FIRE BOAT PROTECTION.*

CONSIDERED FROM THE VIEWPOINT OF THE FIREMAN AND THE ENGINEER.

BY EDWARD F. CROKER, CHIEF OF NEW YORK FIRE DEPARTMENT.

To DESIGN a boat that can be maneuvered in narrow and crowded slips, basins, and channels, it is necessary to lay down some general rules of construction. First, the boat should be twin screw, and her engines of the compound type. In this connection it should be said that for this purpose single expansion engines are not reliable; they are unsuited for maneuvering, are less efficient, and should be eliminated at the start.

The triple expansion engine is likewise not adapted for fire boat use, as it takes some time to warm up the low pressure cylinder. With the compound engine this disadvantage is avoided, and the steam is in better condition as it enters the low pressure cylinder; in consequence the boat can be started more quickly, and it is possible to make better time to a point within

The decks should be flush fore and aft, and as clear as possible of all obstructions as the boat must be ready for action at all times. The common practice of providing a large pilot house should be avoided. The edges of the pilot house should be rounded so the couplings of the hose will not catch; a small skylight between the pilot house and the tower can be provided to ventilate the engine room. A boiler hatch is necessary for the same purpose; this, with the tower, which can be used as a staff for running lights, and the turrets and hose reels, are about all that is located on deck. The turrets stand directly over the pumps. Their features will be described at length in conjunction with the fire pumps, and the water circuit.

The boat should be protected by means of proper

24,000 pounds of water on an estimated consumption of 25 pounds of coal per square foot of grate surface; that is, $120 \times 25 \times 8 = 24,000$.

The turbine pump would consume 17 to $17\frac{1}{2}$ pounds of water per B. H. P. hour, and to throw 8,000 gallons of water per minute at 150 pounds pressure, it would require approximately 1,000 horse-power. Consequently the total steam consumption for the entire pumping main or propelling engines would be, main engine 150 horse-power at 20 pounds per B. H. P. = 3,000.

Auxiliaries, estimated, 75 horse-power at 40 pounds per B. H. P. = 3,000.

Fire pumps, 1,000 horse-power at $17\frac{1}{2}$ pounds per B. H. P. = 17,500.

Total 23,500.

WHEN THE FIRE IS SOME DISTANCE FROM THE WATER FRONT A HOSE IS LANDED AND CARRIED TO THE SPOT. CHIEF CROKER IS THE COMMANDING OFFICER IN THE PICTURE.

FIRE BOAT PROTECTION.

three miles of the station from which the boat is started.

If the turbine could be reversed as quickly and certainly as the reciprocating engine I would favor it; but in this regard many things still remain to be demonstrated with this otherwise excellent prime mover. We cannot afford to experiment in the fire service, and while the turbine is a splendid engine to drive the pumps, for the present at least, I recommend that the reciprocating engine be used as a propelling agent for the boat, and the turbine to operate the fire pumps.

The fire boat that I would recommend, should be 120 feet in length over all, with a 24-foot beam and a 9-foot draft; she should be built of steel. Frames spaced 20 inches, center to center, except forward, where for 18 feet on each bow they should be 12 inches apart, center to center. This feature is necessary to strengthen the boat for forcing her through heavy ice, and against obstructions.

* Abstracted from an address before the International Association of Fire Engineers, Washington, D. C.

guards; there are times at a fire when it is necessary to force the vessel into crowded slips. That she may sustain as little damage as possible, the guards and rails should be strongly built of sound well seasoned white oak.

Deficient steaming capacity has been the weak spot of nearly all fire boats. There is to-day no boat in the fire service that can run her pumps and auxiliaries to their full capacity and also furnish steam for the operation of the main engine, and it is absolutely necessary to operate the latter, as the boat must be under full control at all times.

I shall endeavor to suggest a set of boilers which will run the fire pumps, auxiliaries, and have sufficient steam horse-power in reserve to operate the main engine for maneuvering purposes, or slow towing, if necessary. The boilers should be of the water tube type with large straight tubes, a grate surface of 120 square feet, a heating surface of 4,500 square feet, and with a working pressure of 225 pounds, under forced draft; either a closed ash pit, or an air tight fire room should be employed. Such boilers would evaporate

This is a conservative estimate of the necessary steaming capacity, and as the boilers can easily supply 24,000 pounds of steam there is a comfortable margin of safety. I prefer to install the boilers fore and aft; there would not be room in a boat with 24 foot beam to place them athwartship. Furthermore I am opposed on principle to the latter arrangement of the boilers, as it is difficult to get around to clean, and otherwise take proper care of them.

The coal and water supply for the boilers must be ample for all purposes. The bunker capacity should be at least 35 tons, with a fore and aft arrangement of the bunkers. This is preferable to an athwartship arrangement, as the boat is far less difficult to trim than with the latter. In sea coast cities it is necessary to provide fresh water tanks for obvious reasons, while in cities on the Great Lakes such is not the case. There the feed water for the boilers can be pumped directly from the lake or river in which the boat operates. I am seriously opposed to the use of the built-in tank, and prefer the utilization of the vessel's sides and bottom directly as part of the tank

wall, owing to the greater difficulty in cleaning and repairing the built-in tank.

The main engine, as I have already stated, should comprise two units of the compound type with the high pressure cylinder 11 inches in diameter, the low pressure 24 inches, and the stroke of the piston 18 inches, with a maximum steam pressure of 160 pounds, and at 200 revolutions per minute each unit would develop 275 horse-power, giving a total horse-power of 550. This should be sufficient to drive the boat at a speed of 16 miles per hour if the hull is properly designed.

The auxiliaries would include the air pumps with vertical twin cylinders, two double acting 12 inch water cylinders with a 12-inch stroke, and two feed pumps with steam cylinders $7\frac{1}{2}$ inches diameter, water cylinders $4\frac{1}{2}$ inches, and stroke 10 inches.

Circulating pumps should be of the centrifugal type driven by independent engines, and should have a capacity of 2,000 gallons per minute. There should be a condenser of cylindrical shape with brass tubes and sheets, and having a cooling surface of 2,800 square feet.

I wish to emphasize that the practice of employing galvanized iron pipe for the auxiliaries, or for other purposes, while saving in the first cost, in the end is much dearer than suitable brass pipe; it will last but a short time in salt water, and the cost of the necessary repairs in five years would be far greater than the additional cost of brass pipe. Besides the loss entailed by the absence of the boat during the time that she is out of service for these repairs cannot be estimated; a fire-boat should be kept in service as many days of the year as possible.

On the Great Lakes this stricture regarding the piping would not apply with such force; iron pipe can be used very well in fresh water.

An efficient winding, steam steering engine should be located in the engine room so that it can be under the direct supervision of the engineers; the connection with the steering wheel in the pilot house should be by steel shafts, and cut bronze miter gears. The cylinder of the steering engine should be $4\frac{1}{2} \times 4\frac{1}{2}$ inches. The hand steering wheels are preferably to be of mahogany with brass hubs and mountings; steering columns are to be of brass with rudder, indicator, and warning gongs.

In addition to the steering wheel in the pilot house there should be a second wheel abaft the water tower on the deck, together with proper signal bell pulls; this secondary arrangement is to enable the pilot to work the boat from both ends, fore and aft. This would be quite an aid in working out of crowded slips in strong tides, or currents. In addition a small steam capstan can be placed on the forward deck.

There should be an electric lighting plant, to operate about 75 16-candle-power lamps, and also a searchlight. This would require a generator of about 10 kilowatts output.

The subject that is of the greatest interest to firemen is the question of fire pumps, their style, and capacity; needless to say the success of the boat is largely dependent upon them. There are in the fire service several boats with reciprocating pumps; they have done, and are doing good work; but as already stated it is almost impossible to obtain boilers able to supply sufficient steam to operate reciprocating pumps at their full capacity. Pumps having a normal discharge of say 10,000 gallons per minute, based on predetermined piston speed, will seldom deliver more than two-thirds of the rated quantity under working conditions, because the boilers cannot supply steam sufficient to produce the piston speed, and because of the slip which increases directly as the speed increases. There is also the question of frequent repairs after every working period of any duration. In this connection it may be said that the valves require considerable attention, as the pins on the back of the suction valves corrode quickly in harbors full of sewage, and allow the valves to drop off.

Centrifugal pumps when turbine driven will do the same work with half the steam required by reciprocating units; this will enable the boat to maneuver, and run her battery to the full capacity, a condition which I believe does not exist on any fire boat in service at the present time. I therefore recommend that centrifugal pumps having a capacity of 8,000 gallons of salt water per minute be installed, that they be driven by turbine engines of the impulse type, at a speed of 1,800 revolutions per minute.

The pumps should comprise two units, each unit including a two-stage, direct-connected turbine. Four thousand gallons of water per minute at a pressure of 150 pounds to the square inch would be delivered by each unit, when supplied with sufficient steam, and when exhausting into a condenser having a vacuum equal to 26 inches of mercury. The turbine should be of the horizontal type, equipped with two bearings, and a coupling, with the pumps coupled direct to the shaft, and operated at the same speed as the turbine without the intervention of any form of gearing.

Each of the fire pumps should have a 14-inch sea suction pipe; the outlets should be provided with sea

chests having composition valves and glands, Tobin bronze stems, and wheels operated from the working platform; the strainers should be fitted to the boat's side, and each should have an area $2\frac{1}{2}$ times that of the opening in the valve. They are best placed just over the turn of the bilge, far enough from the bottom to avoid mud in shallow water, and far enough below the water line to avoid debris. The discharge pipes from each pump should be 14 inches in diameter, and should unite in a 16-inch main above the pumps; each discharge into the main to be controlled by a valve. A valve should also be located in the main between the two pumps. The pumps to be so arranged that one can discharge into the other, thereby rendering them the equivalent of a four-stage pump, when extra heavy pressure is required.

On the deck, above the pumps, should be mounted two composition turrets of circular section with oval tops, standing about 35 inches high; with 16-inch inlet and nine $3\frac{1}{2}$ -inch outlets, each one of the latter having a brass gate valve, and standard hose connection. The oval turret top should have a flange for a 5-inch gate valve, and over this valve should be mounted a nozzle of approved design. The cubic contents of each turret would be about 40 gallons.

An 8-inch line controlled by a gate valve should lead from the 16-inch main forward to the underside of the pilot house, from which a 5-inch branch should be carried up to supply the nozzle on top of the house. A 6-inch branch would supply the bow nozzle, and a 6-inch line led aft would supply the nozzle on the tower. Each turret and each line of pipe leading to the fixed nozzles should have a gate valve, leaving a clear water way controlling them, so that each firefighting unit is absolutely independent of the others, in case it is necessary to undertake repairs or reconstruction.

All valves 6 inches and over should be of the rising stem type; in this type the valve stem and nut are maintained from contact with the water, thereby avoiding sediment and incrustation. The ordinary brass-mounted, cast-iron valve provided with composition ring should be avoided, as the iron corrodes rapidly, thereby rendering the devices inoperative. Valves 6 inches and over should each be fitted with a by-pass so the pressure can be equalized on both faces when opening them.

The water tower should be about 27 feet in height above the deck, and provided with a platform or fighting top so constructed that one or two nozzles can be conveniently operated by men standing on the platform. The nozzles on the tower have been found most effective in fighting fires on piers with upper stories; a better range can be obtained with the elevated pipes than from those on the deck. This also is true of warehouse fires.

There should be two reels placed on deck for carrying $3\frac{1}{2}$ -inch, and one for carrying $2\frac{1}{2}$ -inch hose. Experience has shown that two sizes of hose are enough to carry; these are $3\frac{1}{2}$ -inch and $2\frac{1}{2}$ -inch. The first is the better for all around work; hose of larger size cannot be handled with celerity, and the smaller size is unsuited to the pumps. A powerful stream of water can be forced through a $3\frac{1}{2}$ -inch line with a $1\frac{3}{4}$ -inch or 2-inch nozzle; if it becomes necessary to reduce the line for inside work a two-way siamese connection with $2\frac{1}{2}$ -inch hose and $1\frac{3}{4}$ -inch nozzle will give two good streams.

The boat should carry 50 lengths $3\frac{1}{2}$ and 25 lengths of $2\frac{1}{2}$ -inch hose; the practice of utilizing a hose wagon in responding to stations where fire boats are assigned is a good one. The service could be improved by using as auxiliary, a large motor-driven wagon, carrying 60 lengths of $3\frac{1}{2}$ -inch hose, and a full set of reducers, pipes, pipe-holders, etc.

The threads on all fixed nozzles should be in accordance with the fire department standard. I mention this because the manufacturers of the different pipes use different threads; in consequence the tips that fit one pipe will not fit a pipe made by another firm, and this will cause confusion and delay; therefore it is imperative that all tips be interchangeable.

The next subject of importance is that of a wharf or dock for berthing the boat. This should be at the center of the fire zone to be covered, or as near to the center as it is possible to obtain a location. The boat should be moored bow out in a berth free from all obstruction so she can respond instantly to a call.

In the important matter of selecting the members of the company care should be taken to assign men who understand a boat, and who have had experience at sea both in the engine room and on deck. It is bad policy to spend a large sum of money on the construction of a boat, and the installation of an expensive outfit, and then fail through lack of intelligent operation. The captain and lieutenant should not only be good firemen, but also good boatmen. The pilots should be men of long experience in the waters in which the boat is to operate; good pilots will keep down the cost of maintenance.

The engineer and his assistants should be thoroughly competent; in this case the cost of maintaining a boat can be kept down to the minimum; if other methods

are pursued the cost will be high, and the boat often out of service. The firemen should be young and active; if enough men with boat experience can be found in your department they are the best to draft into this branch of the service.

The boat should be under steam at all times. This does not necessarily mean that she should be blowing off. But a steam pressure about 20 pounds below the tension of the spring of the safety valve should be constantly maintained; the pilot and engineer should be stationed on board.

No specific rules can be laid down to govern the important matter of handling boats at fires, but in all cases the first boat or boats to arrive at a pier fire should take position to leeward, and as close as possible, and the third boat to windward, if conditions warrant. Each chief knows best the conditions under which he is working, and governs himself accordingly.

Shore lines can be operated successfully at a distance of 500 feet; $3\frac{1}{2}$ -inch hose with $1\frac{3}{4}$ or 2-inch nozzles give the best results. A good up-to-date pipe holder should be used in order that the line may be thoroughly controlled, and effectively worked. If through accident or catastrophe the water service of a city should become impaired, a fire-boat company could stretch lines of 2,000 feet of $3\frac{1}{2}$ -inch hose; each of these $3\frac{1}{2}$ -inch lines would supply two fire engines of the largest size, which in turn could pump the water 1,200 feet more. This would be effected by putting a two-way connection on the $3\frac{1}{2}$ -inch line, with a male connection, the main line being arranged between two engines close enough to enable each to draw from it with its suction, or hydrant connection, and in this manner each boat could furnish water to 12 or 16 engines. It may be thought that 2,000 feet would be a great distance to force the water through $3\frac{1}{2}$ -inch hose, but it must not be forgotten that the engines would help as they would create a vacuum on the receiving side of the pump. Thus the water would have very little atmospheric resistance, and consequently would be forced along for a much greater distance than if discharged through a small nozzle against the atmospheric pressure.

In the foregoing I have endeavored to give as full and complete data on this important subject as time would permit. In order to do so, I have drawn on the chief in charge of the marine battalion of the New York Fire Department, who is a practical boatman, being both a licensed master and engineer. The subject is therefore discussed not from the standpoint of a marine architect, but from the practical standpoint of fireman, boatman, and engineer. A boat such as has been described, with a full equipment, can be constructed for the sum (approximately) of \$130,000.

NOTES ON THE DESIGN OF REINFORCED CONCRETE BEAMS.*

(1) CONCRETE reinforced with steel will not stretch more before cracking than plain concrete; and the unit elongation of the steel when the first minute crack appears is not greater than from 0.0001 inch to 0.0002 inch, corresponding to a unit stress in the steel of 3,000 to 6,000 pounds per square inch. Consequently the tensile resistance of concrete should not be taken into consideration in reinforced-concrete design.

(2) Until a method has been devised by means of which the coefficient of elasticity of concrete in a beam can be accurately determined, or until sufficient systematic tests have been made for the special purpose of determining the position of the neutral axis for different concretes and different percentages of steel, the neutral axis may, for practical purposes, be assumed to be 0.55 of the depth of the beam above the center of the steel for working loads on beams of rock concrete of good design; that is, where the concrete in compression is not excessively strong relative to the tensile resistance of the steel, and *vice versa*. This makes the lever arm of internal stresses 0.85 the depth.

(3) Horizontal reinforcement is not sufficient in beams of ordinary dimensions, but some provision must be made to transfer the tensile stress from the steel into the compressive area of the concrete.

(4) This can be satisfactorily accomplished for simple beams by running half of the number of reinforcing bars straight through the beam, and bending up the others at the loading points, half of the latter running to the top of beam at the end, and half to mid-depth of beam at end. The inclined cracks as they usually occur in a concrete beam are approximately perpendicular to the direction of these rods; and these rods are, therefore, very efficient in preventing this failure. In most reinforcement heretofore used with bent rods the angle of inclination with the horizontal has been too large, and, consequently, the adhesive area of the rods was too small. Numerous tests on both large and small beams have shown that these methods are not effective in preventing inclined tension failures.

(5) Anchoring the horizontal rods at the ends of a simple beam is of no benefit.

* From a Bulletin issued by the University of Wisconsin.

SCIENTIFIC AMERICAN

SUPPLEMENT. No 1664

Entered at the Post Office of New York, N. Y., as Second Class Matter.
Copyright, 1907, by Munn & Co.

Published weekly by Munn & Co. at 361 Broadway, New York.

Charles Allen Munn, President, 361 Broadway, New York.
Frederick Converse Beach, Sec'y and Treas., 361 Broadway, New York.

Scientific American, established 1845.
Scientific American Supplement, Vol. LXIV., No. 1664.

NEW YORK, NOVEMBER 23, 1907.

Scientific American Supplement, \$5 a year.
Scientific American and Supplement, \$7 a year.

THE FIRE BOAT'S EFFICIENCY IS NOT LIMITED TO THE WATER FRONT. THE BOAT MAY FORCE WATER A QUARTER OF A MILE THROUGH A HOSE, DELIVERING IT TO A FIRE ENGINE TO BE DIRECTED ON THE BLAZE.

A FIRE BOAT AT FULL PRESSURE, SHOWING THE ENORMOUS AMOUNT OF WATER IT CAN THROW, AND ITS MANY JETS.
FIRE BOAT PROTECTION.—[SEE PAGE 329.]