ON THE STEAM-BOILER EXPLOSION AT THE ROLLING-MILL OF J. WOOD & BROTHER, CONSHOHOCKEN, PA.

By W. BARNET LE VAN, Engineer.

The above works are situated on the west side of the Reading Railroad Company's track, and just below the bridge which crosses the same. The building covers a space of 100 by 200 feet. About one-half the works were destroyed by the accident, the upper end being a complete ruin, in which sections of the roof of the destroyed building, bricks, pieces of iron plates, twisted rods, bent bolts, lay in one confused mass. There were in the mill seven boilers, each being separate and distinct. The one that burst was at the northern end of the building, and its course was directly west across the canal.

The Exploded Boiler had been in use for nearly twenty years. When the rupture took place it was lifted from its settings, and shot across the canal like an immense projectile forced from a cannon, at about the same height as its original position, until it reached the building, 150 feet distant on the other side of the canal, known as the Albion Print Works. This immense mass, weighing about 5500 pounds, struck the end of a girder, twelve inches square, over an arched doorway, shattering the same, and tearing away the wall, and bringing up against a large cylindrical vessel of wrought iron, 8 feet in diameter and 12 feet high and $\frac{7}{8}$ of an inch in thickness, called a Kier, in which at the time were two lads, George Smith and James McNulty, who were arranging the pieces of endless muslin within by tramping them down so that the steam and lime-water, which were to be subsequently let in, would not mix up and entangle the material—the only mode of ingress or egress being a small man-hole on the top of the vessel. The two poor little fellows were tramping away when the end of the flying boiler came in contact with the sides of this kier. The heavy iron sides gave way before the shock like wetted paper—the indentation, nearly reaching the opposite side, instantly killing both lads, George Smith being actually cut in two. The force and impact of the blow of the flying boiler was so great that the piece of the wooden girder which

it carried with it was ground into splinters, and the atoms, being packed so closely together, were ignited by the friction that they burst into flames, setting fire to the material contained in the kier.

In the mill where the boiler stood eleven persons were killed and as many more wounded.

Nothing was left of the boiler at its original location except about two feet of one of the flues, the mud-drum and two-thirds of the back-head, H (cut 3).

The balance, consisting of the shell containing the two flues, lodged as above stated, in two pieces, as per sketch :

K, Kier.

B, Shell of boiler, contains the two flues, about 14 feet long.

C, Shell of boiler, about 4 feet long, open on both ends.

F, Flues.

Shell B represents the boiler with one end resting in the indentation of kier, the other end supported by a piece of the shell, C, about four feet long, 54 inches diameter, at right angles to shell B. After the boiler was removed, the hole in the side of kier was found to be about three feet in diameter.

The construction of the boiler is shown by the following cut :

Description of Boiler.—The boiler consists of a cylindrical shell, eighteen feet in length and fifty-four inches in diameter, and contains in its lower half two flues, each eighteen feet long and sixteen inches in external diameter, secured to the heads with angle iron rings. To the bottom, about three feet from the back end, was attached a mud-drum, eighteen inches in diameter, seven feet in length, by a pipe six

inches in diameter and twenty-four inches long, into which the feed-water was pumped. It was set, in the usual way, over the heating furnace, the waste heat of the latter passing underneath the shell, thence, through the flues, to a wrought-iron stack placed over the front end.

The following are its principle dimensions and proportions, namely :

Extreme length, in feet,	18.
Diameter of shell, in inches,	54.
Number of flues,	2.
Extreme length, in feet,	18.
External diameters of flues, in inches,	16.
Extreme length of mud-drum, in feet,	7.
External diameter, in inches,	18.
Thickness of iron in shell, in inch,	$\cdot 259 = \text{No. } 3.$
Thickness of iron in flues, in inches,	$\cdot 238 = \text{“ } 4.$
Thickness of iron in heads, in inches,	$\cdot 454 = \text{“ } 0000.$

The safety valve was three and one-half inches in diameter, and in good order when found, after the explosion, as also was the three-inch stop-valve, the latter being closed. This valve was placed between the boiler and the main line of steam-pipe which conveyed the steam from all the boilers to the engine.

The flues at the point of rupture were but three-sixteenths of an inch in thickness, and as clean cut as if done with a pair of shears, allowing a ring of metal remaining in the angle iron ring, which secured the flues to the head as though it was so ordered. The flues were flattened together as though they were passed through a pair of rollers.

The iron composing the flue plates was very much crystallized at the point of parting, no doubt caused by the constant expansion and contraction; and there is no doubt but a certain amount of this crystallization was due the use of angle iron rings to connect it to the heads; the flue plates would not flange from its being *hot short* iron.

The boiler had been out of use for a few days for repairs, and they were in the act of getting up steam at the time of the explosion.

The Engineer's Statement.—The engineer testified that he had observed the fireman firing up at about two o'clock in the afternoon; the blast was put on the furnace at half-past two, another man having succeeded the first fireman; the explosion occurred at twenty minutes past four, the blast having been on the furnace until that time; there was no unusual forcing of the fires; witness had in the meantime tried the gage-cock and water-gage; usually carry about from eighty to eighty-five pounds on the gage; had about fifty pounds on about ten minutes before the explosion; never knew the safety-valve to stick; carried the weight on the lever of the safety-valve at about eighty-five pounds, at which pressure the boiler would blow off; noticed nothing unusual about the boiler; there had been no water in the boiler until the day on which the explosion took place; he pumped the water into the boiler right out of the river; there was no water in the boiler until half-past twelve on the day of the explosion; it generally took about three and a half hours to generate steam enough to run; the man who took the place of the one that fired up in the first place is among the killed; the boiler was nearly full of water; it blowed water from the top gage-cock; never was in the habit of hanging any weights on the safety-valve lever.

In answer to a question of a juryman, the engineer said that, to the best of his knowledge, there was not more than 55 or 60 pounds of steam pressure when the boiler exploded.

The Verdict.—"That the deceased (names mentioned) came to their deaths by the explosion of a boiler in the rolling-mill of J. Wood & Brother, in the above borough (Conshohocken), and, in the opinion of the jury, said boiler had by long and continued use become, in certain parts, inadequate to carry the required pressure, viz., eighty pounds."

Strength of the Boiler.—The shell of the boiler would have parted at 322 lbs. per sq. inch, taking the value of the plates, single-riveted, at 33,600 for its elastic limit. The *working pressure* should be, for safety,

at least one-sixth of the above, say fifty-three and one-half pounds per square inch. The flues would have collapsed, by Fairbairn's formula, at a pressure of one hundred and forty pounds per square inch, the safe working pressure being only twenty-three pounds. The shell, as will be seen by the above, is about two and one-half times the strength of the flues. The working pressure of the boiler, as stated by the testimony of the engineer, having been eighty-five pounds per square inch.

The Cause of the Explosion.—The cause of the explosion is therefore obvious, viz : weakness of the flues. No flues of such dimensions as those just given can be safely worked with steam at a pressure of eighty-five pounds per square inch, unless strengthened either with hoops or flanged seams, or stayed in some other suitable manner. It may be true, however, that some such flues, though unstayed, are working, and have done so for years with steam of an equal or even a greater pressure than the above ; still they are continuing to do so only at a risk ; and their past exemption from collapse is no security against its occurrence in the future. Thus it will be seen that the above explosion occurred from the most simple cause, and that no mystery whatever need be attached to it, while, by suitable construction of the boilers in the first place, and due attention to their state of repair in the second, explosions would in most cases be prevented.

Very few of the explosions that have come under my notice occur from low water, and I believe that to be a much-abused idea, and the number of explosions resulting from it to be much exaggerated. At inquests it is the general verdict, and the fireman being frequently killed, there is seldom any witness to the contrary. The greater number of explosions occur from the insufficiency of the boiler for its working pressure, either on account of its original construction, or state of repair consequent upon use ; where it occurs from want of water, or from reckless pressure, explosions are rare. The majority of explosions are due more to the weakness of the boiler than to over-pressure of the steam. There is no plan of testing the construction or weakness of a boiler, either new or old, equal to the use of hydraulic pressure ; its application is so simple, and the pump so small, that every boiler owner could at a small cost provide themselves with one. In fact the ordinary feed-pump could be used temporarily for that purpose and should be applied at least once a year. Weak places in the plates may pass undetected, even on careful examination, while some parts may be inaccessible and concealed from view ; but the hy-

draulic test is sure to detect and expose them all. Its application in this case would no doubt have prevented this disastrous explosion.

The Examination of Boilers.—In all examinations of boilers, it should be done in person with the free use of a round-nose hammer on all the stays and flues, and when this has been done in a thorough manner, the hydraulic test should then be applied.

This is what you pay to have done in the case of the Boiler Insurance Company, should you apply to them for a policy of insurance on your boiler. The first outlay for this purpose would furnish you with a test-pump and the necessary appliances to repeat it every six months at a nominal cost; in fact, every one should be able to take his own risk.

Safety Factor.—In conclusion, I would call the attention of the Institute to the factor of safety for boilers as being entirely too low. The great number of disastrous explosions that have lately occurred in different parts of the country are the best evidences of the fact. The Bridge Engineers have long since come to this conclusion, and have fixed their factor of safety at one-eighth the ultimate value of the material.

The elastic limit of wrought iron of high quality is 33·600 pounds per square inch, making an allowance for the loss by rivets of ·56 per cent., we find for the elastic limit of a boiler shell that the factor would be 18816, or 33·600 pounds $\times$ ·56.

All experience has shown that but one-quarter of the elastic limit, say 5000 pounds, making all allowances for rivets or attachments, is all that ever should be used in practice.

February 19, 1873.

A Large Aneroid.—An immense aneroid barometer is about to be placed on the façade of the Paris Bourse. The portion, however, of the instrument which is sensitive to the various pressures of the atmosphere is no larger than the ordinary sized aneroid. The movements of the corrugated plate are transmitted to a train of clock work, by suitable mechanism. This last, which is wound up monthly, actuate a great needle on the exposed face, the latter being four feet in diameter.