

## STEEL BOILERS.

Of steel boilers there are comparatively few. In Class I there is a set of six boilers, partly of steel, upon the steamship "Massachusetts." In Class II there are no steel boilers; in Class III, 3; in Class IV, 1; in Class V, 4; and in Class VI, 16. Of these 30 boilers, 19 are vertical tubular, 1 direct horizontal tubular, 1 return-flue, and 9 return-tubular boilers.

## FLUE-BOILERS.

The return-tubular boilers, often with direct flues, are the prevailing type of marine boiler used in New England and upon the whole Atlantic seaboard, excepting for the smallest classes of steamers, in which vertical tubular boilers are more commonly used. Direct flues for return-tubular boilers often help to increase the heating-surface, as well as having a utility similar to that of combustion-chambers, but the employment of flues differs greatly from what it has been in the past. What may be called the experimental period in marine steam service was characterized by the use of flue-boilers in a great variety of designs, of which few have survived. This was also true of English practice. "The variety of forms and arrangements of flues in marine boilers," wrote Rankine, "is such as to defy classification." Some of the American designs of built-up flue-boilers peculiar to this period are described in *Marine Engines of the United States*, by B. H. Bartol, published at Philadelphia, 1851. Their peculiar arrangements of flues were designed to obtain a great amount of heating-surface, but usually without due regard for the requirements of draft and the all-important condition of accessibility to interior parts for cleaning and repairs. Some of the peculiar malformations of these flue-boilers appear to have been mere caprices of the draughting-room, as useless as fifth wheels to a coach or cog-drivers for a locomotive, but of great advantage to the boiler-making trade on account of the complexity of the work involved. This required a great deal of flange-turning, the most highly skilled work upon a boiler. The introduction of tubes and the use of simpler designs of boilers has changed all this, eliminating the greatest and most difficult portions of the flange-turning and making straight work, requiring less skill, and insuring safer results in the product.

## BOILERS OF THE SMALLER STEAMERS.

Of 32 boilers on vessels of Class II, 18 are return-tubular and 14 drop-flue and return-flue boilers.

Of the less usual types on New England steamers, we find 1 rectangular boiler, 1 small vertical water-tube boiler, 1 plain cylindrical boiler, 1 combined coil and vertical tubular boiler, and 1 vertical tubular boiler with return-tubes. There are 17 coil-boilers. Of comparatively large boilers, the drop double return-flue boilers are a common type. There are about 20 horizontal tubular boilers of the locomotive type, with fire-boxes. But the great preponderance of return and vertical tubular boilers is shown by percentages of all in the classes specified as follows:

Description.	Class III.	Class IV.	Class V.	Class VI.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Return tubular .....	65	64	50	19
Vertical tubular.....	8	26	30	62

Below Class II boilers are used singly, with the exception of one vessel, which has a pair of boilers. In return-tubular boilers, the length is commonly twice the diameter, but drop-flue and direct tubular boilers are relatively longer, the length often being three or four times the diameter. In the vertical tubular boilers the height is usually less than twice the diameter. It is stated by Professor Thurston that the vertical was the first form of tubular boiler, being invented in 1791 by Nathan Read, of Salem.

## COIL-BOILERS.

There are in New England the following steamers with coil boilers. These are omitted from the lists of aggregates and averages, because the boiler capacities can not be considered in the same way:

Inspected at New London: One steamer, 62.09 tons; 1 compound engine, 3.54 cubic feet. One steamer, 48.20 tons; 1 engine, 2.75 cubic feet. Thirteen steamers, about 66 tons; 16 engines, 1.5 cubic feet.

Inspected at Boston: Two steamers, 6 tons; 2 engines, 0.05 cubic feet.

Coil-boilers have the advantages of being light in weight, carrying high pressure, and getting up steam with great rapidity, added to which, like sectional boilers, they give a high degree of security against explosion. Most

of those in the service are of the Herreshoff type, of which a sectional view (Fig. 20) is given. The operation of this boiler may be briefly described. The feed-water is pumped through a spiral coil, A B, which, starting at the top of a furnace, forms an almost cylindrical combustion-chamber. As the water nears the grate (the heat becoming more intense) it is partly converted into steam, and is passed into a separator, D, from which the dry steam is carried through a coil (G), which is wound about the crown of the furnace, finally delivering its superheated steam to the engine. The water carried to the separator is returned to the coil, or may be blown to waste if desired. The following example of the use of this form of boiler may be noted.

A Spanish gunboat, 135 feet long, has engines indicating 400 horse-power and a Herreshoff boiler with 84" diameter of grate and 550' of pipe, varying in diameter from 4" to 2½" (largest at the bottom of furnace), the coil being put together in four sections, with right and left couplings. Speed of gunboat, 16½ miles an hour.

The United States torpedo launch "Lightning": Length, 58 feet; speed, 20.34 miles an hour. Driven by a

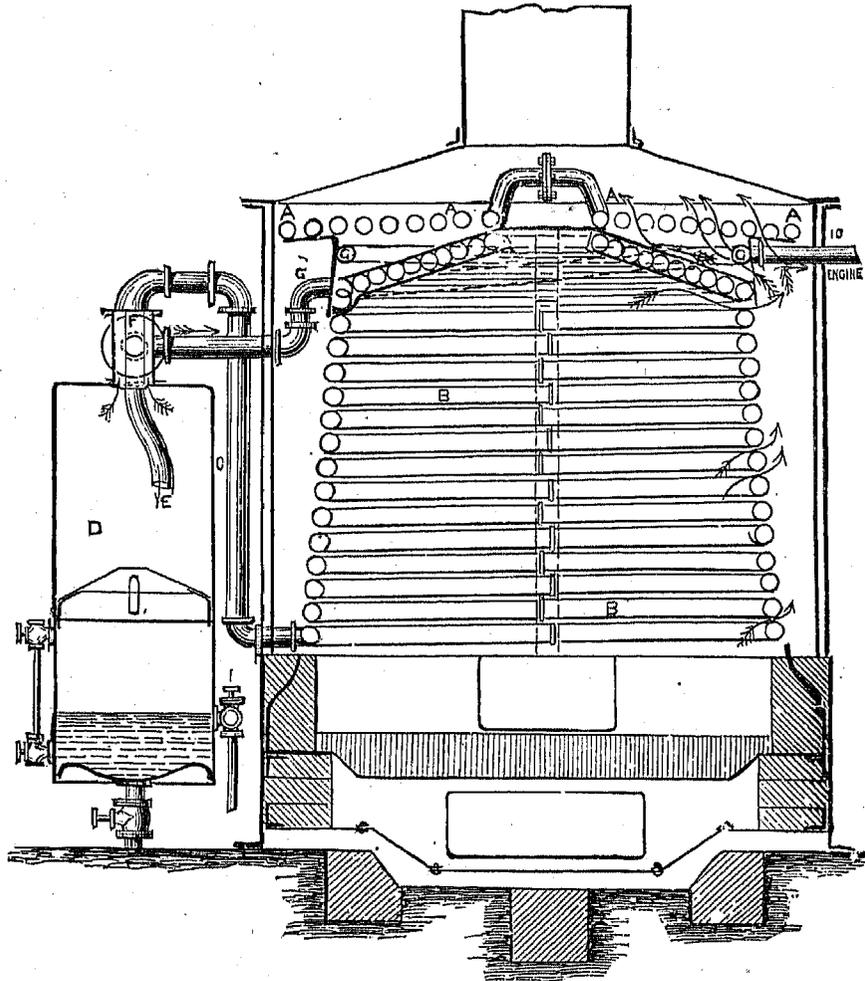


FIG. 20.

pair of 5" by 10" engines, with a Herreshoff boiler, 44" grate; 130 square feet of heating-surface in the coil. The weight of this boiler was 1,500 pounds. Steam has been raised from 100 to 160 pounds within two minutes.

I give a few examples comparing the use of coil-boilers with vertical tubular boilers: The "Gleam," of Bristol, Rhode Island, is a boat of 62.09 tons, 108 feet long, 15.5 feet broad, 6.7 feet deep. It has a compound engine; cylinders, 10½" and 18"; stroke, 18", with pipe-condenser. It has a coil-boiler of 3", 2½", 2", and 1½" pipe; total length of pipe, 750 feet; steam-pressure allowed, 170 pounds. "The Favorite," of Norwich, Connecticut, is a boat of 73.99 tons, 115 feet long, 16 feet broad, 5¾ feet deep. It has a 16½" by 16" non-condensing engine and a vertical tubular boiler 5½" diameter and 10½" high; boiler-pressure, 75 pounds.

On the "Clipper," a small boat, 24 feet long, 5½ feet broad, and 2½ feet deep, plying on the upper waters of the Connecticut river, a coil of ¾" pipe, 90' long, is used, the engine being 3¾" by 4" stroke, and non-condensing; 100 pounds boiler-pressure is allowed. The "Hub," a boat 22 feet long, 5 feet broad, and 2½ feet deep, plying on the Merrimac river, has a 2¾" by 4" (stroke) engine, and a coil-boiler of 1" pipe; length of pipe, 80'; thickness, ¼"; pressure allowed, 100 pounds. On similar small boats, vertical tubular boilers 2' in diameter by 3' high are used.

The Herreshoff boiler on the steam yacht "Leila," whose engines are elsewhere described, contains 654' in length of pipe, of a diameter (outside) ranging from 1 $\frac{1}{2}$ " to 3 $\frac{1}{2}$ ". The interior heating-surface of the pipe is 411 $\frac{1}{2}$  square feet, its exterior surface being 485 square feet. The furnace and boiler is about 7' in diameter by 7' high, these being the dimensions of the enclosing (fire) shell.

An ingenious type of coil-boiler in process of introduction in this district is the Trowbridge boiler with forced circulation, by which the water is kept flowing continuously through a circuit of coiled pipe. This differs from the Herreshoff boiler, the water being circulated by a pump and a certain water-level being maintained in the stand-pipe from which the steam is drawn. This level is preserved by an automatic feeding device, designed by Mr. T. W. Mather, and consisting of two pumps, one of which operates to withdraw water from the boiler if the level be too high, while the other supplies water when the level is too low. The feed is thus automatic and takes care of itself. The furnace is practically a base-burning stove and requires little attention. The boiler evaporates 8 $\frac{1}{2}$  pounds water per pound coal at a rate of combustion of 46 $\frac{1}{2}$  pounds per square foot of grate per hour, and nearly 9 pounds at a rate of 25 pounds per square foot of grate per hour. A 5-horse-power boiler weighs about half as much as a 5-horse-power boiler of the ordinary cylindrical tubular style. It gets up steam enough to drive an engine of 5 horse-power in nine minutes or less, under ordinary conditions.

#### BOILERS OF ALBANY STEAMERS.

CLASS I: Of 14 boilers 3 are specified as drop return-flue, 2 as return-flue, 9 as return-tubular. These are used in sets of 2 and 3. The "Thomas Cornell," 1,160.85 tons, has two return-tubular boilers each 12' in diameter by 25' long. The boilers of the "City of Troy" are return-tubular, 11' in diameter by 21' 3" long. The "Albany" has three drop return-flue boilers each 8' 9" in diameter by 33' long. The "City of Oatskill" has two return-flue boilers each 8' 6" diameter by 25' long. The boiler front is 9' 6" wide. Forty pounds is the usual maximum pressure.

CLASS II: Of 26 boilers 8 are specified as Redfield flue-boilers, 1 is a double-return flue-boiler and 17 are return-tubular boilers. The only steel boilers in the class are two return-tubular boilers each 10' in diameter and 25' long, upon the "Mary Powell." There are no steel boilers on vessels of the preceding class.

Of all the steamers in the Albany district the following nine have, in the order stated, the largest boiler-volumes:

The "Thomas Cornell," 1,160.85 tons, plying between New York and Rondout, two 12' by 25' return-tubular boilers.  
 The "Albany," 1,346.53 tons, plying between New York and Albany, three 8 $\frac{1}{2}$ ' by 33' drop return-flue boilers.  
 The "Chauncey Vibbard," 1,066.98 tons, plying between New York and Albany, three 8' by 31' return-tubular boilers. Instead of as usual having the furnaces of the boilers discharge the products of combustion through one or two smoke-stacks, this steamer is peculiar in having a smoke-stack for each boiler, three abreast across the vessel.  
 The "Connecticut," 728.79 tons, plying between New York and Albany, two 11' by 22' return-tubular boilers.  
 The "Saratoga," 1,438.75 tons, plying between New York and Troy, two 11' by 21 $\frac{1}{2}$ ' return tubular boilers.  
 The "City of Troy," 1,527.83 tons, plying between New York and Troy, two 11' by 21 $\frac{1}{2}$ ' return-tubular boilers.  
 The "Mary Powell," 983.57 tons, plying between Rondout and New York, two 10' by 25' return-tubular boilers.  
 The "Cornelius Vanderbilt," 629.81 tons, plying upon the Hudson river, two 10 $\frac{1}{2}$ ' by 21' return-tubular boilers.  
 The "John Marshall," 330.37 tons, plying upon any inland route, has one return-tubular boiler 13' by 24'. This boat, which has so large a boiler-volume in proportion to its tonnage, is a towing-boat, the others being passenger-boats.

We naturally expect the boiler capacity to vary without regard to the tonnage and according to the speed of vessel and character of service, but the boiler-volumes and cylinder-volumes have no close proportion, as may be seen from the following examples taken from steamers of Class II:

Kind of engine.	Stroke of engine.	Cylinder-volume.	Boiler-volume.	Pressure allowed.
	<i>Feet.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>	<i>Pounds.</i>
Vertical direct-acting condensing-engine ..	3	23.60	1,731.84	35
Do.....	3.8	31.93	1,657.38	40
Beam condensing-engine.....	10	105.56	1,009.71	30
Do.....	10	200.12	1,047.63	45
Do.....	12	339.29	4,181.46	35

The Redfield boiler is described as "a set of plain flue or tubular boilers, such as used for stationary purposes, connected at front and back and surrounded on the sides by a water-shell, which is strongly braced, and takes the place of brickwork as commonly used on stationary boilers".

CLASS III: Of 44 boilers 12 are specified as return-flue, 3 as drop return-flue, 21 as Redfield flue, and only 7 as return-tubular boilers. There is also 1 fire-box tubular boiler. The Redfield boilers are in sets of 2 or 3, except in one instance. All the other boilers are used singly. The fire-box boiler mentioned (10' 9" diameter, 24' 6" long) is upon the "George A. Hoyt," a towing-boat. The drop return-flue boilers are a common ferry-boat type.

The "John Adams," Albany and Greenbush ferry, has such a boiler, 9' 6" by 24' long. All of these boilers have cylindrical shells, and the diameter and length of shell are to be understood as the dimensions specified. The Redfield boilers are nearly all upon steamers plying between New York and Albany. The "Ontario" has three, each 3½' by 28'; the Cayuga three, each 6½' by 28'; the Anna one, 8' by 20½'. The usual pressure allowed is 35 pounds.

CLASS IV: Of 20 boilers 19 are cylindrical and 1 is rectangular; 6 are return-flue, 3 fire-box or locomotive, and 11 return-tubular. There are no steel boilers either in this or in the preceding class. The locomotive-boilers are of small diameter. The Rondout ferry-boat "Riverside," 51.60 tons, has one locomotive-boiler 30" diameter by 12' 6" long. This is exceptional. Two locomotive-boilers on the "Compeer," each 3' by 7', are allowed to carry 100 pounds pressure. The "L. P. Smith," canal-boat, has one 4' 3" by 9' 6" (long) return-tubular boiler.

CLASS V: Of 25 boilers 3 are of the locomotive, 1 of the vertical tubular, and 21 of the return-tubular type. The vertical tubular boiler is on the yacht "Dashaway." The locomotive-boilers are upon the yacht "Bessie" and the tug-boats "Charles P. Grout" and "John S. Ide." There are no steel boilers. Nearly all of the steamers are tug-boats.

CLASS VI: Of 67 boilers 22 are vertical and special tubular boilers commonly used upon steam yachts, 8 are locomotive, and 36 are return-tubular boilers, and there is 1 Redfield flue-boiler. The vertical tubular-boilers are used on 22 steamers, tonnage, 216.48; cubic feet (aggregate) of boilers, 1,450.65. The locomotive-boilers are used on 8 steamers, tonnage, 71.31; cubic feet of boilers, 225.86. The Redfield boiler is used on a boat of 16.68 tons, and has a volume of 135.19 cubic feet. The return-tubular boilers are used on 36 boats, tonnage, 565.31; cubic feet of boilers, 4,997.33. Hence we have cubic feet of boiler-volume per registered ton of steamer as follows:

	Cubic feet.
Return-tubular boilers.....	8.84
Redfield flue-boiler.....	8.10
Vertical tubular boilers.....	6.70
Locomotive-boilers.....	3.17

Average size of boats:

	Tons.
With return-tubular boilers.....	15.70
With vertical tubular boilers.....	9.84
With locomotive tubular boilers.....	8.91

Return-tubular boilers are the common type for tug-boats. There are no steel boilers in this class. All of these small boilers carry high pressures, that is, 60 to 100 pounds, but rarely over 100 pounds per square inch.

#### BOILERS OF NEW YORK STEAMERS.

CLASS I: Number of boilers enumerated, 162; rectangular and semi-rectangular, 14; cylindrical, 148; flue, 8; tubular, including flue and tubular, 154.

There are four vertical tubular boilers of a type already described. The steamer "Hudson," 1,872.68 tons, has four return-tubular boilers, each 9' by 14'. The steamer "Louisiana," 2,840.33 tons, a new and swift steamer of the same line between New York and New Orleans, has eight cylindrical tubular boilers of a peculiar design patented by Mr. Baird. The "Clyde," plying between New York and Aspinwall, has two rectangular boilers 9' high, 18' front, 13' long. The "Hudson City," 1,008.95 tons, has one drop-return flue-boiler 10' in diameter by 33' long. The "Central," 1,023 tons, has one return-flue boiler 10' 3" by 35' long. The "Communipaw," 1,023 tons, has one return-flue boiler 10' 6" by 32' long. The last three are well-known ferry-boats with beam-engines. The "Plainfield," "Fanwood," and other ferry-boats have similar boilers. The "Maryland," 1,093.03 tons, a transfer-boat plying between Jersey City and Harlem, has two semi-rectangular boilers 13' 6" wide and 16' long. These are return-tubular boilers.

The rectangular type of boiler is much more heavy for the same boiler volume and strength than the cylindrical type. It requires a heavier shell and a greater weight of bracing, and is generally designed only for low pressures. It may be considered an old type and belonging to a period when boiler-pressures averaged much less than at present, as they now average less than they will probably average in the future. The idea in building rectangular boilers is an obvious one, viz, to fit the shape of the boiler to conform with the hold of the vessel. On this account some are now built especially to replace worn-out boilers of the same type.

The "Morro Castle," 1,713.61 tons, plying between New York and Charleston, has four return-tubular boilers, each 11' 2" in diameter and 10' long. Each boiler has six hundred and eight 3" tubes.

The "Saint John," 2,645.19 tons, plying between New York and Albany, has two flue-and-tubular boilers, each 13' in diameter by 27' 8" long; tubes, three hundred and forty, 4½"; flues, twenty, of the diameters 16¼", 17¼", and 27½".

The "Rio Grande," 2,556.29 tons, plying between New York and Galveston, has four return tubular boilers 11' 8" in diameter and 10' long. Each boiler has three furnaces with 34" flues and two hundred and six 3" tubes.

The "Manhattan," 1,525.19 tons, plying between New York and Norfolk, has two lobster-back boilers, each 23½' wide and 13½' long. These are return-tubular boilers, and each has three furnaces. The aggregate grate area is 130'.

The "Hudson," of the New York and New Orleans (Cromwell) Line, with four return-tubular boilers, has 7,249.88 square feet of heating surface below the water-line to a boiler volume of 3,562.52 cubic feet; ratio about 2.03. The heating surface as estimated is distributed as follows:

	Feet.
Tubes.....	5,986.40
Furnace.....	521.24
Chambers.....	276.64
Back boxes.....	376.00
Front boxes.....	89.60

The grate surface is 180 square feet; ratio heating to grate, 33.25.

The "City of Augusta," 2,869.64 tons, plying between New York and Savannah, has six 12' 6" by 11 feet long return-tubular boilers of steel. The ferry-boat "New Jersey" has one 10' 3" by 33 feet long return drop-flue boiler of steel. The remaining boilers of this class are of iron. Of 162 boilers, there are 14 used singly, mainly ferry-boat boilers. There is 1 set of 8, and there are 4 sets of 6, 13 sets of 4, and 32 sets of 2 boilers.

CLASS II: Of 105 boilers, 62 are return-flue boilers, 2 sectional-tubular boilers, 2 direct-tubular, and the remainder return-tubular boilers. This is pre-eminently the ferry-boat class, and the drop-flue boiler is the prevailing pattern for ferry-boats.

The ferry-boat "Lackawanna," 891.89 tons, has one drop-return flue and tubular boiler 10' 10" in diameter and 24 feet long, with two furnaces. The ferry-boats "Princeton" (888.43 tons) and "New York" (881.01 tons) are peculiar in having direct-tubular boilers of steel. Each boat has one boiler 9' 4" in diameter and 33' 6" long. These are the only steel boilers in this class, but, like most ferry-boat boilers, carry low pressures. Much lower pressures are carried in the boilers of this than of the preceding class.

The "Benefactor," 843.55 tons, an ocean steamer in the coasting trade, is provided with two Babcock & Wilcox sectional tubular boilers. The high economy of water-tube boilers is generally admitted. The Montgomery water-tube boiler had vertical tubes in the direct, and the Martin water-tube boilers vertical tubes in the return, course of the products of combustion. The tube spaces were not easily accessible for cleaning, and the water was liable to "lift out" on account of defective circulation. In a Babcock & Wilcox boiler there is a series of inclined water-tubes fastened into end connections by expanding the tubes into accurate tapered holes. These end pieces connect with a horizontal steam and water drum located above the tubes, and the end piece at the back of the boiler connects the lowest point of the tubes with a mud-drum. The water-tubes are so placed that each horizontal row of tubes comes over the spaces in the previous row, and each tube is closed at each end by a hand-hole plate made steam-tight by accurately milling the joints. The tubes are thus accessible for cleaning, both within and without, and there is an active circulation, steam passing up the inclined tubes, and water flowing down from the steam-drum through the back connection. These boilers, as placed upon the "Benefactor," are cased in suitable supports for marine service. With the casing, they are 15 feet 6 inches in length and 11 feet 6 inches wide. There are 45 square feet of grate surface and 2,000 square feet of heating surface. The space occupied by this boiler is said to be about two-thirds that of the same capacity in fire-tube boilers.

The "Secaucus," 942.20 tons, has one drop return-tubular boiler 10' 6" by 24 feet. The "Rosedale," 938.65 tons, has two return flue boilers each 8 feet by 30 feet. The "Susquehanna," 921.28 tons, has one return-tubular boiler, 10 feet by 24 feet. The "City of Dallas," 914.55 tons, plying between New York and Jacksonville, Fla., has two rectangular return-tubular boilers, each 14½ feet wide, 11½ feet high, and 10½ feet long. To describe a rectangular boiler as wider than it is long might seem an abuse of terms, but the dimension of length is as usual taken in the direction of the tubes. The "Nassau," 504.37 tons, has one return-flue boiler 9 feet by 24 feet long. The "Minnie Cornell," 503.19 tons, has one return-tubular boiler 8' 3" by 29 feet long.

CLASS III: Of 169 boilers enumerated, about 66 per cent. are return-tubular boilers. There are 6 rectangular boilers. The "Amboy," a towing boat of 272.56 tons, has such a boiler 11' 6" wide, 10' 6" high, and 13' 6" long, of the return-tubular type. There are 3 locomotive tubular boilers. The "Annex No. 3" has such a boiler 7' 2" in diameter by 25' 3" long. There are twelve vertical tubular boilers which are employed mainly upon canal-boats. The largest is a boiler 78" in diameter and 11 feet high upon the canal-boat "A. H. Smith," 126.23 tons. The canal-boat "City of Rochester," 126.23 tons, has one vertical tubular boiler 4 feet in diameter by 6' 3" high, with 162 2" tubes. The freight-boat "Joseph Hall," 161.88 tons, has a Redfield flue-boiler, 4' 6" by 10' 9" (long). The inland passenger-steamer "Erastus Corning" has two return-flue boilers each 6' 10" by 26 feet long, and 33 other boats have flue boilers. The vertical boilers are characteristic of the canal-boats and the return-flue boilers of the ferry-boats, but the towing and inland passenger-boats have return-tubular boilers in the vast majority of cases.

Few boilers are of steel; not more than 4 or 5 out of 169.

The inland passenger-boat "Shadyside," 444.17 tons, has one return-flue boiler of steel. This is 7' 9" in diameter by 30' long. The yacht "Polynia," 158.02 tons, has two 9' by 10' return-tubular boilers of steel. Each boiler has 210 2½" tubes. The lighter "Transit" has one 7' 6" by 14' return-tubular boiler, partly of steel.

Most of the elevator-boats have return-tubular boilers. The canal-boat "Steam Enterprise," 120.76 tons, has one 4' 6" by 19' 2" locomotive-boiler. The yachts "Corsair" and "Stranger," 247.40 tons, each have two tubular boilers, placed fore and aft, one on each side of the vessel. The boilers are 11' in diameter and 10' 6" long, and each has two corrugated iron furnaces, 3' 9" in diameter, 148 3" tubes, 42 square feet of grate, and 1,000 square feet of heating surface. The smoke-stack is 4' in diameter and 24' high. The ordinary boiler pressure is 90 pounds. The boiler volume in cubic feet nearly equals the heating surface in square feet.

The ferry-boat "Midland," 402.88 tons, has one drop return-flue boiler 8' 6" by 20'. This has 16 flues of different diameters, 11, 14, and 19 inches.

CLASS IV: Of 149 boilers enumerated, 4 are return-flue, 5 vertical tubular, and 149 return-tubular. One boiler is rectangular. The vertical boilers are upon yachts, fishing-boats, and small freight-boats. The inland passenger-boats "Only Son" and "Tiger Lily" have return-flue boilers. But the tug-boats, which make up the body of this class, have steam machinery of a uniform pattern, return-tubular boilers, and short-stroke, direct-acting, non-condensing engines.

The steel boilers in this class may be very briefly specified. The passenger-boat "C. R. Stone," 5,540 tons, has one return tubular steel boiler 7' by 13' long. The freight-boat "Clara," 73.65 tons, has one return-tubular steel boiler 5' 6" by 10' long. The passenger-boat "Varuna" also has a return-tubular boiler of steel.

CLASS V: Of 145 boilers, 8 are vertical tubular, 5 Redfield, 2 locomotive, 1 vertical water-tube, and 129 return-tubular.

The inland passenger-boat "Rival," 45.51 tons, has an upright water-tube boiler. The inland passenger-boat "Governor Fenton," and the tugs "George H. Starbuck" and "S. E. Babcock," have Redfield boilers. There are four steel boilers upon the "Theresa," "Skylark," "Promise," and "Thomas Purcell," respectively.

CLASS VI: Of 106 boilers 39 are vertical tubular, 4 locomotive tubular, 1 water-tube, and the rest mainly return-tubular. There are 4 small rectangular boilers, beside the water-tube boiler, which is 6' high on a 4' square base. This is upon the yacht "Evil," 15.35 tons. The steam pressure allowed is 65 pounds. The yacht "Duplex" is returned as having 2 vertical tubular boilers of steel, each 3' diameter by 4' 2" high. There are in all 8 small boilers of steel, most of them being upon yachts of less than 5 tons measurement.

#### EXAMPLES OF BOILERS FROM NEW YORK STEAMERS.

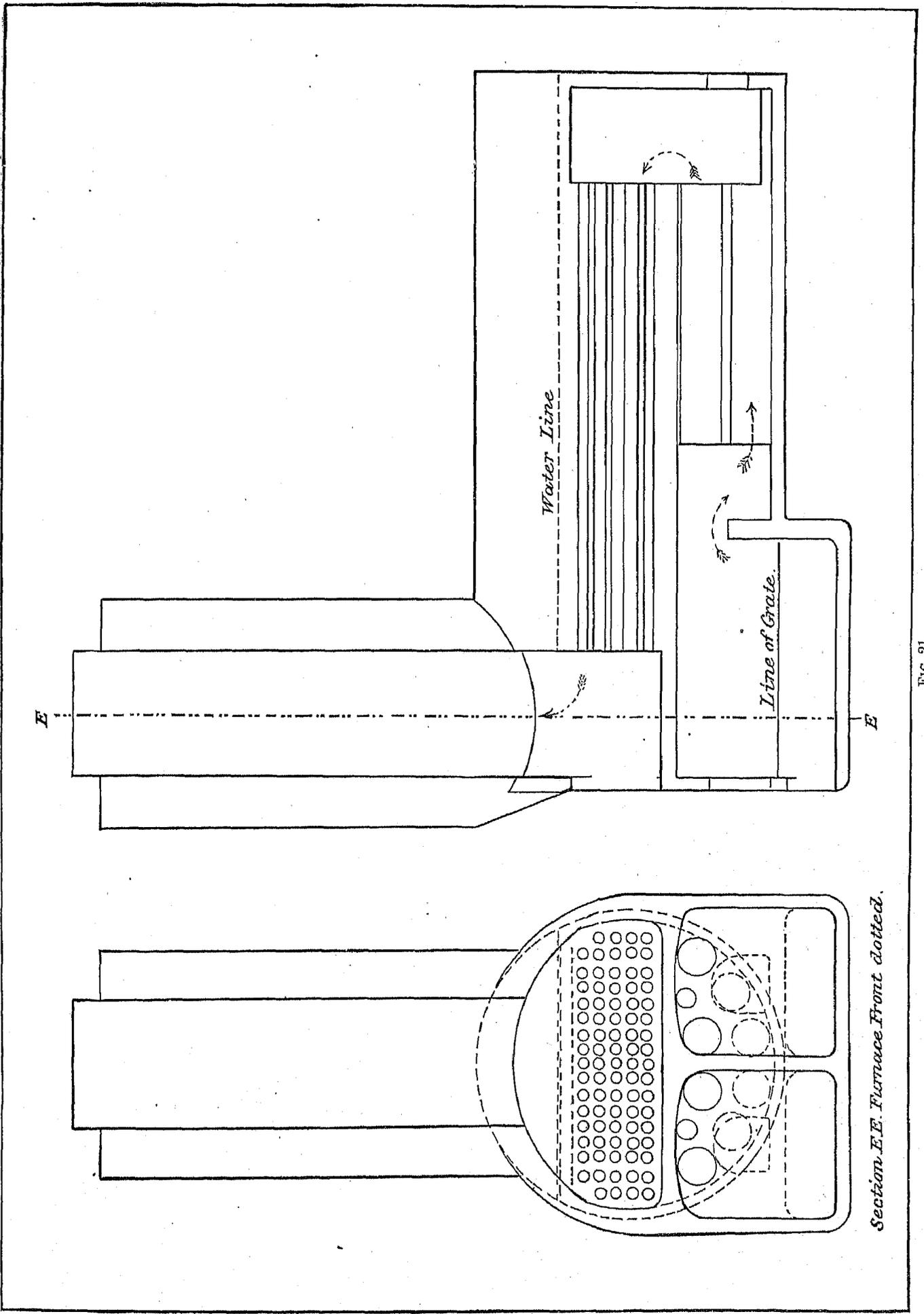
The statistics of the subject having been thus outlined, a more specific description of some of the more notable forms of boilers employed upon steamers plying from New York is here given. Return-tubular boilers are the common type for bay and ocean service, but the name covers considerable variety in detail.

What is commonly known as the marine type has a large shell, cylindrical or rectangular, containing one or more furnaces, and the grate bars extend over half the length of the boiler, the products of combustion passing into an uptake or rising box or flue at the back of the boiler and thence through return tubes over the furnace to the uptake proper or front uptake leading into the chimney. The uptakes are sometimes called front and back boxes. The return tubes are no longer than the furnace, but if they be extended in length, as we may often see that they must be from the stated length of a boiler, it is necessary to have flues to lead the products of combustion to the back uptake, and then we have the type of return-tubular boiler which may be fully described as the direct-flue and return-tubular boiler. Finally the boiler cylinder may be limited to the part inclosing the return tubes; and being properly supported, there may be a special iron or steel fire-box for the furnace or it may, with the bridge and back box, be built up entirely in fire-proof masonry. This is the land type of return-tubular boiler, but it is also employed upon steamers, especially upon river-boats. It is an arrangement which permits a small diameter of boiler and the employment of high pressures with safety. In case a water bottom is employed, as is quite usual, the direct flues or passages are inclosed within the cylindrical shell, as are also the furnaces when these are not accommodated by a separate rectangular front fire-box, which may also be surrounded by the water space.

The usual form of return-tubular boiler with water bottom is illustrated in Fig. 21. In this boiler there are 68 square feet of grate to 2,215 square feet of heating surface. The scale of the drawing is  $\frac{1}{4}$ " per foot.

The boilers of the steamer "Hudson" are of the return-tubular type and have 180 square feet of grate surface and 7,249.88 square feet of heating surface, divided as follows:

	Square feet.
Tubes .....	5,986.40
Furnace .....	521.24
Chambers .....	276.64
Back boxes .....	376.00
Front boxes .....	89.60



Section E.E. Furnace Front dotted.

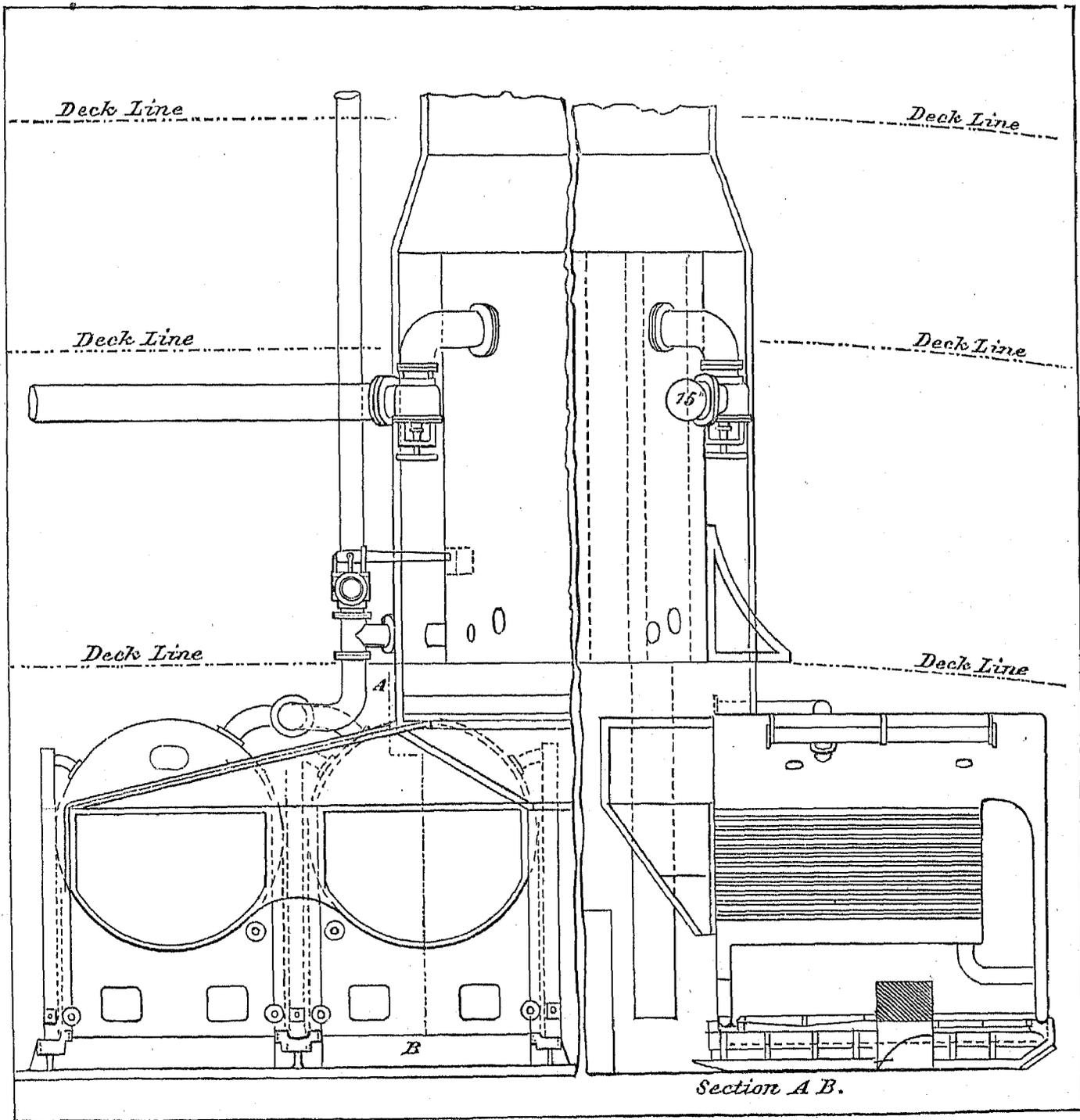


FIG. 22.

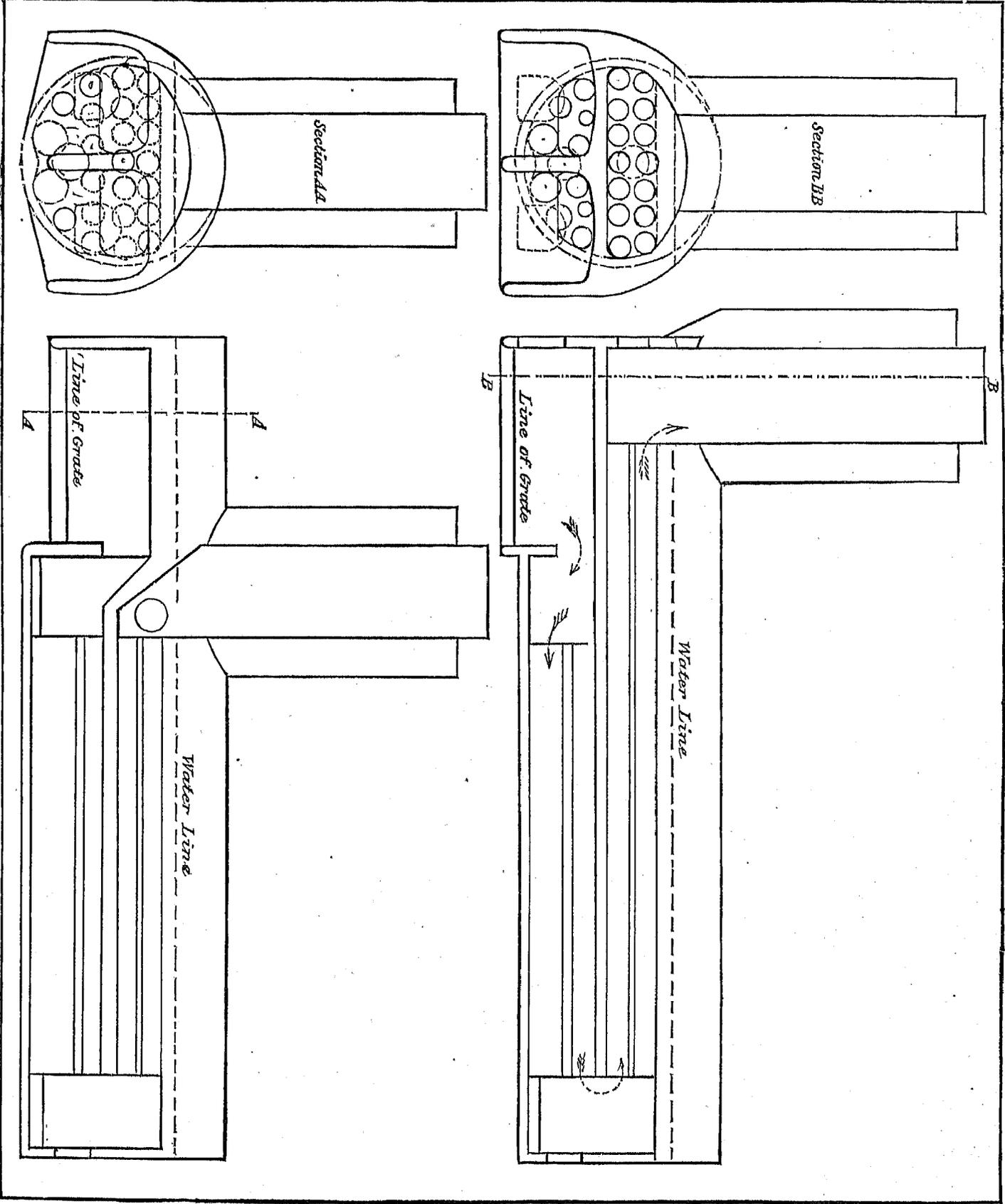


FIG. 23.

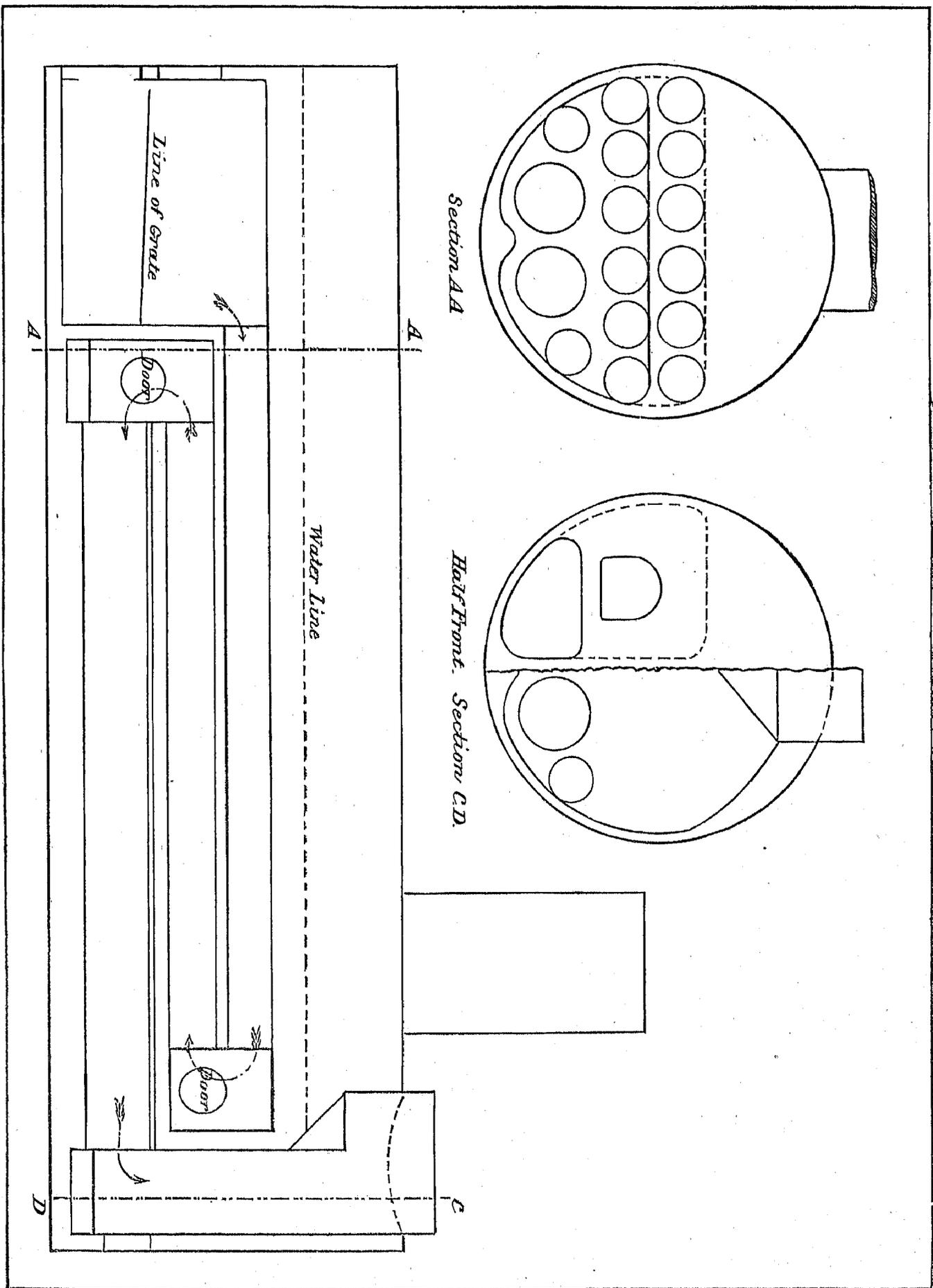


FIG. 24.

This is below the water-line, superheating surface not being included. There are four boilers, 13' 8" long, 9' 4 1/2" in diameter, the height of front or fire-box being 12' 6". Each has three furnaces 6' long and one hundred and forty 3 1/2" diameter by 11' 8" long tubes. The following are the kinds and weights of material entering into the construction of these boilers :

	Pounds.
Plating.....	157,635
Cast iron.....	41,429
Forgings.....	58,959
Rivets.....	11,962
Sheet iron.....	1,620
Angle iron.....	1,481
Brass.....	399
Washers.....	400
Tubes.....	27,896
Total weight.....	301,780

The boilers of the steamer "Pilgrim" are of the Redfield type. There are 4 batteries of boilers, each with a set of 3 shells, each shell 7' in diameter. The extreme outside width of boiler is 23' 6", length 15'. Each shell has one hundred and thirteen 3 1/2" by 12' (long) tubes, and a furnace 7' 6" deep. The boilers are placed athwartship, and each battery has two 36" by 12' drums. They are connected by double breechings to two steam-chimneys or super-heaters 26' high. The peculiarity of the Redfield type consists in the braced water-shell, which constitutes the framing. There is also a donkey boiler, of the locomotive type (used for pumping and other purposes), on board the "Pilgrim."

The "Mary Powell" has two steel boilers, each of the following dimensions: Length over all 26', cylindrical shell 10' diameter and 16' 1" long, fire-box 9' long 11' wide. There is a 5' 10" diameter steam-drum, and a 4' 2" diameter steam-chimney, the height of the steam-drum being 12'. The smoke-stacks are 4' 6" in diameter and 68' high above the grate. There are two furnaces 4' 10" wide and 8' long. There are ten direct flues 9' 1" long, two 14", six 16", and two 9" in diameter, and the return-tubes are 4 1/2" in diameter. The grate surface for both boilers is 152 square feet; heating surface, 2,660 square feet; super-heating surface, 340 square feet; cross area of lower flues, 23 square feet; cross area of tubes, 17.2 square feet; chimney area, 25 square feet.

The "Louisiana" has eight boilers, having a total grate surface of 374 square feet and a total heating surface below water-line of 15,840 square feet. An illustration of a pair of these boilers is presented in Fig. 22. Each boiler has a length of 12' 2" and a diameter of shell of 8' 6", and there are 216 tubes in each. There is no water bottom extending under the furnace, but the cylindrical shell is supported by a detached water-jacket, the peculiar construction of which is exhibited in the drawing. The boilers are shown with steam super-heater, and smoke-stack connections in two views centering upon the smoke-stack. On the right hand side is a section looking forward, athwartship, and on the left hand is a fore and aft view showing half the smoke-stack and the set of two boilers on one side, there being in all four sets of two each. The deck lines are indicated, but to avoid confusion the ventilator pipes and some other ship details are not shown.

FLUE BOILERS.

The great number of flue-boilers employed in steamers running from New York and in the vicinity, in river, harbor, and coastwise service, calls for special mention of this class of boiler, which are principally of three types: the ordinary return-flue boiler, the lobster-back return-flue boiler, the drop return-flue boiler. The "lobster" pattern differs from the ordinary return-flue boiler mainly in having the furnace forward of the chimney. The drop return-flue boiler has three sets of flues, one extending from the upper part of furnace to a back box, and from this the products of combustion pass forward by a second and lower set of flues to a forward box or connection in which they drop a second time and traverse the length of the boiler by a still lower set of flues, finally passing out of the back uptake leading to the chimney. These important types of boilers, as built by Messrs. W. & A. Fletcher, are illustrated in Figs. 23 and 24. The ordinary return-flue boiler as shown has 72 square feet of grate to 2,000 square feet of heating surface. The lobster pattern return-flue boiler has 72 square feet of grate to 1,800 square feet of heating surface. The drop return-flue boiler has 64 square feet of grate to 2,015 square feet of heating surface. The flue-boilers of the lobster and ordinary types are shown without water bottoms under the furnaces, but they are often built with water bottoms.

BOILERS OF PHILADELPHIA STEAMERS.

In Class I all the boilers enumerated are return-tubular. The "Juniata," plying between Philadelphia and New Orleans; the "Norman," plying between Philadelphia and Boston; and the "Saxon," in general coasting service, have rectangular boilers. The "Juniata," 1,320.31 tons, has 2 boilers, each 10' by 14' 9" (wide) by 10' 6" (long). The "Norman," 1,203.26 tons, has 2 boilers, each 9' 10" by 17' 2" by 9' (long). The collier "Perkiomen," 1,035.35 tons, has 2 cylindrical return-tubular boilers 10' 3" by 8' 8" (long).

In Class II there are a considerable number of rectangular boilers, many of them upon vessels of recent build and some allowed no more than 20 pounds pressure. The boilers are almost invariably return-tubular, but the "Long Beach," 519.51 tons, has a 10' by 28' (long) drop-flue boiler. The city ice-boats have enormous boiler capacities, necessary to supply the power for breaking up ice on the Delaware Bay and River. No. 1, 325.97 tons (Class III), has four 8' 6" by 23' boilers; No. 2, 458.02 tons, four 9' 7" by 22' boilers; No. 3, 637.20 tons, eight 10' by 12' boilers, all being of the cylindrical return-tubular type. The collier "Berks," 553.09 tons, has one cylindrical return-tubular boiler, 8' 8" by 12' (long).

In Class III the following four steamers have vertical tubular boilers.

The inland passenger-boat "Twilight," 466.93 tons, one rectangular vertical tubular boiler 11' 6" wide, 15' high, allowed 35 pounds pressure.

The "Acadia," 387.26 tons, plying to the West Indies, two vertical tubular boilers, each 8' diameter and 12' 5" high.

The yacht "Concord," 225.22 tons, one vertical tubular boiler 6' 9" diameter, 11' 2" high.

The inland passenger-boat "Cinderilla," 131.22 tons, one cylindrical vertical tubular boiler 5' 1" by 10'.

Most of the ferry-boats are in this class. They have cylindrical tubular boilers, 8' diameter by 22' long being an ordinary proportion. Most of the large canal-boats are also in this class. The canal-boats "Raritan," 166.83 tons, and "Delaware," 166.53 tons, have each a cylindrical return-flue boiler 7' by 14'. The canal-boat "Fannie," 186.98 tons, has a 7' 6" by 13' (long) return-tubular boiler. On the whole, while it may be said that there are relatively more rectangular boilers in the Philadelphia than in the New York district, there are relatively fewer flue-boilers in the former than in the latter district.

In Class IV, nearly all of the boilers are return-tubular, and the same holds true of the remaining classes with a larger number of vertical boilers as might be expected upon the smaller boats. The "Ibis, jr.," a small boat of 4 tons, has a Herreshoff coil boiler which is allowed 133 pounds pressure, and some of the small boats have locomotive-boilers.

But for a few exceptions upon boilers of steamers of the smallest class, it might be said that there were no steel boilers inspected in this district. There is, however, a 48" by 42" by 72" high vertical tubular boiler of steel upon the boat "River Queen," 10.08 tons; a 5' by 9' cylindrical return-tubular boiler, partly of steel, on the yacht "Columbia," 19.87 tons; and a steel boiler, cylindrical vertical tubular, 3' 10" diameter and 5' 6" high upon the "Comet," a boat of 23.30 tons.

The frequent employment of large rectangular boilers in the Philadelphia district has been noted. The dimensions of such a boiler, one of a pair supplying steam to a 30" and 50" by 36" compound engine are as follows: Length, 14' 6"; breadth, 8' 6"; height, 9'; type, compound direct-flue and return-tubular; flues, 4-11" and 2-18", all 5' 6" long; tubes, 64-4½" diameter and 12' long; heating surface, 1,241 square feet; grate-surface, 42 square feet; there being in each boiler 2 furnaces 6' long and 3' 6" wide.

#### BOILERS OF BALTIMORE STEAMERS.

In Class I are sixteen boilers, all return-tubular, and one pair rectangular. The "Johns Hopkins," 1,470.97 tons, has two boilers, each 192" in diameter and 13' long. This steamer plies between Baltimore and Boston. The "Lancaster," 1,283 tons, a steamer plying from Philadelphia to points on the Atlantic coast, has two boilers, each 11' diameter by 9' 6" long, with three hundred and seventy-two 3" tubes.

In Class II are forty-seven boilers, the majority return-tubular. There are eight boilers of the Scotch type (flue and tubular), two of 10' diameter by 12' 6" long on the "Saragossa," plying between Baltimore and Boston, and six of 9' diameter by 11' long on the "F. C. Latrobe," plying upon Chesapeake bay. The last are allowed 60 pounds pressure. Seven boilers are specified as flue-boilers and four are specified as rectangular boilers.

The "William Kennedy," 974.57 tons, plying between Baltimore and Providence, R. I., has one return-tubular boiler 12' in diameter by 20' long. This boiler has ten flues of several diameters, 16", 14", and 10½", and one hundred and forty 4" tubes 14' 6" long. The pressure allowed is 35 pounds.

In Class III, seven out of fifty-four are specified as return-flue boilers, and one as a rectangular boiler. Nearly all are return-tubular boilers. The river boat "Mary Washington" has two 3' 6" by 18' tubular boilers; pressure allowed 80 pounds. In Class IV, nearly all of the boilers are of the usual return-tubular type, but the river boat "Virginia," 51.14 tons, has a 36" by 12' locomotive-boiler, and the river boat "William McKinney," 74.07 tons, has a 4' 6" by 10' fire-box tubular-boiler. In Class V, there are specified 2 Scotch type, 3 vertical, and 1 locomotive boiler out of a total of 44, the rest being return-tubular boilers either with outside or inclosed furnaces. In Class VI there are 9 vertical tubular, 1 return-flue, and 39 return and direct tubular boilers.

Only four small steamers in this district have boilers of steel or partly of steel. The so-called Scotch-type boilers of the "Saragossa" are direct-flue and return-tubular, each having three 34" direct furnace flues and one hundred and twenty-eight 3½" return tubes. The tubes are 12' long. The boilers are cylindrical in form, with an independent steam drum.

## BOILERS OF NORFOLK, CHARLESTON, AND SAVANNAH STEAMERS.

In the Norfolk district, we find the same types of boilers as in the Baltimore district and in about the same numerical proportions. The "B. and J. Baker," 212.67 tons, plying between Norfolk and the West Indies, has one 7' by 16' flue and return-tubular boiler of steel and iron. This is the only steel boiler specified.

In the Charleston district, of 76 boilers enumerated, 16 are of the locomotive type. These are upon boats plying upon the Santee, Pedee, and Cape Fear rivers. The "Farmer," 470.01 tons, the "Merchant," 405.58 tons, and the "Planter," 384.35 tons, plying from Charleston to Cheraw and points on the Great Pedee and Santee rivers, have each two 54" by 14' tubular boilers of steel. These have shells  $\frac{3}{16}$ " thick and are allowed a pressure of 120 pounds per square inch. The small steamers "Elizabeth" and "Oklahoma" have vertical tubular boilers of steel.

In Class VI, of the Savannah district, five boats have coil-boilers of the Herreshoff type. The largest is the "Ogeechee," 8.39 tons, which has one 8' by 12" engine. The yacht "Josie," plying from Saint Augustine to Matanzas Inlet, has a coil-boiler with 100 feet of 1" pipe and one 3 $\frac{1}{4}$ " by 6" engine. The small yacht "Marie," with one 2 $\frac{1}{2}$ " by 3" engine; the "Major Tilton," with one 3 $\frac{1}{2}$ " by 7" engine; and the yacht "Olivia," with two 3" by 5" engines, have coil-boilers.

In Class VI, Charleston district, six out of fifteen boilers are vertical and five out of fifteen locomotive tubular boilers. In Class VI, Norfolk district, twelve out of thirty-five are vertical tubular. In Class VI, Savannah district, out of twenty-five boilers nine are vertical tubular, two locomotive, five coil, and the rest return-tubular.

The tug-boat "Arrow," 173.50 tons, plying upon Saint John's river, has one 54" by 20' locomotive-tubular boiler. The passenger-boat "Athlete," 178.85 tons, plying on Saint John's river, has one 8' by 17' 6" return-tubular boiler. The "Florida," 475.71 tons, plying between Savannah and Palatka, has two 5' by 19' 10" return-tubular boilers of steel. These have shells  $\frac{3}{16}$ " thick and are allowed 120 pounds pressure. The small boats "Dart" and "Parole" have vertical tubular boilers of steel.

The "City of Macon," 2,092.80 tons, plying between Savannah and New York, has four 12' 8" by 10' 6" (long) cylindrical return-tubular boilers. These have shells  $\frac{3}{8}$ " thick, of iron, and are allowed 80 pounds boiler-pressure. The "Gate City" and "City of Columbus," ocean steamers, plying between Savannah and New York, have each four 12' 8" diameter by 10' 6" long cylindrical return-tubular boilers, shells  $\frac{1}{4}$ " thick; pressure allowed, 80 pounds. These are of iron. It may be remarked that the 12' 6" diameter steel boilers of the "City of Augusta" have a thickness of material of 0.762" and are allowed 100 pounds pressure, and that the 14' 6" iron boilers of the "City of Alexandria" have a stated thickness of material of 1" and are allowed 80 pounds pressure. Than the latter there are no thicker boiler-shells upon the coast.

## BOILERS OF GULF STEAMERS.

Passing from the Atlantic to the gulf ports of the southern states, the influence of Mississippi river practice appears even as far as Key West, in the greater number of flue-boilers.

Of 25 boilers enumerated in the Apalachicola district, 8 are return-flue, 3 vertical, and the rest return-tubular. Plying upon the Apalachicola river we find the "Rebecca Everingham," a boat of 592.20 tons, with two 38" by 16' return-flue boilers of steel, and allowed the high pressure of 183 pounds per square inch. This is the only steel boiler specified. The ocean passenger- and most of the tug-boats have return-tubular boilers. The inland passenger-boats, many of which make short runs along the coast, have flue-boilers. The freight-boat "D. L. Yulee," 139.66 tons, has one 4' by 22' (long) return-flue boiler; pressure allowed, 108 pounds. For the same boiler capacity, the flue-boilers, being of small diameter, are commonly used in sets of two or more, while the tubular boilers are used singly.

When we reach the Mobile district the return-tubular boilers from being the rule have become the exception. The large propeller towing-boat "Lone Star," 482.10 tons, has one 10' by 22' 6" (long) flue- and return-flue boiler. The John T. Moore, 457.31 tons, has four 38" by 26' (long) double return-flue boilers. Both of these boats are propellers. The "Bradish Johnson," an inland passenger-boat with paddle-wheel, has three 40" by 28' two-flue boilers. The paddle-wheel boat "Annie," 200.10 tons, has one direct-flue and return-tubular boiler, 7' 10" diameter by 20' 8" long. The tubes are 14' 10" long. The paddle-wheel tug-boat "Escambia," 94.98 tons, has two double return-flue boilers 3' 6" diameter and 20' 6" long. The boiler of the "Annie" is allowed 25 pounds; that of the "Escambia," 110 pounds pressure. There are in this district a considerable number of fire-box and locomotive tubular boilers, this being the usual type for towing-boats. The tug-boat "Coosawattie," 38.45 tons, plying on the Coosa river, has one 40" diameter by 11' 2" long locomotive-boiler, which is allowed 100 pounds pressure. There are three or four vertical tubular boilers upon small yachts and tug-boats. The yacht "Lulu Burns," 3 tons, has a small steel boiler, and the passenger-boat "Maggie F. Burke," 284.37 tons, plying upon the rivers of Alabama, has two flue-boilers 42" by 32' of steel. The thickness of material is  $\frac{3}{16}$ " and the pressure allowed is 173 pounds. The river freight-boat "Lillie Low," 64 tons, has two 3' by 16' flue-boilers of steel. The remaining boilers in the district are of iron.

Of the Galveston steamers, an enumeration made subsequent to the close of the census year by Mr. Lewis C. Hershberger, local inspector, gives the following data of boilers: Total number, 48; iron boilers, 45; steel, 3. The steel boilers are a return-tubular, 5' 6" by 11' on the freight-boat "Daniel Peggotty;" a vertical tubular on the "E. D. Sidbury;" and an 8' by 11' return-tubular on the "Continental." There are 2 vertical tubular boilers, and of the horizontal boilers 15 are return-flue, 27 return- and 2 direct-tubular, and 2 flue- and return-tubular. The return-tubular boilers range in size from 2' 4" diameter and 3' 6" long to 8' diameter and 16' long. The return-flue boilers range in size from 3' (diameter) by 12' to 3' 4" by 24'. Sixteen boilers are used in sets of 2. Of these, 12 are return-flue boilers.

The steamers inspected at the port of New Orleans are divided, geographically, into two classes, the river-service and the gulf-service. The flue-boilers are mainly employed in the river-service. Steel boilers also are very common upon the river, but rare upon the gulf and harbor steamers. The "Enterprise," 1,041.20 tons, plying between New Orleans and Algiers, Louisiana, has four steel boilers of the return-flue type, each 4' by 20' (long).

The ferry-boat "Nathalie Hamilton," 148.99 tons, plying between New Orleans and Algiers, Louisiana, has one return-flue boiler 44" by 26' 6" (long) of steel. The "Ella Andrews," 64.29 tons, plying between New Orleans and Pensacola, has one return-tubular boiler 7' 6" by 13' of steel.

The "Chalmette," 2,982.96 tons, plying between New Orleans and New York, has four return-tubular boilers, each 13' in diameter by 12' 2" long.

Of the steamers inspected at New Orleans, by far the greater proportion belong to the river-service. Of steamers of Class I, 14 out of 26; of Class II, 6 out of 15; of Class III, 3 out of 91; of Class IV, 6 out of 40; of Class V, 3 out of 30; and of Class VI, 2 out of 44 are specified as plying upon the Gulf; this not including boats specified as plying from New Orleans to the sea and the local service, nor the boats specified above as plying between New Orleans and Algiers. Of the thirty-four steamers specified the return-tubular is the characteristic type of boiler. The coasting-steamer "Chase," 576.47 tons, has one 9½' by 20' fire-box return flue boiler. The "Heroine," 180.14 tons, classified as a lake, bay, and sound passenger-steamer, plies between New Orleans and Mobile, and has a haystack tubular-return boiler. This steamer was built at Glasgow, Scotland, 1862. Its boiler is 12' in diameter and 13' high, and has four furnaces and one hundred and fifty-two 2½" tubes to each furnace.

Among the boilers peculiar to stern-wheel steamers and propellers in the Mobile and New Orleans districts, there is little blending of type. We do not as a rule find the high-pressure flue boilers upon the propellers nor the lower-pressure tubular-boilers upon the stern-wheel boats. The style of boiler suited for a large light-draft boat is not suitable for a small harbor-tug; but high-pressure boilers of small diameter are used upon the propellers, while tubular boilers are the prevailing type for light-draft river-boats upon the Pacific seaboard. The preservation of the distinguishing types is due in no small degree to the fact that boats and boilers are for the most part built in two far-separated sections of the north, the Ohio river furnishing one type while the Atlantic seaboard of the middle states furnishes the other. If we have before us a list of New Orleans steamers with the places of build and the boiler-pressures allowed, either item will enable us to draw a probable inference as to the character, both of the boilers and engines, of any steamer in question. The following tables show how the boiler-pressures allowed range for the several districts and classes of vessels:

	New Orleans.		Mobile.		Galveston.		Apalachicola.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Class I.....	174	28				25	183	
Class II.....	170	26						
Class III.....	181	30	173	25	135	50	150	30
Class IV.....	173	45	120	40	120	75	80	70
Class V.....	159	50	100	40	120	00	80	40
Class VI.....	115	50	130	55	100	05	80	60

For New Orleans the enumeration of steamers with boiler-pressures above and below 90 pounds is as follows, by classes:

	Number of steamers.	Boiler-pressures.	
		Above 90 pounds.	Below 90 pounds.
Class I.....	26	12	14
Class II.....	15	8	7
Class III.....	91	70	21
Class IV.....	40	30	10
Class V.....	30	17	13
Class VI.....	46	12	34

## PROPORTIONS AND ARRANGEMENT OF STEAMERS.

Under this head I present some comparisons of the principal dimensions of steamers in various classes of service and built at various dates, so as to exhibit the peculiar requirements of different services and the tendencies of different periods. Accounts in some detail are also given of the constructive arrangements of a sufficient number of steamers in different classes of service to fairly illustrate the subject.

## OCEAN STEAMERS.

Paddle-wheel steamers in ocean service are becoming the exception. They are less frequently used on the Atlantic than on the Pacific ocean, but a considerable number are inspected at the port of New Orleans, while in New England they are the prevailing type. The following examples may be cited:

*Built before 1866.*

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Charleston.....	1850	1,227.03	233.0	37.2	23.8
Clinton.....	1863	1,187.11	220.0	34.5	18.2
Albermarle.....	1864	871.43	172.0	33.5	19.2
J. C. Harris.....	1865	904.51	210.0	33.1	16.0
Morgan.....	1865	994.51	210.0	33.1	16.0

Ratio length to breadth varies from 5.13 to 6.61; length to depth from 8.96 to 12.61.

*Built since 1865.*

Harlan.....	1866	1,103.02	210.0	34.1	16.0
Josephine.....	1868	1,282.58	236.8	24.3	18.0
Wyanoke.....	1870	2,007.02	208.0	40.5	21.4
Whitney.....	1871	1,337.04	235.5	35.0	17.1
Saint Johns.....	1878	1,008.84	250.0	38.0	12.7

Ratio length to breadth varies from 4.20 to 9.74; length to depth from 9.72 to 19.08.

The later-built boats embrace a wider range of service.

Of screw steamers and steamships the following examples are cited:

*Steamships built since 1874.*

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
City of Atlanta.....	1875	1,020.95	212.0	40.0	20.3
Niagara.....	1877	2,265.28	288.0	30.4	23.0
City of Rio de Janeiro.....	1878	3,518.30	345.0	38.0	28.8
City of Para.....	1878	3,532.25	345.0	38.0	28.5
Saratoga.....	1878	2,426.13	298.0	38.0	23.5

*Steamships built before 1875.*

Geo. W. Clyde.....	1872	1,804.89	250.0	35.0	10.2
Richmond.....	1872	1,437.96	200.0	33.0	21.0
Pennsylvania.....	1873	3,104.28	343.0	43.0	32.0
Colou.....	1873	2,085.75	292.0	40.0	20.3
Carondelet.....	1873	1,508.29	248.0	30.0	21.0

The ratio of length to breadth is 8.93 for the "City of Rio de Janeiro," 7.99 for the "Pennsylvania," 6.24 for the "Richmond," and 6.03 for the "City of Atlanta."

*Screw steamers built before 1870.*

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Crescent City.....	1860	2,008.41	265.4	34.0	16.0
Santiago de Cuba.....	1861	1,079.76	231.0	38.0	27.5
Cortez.....	1863	1,246.18	209.5	35.3	17.2
Saxon.....	1862	1,293.43	200.0	34.0	18.0
Morro Castle.....	1864	1,713.61	255.8	40.0	23.1

*Screw steamships built since 1870.*

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
City of New York.....	1873	1,715.73	242.0	37.0	19.5
Hudson.....	1874	1,872.68	280.0	34.0	25.8
City of Washington.....	1877	2,618.27	300.5	38.4	27.5
Manhattan.....	1879	1,525.19	228.0	35.2	20.2
City of Alexandria.....	1879	2,480.82	307.0	38.5	23.7

The ratio of length to breadth is 5.88 for the "Saxon," 7.81 for the "Crescent City," 6.54 for the "City of New York," and 8.24 for the "Hudson." The general bluffness of build as compared with English practice is obvious, and the tendency toward greater relative lengths is slight.

## EXAMPLES OF LARGE COASTING STEAMERS.

The "Decatur H. Miller," of the Merchants and Miners Transportation Company, is an iron steamer of 2,296.14 tons. It is 257 feet long on deck, 250 feet long on the 6 feet water-line from outside of stem to outside of main post, 38' 6" breadth of beam at the widest, 26 feet depth of hold, and 31½ feet depth over all. It is called a full three-deck vessel. The hold, 8' 3" deep, and above that the lower between-decks, 7' 6" high, are used for freight. Above these are the upper between-decks, 7' 6" high, and the promenade deck, upon which are houses coming above the body of the vessel. Upon the upper deck, apart from spaces for freight, hatches, stores, etc., there are three sections, the passenger saloon, 60 feet long aft, the machinery and steerage space, 70 feet long amidships, the fore-castle, 46 feet long forward. On the promenade deck are two houses, one 70 feet long aft, containing the engine, mess, and officers' rooms, social hall and state-rooms for passengers, and one 40 feet long forward, containing the pilot-house and captain's and officers' rooms. The machinery space on the upper deck and in the upper between-decks contains not only the machinery but the kitchen, ice-house, and steerage. The machinery consists of four cylindrical tubular boilers, 11' by 11' and two 24" and 54" by 48" compound engines with the high-pressure over the low-pressure cylinders. It occupies about 55 feet of the length of the vessel. Of the depth of hold, 26 feet, 23' 3" is clear space and 2' 9" decks, floors, and ceilings. On the upper deck, with the passenger saloon are 18 state-rooms, and in the fore-castle are the quarters of sailors and firemen.

The iron framing of the vessel it is not within my present province to describe, but about the rudder and propeller it may be considered as the framing of the machinery, and the description of this is pertinent to our subject. The stern is of 8' by 4½" hammered iron, with a solid eye for the screw shaft, the eye being 10" deep and 27" in diameter. The rudder-post is 8' by 4½", bosses for rudder-pentles 8" in diameter and 7" deep, with lignum-vitæ bushing; opening for wheel, 5' 3" wide. The rudder-stock is 6½" in diameter, extending above the upper deck and fitted with a quadrant and steering wheel. The rudder-frame is forged solid to the stock with two stiffening bars hanging on three pentles; heel pentle 4" in diameter and 4½" long, capped with brass; upper pentles 3½" in diameter. The rudder is filled with white pine covered with ¾" wrought-iron plates. In the machinery section from the forward-boiler bulkhead to the aft-engine bulkhead the framing of the vessel is doubly heavy. Like most coasting steamers the "Decatur H. Miller" is designed for a mixed freight and passenger service, but the freight service is the more important feature. Land communication by rail is so much more rapid that the coasting steamers can only absorb a small proportion of the passenger traffic. This steamer is considered a swift vessel. It makes the trip from Boston to Norfolk in forty hours and fifty minutes, but a person can go from Boston to Baltimore by rail in less than one-fourth the time required by the boat under most favorable circumstances.

The screw steamer "Chalmette," one of the largest and most important steamers in the gulf trade, is of 2,982.96 tons register, length between stem and propeller-posts, 320'; over all, 340'; breadth of beam, 42'; depth from base line, 31'. Like the "Decatur H. Miller" the "Chalmette" has three decks, but with different arrangement and no provision for passengers. The sides of the vessel are iron to above the upper deck, which is flush, fore and aft. On this deck are the dining-room, kitchen, package-freight house, machinery hatch inclosure, captain's and officers' rooms, and pilot-house, the fore-castle being below and forward on the main deck. In the completeness and excellence of her appointments for freight service the "Chalmette" merits especial mention. Steam power is called into play at every point where manual labor can be conveniently saved. An independent engine operates the windlass and forward capstan, which were made by the American Ship Windlass Company, of Providence. These windlasses are among the most commendable features of American marine machinery. There are also five separate freight-hoisting engines, which serve not only to handle the cargo but to work the aft capstan and handle the sails. There are three steam winches for handling sails and hauling. There are two large donkey-pumps for bilge and fire purposes, beside which there is a circulating-pump, also two 6" Hancock inspirators and a boiler feed-pump. There is a steam steerer in the pilot-house forward, and for further security against accident there is a separate safety steering apparatus located in a house over the rudder-head. In all, there are fifteen engines on

board. The main engine is compound, 35" and 70" by 54" stroke, of the steeple type. There are four 13' by 12' 2" main boilers with a total of 12 furnaces, and there is one large donkey-boiler for furnishing steam for the numerous small engines. The screw propeller is 16' in diameter and 22' pitch.

The "Chalmette" has nine athwartship iron bulk-heads and three water-ballast compartments. A novel and effective apparatus is employed for signalling between engine-room and pilot-houses. The machinery for propulsion, including the boilers, occupies less than 60' of length; but the labor-saving machinery is, as we have seen, distributed throughout the vessel.

The "Manhattan," of the Old Dominion Line, is a steamer of 1,525.19 tons, length 228 feet, breadth 35.2 feet, depth 20.2 feet. This steamer plies between New York and Richmond and is largely engaged in the fruit and vegetable trade. Besides accommodations for officers and crew, it has provision for 40 cabin and 30 steerage passengers. There are four water-tight bulkheads, and bulkheads around the boilers and machinery. There is one 28" and 53" by 4 feet compound engine with steam reversing gear, steam syphon and independent circulating-pump, and there are two lobster-back boilers, each 10' 5" in diameter and 22' long. These have 130' of grate-surface, there being three furnaces in each boiler. Of auxiliary-machinery, there is a platform elevator for cargo in the forward hold and improved hoisting machines and windlasses. There are three anchors, of 3,000, 1,500, and 800 pounds, respectively. The propeller is 13' in diameter and 20' 6" in pitch. The hub is of cast iron with steel blades.

The "City of Augusta," of the Ocean Steamship Company, is more particularly a passenger-steamer, and one of the finest upon the coast. It is 302 feet long, 42.2 feet broad, and 17 feet deep, with a registered tonnage of 2,869.64 tons. It is a three-deck vessel, with main deck, spar-deck, and hurricane-deck, the last the whole length and width of the ship, with a pilot-house and officers' rooms upon it forward and a long saloon aft, the lower decks being occupied by dining-halls, parlors, state-rooms, fore-castle quarters for seamen and firemen, steerage quarters with 30 berths, an ice-house of 15 tons capacity, butcher shops, lockers, store-rooms, and the like. The principal machinery space begins at the middle of the vessel and extends some 60 feet forward. The machinery has already been described.

SIDE-WHEEL STEAMERS.

In the arrangement of side-wheel steamers the most characteristic feature consists in the guards, which are extensions of the main deck fore and aft of the wheel batteries to the full width of the steamer over all. The effect of this is to greatly increase the available space upon the main deck, and, as the guards are tapered off fore and aft, the plan of the main deck has a tendency toward the lozenge shape. This and the utility of the increased space

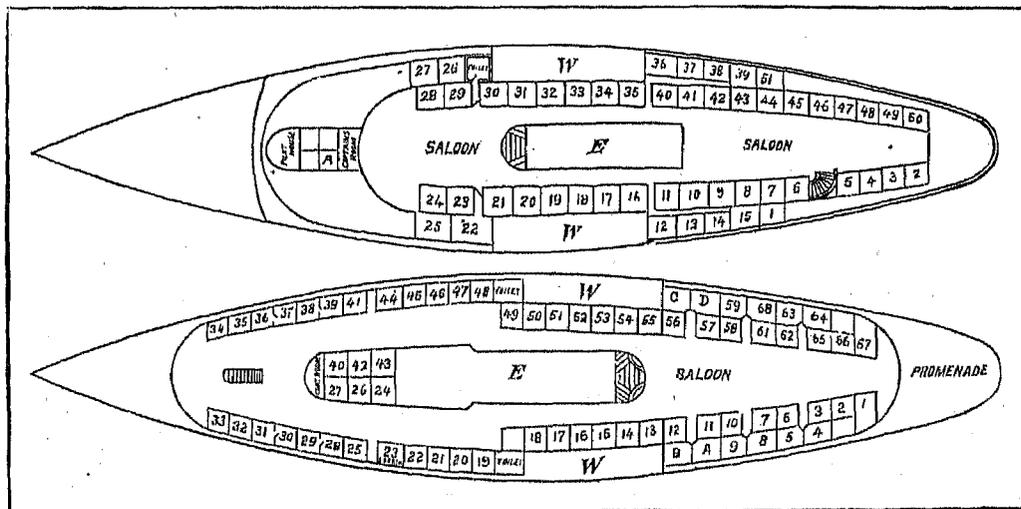


FIG. 25.

is well illustrated by the deck plans of two New England steamers, shown in Fig. 25. The engine and boiler spaces are shown by the letters E and the wheel spaces by the letters W, and we see at a glance how large a proportion of the state-rooms are accommodated upon the guards. The guards are supported by cross timbers, called sponsons, projecting from the hull of the vessel, and in some cases these extensions are carried so far that the width of deck is nearly double the breadth of beam. Sometimes the boilers are placed upon these guards.

The following dimensions of the "Mary Powell" are given by Theron Skeel: Length over all, 294'; on water-line, 286'; beam over all, 64'; on water-line, 34' 3". The mean draft is 6'; depth of hold, 9'; height from main deck to promenade deck, 10'; promenade deck to upper deck, 8'. The displacement is 28,000 cubic feet; midship section, 200 square feet; projected area of head-wind surface, 2,000 square feet. The crew of the "Mary Powell" comprises fifteen men, captain, clerk, baggage-master, two pilots, two engineers, four firemen, and four deck-hands.

The usual arrangement of sound and river boats is with engines and boilers upon the main deck, where most of the state-rooms are located. The hold accommodates the freight, and contains the quarters of deck-hands and others, the kitchen, and often a dining hall or ladies' saloon. The main deck is taken up by saloons and state-rooms, and the promenade deck by parlors, promenades, and state-rooms. The pilot-house is upon the top or hurricane deck, which is little utilized. A new plan of building river steamers is to put the machinery in the hold. This gives more room upon the main and promenade decks, and by imparting greater steadiness to the boat permits the use of the hurricane deck as a promenade. The new sound steamer "Pilgrim" has her machinery in the hold. The "Pilgrim" is 400' long over all, 50' beam, 88½' over guards, 17½' depth of hold, 11' draft, having three decks and accommodations for three hundred passengers. The strength of the hull is much greater than usual. There is practically a double hull braced upon the longitudinal bracket plate system. The space between the so-called hulls is 24" at the sides and 36" at the keel. It is divided into a great number of water-tight compartments by the longitudinals and floor brackets, added to which there are six athwartship water-tight bulk-heads of  $\frac{1}{8}$ " ,  $\frac{5}{16}$ " , and  $\frac{3}{8}$ " plate. The machinery, boilers, smoke-pipes, kitchen, and wheels are inclosed in iron as a precaution against fire.

## FERRY-BOATS.

In the ferry-boat the space in the hold is of little value, single deck room being the all-important consideration. This has, in some cases, led to the employment of inclined engines, which occupy the hold and leave more deck room; but the beam-engine ferry-boat still remains the more usual type. These differ considerably in their principal proportions, as may be seen by comparing the Jersey City ferry-boat "Erie," 981 tons, with the Hoboken ferry-boat "Lackawanna," 891.89 tons.

Name.	Length.	Breadth.	Depth.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Erie .....	136.5	40.0	14.1
Lackawanna.....	195.8	35.8	12.8

The Brooklyn ferry-boats and those plying between Boston and East Boston have inclined engines. The "Montana," 734.25 tons (Brooklyn), and the "Revere," 550.94 tons (East Boston), have the following dimensions :

Name.	Length.	Breadth.	Depth.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Revere .....	150	33.4	12.2
Montana.....	172	35.8	12.5

In all these cases, while the ratios of length to breadth vary considerably, there is great uniformity in the ratios of breadth to depth, these ranging from 2.74 to 2.86.

The "Lackawanna" is a new boat. It is 62' wide over the guards, and has wheels 19' in diameter and 8½' across the face. The beam-engine has a bore of 44" and a 10' stroke. The drop-return flue-boiler, elsewhere described, is the type principally used on ferry-boats. That upon the "Lackawanna" is 24' long and 11' feet in diameter, and has two furnaces. The draft of the boat is about 7½'. This boat is of iron and is considered the strongest ferry-boat afloat. It has two water-tight bulk-heads and is specially strengthened at the ends to resist the shock of ice.

## TRANSFER BOAT.

The "Excelsior," 774.43 tons, of the Potomac Steamboat Company, is a railroad transfer-boat, with passenger accommodations. There is on the main deck a single track capable of accommodating a train of four cars. There are two inclined engines 40" by 10' cylinders with a jet-condenser, and the main deck is left clear for cars, all the machinery being in the hold. The "Excelsior" is 232' long, 37' broad, 10.5' deep. There is a large passenger saloon on the promenade deck, and there are a number of state-rooms on the guards. The water-wheels are "composite," with two lengths of arms, and are of oak and iron. The wheels are 28' in diameter and 8' face. In place of the usual hog frames, the "Excelsior" has a double row of Howe truss framing. Besides a 44" (diameter) by 7' donkey boiler, there are two through-arch and return-tubular boilers each 10¼' in diameter and 29' long, and with 75 square feet of grate- and 2,250 square feet of heating-surface.

## SOUND STEAMERS.

The following examples are cited of large side-wheel steamers plying upon Long Island sound:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
City of Boston.....	1861	1,591.90	301.0	40.0	12.3
Old Colony.....	1865	1,057.55	310.0	42.0	14.0
Bristol.....	1867	2,062.20	362.0	48.0	16.6
City of Lawrence.....	1867	1,078.00	243.0	62.5	11.0
State of New York.....	1866	1,417.03	280.0	36.0	9.6
C. H. Northam.....	1873	1,436.80	312.0	44.0	10.0
Rhode Island.....	1873	2,742.42	325.0	45.0	15.4
Massachusetts.....	1877	2,006.83	323.8	42.5	15.0

For these, except the "City of Lawrence," the average of length to breadth is 7.55, and to depth 23.66.

## RIVER STEAMERS.

Of Hudson river passenger-steamers, the following examples are cited:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Metamora.....	1810	304.27	168.0	25.0	8.0
Armenia.....	1847	528.20	212.0	30.0	9.0
Eagle.....	1852	422.00	160.0	26.0	7.0
Daniel Drew.....	1860	930.35	260.0	30.0	10.0
Mary Powell.....	1861	983.57	288.7	34.4	9.0
Thomas Cornell.....	1863	1,160.85	286.0	38.8	10.0
Chauncey Vibbard.....	1864	1,006.98	281.0	35.0	9.6
Albany.....	.....	1,346.53	284.0	40.0	10.1

Of these steamers, the average ratio of length to breadth is 7.51; length to depth, 26.55. The examples of side-wheel steamers in the coasting trade, previously cited, give average ratios of length to breadth 6.21 and length to depth 11.28 for the steamers built before 1866, and the ratios 6.35 and 13.40, respectively, for those built since 1865. The river steamers average about five-sixths as broad and half as deep as the ocean steamers for the same length. The Hudson river is so deep and easily navigable that it is sometimes spoken of as being more like an arm of the sea than a river, and the steamers plying upon it, although smaller than those of the principal lines through Long Island sound, are relatively (not actually) deeper.

The following examples are cited of large towing-boats upon the Hudson River. These are side-wheel boats, and some of them, as will be seen, nearly half a century old, the oldest steamers in service in the United States:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Belle.....	1835	433.87	220.0	27.0	9.0
Norwich.....	1836	255.68	160.0	25.0	8.0
Niagara.....	1846	510.54	251.0	30.0	9.0
C. Vanderbilt.....	1847	683.81	300.0	36.0	9.0
Connecticut.....	1848	723.70	303.0	36.0	8.0
America.....	1852	407.10	212.0	30.0	9.0
Austin.....	1853	380.50	197.0	31.3	8.3
Geo. A. Hoyt.....	1873	208.21	105.2	30.5	9.4

Of these boats, the average ratio of length to breadth is 7.36; length to depth, 25.50. The "Connecticut" is relatively broader and shallower than the "Belle," and the "Geo. A. Hoyt" is relatively broader and deeper than the "Connecticut."

## MARINE ENGINES AND STEAM VESSELS.

Of the proportions of river steamers, the following examples are cited from other sections :

Locality.	How employed.	Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Delaware river	Towing	Camden	1814	151.25	<i>Feet.</i> 126.0	<i>Feet.</i> 19.2	<i>Feet.</i> 8.8
Do	do	Bristol	1871	152.65	115.3	22.3	8.3
Do	do	Col. Thomas A. Scott	1875	154.53	130.1	21.0	8.0
Do	Passenger	Nellie White	1860	444.30	172.0	38.0	8.0
Do	do	Thomas Clyde	1878	625.73	212.0	31.0	7.0
Do	do	Republic	1878	1,285.02	272.4	37.0	10.8
Do	do	Clio *	1878	117.10	94.0	22.0	6.0
Potomac river	do	Mary Washington	1859	297.70	135.0	28.0	5.5
Do	do	Mattano	1859	278.60	143.50	22.0	6.8
Do	do	Mystic	1866	194.56	116.65	21.3	6.6
Do	do	W. W. Corcoran	1878	441.31	147.3	27.8	7.9
James river	do	Ariel	1858	493.82	180.9	29.0	18.8
Do	do	N. P. Banks	1863	333.99	159.6	26.6	8.8
Do	do	Accomack	1877	434.57	136.8	25.5	8.3
Altamaha and Savannah rivers	do	Carrie	1867	212.90	133.9	27.1	6.5
Do	do	Katie	1867	190.03	130.0	25.2	5.2
Do	do	Clyde	1870	211.89	102.4	20.2	4.2
Do	do	Gentennial	1875	150.87	120.6	31.3	6.2

\* A screw propeller.

Of the smaller boats, propellers and small tugs, the proportions are relatively deep and wide, the ratio of length to breadth generally ranging between  $3\frac{1}{2}$  and 5, and of length to depth between 10 and 20.

## FREIGHT-BOATS.

Of New York freight-boats, the following examples of proportionment are cited :

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
John Stevens	1845	1,380.41	<i>Feet.</i> 237.6	<i>Feet.</i> 30.7	<i>Feet.</i> 10.4
Marina	1849	144.96	85.0	20.0	7.0
Colden	1851	781.21	180.0	32.0	11.0
Ellen	1853	94.15	93.0	17.6	7.0
Lone Star *	1875	2,255.39	281.0	38.1	27.2
Edward Clark	1870	206.80	109.6	23.5	8.4
Flora	1878	99.83	91.6	24.0	6.6
Pioneer	1865	326.85	137.0	23.2	7.5

\* Ocean freight steamship.

All of these, except the "Colden," are screw propellers.

The Reading colliers of Philadelphia have the following proportions :

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Rattlesnake	1868	417.44	<i>Feet.</i> 170.0	<i>Feet.</i> 29.6	<i>Feet.</i> 12.4
Centipede	1869	436.88	169.0	29.6	11.5
Achilles	1870	763.51	106.6	37.0	13.2
Hercules	1870	764.33	200.4	37.0	13.5
Panther	1870	699.10	190.5	36.0	13.3
Perkiomon	1874	1,035.35	219.0	36.8	17.2
Berks	1874	553.09	189.0	29.0	14.4
Reading	1874	1,283.00	248.4	37.1	18.3

As five others of this last type were built in 1874, it may be considered as the conclusive result of experience in ocean freight steamers for the coal trade. The ratios of length to breadth have been gradually increased in the above series without much change in the relative depth. The ratios are as follows:

Name.	Year.	Length to breadth.	Length to depth.
		<i>Feet.</i>	<i>Feet.</i>
Rattlesnake .....	1868	5.74	13.71
Centipede .....	1869	5.71	14.70
Achilles .....	1870	5.31	14.89
Hercules .....	1870	5.42	14.84
Panther .....	1870	5.20	14.32
Perkiomen .....	1874	5.00	12.73
Berks .....	1874	6.58	13.12
Reading, and others .....	1874	6.00	13.57

## STEAM PILOT-BOATS.

The first steam pilot-boat, the "Jennie Wilson," 77.53 tons, was built in 1878, at Camden, New Jersey, for the New Orleans service. It is 78.5' long, 18' broad, 8.9' deep. It has one 15" and 26" by 20" (stroke) compound engine and a cylindrical tubular boiler, 8' and 8' 10" in diameter and 12' long, allowed 85 pounds pressure. The second steam pilot-boat was improvised from the Philadelphia sea-going tug "Hercules" for the New York and Sandy Hook Pilot Association. The third steam pilot-boat was built by the Harlan & Hollingsworth Company for the Board of Maryland Pilots. The dimensions of this boat are 113' between main posts, 122.6' long over all, 23' beam, 12.9' depth. It has a quarter-deck 3' 3" above the main deck for about 68', commencing about 20' from the stern. Upon this deck are the pilot-house and captain's room, and here are carried two boarding-yawls, each 17' long. Under the quarter-deck is a main cabin, with sleeping berths, engineer's room, kitchen, and store-rooms, and the fore-castle contains chain-lockers, bunk-room, and store-rooms. There are three anchors, 800, 500, and 175 pounds in weight; 60 fathoms of  $\frac{3}{4}$ " and 60 fathoms of  $\frac{5}{8}$ " cable, and a pump-brake windlass. There are two 1,000-gallon water-tanks, and the boat is heated throughout by steam. The power is furnished by one inverted direct-acting compound engine, 22" and 36" by 26" (stroke), with tubular surface-condenser, and air, feed, bilge, and circulating pumps. There is a separate reversing engine for shifting the main valve-links. There is one cylindrical return-tubular boiler, carrying 70 pounds of steam, and an independent steam-pump for boiler-feeding, washing decks, and fire and other service. The boat is of iron, and there are two close iron bulkheads, one forward of the boilers. Coal-bunkers on each side of the boiler, from the boiler bulkhead to the fire-room, accommodate 40 tons of coal, and there is additional storage-room for 40 tons more. It is said that steam-boats of this character will soon supersede the sailing pilot-boats at our principal ports. These facts in regard to steam pilot-boats are derived mainly from the columns of the Nautical Gazette.

## CANAL-BOATS.

The following are examples of New York canal-boats, giving some idea of the size of the Erie canal:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Wm. Wells .....	1859	130.31	96.0	17.0	9.8
City of Detroit .....	1875	122.00	97.0	17.8	9.0
City of Rochester .....	1874	126.23	96.5	17.5	9.4
A. H. Smith .....	1866	118.40	95.3	17.0	8.9
City of Troy .....	1874	124.10	95.5	17.5	9.4

The following are examples of canal-boats of the Philadelphia district:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Annie .....	1861	288.03	130.0	22.2	8.4
Anthracite .....	1862	226.32	121.7	24.2	6.8
Ann Eliza .....	1855	233.82	111.7	22.4	7.9
Black Diamond .....	1863	211.25	110.0	22.0	7.1
Novelty .....	1850	204.31	99.5	24.5	8.1
Vesper .....	1871	331.25	146.0	22.1	8.1
Triplet .....	1874	338.79	152.8	23.0	8.0
Sarah Fleming .....	1873	70.07	95.5	22.0	5.5
Richmond .....	1862	44.10	73.0	15.0	6.2

These proportions call for little remark. Breadth and depth are limited by the size of the canal, and length is limited by the size of locks. All of these boats are propellers.

#### YACHTS.

Of the arrangement of machinery upon small yachts and tug-boats there is not very much to be said. The boilers, of whatever type, are usually placed forward of the engines, which occupy little space. The advantages of condensation are often obtained by a simple arrangement which is illustrated in Fig. 17, page 45. The sketch shows the after part of a boat. A pipe passes from the exhaust of the engine through the side planking of the boat, where it is elbowed in a shoe or sabot and continues back around the stern post and forward upon the other side of the boat which it enters through the elbow of another sabot and connects with the air-pump. The tube is sometimes tapered down continuously from the engine to the air-pump, but good results are obtained by diminishing the diameter of the tube at the stern elbows. Thus from a 3" exhaust-pipe leads a 3" condenser-tube of hard drawn brass. At the stern a reducing elbow changes the tube to a 2" diameter.

On the large yachts "Corsair" and "Stranger" there are two cylindrical boilers set fore and aft—that is, with length parallel with the length of the vessel. The fire-room is between the boilers, and coal bunkers, with a capacity of 40 tons, are located forward at the back of the boilers. The coal consumption of these yachts is about 10 tons a day.

In yachts, tugs, and the smaller steamers of whatever kind, the boilers, if horizontal, are set fore and aft. They are so set in some large ocean steamers, and necessarily so in the river steamers and ferry-boats with long flue-boilers. Short return-tubular boilers of large diameter (such as employed on many ocean steamers) and short rectangular boilers are set athwartship, and the fire-room is in the middle of the ship between the boilers.

#### SPEED OF STEAMERS AND GOVERNMENT OF ENGINES.

The very interesting subject of the speed of steamers is one which cannot be treated with exactitude for the following reasons:

Tests of speed are not made with a scientific observance of the conditions. On long runs distances are often roughly approximated, and the help or hinderance of winds and currents is not accurately considered. Ships under sail have been driven long distances at the rate of over 17 miles an hour, and with the power of steam added to that of a favoring wind much higher speed can be made than without the wind. As there are no claims of speed over 25 or 26 miles an hour under any circumstances, it is reasonable to suppose that the highest simple steaming speed is several miles an hour less for any considerable distance.

It has been noted as a curious fact in one of our engineering journals (*Mechanics*) that speeds made over the measured mile can seldom be made at that rate for a full hour. The conclusion has usually been jumped at that what was true for one minute would hold equally true for sixty, but this does not seem justifiable. Boats which can steam for three or four minutes at the rate of 15 miles an hour are found to have made no more than 11 miles at the conclusion of a full hour, and boats which can steam for a few minutes at 20 miles an hour fail to make more than 15 miles in a full hour.

Of swift steamers, the engine of a large paddle-wheel boat will make only about 60 or 70 revolutions in going a mile, the engine of a large screw-steamer will make 150 or 200, and of a small yacht 600 or 700. If the boiler-pressure and admission be maintained, while the speed made for 1 or 2 miles is not maintained, we have only to look to the inefficiency of the propelling-wheels for an explanation of the phenomenon. As a rule, marine-engines do not carry governors. Silver's, Fairbairn's, and other forms of marine governors have been applied to prevent the racing of propeller-wheels when the water-pressure upon the wheel is variable, as it may be in stormy seas, but the speed of the steamer is the ordinary governor of the engine. It is a matter which calls for practical experiment, but it may be remarked that slight variations in the speed of engines appear to cause serious variations in the efficiency of action of the propelling-wheels, that the periodicity of such variations appears to extend over a considerable number of revolutions, and that the steadiness of the engines appears to be maintained by variations in equilibrium between the effective and non-effective portions of the effort of the propelling-wheel.

Knots (sometimes called nautical miles) and miles are often confused in reports of speed. The knot is 1.1508 miles, or a little over a mile and a seventh long. In the following notes of speeds reported some may have to be taken with allowances. Not all are given as examples of high speed, but some of ordinary speeds with steamers of the classes specified.

The well known report of Mr. Theron Skeel upon the performance of the "Mary Powell" gives the following data: Wheels, 31' total diameter; buckets, 10' 6" long by 1' 6" wide, 26 to a wheel; immersion of buckets (maximum) at mean draft, 3' 6"; revolutions, 12,000 to 13,000 in 90 miles at a speed of 19 to 20 miles an hour, with a slip from 11.9 to 14.5 per cent. Revolutions per minute, 21 or 22. Initial pressure, 40 pounds; cut-off, 0.47; vacuum of condenser, 25"; pressure at end of stroke, 16.4 pounds; mean back pressure, 5.6 pounds; indicated horse-power, 1,540. The "Mary Powell" has run from Poughkeepsie to Vesey street, New York, in 3 hours and

33 minutes, exclusive of 6 landings, and is stated to have run from Milton to Poughkeepsie in 9 minutes. The steamer "Albany" has made a straight run from Poughkeepsie to the Twenty-fourth street landing, New York, in 3 hours and 13 minutes, and from Cozzen's Landing to West Point in 2½ minutes. From Poughkeepsie to Twenty-fourth street is 74½ miles. The "Albany" in her fast run carried 47 pounds steam and the engine made 26½ revolutions per minute. The "Carolina," a steamer of Chesapeake bay, makes a regular run of 60 miles in 3 hours 49 minutes. The "Sun," one of the early Hudson river steamers ran from New York to Albany in 12 hours. The "North American," built in 1827 for Hudson river service, made 17 miles an hour. The sound steamer "Rhode Island" makes 18 or 19 miles an hour, and averages 16 miles an hour over a 160-mile route. Her wheels are 37½' in diameter and 12' broad, and at her best speed she makes only about 17 revolutions. The speed of the "Albany," about 24 miles an hour, is stated never to have been exceeded for a long run except by the "Idaho," in a run to Japan. The English "Yarrow" yachts and torpedo boats have made 23 or 24 miles an hour. The "Ho-nam," a large Chinese river boat with compound beam-engine, of English build, went over the measured mile at a rate of about 16 miles an hour.

Turning now to ocean steamers, we find that the "Ohio," of the American line, makes an average speed of 14½ miles an hour, at which rate the slip is 6.8 per cent. This steamship has run nearly 400 miles at about 15½ miles an hour. In 1856 the United States steamer "Wampanoag" made 407 knots in 24 hours with the wind forward and no sail. This is equal to 19.51 miles an hour, and has scarcely been exceeded; never, under the same conditions. The English steamer "Stirling Castle" is stated to have made the measured mile at a rate of 21.3 miles an hour, but its speed for long runs would probably be several miles an hour less. The first Cunarder, "Britannia," crossed the ocean in 1840 at a rate of 8.5 miles an hour. By 1852 the rate was only 9.11 miles an hour. It has since been doubled for swift runs of the best transatlantic steamers. One of the best runs of the "Alaska," of the Guion line, was 419 miles in 24 hours (Benjamin). The "City of Rome" went over the measured mile at a rate of 18.01 miles an hour. The speed of the "Assyrian Monarch" is 14.57 miles an hour.

The performances of the large American coasting steamers show some of the highest speeds yet attained in long-route ocean service. The "City of Washington" ran from Havana to New York in 75 hours 21 minutes, the fastest time from Havana, and stated to be the "fastest time by an ocean steamship for 75 consecutive hours." The speed was 19.27 miles an hour. July 4, 1875, the steamer "Hudson" left New Orleans and made the quickest time on record to New York, viz, 5 days 9 hours. July, 1880, the record was lowered by the steamer "Louisiana," as follows:

July 7, 8.30 a. m. Sailed from New Orleans.  
 7, 3.20 p. m. Crossed the bar.  
 8, noon. 381 miles from New Orleans.  
 8, 11.15 p. m. Off Tortugas.  
 9, noon. 330 miles additional.  
 10, noon. 413 miles additional.  
 11, noon. 364 miles additional.  
 12, 4 a. m. 228 miles, Sandy Hook abeam.  
 12, 5.10 a. m. 20 miles, New York.

Allowing 1 hour 4 minutes for difference in time, this is 15 knots an hour, the distance being 1,736 miles; time, 4 days, 19 hours, 36 minutes. The "Louisiana" has since lowered this record by several hours, and has made long runs at the rate of 17½ knots, or over 19½ miles, an hour. The "City of Peking" has made 15.8 knots or 18.18 miles an hour. The "Decatur H. Miller" runs from Boston to Norfolk in 40 hours 52 minutes, a rate of about 17 miles an hour. The coal consumption of these steamers is at least fairly economical.

Upon smooth water and with adequate boiler and engine power, small steamers can be made to make as fast time as large ones. A number of torpedo boats and small steam yachts have made over 20 miles an hour, but these are usually the records of short runs, and their maintenance of the speed even for a single hour is not always beyond question. At sea, small boats cannot compete with large steamers in speed. The smallest steamers that have crossed the Atlantic, such as the "Game Cock" and the "Anthracite", have made only 7 or 8 miles an hour. The little tug "Mea" ran from Philadelphia to Galveston in 180 hours (7½ days) at the rate of nearly 12 miles an hour, and with an economical consumption of fuel.

It is fairly presumable that with steadily-governed marine engines more steady speed could be made, and high speed could be better maintained. Marine governors of the Westinghouse type are employed by Messrs. William Cramp & Sons, not to act upon the throttle-valve, but by the throw of a lever to admit steam behind a piston, and cause the link to shift its position. This attachment is made to the steam-cylinder of the reversing-gear, by which an engine may be completely reversed in five seconds. Governors are sometimes connected with the stop-valve, but this connection does not serve well with compound-engines, because there remains steam enough in the receiver between the engines, together with the vacuum in the condenser, to prevent the throttling from being immediately felt. To prevent racing, the steamer "City of Atlanta", of the Charleston line, has a Fairbairn governor. The operation of this is very simple. A leaden ball weighing over 1,000 pounds is hung in a joint of the main shaft forward of the engine, and is free to swing in any direction. When the steamer rolls there is no trouble from racing, because the propeller is not thrown out of the water; but when the steamer

pitches fore and aft there is liability to trouble from racing, because the propeller is thrown up. The weight swings sidewise without affecting anything, but as soon as the boat pitches, it begins to swing fore and aft, and by a train of mechanism partly closes a regulator-valve between the stop-valve and the cylinder, thus closing up the engine until the propeller and the boat pitch back to their normal positions, when the weight falls back also and releases the valve. The "City of Atlanta" has a 4' diameter by 5' stroke simple condensing-engine.

CARRYING CAPACITY OF STEAMERS.

PASSENGERS: Upon ocean steamers the number of passengers of all grades per ton of vessel does not exceed 40. The "City of Pekin", per 100 tons register, has accommodations for 36 steerage and 3 cabin passengers. Large ocean steamers used as troop ships accommodate less than 40 soldiers per hundred tons of vessel. For long voyages the necessary carriage of coal and supplies is great. A large ocean steamer often employs one-third or more of its freight capacity in carrying coal for power.

Inland steamers and excursion boats, which make short runs and carry but a small weight of supplies, have a maximum carrying capacity of 2 persons per ton. The ratios of maximum numbers of passengers allowed per ton of vessel are as follows for the specified steamers plying in and about New York:

Plymouth Rock.....	1.66	Twilight.....	1.88	Bay Ridge.....	1.66	Jesse Hoyt.....	1.15
Grand Republic.....	2.16	T. V. Arrowsmith.....	1.89	Adelphi.....	1.55	Harlem.....	1.22
Tiger Lily.....	2.70	Sylvan Dell.....	1.70	St. Johns.....	1.05	Chrystenah.....	1.05
Thos. Collyer.....	2.33	Rosedale.....	1.92	Shadyside.....	1.35	Chaucollor.....	1.36
Seth Low.....	2.05	Pleasant Valley.....	1.99	Sylvan Grove.....	1.41	Wm. Fletcher.....	0.96
Norwalk.....	2.10	Minnie Cornell.....	1.59	Riverdale.....	1.39	Sylvan Glen.....	0.76
Long Branch.....	2.29	J. B. Schuyler.....	2.01	Richard Stockton.....	1.43	Sea Bird.....	0.43
John Sylvester.....	2.52	Idlewild.....	1.98	Osseo.....	1.22	Mary Powell.....	0.51
Eliza Hancox.....	2.14	Gen. Sedgwick.....	1.71	Morrisania.....	1.43	J. H. Starin.....	0.57
D. R. Martin.....	2.30	Fort Lee.....	1.53	Josephine.....	1.17	Black Bird.....	0.60
Americus.....	2.02						

In some cases there is a passenger to as little as 3½ square feet of single deck area with the maximum number on board, but as there are usually several decks, the space per passenger would be somewhat greater.

COAL.

The collier "Pottsville" carries 1.29 tons coal per registered ton of vessel. The "Berks" carries 1.08 tons per ton of vessel. The fleet of Reading colliers has carried 3,290,283 tons coal since 1869 (to end of 1879), running

3,017,853 miles—that is they have averaged nearly a mile run to every ton carried. A diagram (Fig. 26) exhibits more forcibly than words or figures the work of one of these colliers. Coal weighs per cubic foot about 50 pounds heaped, 75 or 80 pounds solid. The large square of the diagram represents approximately the area of 4 foot deep solid coal seam necessary to be mined to supply this collier with cargo for 5½ years' service. A smaller square exhibits the amount of coal carried in a year and a still smaller one the amount carried per voyage. The plan of the collier is also sketched to the same scale.

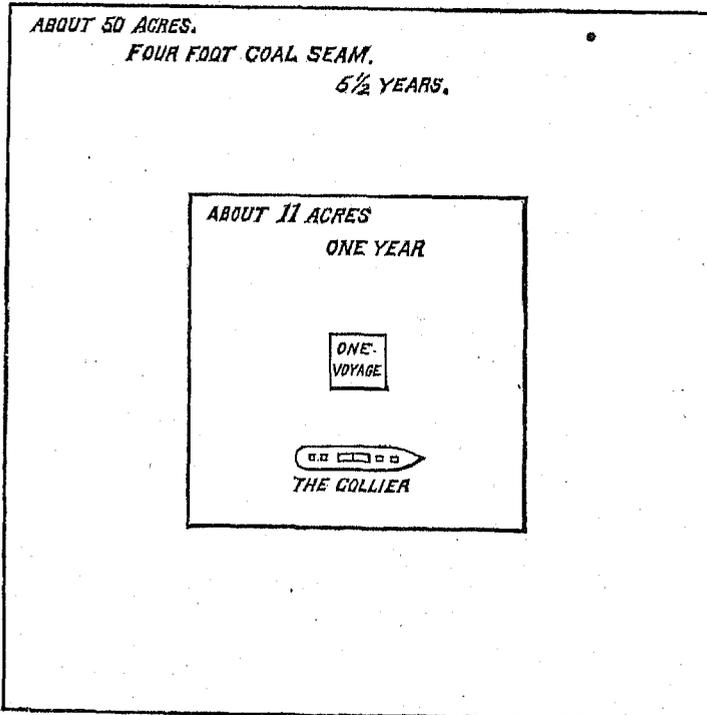


FIG. 26.

GENERAL FREIGHT.

The large coasting-steamers carry 2 or 3 bales of cotton per ton of vessel. The "Louisiana" carries 3.17 bales per ton, her cargo being 9,000 bales. Two hundred gallons of molasses in hogsheads are carried per ton of steamer in some cases, and upwards of 7 barrels of rice, oranges, and other products, and upwards of 18 or 20 bags of coffee. Molasses has been carried in the bulk, in which way the capacity may be increased. The necessity for carrying so much coal always takes a great slice out of the cargo space. The whaler "Mary and Helen" had storage space

for 6½ barrels of oil per ton of vessel, in addition to which she carried nearly half a ton of coal per ton of vessel, without which her oil-carrying capacity would be fairly doubled. The great ferry-boat "Solano" carries about half its registered tonnage in weight of freight-cars.

STEAMERS OF THE PACIFIC COAST DISTRICT.

GEOGRAPHICAL DISTRIBUTION.—The employment or service of steamers may in some cases be definitely stated within geographical limits, but in many cases, especially in the river and coasting trade, there is no practicable method of classification which can indicate exactly the ranges and routes of service, simply because there is no uniformity of route. Nevertheless, as a basis for further considerations of the subject, and as a general index of the distribution of the steam tonnage, tables have been formulated assigning the steamers to various bays, rivers, and ocean routes, as far as their service could be defined from the obtainable data. Of this classification of the steamers of the Pacific coast, it may be said that the small craft specified as in the coasting trade are boats similar to those employed in bay and sometimes in river service, often with non-condensing engines, and making short runs along the coast. The larger vessels enumerated under the caption "Pacific Ocean and Coasting" comprise the ocean steamships plying from San Francisco to China, Panama, British Columbia, Oregon, and Southern California. Many of the steamers specified as plying upon the Sacramento and San Joaquin rivers ply also upon San Francisco and San Pablo bays.

	STEAMERS OF 1,000 TONS AND OVER.				STEAMERS OF 500 TO 1,000 TONS.				STEAMERS OF 100 TO 500 TONS.			
	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.
Pacific ocean and coasting.....	17	39,052.24	19	3,544.34	7	5,250.00	10	230.17	17	4,284.39	25	184.54
San Francisco and San Pablo bays.....	8	13,937.85	10	1,783.35	6	4,899.05	7	752.33	16	3,301.82	25	258.07
Humboldt bay.....									1	104.07	2	3.45
Puget sound and adjacent waters.....									15	3,051.62	23	401.17
Sacramento and San Joaquin rivers.....									28	7,007.44	53	425.71
Columbia and Willamette rivers.....	2	2,358.84	4	136.74	19	12,205.40	38	361.56	27	7,799.36	54	252.33
Coquille river.....												
Umpqua river.....									1	101.02	2	2.05
Colorado river.....									4	829.46	8	55.32
Lake Tahoe.....												

	STEAMERS OF 50 TO 100 TONS.				STEAMERS OF 25 TO 50 TONS.				STEAMERS OF LESS THAN 25 TONS.			
	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.
Pacific ocean and coasting.....	6	499.87	8	25.03	3	159.01	4	3.66	8	50.15	4	0.74
San Francisco and San Pablo bays.....	4	308.53	6	31.28	9	300.05	11	25.16	6	38.97	8	1.00
Humboldt bay.....	2	174.03	4	19.33	4	167.76	7	8.52				
Puget sound and adjacent waters.....	11	893.25	18	47.13	5	187.19	6	2.52	7	91.20	8	1.55
Sacramento and San Joaquin rivers.....	15	1,161.94	29	65.74	6	192.95	7	9.99	15	143.04	16	6.40
Columbia and Willamette rivers.....	8	701.71	14	20.43	11	418.73	17	7.46	11	108.44	14	1.95
Coquille river.....	1	85.55	2	2.05					1	16.81	1	0.23
Umpqua river.....									2	16.54	3	0.20
Colorado river.....												
Lake Tahoe.....	1	68.14	2	6.20	1	28.00	1	0.70	2	35.00	3	1.54

ENGINES.—Of engines in steamers of over 1,000 tons, 12 are used in pairs, 21 singly; 15 are compound, 12 simple condensing, and 6 simple non-condensing. The length of stroke is less than the diameter of cylinder in 2 engines, once to one and a half (inclusive) times as great in 8 engines; once and a half to twice (inclusive) as great in 6 engines; twice to thrice (inclusive) as great in 10 engines; and over three times as great in 7 engines, the smaller cylinder only being considered in compound engines. The two very short-stroke engines were built in the early part of the past decade. These are compound engines in ocean service. In compound engines the relative diameters of large and small cylinders are chiefly shown in the following sizes:

Large.	Small.	Ratio of cross-section areas.
<i>Inches.</i>	<i>Inches.</i>	
80	50	2.00
73	42	3.02
60	36	2.78
56	30	3.46
44	24	3.86
40	21	3.70

The strokes range from a length equal to the diameter of the larger to a length less than the diameter of the smaller cylinder.

In only one beam condensing-engine does the stroke exceed three times the diameter. This engine is a new one, a similar engine of the same stroke and nearly twice the diameter being built a dozen years ago, and carrying half the pressure. Upon averaging a considerable number of beam condensing-engines upon boats of over 500 tons, we find the ratio of length of stroke to diameter of cylinder to be, for boats built in the periods—

Period.	Ratio.
1805-1870.....	2.34
1870-1875.....	2.41
1875-1880.....	2.55

The respective average pressures being 33,41 and 50 pounds. For a single boat built twenty-five years ago, the stated ratio is 2.03 and the pressure allowed only 20 pounds. In such cases the limitation of pressure is due to the engines not less than to the boilers, the machinery as designed for low pressures being too light to permit any great increase of pressure.

There is thus indicated the usual tendency toward higher pressures and higher piston speed. The rotative speed is limited by the resistance of large non-feathering paddle-wheels, a beam-engine with 12' stroke and 480' piston speed having about 20 revolutions a minute. With this type of engine and wheels the progress of pressure and rotative speed stops at about 50 pounds pressure and a small number of revolutions, while with direct-acting marine-engines for ocean service screw-propulsion, and with the non-condensing engines and small wheels of light-draft river boats, both the speeds and pressures have continued to increase. Engines for screw-propellers use from half as great again to double the pressures employed in beam-engines, with from three to seven times the rotative speed, and while the river-boat engines driving paddle-wheels cannot have so great a rotative speed, the pressures allowed are much higher, the range being about as follows:

With simple direct-acting non-condensing engines .....	Pounds. 90 to 150
With compound direct-acting condensing engines .....	60 to 90
With simple condensing beam-engines.....	20 to 60

It will thus be seen, taking into consideration both pressure and speed, that the value of cylinder capacity in the production of power may for the same volume and ratio of expansion be over five times as great in the first as in the last type of engines. As a matter of fact, where the ocean steamships have 11 tons of vessel per cubic foot of cylinder the large boats of the Columbia river have 17 and the large ferry-boats of San Francisco bay 8 tons burden per cubic foot of cylinder. For the next class of steamers (from 500 to 1,000 tons) there is still greater discrepancy in the ratios, the average number of tons burden per cubic foot of cylinder being for the ocean and coasting steamers about 22, for the ferry- and towing-boats of San Francisco and San Pablo bays about 6½, and for the boats of the Columbia and Willamette rivers about 33, the larger ratios being partly due to the slow freight as compared with the passenger service, while the towing-boats have relatively large engine powers.

Of the engines of steamers of between 500 and 1,000 tons, 46 are used in pairs, 9 singly; 6 are compound, 9 simple condensing, and 40 simple non-condensing. The length of stroke is from once to twice (inclusive) the diameter of the cylinder in 12 engines, twice to three times (inclusive) in 10 engines, three to four times (inclusive) in 13 engines, and over four times in 20 engines.

With the exception of two pairs of compound engines on ocean steamers, all of the paired engines of this class are upon the boats of the Columbia and the Willamette rivers, and with but one exception all of the long-stroke engines (ratio stroke to diameter between 3 and 5) are paired engines upon these river boats. In this class all of the condensing-engines are upon boats running in or from San Francisco bay, except one pair of engines on a boat running between Portland and Sitka.

The river boats comprise a series of examples with a great degree of similarity in relative length, breadth, and draft, and in character of service. Most of them were built in Oregon within the past five years, and in them if anywhere would we expect to find uniformity in the proportions of steam machinery. A small number of patterns would probably serve to equip such a fleet of steamers in a manner which would enable them to do their work as well and as economically as with a separate design of cylinder for nearly every boat. As it is there are in this class only six pairs of engines having like dimensions of cylinder, three 17' by 6' in boats from 165' long, 37' broad, 5½' deep, 710.13 tons, to 154' long, 36' broad, 5.3' deep, 555.99 tons, and three 16' by 6' in boats from 157' long, 36' broad, 5' deep, 502.35 tons, to 154.4' long, 35.8' broad, 5' deep, 586.98 tons; while the others present an assortment of individual patterns. Six boats, with tonnages ranging between 600 and 700 tons, have an average cylinder capacity of 14.4 cubic feet each, while seven smaller boats, with tonnages ranging between 500 and 600 tons, have an average cylinder capacity of 19.5 cubic feet each, all of the engines being of similar types and using high pressures, the average boiler-pressure allowed being for the six boats 121 pounds, and the average for the seven 118 pounds, per square inch.

Of the condensing-engines in this class there are six beam-engines of five sizes (two having 50'' by 11' cylinders), three simple direct-acting engines, and four sizes of compound engines.

Of engines in steamers of from 100 to 500 tons, 160 are used in pairs and 28 singly, and one vessel in the Willamette district is driven by a 4-cylinder engine. Nineteen out of 192 are compound engines, 25 are simple-

condensing, and 148 simple non-condensing engines. The length of stroke is less than or equal to the diameter of cylinder in 9 engines, once to one and a half times (inclusive) the diameter in 17 engines, once and a half to twice (inclusive) in 20 engines, twice to three times in 20 engines, three to four times in 86 engines, four to five times in 38 engines, and over five times in 2 engines (a pair upon the "Satellite").

In the Willamette district there are in this class only 3 condensing-engines, 2 being compound. All of the remaining compound engines are in the San Francisco district, and of the remaining 24 simple condensing-engines 17 are in the San Francisco and 7 in the Puget sound district. In the entire first or Pacific district, on account of a few large ocean steamers, nearly two-thirds of the steam tonnage is driven by condensing-engines, but the river boats are driven almost exclusively, and the bay and harbor boats very largely, by non-condensing engines.

The 4 boats on the Colorado river (San Francisco district) have the following dimensions and engines:

Length.	Breadth.	Depth.	Tonnage.	Engines.	
				No.	Dimensions.
149.8	38	3.6	236.47	2	10" x 5'
147.5	28	3.8	231.37	2	10" x 5'
150.0	32	4.0	183.03	2	10" x 6'
127.0	26	4.0	178.50	2	14" x 5'

These are very light-draft boats for the tonnage.

Of the simple engines in steamers of from 100 to 500 tons there are four 22" by 8' cylinders, four 20" by 6', six 18" by 6', eight 16" by 6', ten 16" by 5', eight 16" by 4', four 15" by 5', twelve 14" by 5', four 14" by 4½', twelve 14" by 4', sixteen 12" by 4', eight 12" by 3', four 10" by 4', four 10" by 3', eight 10" by 1½', and four 9" by 3' cylinders, 57 sizes of cylinder remaining, of which there is a single engine or a pair of each.

Of engines in steamers of from 50 to 100 tons the following enumeration is made:

	In pairs.	Singly.	Compound.	Simple condensing.	Simple non-condensing.
San Francisco district .....	38.0	4.0	1.0	6.0	35.0
Willamette district .....	16.0	5.0	1.0	4.0	16.0
Puget sound district .....	16.0	4.0	0.0	4.0	12.0

Of the cylinder proportions, ratios length of stroke to diameter of cylinder:

District.	1 or less.	1 to 1½.	1½ to 2.	2 to 3.	3 to 4.	Over 4.
San Francisco .....	8	3	3	0	22	.....
Willamette .....	2	4	2	4	7	2
Puget sound .....	.....	3	.....	1	11	5
Total .....	10	10	5	11	40	7

One boat in the Willamette district is driven by two engines of different sizes, and in the Puget sound district there are several small engines of unusually long stroke. Among the non-condensing engines in the San Francisco district there is a noticeable number of vertical direct-acting engines of short stroke, but the horizontal long-stroke direct-acting engines, working in pairs, are the more usual type.

Of engines in steamers of from 25 to 50 tons, 30 out of 53 are used in pairs; 49 out of 53 are simple non-condensing, 1 being simple condensing and 3 compound. Ratio of stroke to diameter is 1 or less in 15 engines, 1 to 1½ in 17, 1½ to 2 in 8, 2 to 3 in 6, 3 to 4 in 4, and over 4 in 3 engines. The long-stroke horizontal or slightly-inclined engines have in this class given place to the short-stroke vertical engines used in screw propulsion. With ratios of stroke to diameter of under and over 2 we have, respectively:

Steamers.	Ratio.	
	Under 2.	Over 2.
50 to 100 tons .....	25 engines .....	58 engines.
25 to 50 tons .....	40 engines .....	13 engines.

The steamers of from 50 to 100 tons are mainly freight and inland passenger-boats, and those from 25 to 50 tons are mainly tug-boats. Despite this fact the ratio of cylinder capacity to tonnage continues to diminish, the cylinder capacity being, per hundred tons, 5.61 cubic feet for vessels of 50 to 100, and 3.91 cubic feet for vessels of 25 to 50 tons.

The "Silva," a boat of 50 tons, plying from Eureka to landings on Humboldt bay, is driven by two 8" by 12" oscillating engines.

All steamers under 25 tons are driven by simple non-condensing engines. Of 58 engines, 22 are used in pairs, 36 singly. The "Jane West," plying between Astoria and Portland and the Cascades, a boat of 13.44 tons, is driven by one 8" by 24" engine. Of all the steamers under 25 tons in the Pacific district, this is the only one having an engine with cylinder-stroke greater than twice the diameter. The stroke is equal to or less than the diameter in 22 out of 59 engines. The most common cylinder proportions for small engines are 6" by 6", 8" by 8", 9" by 9", and 10" by 10".

## BOILERS.

Of 98 boilers in steamers of over 1,000 tons 8 are oval and 90 cylindrical. Of the 90 cylindrical 15 are returned as fire-box and cylindrical boilers. Tubular boilers have largely displaced flue-boilers. The boilers of the side-wheel boats commonly range from 7' to 10' in diameter and 18' to 30' long; and for the screw steamers with compound engines the boilers range from 10' to 13' in diameter and average about 10' long. The two largest river boats in the Pacific district have cylindrical tubular boilers 7' in diameter and 32' long, one boiler in each boat, but the boats in ocean and ferry service usually have short return-tubular boilers in sets. There are 6 single boilers, 7 sets of 2, 1 set of 3, 6 sets of 4, 1 set of 5, 3 sets of 6, 1 set of 8, and 2 sets of 10 boilers. The smallest diameter of boiler used is 3' 6", one of the ferry-boats—the "Thoroughfare"—being fitted with 5 such boilers, each 16' long, and allowed 100 pounds pressure. Of the larger boilers those of sea-going vessels are commonly thicker than the ferry-boat boilers and carry heavier pressures for the same diameter of shell. Excepting a set of 8 new steel boilers upon the ferry-boat "Solano," all of the boilers in this class are of iron. Pressures allowed range from 120 pounds (river-boat boilers) to 25 pounds (in a large ferry-boat boiler), 50 pounds being allowed for the steel boilers mentioned, which are 7' in diameter and of 0".36 thickness of shell. The two large river steamers of the Columbia river may be compared with some of the Mississippi steamers, for example:

No.	Name.	Locality.	Stated tonnage.	Length.	Breadth.	Depth.	Non-condensing engines.	Cylinders.	BOILERS.				
									Kind.	Diameter.	Length.	Material.	Pressure allowed.
									Feet.	Feet.	Pounds.		
1	Wide West.....	Portland, Oregon..	1,200.80	218'.2	39'.5	8'.2	2	28" by 8'	1 tubular.....	7	32	Iron.....	120
2	R. R. Thompson....	Dallas, Ohio.....	1,158.04	215'.0	38'.0	9'.6	2	28" by 8'	...do.....	7	32	...do.....	120
3	W. P. Halliday.....	Saint Louis, Mo...	1,375.40	287'.4	40'.8	8'.0	2	24½" by 10'	5 two-flue.....	3½	30	Steel.....	175
4	City of Helena.....	Saint Louis, Mo...	1,058.28	209'.0	49'.6	7'.8	2	26" by 8'	5 four-flue.....	3½	20	Iron.....	122

The shells of the boilers in the two former cases are one-half inch thick; in the two latter  $\frac{20}{100}$ " and  $\frac{14}{100}$ ", respectively. The difference in boilers is a characteristic one, and shows how in the usage of different sections similar conditions and requirements may be met by widely-different practice. The volume of boilers is 122.96 cubic feet for the two Mississippi and 136.74 cubic feet for the two Columbia river steamers, despite the greater number of boilers upon the former, and the heating surface is relatively greater in the tubular boilers. But the cylinder surface of the ten small flue-boilers is more than twice as great as that of the two tubular boilers of larger volume.

Of 43 boilers in steamers of between 500 and 1,000 tons, the great majority are cylindrical tubular boilers, 9 being fire-box boilers. There are four oval boilers and there is one rectangular boiler, a type which is becoming obsolete. This boiler is upon the steamer "Wilmington", built in 1865 at Wilmington, Delaware, and now plying between San Francisco and Panama. The steamer is of 940.76 tons with a condensing beam-engine, cylinder 44" diameter, 6' stroke (comparatively short), and the single boiler is 18' wide, 9' 6" high and 13' 9" long, shell  $\frac{5}{16}$ " thick, pressure allowed 25 pounds. The boats of the Columbia and Willamette rivers have almost invariably long tubular boilers ranging in diameter from 3' 10" to 5' 4" and in length from 20' to 32', a single boiler to a boat, except in the case of one ferry-boat which has three tubular boilers each 4' 4" diameter by 16' long. In the San Francisco district most of the ferry-boats have long tubular boilers, the diameters (ranging from 5' 6" to 11' 6") being greater than in the river-boat boilers of the Willamette district. For ocean service the usual form of boiler is the return-tubular with a length about equal to its diameter. The range of pressure allowed per square inch is from 100 to 150 pounds in river-boat boilers, 35 to 100 pounds in the ferry-boat boilers, and 25 to 80 pounds in the boilers of ocean steamers, in which, however, the pressure will average greater than in the ferry-boat boilers. There are in this class six sets of 2, one set of 3, and one set of 4 boilers, the remaining boilers being used singly.

In order to emphasize the difference of practice on the Columbia and Mississippi rivers the nineteen river steamers of this class in the Willamette district are compared with nineteen boats of similar tonnage in the Saint Louis district, as follows: Aggregate tonnage of the nineteen: Saint Louis, 12,219.83; Willamette, 12,205.49. Each steamer in both cases has 2 engines, and all are simple high-pressure non-condensing engines except 2 Hartupce compound moderating engines on a Saint Louis boat. Average diameter of cylinder, Saint Louis, 20".82; Willamette, 17".71. Average length of stroke, Saint Louis, 77".05; Willamette, 72".32. Average volume of cylinder, Saint Louis, 33.01 cubic feet; Willamette, 19.03 cubic feet. Ratio, number of boilers to number of boats,

Saint Louis, 3.79; Willamette, 1.10. Average diameter of boiler, Saint Louis, 39".02; Willamette, 56".58. Average length of boiler, Saint Louis, 24'.73; Willamette, 26'.06. Average volume of boiler, Saint Louis, 208.85 cubic feet; Willamette, 440.58 cubic feet. Aggregate volumes of boilers, Saint Louis, 15,037.53 cubic feet; Willamette, 9,241.73 cubic feet. Average pressure allowed, Saint Louis, 110 pounds; Willamette, 126 pounds. Thickness of boiler-shell (average), Saint Louis, 27.2 hundredths, and Willamette, 35.5 hundredths of an inch. The boilers of the Willamette steamers are nearly all tubular, and of the Saint Louis steamers all are flue-boilers, some with four or five but the majority with only two flues. The boilers specified are all of wrought-iron plate except in one Saint Louis boat, which has boilers of low steel or homogeneous iron.

In steamers of between 100 and 500 tons in the Pacific district there are 158 boilers, only 4 of them being of steel. Forty-two are returned as fire-box boilers. There is 1 oval boiler. Most of the boilers are either direct- or return-tubular. Of 22 boilers in the Puget sound district, 1 is a return-flue 8' 10" diameter and 24' long (upon an ocean steamer), 1 a fire-box flue and tubular, 7' 2" diameter by 18' long (upon an ocean steamer), 10 fire-box return-tubular and fire-box tubular, and 10 return-tubular boilers. The material is usually specified as Tennessee flange iron or as American C. H., No. 1. I note the following examples: One marine fire-box return-tubular, 14' 8" diameter by 18' long with beam condensing-engine on paddle-wheel boat, 150' long by 30' wide by 10' deep, built in 1849, at New York; 1 fire-box flue and tubular, 7' 2" by 18', with beam condensing-engine on side-wheel boat, 129' 5" by 21' by 8' 9", built in 1866, at Sitka, Alaska; 2 fire-box tubulars, 6' by 22' with vertical condensing-engine on paddle-wheel boat, 120' by 24' by 12', built in 1869, at Point Discovery, Washington territory; 1 marine return-flue, 8' 10" by 24', with beam condensing-engine on paddle-wheel boat, 166' by 29' by 10'.35, built in 1871, at San Francisco; 4 return-tubulars, 3' 6" by 16', with non-condensing engines on paddle-wheel boat 132' by 28' 2" by 9' 8", built in 1874, at Portland, Oregon; 2 fire-box return-tubulars, 4' by 20' 3", with vertical condensing-engine on screw-boat, 136' by 26'.08 by 12½', built in 1876, at San Francisco; and 1 fire-box tubular, 3' 8" by 17' with non-condensing-engines on paddle-wheel boat, 80'.2 by 19'.2 by 4'.7, built in 1876, at Seattle, Washington territory.

In the Willamette district every boiler in boats of this class is a tubular boiler.

Only 24 out of 158 boilers in this class are over 6' in diameter, and these are peculiar to ocean or coasting steamers.

In steamers of from 50 to 100 tons there are 61 boilers, mainly cylindrical tubular. None are of steel. Fifteen are specified as fire-box boilers. In steamers of from 25 to 50 tons there are 39 boilers, all horizontal tubular, except 1 fire-box flue and tubular and 1 vertical tubular boiler. In steamers of less than 25 tons there are 48 boilers, only 2 of them being of steel, and 14 being vertical tubular boilers.

The steel boilers of the "Modoc" (468.27 tons) and the "Apache" (468.27 tons), of the Sacramento river service, are 61¾" diameter by 26' 4" long; 2 boilers on each boat; material, Otis steel, double-riveted and plated inside; shells, ¾" thick; pressure allowed, 80 pounds. These boilers are of the fire-box and cylindrical type, similar to locomotive tubular. For river service, San Francisco authorities pronounce this style of boiler to combine the "greatest lightness with the greatest serviceable qualities and strength."

MARINE BOILERS OF SAN FRANCISCO.

Through the courtesy of Mr. James Hillman, inspector of marine boilers at San Francisco, California, I am enabled to present the following classification of boilers in use on the different classes of steamers at that port. This enumeration was made subsequent to the close of the census year:

Description.	Ocean passenger.	Inland passenger.	Ferry.	Freight.	Freight and towing.	Towing.	All classes.
Cylindrical tubular .....	2	22	4	4	3	12	47
Cylindrical, with furnaces and tubes.....	16	1	2	4		4	27
Cylindrical flue and tubular .....	1	0	1	1	1	4	14
Cylindrical flue .....			1				1
Vertical tubular .....		4			3		7
Fire-box cylindrical tubular .....		25	2	5	5	2	39
Fire-box cylindrical flue and tubular.....	4		10	5		14	33
Fire-box cylindrical flue .....			4				4
Fire-box flue and return-tubular .....		1				1	2
Oval tubular .....	1			1			2
Oval, with furnaces and tubes.....	2						2
Oval flue and tubular .....				1			1
Rectangular tubular .....	1						1
Rectangular, with furnaces and tubes .....		1				1	2

## POWER AND SPEED OF ENGINES

The boiler volume in cubic feet per ton of vessel is 5.01 in the "Orizaba," 3.31 in the "Geo. W. Elder," 2.82 in the "Dakota," 2.78 in the "State of California," 2.74 in the "City of Tokio," while it is 0.69 in the "Thoroughfare," 0.87 in the "Victoria," 2.14 in the "Wide West," 1.61 in the "Ancon," and 1.78 in the "Colima." The number of tons of vessel per cubic foot of cylinder space is 4.91 in the "Orizaba," 4.97 in the "Dakota," 6.43 in the "Newark," 8.22 in the "Solano," 10.40 in the "City of Tokio," 13.78 in the "State of California," 17.27 in the "Geo. W. Elder," 19.43 in the "Oregon," 17.56 in the "Wide West," 27.43 in the "Thoroughfare," and 33.85 in the "Victoria." These figures are stated separately to show how widely these ratios range for the various classes of service. The character of the vessels specified will be recognized from previous statements. If we take the boiler volume into the allowed pressure as the criterion of relative boiler power per ton, the boiler power per ton is shown relatively in the following figures:

Geo. W. Elder .....	264.80
State of California .....	222.40
City of Tokio .....	178.10
Wide West .....	136.80
Orizaba .....	100.20
Dakota .....	70.50
Thoroughfare .....	69.00
Victoria .....	65.25

In like manner, we may find that the cylinder capacity per ton of vessel (considering the steam-pressure allowed) is represented relatively by the following figures:

Wide West .....	6.83
City of Tokio .....	6.03
State of California .....	5.80
Dakota .....	5.03
Geo. W. Elder .....	4.63
Orizaba .....	4.07
Thoroughfare .....	3.64
Victoria .....	2.22

The nominal horse-power per ton as stated in the list of merchant steam vessels of the United States is for the

State of California (2,266.03 tons, 1,800 horse-power) .....	0.79
Dakota (2,135.04 tons, 2,000 horse-power) .....	0.94
Orizaba (1,244.08 tons, 500 horse-power) .....	0.40
Thoroughfare (1,012.27 tons, 400 horse-power) .....	0.39
Victoria (1,462.13 tons, 500 horse-power) .....	0.34

These nominal powers are, however, neither well defined nor consistent with any uniform rule.

Of 25 steamers of over 1,000 tons of the port of San Francisco, the average length of stroke is about  $7\frac{1}{2}$ '; average boiler-pressure, about 58 pounds. For a total tonnage of 52,990 tons the cylinder volume is 5,327.69 cubic feet, nearly half of which is in compound cylinders, the rest being in simple cylinders of long stroke. The aggregate nominal power is about 29,000 horse-power.

The "City of Tokio," 5,079.62 tons. This and the "City of Pekin" are the largest ocean steamers of the Pacific district. At 55 revolutions, 60 pounds initial, 10 pounds terminal, the engines of each vessel develop 4,000 indicated horse-power.

The "State of California," 2,266.03 tons. The engines of this ocean steamer, running at 63 revolutions, with 74 pounds per square inch boiler-pressure, developed an indicated horse-power of 1,500.08. With 80 pounds pressure, 73 revolutions, and a later cut-off, 2,323.83 horse-power were developed. The following data of these trials is derived from a communication of Mr. J. Haug, marine engineer, to the *Nautical Gazette*.

The following are the particulars of the engines of the "State of California":

Diameter of high-pressure cylinder .....	inches..	42
Area .....	square inches..	1,385.44
Diameter of low-pressure cylinder .....	inches..	73
Area .....	square inches..	4,185.4
Ratio of cylinders .....		3.021
Stroke .....	feet..	$4\frac{1}{2}$

Constants for power:

$$\frac{1385.44 \times 2 \times 4\frac{1}{2}}{33,000} \text{ for high pressure cylinder} = 0.356356;$$

$$\frac{4185.4 \times 2 \times 4\frac{1}{2}}{33,000} \text{ for low-pressure cylinder} = 1.07806.$$

The cards are shown in Fig. 27. The particulars of the cards are:

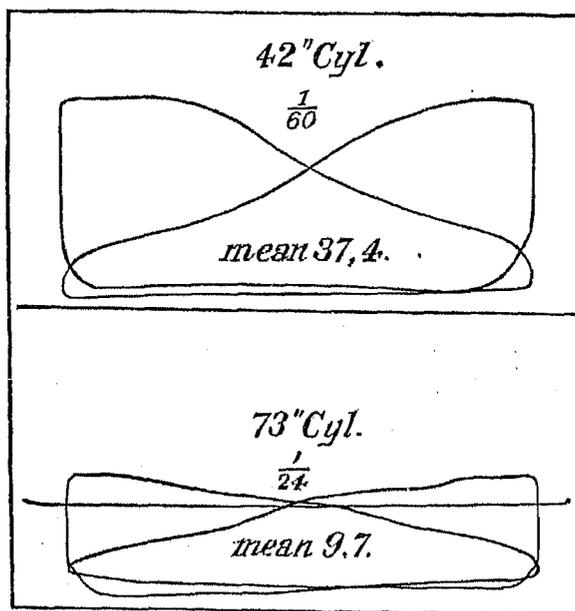


FIG. 27.

Boiler-pressure, per square inch.....	pounds..	74
Receiver, per square inch.....	do.....	+9½
Vacuum.....	inches..	27
Cut-off.....	do.....	23
Mean pressure in high-pressure cylinder.....	pounds..	37.4
Mean pressure in low-pressure cylinder.....	do.....	9.7
Revolutions per minute.....		63
Indicated horse-power—		
Of high-pressure cylinder.....	$0.356856 \times 37.4 \times 63 =$	841.32
Of low-pressure cylinder.....	$1.07806 \times 9.7 \times 63 =$	658.76
Total.....		1,500.08

The following are the particulars of other cards taken from this engine:

Steam .....	68	73	80
Vacuum .....	27½	26	24
Receiver.....	+3½	+14½	+18
Cut-off.....	23	30	35
Revolutions .....	68	68	73
Power high-pressure cylinder.....	814	891.71	1,049.51
Power low-pressure cylinder .....	572	632.41	1,274.33
Total indicated horse-power .....	1,386	1,524.12	2,323.83

The "Solano," 3,549.31 tons. This great ferry-boat has a piston area of nearly 40 square feet (in two cylinders). The new steamer "Pilgrim" has a piston area of nearly 66 square feet in one cylinder, and is expected to develop 6,500 horse-power; but the speed of the engine will be greater than in those of the "Solano," which, in the merchant list of steam vessels of the United States, is credited with a nominal horse-power of 2,000.

The "Oakland," 1,672.24 tons, is a ferry-boat plying between San Francisco and Oakland, and having beam-engines, condensing.

The "Garden City," 1,080.70 tons, is a ferry-boat plying between San Francisco and Alameda. It has a beam-engine, condensing, and with a very small bore for the length of stroke.

The "City of Chester," 1,106.21 tons, is a screw steamship plying from San Francisco to Victoria, British Columbia. It has a compound engine with surface-condenser.

The "Wide West," 1,200.80 tons, is a paddle-wheel boat of the Columbia River, Oregon. It has two 28" by 8' engines, and is allowed a boiler-pressure of 120 pounds.

Of small boats and their engines we note the following examples:

The "Sansalito," 692.43 tons, is a ferry-boat plying between San Francisco and Sansalito. It has one beam-engine, 50" by 11', condensing.

The "Champion," 634.09 tons, is a paddle-wheel passenger-boat plying on the Willamette river, from Portland to Eugene City, the Cascades, and Woody island. The power is small, the boat having a steam cylinder volume of only 8.54 cubic feet in two 14" by 4" engines, and the boiler-pressure allowed being 110 pounds.

The "Alexander Duncan," 236.76 tons, is a passenger-steamer coasting from San Francisco to Humboldt bay and to San Diego. It is driven by a pair of compound engines.

The "Goliah," 235.86 tons, is a Puget sound passenger-boat with side-wheels, and a beam-engine.

The "Tiger," 85.37 tons, is a side-wheel tug- and passenger-boat with direct-acting engines.

The "Neponsett," 60.22 tons, is a Sacramento river freight-boat, a propeller driven by two non-condensing engines.

The "Fearless," 95.40 tons, is a towing-boat, plying from Empire City to Gardiner and the head of navigation from Coos bay. It is a propeller and has a compound engine.

The "Gov. Irwin," 80.94 tons; the "C. M. Small," 97.99 tons; the "Donald," 148.30 tons, and the "H. H. Buhne," 97.72 tons, are San Francisco towing-boats, the first a screw-tug, the second a stern-wheel boat, and the others screw-tugs. The cylinder capacity of the "Gov. Irwin" is 5.30 cubic feet, of the "C. M. Small" 6.29 cubic feet, of the "Donald" 8.83 cubic feet, and of the "H. H. Buhne" 10.54 cubic feet. On account of the higher speed the small propellers develop more power from the same cylinder capacity under the same boiler-pressure than is practicable with the stern-wheel boats.

The following data of the "City of Pekin" may be compared with the data of English steamers elsewhere cited: Cylinders, two 51" and 88" by 54" stroke; 495' piston speed; 10,000 square feet condensing-surface; Hirsch screw, 20½" diameter, 30' pitch; 60 pounds boiler-pressure; 10 boilers, 13' shell by 10½" long, with 30 furnaces and 2,040 tubes, each 3¼" outside diameter; grate-surface, 520 square feet; total heating-surface, 17,000 square feet. At 4,000 horse-power using 80 tons coal, shows a consumption of 1.86 pounds per horse-power per hour. The heating-surface per indicated horse-power is 4.25 square feet. The boiler volume is 13,936.96 cubic feet, 3.48 per indicated horse-power; ratio surface to volume, 1.22; grate-surface per indicated horse-power, 0.13 square feet; condensing-surface per indicated horse-power, 2½ square feet.

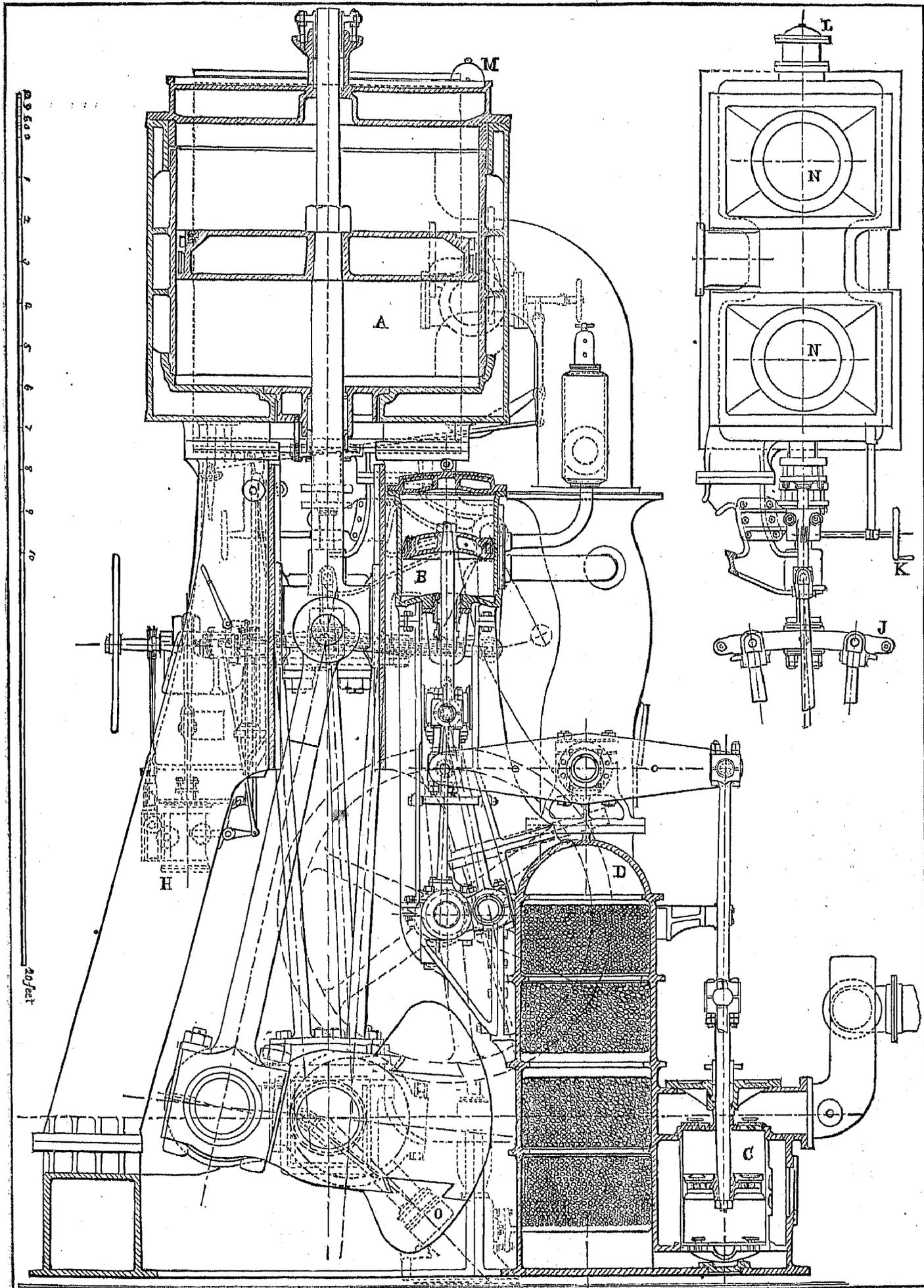
Of the boiler power of steamers of the Pacific district, the volumes and dimensions of boilers have been stated at some length, and the styles employed in various classes of service have been remarked upon. They are mainly tubular boilers, either of the marine (return-tubular) or locomotive (fire-box and cylindrical) types. The heating-surface of boilers per indicated horse-power of engines increases with the decrease in size of boilers and engines.

Were proportions similar for all sizes of boilers the volumes would increase as the third and the surfaces as the second powers of linear dimensions. In the Pacific district the average volume of a single boiler is, for steamers of over 1,000 tons, 1,368.91 cubic feet; steamers from 1,000 to 500 tons, 791.25 cubic feet; steamers from 500 to 100 tons, 349.75 cubic feet; steamers from 100 to 50 tons, 201.85 cubic feet; steamers from 50 to 25 tons, 157.03 cubic feet; steamers of 25 tons and under, 58.70 cubic feet. If for a boiler of 1,368.91 cubic feet volume the ratio of heating-surface to boiler-volume be 1.22 and the heating-surface per indicated horse-power of connected engines be 4.50 square feet, in the smaller boilers we would have for similar proportions and pressures:

Volume of boiler.	Ratio heating-surface to boiler volume.	Heating-surface per indicated horse-power.
<i>Cubic feet.</i>		<i>Square feet.</i>
791.25	1.46	5.40
349.75	1.02	7.09
201.85	2.28	8.41
157.03	2.51	9.27
58.70	3.30	12.52

At the same rating the heating surface per indicated horse-power would be about 25 square feet for the smallest boiler in the district, a boiler on the steam yacht "Magnet," which is allowed 125 pounds pressure. This yacht has a 4" by 4" engine, a size commonly rated at 4 horse-power, but which, under high pressure, might develop 6 horse-power or more. The heating-surface in the boiler can scarcely exceed 40 square feet, but some boats with 4" by 4" engines have three times as large boilers.

In rating heating-surface of boilers by horse-power of engines everything depends upon the amount of steam required by the engines, and as the smaller engines are, as a rule, much less economical than the large compound engines of ocean steamers, they would require a much greater heating-surface for indicated horse-power were it not for the higher average of pressures employed in the smaller boilers, especially of river boats. In the long flue-boilers commonly in use in the Mississippi valley the heating-surface is of course much less relatively to the boiler-volume than in the tubular boilers used upon the rivers of the Pacific seaboard.



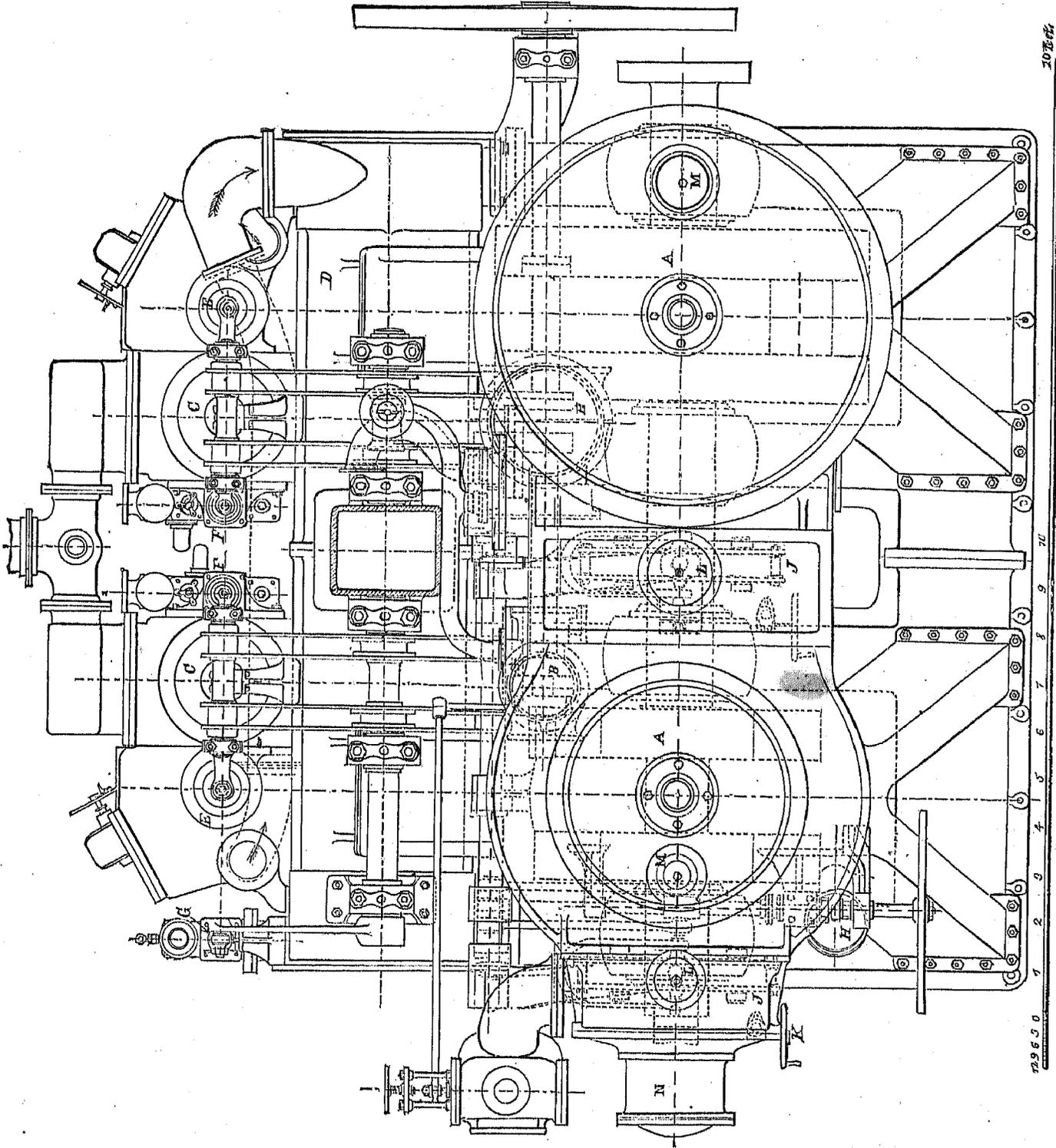


FIG. 29.

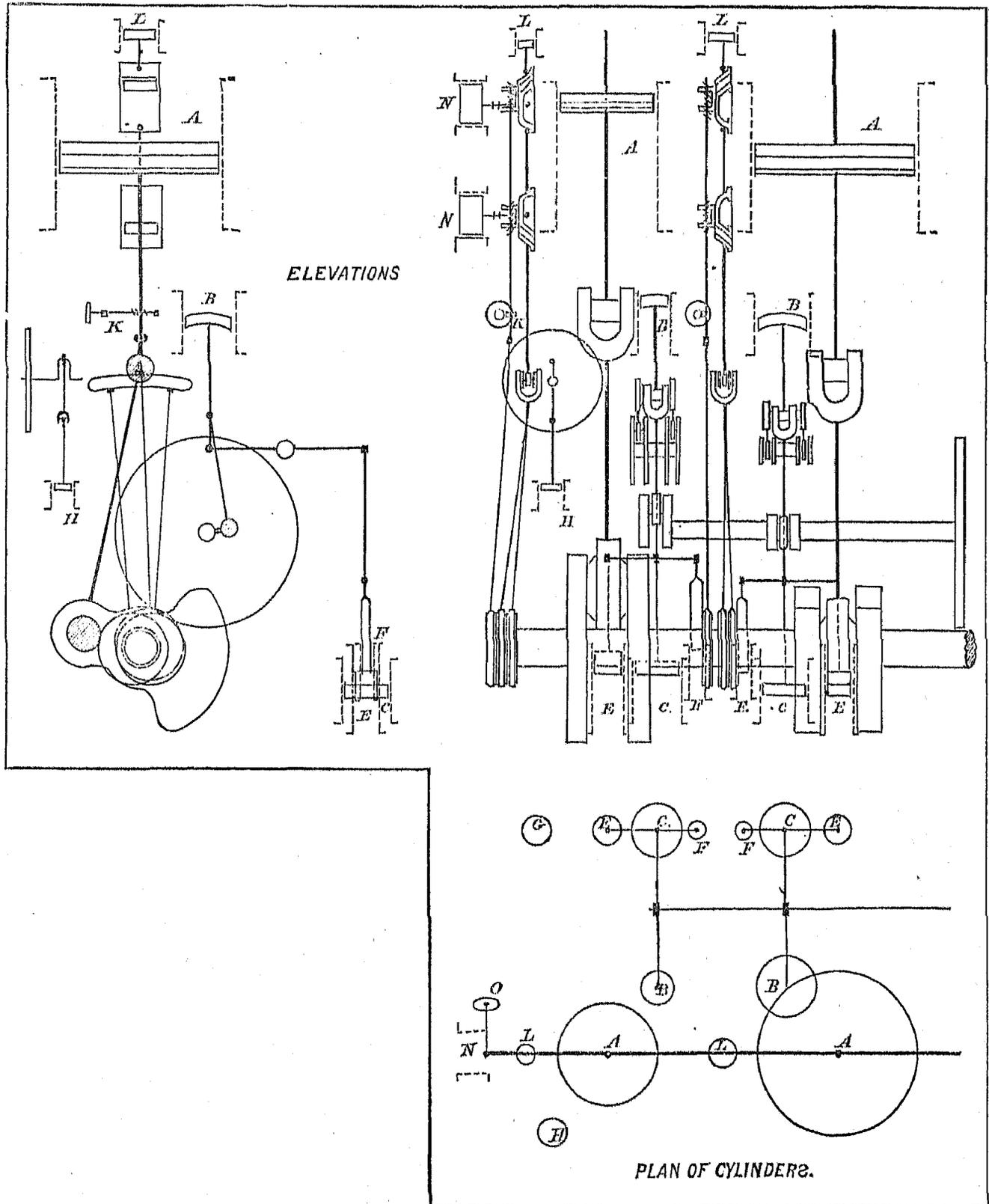


FIG. 30.

ENGINES OF A PACIFIC MAIL STEAMSHIP.

A description is here adduced of the engines of the Pacific mail steamship "City of San Francisco," built by John Roach & Son, at Chester, Pennsylvania. Three drawings are presented, an elevation looking aft (Fig. 28) and a plan of the engine (Fig. 29) (these have previously appeared in the London *Engineering*) and a skeleton sketch or drawing in plan and two elevations (Fig. 30), showing the inter-relations of the various moving parts, and the arrangement of pumps, valve-gears, and auxiliary engines.

The machinery embodies three engines in one and five steam cylinders, two of the engines being compound. The letters A A indicate the cylinders of the principal engine. The smaller or high-pressure engine is surrounded by an annular space which serves as a receiver between high- and low-pressure cylinders. The linings within which the pistons work are cast separately and bolted in, and the cylinders are steam-jacketed—sides, tops, and bottoms. This main engine is of simple arrangement, for, beside driving the propeller, its only duty is to operate a bilge-pump, indicated by the letter O upon the drawings. This is conveniently driven from the forward end of the main crank-shaft. There is a reversing engine, H, and a compound pumping-engine, B B, with its receiver and valve-gears conveniently located under the large cylinders. This drives two air-pumps, O O, two circulating-pumps, E E, two feed-pumps, F F, and a bilge-pump, G. This independence of the pumps has several advantages. The pumps are not affected by racing of the main engines in rough weather, both pumping- and reversing-engines being governed by fly-wheels, as shown in the illustrations. The piston areas and cylinder volumes are given as follows comparatively, so that their relative capacities may be seen at a glance :

	Diameter.	Stroke.
	<i>Inches.</i>	<i>Feet.</i>
Main high-pressure cylinder.....	51	5
Main low-pressure cylinder.....	88	5
Pumping high-pressure cylinder.....	16	2
Pumping low-pressure cylinder.....	27	2
Starting-engine cylinder.....	10	1
Air-pumps (single acting).....	24	2
Circulating-pumps (double acting)....	14½	2
Feed-pumps (single acting).....	6	2
Bilge-pumps (single acting).....	6	2
	8	13½

Main and pumping engines make the same number of revolutions, and their piston speed is therefore as 5 to 2. The volumes swept by the pistons per revolution are as follows :

	Cubic feet (actual).	Relative to main engine cylinders.
Main engine cylinders.....	1,0000	504,190
Main high-pressure cylinder.....	0,2514	141,800
Main low-pressure cylinder.....	0,7480	422,330
Pumping engine.....	0,0381	21,480
Pumping high-pressure cylinder.....	0,0090	5,580
Pumping low-pressure cylinder.....	0,0282	15,000
Starting engine.....	0,0010	1,088
Two air-pumps.....	0,0223	12,568
Two circulating-pumps.....	0,0163	9,181
Two feed-pumps.....	0,0013	0,781
Two bilge-pumps.....	0,0013	0,777

This table furnishes an interesting comparison of the relative power employed in pumping and propelling service, which appears about as 1 to 26, and of the relative capacity of pumps. Taking the feed-pumps as a standard of comparison, the bilge-pumps have about the same capacity, but the bilge-pump O may be disconnected when desired. The capacity of the circulating-pumps is about 12½ and of the air-pumps about 17 times as great, of the starting engine 1½, pumping engine about 20, and main engine about 770 times as great.

The valves of the main cylinders are single-ported valves, cutting off at about two-thirds stroke, with plain plate expansion valves arranged to reduce the cut-off to one-tenth when desired. The change of cut-off is effected by right and left screws operated by a screw and worm wheel, the latter upon the expansion valve rod, as shown at K in the figures. The main valves are counterbalanced for weight by the steam pots shown at L L, which have a piston diameter of 8½" for the high, and 15½" for the low-pressure cylinder, and the valves of the high-pressure cylinder have the pressure upon their faces counteracted by being connected by links with the pistons of vacuum pots indicated by the letter N in some of the figures. These have a diameter of 20" each. The main valves are

driven by a pair of eccentrics and double-bar link, making the travel of the valve equal that of the eccentric when the link is in full gear. The travel of the high-pressure main valves is 10", expansion valves 12", low-pressure main valves 12", expansion valves 14½". The high-pressure steam ports are 4½" wide by 36" long, cut-off ports 2½" wide by 33" long. The low-pressure steam ports are 5½" wide by 60" long. Main and cut-off valves are held to their faces by bars bolted at their backs, and the cut-off valves by flat springs. The expansion eccentrics are set opposite the crank pins and the eccentric rods lead direct to the valve-stems. The auxiliary engines, pumping and starting, have plain slide valves cutting off at two thirds stroke and operated, the former by single and the latter by a pair of eccentrics with links which are not shown upon the skeleton sketch. The reversal of the main engines is effected by the shifting of the valves by the small starting engine II, which operates through a reversing screw fitted with a cross-head, which is connected to a rock-shaft and reversing links. The starting engine is itself fitted with self-acting reversing gear. To admit steam to the main cylinders for warming them up before starting there are pass-over valves, as shown at M in several views.

The condenser shown at D forms the base of the supporting columns of the frame on the starboard side. It is made in two pieces, each with an air-pump cast on. It is also in two sections, upper and lower, and the water passes twice through its length, the steam first reaching the coldest surface, but being prevented from striking directly against the condenser tubes by a deflecting plate. The exhaust-pipe is of cast-iron and has an expansion joint in the middle. It is 20" by 25" in section. The condenser contains 2,380 tuned brass tubes ¾" diameter, 13' 9" exposed length, 6,425 square feet condensing-surface.

Eccentrics are of cast-iron, eccentric-straps of wrought-iron, valve-spindles of steel. The valve-facings of the main engines are of hard cast-iron and are bolted on. The piston-rods of the main engines have their lower ends forked and fitted with brasses 9½" in diameter and 14" long and with caps, bolts, nuts, and gibs for wearing on the guides. Condenser tube-plates are of hard cast-iron 1½" thick and the tubes are packed with paper packing. The bed-plate of the engine is cast in two sections, and upon each are two pillow-blocks with journals 17" in diameter and 26" long. The bottom brasses of these are set in removable chocks, so that they may be taken out without removing the shaft. The crank-shaft is made in pieces and shrunk together; line shaft is 16" in diameter; crank-pins 16" in diameter by 18" long. Crank-shaft counterbalances are forged on.

#### PROPORTIONS AND ARRANGEMENT OF STEAMERS.

The following twenty-four examples of steamers of over 1,000 tons are arranged in the order of lengths relative to breadths:

Name.	Ratio length to breadth.	Ratio breadth to depth.	Tonnage.	Class of service.	Method of propulsion.	Where built.	Date of build.
Victoria .....	10.23	1.76	1,462.13	Ocean .....	Screw .....	Hull, England .....	1866
City of Tokio .....	9.85	1.51	5,079.62	do .....	Screw (ship) .....	New York .....	1874
State of California .....	8.78	1.38	2,266.03	do .....	do .....	Philadelphia, Pennsylvania .....	1870
Geo. W. Elder .....	8.77	1.32	1,709.59	do .....	do .....	Chester, Pennsylvania .....	1874
City of New York .....	8.43	1.42	3,019.56	do .....	do .....	do .....	1875
City of Sidney .....	8.43	1.41	3,016.70	do .....	do .....	do .....	1875
Transit .....	7.74	2.68	1,566.81	Ferry .....	Paddle .....	Oakland, California .....	1875
Colima .....	7.66	1.95	2,965.60	Ocean .....	Screw (ship) .....	Chester, Pennsylvania .....	1873
Oregon .....	7.57	1.57	2,325.38	do .....	Screw .....	do .....	1878
Granada .....	7.25	2.00	2,572.38	do .....	Screw (ship) .....	Wilmington, Delaware .....	1873
Ozizaba .....	7.19	2.26	1,214.08	do .....	Paddle .....	New York .....	1854
Dakota .....	6.75	2.00	2,135.04	do .....	do .....	Green Point, New York .....	1878
City of Panama .....	6.72	1.80	1,490.24	do .....	Screw (ship) .....	New York .....	1874
Thoroughfare .....	6.46	3.02	1,012.27	Ferry .....	Paddle .....	San Francisco, California .....	1871
Newark .....	6.38	3.28	1,781.80	do .....	do .....	do .....	1877
Oakland .....	6.38	2.50	1,072.24	do .....	do .....	do .....	1875
Bay City .....	6.25	2.71	1,233.42	do .....	do .....	do .....	1878
Solano .....	6.21	1.73	3,549.41	do .....	do .....	Oakland, California .....	1874
City of Chester .....	6.00	2.00	1,106.21	Ocean .....	Screw (ship) .....	Chester, Pennsylvania .....	1875
Capitol .....	5.90	4.31	1,980.20	Ferry .....	Paddle .....	San Francisco, California .....	1866
R. R. Thompson .....	5.66	3.00	1,158.04	River .....	do .....	Dallas, Oregon .....	1878
Aneon .....	5.65	2.27	1,540.78	Ocean .....	do .....	San Francisco, California .....	1868
Garden City .....	5.62	2.72	1,080.70	Ferry .....	do .....	do .....	1870
Wido West .....	5.52	4.82	1,200.80	River .....	do .....	Portland, Oregon .....	1877

The largest steamships under the American flag are in the Pacific district. The "City of Pekin" and the "City of Tokio" are each of 5,079.62 (registered) tons burden, and ply between San Francisco and Hong-Kong, Yokohama, and other ports. The relative size of these vessels may be compared with that of other large American steamers. The "Solano" (ferry-boat), of this district, is of 3,549.41 tons. The "City of Rio Janeiro," 3,548.30 tons, and the "City of Para," 3,532.25 tons, are the largest steamers of the New York district. The "Pilgrim," of the Fall River

line, is of about 3,500 tons burden; the "Bristol" and the "Providence" each 2,962.20 tons. The tonnage of the "Daniel Drew" is 2,902.24; of the "Rhode Island," 2,742.42. The "Pennsylvania," of the American line (trans-Atlantic), is of 3,104.28 tons. The largest coasting steamers are the "Chalmette," 2,982.96 tons, and the "Louisiana," 2,840.33 tons. On the Mississippi we have the "James Howard," 2,321.44 tons, the "J. B. M. Kehloe," 2,293.78 tons, and the "Ed. Richardson," 2,048.34 tons; and on the lakes, of the Buffalo and Chicago line, the "Rochester," 2,220.05 tons, and the "Commodore," 2,082.02 tons. In 1860 the only English steamer exceeding 3,500 tons was the "Great Eastern," whose registered tonnage was 13,344 tons, and at present the new English (Cunard) steamer "Sahara," 7,500 tons, is the nearest approach to this enormous tonnage.

It will be seen that the "City of Peking" and the "City of Tokio" are very large steamers, even when compared with the mammoths of English engineering skill. The "City of Peking" is 423' long and 48' broad; the Cunard steamer "Gallia" is 450' long and 44' broad, and the "Sahara" 500' long and 50' broad. In the "City of Peking" the boilers occupy some 60' of the length of the vessel in the hold, being set, as usual, five on each side, cylinders transverse to the length of the steamer, and a fire-room in the middle. The boilers are of the usual type for large sea-going vessels, compound return-tubular, three furnaces to a boiler, and five boilers on each side of the steamer; the engine-room abaft or back of the boiler-room, and the main deck above the boiler-room. The bunkers will contain 1,500 tons of coal, which, rated at 50 pounds (heaped) per cubic foot, would occupy 67,200 cubic feet, equal to a cube of about 41 feet, or a parallelepipedon 20 by 20 by 168. This would leave over twice as much space for cargo below the main deck, allowing for boiler and engine space. It may be remarked that the bunkers of the Cunard "Gallia" have space for 1,700 tons of coal. The "City of Peking" is arranged to accommodate 150 cabin and 1,800 steerage passengers.

The "Solano" is the largest ferry-boat in the world. The boat was built at Oakland, but the steam machinery was built at Wilmington, Delaware. It will take 48 freight-cars at a time, and has about five times as much deck space as one of the large Jersey City ferry-boats.

The dimensions of some smaller steamers are as follows:

	Tonnage.	Length.	Breadth.	Depth.
		<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Sansalito .....	692.43	205.5	32.0	9.8
Willamette Chief.....	693.19	163.0	35.8	5.4
Arcata .....	560.21	180.0	26.2	8.0
S. T. Church.....	553.00	154.0	36.0	5.3
Los Angeles .....	493.00	170.0	27.0	11.0
Almota .....	502.35	157.0	36.0	5.0

All of these have paddle-wheels except the "Los Angeles," which is a screw-propeller. The stern-wheel boats are usually of lighter draft than those with side-wheels. Of the engines of the above boats the "Sansalito" has one vertical beam-engine 50" diameter by 11' stroke; the "Willamette Chief," two 20" diameter by 5' stroke direct acting engines. The "Arcata" has one compound engine 14½" and 20" diameters of cylinder by 28" stroke. The "S. T. Church" has two 17" diameter by 6' stroke direct-acting engines. The "Los Angeles" has one compound engine 19½" and 43½" diameters of cylinder by 28" stroke. The "Almota" has two 16" by 6' direct-acting engines. Of these steamers the river boats are most bluff in build, the ratios of length to diameter being for the "Willamette Chief," "S. T. Church," and "Almota" 4.55, 4.27, and 4.36, while the ratio is for the "Sansalito" (ferry-boat) 6.42, the "Arcata" (ocean passenger) 6.87, and the "Los Angeles" (inland passenger and coaster) 6.29. The "Santa Cruz," a freight-boat on the same route as the "Los Angeles," and having similar machinery, is a much shorter boat, the ratio of length to breadth being only 4.58.

The Sacramento river boats have usually a greater breadth for the length than those on the Columbia river. A comparison from averaging a number of them, all vessels of nearly 500 tons, gives the showing: ratio of length to breadth, 4 for the Sacramento and 5½ for the Columbia river boats considered. The stern-wheel boats will be more fully considered under the head of Mississippi valley steamers. A Sacramento river stern-wheel steamer of recent build and which may be taken as a type of the river steamers of the Pacific seaboard, is 180' long by 40' wide and about 8' deep, with a draft from 3' to 4½' according to load, the carrying capacity being 300 tons. It has a saloon deck 136' long by over 30' wide, of which length 36' is in open decks and 100' in cabins of 10' height, a forward cabin 30' wide, and an aft-cabin 14' wide, lined with state-rooms. The boat is upward of 450 tons burden. The "City of Stockton," running from San Francisco to Sacramento or Stockton, is of unusually short build for a passenger-boat, viz: 175' long, 50.8 broad, and 8.15 deep; tonnage, 485.63; ratio length to breadth, 3.44. It was built at Stockton, 1876. Another very wide boat is the beam-engine ferry-boat "Carquinez," 102 tons, plying between Carquinez and Benecia. This boat has length, 82.6; breadth, 24.8; depth, 6'; ratio length to breadth, 3.33; and was built at Martinez, California, 1854.

Most of the river boats in the Willamette district have the ratio of length to breadth between 5 and 6. The "Alice," 457.16 tons, and the "E. N. Cook," 415.95 tons, are among those of most narrow build. These boats are

25' broad and 6' deep. The "Latona," 128.91 tons, length 90'.4, breadth 18'.4, depth 3'.9, running from Portland to Lewis and Lake river, is the shallowest boat of over 100 tons. The "Astoria," 124.61 tons, length 98', breadth 24'.4, depth, 10'.5, running from Portland to Shoal Water bay, is an unusually deep boat.

The tendency in tug-boats is for the substitution of screws for paddles, but there are many paddle-boats in the service, especially among the larger tugs. An example of a very narrow tug-boat is the "C. M. Small," a stern-wheel boat with two 12" by 48" non-condensing engines. It is of 97.99 tons burden, length 137', breadth 20', depth 6', ratio length to breadth 6.85. The "Daisy Whitelaw," a small steam freight-boat plying between San Francisco and Point Reyes, is of the dimensions 60'.5 by 14'.4 by 8'.6, tonnage 44.42. Boats of 3' or 4' draft ply from Celilo to the head of navigation on the Columbia river, but the depth of boats plying from Portland to Eugene City, on the Willamette, does not appear to exceed 5- $\frac{9}{10}$ ', with a draft probably half that, as the stern-wheel boats stand high out of the water. The "Mohave" and "Colorado," running from Yuma to Colorado river landings, have a depth of only 4', and the "Gila" of only 3- $\frac{9}{10}$ ', although the last is of 236.47 tons burden. The "Little Annie," 85.56 tons, plying to the head of navigation on the Coquille river, has the dimensions: length 67'.51, breadth 16'.47, and depth 4'.21. The "Restless," plying from Winchester bay to the head of navigation on the Umpqua river, has a tonnage of 101.02 tons, length 72', breadth 16', and depth 4 $\frac{1}{2}$ '. The largest steamer on lake Tahoe is 92' long, 16' 5" broad, and 4 $\frac{1}{2}$ ' deep. The "Gov. Dana," running to the head of navigation on the Sacramento river, is of 299.77 tons, and of the dimensions: 145' long, 30'.6 broad, 3 $\frac{1}{2}$ ' deep.

Considering the boats of the San Francisco district alone, the inland passenger steamers built in and prior to 1865 have a ratio of length to breadth 4.72 and to depth 22.32, while for such steamers built in and since 1875 these ratios are 4.19 and 22.60. In like manner, comparing the ferry-boats built in and before 1870 and in and after 1875, we find the stated ratios for the averages to be 5.12 and 16.53 for the earlier and 5.79 and 15.47 for the later built boats. The "Solano" is omitted from this comparison, on account of being designed for a peculiar service.

Of carrying capacity it may be noted that the "Solano" will take a weight of freight-cars equal to upwards of half its registered tonnage; the whaler "Mary and Helen," of 420 $\frac{1}{2}$  tons, will take 200 tons coal and 2,700 barrels of oil, an equivalent of 6 $\frac{1}{2}$  barrels of oil and nearly half a ton of coal per ton of vessel. The Sacramento passenger-boat "Modoc" carries, in addition to passengers, about  $\frac{3}{8}$  of a ton actual weight of cargo per ton of vessel. Stern-wheel boats, such as the "Modoc," being comparatively flat-bottomed, carry immense amounts of cargo on a light draft.

The steam whaler "Mary and Helen" was built at Bath, Maine, and sent to the Pacific coast, where it was purchased by the United States Government for Arctic service. This steamer is 155' long, 30' breadth of beam, 16 $\frac{1}{2}$ ' depth of hold. It has a flush deck, frame of white oak, with planking 6" thick, and double or 12" thick forward of the foremast, where it is braced with pointers set 2' apart from keel to deck, and these in turn are braced with 10" cross-timbers. On deck there is a galley for the cook on the starboard side, and on the port side a companion-way leads down to the forward cabin, which has state-rooms on the port and pantry and engineer's room on the starboard side. Two doors lead into the after-cabin, on the starboard side of which is the captain's cabin. The engine-room, with a vertical engine 20" by 20", is between main and mizzen masts, and the boiler, a horizontal return-tubular of 200 nominal horse-power, is in the hold below the engine-room. The boiler extends forward of the engine-room, and above it are the drying-room, sail-pens, and store-room. Oil is stored in the hold forward of the mainmast. There are two donkey-engines for hoisting the anchor, cutting ice, and other work; steam fire-pumps and other accessories. A jet condenser is employed.

The above account will give a fair idea of a steamer of this character. It is of low power, say 7 or 8 knots per hour in speed under steam and against a head-wind, but is intended to be propelled mainly by sail, reserving the coal for use in calms and among the ice-floes.

The Pacific Mail steamship "City of San Francisco," built by Messrs. John Roach & Son, and the machinery of which is elsewhere described, is 352' long over all, 40' beam, and 28' 10" deep under the spar deck. It is termed a three-deck steamship, having a hurricane deck running all fore and aft, and an orlop deck additional forward, extending from the forward coal-bunker bulkhead to the stem.

The river towing-boats of the Pacific seaboard are almost invariably stern-wheel boats, there being only a few small boats with screw-propellers. The tug-boats of San Francisco and San Pablo bays are nearly all propellers, and there is but one side-wheel tug, the "Tiger," which is of the English type. The "Tiger" has a length of 100', breadth 21', depth 5- $\frac{1}{10}$ ', tonnage 85.37 tons. It has three boilers, each 3 $\frac{1}{2}$ ' in diameter by 14' long, and is driven by two condensing-engines, each 16" in diameter by 4' in stroke.

#### STEAMERS OF THE MISSISSIPPI VALLEY.

GEOGRAPHICAL DISTRIBUTION.—The attempt to classify the steamers according to routes of service is attended with difficulty on account of the great number, especially of freight-steamers, which have no definite routes. But although the grouping of steamers may on this account be vague and approximate in some cases, it will still be found valuable as affording tolerably clear ideas of the scope and direction of the great steam service which gives to the Mississippi river system its obvious commercial value. There are, in the first place, the ferries, and, hardly

distinguishable in character of service, the short runs of boats which ply between points not many miles distant. In the second place there is a class of steamers regularly plying between certain large cities over long river routes. In the third place, there is a class of steamers which may be specified as plying mainly upon certain small or tributary rivers or sections of rivers. The grouping of these, if it fails to include all the steamers visiting such rivers, will at least convey some ideas of the magnitude of commerce and the conditions of navigation. In the fourth place there are large numbers of steamers which can only be specified as plying inland from the principal cities. In this expression inland is sometimes understood as meaning up the river, but it sometimes signifies any where in the entire river system.

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
	* 1	1,011.20	2	08.74
	10	2,106.00	18	140.02
	* 21	3,290.80	20	450.44
Ferries and short runs on the lower Mississippi, below the Ohio river, also including steamers plying from New Orleans to the sea and in the New Orleans harbor and local service, the latter being designated by a star.	3	208.51	5	8.70
	* 0	470.22	10	23.04
	3	117.03	5	5.20
	* 2	73.26	2	4.78
	11	100.18	15	8.53
	* 0	115.17	10	3.37
	22	5,035.90	31	410.02
Ferries and short runs on the upper Mississippi, including the ferries and local service at Saint Louis.	17	1,223.64	20	04.25
	10	020.15	22	22.07
	11	144.53	15	4.20
	3	3,173.77	0	108.77
Ferries and short runs on the lower Ohio, below Cincinnati.....	1	740.00	2	40.10
	13	3,172.23	25	130.78
	3	215.61	5	0.38
	5	86.62	0	1.20
	1	27.80	1	0.88
Ferries and short runs on the upper Ohio .....	5	3,420.00	10	175.17
	20	5,100.70	51	276.05
	25	1,761.38	43	70.00
	0	140.11	11	3.44
	10	694.57	24	22.25
Ferries and short runs on the Missouri river.....	10	1,084.24	15	131.08
	12	850.70	20	51.06
	3	90.34	4	5.20
	2	21.15	3	0.66
Plying between Saint Louis and Saint Paul and Stillwater .....	1	540.21	2	10.44
	21	3,234.41	42	178.00
	7	030.70	14	38.10
	2	72.02	4	5.84
Plying from Saint Louis, Cairo, and Memphis to Wheeling, Pittsburg, and Cincinnati.	7	4,337.37	14	138.04
	7	1,800.51	14	100.93
	5	168.07	7	5.00
Plying from Saint Louis and other principal ports to Yankton, Omaha, and Sioux City.	10	4,070.20	30	102.54
	1	70.98	2	8.54
	1	44.01	2	1.07
	1	4.00	1	0.03
Plying from Saint Louis and Memphis to New Orleans and Vicksburg.	3	4,521.70	6	250.34
	2	1,231.72	4	01.20
	1	23.83	1	0.98
	5	5,031.85	10	217.07
Plying between New Orleans and Pittsburg, Cincinnati, and other ports of the upper Ohio.	5	3,871.51	10	130.04
	15	4,257.17	32	302.40
	2	122.20	4	8.09
	1	22.62	1	0.54
	1	1,200.84	2	00.32
Plying on Red, Washita, and Atchafalaya rivers.....	3	458.17	6	16.00
	2	131.85	3	2.57
	2	82.35	3	2.27
	5	71.02	6	2.34
Plying on the Illinois river. (See also lake steamers).....	1	114.00	2	6.28
	2	150.72	4	2.84
	2	72.50	2	0.63
	10	84.04	11	1.48

## MARINE ENGINES AND STEAM VESSELS.

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Plying on the Arkansas, White, and Saint Francis rivers.....	8	1,404.04	16	40.48
	15	1,140.05	26	25.16
	7	238.03	10	4.07
	3	62.20	4	2.70
Plying on the Tennessee river.....	9	1,952.85	18	62.72
	2	187.53	4	4.50
	5	203.16	8	6.32
	1	21.14	1	0.35
Plying on the Cumberland river.....	9	2,191.86	17	82.06
	6	488.13	12	16.68
	2	42.00	4	2.30
Plying on the Wabash and White rivers.....	8	524.01	13	15.05
	5	183.70	7	3.87
	7	117.19	8	4.78
Plying on the Kanawha, Big Sandy, Licking, Kentucky, and Green rivers.	6	1,265.07	14	60.57
	10	740.08	18	41.63
	10	400.16	19	16.11
	6	93.78	11	4.03
Plying on the Muskingum, Scioto, and Miami rivers.....	7	1,009.93	14	56.81
	3	193.61	4	2.01
	2	76.24	2	1.56
Specified as plying upon the Monongahela and Alleghany rivers.	3	53.79	3	1.61
	4	1,152.00	8	99.04
	3	214.17	6	10.23
Plying on the Osage and Gasconade rivers.....	3	98.50	6	6.39
	4	77.37	8	7.05
	1	66.06	2	3.26
Plying on the Osage and Gasconade rivers.....	2	75.73	3	1.83
	2	7.00	3	0.39
Plying on the Missouri river, above Yankton.....	9	2,169.44	17	85.26
	1	72.18	1	5.58
	1	19.00	2	3.93
Plying from New Orleans and Vicksburg inland, unspecified....	11	15,610.81	22	1,130.13
	10	6,929.83	20	324.20
	67	10,119.81	131	728.01
	27	1,954.78	51	64.77
	23	846.07	31	49.32
Plying from Saint Louis inland, unspecified.....	28	282.02	38	10.65
	11	15,247.48	22	712.52
	27	10,003.67	54	1,002.23
	50	15,044.06	98	1,039.80
	11	950.10	20	82.86
Plying inland from Saint Paul and ports of the Upper Mississippi, as far south as Burlington, to ports unspecified.	4	165.89	7	7.03
	8	65.30	10	2.90
	36	7,221.51	72	422.06
	23	1,628.04	41	77.27
Plying from Pittsburg and Wheeling inland, to ports unspecified.	14	507.23	26	26.20
	10	179.40	13	5.03
	1	1,034.15	2	25.72
	18	12,117.93	36	1,008.53
	97	21,838.04	194	2,095.35
Plying inland from Louisville, Cincinnati, Evansville, Owensborough, and Metropolis.	15	1,129.75	29	192.60
	6	257.68	9	18.07
	8	114.30	12	6.83
	16	11,178.16	32	623.50
Plying from Memphis and Cairo inland, unspecified.....	29	6,786.13	58	362.59
	26	1,681.65	43	76.19
	6	252.73	7	5.83
	7	111.30	11	8.62
Plying from Memphis and Cairo inland, unspecified.....	2	1,586.18	4	110.71
	14	4,617.51	28	182.19
	6	451.52	10	20.03
	4	165.85	6	5.96
	6	83.67	7	6.05

After the numbers of engines are specified their aggregate volumes in cubic feet. This is a better indication of the relative powers for stern-wheel engines, such as the majority of the foregoing, than for propeller engines.

ENGINES OF MISSISSIPPI RIVER STEAMERS.

Of steamers of over 1,000 tons, there are the following thirty-three, of which the following list is given in full with the kinds and dimensions of engines, which, unless specified, are simple non-condensing engines: the "J. B. M. Kehloe," 2,293.73 tons, has two, 18" and 44" by 6' compound engines.

*Engines, simple non-condensing.*

Name.	Tons.	ENGINES.		Name.	Tons.	ENGINES.	
		No.	Dimensions.			No.	Dimensions.
Thos. Sherlock .....	1,353.02	2	24" by 8'	Chas. P. Chouteau .....	1,304.12	2	22" by 8'
R. R. Springer .....	1,215.35	2	24" by 8'	W. P. Halliday .....	1,375.40	2	24½" by 10'
Fred. A. Blanks .....	1,200.84	2	26" by 9'	Commonwealth .....	1,105.05	2	22" by 9'
Charles Morgan .....	1,224.20	2	28" by 8'	Centennial .....	1,077.40	2	20" by 7'
Guiding Star .....	1,121.07	2	22½" by 7½'	City of Helena .....	1,058.28	2	26" by 8'
United States .....	1,083.02	2	20" by 10'	Grand Tower .....	1,058.28	2	26" by 8'
Genl. Lytle .....	1,051.25	2	20" by 9'	Ed. Richardson .....	2,048.34	2	38" by 10'
Fleetwood .....	1,030.60	2	20½" by 8½'	J. M. White .....	2,027.70	2	43" by 11'
Will Kyle .....	1,017.25	2	22½" by 7'	Thompson Dean .....	1,504.38	2	30" by 10'
Wyoming .....	1,034.15	2	18" by 7'	Robert E. Lee .....	1,470.10	2	40½" by 10'
Henry Frank .....	1,100.04	2	28½" by 9'	Natchez .....	1,477.27	2	31" by 10'
City of Vicksburg .....	1,058.28	2	25" by 8'	Robt. Mitchell .....	1,219.81	2	22½" by 8'
James Howard .....	2,321.41	2	31" by 10'	Annie P. Silver .....	1,199.52	2	22" by 8'
John A. Scudder .....	1,747.22	2	28" by 8'	New Mary Houston .....	1,103.00	2	22½" by 7'
City of Alton .....	1,458.33	2	36" by 9'	John W. Cannon .....	1,144.34	2	31½" by 9'
City of Greenville .....	1,438.06	2	26" by 10'	U. P. Schenck .....	1,030.72	2	21" by 7'

This includes only the characteristic river boats, passenger-steamers, many of them of high speed, such as the "J. M. White" and "Guiding Star." All of the swift passenger-boats have side-wheels, all of the stern-wheel boats being of slow speed, although some are used in and equipped for passenger service. We see that there is scarcely an exception to the usual type of paired simple long-stroke non-condensing engines. "The condensing-engine has been used on the "James Howard," but when the condenser was in use a double force of firemen had great difficulty in maintaining the steam-pressure" (Bryant). The "Wyoming" is an example of a stern-wheel boat, but there is no usual or distinguishing difference in the proportions of engines between stern- and side-wheel boats. High powers are realized for the proportions on account of the profligate use of steam, the terminal pressures being great enough for the initial pressures of ordinary high-pressure engines. Engines which throw away three or four tons of fuel where they utilize one are certainly subjects for future improvement. Condensers would certainly be a great improvement upon such practice, even if the vacuum was poor; but with such high-pressures and proper expansion the power of the steam could be as fully realized without as with the use of condensers. With proper expansion, condensers would be found an adjunct entirely undesirable for high-pressure river engines, not only involving increased first cost but a positive detriment to economy. To admit 170 pounds steam into a long-stroke cylinder chilled by connection with a condenser is to seriously lower the mean effective pressure.

Special surface-heaters are commonly used and the feed is heated nearly to boiling point, while upon ocean steamers 120° is a common temperature of feed. Comparing the feeding capacity of the engines of the "Ed. Richardson" with those of an ocean steamer (compound):

Class.	Tonnage.	Feed pumps.	Passed per revolution.		Ratio.	Boiler-pressure.
			Cylinder volume.	Pump volume.		
River steamers .....	2,048.34	1-7½" by 26"	Cubic feet. 314.72	Cubic feet. 0.065	.0021	Pounds. 173
Ocean steamers .....	3,010.50	2-6" by 24"	664.10	0.781	.0013	73

Although these river engines are of long stroke, the actual length of stroke is seen to range considerably below that of the beam-engines upon the Hudson river and Long Island sound. The side-wheel boat "J. M. White," probably the swiftest on the Mississippi, has except ionally large cylinders, the cubic volume being about 222 cubic feet.

Upon steamers of Class II the engines are of precisely the same type as in the preceding class, and invariably paired. A steamer driven by a single cylinder engine is unknown among these large vessels.

In this class most of the steamers are of the stern-wheel type, which is much more common than any other type. This class also includes the largest towing-boats. Of 183 engines in this class 180 are of the simple non-condensing type and 8 are of the Hartapee compound-moderator type.

## COMPOUND ENGINES.

Name.	Tons.	ENGINES.	
		No.	Dimensions.
E. O. Stannard .....	824.51	2	12" and 26" by 5'
Mollie Moore .....	601.70	2	12" and 26" by 5'
John A. Wood .....	687.52	2	18" and 41" by 8'
Joseph B. Williams .....	801.01	2	10½" and 41½" by 9'

The two former are inspected as passenger-steamers and the two latter as tow-boats. The "E. O. Stannard" and the "Mollie Moore" are specified as plying from Saint Louis inland; the "John A. Wood" and the "Joseph B. Williams" from Pittsburg inland. The latter are the most powerful towing-boats upon the river, the aggregate cylinder capacity of their engines being 5 or 10 times as great as that of other boats of this class. But in illustration of their greater economy of fuel it should be noted that relatively small boiler capacities are required.

The "Belle of Memphis," 919.69 tons, has 2 simple engines, 26" by 8', volume 59.96 cubic feet, 5 four-flue boilers, 44" by 26', volume about 1,372 cubic feet. The "Oakland," 628.81 tons, has 2 simple engines, 26" by 9', volume 66.32 cubic feet, six-flue boilers, 40" by 30', volume about 1,568 cubic feet. The "Joseph B. Williams" has six-flue boilers, 40" by 28', volume about 1,463 cubic feet. The "John A. Wood" has six-flue boilers, 40" by 26', volume about 1,359 cubic feet.

The boiler-pressures allowed are: for the "Belle of Memphis" 131 pounds, "Oakland" 150 pounds, "Joseph B. Williams" 174 pounds, and "John A. Wood" 150 pounds. The boiler-volumes are 6.94 times the cylinder-volumes for the compound condensing and 23.28 times the cylinder-volumes for the simple non-condensing engines.

The tow-boat "John Dippold," 554.97 tons, with two 24" by 8' engines, has boilers of precisely the same size as those of the "Joseph B. Williams," pressure 140 pounds; but the cylinder-volume of the "John Dippold" is less than one-fourth that of the "Joseph B. Williams." None of these engines exceed 9' in stroke, and the cylinders of the simple engines seldom exceed 26" in diameter for this class of steamers.

The non-condensing engine is the all but universal type; but the "Bonanza," 776.38 tons, a passenger-steamer plying between Cincinnati and Marietta, has two 22¾" by 7½' simple condensing-engines.

In steamers of Class III we begin to find a few variations from the prevailing types of engines and boilers, but they constitute a very small minority. Plying from New Orleans to the sea and inland are a few screw-propellers with return-tubular boilers, and in the upper Ohio district there are quite a number of slide-valve engines, in place of the usual poppet-valve engines. But apart from these New Orleans boats running to the sea, there are no screw-propellers of considerable size upon the Mississippi or its tributaries. These New Orleans boats have return-tubular boilers and in some cases condensers, but tubular boilers and condensers are of very rare occurrence upon Mississippi river steamers.

In this class, in the Pittsburg, Evansville, and Nashville districts, every boat is driven by paired engines. In the Saint Louis district 21 out of 90, in the Galena district 2 out of 73, in the Memphis district 2 out of 31, in the Louisville district 2 out of 29, and in the Cincinnati district 1 out of 50 steamers are driven by single engines.

In the Saint Louis district, in this class there are 6 out of 159 Hartupée compound engines, the rest being simple non-condensing. The "Katie P. Kountz," 468.25 tons, has two 10" and 23" by 4½' Hartupée engines. The "Henry C. Yager," 373.44 tons, has two 23" and 45" by 6' engines. The "General Meade," 171.46 tons, has two 8¾" and 23" by 4' engines. The last-named boat plies from Omaha inland. All of the Hartupée engines are upon boats built between 1870 and 1878, and no compound engines appear to have been since applied in the Mississippi service.

The ferry-boat "Denver," of Bismarek, Dakota, has one 22" by 7' engine. The ferry-boat "Lyons," city of Lyons, Iowa, has one 18¾" by 5' engine. Nearly all of the single engines are upon side-wheel ferry-boats. The passenger-steamer "Henry Logan," 111.21 tons, plying between Cincinnati and Parkersburg, West Virginia, has two 9" by 3' condensing-engines. The "Rapid Transit," 111.29 tons, a passenger-steamer plying between Cincinnati and New Orleans, is one of the largest screw-propellers plying upon the Ohio river, and has four 12" by 10" non-condensing engines. In the Wheeling district an entirely exceptional type is presented in the paddle-wheel steamer "Little Boone," 137.66 tons, plying from Gallipolis to points on the Kanawha river. This boat has two 8" by 16" oscillating engines and a 44" by 10' marine boiler. The slide-valve engines, of which there are a considerable number upon Wheeling steamers of this class, are long stroke engines, driving paddle-wheels, and are modifications of the usual practice with land engines. Most of them are tow-boat engines. The "Bell Prince," 109.12 tons, is a tow-boat, with 2 slide-valve engines 12½" by 4½', and 2 double-flue boilers 38" by 24'. It is stated to consume 500 tons of coal in running from Wheeling to Pittsburg and return, towing an ordinary load.

The ferry-boat "Porter," 280.35 tons, of New Orleans, is a screw-propeller with four 16" by 16" condensing-engines and two 6' by 15' fire-box cylindrical tubular return boilers. The pressure allowed is only 45 pounds. The screw-propeller "Martha," 175.11 tons, with one 32" by 32" condensing-engine and a fire-box return-tubular boiler

(allowed 30 pounds pressure), plies from New Orleans inland. The more usual type of boat plying inland from New Orleans may be exemplified in the steamer "Jewel," 237.92 tons, which has two 12 $\frac{1}{2}$ " by 5' non-condensing engines and two 40" by 26' return-flue boilers of steel, and allowed 181 pounds pressure. The "Jewel" has a 3 $\frac{1}{4}$ " by 11" feed-pump single-acting; the feed is heated to 180° Fahr., and the safety-valve area for the boilers is 25.13 square inches.

Steamers of Class IV are propelled in the majority of cases by stern wheels, but there are a great many screw-propellers, especially among the tug-boats. Freight- and passenger-boats have more commonly stern wheels. Simple short-stroke non-condensing engines are used upon the propellers. These have slide-valves in most cases, while the paddle-wheel engines have poppet-valves, but not without occasional exceptions. The paddle-wheel steamer "Georgie Lee," 91.19 tons, of Saint Louis, has two 9" by 3' engines with slide-valves, and in some districts, notably that of Wheeling, they are quite commonly met with. Mr. W. H. Bryant states that slide-valves were formerly much in use, but that they have been abandoned for the poppet-valve on all but small boats. The objections to the slide-valve are stated to be unreliability under high pressures, failure to open as promptly and sharply as desired, and, as usually built for river engines, excessive clearance. While these objections might doubtless be overcome by suitable designs and valve-gears and good workmanship, the poppet-valve is admitted to be better for long-stroke engines, and in spite of predictions to the contrary, we find the poppet-valve achieving a high success, even in engines for screw propulsion. There are no more creditable nor original examples of American ocean-going practice than the poppet-valve engines of the "Hudson" and the "Louisiana," but here upon the rivers the poppet-valve has a peculiar province and will probably never be displaced.

With propeller-engines, as we pass from large to small, the piston-speed is very nearly maintained, the number of revolutions increasing as the stroke shortens, but with paddle-wheel engines the speed of revolution is limited and the small engines for stern-wheel boats are slow both in piston and rotative speed. The evils peculiar to any type of valve are therefore minimized, and either poppet- or slide-valves fulfill every requirement. Some of the small paddle-wheel boats are driven by very short-stroke engines. Thus the tug-boat "Gopher," 59.88 tons, of Saint Paul, has one 10" by 12" engine, but a more usual type may be exemplified by the steamer "Last Chance," 50.47 tons, which has two 10 $\frac{1}{2}$ " by 3 $\frac{1}{2}$ ' engines. The "M. T. Powell," plying from Little Rock, Arkansas, has two 6" by 2' engines. The "Rose City," 80.69 tons, plying on Red river, has two 8" by 2 $\frac{1}{2}$ ' engines. The "Athletic," 81.76 tons, plying on the Monongahela river, has two 12 $\frac{1}{2}$ " by 4' engines. In every section of the great valley we find the same types with but little variation. In the Wheeling district we find side by side engines of the same dimensions, some with slide- and some with poppet-valves. The paddle-wheel passenger-steamer "Luella," 50.50 tons, of Gallipolis, has two 9 $\frac{1}{2}$ " by 3' engines with rotary-valves. The "Sylvan Dell," 53.08 tons, a small screw-steamer, plying inland from New Orleans, has four 12" by 8" engines. This as usual has non-condensing engines, but it has tubular heaters which raise the feed to 180°, although the boiler-pressure allowed is only 90 pounds. The feed-heaters are important adjuncts to the river engines. The "Sylvan Dell," with four 12" by 8" engines, aggregating about 2.1 cubic feet cylinder volume, has one 3" by 6" feed-pump, about .007 of the capacity of the cylinders per revolution.

The same types of engines are found upon the steamers of Classes V and VI. There are no compound engines in these classes, and condensing-engines are the very rare exception. The "S. O. Hall," plying from New Orleans to the sea and inland, has a 20" by 22" condensing-engine.

#### ENGINES OF THE MONTANA.

There are two engines with cylinders 18" in diameter by 7' stroke, of cast-iron, 1" thick at the thinnest point. The engines are right- and left-handed, but otherwise similar. They are placed at the inclination of about 6° from the horizontal. The valves are poppet, two steam-valves on one side of the engine and two exhaust-valves on the other side. The valve-stems are lifted and lowered by arms pivoted beyond the ends of the cylinder and extending to the middle, where they nearly meet, a pair of these levers on each side of the cylinder, and under them a pair of wipers or lifters upon a rock-shaft. These lifters have toes of equal length, and the rock-shaft being over the middle of the cylinder, and the lifters set at an angle with each other, they may be so arranged that two valves will be continuously open, first the steam-valve at one end and the exhaust at the other, and then the reverse alternately. This is accomplished by giving the rock-shaft a motion from what is called a full-stroke cam, a cam of two curves working within a rectangular frame, which incloses the main shaft, and is itself suitably supported in slide-bearings. If now we connect the lifters on one side (the steam-valve side) with a cam having a shorter throw, the valves would close sooner and cut off, giving the advantage of expansion of the steam, but, in order that the valves may open properly, it is necessary to use a different cam, namely: one with three points and three curves and four positive motions, where the full-stroke cam has but two. This, instead of admitting steam for half a revolution, admits it for a quarter or more of the revolution, while the full-stroke cam continues to operate the exhaust-valves as before. Such is the operation of the poppet-valve gear of a western river engine. In starting or reversing, or when full power is required, the full-stroke cam rocks both lifters and operates all four valves, but when under way the steam-lifter is connected with a new cam which operates as described. An endeavor has been made to illustrate

this action by the skeleton sketch of Fig. 31. This shows the crank and the two cams. Only the valves on the steam side are shown, the others being behind them. A is the cut-off rod shown as lifting the exhaust-valve on the right-hand side. The piston is at the beginning of its stroke and the three-pointed cam is about to throw up the left-hand toe of the nearer lifter (the steam-lifter), and to lift the steam-valve at that end. The engine is of very long stroke, and to save space the connecting-rods are shown broken, but the actual relative sizes of the parts are shown by a sketch to a smaller scale. In another illustration (Fig. 32) the cylinder is shown with its valve connections in three views of two sections through the valves. The cut-off cam is shown in the same figure. The

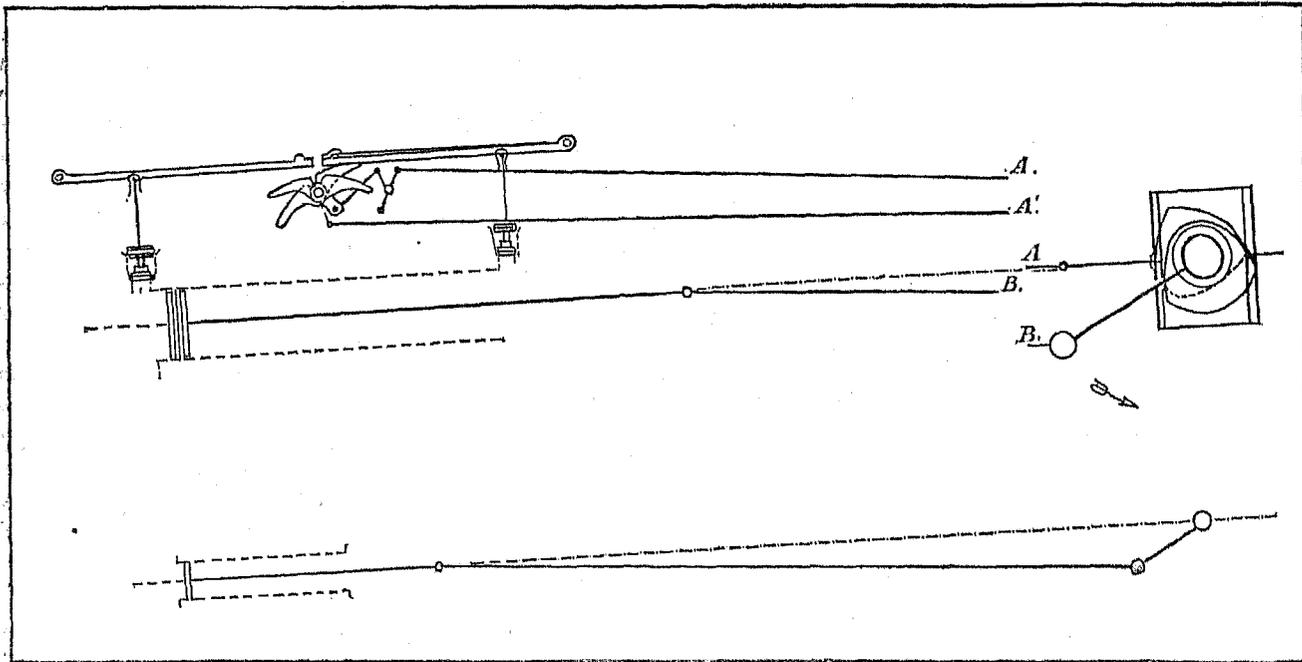


FIG. 31.

main cranks overhang outside the frame which supports the stern-wheel, and the cams are upon the crank-shaft within the frame. The connecting-rod is of wood of a cruciform section. It is strengthened by iron bands at top and under side bolted together. The cross-head journal is not strapped and keyed upon the rod on the connecting-rod side, but the iron bands of the rod extend over the journal-boxes and are keyed together on the further side. The piston-rod extends into a socket of the cross head, to which it is fastened by a single large key. It is also keyed to the piston, which has two  $\frac{3}{4}$ " copper rings, lined by a  $\frac{1}{4}$ " iron ring held out by elliptic springs secured by set screws. The rings are kept in place by a follower bolted on with square-headed bolts. The piston and follower are of cast-iron.

The distance between the center lines of the two engines of the "Montana" is 40'.5, the cranks are at right angles and the connecting rods are 30' long. The timbers which support the frame extend 18'.4 beyond the after end of the hull forming the support of the main journals and the stern-wheel and supported in turn by a system of hog-chain bracing.

	Cubic feet.
Effective volume of cylinder .....	12,375
Volume of clearance at one end .....	.8343
Total .....	13,2093

Clearance, per cent. of entire volume, 6.3.

The valves are double and balanced. Of the steam-valves the upper poppet is 5" and the lower one 4 $\frac{1}{2}$ " in diameter. Of the exhaust-valves the upper poppet is 4 $\frac{1}{2}$ " and the lower one 5" in diameter. The valve arms or levers are of cast-iron 5' 3" long, 1" thick, and 4" wide. There is a 9-pound weight on each lever and the valves are kept well seated by an effective pressure of 132 pounds at the valve-stems. The two lifters, steam and exhaust, work upon the same shaft but independently of each other.

The piston-rod is of wrought-iron and 4" in diameter. The cross-head is of cast-iron, with the pin cast in. The guides are flat 3" by 2" and 7' 6" long. They are embraced by jaws attached to the cross-head. The iron straps of the connecting rod are 3 $\frac{1}{2}$ " wide by  $\frac{1}{2}$ " thick. The sectional area of the wood is about 50 square inches at the ends and about a square foot in the middle of the rod. The crank tapers from 8 $\frac{1}{2}$ " to 4 $\frac{1}{2}$ " thick. It is shrunk upon the shaft and also upon the crank-pin. The cams are of cast-iron, made in halves and bolted to a collar forging on the main shaft.

Stern wheels have longer buckets than side wheels, but are usually of a less diameter. The wheel of the "Montana" is of wood (the usual material). It is 35' wide on shaft, and its diameter is 16' center to center of buckets and 19' over all. There are 7 sets of wheel-arms, each with 13 arms, brace together by cross-pieces. The

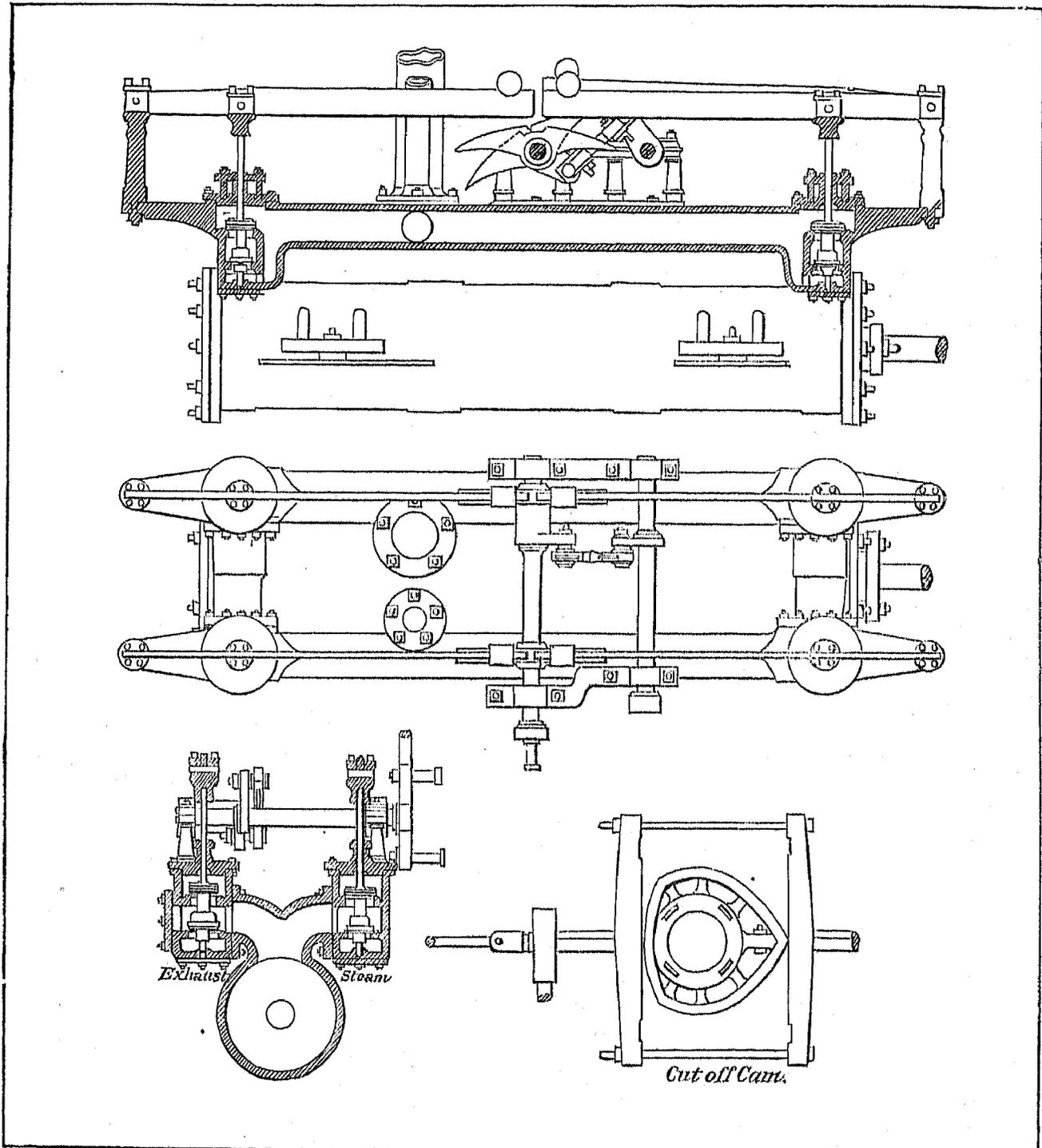


FIG. 32.

main shaft is cylindrical throughout, of wrought-iron, 40' long, 10½" in diameter, and weighing 44,026 pounds. For each set of wheel-arms there is a 44" (diameter) flange, 1" and 2" thick, and let into the arms. The buckets are oak planks bolted to the arms and extending the width of the wheel. The cranks are balanced by pine beams extending the entire width of the wheel.

The above details regarding the steamer "Montana" are mainly derived from a paper by Mr. W. H. Bryant, of Saint Louis, this paper being the most complete and comprehensive description of the western river stern-wheel boats which has yet been published.

The "Montana" makes, at the highest, 25 revolutions, and commonly 18 or 19 or less, per minute, the piston speed at 19 being 266' a minute. She is allowed 140 pounds pressure in her boilers, and, having 2 cylinders of 18" diameter, would have a nominal horse-power of about 243, based on a mean pressure of half the boiler-pressure and a piston speed of 230', or about 16½ revolutions per minute. The admission as usual for these steamers ranges from ½ to ¾ of the stroke when cut off at all, and, as some of these western river engines *discharge* their steam at half boiler-pressure, it is obvious that a much higher power is realized than appears in the nominal rating.

The slow rotative speed of these river-engines makes them easy to handle, and the engines are as usual governed by the movement of the boat.

Of the forms of poppet-valve used, the balanced valve is deservedly the most popular. The relief valve, in which a small valve opens first and relieves the pressure upon the principal valve, is also in extensive use, but the single valve, which with the high boiler-pressures used requires from a ton to a ton and a half to lift a 4" or 5" valve, is going into disuse. The great strain brought by such valves upon their actuating mechanism needs scarcely to be remarked. The balanced valves are sometimes made with poppets of equal area and sometimes, as in the "Montana's" engines, with a slight difference of area to assist in the seating of the valve.

Eccentrics are not commonly used on river engines, not giving as quick a movement of the valves as the cams. The Rees cut-off requires only one cam, the cut-off being connected with the cross-head and variable while the engine is in motion.

#### ENGINES OF THE "JOSEPH B. WILLIAMS" AND OTHER STEAMERS.

The "Joseph B. Williams," in common with a few other steamers, contains a form of engine much more elaborate than the usual type. This in the present river practice constitutes an objection to it, the ordinary single cylinder-engine being considered better adapted to the character of the service, but as a type of engine entirely unique and the principal application of the compound principle in Mississippi river service the Hartupee engine merits consideration. The principal features of the engine are exhibited in an illustration (Fig. 33) showing it in plan and elevation. This has previously appeared in the *London Engineer*. There are compound engines with a receiver called a moderator, in which the pressure of the steam is reduced before passing into the large cylinder. Steam enters the high-pressure steam-chest through the pipe marked "to boiler." The high-pressure cylinder has the usual form of poppet-valves and lifters actuating levers, but the cut-off is regulated by a link. The steam passes from the exhaust of the small cylinder, as shown, to the moderator and steam-chests of the large cylinder, which has four poppet-valves actuated directly by rock-shafts without the intervention of lifting levers. The arrangement of the exhaust from the large cylinder is shown in a separate figure, the feed being heated from the exhaust before passing to the condenser. The air-pump is independent and operated by a separate engine, which is a beam-engine. This also works the feed-pump. It will be seen from the illustration that the large main cylinder has two piston-rods, one passing on each side of the small cylinder. The size of the large cylinder relatively to the small is greater than usual in compound engines. Where the ratio of piston areas is usually 4 to 1 or less, it is here nearly 6 to 1. The dimensions of cylinders are:

	Diameter.	Stroke.
	Inches.	Feet.
High pressure.....	10	9
Low pressure.....	44	9

The stern-wheel of the vessel is 29' in diameter and 29' across, with buckets 38" deep, hung on a hexagonal shaft 35' long with journals 15" in diameter. The cranks are of wrought-iron keyed upon the shaft. The weight of the shaft is 25 tons.

Side-like stern-wheel boats are almost invariably driven by direct-acting inclined engines, and some of the side-wheel boats are very swift. The "Guiding Star" has made 17 miles an hour with 1,400 tons of cargo, and the "T. M. White" is even swifter. And while the stern-wheels are almost peculiar to western waters, the stern-wheel boats outnumbering the side-wheel boats about 3 to 1 on the Ohio, the inclined engines have in some cases displaced beam-engines in steamers on the Atlantic seaboard, notably in the ferry-boats of East Boston and Brooklyn, whose engines were designed by Mr. Charles W. Copeland.

In the West we find the regular steamboat poppet-valve engines sometimes used on land for manufacturing purposes. The engines used on small boats are commonly adaptations of the land engines of the ordinary slide-valve type with a change of valves, the poppet cut-off being usually put upon the steamboat engines. Corliss or rotary valves are not used, except in one or two cases of small boats having engines with rotary valves.

While the stern-wheel boats are not used on the Atlantic seaboard of the United States, they have been built there for South American rivers. Such a boat was the steamer "Tolima," built by Messrs. Pusey & Jones, of Wilmington, to ply upon the Magdalena river, New Grenada. This had two 13" diameter by 5' stroke simple non-condensing engines, with independent feed-pumps.

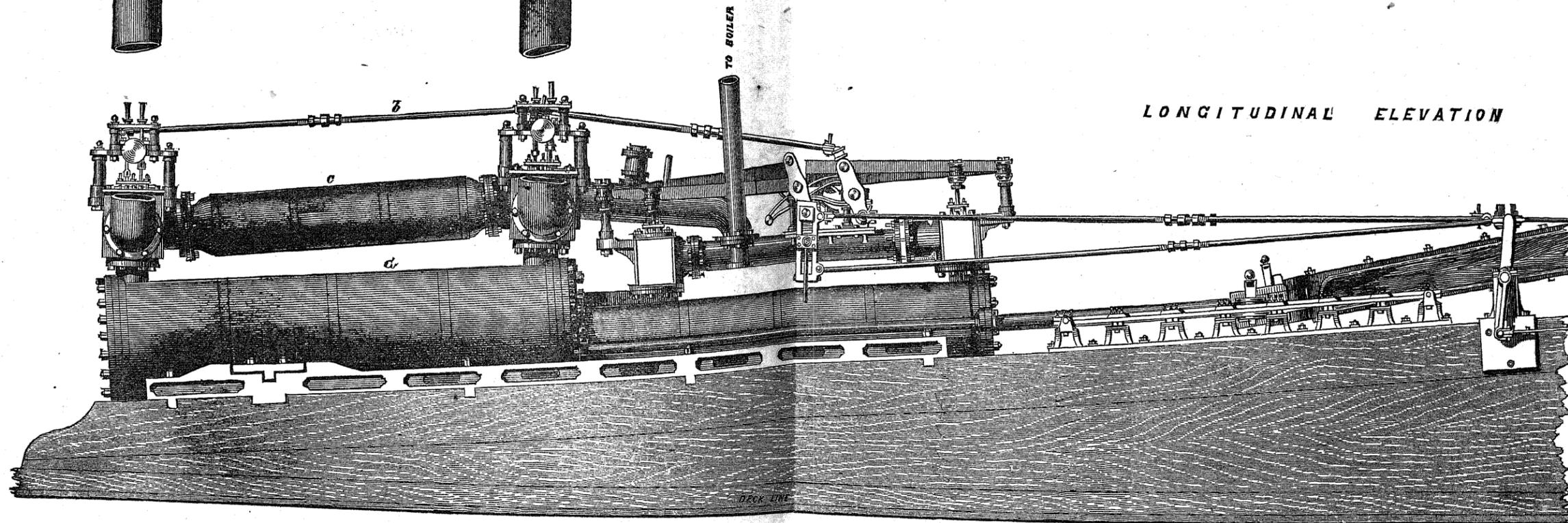
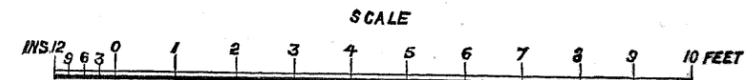
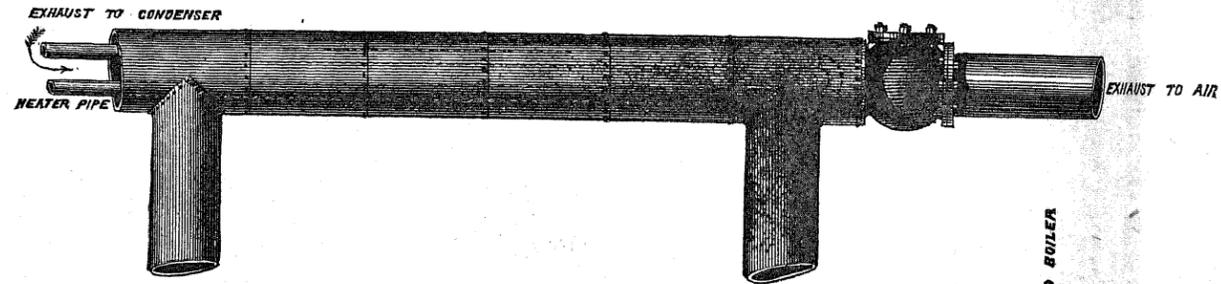
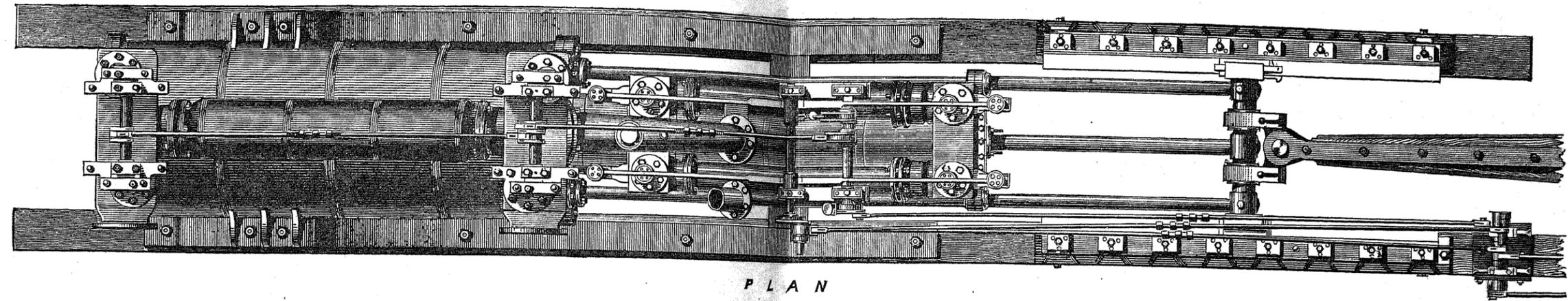


FIG. 33.

PHOTO ENG. CO. N. Y.

BOILERS OF MISSISSIPPI STEAMERS.

Upon river steamers of over 1,000 tons flue-boilers of small diameter and great length are invariably used. The following examples are given, name of steamer, number, material, and dimensions of boiler, and maximum pressure allowed :

Name.	No.	Dimensions.	Material.	Pressure.	Name.	No.	Dimensions.	Material.	Pressure.
				Pounds.					Pounds.
J. B. M. Kehloo .....	4	38" by 24'	Iron .....	150	Chas. P. Chouteau .....	4	42" by 32'	Steel .....	145
Thos. Sherlock .....	5	40" by 28'	Iron and steel ..	150	W. P. Halliday .....	5	42" by 30'	do .....	173
R. R. Springer .....	0	40" by 30'	Iron .....	150	Commonwealth .....	6	37" by 28'	Iron .....	150
Fred. A. Blanks .....	6	42" by 30'	Steel .....	173	Centennial .....	4	42" by 22'	do .....	120
Chas. Morgan .....	6	40" by 28'	Iron .....	141	City of Helena .....	5	44" by 26'	do .....	122
Guiding Star .....	5	42" by 28'	do .....	170	Grand Tower .....	5	41" by 26'	do .....	123
United States .....	7	38" by 20'	do .....	146	Ed. Richardson .....	9	42" by 32'	Steel .....	173
Gen. Lytle .....	7	37" by 24'	do .....	135	J. M. White .....	10	42" by 34'	Iron .....	150
Fleetwood .....	4	47" by 30'	Steel .....	154	Thompson Dean .....	7	37" by 30'	do .....	163
Will Kyle .....	4	42" by 30'	do .....	173	Robert E. Leo .....	9	42" by 32'	do .....	163
Wyoming .....	4	42" by 26'	Iron .....	140	Natchez .....	8	43" by 36'	Steel .....	160
Henry Frank .....	1	42" by 28'	Steel .....	134	Robt. Mitchell .....	4	40" by 28'	Iron .....	139
City of Vicksburg .....	1	44" by 26'	Iron .....	123	Annie P. Silver .....	4	42" by 32'	Steel .....	174
James Howard .....	0	40" by 30'	do .....	117	New Mary Houston .....	1	42" by 30'	Iron .....	143
John A. Scudder .....	6	40" by 26'	do .....	125	John W. Cannon .....	7	42" by 34'	Steel .....	173
City of Alton .....	5	44" by 28'	do .....	130	U. P. Schenck .....	3	42" by 30'	Iron .....	148
City of Greenville .....	5	42" by 32'	Steel .....	173					

The two-flued type of boiler is the most usual form, but some have a greater number of flues, the "City of Helena," for example, having four-flued boilers. The usual thickness of material is 1/4", although some of the above boilers are of 3/16" iron. Of the boilers enumerated above, 62 out of 173 are entirely or partly of steel.

In steamers of Class II we find the same types of boilers. The diameters in many cases are no smaller, and the reduced size is obtained by using shorter boilers, 24' and 26' being common lengths.

In Class II, 111 out of 372 boilers are of steel. Most of the boilers have two flues, but there are many four-flue boilers.

EXAMPLES OF TWO-FLUE BOILERS.			EXAMPLES OF FOUR-FLUE BOILERS.		
Name of vessel.	No.	Dimensions.	Name of vessel.	No.	Dimensions.
John B. Maule .....	4	40" by 26'	Belle of Memphis .....	5	44" by 20'
E. O. Standard .....	3	36" by 24'	Tidal Wave .....	3	38" by 22'
Belle of Shreveport .....	4	38" by 24'	St. Genevieve .....	4	42" by 24'
Iron Mountain .....	5	40" by 28'	Colorado .....	3	40" by 26'

In Class III, although there are few river boats with tubular boilers, excepting a number peculiar to the vicinity of New Orleans, there is at least some tendency in this direction, flues being in some instances more numerous and smaller. The few ferry-boats with single engines have, as a rule, short boilers, no more than 16' or 18' long. The following are examples of five-flue boilers in the Saint Louis district :

Name.	No.	Dimensions.
Belle of La Crosse .....	3	40" by 26'
Spread Eagle .....	3	38" by 20'
East St. Louis .....	3	40" by 20'
Helene Schulenburg .....	2	42" by 26'

The flues vary from 8" to 12" in diameter. For two-flue boilers the effective heating-surface in square feet is about equal to the boiler-volume in cubic feet including the flues, and the total heating-surface is about 40 per cent. more. For five-tube boilers of 40" to 46" in diameter, and 18' to 26' long, the number of square feet total heating-surface is between 1.7 and 1.8 times the number of cubic feet total volume.

Some boilers on this class of steamers have more than five flues. The "Thos. D. Fits," of Nashville, has two 40" by 18' boilers, each with nine 6" flues. The "Selkirk," 119.08 tons, of the Galena district, has two 44" by 14' six-flue boilers, and the "Col. Macleod," 171.69 tons, has two 42" by 22' ten-flue boilers. The "Aunt Betsy," 160.61 tons, a passenger-steamer of Saint Paul, Minnesota, has one 62" by 18' locomotive tubular boiler, but this is exceptional. The "Kitty Nye," 121.94 tons, plying inland from New Orleans, has a 48" by 18 1/2' locomotive-boiler in which the pressure allowed is 115 pounds. There seems to be no insuperable obstacle to the use of tubular

boilers on these river steamers as they are used in similar service on the Pacific coast, but the flue-boilers seem particularly adapted to a low grade of fuel, a low grade of water, and a low grade of management, and have thus maintained their uncontested popularity.

Of steel boilers in river steamers of this class the following enumeration is made: Saint Louis district, 34 out of 239; Galena district, 20 out of 147; Nashville district, 2 out of 22; Memphis district, 21 out of 70; Evansville district, 8 out of 41; Louisville district, 22 out of 77; Pittsburg district, 88 out of 286; Cincinnati district, 38 out of 130; Wheeling district, 21 out of 88; New Orleans district, 32 out of 161, exclusive of boilers of coasting steamers.

Upon steamers of Class IV, flue-boilers with 2 or 4 flues make up the great majority, but there are many multi-flue and tubular boilers, although scarcely any vertical. The "Jacob Tamm," 92.36 tons, of Saint Louis, has one 48" by 18' 12-flue boiler, and the "John L. Ferguson," 79.81 tons, of Saint Charles, Missouri, has one 42" by 16' boiler with 12 tubes. The ferry-boat "S. C. Clabb," 52.69 tons, plying between Saint Louis and East Saint Louis, has two 14-flue boilers 42" by 16'. The ferry-boat "Resene," 57.79 tons, of Saint Louis, has one 58" by 18' boiler with 39 tubes. The passenger-steamer "Pete Wilson," 69.36 tons, of Dubuque, has one locomotive-boiler 36" by 8'. The "Pete Wilson" is a paddle-wheel boat with a 10" by 12" engine, but the "S. C. Clabb" and the "Resene" are screw-propellers. The passenger-boat "Philip Sheckel," of Reed's Landing, Minnesota, has a 42" by 10' boiler, with water back and sides.

Many of the smaller boilers have fire-boxes. In this class in Memphis district 7 out of 26 boilers are specified as having fire-box boilers. The larger river boilers do not have fire-boxes. The usual method of setting with brick-work, and in many respects like the setting of stationary boilers, will be elsewhere illustrated. The "Madison," 53.21 tons, of Louisville, Kentucky, has one 36" by 9½' fire-box tubular boiler. Pressures continue high in these small boilers, but the average is less than in the larger sizes, quite the reverse of the case upon the Atlantic seaboard. The paddle-wheel boat "Katy Did," 84.61 tons, of Little Rock, Arkansas, has a coil-boiler or steam-generator of four concentric coils, which is allowed a pressure of 210 pounds. The paddle-wheel boat "Wild Goose," 70 tons, of Wheeling, West Virginia, has a coil-boiler which is allowed 190 pounds pressure. The "Wild Goose" has two 9¼" by 3' slide-valve engines, and the "Katy Did" two 11¾" by 4' slide-valve engines. The "Jessie," 98.46 tons, a paddle-wheel steamer plying inland from New Orleans, has one 42" by 9' vertical tubular boiler.

In this class about 8 per cent. of the total number are of steel, and in Classes V and VI there are few steel boilers. The boilers of these latter classes present few features of special interest. Where vertical tubular boilers are the prevailing type upon small steamers of the Atlantic seaboard they are the exception here. There are a great many fire-box tubular boilers, but simple two-flue boilers are found upon some of the smallest steamers. If anything, the diameters of boilers increase as we pass from the larger to the smaller steamers, for some of the smallest have boilers over 50" in diameter, while in the list of the largest steamers previously given few will be found with boilers over 42" in diameter.

#### DESCRIPTION OF RIVER-BOAT BOILERS.

The simple form of flue-boiler commonly employed on western river boats, although not the most economical of space nor furnishing the greatest amount of heating-surface, is comparatively easy to build and easy to clean. The latter is an important point in any boiler, but especially so if, as is the case on these rivers, the water is liable to contain sediment and impurities. But the feature which more than any other served to establish the plain-flue boiler in undisputed popularity is its adaptability for a low grade of fuel. Coal is now much used upon the Ohio and upon the large Mississippi river steamers, coal and wood being used in about equal quantities on the lower Missouri, while on the upper Missouri and the Yellowstone wood is the only fuel to be had. "Experience seems to show that the best results of the heating value of these fuels are obtained by mixing them in about equal quantities in the furnace."—(Bryant.) The river boilers are designed with especial reference to wood-burning, and few steamers use coal exclusively, and the abundance of fuel in some sections makes the practice wasteful.

We cannot expect the best engineering practice until necessity demands it, and even then the methods and proportions incident to wasteful practice having the force of precedent may be expected to assert themselves long after they have outlived their conditions of special usefulness. The features peculiar to boilers adapted to a low grade of fuel are such as might be suggested for a greater volume, both of fuel and products of combustion, for the same heat evolved. The grates must be large, and the fire-flues of the boiler must be large relatively to the water-spaces, for to furnish the same amount of heat a greater volume of products of combustion must pass over the heating-surface. If, however, the draught be forced, we have the same result with smaller flues. Dilute products of combustion, if we may so speak, are rapidly cooled, and low grades of fuel require relatively shorter and larger flues and larger furnaces for the same heating-surface.

The following description of the furnaces and boilers of the "Montana" (which may be taken as typical) is given in the *American Engineer* by Mr. W. H. Bryant, of Saint Louis:

In general the furnace and boilers on western river boats are placed about one-third of the boat's length from the bow. While this arrangement gives the best distribution of weight, it at the same time renders it necessary to carry the steam to the engines through a

long exposed pipe, and serious condensation may occur before the steam reaches the cylinders. This, however, can be largely reduced by properly covering the steam-pipe. To remove this difficulty altogether, and also to secure more room on the forward decks, the boilers have in some cases been placed near the after end of the boat, close to the engines themselves. This, however, gives such unequal distribution of the load upon the hull that it has not met with general approval.

The common type of furnace in use has low ash-pits, grate-surface horizontal, and from 12" to 18" from shell of boiler, and the flame-bed reaches from the top of the bridge-wall to the after end of the boiler, not more than for 3' to 6" below the shell. In the spandril between the boilers, when more than one is set in the same furnace, the combustion-chamber reaches to within a few inches of the water-line. It is lined with fire-brick only where the heat is most intense, red brick being used everywhere else. They differ from marine furnaces in being much longer, with ash-pits and long shallow combustion chambers, level grate-surface; and must often be adapted for burning particular kinds of fuel. They also differ from the usual type of stationary boilers in not having combustion-chambers as well proportioned, and, in general, using some kind of artificial draught. They differ also from the locomotive furnace in having a stationary grate near the heating-surface, return passages through boiler, large grate-surface, and high stacks.

The furnace of the "Montana" may be taken as a general type. Its detailed dimensions are as follows: The fire-box or furnace proper is 14' high under shell, and 37" high in spandril between boilers. It is 17' wide (there being four boilers, 26' long by 41" diameter, set in one furnace), 6½' long to top of bridge-wall, and lined with fire-brick.

The grate is horizontal, 17' wide by 4' 2" long, 70.8 square feet of grate-surface. The bars are the most common form, of cast-iron, having an inch space longitudinally in center, making each bar really two. The bars themselves are held 1" apart by ¾" lugs on each side, and are supported by cast-iron bearing-bars. The top of grate is 30" above main deck and 2" below bottom lining of fire-door.

There is no hearth- or coking-plate, nor is any part of the grate dead.

The mouth-pieces consist of doors, 18" wide by 14" high between the boilers, and half doors, 12" wide by 13" high, on the outboard side of the outboard boilers. Also a poker-door, 10" by 5" immediately under each boiler.

The fire-doors are of cast-iron, corresponding to the openings above named and close to them. There are two or three ¼" holes in each door to admit air above the fuel bed.

The furnace front is of cast-iron, made in several pieces so as to fit boilers. It rests on a 6" by 10" wooden beam athwart decks. It supports forward end of boilers and grate, and is lined with fire-brick.

The ash-pit is the same width and length as the grate-surface, and is 18" high to grate bars. The water of condensation from the exhaust steam in the long escape-pipe leading to smoke-stacks is run into the ash-pit to put out the live particles falling through the grate.

The ash-pit doors are of sheet-iron, and are 5 in number, 3 large and 2 small ones.

The bridge wall, immediately behind the grate, is 11' high, reached by a slope of 2' horizontal length. It is supported, together with the after end of the grate bars, by a special frame, and is lined with fire-brick tiles.

The bed of the flame-chamber slopes gradually back from the bridge, where it is only 3" below the boiler-shell, to the after end of the boiler, where it is 6" below. It consists of red brick laid in and covered by earth, the whole being about 4" thick. It is perforated by the connections of the mud and feed-water drums from each boiler. There is a 12" space between the after end of the boiler and the end of the flame-chamber, where the hot gases enter the flues. The side-walls are lined with common red brick.

There are no air-passages other than those through the ash-pit and fire-doors.

The flues are two, 26' long by 15" in diameter, in each boiler, eight in all. No bafflers are ever used, so far as we know. The smoke-box or uptake, here known as the "breaching," receives the gases from the eight flues, and extends all the way across top of boiler front. It is about 24" wide and 2' to 3' high, joined at each end to the stacks.

The stacks, two in number, are of sheet-iron, not over ¼" thick and 3' in diameter. They are 40' high above hurricane roof, and 55.3 effective height above grate-surface. The weight of each stack is borne by a 2" wrought-iron post resting on boiler-beams, and they are held in position by wrought-iron guy-rods attached at proper heights.

Blowers, or the ordinary steam-blast, are in common use to produce draught, but in general the exhaust steam is discharged into the smoke-box, or breaching, as in the locomotive. No data can be given to the economic value of the exhaust in giving additional draught, but the practical results are good.

No dampers are in use, the flue-caps and ash-pit doors answering their purpose.

## THE BOILERS.

Steamboat boilers are *sui generis*, those in use on western rivers are especially so. Similar boilers, similarly placed and connected, are seldom met with elsewhere, for they are expected to stand harder strains and work under more difficult and trying circumstances than almost any other class of boilers. The type of boiler now in use answers all requirements and gets along with less attention, and is less liable to accident than any other kind yet tried on the river, hence this type is retained.

Many years ago, when knowledge of the properties of steam was dim and misty among river engineers and firemen, and very high pressures were always carried, racing was common. The disastrous results which so often followed led to the enactment of very stringent laws governing the construction of river boilers, and to a very general prejudice, both among the public and river men, against certain classes of boilers, particularly tubular and those of over 42" diameter of shell. So general is this feeling that, so far as it is ascertainable, no boilers of those types are now in use, except on boats built and owned by the government. The great amount of sediment in the water no doubt led the closely-crowded tubular boilers to give trouble.

Through the kindness of the local inspectors at Saint Louis we are enabled to give the following outline of the principal laws governing the construction and working of river boilers:

1. Boilers must be tested at least once per year, by hydrostatic pressure; and the test applied must exceed the working-pressure allowed in the ratio of three to two.
2. Fire-line must be at least 2" below minimum water-line.
3. Water-level must be kept not less than 4" over flue.
4. Feed-water must be so delivered as not to injure boiler when entering it.
5. Fusible plugs must be placed in such position as to melt when water gets too low.
6. Boilers 42" diameter and ¾" thickness of shell may be allowed a working-pressure of 150 pounds per square inch; and this standard will be used in regulating pressures allowable on all boilers.
7. Each plate must be stamped with the number of pounds tensile strain it will bear.
8. The working-pressure allowed must not exceed one-sixth of the tensile strain of the sheets, unless the longitudinal seams are double-riveted, in which case 20 per cent. additional may be allowed.

9. The plates of boilers exposed to the action of the heat must not be over  $\frac{3}{16}$ " thick.

10. The flues or tubes must have not less than 3" clear space between and around them.

11. Steam connection joining sets of boilers must have an area of opening into each boiler of 1 square inch for every 2 square feet of effective heating-surface.

As will be noticed, these rules impose limitations on river boilers not met with on any other kind.

River boilers differ from the marine type in being of less diameter, much larger, and in using flues instead of tubes. Their cost is also smaller, being of simpler construction. They differ from the common stationary boiler in using large flues only, and in the variety of pressures in use and work done. They differ from the locomotive-boiler in having no water-space on sides of furnace, and having return-tubes.

The boilers of the "Montana" are 4 in number, of the cylindrical, two-flued type. They are 26' long, 42" diameter, with flues of 15" diameter, and are connected together to form one battery. They are made of C. H. No. 1 iron, and were built by D. W. C. Carroll, of Pittsburg, Pennsylvania.

The shell is of  $\frac{3}{16}$ " wrought-iron. The plates are 24" in length, with 1" lap at each end. Circumferentially they are single-riveted, rivets  $1\frac{1}{2}$ " apart; longitudinally they are double-riveted, rivets  $1\frac{1}{2}$ " apart, rows  $1\frac{1}{2}$ " apart.

The ends are flat,  $\frac{3}{4}$ " thick, flanged inward 3" to join cylindrical portion, rivets  $1\frac{1}{2}$ " apart.

The steam-chest or dome is horizontally cylindrical, extending across top of boilers, and is connected with each one by a 14" leg. Its center is 16" above top of shell, and it is 15' long and 20" inside diameter.

The furnace is entirely external, and has already been described.

There are 2 internal flues, 15" in diameter and of  $\frac{1}{2}$ " wrought-iron. At the after end the  $\frac{1}{2}$ " end-plate is flanged outward, incasing the projecting end of the flue, to which it is then riveted. This arrangement is supposed to offer the least hindrance to the passage of the hot gases. The top of flues is 17" below top of shell, and the two flues are 18" between centers, leaving 3" clear space between them.

There is 1 man-hole, 9 $\frac{1}{2}$ " by 15", in the after end of each boiler; its lower edge is  $\frac{3}{4}$ " below low-water line, 13 $\frac{1}{4}$ " from top of shell. To strengthen the boiler a wrought-iron elliptical ring  $\frac{3}{4}$ " thick is riveted around the man-hole. The man-hole cover is of cast-iron, and of the ordinary shape.

There is a hand-hole, 4" by 6", in the lower part of forward end; its lower edge is 2" from shell. It is not strengthened in any way.

There is no superheating area or apparatus connected with these boilers.

The feed apparatus is the usual "doctor," using the upright outside-plunger rotary-pump. It has two sets of pumps; the first draws the water from the river into the heater, and the second forces it into the boiler at a temperature of about 180° and a pressure of often 150 pounds per square inch. The pumps are 5" diameter by 13" stroke. The Snowden heater, a type of open heater in common use on western rivers, is here employed.

No surface blow-off is in use, but the ordinary bottom mud blow-off apparatus is attached to the mud-drum.

Two mud-drums are used as sediment collectors. One of them is placed at the second sheet from the after end of the boiler and the other just aft of the bridge wall. The feed-water passes through the after one, and the former one is used as the principal blow-off. They are 15' long by 16 $\frac{1}{2}$ " inside diameter, with center lines 20" below bottom of shell. They are set up at right angles to center line of boilers, and are joined to each boiler by 8" cylindrical legs.

A copper steam-pipe, 6" diameter, leads from steam-drum to throttle.

The safety-valve is of the ordinary weight and lever type, one on each boiler. Each valve has an area of 11 square inches. The lever is 4' 3" long, notched at intervals. The weight is 9 $\frac{1}{2}$ " by 9 $\frac{1}{2}$ " by 8, of cast-iron, and weighs 200 pounds. It is set to blow off at 140 pounds pressure per square inch, and its position must be 31" from fulcrum, or 27" from valve-stem.

Fusible plugs are put in top of flues and in shell just below water-line.

One pressure-gauge is placed at the throttle and one at front of boilers for guidance of firemen.

Two kinds of water-gauges are put on each boiler. The ordinary gauge-cocks, ten on the four boilers, and one low-water globe-gauge on each.

The ends of the boilers are strengthened by stay-rods joined to the shell, two at each end of each boiler. They are  $1\frac{1}{2}$ " wrought iron and ends are riveted to shell and boiler-heads.

The only clothing the boiler has is a covering of red bricks laid in sand. The spandrils above top of combustion chamber are filled with mortar.

Each boiler is supported by a  $\frac{1}{2}$ " wrought-iron ring, 3" wide, riveted to the boiler and resting on the boiler front. This in turn rests on a 6" by 10" wooden beam, resting on main deck. At the after end of the boiler the support comes through the mud-drum, which is carried by cast-iron legs, 3" by 5", resting on a 5" by 12" wooden beam, similar to the one at the forward end.

Under the boilers the hull framing is much strengthened. Just under the forward and after supports "boiler beams" and braces, forming a truss, are placed, and between a pair of deck-beams is fixed a pine beam, 15" by 10", 15' long, joining at each end to a curved oak beam, 9" by 7", resting in a shoe on the outer row of bottom stringers. This end is tied to the one on the opposite side of the boat, by a wrought-iron bar, 2 $\frac{1}{2}$ " by  $\frac{1}{2}$ ". The weight of the boiler and contents is thus distributed more uniformly over the boat's bottom.

#### GENERAL DESCRIPTION.

Number of boilers.....	4
Number of furnaces.....	1
Grate area.....	70.8
Total heating-surface.....	1,431.2
Effective heating-surface.....	1,022.6
Square feet total heating-surface per square foot grate area (about).....	20
Best practice (Shock).....	25 to 35
Square feet effective heating-surface per square foot of grate area.....	14 $\frac{1}{2}$
Square feet calorimeter through flues.....	9.82
Square feet grate-surface per square foot of same.....	7.2
Best practice (Shock).....	5 to 8
Square feet area stacks (2).....	14.14
Square feet grate-surface per square foot of same.....	5
Best practice (Shock).....	6 to 9

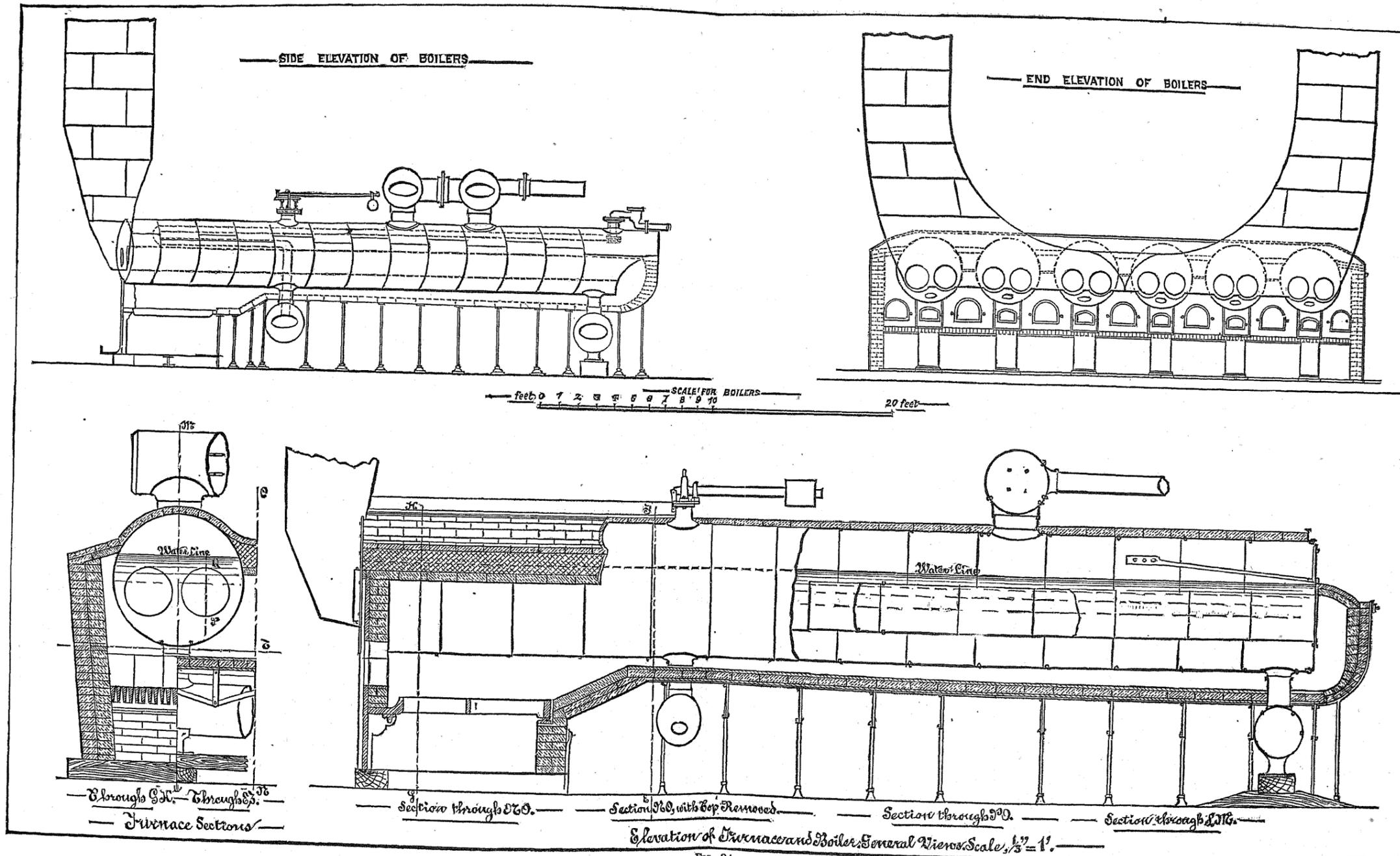


FIG. 34.

Square feet calorimeter over bridge.....	15.27
Square feet grate-surface per square foot of same.....	4.6
Best practice (Shock) .....	7 to 8

(But with forced draft this must be less, and present proportions are nearly correct.)

Height of stack above grate .....	feet..	53.3
Total cubic feet steam room .....		562.26
Total cubic feet water room .....		204.4
Same in United States gallons.....		2,208
Total estimated weight of four boilers, with steam dome and mud-drums.....	pounds..	29,263.7

(The weight of other attachments to boiler will bring this up to 15 tons.)

Weight of stacks.....	pounds..	2,357
Weight of grate.....	do.....	5,700
Weight of water in boilers .....	do.....	18,350.9
Total weight of boilers, water, stack, grate, etc.....	do.....	55,671.6
Height of boilers from deck to top of shell .....		7' 2"
Height of boilers from deck to top of dome.....		9' 5"
Length taken up in vessel by boilers, etc .....		29' 7"
Length, including fire-room and coal-bin.....		40'
Width of same .....		19' 3"
Area displaced in vessel .....	square feet..	77.2

In the above description, the term "furnace" is applied to a battery of several boilers.

The illustration, Fig. 34, exhibits two batteries or sets of river-boat boilers, the upper part showing two views of the boilers of the "Joseph B. Williams," and the lower part two views of the boilers of the "Montana." These represent the best class of boilers on the Mississippi valley steamers, and are very similar in general design and arrangement, both having furnaces between the cylindrical boiler-shells and a like arrangement of breeching and supports. The six boilers of the "Joseph B. Williams" are 40" by 28', of steel, shells  $\frac{3}{16}$ " thick, 174 pounds pressure allowed, while those of the "Montana" are four in number, 42" by 26', of iron, shells  $\frac{3}{16}$ " thick, 140 pounds pressure allowed. The "Joseph B. Williams" has two smoke-stacks, each 56" in diameter and 56' high.

The great relative size of boilers upon the Mississippi steamers is only with respect to the pressures. Actually the low-pressure boilers of the Atlantic are upon average larger for the same tonnage than the river-boat boilers, but in Class III, for example (steamers between 500 and 1,000 tons), multiplying the average boiler-volumes per 100 tons by the average boiler-pressures, we have the following products for the several districts specified:

Gulf district (Mississippi).....	24,548
Lower Ohio district.....	24,230
Upper Ohio district .....	21,596
Saint Louis district .....	16,670
Upper Mississippi district .....	14,638
Pacific district (with Columbia river boats).....	14,460
South Atlantic district.....	12,603
Western lake district.....	12,462
Eastern lake district.....	10,384
Middle states district.....	10,368
New England district .....	8,394

Where the "Dacotah" and the "Montana," of the Mississippi river, with about 25 cubic feet cylinder (of engine), each have about 1,000 cubic feet of boiler-volume, the "Harvest Queen," of Columbia river, Oregon, with tubular boiler and the same pressure (140 pounds), has about 670 cubic feet of boiler-volume to about 35 cubic feet of cylinder.

The arrangement of boilers on the river boats has been mentioned as requiring a great length of steam-pipe. The size of steam-pipe is a matter of engineering computation rather than a subject for statistics, but the saving in first cost of steam machinery by the use of high-pressures on the Mississippi steamers may be strikingly illustrated by a few comparisons. Where the main steam-pipe for the engine of the "Mary Powell" is 2' in diameter, that of the "Montana," a boat of about the same tonnage, is only 6"; that of the "J. B. M. Kehloc," one of the largest steamers on the Mississippi, is only 7" in diameter, and that of the powerful engines of the "J. M. White" is 12", being uncommonly large for the Mississippi, while much smaller boats on the Atlantic have 15" or 18" steam-pipes.

PROPORTIONS AND ARRANGEMENT OF STEAMERS.

While there are some swift boats upon the western rivers they are principally side-wheel boats, stern-wheel boats not usually exceeding a speed of 10 miles an hour, although some state the maximum speed at 12 miles an hour. The stern-wheel boats, as peculiar to this section and as constituting about three-fourths of all the river steamers of considerable size, merit the chief attention, but the side-wheel passenger-steamers are also an important

type, their most characteristic feature being the employment of paired engines of long-stroke inclined from the horizontal. Of the proportionment of large side-wheel steamers upon the rivers of the Mississippi valley as compared with eastern practice, the following are fair examples :

Name.	Locality.	Tons.	Length.	Breadth.	Depth.	Ratio length to breadth.	Ratio breadth to depth.
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>		
J. M. White .....	Mississippi river .....	2,027.76	312.6	47.8	10.2	6.55	4.68
Newport .....	Long Island sound .....	2,151.51	342.0	43.0	14.0	7.95	3.07
Guiding Star .....	Ohio river .....	1,121.97	304.0	41.6	7.1	7.31	5.86
Laura .....	Long Island sound .....	1,098.31	232.4	35.4	11.4	6.56	3.11
Bostona .....	Ohio river .....	993.52	362.0	48.4	6.0	7.17	7.23
Daniel Drew .....	Hudson river .....	930.35	260.0	30.0	10.0	8.66	3.00

The "Bostona" has side-wheels 27' in diameter and 16' face, and the "J. M. White" has side-wheels 44' in diameter and 19' face.

The "Wyoming," 1,034.15 tons, is one of the best examples of a stern-wheel boat. It is 257' long, 45'5" broad, 6'3" deep; ratio of length to breadth, 5.65; ratio of breadth to depth, 7.22. The "Dacotah," 956.48 tons, is 252' long, 48'8" broad, 5'5" deep; ratio of length to breadth, 5.16; ratio of breadth to depth, 8.86. A third example of a stern-wheel boat is one whose engines and boilers have already been illustrated, the "Montana." This has a registered tonnage of 959.47; length, 250'; breadth, 48'8"; depth, 6'; ratio length to breadth, 5.12; ratio breadth to depth, 8.13. The "Joseph B. Williams," 801.91 tons, is 220' long, 40' broad, 6'5" deep; ratio length to breadth, 5.5; ratio breadth to depth, 6.15. The "Mollie Moore," 601.70 tons, is 238' long, 40'4" broad, 5'2" deep; ratio length to breadth, 5.88; ratio breadth to depth, 7.77. Scarcely any boats that ascend the Mississippi are over 10' deep, that being the depth of the "James Howard," 2,321.44 tons, while the "J. B. M. Kehloe," 2,293.78 tons, has a depth of only 8'5", and the great majority of boats are less than 7' deep. The draft of these boats, when heavily loaded, is a good part of their depth. The "Montana," 6' deep, draws 5½' of water (with a load of 1,300 tons).

Glancing over the data of the above boats, we notice that the ratio of breadth to depth is usually greater in the stern-wheel than in the side-wheel boats. Thus for five stern-wheel boats it is 8.86, 8.13, 7.77, 7.22, and 6.15, while for three side-wheel boats it is 7.23, 5.86, and 4.68. The ratio of length to breadth is also less in the stern-wheel boats, being 5.88, 5.65, 5.5, 5.16, and 5.12 in five cases, while in three side-wheel boats it is 7.31, 7.17, and 6.55.

Stern-wheels are of smaller diameter than side-wheels but of great relative width. Upon stern-wheel boats the boilers are placed forward in a position similar to that usual upon side-wheel boats, but as the machinery is placed so much farther back in the former, it is sometimes balanced by placing the boilers farther forward. The stern-wheel construction saves a great weight of wheels and housings, and under the same load and with vessels of similar length the stern-wheel boat will draw only from half to two-thirds as much water as the side-wheel boat. It also affords more deck-room and is better adapted for freight service.

It is also said that in the elements of speed and adaptability for passenger traffic the latest stern-wheel boats approach very nearly the best side-wheelers. The "Montana" runs from Saint Louis to Pittsburg and return in about 18 days actual running time. This may be very good time for a freight-boat, but it could hardly be called high speed. Western river steamers are flat-bottomed boats, more or less carefully modeled, especially near the stem, and with a shear at the stern to facilitate backing and steering, as several rudders instead of one have often to be used upon boats with square sterns.

Of the stern-wheel steamer "Montana," the weight of hull (of oak and pine) is estimated to be about 310 tons, and an iron hull would probably weigh less than two-thirds as much. The bottom of the boat is slightly concaved near the stern, which is of advantage in reversing and increases the efficiency of the rudders in going forward. The keelson is entirely within the hull. The "Montana" has four rudders, two balanced rudders near the middle of the stern and two wing-rudders, one near each corner. The wing-rudders are 6' or 8' long and 6' high. The displacement of the "Montana" is about 594 tons when drawing 18" forward and 26" aft, and about 1,855 (net) tons when drawing 5' 2" amidships under a load which causes the guards to touch water.

The arrangement of hog-chains and braces is in several systems of trusses both fore and aft, and across decks in some steamers. In Fig. 36 is shown a deck-plan of the "Montana," exhibiting the arrangement of boilers and engines and the positions of eight fore-and-aft trusses, beside the trusses which support the timbers bearing the stern-wheel. The "Montana" has no cross-deck systems, but has an additional system of fore-and-aft trusses on each side, which is commonly dispensed with. Side-wheel boats have these cross-deck trusses to support the guards and wheels, and many wide stern-wheel boats have them ranged about 20' or 30' apart. When a steamer is improperly loaded, or when, as is often the case, she gets aground, an immense strain may be brought upon these hog-chains. The flat bottoms of the boats are also designed with reference to their being stranded.

In Fig. 35 is exhibited a sheer plan of the towing-boat "Joseph B. Williams," showing the wheel, engines, principal boilers and smoke-stacks, and other details. The smoke-stack of auxiliary boilers for supplying steam for the engines of four steam-capstans is seen near the main engines. This boat is smaller than the "Montana,"

SHEER PLAN.

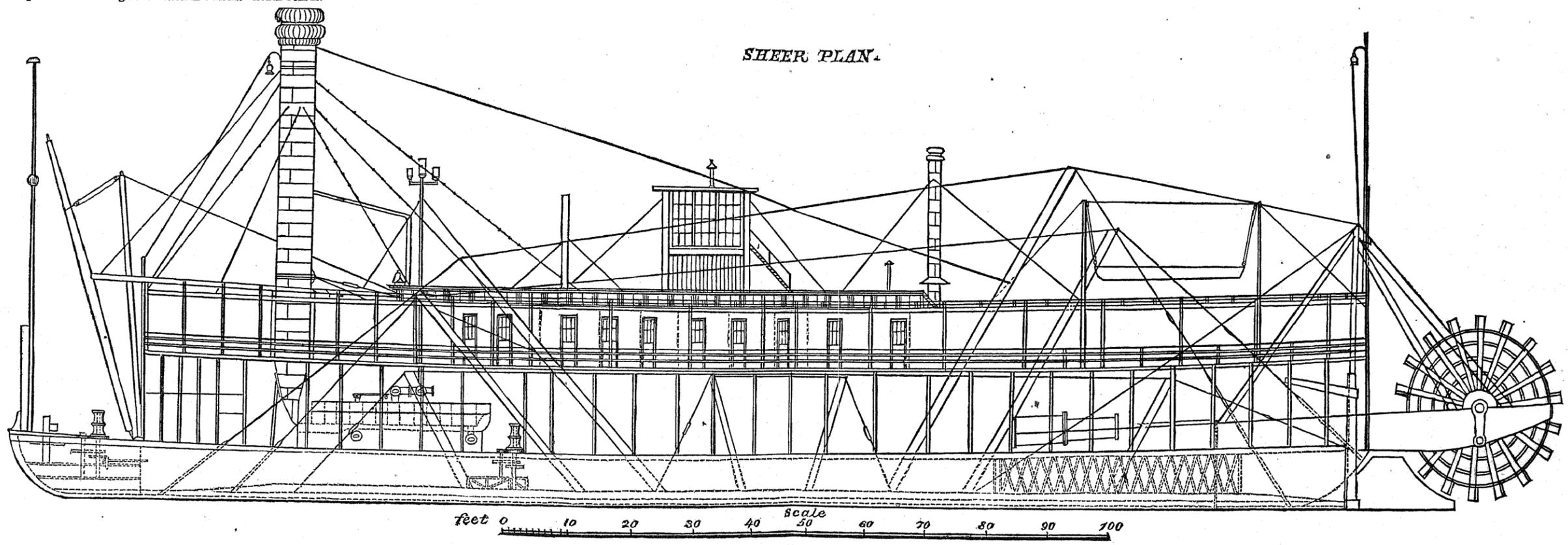


FIG. 35.

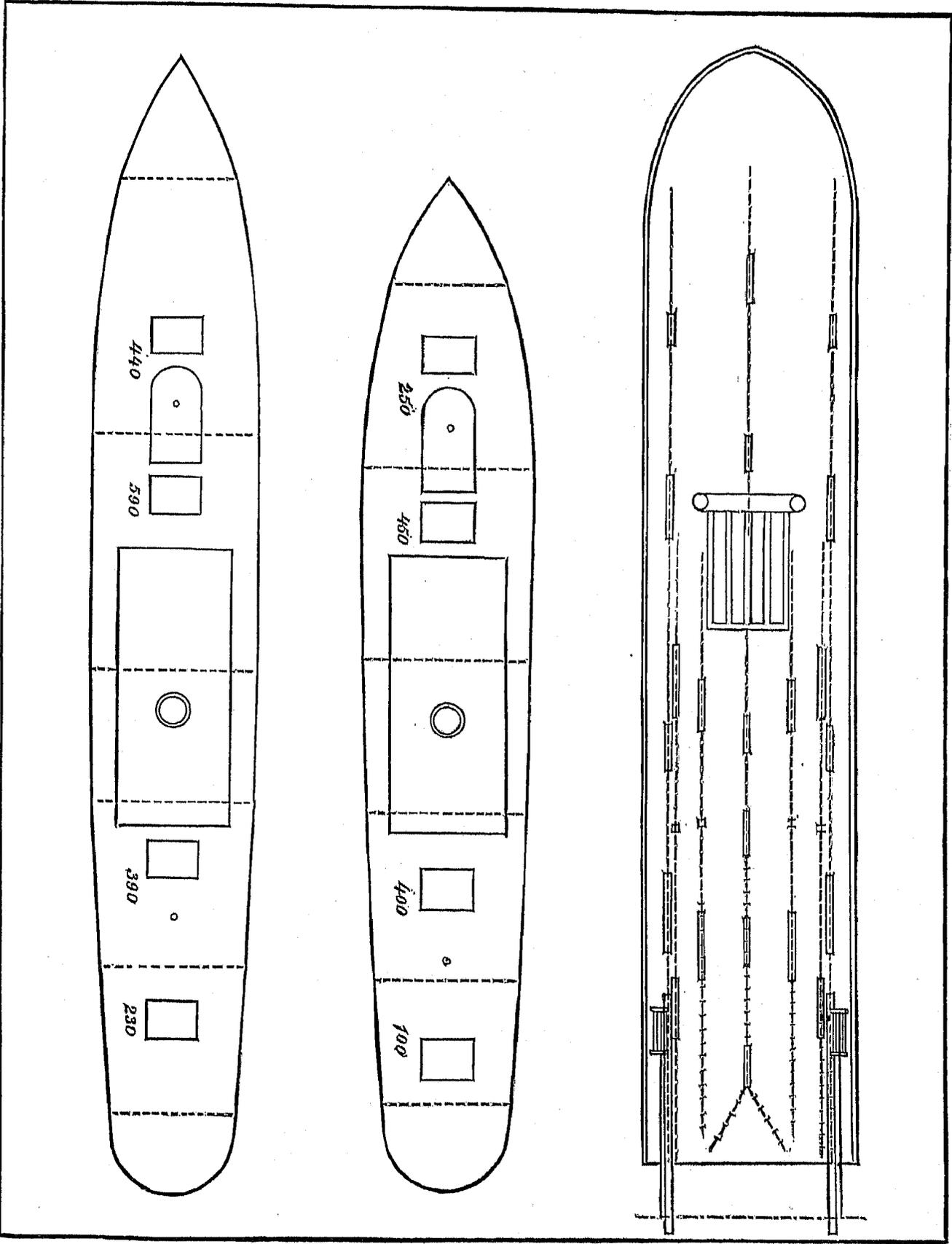


FIG. 86.

but it has very powerful engines. It carries 456 tons of coal on deck and consumes 27 tons a day as fuel. The towing capacity of the "Joseph B. Williams" is very remarkable, and illustrates the value of free inland waterways and the comparative cheapness of river transportation when contrasted with coasting traffic. In Fig. 36 are shown three plans of steamers, one of a stern-wheel river boat somewhat larger than the "Joseph B. Williams," while the others are of two Reading colliers—the "Perkiomen," which carries 1,200 tons, and the "Pottsville," which carries 1,650 tons of coal. The difference in plan itself presents a striking contrast between river and ocean practice. Upon the plans of the colliers, the large rectangle incloses the machinery and boiler space, with the smoke-stack. Smaller rectangles show the hatches, and very small circles the masts. The pilot-houses are also shown, and the numbers of tons accommodated by the several cargo spaces between the dotted cross-lines are marked in figures. In a year's time the "Perkiomen" made 41 voyages, carrying about 50,000 tons of coal and running in all nearly 39,000 miles. In a year the "Pottsville" made 41 voyages, carrying about 69,000 tons of coal and running in all nearly 38,000 miles. But the "Joseph B. Williams," in a *single* trip from Louisville to New Orleans, towed 32 coal-boats and barges, carrying 23,000 tons of coal, in one voyage transporting as much as the "Pottsville" would have done in one-third of a year or the "Perkiomen" (a boat of greater tonnage) in more than half a year. The "Pottsville" "cleared" 11 acres of 4' coal-seam in one year, but the "Joseph B. Williams" "cleared" about 6 acres of 4' coal-seam in a single voyage.

The average rate of freight received per ton of coal by the Reading colliers was as follows:

Year.	Rate.	Year.	Rate.
1872.....	\$2 03	1876.....	\$1 00
1873.....	2 32	1877.....	1 09½
1874.....	1 20	1878.....	01½
1875.....	1 15	1879.....	1 07½

The freight-bill for this trip of the "Joseph B. Williams" amounted to \$11,500, or 50 cents per ton of coal.

Of a smaller stern-wheel boat, a good illustration is furnished by the "Tolima," a boat shown in plan and elevation in Fig. 44. This boat is 100' long, 24' broad, and 3½' deep. It carries in all 50 tons on a 1' draft, 100 tons on a 2' draft, and 160 tons on a 3' draft. It has a locomotive tubular boiler and a knock-down smoke-stack, being built for South American river service.

There are many small ferry-boats upon the smaller rivers. These are sometimes propellers, but often side-wheel steamers. The snag-boats are sometimes stern- and sometimes side-wheel boats. There are in the Mississippi valley comparatively few steam boats of small tonnage.

LAKE STEAMERS.

DISTRIBUTION OF THE SERVICE.

The following groups of steamers will specify the locality and character of the service comprehensively and with as much detail as the subject conveniently admits:

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Steamers making long trips between the principal cities, Buffalo, Chicago, Milwaukee, Duluth, and Detroit. <sup>a</sup>	44	62,751.00	66	2,670.00
	22	18,718.86	24	588.78
Plying between Ogdensburg and Chicago.....	3	574.01	3	13.71
	1	80.00	1	0.54
Steamers plying upon the Illinois river. (See also Mississippi river steamers for boats plying below Peoria.)	1	536.08	2	44.00
	8	1,240.05	14	77.32
	13	1,178.31	19	12.70
	1	30.84	1	4.83
	5	64.73	6	2.25
Plying upon the Saint Lawrence river, not otherwise specified...	2	200.85	4	10.46
	7	554.07	7	16.61
	8	270.81	8	5.87
Plying in the vicinity of Chicago and Milwaukee, including canal service.	17	130.60	17	2.95
	4	550.71	7	10.25
	8	623.77	10	20.01
Plying in the vicinity of Buffalo and Erie and upon the Niagara river.	40	1,422.76	52	108.32
	28	461.08	30	29.58
	3	688.06	4	33.03
	6	373.62	6	21.41
	14	402.90	10	25.37
	40	654.32	49	34.83

<sup>a</sup> The heaviest part of the traffic is between Buffalo and Chicago, but many of the large steamers also run to Duluth, and stop at Milwaukee or at Detroit. It is needless to remark that these are the largest and most important steamers upon the lakes.

## MARINE ENGINES AND STEAM VESSELS.

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Plying from Buffalo and Erie to New York (canal service).....	26	3,413.53	26	83.59
Plying upon lake Saint Clair, the Detroit river and vicinity as far as Sandusky.	4	1,428.42	4	147.91
	7	493.02	7	9.83
	8	304.20	8	12.86
	16	183.00	16	8.06
Plying upon and from Green bay and tributaries .....	9	2,588.92	13	81.02
	14	1,043.46	27	50.36
	24	961.99	37	51.07
	22	348.21	28	14.59
Plying mainly along the east shore of lake Michigan.....	3	1,800.83	3	134.00
	24	6,952.72	26	165.71
	14	953.61	16	45.86
	28	1,020.05	32	52.62
Plying mainly along the west shore of lake Michigan, north of Milwaukee and south of Green bay.	39	567.17	42	26.16
	3	729.18	3	10.40
	1	75.00	1	2.05
	1	95.41	1	2.65
Plying mainly in the vicinity of Grand Traverse bay and the straits of Mackinaw, and to the fishing grounds.	3	25.86	3	2.24
	1	1,153.33	1	14.78
	1	335.64	1	12.28
	1	87.37	1	5.27
Plying mainly on and from Thunder and Saginaw bays.....	10	587.10	21	28.44
	32	513.24	34	14.54
	4	2,492.05	5	113.28
	17	4,774.70	19	442.19
Plying upon lake Superior, not otherwise specified.....	11	323.00	14	43.60
	11	376.14	11	17.41
	23	385.26	25	16.14
	2	624.14	2	44.47
Plying upon lake Champlain.....	9	580.14	11	43.15
	14	474.68	16	29.90
	23	284.00	24	12.80
Plying from Oswego and upon lake Ontario, not otherwise specified.	1	1,124.53	1	205.20
	1	643.14	1	105.50
	4	750.41	4	98.87
	7	455.86	7	42.19
Plying from Chicago and Milwaukee, not otherwise specified. Such steamers are engaged in a general lake service, which can not be more distinctly detailed.	2	70.26	2	2.31
	11	102.79	18	3.56
	3	381.28	3	16.08
	3	234.44	3	6.11
Plying from Detroit and Toledo, not otherwise specified .....	8	277.57	10	11.81
	17	228.83	18	11.56
	4	4,746.71	5	198.13
	8	5,146.07	9	425.28
Plying from Port Huron and Algonac, not otherwise specified....	8	3,069.80	8	146.28
	4	261.85	6	17.03
	6	215.05	7	14.73
	4	78.07	4	6.70
Plying from Cleveland and Sandusky, not otherwise specified....	11	13,057.25	16	834.14
	12	8,420.77	12	885.34
	42	10,322.34	48	605.38
	5	403.86	6	29.04
Plying from Buffalo and Erie to New York (canal service).....	1	34.85	1	2.05
	17	202.17	17	13.93
	4	2,603.63	6	69.15
	21	5,658.78	21	155.88
Plying upon and from Green bay and tributaries .....	4	328.01	4	6.38
	1	36.79	1	2.05
	3	32.77	3	0.88
	2	2,752.38	3	120.60
Plying mainly along the east shore of lake Michigan.....	8	6,988.80	10	143.80
	21	5,410.55	22	198.79
	0	698.77	10	28.43
	18	648.74	26	37.61
Plying mainly along the west shore of lake Michigan, north of Milwaukee and south of Green bay.	20	270.04	26	19.10

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Plying from Buffalo and Erie upon the lakes, not otherwise specified.	20	25,944.59	28	759.98
	5	3,349.12	5	75.60
	11	2,545.21	16	133.30
	2	151.16	2	9.17
	2	88.87	2	4.98
	3	66.07	3	4.98

To the casual observer in glancing over these figures it may appear that the aggregate cubic feet cylinder capacity of engines in certain groups is sometimes disproportionately large compared with other groups of steamers of nearly the same aggregate tonnage. This is an indication of the larger employment of long-stroke paddle-wheel engines, while the smaller relative cylinder-capacities are peculiar to short-stroke engines driving screw-propellers.

ENGINES OF LAKE STEAMERS.

If compound and condensing engines be considered the standard of economy, the most advanced American practice in marine engines is found upon the large lake steamers. The following table presents by ports of inspection the numbers of engines used in propelling steamers of over 1,000 tons, the numbers of compound, simple-condensing, and simple non-condensing engines, and the numbers of engines used in driving screws and paddle-wheels :

Port of inspection.	No. of engines.	Type.			Used in driving—	
		Compound.	Simple-condensing.	Non-condensing.	Paddle-wheel.	Screws.
Buffalo.....	64	48	13	3	0	61
Cleveland.....	21	2	15	4	0	21
Detroit.....	20	6	12	2	3	17
Milwaukee.....	5	2	2	1	0	5
Chicago.....	4	1	3	0	0	4
Port Huron.....	2	2	0	0	0	2
Marquette.....	2	0	2	0	0	2
Burlington.....	1	0	1	0	1	0
Grand Haven.....	1	0	0	1	0	1
Total.....	120	61	48	11	4	110

In the relative showing of compound and condensing engines on large steamers, no other section of the United States will compare with this. These boats are almost invariably freight-boats, and as finely-built engines are put into them as into the finest passenger-boats. They make long runs and carry heavy cargoes, and economy of fuel is a more important consideration than upon the rivers of the Mississippi valley. The passenger-boats are more commonly of the side-wheel type with beam-engines, although some of the large propellers do a mixed freight and passenger traffic.

The compound engines are mostly of the steeple type, the high-pressure cylinder being placed above the low-pressure cylinder, but in other cases the cylinders are placed fore and aft, as is usual upon the Atlantic seaboard. In most of the steeple engines the high-pressure cylinder is made half the diameter of the larger cylinder.

Examples of steamers with fore and aft compound engines: The "Thos. W. Palmer," 1,096 tons, of Detroit, is 205'.8 long, 34'.5 broad, and 17'.7 deep. It has one 27" and 44" by 40" engine, the smaller cylinder forward. The steamer "Amazon," 1,406.87 tons, had twin screws, driven by double compound engines 20" and 40" bores by 30" stroke. These engines were built at the Onyaboga works in Cleveland. The twin screws were 8' 9" in diameter, and 13' in pitch.

The following are examples of steeple compound engines: The "Boston," 1,829.52 tons, is a steamer 263'.2 long, 36' broad, 15'.4 deep. It has two steeple compound engines 20" and 40" bores by 42" stroke. The steamer "Wocoken," 1,400.37 tons, of Cleveland, has a 30" and 56" bore by 48" stroke steeple compound engine. The propeller-wheel is 11' in diameter and 15½' in pitch.

The "Waverly," 1,104.02 tons, is a steamer 191'.2 long, 33'.7 broad, 13'.45 deep. It has one steeple-engine 24" and 54" bores by 36" stroke, driving a propeller-wheel 11' in diameter and 15' in pitch. The steamers "Delaware" and "Conestoga," plying between Buffalo and Chicago, have each one 24" and 48" by 48" steeple compound engine, driving a screw 11' in diameter and 15' in pitch.

The new steamers "City of Rome" and "Cumberland" have compound engines with cylinders fore and aft, dimensions 32" and 60" by 48", driving propellers 12' in diameter by 14½' pitch. For most of the foregoing steamers there are double feed-pumps, each having a 5" plunger with 8" stroke, and an air-pump 26" in bore by

14" stroke. Sixty-five to 75 revolutions per minute is the ordinary speed of engines, and the steamers are slow, making 8 or 9 miles an hour with a coal consumption of about a ton an hour. The usual draft of these steamers is 13' or 14' on the even keel.

The following description is given of the steeple-engines of the "Buffalo" and the "Chicago," of the Western

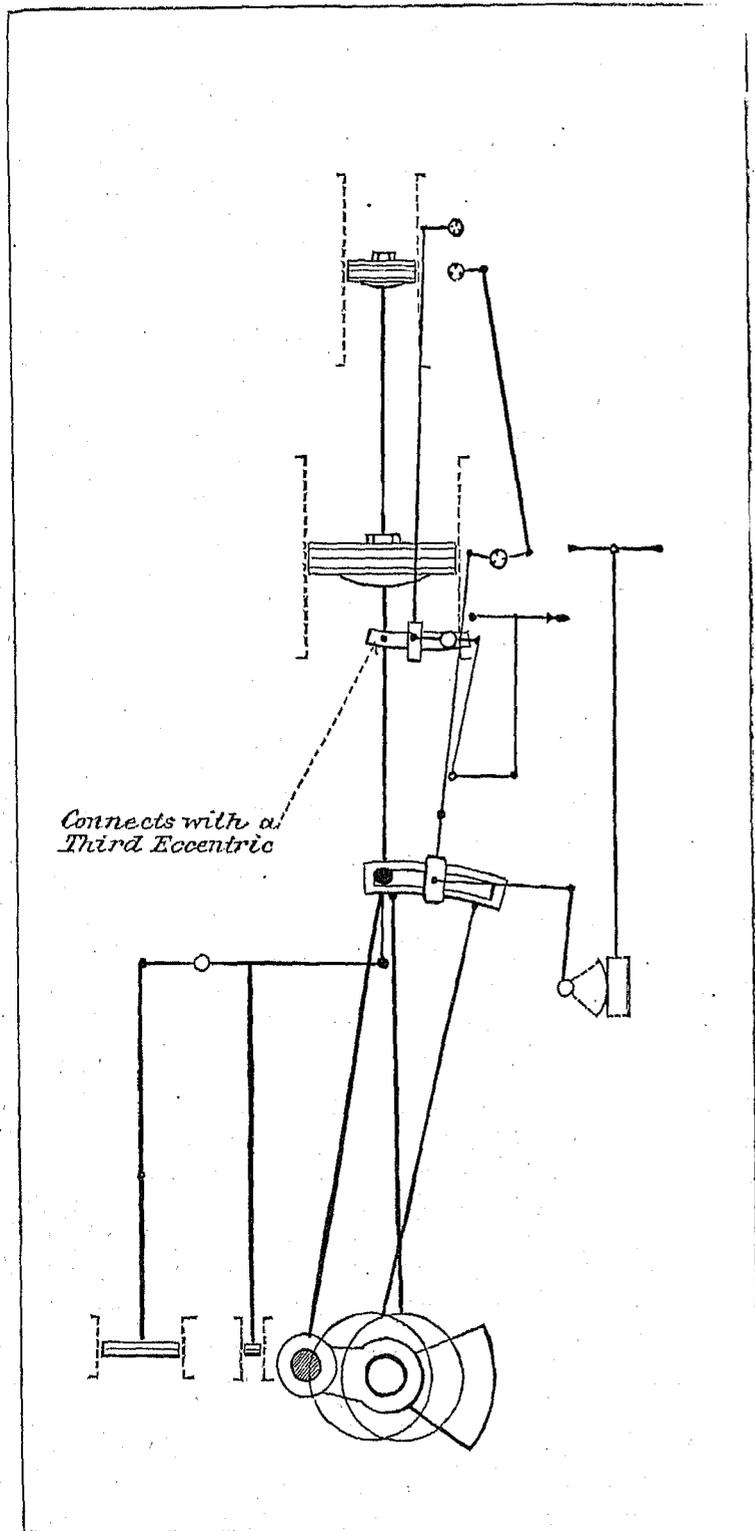


FIG. 37.

Transportation line. These engines were built at the Globe Iron Works, Cleveland, in 1878-'79. The "Chicago," 1,847.37 tons, is 265' long, 36'.8 broad, and 16'.4 deep. The "Buffalo," 1,762.85 tons, is 258'.8 long, 35'.9 broad, and 16'.2 deep. The engines are identical, two with four cylinders upon each steamer. They have rotary-valves and the general arrangement is illustrated in Figs. 37 and 38. Fig. 37 is a sketch in skeleton designed to show more clearly the connections of the moving parts and of the valve-gearing. In this figure fixed bearings are indicated by open circles and the framing is not drawn. At the right is indicated a hand-wheel with a screw operating a sector of a worm-wheel upon a rock-shaft, by which the link may be shifted. At the left the air- and feed-pumps are shown. The other figure shows the exterior appearance of the cylinders and connections. Since, for the sake of clearness, shading and details of the supporting frame are omitted, it ought to be said that for handsome and thorough workmanship these engines are to be highly commended. In the figures only one engine is shown in side view, there being two engines combined, two 20" by 40" cylinders and two 40" by 40" cylinders. The high-pressure cylinders cut off at 8", expanding 32". There are two air-pumps, each 22" bore by 12" stroke, and two double-acting feed-pumps, each 4" in diameter by 12" stroke.

At an engine speed of 80 revolutions per minute the speed of steamers is 10 miles an hour. The coal consumption does not probably exceed 2½ pounds per horse-power per hour. The draft of the steamers is 16' on the even keel. The engines and boilers weigh about 100 net tons. All of the bearing surfaces have brass boxes instead of the cheaper expedient of Babbitt metal.

Of the simple condensing-engines for screw propulsion upon the lakes perhaps no better example could be adduced than the double engines of the "E. B. Hale" and "Glydon." The "E. B. Hale," 1,186.15 tons, of Cleveland, is a steamer 217'.3 long, 34'.8 wide, and 17'.9 deep. It has two 36" by 36" inverted engines. These were built by the Globe Iron Works and have slide-valves. They have two 22" bore by 12" stroke single-acting air-pumps, and two 4" by 12" double-acting feed-pumps. The engines make 80 revolutions per minute; the speed of vessel is 10 miles an hour, consuming about 1,400 pounds of coal

per hour. The engines and boilers weigh about 80 net tons. The draft of the steamer is about 14' on the even keel.

The steamer "Commodore," 2,082.02 tons, plying between Buffalo and Chicago, has two 22½" and 48" (diameters) by 3' stroke compound engines, driving a propeller-wheel 12' 3" in diameter, said to be the largest propeller upon lake Michigan.

The steamer "Transport," 1,594.93 tons, has four 28" by 48" condensing-engines.

The "Vermont," 1,124.53 tons, plying on lake Champlain, has one 56" by 12' beam-engine. The "City of Cleveland," 1,221.93 tons, of Detroit, has one 50" by 11' beam-engine; and the "Northwest," 1,109.19 tons, has one 60" by 12' beam-engine. Jet-condensers are used with all of these beam-engines.

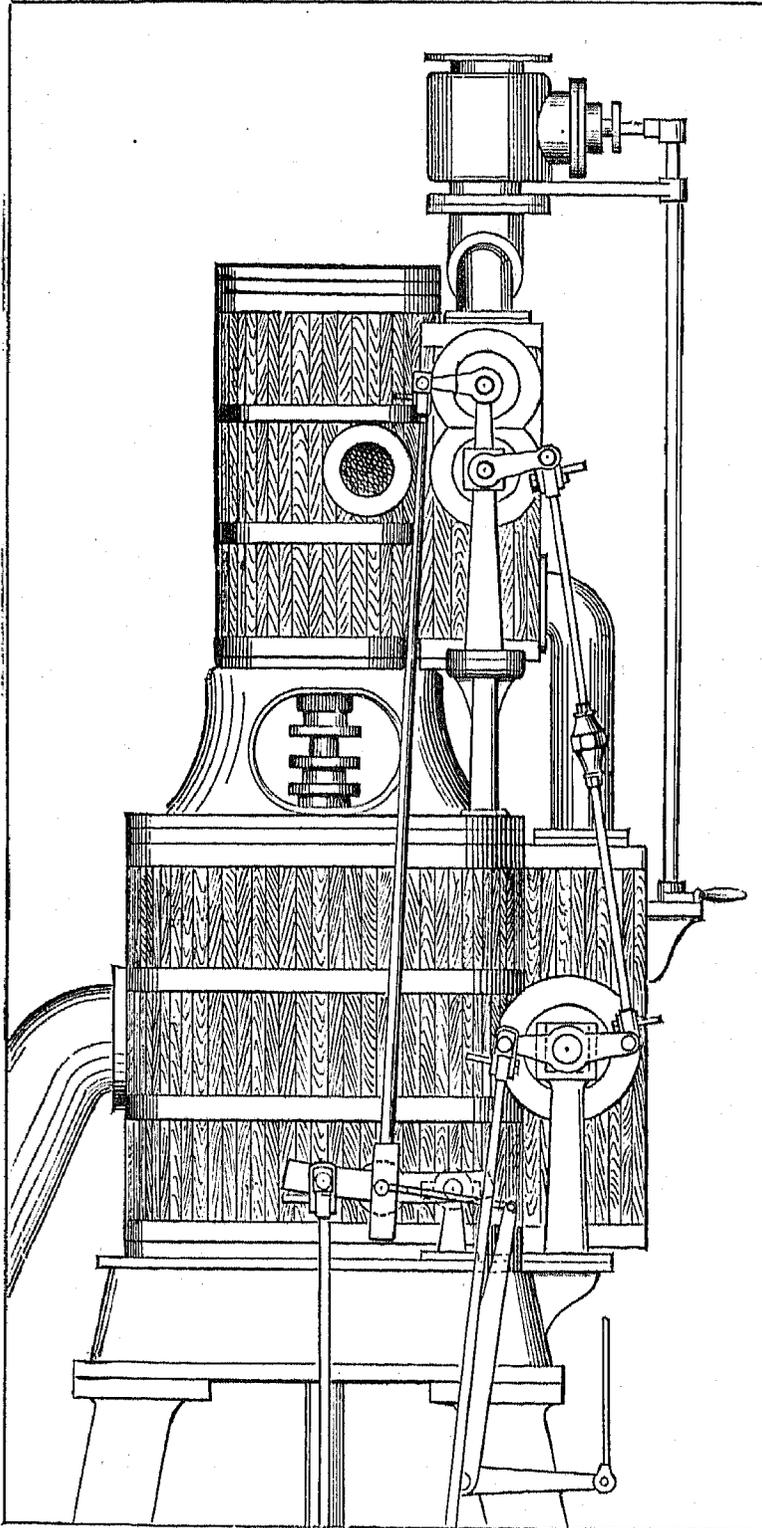


FIG. 38.

Upon steamers of Class II, of 77 engines 7 are compound (all these being upon steamers inspected at Buffalo) and of the remainder about half are non-condensing engines. Nearly four-fifths of them are short-stroke propeller engines, and the rest mainly beam-engines.

Upon steamers of Class III, of 248 engines 18 are compound, several of these being upon boats of the Erie canal. The non-condensing engines constitute about two-thirds of the remainder. Many of the condensers are used with beam-engines. The screw-propellers outnumber the paddle-wheel boats about 7 to 1. The "Relief," 267.33 tons, a towing-boat plying from Tonawanda to Lake Huron ports, has a non-condensing engine, one cylinder 25" bore, 20" stroke, with two pistons.

Upon steamers of Class IV all of the engines are simple non-condensing except 6 compound engines. The tug-boat "Brilliant," 66.69 tons, of lake Champlain, has one 17" and 35" by 22" compound engine. The passenger-boat "Orizaba," 76.26 tons, plying from Buffalo to the Northwestern lakes, has one 15" and 28" by 16" compound engine. The "Mystic," 74.90 tons, of Erie, has one 9" and 16" by 12" compound engine. The canal-boat "B. and O.," of Chicago, 99 tons, has two 7½" and 14" by 12" compound engines. The canal-boats "M. Talcott" and "Advance" also have compound engines.

While most of the small boats are propellers, some have side-wheels, with little distinctive change in the type of engine. Thus the little boat "Julia 2d," 6 tons, of lake Champlain, has side-wheels driven by an 8" by 12" engine.

The propeller "Jennie A. Sutton," 25.33 tons, plying between Elk rapids and Traverse bay, has a 10" by 10" simple non-condensing engine, and a 4' (diameter) propeller which, under 80 pounds steam in the boiler, makes 205 revolutions per minute. The "Valley Mills," of Cleveland, is a paddle-wheel steam scow. Its dimensions are, length 70', breadth 13', depth 5'. It has two 6" by 32" non-condensing engines, and a 4' by 9' tubular boiler. It plies over a 12-mile route on the Cuyahoga river. Among these small boats one will look a long way to find a condensing-engine, but a few boats have them. The "Bonnie Castle," 4.75 tons, plying on the Saint Lawrence river, has one 5½" by 8"

condensing-engine. The yacht "Truant," 32.14 tons, of Detroit, has a 9" and 16" by 12" compound engine, and a patent vertical boiler 5' by 9' (high) of steel. The "Sylph," 8.86 tons, plying upon Detroit river, has a 14½" by 6" trunk engine. The yacht "Maud Lilley," 13.79 tons, of Grand Haven, Michigan, has an 8" diameter by 6" stroke oscillating engine.

## EARLY EMPLOYMENT OF COMPOUND ENGINES ON THE LAKES.

In 1850 the engines of the "Buckeye State" were built at the Allaire Works, New York, from designs by John Baird and Erastus W. Smith,\* and the following year the steamer was put upon the lake route between Buffalo, Cleveland, and Detroit, and, having compound engines, consumed less than two-thirds as much fuel as a steamer of the same line having a single-cylinder engine. The "Buckeye State" had a beam-engine of 11' stroke, compound, a high-pressure cylinder of 37", and outside of it like an annulus a low-pressure cylinder of 80" diameter, the low-pressure cylinder thus having about  $3\frac{1}{2}$  times the area of the high-pressure cylinder. The pistons were connected with one cross-head (something like the Hartupee compound engines) and the remaining mechanism was similar to that of ordinary beam-engines. The engine is stated to have been the first compound vertical beam-engine built for marine service, and its early employment upon the lakes seems to have been a lesson not lost upon lake practice. Other compound beam-engines were built (for Hudson river service) having a second cylinder something as in the engines of the "Louisiana," but all have now gone out of use. The beam-engines of the lakes and the side-lever engines of the ocean were soon crowded aside by screw propulsion, with its short-stroke direct-acting engines, but upon the lakes the compound principle seems never to have been lost sight of.

## BOILERS OF LAKE STEAMERS.

On steamers of Class I nearly all of the boilers are return-tubular, either of the fire-box or marine type, generally the former. The "C. J. Hershaw," 1,323.95 tons, of Milwaukee, with one 48" by 3' condensing-engine, has one 9 $\frac{1}{2}$ ' by 18' cylindrical flue and tubular boiler, called of the marine type. It has seven 13" and two 9 $\frac{1}{2}$ " flues and one hundred and sixty 3" tubes. The area of safety-valve is 28"; the pressure allowed, 50 pounds. The feed is heated to 100° Fahr., and one 4 $\frac{1}{2}$ " by 12" feed-pump is employed. The "E. B. Hale" has one 12' by 18' tubular boiler, with two furnaces, 70' of grate and 3,300' of heating-surface, about  $1\frac{1}{4}$  times as many square feet of heating-surface as total cubic feet of volume. The "Buffalo" and "Chicago" have each two 8' by 16' compound cylindrical tubular boilers, with fire-boxes and two furnaces to each boiler. For the two boilers in each vessel the grate-surface is 100 square feet; effective heating-surface (below water-line), 3,346 square feet; ratio of heating-surface in square to total volume in cubic feet, about 1.8.

Forty-three out of one hundred and eighteen boilers are of steel, or have steel shells, some boilers having steel shells and iron furnaces. The steamer "Transport" has four 9' 4" by 16' fire-box cylindrical return-tubular boilers of Otis steel. The thickness of shells ranges from  $\frac{5}{16}$ " to  $\frac{7}{8}$ ", and the boiler-pressure allowed from 36 to 113 pounds per square inch.

Of boilers upon steamers of Class II, about 5 per cent. are of steel, or partly of steel, some having steel furnaces or fire-boxes and iron shells. The fire-box return-tubular is the usual type, and the ordinary range of pressures allowed is from 40 to 90 pounds. The steamer "Iron Age" has a wagon-top boiler.

Upon steamers of Class III fire-box and return-tubular boilers are the prevailing type. There are a few direct-tubular boilers, and out of a total of 244 about 30 vertical tubular boilers, 25 of which are upon boats inspected at Buffalo, and mainly in the canal and freight service. One boat, 336.10 tons, of Green Bay, is specified as having two 54" by 12' vertical boilers, without tubes or flues. The new passenger-steamer "Grace McMillan," of Detroit, has a registered tonnage of 312, one 32" by 10' beam-engine, and one 9' by 16' cylindrical arch-flue and return-tubular boiler of Otis steel. The shell is  $\frac{1}{8}$ " thick, and 58 pounds pressure is allowed. The vertical tubular boilers upon the canal-boats are from 37" to 57" in diameter and 9' to 10 $\frac{1}{2}$ ' high. Some of them have automatic feeding attachments, and are known as the Wright automatic self-feeding canal type of boiler. Less than 10 per cent. of the boilers of this class are of steel, and nearly all of these are the vertical tubular boilers upon the canal-boats.

The return-tubular type holds its own even upon steamers of 25 tons and under. Among the smaller steamers there are of course a considerable number of vertical and locomotive tubular boilers and occasionally a wagon-top or other exceptional boiler appears in service or a return-flue boiler borrowed from river practice, but these cases are unimportant. I do not know of a rectangular boiler upon the lakes. Steel boilers are the rare exception. The canal-boat "Whale," 88.99 tons, of Chicago, has one 44" by 12' 6" locomotive-boiler; thickness of shell,  $\frac{3}{16}$ "; material, steel; pressure allowed, 130 pounds. The canal-boat "B. and O." has a 54" by 11' vertical tubular boiler of iron; thickness of shell,  $\frac{3}{16}$ "; pressure allowed, 142 pounds. These pressures are much above the average.

A number of the small boats on Lake Champlain have vertical tubular boilers. The "Little Nellie," 15.57 tons, has a 4 $\frac{1}{2}$ ' by 6 $\frac{1}{4}$ ' vertical tubular boiler; thickness of material (iron),  $\frac{3}{8}$ "; pressure allowed, 70 pounds; safety-valve area, 4".4. The feed is heated to 180°, and an injector and a 3" by 4" pump are used.

## PROPORTIONS OF LAKE STEAMERS.

While the practice in the employment of engines upon the lakes may be considered to be highly advanced, until recently but very little attention has been given to the modeling of large vessels, and the large freight-

\* Erastus W. Smith was the designer of the engines of the "Bristol" and "Providence," and other notable steamers.

boats have been described as boxes modeled only at the ends. Of a large freight steamer, the "Woooken," recently launched, it was said that her model was unusually fine, more like an ocean steamer than a lake vessel, showing that the models of lake do not commonly compare with those of ocean steamers. The principal dimensions of some of the large freight propellers are as follows :

Name of vessel.	Length.	Breadth.	Depth.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Rochester .....	205.9	40.0	10.0
Commodore .....	205.4	42.2	15.4
Woooken .....	251.6	37.3	18.5
Conestoga .....	252.8	36.0	10.2
E. B. Halo .....	217.3	34.8	17.0
Henry Chisholm .....	256.5	30.3	20.3
Buffalo .....	253.8	35.0	16.2
Philadelphia .....	236.0	34.3	14.0
Colorado .....	254.6	35.0	13.0

For the average of these, the ratio of length to breadth is 6.75 and the ratio of breadth to depth is 2.27. In point of depth they stand intermediate between the river and ocean steamers.

The following are examples of Chicago canal-boats :

	Length.	Breadth.	Depth.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Victor .....	99.0	17.4	7.0
Advance .....	113.1	10.0	6.4
B. J. Moore .....	124.6	16.0	5.6
Novelty .....	104.0	17.2	7.0

There are upon the lakes a greater relative number of small yachts and steamers of under 50 tons than in any other section. The western rivers have few such craft, but they constitute by number more than half the steamers on the lakes, and these small boats upon the lakes constitute over 10 per cent. of the whole number of steamers in the United States, and over one-fourth of all the small steamers in the United States. (Of the whole number of steamers in the United States, it may be remarked that 6½ per cent. are over 1,000 tons, 15 per cent. over 500 tons, 43½ per cent. over 100 tons, 60½ per cent. over 50 tons.) The following are the dimensions of some of the steam-yachts upon the lakes :

	Tons.	Length.	Breadth.	Depth.
		<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Bon Drake .....	47.37	71.2	17.0	7.7
Willis Cotton .....	37.08	63.0	14.4	7.6
Golden Eagle .....	48.30	63.2	18.0	6.6
Gem .....	41.83	67.0	14.6	5.4
W. C. Tillson .....	49.44	53.0	15.0	7.0
C. P. Morey .....	20.28	63.0	14.0	7.0
E. P. Ross .....	28.12	57.4	16.0	6.0
Truant .....	32.14	76.0	15.0	5.0
Lillie .....	31.65	62.0	15.0	4.3
Herald .....	39.44	80.2	11.5	5.5
Nonantum .....	37.04	59.4	13.5	4.5
Bret Harbo .....	28.25	55.0	15.0	5.7

Excepting the "Herald," the above are comparatively bluff boats, ratio of length to breadth averaging about 4, of breadth to depth from 2 to over 3, showing them to be comparatively deep.

The side-wheel steamers of the lakes are of similar proportions to those used in sound and seaboard service. The "City of Cleveland," 1,222 tons, is said to be the fastest boats on the lakes. This boat was designed by Frank E. Kirby, and is unique in having feathering paddle-wheels. These wheels are 23' in diameter, 9' face, and 33" wide, with 12 buckets on each wheel. The registered dimensions of the boat are: Length, 225' 2; breadth, 32' 4; depth, 13' 3. The keel is 226' long, the length over all is 238', and the breadth over all 54'. The draft is 7'. A beam-engine, condensing, 50" diameter and 11' stroke, and two fire-box and return-tubular boilers comprise the principal machinery. Each boiler-shell is about 11' in diameter by 18' long, and in each boiler there are 3 furnaces, and one hundred and twenty-two 4" tubes 12' long. The total grate-surface is 120 square feet; heating-surface, 4,400 square feet.

The feathering paddle-wheels as employed on the "City of Cleveland" are a departure from American in favor of English practice. English side-wheel steamers have usually small feathering-wheels, but with direct-acting engines. It is maintained by some engineers that these are preferable to the American type of large fixed paddle-wheels with beam-engines, but the latter certainly give great speed and endure great wear. On the other hand, side-wheel tugs are the most usual English type, while, except upon the rivers, the screw tug is almost universally employed here, being regarded as an improvement upon the side-wheel tug.

#### COST OF STEAMERS.

In large steamers the machinery, engines, boilers, and shafting, with propellers, usually weigh from 6 to 12 per cent. of the tonnage of the vessel, and for iron steamers cost between one-third and one-fifth of the whole cost. By the pound the machinery costs three or four times as much as the hull. For smaller boats the relative weight and cost of the machinery is greatly increased, and for small tug-boats the machinery may weigh one-fourth of all and cost fully as much as the hull.

Steamers are short-lived property. Their average life is inside of twenty years, and their value meanwhile rapidly depreciates, so that the selling value is no criterion of the cost. Other forms of property may increase in value, but as a rule the steamboat is worth more the year it is launched than it ever will be again. This point deserves to be emphasized, because false ideas of the relative cost of steamers in this country are often derived from comparisons between the cost of construction here and the advertised selling prices of old English steamers which have seen their best days, if they have not, with due respect to prudence, entirely outlived their usefulness. But if it be economy to buy old boats because they are cheap, old boats of American build are equally cheap. A large propeller was recently sold at a price equal to \$15 per ton ( $\frac{3}{4}$  cents per pound). This was built twenty-one years ago, and to-day would cost to build anew about \$85 per ton, being a wooden boat. In attaining its majority it had thus aged away about 78 per cent. of its worth. A large Mississippi river steamer, with a wood hull, was built ten years ago at a cost, inclusive of machinery, of \$80 per ton. After ten years' service it was valued about 37 per cent. off, or \$50 per ton, and recently went out of service under conditions which cost the underwriters at the rate of \$40 per ton.

Within the past few years the cost of English steamers of iron, large steamers of the best construction and with powerful engines, has been as low as \$105 per ton, and steamers of an undesirable quality have been contracted for at as low as \$50 per ton; but these rates were not maintained, and the tendency has since been upward, so that we may reckon the cost of large high-power passenger-steamers at \$125 to \$130 per ton, and smaller low-power cargo steamers at \$80 to \$90 per ton, these being iron boats. American ocean-going steamers are more costly, if of iron, but most iron steamers built in this country are vessels of a fine character, strong in build and of high power. The grain fleet running from New York is entirely of foreign vessels, but these are mainly an inferior and unsafe class of steamers, low-power freight-boats of foreign build, and not to be compared in quality with our swift coasting steamers.

In 1833 wooden ships were built in the United States at \$50 per ton, and they can be built nearly as cheaply now, but steamers are more costly, as are iron vessels, although for the same carrying capacity the latter are lighter than those of wood. In California, where labor is not cheap, several large stern-wheel river boats have recently been built at a cost, inclusive of engines and boilers, of less than \$65 per ton. These were good, serviceable boats, but not highly finished. The hulls were of wood.

Some of our large iron coasting steamers of recent build have cost over \$200 per ton, but these were handsomely built and equipped and involved many experimental features. It is unquestionable that with an assured demand the best iron passenger-steamers could be built at less than \$150, and good cargo steamers, with iron hulls, at less than \$100 per ton. These figures are probably too high. Within the past year an iron side-wheel steamer, a swift, staunch, and finely finished boat, with a powerful beam-engine, has been turned out at a cost of \$143 per ton. Some of the largest propellers upon the lakes, with iron hulls and compound engines of superior finish, have been built at a cost of less than \$95 per ton. With a larger demand these figures could be reduced without loss to invested capital. It is of the highest consequence that the matter should be broadly considered, and that the types of marine machinery adopted should be of such wide adaptability as to secure an economical degree of uniformity in the system of manufacture. The preceding pages may be considered to contain an outline sketch of the entire marine plant of the United States. The building up of this plant makes a large demand, which, if properly met, permits in its very magnitude the exercise of the most profitable and economical methods of construction.

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