ON STEAM BOILER INSPECTION.

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Steam boilers are now so common, and so often seen working with apparent safety on steamboats or railways or in manufactories that familiarity is apt to breed contempt for the danger that surrounds them if they should be faulty or used without due care.

The wreck produced by the explosion of a steam boiler is often so extensive that the casual observer is easily persuaded that there must have been some sudden accession of power at the moment of explosion, and is readily made to believe in mysterious theories involving intricate suppositions as to the influence of electricity, the spheroidal condition of water in contact with hot plates, the decomposition of water and ignition of the gases, the sudden generation of steam from water heated to a high temperature, and a host of other phenomena which are themselves true and perfectly understood, but have little or nothing to do with boiler explosions.

A very simple calculation will enable any one to realize that there is plenty of force accumulated in an ordinary boiler to account for all the mischief, if it is liberated suddenly. A boiler of an average size contains when at work sufficient accumulated "force," in the shape of steam and heated water, to work a thirty-horse engine for about ten minutes without additional firing; and if this should be liberated *in one second* by the rupture of the boiler, the power to cause explosion is equal to the united effort of 18,000 horses. A boiler forms a reservoir of power, and, like a reservoir of water, is capable of producing much useful work if allowed to flow gradually through a proper mill or engine, but capable of vast destruction should the rupture of the sides allow the contents to escape suddenly.

It has been calculated that the explosive effect of each cubic foot of water in a boiler at sixty lbs. pressure is equal to the detonation of one pound of gunpowder; so that in the case before given there would be the same effect as from the explosion of about 500 lbs. of gunpowder.

The explosions of vessels containing high pressure steam, but not exposed to any fire which would render possible any overheating or decomposition of steam, etc., cause as much havoc as the bursting of ordinary boilers when the contents are suddenly liberated by rupture of the sides.

It has long been the object of engineers who have given especial attention to this subject to obtain accurate records of every case of boiler explosion, and I have done my utmost to assist in that object, and have obtained notice of more than 1,500 explosions, causing the death of over 5,000 persons, and the injury of some 4,000 others.

The records are discouraging in many respects, as they contain the names of some of the best and most careful engineering firms as owners of exploded boilers, and also give instances of explosion of nearly every form of boiler which has been in use for any length of time; for there are plenty of exploded locomotives, Cornish, Lancashire, and other boilers, once held to be almost incapable of explosion, as well as the more old-fashioned Balloon, Haystack, Butterley, or plain cylinder boilers.

In but few of the earlier explosions are trustworthy records obtainable; but for some ten or twelve years they have been far more complete and accurate, and their careful consideration has led to the conclusion that most of the explosions could have been prevented had the actual condition of the boilers been known.

Nearly all who have given special attention to the matter being agreed that most explosions could be prevented if the conditions of the boilers were known, the problem suggests itself—how are owners to keep themselves informed of the condition of their boilers; and the simple answer is, by periodical inspection.

Inspection may be done by any one, and its value will differ according to the care and intelligence of the inspector.

It may be well to describe what is usually meant by boiler inspection. To insure due attention a written report should be made, which must be perfectly intelligible to any one who has not seen the boiler, and to prevent confusion no two boilers should be mentioned on one paper, and the report should be made complete at once, so as not to need fair copying, and illustrated with sketches. In the first place, every particular of boiler and fittings and setting should be noted that can be seen from the outside of the boiler, with sketches and sufficient dimensions to make complete detailed drawings if required.

The boiler should then be entered, and internal sketch and dimensions taken sufficient to make a complete drawing. The plates should then be felt in every part with a light hammer, and the general condition noted.

The flues should be reserved for the last, because they are generally dirty, but this is often the most important part of the inspection. The fire grate and each flue should be entered and traversed, and every part of the boiler plates felt with a hammer, and also dimensions taken as before.

This is not all that is necessary to obtain complete information, for there still remain those parts of the boiler in contact with the brickwork, and the neglect of which often leads to disaster. It is easy to clear the brickwork sufficiently for examination, but a little arrangement when setting the boilers would make it far easier, and will be again alluded to.

It may be well to mention the chief impediments to carrying out this inspection. It is often impossible to make even the external examination, because boilers are so smothered up with brick and stonework. The clothing of boilers is often justly urged as leading to economy of fuel, but it should not be done in such a way as to preclude examination. The most rapid corrosion goes on if a leak should take place beneath the covering, especially if it consists partly of sand or ashes.

Internal examination is sometimes prevented by too small a man-hole, or one so awkwardly placed as to make it almost impossible to twist into the boiler; but the most usual difficulty is the want of room to move about, or to use a hammer. Sometimes also there is no means of cooling sufficiently to remain in the boiler many minutes.

Each form of boiler has its peculiar difficulties. The Cornish or one tube boiler is one of the most awkward, as there is so little space between the tube and shell at the sides and bottom, and a false step may cause the inspector to slip and become wedged. An instance of this occurred last year, where the plates of a boiler had to be cut out to extricate a man.

The Lancashire or two tube boiler obviates this difficulty, but involves another man-hole to get at the space beneath the tubes.

Most of the multitubular boilers, such as the locomotives, are too small to enter, and the impossibility of internal examination has led to many explosions.

Of course the difficulty of examination is much increased if the scale is not well cleaned off, as without this many a fault will be overlooked.

The easiest boilers to examine internally are the plain cylinders, or others without internal tubes, and this facility for examination is one of their chief recommendations.

The upright boilers, such as work from the waste gases from iron furnaces, are particularly easy to examine, as there is plenty of room to stand upright both inside and in the flues.

The flue examination is attended with some impediments, as in most boiler settings facility for entrance to the flues appears to have been the last consideration. In many cases entrance is simply impossible, as the brickwork is only a few inches from the boiler. In not a few cases the man-holes are little cast-iron frames and doors, and too small for even a lad to pass through. Even when the flues of the Cornish and Lancashire boilers are large enough to pass along, the narrow space and inclined or crawling position are awkward. The plain flash flues of the externally fired boilers are easiest to examine.

The value of the examination when all the above impediments are overcome must depend on the knowledge of the inspector as to the points to observe, and as to what mischief to be on the look out for. Of course it is presumed that the boiler when fixed was a good one; the object of inspection being to ascertain whether it has become weak or dangerous while working.

It is often found that boilers have been injudiciously altered in form. In one case the tube had been removed without due care in compensating for the loss of the support of the tube and the extra area exposed to pressure in the flat ends by suitable stays, and, of course, the end was blown out.

Great loss of strength is often caused by injudicious repair, even when there is no intended change in the form of the boiler. Plain cylinder boilers originally constructed in rings with joints crossed, are often found so much repaired with patch upon patch that the seams become nearly continuous from end to end. The strength of such boilers it is impossible to calculate, as the metal must be exposed to unequal strains from the new and more elastic plate not taking up its exact proportion.

The faults visible from the outside of the boiler are generally so apparent when the covering is removed that they can hardly escape detection. The chief danger is from corrosion from the neglect of leaking of joints.

The faults visible from the inside may more easily escape detection. In those boilers which depend upon stays for their strength, the stays need very careful examination to ascertain if there is any sign of weakness. It is not at all uncommon to finds stays of proper and good construction, but with the rivets attaching them to the boiler loose or nearly sheared off.

The effect of internal corrosion is generally easily detected, but there is a form of it called "furrowing" which may escape attention. It is found in Lancashire boilers, sometimes in the angle iron, and sometimes in the plate close to it, and as scale often fills the crevice or "furrow," it may escape notice. The same thing is found in locomotives just by the lap of seams. The furrows are supposed to be caused by the "fatigue" of the metal in certain lines of strain due to the bending backwards and forwards of the end of the boilers to accommodate itself to the varying lengths of the tubes and shell when expanded or contracted by alternate working and cooling. The same lines of strain are produced in the barrels of locomotives by their efforts to assume the truly circular shape. Not only is the metal in these lines rendered more open in texture and more liable to corrosion, but the scale is continually thrown off, exposing fresh surface. "Furrowing" should never be neglected, as it increases very rapidly when once set in.

The faults to be observed in the flues are numerous, but two or three only will be noticed. When boilers are patched the old metal is often strained and punished by the removal of the old rivets and the "drifting" to pull it up to the new plate. This not unfrequently sets up "seam rips" or cracks from hole to hole, which not only throws extra and ever increasing strain on to the rivets at each end of the "rips," but often produces a jerk which causes such enormously increased strain on each succeeding rivet that the whole seam rips round and allows the boiler to break up.

External corrosion is another most frequent fault visible from the flues. The leakage from a sprung seam will often run down the lap causing a "channel" or narrow line of corrosion. This is often found also in the seams of upright boilers on the upper side of the lap. As the channel is seldom more than one or two inches wide it is easily seen by marked contrast with the sound plate, but when corrosion is more general from dampness in the flues it is not so quickly noticed, as the edge of the upper lap also corrodes, leaving the same apparent thickness at the edge of the plates, whereas, in reality, the lower plate may be eaten more than half way through. The same thing may deceive where a new piece of plate has been inserted on to a thin plate. Very slight corrosion of the already thinned plate may be much more dangerous than would be supposed from anything seen on the outside.

The corrosion which goes on at a point of contact with brickwork is one of the most frequent causes of anxiety to those who have the inspection of boilers, as it is sometimes found when least suspected. It is caused by the damp being held against the plate, and is the more dangerous as it produces weakness in long continued lines in the directions of the greatest strain. The walls are often now constructed with removable bricks, or slight holes at each seam.

It is very frequently asserted that corrosion cannot be the cause of explosion, as the weakened place would blow out and relieve the boiler. This may be the case when it is only local, but when in continuous lines, and the giving way of one point throws the strain on the surrounding parts, it leads to a break up as described in the case of seam rips. In tubular boilers it is very necessary to measure both diameters of the tubes to detect the first signs of weakness from the departure from the true circle.

Some few words are necessary as to the testing of boilers by steam or hydraulic pressure. The former is so dangerous, and has led to so many accidents, that it should be avoided. Attempts to caulk leaking seams while under steam pressure have led to many fatal explosions. Many more fatal explosions would be caused by proving from steam pressure, were it not that makers often deceive themselves and their customers by supposing that a large boiler can be proved by connecting a small inch pipe to another boiler, the gage upon which shows the required pressure; whereas condensation goes on so rapidly that not half the pressure is ever reached in the tested boiler.

The hydraulic test is not attended with danger if all air is excluded from the boiler, but it is found in practice that it does not always detect dangerous furrows or corrosion. It is undoubtedly most useful when applied with judgment during the time of inspection, and should always be considered a necessary part of inspection, but it cannot be relied upon alone or as a substitute for inspection.

Many attempts have been made to construct boilers that should be free from all danger of explosion, by having all the parts exposed to pressure of very small diameter and avoiding the large quantity of steam and water accumulated in ordinary boilers. Such boilers are made of both cast and wrought iron, but the experience with them is short, and for ordinary work the absence of accumulations of power makes it difficult to maintain regularity. In all descriptions of such boilers, however, although absolute safety from explosion is unhesitatingly promised, facility for inspection of every part is mentioned as one of the advantages.

In conclusion, I would submit that periodical inspection is the surest means of securing the safety of steam boilers. Also, that this inspection is a very good and useful safeguard, if only done by the man in charge; but that it is a still greater safeguard if done by independent inspectors, who have the experience of seeing many boilers and are not influenced by the exigencies of the manufacturers, for whom the boiler may be used.

Such was the opinion of those who formed the Midland Boiler Inspection and Assurance Company, under whose auspices I have obtained a great deal of the information as to boiler explosions which I have been enabled to give to the public, and to whose courtesy I am indebted for permitting me to give whatever may be deemed useful in the present paper.

THE ARTISAN IN PRUSSIA.

Compulsory education being the rule in Fatherland, the German artisan has that much in his favor; yet his English brother would not care to change places; low wages and meager diet sadly counterbalancing a little extra culture. $3·00 a week is very good pay in Prussia, as determined from a long list of the rates of weekly wages in that country in 1867. In most cases twelve hours, and in many, thirteen, go to the working day. Women form more than a fifth of the factory operatives, and earn, comparatively, good wages; but public labor brings its too frequent consequences, and the female operatives bear a very indifferent character. As for seamstresses and milliners, those who work for commercial houses are, as usual, most miserably paid; so miserably, indeed, that to live at all they are compelled to eschew morality.

The wages quoted above are said to suffice thrifty men while single, and even leave a margin for saving; but to keep a family upon them, unless the mother as least can contribute something towards the income, is out of the question; and those who know most about the matter do not set the cost of a family at a very extravagant rate. According to official calculations, a man with a wife and three or four children can provide food enough for all at an annual expense of $60·00, if he lives in the province of Prussia; in Posen it would take more than double the amount; while in Pomerania it may be done for a little less. Certainly the Prussian dietary standard is not a very high one, bread, vegetables, butter, and milk being all that is considered necessary; meat, except, perhaps, on holidays and Sundays, coming in the category of luxuries. The daily fare of a workman in the Rhen-