

in them. To make this front head equal in strength to the rear one, omitting now all comparison with the strength of the cylindrical portion of the boiler, it seems evident that a rib is necessary around the man-hole of sufficient depth to fully compensate for the removal of so important a part of the disk.

But without a full line of ultimate experiments on the strength of these forms it would be difficult to specify the depth of the rib.

It may be said, and is strongly maintained by some engineers, that the concave form, shown in figure 6, is stronger than the flat; but how these two forms compare in strength when they have equal inward projections, experiment only can determine.

No respectable guess, therefore, can be made at how much internal pressure was required to break this boiler. Either of its heads had less resisting power than the cylindrical portion, on which form plenty of experiments have been made.

The arguments used against the hydrostatic pressure as a test of the strength of unequally heated and complicated boilers, do not so well apply to this case, for this head was in a fairly uniform condition of temperature throughout, so that unequal tension, except such as might arise from a badly fitted man-hole plate, is hardly admissible. Its strength, if uniformly heated to 350° or 400° Fah., would not differ greatly from its strength when the cold test of 115 pounds was applied. And here are its neighbors, cast from the same pattern apparently, they have held out for two years, while no doubt many of the hundreds of cast iron boiler heads now in use in Philadelphia and elsewhere in America, are no better and have stood longer and heavier strains than those now under consideration.

A defect is noticeable in the circular fracture, as much as 3 or 4 inches long by width of 0 to  $\frac{1}{2}$  inch, in the middle of the plate and near the lower part, consisting of confluent blow holes; but it is difficult to conceive how the rupture could start at any point in the circle from which lines of fracture should converge toward the man-hole so as to break the head as shown. The rupture, no doubt, began almost simultaneously at the inner end of the four radial lines, in which case a defect in the circular line would not affect the weakest point at the margin of the hole.

It is not pleasant to think that a boiler which ought to be able to stand five times the working load would be so capricious as to blow up upon slight provocation. Scully, the fireman, stoutly and persistently denies having wet this head with his hose, although it was sought to be proved that he did so, and it was assigned as a sufficient cause of the breaking of the head.

Many of the steam valves were found to be closed when dug out of the *débris*; in fact the writer has not seen one that was open when found, but has seen four that were closed, and under such conditions that no amount of swearing by interested witnesses to the contrary would stand as truth.

The diagram, Fig. 5, is a plan of the neighborhood of the explosion. The buildings occupied by Gafney & Co. are (were) located between Martha and Collins sts., the boilers in the lower story of the three story brick building, A, adjoining the one story dye house, E. To the left is the shed M, on the roof of which the dyed material was sundried in fine weather. The dye tubs, F, were square wooden vats, heated by direct steam, admitted by branch steam pipes, in each of which was a steam stop valve, controlled by each dyer, according to his requirements. G is the small detached office building of the proprietors. H is the location of the two story dwellings, one of which was badly smashed and took fire, but it was soon extinguished. Beds, cooking stoves, and household utensils in the ruins, were painfully suggestive of the horrors that attend a first-class boiler explosion. The stable, L, was also destroyed by the falling of adjacent walls. The boiler gave out by the bursting of the front cast-iron head, which broke into four quarters, the fracture running from the man-hole radially, as shown in drawing; thence the break continued along the circular base of each quarter of the head, leaving the entire rim or flange outside of its junction with the disk attached to the shell plates. This rim was smashed, as shown in the cuts (Fig. 3), by the fall upon the ground at D, or possibly by contact with some solid object in its flight. On leaving its bed the main portion of the boiler took a direct, nearly horizontal, course in the line of its projected axis, and striking the terrace at the corner of the graperie in front of the dwelling, B, it rose and turned to the left, some 15° or 20°, passing over or in front of a passenger street car, at N, which was about to enter the station house of the Second and Third street horse railroad, shown at C, whence the cars depart at the opposite end on Frankford road. In striking the terrace,

the rear head, which was foremost in the flight, was demolished, and the adjoining shell sheet torn and turned inward, as seen at Fig. 3.

The four quarters of the front boiler head were found scattered at various points in the foreground, the lower piece, in which was the feed water opening, was found on removal of a large mass of *débris*, about twenty-five feet from, and directly in front of its former site. Here also were found a 2½ inch steam pipe (easily distinguishable from the feed water pipe of same size), in which was a stop valve closed; to this pipe were connected several 2 inch branches, and valves, also closed when examined by the writer, before they were touched by any person, after the explosion. Mr. Farran, of the Hartford Steam Boiler Inspection and Insurance Company, observed the same thing, and the attention of bystanders was called to this important fact. Mr. Williams, a member of the coroner's jury, was informed, and the valves shown to him before their removal. That gentleman remarked that other steam valves were also closed when found, notably the one in the pipe connecting this boiler with the others. In fact all steam valves were found closed when taken from the ruins so far as known.

The man-hole crossbar, a pretty heavy one, with its bolt, which engaged with the plate by means of a pocket in the plate, into which the head of the bolt fitted loosely, was detached when the boiler head was broken and its tension relaxed, and it flew to the front, crossing Martha street, to the second door on the cross street, when it struck the brick door jamb. A man was found dead or fatally injured at this point, marked J on the diagram, having been hit by this piece before it struck the brick-work. It made an indentation of a depth indicating that its force was far from being spent upon the body of the man. The man-hole plate itself flew a greater distance in the same direction, said to have been more than two squares, where it lodged on top of a building. This is the longest distance traversed by any of the pieces. A piece of the rear head bounded from D into Frankford road and landed in front of a boarding saloon where a number of people were taking dinner. This was warm, said to be hot, as well as the main piece of the boiler, which caused steam to arise from the damp manure heap on which it landed. A rumor gained circulation that the boiler flew through the air like a glowing meteor, red hot, but no evidence of an extraordinary temperature was found on any part of the fragments.

Some search was made for the steam gauge that was said to have been attached to this boiler, but its condition could have given no clew to the pressure at the time of the explosion, and it could not have contradicted other phenomena.

The fact that the plate and crossbar of the man-hole of the broken head were shot with violence as from a gun, indicates that the head, weak though it is acknowledged to be, resisted considerable pressure, and at last gave way with a snap. This wreck has been studied from a disinterested standpoint, and the

#### CONCLUSION IS

that the flow of steam from this boiler was stopped or obstructed by the defective condition of the safety valves, the distributing valves having been incidentally closed at the noon hour, by the several workmen who were in the habit of handling them according to the several demands for steam, and that the pressure gradually increased the fire being active, till the boiler gave way at its weakest point, which was manifestly the front head.

#### STEAM BOILER NOTES.

We learn from Chief Engineer McDougal's annual report for 1881, that the French decree relating to inspection of stationary steam boilers requires that all new boilers pass a test which consists of subjecting them to hydraulic pressure superior to the working pressure allowed, to be maintained during the examination of every part of the boiler. As a general rule the pressure to be double the working pressure, but never to be less than 7 pounds nor more than 85 pounds above such pressure. There must be two safety valves, so loaded that the steam will escape at maximum limit, which is stamped upon the boiler in a conspicuous place, together with the date of the last test.

The area of each safety valve (two on each boiler) must be sufficient to prevent the pressure exceeding the limit, whatever may be the intensity of the fire.

Every boiler must have a pressure gauge in good order, marked plainly to show the point that must not be exceeded by the pressure; a check valve, a steam stop valve on the boiler itself,