and adjoining the pump-pit wall, an electric elevator and cab is provided for carrying people from the engine-room floor level to the pump-pit floor, or any of the main engine levels. Warner Elevator Manufacturing Company, Spring Grove Avenue, Cincinnati, Ohio provided the 2,500 lb. capacity, 230 Vdc motor driven elevator.

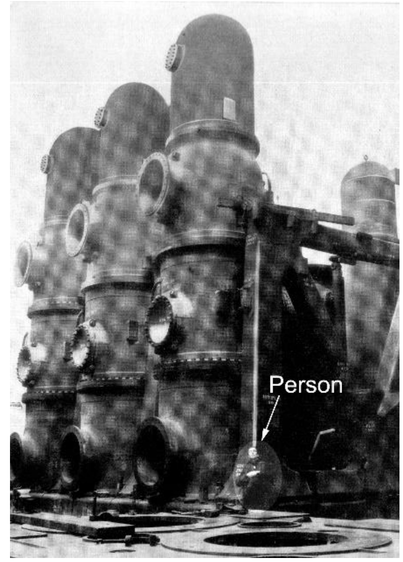
The Warner Elevator Manufacturing Company was the third largest elevator manufacturer in the country and was the first to supply water driven hydraulic elevators to the local area. When electric power superseded water pressure in the late nineteenth century, Warner kept stride with progress by designing electric-driven elevators. They made every type of elevator, from the high-speed passenger and freight elevator to the dumbwaiter. An exclusive product was their electrically driven, plunger type elevator for residential use.

Local elevator manufacturers also included:
Shepard Elevator Company (1921), 2425 Colerain Ave, which had its own foundry.
Cincinnati Elevator Works, 212 West Second St.
Economy Elevator Company, 12 Laurel St.
National Elevator Manufacturing Company, 7 West Second St.
Schatzman Elevator Works, 119 West Second St.

Pump Pit Hydraulics: Several attempts were made to lower the caisson deck to its original position. The final and successful attempt was made at low river level and included the weight from the 4,200 tons cast iron center ballast, 6,800 tons from rapid assembly of the engines and 31 feet of water (7,300 tons) flooding the pit floor. This added 18,300 tons to the floor and helped to lower the floor to within 1/16 inch of its original position.



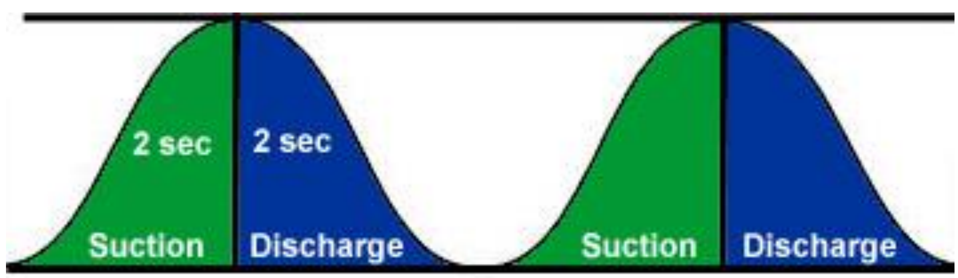
Water Pumps: The pump stands 36 feet high and includes a 48-header inch inlet port, a poppet valve chamber housing the inlet and discharge valve assembly, a 48-inch discharge port and a 72-inch force chamber. The poppet valve assembly contains 280, 3½" OD valves, for a total of 560 for each pump, 1,680 for each engine and 6,720 for the station. The effective pass thru area for each valve is 5.23 square inches. This provided 1,464 square inches of passage and 32% above the required area by the pump plunger at 1,104 square inches.



The three displacement water pumps attached to each engine have a 96-inch stroke using a nickel iron plunger measuring 37.5-inch diameter, 14 feet long.

Each pump plunger on the engine attaches to its associated steam piston. The three pistons move 6 tons of water, 1360 gallons, into the 48-inch discharge nozzle for each revolution of the engine. The delivery pressure was 60 p.s.i., for a daily volume of 30,000,000 gallons per day per engine. The station discharged water against a 139-foot head.

Each engine moved 12 tons of water for each revolution of the flywheel for a station total of 48 tons for each revolution. 20 tons of force is required to stop the 2 tons of water moving into each pump chamber at 3 MPH, therefore requiring the use of force chambers.



Since water does not compress when its flow is stopped, the weight of the water causes a large force to be exerted on the pump and piping system. Water pressure from pumping is a sine wave, as shown here. The speed of the piston is slowing down at the very end of the cycle but never stops taking suction until there is a sudden change in motion from suction to discharge.

For purposes of calculations, I allowed water to compress a ¼ inch in a 48" pipe and with that amount of compression, 20 tons of force is required to stop 2 tons of moving water. This is why a force chamber (air chamber) is required on both the suction side and the discharge side, and why they are made from thick cast iron.

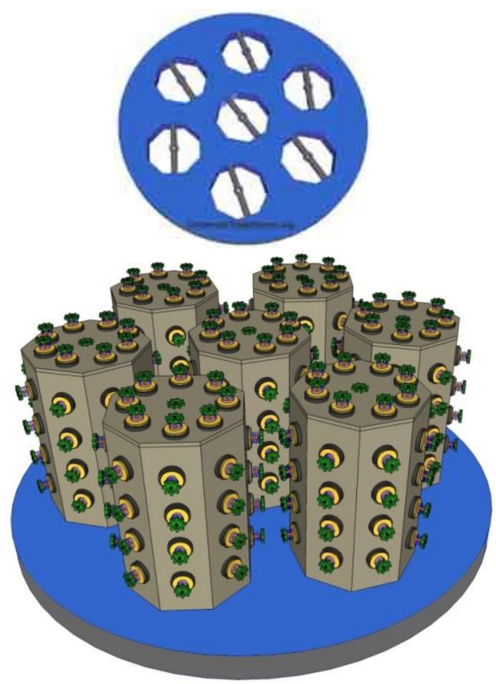
Water Pump Poppet Valves

Valve seat: brass, 3 5/8” OD, 3 1/8” ID, 11/16” thick with 5 - 1/8” spiders connected to a 1-inch center hub drilled and taped for ½” – 16 TPI thread. The threads on the OD of the seat are tapered 12 TPI.
Valve seat washer: rubber, 3 5/8” OD, ½” thick, 5/8” center hole
Valve spring washer: brass, 2 ¾” diameter, 1/16” thick, 9/16 center hole
Valve Spring: #10 copper spring wire, 2” diameter, and 2” tall
Valve Nut: 8 point knurled and recessed knob, accepts 2” spring, attached bolt 1 ¾” long x ½”, 16 TPI.
Flow Area: 5.95 in. sq.
Manufacture: unknown

Water Pump Valve Cage and Assembly

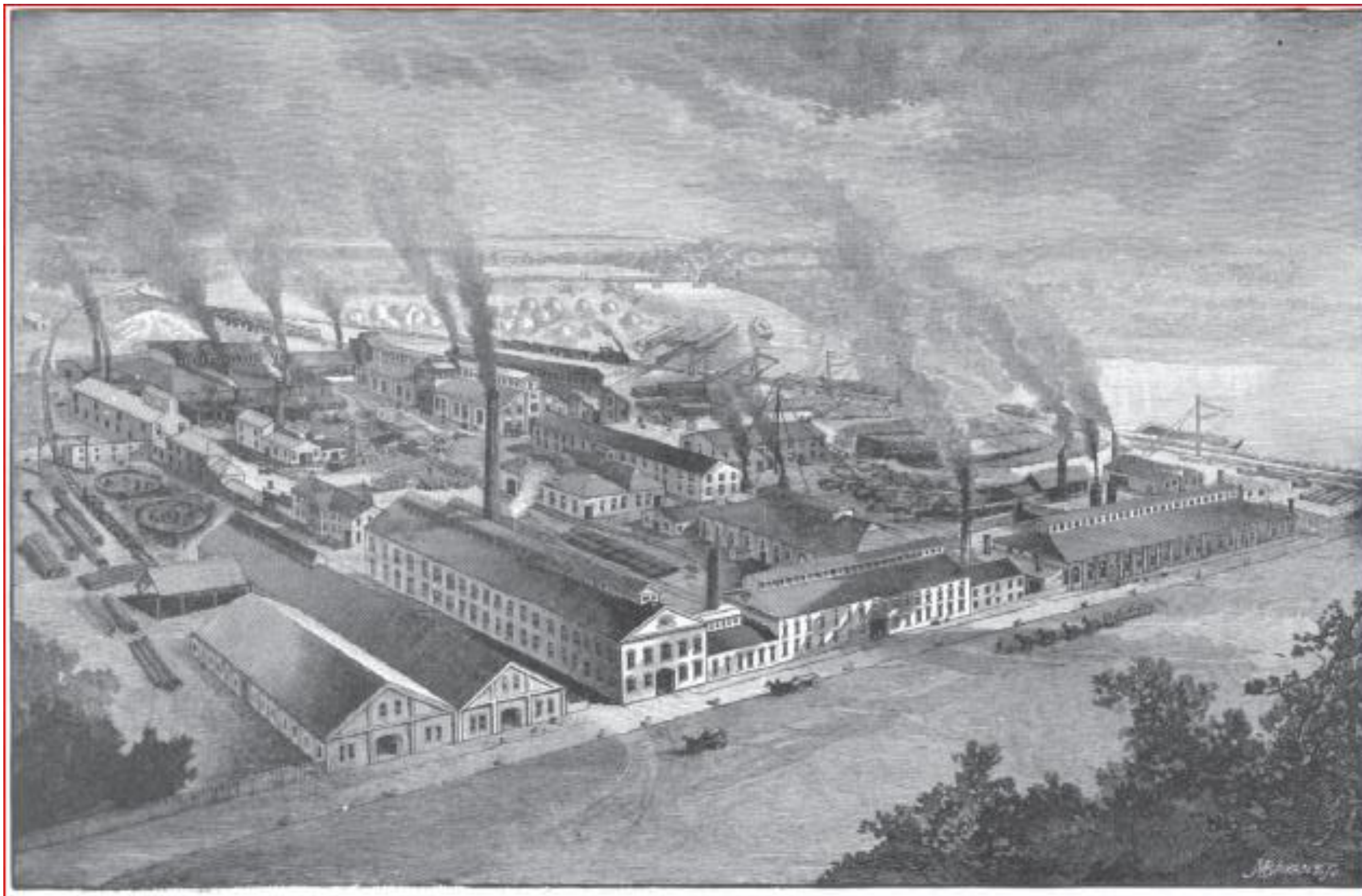
Valve Cage

Valve Cage Chamber showing Pump Piston in the background



Valve Cage Assembly

The riveted and caulked, steel liner and station standpipe were assembled using a Hydraulic Fixed Riveter probably from the R. D. Wood & Co. as shown below.

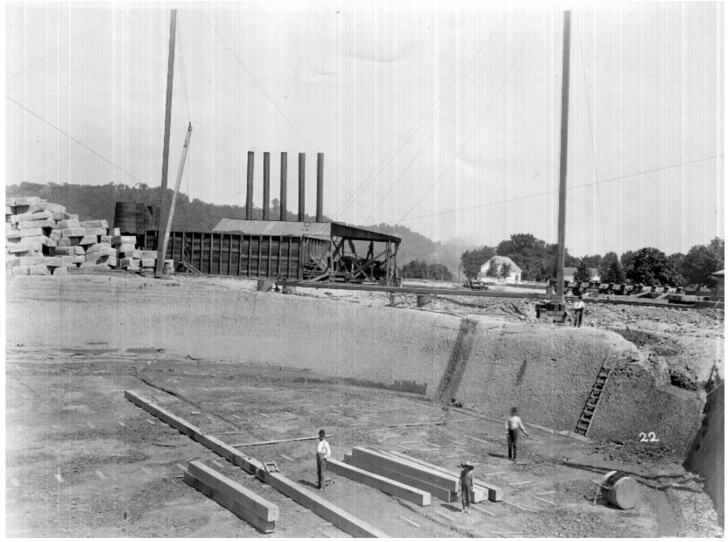


THE CAMDEN IRON WORKS.

River Station Construction

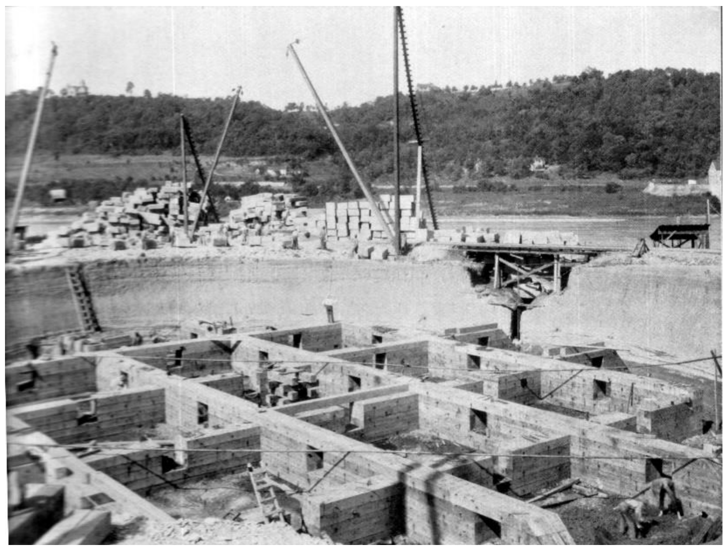
Pump House Construction

Construction began with a pit eighteen feet deep and 134 feet in diameter at the base, tapering outward to a larger diameter at the surface. A one-inch-thick circular steel plate locating ring measuring twenty-four inches high with an eight inch T-base rested on the floor of the construction pit. This ring defined the outer most edge of the caisson and served to restrict radial movement of the caisson shoes during the sinking operation.



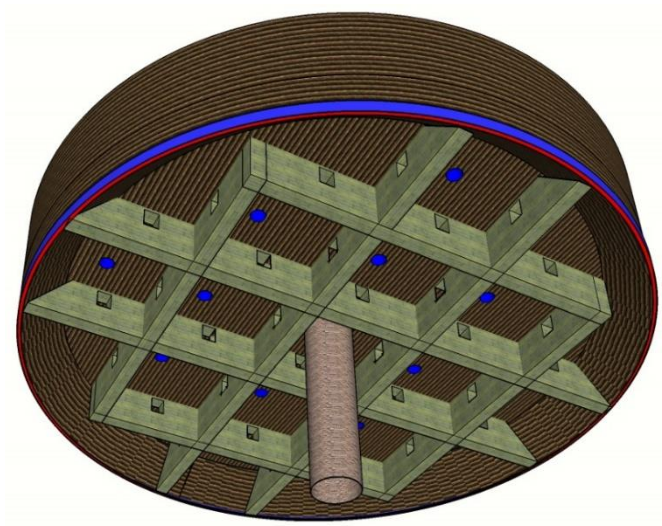
Caisson Deck and Shoe Construction

Eight crisscrossed shoes, four of which were end tapered to fit the knife-edge of the caisson, are three feet wide and seven feet high. Made from 12 inch square air-dried and drift-bolted, white oak timbers, the shoes provide support for the circular solid wood caisson deck floor, 12 feet thick by 128 feet in diameter.



Walled space within the shoes provided twenty-one working chambers, twelve of which were provided with excavation shafts three feet in diameter that extended through the floor of the caisson deck. The twelve, three foot diameter shafts provided for worker access and soil removal from the sinking operation. Thirty-two passage ways through the cross walls provided access among the twenty-one chambers to assist soil removal and communications for the sinking operation.

The center chamber provides a circular steel encased opening, sized to fit the ten-foot diameter standpipe passing up and through the caisson floor, and was supplied by the Variety Iron Works of Cleveland, Ohio.

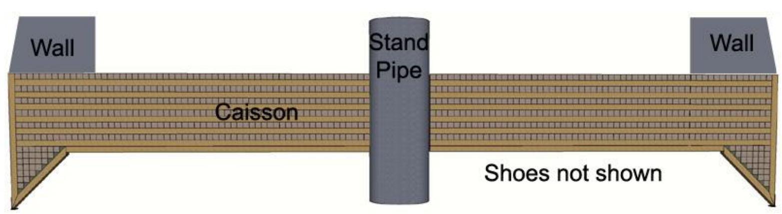


Completion of the caisson deck lasted twelve months and was delayed in part by a short supply of locally grown white oak to make the timbers. The deck has a finished diameter of 128 feet and measures nineteen feet thick at the outer most edge and tapers inward to a thickness of twelve feet. At the proper position for each engine, sixty-four one-inch bolts were installed vertically through the caisson timber deck to secure the crisscrossed timbers in preparation for the 30" high cast iron engine base plate. 256 vertical bolts were used to secure the closely spaced timber deck at the four engine locations. Twelve inches of concrete was poured on the deck floor after the construction of the pump pit wall and deck stabilization.

Sinking the Caisson

The caisson was lowered in 6 months beginning May 1, 1899 and ended October 12, 1899. That effort placed the bottom of the wood support shoes at 105 feet below grade and the top of the wood deck at an elevation of ten feet below the extreme low water level, which placed it eighty-five feet below grade and 5.5 feet below the bed of the Ohio River. Simultaneously, as the caisson was being lowered, the masonry stone wall and steel liner was constructed on the caisson floor, and was intended to provide sufficient weight to keep the caisson from floating. The rate of excavating closely matched the rate of stone construction on top of the caisson, which allowed the stone construction to occur mostly at ground level.

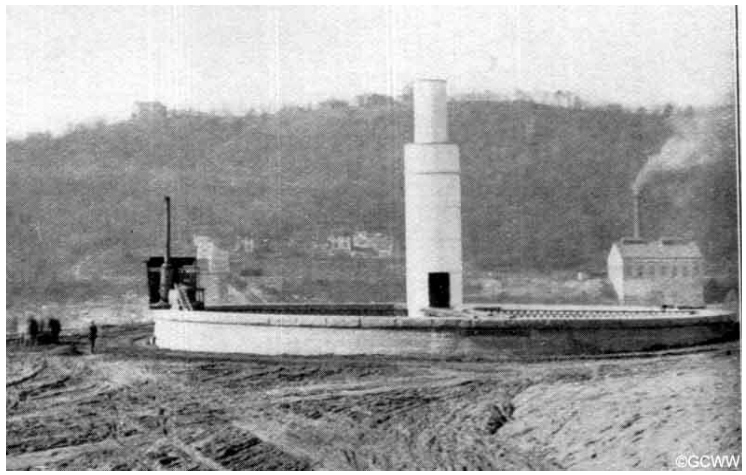
The sinking operation was a coordinated effort from many workers simultaneously excavating the clay and sand in the working chambers and hoisting it through the twelve 36 inch diameter working shafts. Excavation progressed through about twenty feet of surface clay and the remainder through the water-bearing sand under the clay.



Part of the sand excavation was deposited on the caisson deck floor as ballast to assist in overcoming the sinking friction and the lifting tendency of the compressed air, which was used in the working chambers after the caisson had reached the stage of ground water. The working air pressure was just above standard atmospheric pressure and did not exceed 17 p.s.i.

The First Surprise

As the sinking operation preceded it became obvious from the movement of the caisson that the anticipated weight of the engine house and engines would not be sufficient to prevent shifting of the caisson, as had originally been planned. It did not prove feasible to rest the caisson on bedrock and, as a result, the station had the undesirable possibility of "floating" during periods of high river levels from the hydraulic pressure that resulted from high groundwater levels.



Even the slightest movement of the pump pit floor would interfere with the smooth operation of the huge engines that were to be installed. A 1/8-inch movement to the level of the floor resulted in a 3/8 inch movement at the top of the 104 feet high engine. Engine alignment was to be within 1/100 of an inch and would not be feasible if the pit floor moved every time the river level changed.

After the sand ballast from excavations was removed from the deck floor on December 12, 1899 and prior to engine placement, the caisson wood deck deformed taking the shape of an inverted ice-cream cone. The center rose 3 5 /8" while the wall-edge fell 1½ inches. Deformation was caused in part for three reasons.

First and prior to engine placement, a disproportionate amount of weight from the pump pit stone wall rested on the outer most section of the caisson. 100% of the walled weight (about 15,000 tons) rested on the outer most 33% of the caisson deck. This unbalance tended to cause the caisson to sink at the outer most edge and rise at the center. Secondly, for the first twelve months or so, the caisson was under extreme radial pressure caused by the moisture expansion from the closely space and bolted timbers. Dry white oak can easily expand 5% or more when saturated with water. This high radial pressure tended to destabilize the deck structure. Thirdly, hydraulic pressure from high ground caused by high river levels in the Ohio River provided the necessary force to nudge to center upward.

Below is the timeline for the *extraordinary effort* to deal with and correct this deformation.

12 months duration, May 18, 1898 to May 1, 1899, Caisson construction,

6 months later, May 1, 1899 to October 12, 1899, sank the caisson to 105 feet.

2 months later, December 12, 1899, river rises, caisson deforms, center rises to 3 5/8", and wall-edge falls 1½ inches.

12 months later, November 30, 1900, high river level, center reached 4 ¼ inches above normal, the wall edge remained 1½ inches below normal. The center fell about ½ inch at low river level.
5 months later, April 27, 1901, at high river level, the center took a set at 3 5/8" at high water and fell slightly at low water.

12 months later, March 1902, at high river level, the center took a set at 4 7/16" at high water and fell slightly at low water level.

12 months later, again in March 1903 at high river level, the center took a set at 4 7/16" and fell slightly at low water level.

Since the center was high in elevation, the logical correction was to push down in the center. To provide this push, a center located counterweight was selected as the most appropriate solution. Supplied by the Bullman-Wilson Foundry Company of Cincinnati, the ballast took the form of a circular wall concentric to the pump pit standpipe. The ballast was constructed using tapered cast iron sections weighing 6 tons each, for a total ballast weight of 4,200 tons.

6-ton Cast Iron Ballast Segment

2 months later, February 6 to April 15, 1904, 4,200 ton of cast Iron ballast was installed in 60 days.

The Second Surprise (Now 3 ½ years since the original deformation)
1 month later, May 13, 1904, at low river level, the center lowers an insignificant amount. Even at low river level and 4,200 tons of ballast the caisson center resisted movement downward. This resistance was caused by the friction from the closely spaced and bolted, and water expanded timbers, not allowing individual movement among the timbers inside the caisson. Three and a half years had passed since the original deformation of the deck, allowing for maximum pressure to build from the water soaked and expanded timbers.

The Third Surprise
2 months later, May 13 to July 7, at low river level, 31 feet of water was added to the bottom of the pit, adding an additional 6,880 tons to the existing cast iron ballast of 4,200 tons, and served to lower the deck to within 3/8 inch of the original location, but no further.

1 month later, August 1904, low river level, in an effort to nudge the center downward another 3/8 inch the engine bedplates were anchored to the caisson deck but no additional lowering of the center occurred.

1 month later, October 1904, at low river level, a second major attempt was made to lower the caisson to its original location. 796 tons of engine castings were scattered about the pit floor and 34 feet of water (7,440 tons) was added. This effort produced a total additional floor weight of 12,440 tons (7,440 +4,200 + 796). This extraordinary ballast weight was required to overcome high internal friction of the deck from the moisture-expanded timbers.

Success
2 months later, December 1904, the floor returned to within 1/16 inch of the original location. The engine castings were removed and the engine bedplates were re-leveled and set in twelve inches of concrete. Final re-erection of the engines began.

Caution Exercised
2 months later, February 27, 1905, as engine erection continued, 15 feet of water was added to the pit floor to counterbalance a rise in river level, and removed by late April as the river level fell. 3 months later, May, 1905, 10 feet of water was added to the pit floor because of a rise in the river level.

More Caution
3 months later, from May 23 to August 1, all four engines were quickly assembled without regard to alignment or leveling to add weight to the pit floor in anticipation of a river rise in November and December.

5 months later, January 10, 1906, one by one, each engine was disassembled and accurately reassembled regarding accurate placement, leveling and bearing alignment.

More Success
9 months later, September 18, 1906, engine two was started for the first time, running a few hours on that day and the following day.

1 month later, October 29, 1906, engine two went online full time.

5 months later, April 28, 1907, engine three went online and by May 9, Engine 1 was online

3 months later, August 13, 1907, engine four went online.

When the Ohio River reaches a pre-specified level, water is added to the caisson. This precaution has been taken several times in over 110 years of pump house operation.

Pump Pit:
The tapered pit wall is formed from circular blocks, inside radial sawed (6’ long, 23” high and 24” deep, weighting 3,800 lb.), oolitic-dimensioned Bedford limestone, with the inside face being plumb and fine-pointed. A cylindrical shell of riveted and caulked steel plate is built into the stone and masonry wall to render the pit watertight. The station standpipe is of caulked and riveted steel construction and extends 60 feet beyond the cassion to bedrock for intake from the river tunnel.

Pump House
The above grade exterior wall was designed using the Romanesque Revival architectural style by Gustave W. Drach. The limestone stone is from Bedford, Indiana, Oolitic* dimensioned with the outside surface being rock-faced and fine pointed. The above grade interior wall is finished with Tiffany white-enameled brick while the below grade interior wall is circular sawed and fine pointed.

At the top of the below grade wall three steel horizontal struts are anchored into the wall and riveted to the steel standpipe. Opposite the middle strut and in line with the entrance to the engine house a railroad plate girder is built from the wall to the steel standpipe, and supports a standard-gauge, 4' 8.5" railroad track, which permits railroad cars being run into the engine house.

The pump house is covered with a cone-shaped conical steel roof using lantern frame construction and covered with hard burnt American red vitrified** "S" tile. Each tile has a serial number and can be reproduced by the source factory in Italy.

*Oolitic dimensioned limestone = grain size .25-2 mm.

**Vitrified Tile is a tile created by the Vitrification manufacturing process which causes a very low porosity and water absorption, making it stain-resistant and strong.

Station Specifications

Building Design	Cincinnati Architect, Gustave W. Drach
Engine Design	John H. Lewis - R. D. Wood & Company 400 Chestnut St.- Philadelphia, PA
Engine Manufacture	Camden Iron Works, Camden, New Jersey
Engine Type	Vertical triple expansion crank & flywheel
Bids from	Lane & Bodley Company of Cincinnati, Ohio originally won the contract to supply the engines. After two years of non-performance and an unfavorable decision by the Ohio Supreme Court, their contract was canceled, and the re-bid was among the following: Camden Iron Works, Camden, NJ Holly Mfg., Lockport, NY E. P. Allis Co. Milwaukee, WI Kilby Mfg. Co. Cleveland, OH
Cost	Engines, Boilers & Overhead Crane, $1,331,000
Service	October 29, 1906 to May, 1963

High pressure cylinder	29 inches diameter 150 p.s.i.g.
First receiver	27 p.s.i.g.
Intermediate pressure cylinder	54 inches diameter
Second receiver	-2 p.s.i.g.
Low pressure cylinder	82 inches diameter, 22-inch exhaust port
Re-heaters	2
Surface area of re-heater	1^{st} =122 ft^2 and 2^{nd} =276 ft^2
Stroke	96 inches
Steam pressure	150 p.s.i.g.
Efficiency	21.6% coal to water. See Coal to Water Efficiency
Steam valve gearing	**Corliss** with dual chamber vacuum dashpot for the HP cylinder and the inlet to the IP cylinder. **Balanced Poppet** on the exhaust for the IP cylinder and for both the inlet and exhaust on the LP cylinder (inlet spring loaded, exhaust weight loaded)
R.P.M.	15.5 (range 11 to 15.5)
Piston speed	248 feet/minute or 2.82 m.p.h.
Horsepower	1,000
Flywheel	2 x 24 feet diameter, 40 ton, assembled in sections and secured with dog bone locking keys.
Starting/Stopping	The traditional Barring engine (also called a Jacking engine or Kicking engine) was not used to start this engine. Instead, the engine was rolled using the procedure listed below. (Nominal process steam was 150 p.s.i.g.) Start engine procedure:***** 1. Preheat engine setting jacket steam and re-heater steam to 65 p.s.i.g. 2. Begin oil drips 10-15 minutes prior to starting. 3. Open engine drains to bypass steam traps. 4. Adjust air pressure in both the suction and the discharge force chambers. 5. Load the water pumps using the bypass source until about 65 p.s.i.g. 6. Open the main water inlet valve prior to opening main discharge valve. Later on cone valves replaced the gate valves and required verification of 200 p.s.i.g. water pressure for cone valve operation. 7. Set governor to lowest speed

	Roll engine by: 8. Charging the first receiver to 30 p.s.i.g. steam. 9. Slowly apply process steam to the HP cylinder until about -7 p.s.i.g. is achieved in the condenser and throttle back until the condenser achieves -13 p.s.i.g., and the governor has kicked in. 10. If the HP piston is at dead center for crank-end or head-end, the overhead crane is used to nudge the flywheel off dead center. 11. Close bypass to first receiver and adjust to about 22-24 p.s.i.g. 12. Close drains and check for about -5 p.s.i.g. in the second receiver. 13. Slowly bring engine to operating speed. 14. Check dashpots and valves for proper operation 15. In case of trouble or emergency, knock out the vacuum breaker and the engine will immediately stop. Stopping the engine in normal operating conditions required skill and practice to prevent the HP cylinder from ending at TDC. ***** Starting procedure from Stationary Engineer Jim Hoctor Sr. operating notes and input from Paul Kraus.
Bearing Gland Packing	Initially oakum impregnated with paraffin and later asbestos impregnated with graphite
Length of eccentric shaft	30 feet
Length of main shaft	10 foot 2 inches
Diameter of main shaft	19 inches
Length of main shaft journals	28 inches
Diameter of main shaft journals	19 inches
Length of crank pin journal	10 inches
Diameter of crank pin journal	High pressure and low-pressure journal, 10 inches. Intermediate pressure journal, 14 inches
Length of cross head pin journal	10 inches
Diameter cross head pin journal	10 inches
Weight	1,400 ton = 2,800,000 lb. including attached ancillaries
Height	104 feet
Base, cast iron	23 foot 7-inch-deep X 36 foot 4 inch wide x 28 inch tall

Working decks	11 decks accessed by stairs and elevator. The cast iron valve decks were replaced with cast steel decks in 1915
Ancillary Equipment Attached	A surface condenser, wet air pump, boiler feed pump, air compressor, bilge pump, and exhaust heater
Condenser	The attached surface condenser is in line with the 48-inch discharge header with the entire water discharge passing through it. In addition, two-Wheeler surface condensers each equipped with a Mullan air pump were in the boiler room to handle the exhaust steam from the ancillary engines
Condenser size	62-inch diameter x 12 feet, 4 3/4 inches long
Condenser pressure	-13.8 p.s.i.g. nominal
Condensing surface	2,130 ft^2
Air compressor, attached	3 3/8-inch plunger X 96-inch stroke
Bilge pump, attached	3-inch plunger X 96-inch stroke
Boiler feed water pump, attached	2 3/4-inch plunger X 96-inch stroke
Wet air pump, attached	28-inch diameter X 30 inch stroke
Heating surface of exhaust heater	150 sq. ft.
Ancillary Equipment Detached	
Boiler feed water pumps	2- Henry R. Worthington 10" x 6" x 10"
Boiler feed water pump for auxiliary equipment	1- Berryman
Detached air compressor	by Westinghouse
Pumps	
Pumps/engine	3
Pump type	Plunger, a nickel iron plunger replaced all the cast iron plungers in 1932.
Pump plunger	Diameter = 3 1/8 feet or 37.5 inches, Length = 14 feet 24 Tons
Diameter of pump barrel	54 inch outside packed
Diameter of pump valve force chamber	74 inches
Pumping capacity/engine GPD ***	Rated at 30,000,000 rated; Tested at 30, 878,124
Gallons/Revolution	Rated at 1,361.7, tested at 1,377
Tons of water moved / Revolution	11.46 tons/engine, 45.84 tons/station/revolution

Stroke	96 inches
Inlet nozzle	48-inch to engine header, 40-inch to pump
Outlet nozzle	40-inch to header, 48-inch to dual 60 inch outlets
Discharge pressure	60 p.s.i.g. nominal
Effective area of pump valves/pump	1,665 sq. in which is 51% above plunger area
Suction poppet valves/pump	280 at 3.5-inch OD, 7 cages, 40 valves/cage
Discharge poppet valves/pump	280 at 3.5-inch OD, 7 cages, 40 valves/cage
Boilers	
Boilers	9-Stirling water tube boilers, eight at 424 HP and one at 529 HP, plant HP = 4,500 in 1921. New boilers in 1920 and 1921 In 1906 the Stirling Company, with works in Barberton, Ohio, merged with Babcock and Wilcox of New York.
Coal feed	American underfeed stokers, later on, Forced draught Riley Stokers
Boiler tubes	176 tubes, 3-inch diameter
Steam drums	3 at diameter of 36-inch , length 10 feet 9 inches
Mud drum	42-inch X 9 feet 3 inches.
Steam pressure	150 p.s.i.g.
Seam piping	Fourteen-inch pipe delivers steam to the engine room arranged to use either saturated or super-heated steam and branches into two lines with two engines taking steam from each branch. Exhaust steam from the LP cylinder flows through the exhaust heater into the condenser. The air pump removed air, oxygen, CO2 and uncondensed steam from the condensate chamber while maintaining a near perfect vacuum (-13.8 p.s.i.g) in the chamber.
Steam moisture	2.2% at engine, 2% at boiler
Heat boosters	**Green Economizer:** Steel tube boiler feed-water heater **Foster super-heater:** is a drawn steel tube with cast iron radial fins heat shrunk onto the tubing and allows better heat transfer from boiler gases to steam than tubing without fins. The foster Super-heater added 100°F to the steam temperature and contributed another 200 HP **Auxiliary Hearer:** exhaust steam from the ancillary engines flowed through a Berryman type

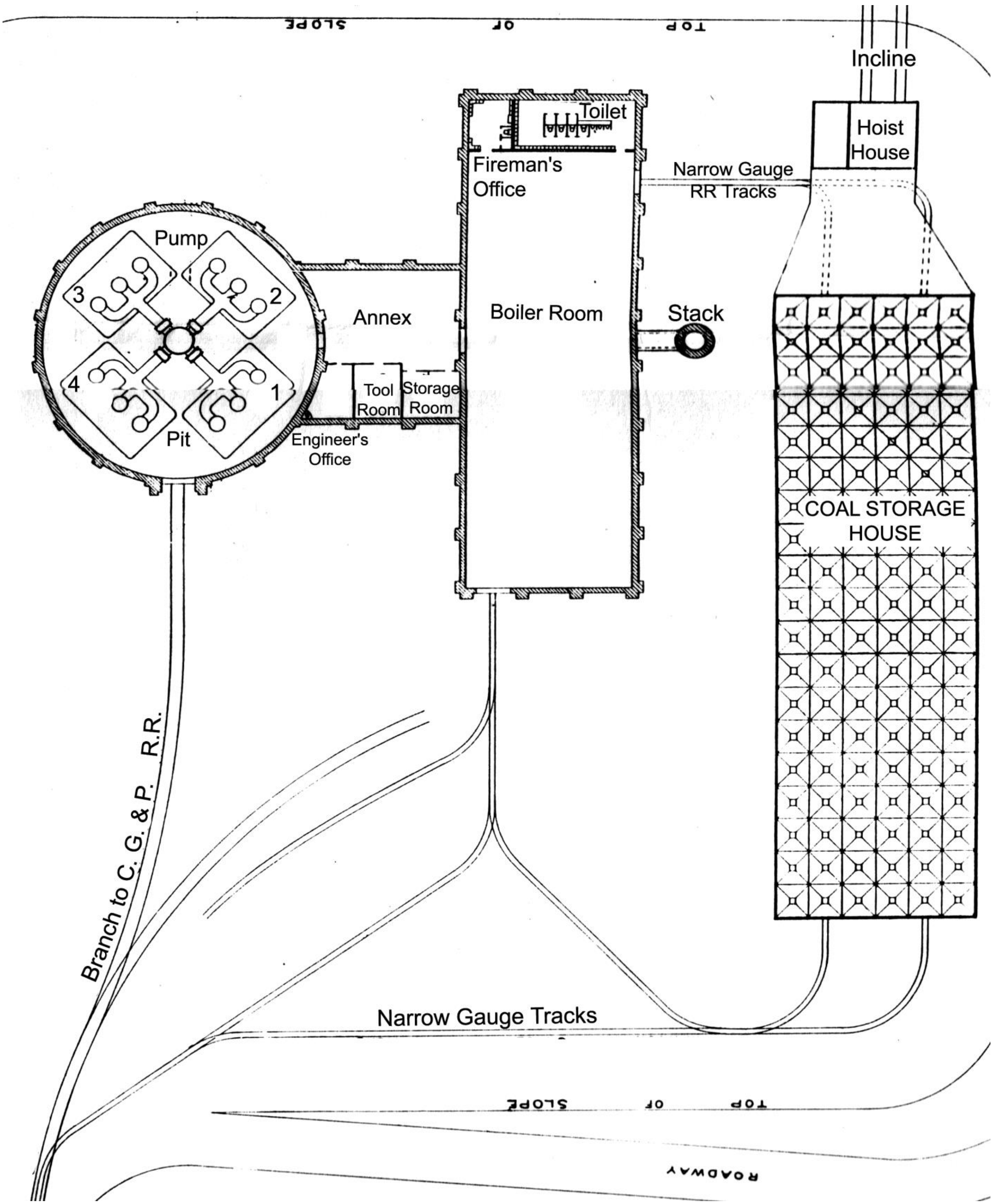
	boiler feed water heater and grease separator prior to entering the Green Economizer.
Gases leaving boiler	437°F
Gases leaving super heater	373°F
Stack temperature	196°F
Water evaporated per 1 lb. dry coal	10.687 lb., boiler contribution 95%, economizer contribution 5%
Condensate from the R. D. Wood Engines	Boiler feed water originated in the hot well for the surface condenser and was collected in dual condensate storage tanks where the boiler feed pump attached to the main engine takes suction. From there water was forced by the attached feed pump through the exhaust heater, through the deaerating plant, through the auxiliary heater and through the Green economizer into the boiler. Water from the softening and deaerating plant was 92°F, increased to 142°F from the exhaust heater and left the economizer at 200°F. Deaerating plant installed in 1922
Feed water from auxiliary engines	Two 10 inch x 6 inch x 10 inch H. R. Worthington boiler feed pumps.
Work duty coal	Rated at 115,000,000 ft. lb. of work for every 100 lb. of coal (Tested at 152,875,648 ft. lb.) See Coal to Water Efficiency
Work duty steam	172,925,997 ft. lb. per 1,000 lb. of dry steam, weir measurement
Boiler House	60-foot X 180 foot, Oolitic* dimensioned Bedford limestone, exterior rock faced, and inside sawed smooth and rubbed. Boiler room floor of concrete, toilet room red American tile, office and storeroom was matched yellow pine flooring. Steel roof and lantern frame covered with vitrified** "S" tile. Individual lockers for all employees, toilet rooms with shower baths and other conveniences. *Oolitic dimensioned limestone = grain size .25-2 mm. **Vitrified Tile is a tile is created by the Vitrification manufacturing process which has exceptionally low porosity and water absorption, making it stain-resistant and strong.
Smokestack	8-foot ID, 175 foot high of brick on circular stone base resting on a concrete foundation with a diameter of 35 foot and 8 foot deep. The stack is faced with light buff-colored radial Kittanning pressed brick and topped with a cast-iron cap.

	Forced draught was provided by two 8-inch by 10-inch Buffalo Forge Co. engines each direct driving an 85-inch Buffalo Forge Co. fan, nominal R.P.M., 200.
Coal	
Coal storage	An elevated steel building supported by steel columns, 69-foot X 225 foot kept the coal dry during periods of high water and provided sufficient coal storage for periods of low river level. 7,980 tons were stored in 114 elevated pocket hoppers each holding 70 tons and equipped with a coal spout valve leaving 6 1/2 feet of head room above the narrow-gauge tracks running lengthwise underneath the pocket hoppers.
Coal usage	26 tons (average daily)
Coal supply	Coal was originally received by barge and occasionally by truck in the later days. A railroad siding had been extended to the coal bunkers to provide for rail delivery, but never use for that purpose.
Coal delivery	Coal was elevated from river barges via a dual narrow gauge rail system installed from low river water level to the top of the three-story coal hoisting house using a steam hoist cable pull for dual two-ton capacity steel dump cars (one traveled up while the other returned to river's edge) and deposited onto a cross belt conveyor, and distributed by means of shuttle belt conveyors to the 114 pocket hoppers.
Boiler coal delivery (Coal Passers)	Coal was switched to the boiler house from the coal storage building using a narrow-gauge rail system with boiler charging cars powered by an electric locomotive engine about the size of a golf cart, called the "Dinky". Boiler ash cars were switched using the same locomotive. Coal was dumped on the floor in front of each boiler and shoveled into the stoker hopper using coal shovelers. 1924, an overhead rail suspended hopper system called the "Lorry" delivered coal to each stoker hopper and was supplied by a coal hoist in a new three story poured concrete lifting house at the front of the boiler house.
Coal size	Pittsburg Nut & Slack which is 1 1/2 inch and 3/4 inch respectively provided 13,000 BTU per pound of coal.
Coal tests	Moisture 2%, Ash from coal 8%, Slate in coal 1%

Pump Pit	Built by F. H. Kirchner & Co., of Cincinnati, the circular tapered, below grade wall, is 98 feet inside diameter and 85 foot high, using circular sawed Oolitic dimensioned Bedford Limestone* fifteen feet thick at the bottom and four feet thick at the top with the inside face being plumb and fine-pointed. The above grade masonry uses a Romanesque Revival architectural style with rock faced Oolitic dimensioned Bedford limestone, and the inside lined with Tiffney white enameled brick. Vitrified* "S" tile covers the conical roof
Steel Casing	A masonry embedded 1/4 inch riveted and caulked steel cylinder extending from the pit floor to 70 feet high assures a watertight pump pit.
Pit floor	85 feet below elevation, -5.5 feet below riverbed
Foundation and caisson	128 feet diameter by 12 feet thick solid 12" x 12" air-dried white oak timber crib foundation rest upon the 7 feet high tapered-edge caisson cribbing using crisscrossed wood shoes with 21 excavation chambers.
Inlet stand pipe	10-foot diameter riveted steel setting on bedrock
Caisson ballast	72 foot high with an OD of 23 feet and an ID of 13 feet, cast iron, 4,200-ton, Individual sections weighing 6 ton each.
Station Electrical Supply	Three units, each consisting of a DeLaval steam turbine driving two 75 KW, 4 pole Crocker Wheeler, 230-volt direct current generators provided electricity to both river station and the filtration/treatment plant.
Station Elevator and Stairs	Warner Elevator Manufacturing Company from Cincinnati, Ohio provided a 2,500 lb. capacity, 230 Vdc motor driven elevator that traveled between the engine operating floor level and the pump pit floor level. Two spiral staircases extended from the pit floor to the eccentric deck. A railed staircase extends from the engine floor to the wheel deck. The railing for all stairs and elevated walkways was bright work polished brass.
Overhead Hoisting Crane	From the Morgan Engineering Company, Alliance Ohio provided a 3-motor circular traveling radial crane with a span of 49 feet 6 inches and a 30 ton lift of 110 feet. The electric motors use Morgan controllers with adjustable speed and direction controls. All motors are 230 Vdc and included a 30 HP hoisting motor, a 25 HP a bridge motor and a 5 HP trolley motor. The crane was ordered on April 26, 1901 by the Camden

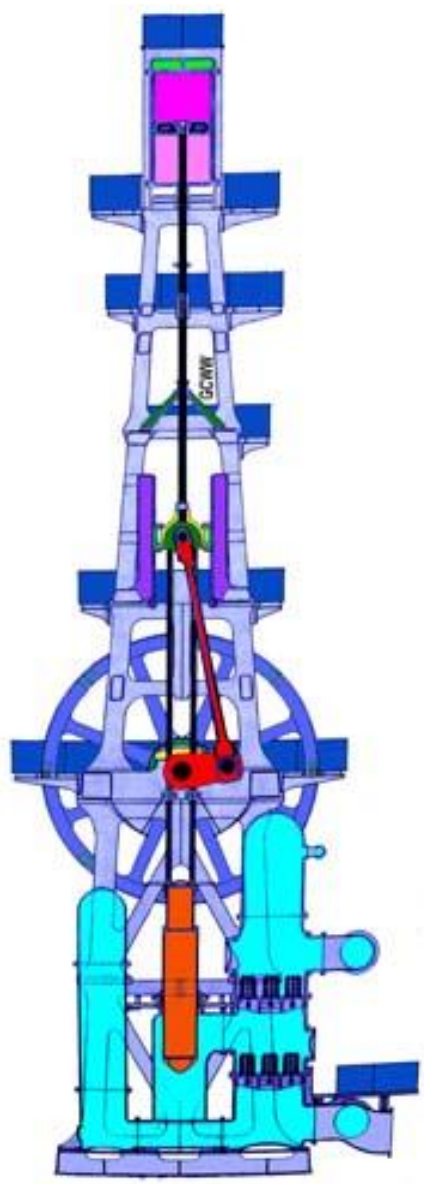
	Iron works and shipped to the California, Ohio facility on November 18, 1903. Design of the engine and its pumps allowed every principal part to be reached and removed by the overhead hoisting crane without disturbing any other part of the machinery.
Operations	Three engines could be operated at rated capacity without increasing the regular daily staffing of 36 employees. The Station Chief was in charge of the entire operation while the licensed stationary engineer was in charge of the engine room and the licensed fireman was in charge of the boiler house. Each eight-hour shift maintained a minimum staffing of one licensed stationary engineer, four oilers, one licensed fireman, two coal-passers, and an assistant Chief Engineer. Daily staffing includes a clerk, one machinist and helper, one boiler cleaner, one locomotive operator, a janitor, and three or four grounds keepers.
Number of steam engines at River Station (21)	4 - water pumping engines, R.D. Wood 4 - economizer engines 2 - stack draught engines, Buffalo Forge Co. 2 - boiler feed water engines for pumping condensate from ancillary engines and ancillary equipment , Henry R. Worthington 9 - stoker engines
* * * GPD, Gallons Per day	

Site Plan

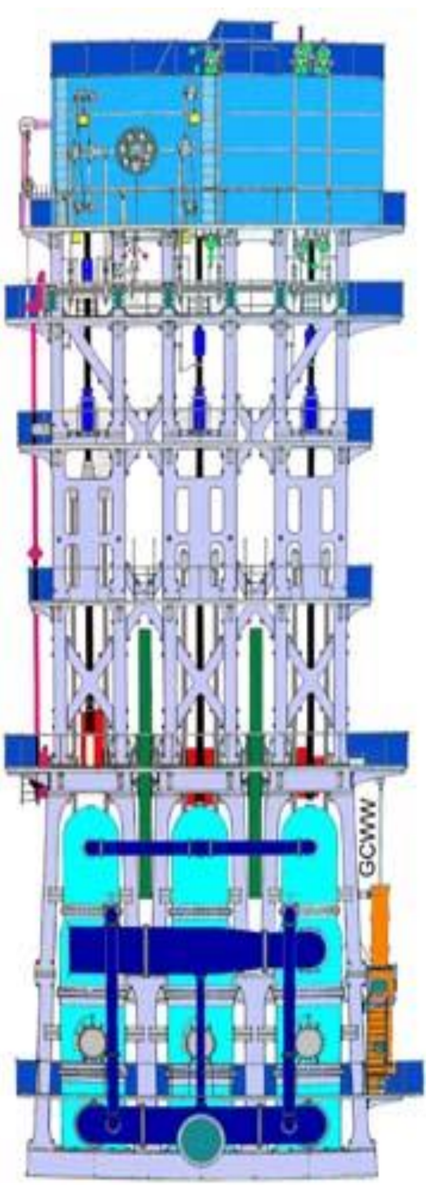


TOP OF SLOPE
Incline
Toilet
Hoist House
Fireman's Office
Narrow Gauge RR Tracks
Pump
3
2
Annex
Boiler Room
Stack
4
1
Tool Room
Storage Room
Pit
Engineer's Office
COAL STORAGE HOUSE
Branch to C. G. & P. R.R.
Narrow Gauge Tracks
TOP OF SLOPE
ROADWAY

Sources:
A Conversational History of Greater Cincinnati Water Works, 1788 through 2001
by: William F. Reeves, Jr.
Jim Hoctor Sr., River Station Operating Engineer personal operating notes and interview
Paul Kraus, Principal Engineer, GCWW, retired in 2012
Larry Moster, Assistant Treatment Superintendent
Cincinnati Water Works System document, 1935
Report to Trustees, 1909
Lane and Bodley Co. by Sandra R. Seidman
Robert & Mark Smith, GCWW employees (Father/Son)
Leland L. Hite is an outside volunteer that never worked for GCWW, but took an interest Old River Station, eventually conducting tours, creating a website (CincinnatiTripleSteam.org) and writing about its history. Complete access to the vast amount of archives by the water works has allowed this amazing history to be better understood.



Side View



Front View

R.D. Wood, Triple Expansion, Crank & Flywheel, Water Pumping Steam Engine