# Civil and Mechanical Engineering.

## THE STEAM BOILER.

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Of all the elements that have been pressed into man's service, to increase his comforts and conveniences, water turned into steam holds a most important place. And strange as it may appear to the uninformed, it might almost be said, that the steam-engine as matured by James Watt, came from his hands nearly perfect in principle, and, like Minerva from the brain of Jupiter, fully armed and ready to do battle in the varied fields in which it has since been employed. James Watt knew all, and acted with a knowledge of all, or nearly all, the principles that are now known. The main improvements in the steam-engine of our time, consist in a better and simpler arrangement and proportions of parts, better material, better workmanship, and vastly increased size. Many of its better qualities are the result of improved means of manufacture in the use of the steam-hammer,—the planing machine, slotting machine, etc., etc., which with equally improved quality of material, has enabled the steam-engine builder to do such work, as could not have been done under a less improved system, and for which Watt might have sighed in vain.

Not so the steam-boiler. It, from the very first application of steam as a useful agent, has been the constant trouble of the engine-builder, and the engine user, the great source of anxiety, danger and expense. The first patent regularly issued in England for a steam-boiler, dates about a century back, and from that time to this, patents for new designs or improvements, numbering thousands, have been issued in England,—on the continent of Europe, and in this country. Notwithstanding the vast amount of labor and thought that has been bestowed upon the subject, the whole engineering profession still is in doubt as to which is the best steam-boiler, no single one, at this moment, proving so much better than the legion that surrounds it, as to take any very prominent place in the general estimation, and not one combining the most important principle of security against destructive explosion. We might, perhaps, except the locomotive boiler; but even this occupies

its apparently permanent place, more because it adapts itself to the machine in form, than from any inherent value possessed by it as a safe or economical steam generator. Stone, wood, cast and wrought iron, copper, steel and various alloys of other metals, have been tortured, bent and twisted, from the beginning, into almost every conceivable form to make a steam-boiler. Still the work of change goes on, patent upon patent being continually issued for attempted improvements in this much needed object. In the various phases in material and form through which the steam-boiler has passed, it is remarkable that changes have tended more towards saving weight, cost or fuel, than in the more important object of making it safe from explosion. It can hardly be controverted that the paramount aim in the use of steam should be safety, and yet, with all that has been done, no single boiler now in general use, *approaches* this essential requisite in its construction, compared with what is demanded of it. Hence the frightful loss of life—the dreadful maiming and suffering that we find recorded almost daily in our newspapers, and the immense amount of valuable property annually destroyed by steam-boiler explosions. It may be said that there is no remedy for this state of things,—that all has been done and is being done, that skill and ingenuity can devise, to stop such fearful results, but as yet without success. If we *have* arrived at the end, and found no remedy, then must we accept the situation, trusting rather to Providence, care or chance, to protect us from harm, than to any inherent controlling principle in the thing used, voting steam a good servant but a very bad master.

Before concluding this paper, I will endeavor to show that all has not been done in the general use of steam to render it as safe an agent as its wide-spread utility and necessity demand. Nay, more, it will be shown from many years of practical experience in the use of a steam-boiler of singularly original design, and of material not heretofore considered best for the purpose, that the employment of steam at any practicably useful pressure, *can* be made entirely safe from any explosion destructive to life or property.

Some give to Dr. Alban, of Plau, in Mecklenburg, the credit of first enunciating the grand idea that "*all boilers should be so constructed that their explosions may not be dangerous;*" but it is scarcely possible that Evans, Hancock, Gurney and others at a much earlier date, should not have as fully appreciated this most important principle. When the low pressure of the earlier era of the steam-engine was used, the form or material of the steam-boiler mattered little, and we find Savery

using cast iron, Newcomen wrought iron, but from the difficulty of getting good plates of the latter material, Watt even recommended that boilers should be made of *wood*, hooped in the manner of the soap boilers' kettle, with cast iron curb or furnace at the bottom. But when the first really high pressure engine was introduced by our own countryman, Oliver Evans, carrying steam as high as *one hundred pounds to the square inch*, and upwards, it then became necessary to look for material and form capable of sustaining such pressure. Oliver Evans used wrought iron plates in plain cylinders of any given length, and of small diameters, sometimes, with internal return flue, through which the heated products of combustion passed, after coursing the whole length of the lower half of the boiler. These two kinds of boiler are at this day more extensively used in the United States than any other, and may be found almost exclusively on our Western river steamers. Perhaps no other boiler now in such general use, has greater safety in its principle of construction, than this early introduction of Oliver Evans. It is true that the most disastrous explosions on record have occurred with cylinder boilers on our Western rivers, but these calamities have been the result of scanty proportions in the first place, in order to save cost and weight, or from depreciation after long use, rather than from any original defect in principle. If the grand idea insisted upon by Dr. Alban be the true one, then have our engine-builders wandered far away from it since the days of Oliver Evans. Look at the immense structures built up of wrought iron, now so largely made and used on ocean and river steamers! Is this principle of safety attained, or even aimed at, in these boilers? Are they so made that "*explosions are not dangerous?*" Witness the disaster on board the North River steamer *St. John*, in 1865. Here a boiler exploded, made on an approved and often used plan, which, according to the testimony of experts on the Coroner's jury, "*pulsated*" at every stroke of the engine. Has any one seriously considered what this "*pulsating*" means? If anything, it means a movement in certain parts of the boiler, which being kept up for a given, and almost calculable length of time, must inevitably destroy the structure of the material of which these parts are made, and which, like the *wire*, bent backwards and forwards continuously, will eventually break. It is but too true, and not very assuring to the traveling public, that all of the best ocean steamers, as well as those on our rivers, lakes and sounds, have at this moment, boilers theoretically, if not actually, as unsafe as the one that blew up in the *St. John*. It is not too much to say, that all boilers of large di-

mensions, whether of square form, dependent upon stays or braces for their strength, or cylinders of large diameter, with or without internal flues, cannot be safe. Neither is it too much to say, that no boiler is safe, whatever its form or material, that can, under any circumstances, rend and scatter large masses of material, liberating at the same time large volumes of highly charged water and steam.

Take a boiler, if you please, that depends entirely for its strength upon being properly stayed, and there are thousands of such in use, especially for marine purposes. In the nature of boiler work, it is not possible to make such a boiler safe. Let any one, with a full knowledge of how it should be done, watch the making of such a boiler. The drawings are perfect, every strain calculated to a decimal, every proportion exact. If it were possible to execute the work just as laid down, all might be well: but if such a thing is possible, we never have seen boiler work made with such accuracy. In the matter of the stays, (a most important point,) every hole should be exactly smooth and true, and made to come in true line with the one it has to meet. Every bolt should be turned and fitted to its appropriate hole. But all who are acquainted with boiler work, know that it is not even attempted to do it in this manner. Ill-shaped stays, badly made and badly fitted, or strained into ill-shaped places, often out of reach of the eye and hand of the workmen, rough holes most frequently made in the smith's shop, with as roughly made bolts. If the holes are bored, so rudely do they adjust themselves to one another, that the ever ready drift, that bane of safe and good boiler work, brings the parts together under a tension that puts to flight all decimal calculations, and but too frequently dismembers the parts themselves. Can such a boiler be safe? And again, take plate riveting. An English writer on the subject says: "It is a truism, 'that the strength of any structure is its weakest point; but who can say where the weakest point of a steam-boiler is, as ordinarily made?'" "Take a simple cylinder boiler, for instance, the sheets are run through the rolls and bent to the proper radius, and when the riveting gang get to work they close up the rivets with great rapidity, but when the holes come out of line with each other the drift pin is resorted to, and the sheets are literally stretched until the rivets can be inserted; when the drift pin is knocked out, the sheet goes back to its place, and there is already, without a pound of steam pressure, strain enough to cut the rivets off." "Repeat this performance through twenty or thirty feet, the length of an ordinary cylinder boiler, and who can say where the weakest point of the structure is? Suppose such a

boiler made of silk or any flexible material, what shape would it be in?" "It would be full of puckers, folds, seams and gathers, and represent most accurately the various trials to which that most abused of all modern engineering apparatus—the boiler—is exposed." "The case is aggravated, not benefited, when we construct a square boiler, for this shape seems, by general consent, to have been adopted for marine service." "When the angles or flanges of the sheets are not broken by the flange turners, they are cracked out by the drift pin of the riveting gang, and it ought to be made a capital offence to have such a tool (drift) on the premises of any boiler works." "New boilers burst under the most mysterious circumstances; old boilers are patched and then burst; and we are told that 'putting new cloth into old garments is the solution of the trouble.'" "On each occasion the Coroner examines a host of 'experts,' who proceed to declare that the 'iron was burnt,'—'the water low,'—'the stays insufficient,'—'the water changed into explosive gases,' etc.; but it never occurs to these worthies, that the actual strength of the boiler was, in many cases, unknown, and that it may have been at the bursting point for many days, weeks or months, until at length it gave way." "It is ridiculous to suppose that safety is secured by neat-looking rivet-heads or handsomely caulked seams." "Holes will come out of truth with the utmost care, especially in such hap-hazard work as punching is usually made." "Neither are the braces (stays) properly set, for some draw all one way, while others do not draw or hold at all, and are perfectly loose; thus a portion do all the work, and the rest are idle; they impart no strength, and are an element of weakness; for the engineer relies upon them when they are doing no good." "We are confident that a great deal of attention can profitably be given to the mere workmanship of steam-boilers; they are not tanks for boiling water, but great magazines wherein tremendous power is stored, the safe custody of which is of paramount importance to all in the vicinity."

Assuming that a boiler of large dimensions, whether cylinder or marine, *can* be made so that all the parts are joined together without strain, this state of things can only exist at the uniform temperature throughout, under which the boiler has been made. Put fires at white heat, into or under such a boiler, heating the plates in the immediate vicinity of the fire, as must occur, in a much greater degree than at the external or more remote parts of the structure. Surely then the parts that had previously lain quietly together, assume a new and constantly changing condition, and who can tell what these changes are,

their frequency, or to what extent the strength of the boiler is impaired thereby?

Let us now turn our attention to another equally, or perhaps more, important point, than those we have been considering,—the wear and tear of plate-iron boilers. A writer in the *London Mechanics' Magazine* says: "It is not too much to say, that nine out of ten explosions are directly the result of corrosion." "Setting aside the value of human life and limb, we find that the mere pecuniary interests involved in either the gradual or sudden destruction of a boiler are very considerable." "Repairs are, at all times, expensive, and the time lost in making them is often a serious source of pecuniary loss, worry and trouble." "Hence the replacement of a plate, or the alteration in a defective flue, is often staved off from day to day until irreparable mischief is done." "Reflecting upon these things, it seems strange that boilers are made, fired and worked with a negligence, which apparently regards iron plates as indestructible, and the results of an explosion trifling to a degree." "We cannot set such a system,—or rather such a want of system,—down wholly to stupidity or neglect." "We know that boilers in the best hands, and under the most careful management, often become worthless with a startling rapidity, which no amount of theoretical reasoning can account for, nor practical skill arrest or delay." "The utter uncertainty in which the engineer is doomed to live, as to what does or does not promote durability, leads naturally to recklessness, neither the result of want of thought or indolence." "Corrosion is too often regarded in the light of a fate—a destroyer, merciless and indiscriminate, before which as a *fetish*, the manufacturer and ship-owner bow down and submit."

Mr. Colburn, in a paper read before the British Association, in 1864, says: "As a boiler malady, corrosion corresponds in its comparative frequency and fatality to the great destroyer of human life, consumption. It is the one great disease." "A trickling of condensed steam down the outside of a boiler will inevitably produce corrosion, and to this, was directly traced a large number of the forty-seven boiler explosions which occurred in the United Kingdom in 1863, and which caused the loss of seventy-six lives, with injuries more or less serious, to eighty persons."

In the report of the Manchester and Midland Boiler Association, for 1863, we find the following: "Furrowing along a seam of rivets, or rather under the line of an overlap, is found to be the usual malady, but the iron is eaten away almost everywhere; not uniformly over the

whole surface, but in numberless holes." "So far as furrowing is concerned, there can be no doubt that wrought iron is the *worst* material that can be employed for a steam-boiler."

Thus much on the subject of corrosion. Says another article in the *London Mechanics' Magazine:* "Until a comparatively recent date the belief obtained with most engineers, that a riveted joint, if the work were properly done, was superior to the plate itself."

Mr. Wm. Fairbairn, in a series of carefully conducted experiments, upset this fallacy by proving that, "the strength of the plate being taken as one hundred, that of a double riveted joint will be seventy, and a single riveted joint fifty-six;" and this with first rate workmanship. "Fifty-six per cent. of the whole strength of boiler plates, is certainly not much to realize with the best workmanship, but as many boilers are put together, this per centage must be regarded as too high." "There are difficulties involved in the nature of the process, which the best mechanic can only combat,—seldom or never overcome." "However accurately two plates may correspond before being punched, that process inevitably distorts them, and occasions a bad fit when subsequently put together." "The hammering and bending at the edges is invariably injurious to cold plates." "Again, the best workmen, with the best machinery, find it out of the question to make all the holes in a long seam correspond." "The constant use of the drift is certain to follow, and when plates are of inferior quality or very thin, cracks are frequently established from one hole to the other." "The judicious use of the caulking chisel easily conceals the defect, which is none the less serious because it is invisible." "The best rivets too seldom completely fill the holes they occupy." "They are never truly at right angles to the plates, and are often exposed to enormous strain in drawing plates together when they are badly fitted." "We have seen, from this cause, the heads fly off half a score of '*Best, Best,*' rivets at once, in rolling a new boiler from one side of the shed to the other."

Blistering of plates is another trouble in the use of plate iron. Says, —*Engineering Facts and Figures*, for 1863, page 21, "The fact of plates by good makers being liable to blister unawares, and which previous examination fails to detect, shows the importance of not hazarding an expression upon their soundness. Thus the strength of no unassisted plate, exposed to the action of the fire, should be relied on, and consequently it becomes most desirable that furnaces should be in every instance stayed either with flanged seams, or with hoops of angle iron, T-iron or other advantageous form." Thus, at every turn, the

boiler-maker, in using wrought iron, either in plates, rivets or stays, meets with difficulties which can only be partially, never perfectly, overcome. These difficulties occur most frequently at the very points in the structure where danger from defective work or material is most imminent, and where it is least easy to avoid it.

The maintenance of a well made steam-engine is of slight import, nor does the engine proper give the user any great anxiety or trouble as a source of danger to life or property. So true is this, that engines are doing good service now in England, that were made by Watt and his contemporaries; the sun and planet-wheel even yet making their regular revolutions. Where are the boilers that started with these engines? Gone, gone, and many succeeding the first, gone also.

The elements that destroy a steam-boiler commence their work from the moment of its completion, and from the hour it is first filled with water and fired; whether much used or not, the slow, steady, insiduous process goes on, and it is fortunate if its life reaches a decade, ere it is thrown out as worthless, scarce selling in this country for one cent per pound, even after its full original cost has been expended in almost continuous repairs from the beginning. From *Engineering Facts and Figures*, for 1865, we quote the following: "The saying of that distinguished authority in matters mechanical,—Wm. Fairbairn,—'that danger in the use of high pressure does not consist in the intensity of the pressure to which the steam is to be raised, but in the character and construction of the vessel which contains the dangerous element,' may be set down as a truism, containing a great deal of suggestive truth, but which is often overlooked, if not entirely ignored." "Else how is the public sense of what ought to be, but unfortunately is not, every now and then shocked by a recurrence of those accidents which result in such extensive loss of life and property." "It is the saying of one who has said many good things in his day, that 'self-interest is always intelligent.'" "In the matter of the use of boilers notoriously defective in form, material and construction, self-interest is *not* always intelligent; for however easily employers may take the loss of life from accidents in the use of steam-boilers, one would think that self-interest would prompt them to avoid, by all means in their power, the loss of property."

What are the conclusions that are forced upon us by all that has been adduced? Plainly that wrought iron is entirely unfit for steam-boilers,—that it is unreliable and unsafe to use it for such purposes, and that neither in principle nor workmanship in the use of this ma-

terial, have we advanced one step, in a century, towards making the steam-boiler, as now generally used, safe from destructive explosion. On the contrary, just in proportion as we have increased the working pressure, so have we run into greater danger; and at this moment boiler explosions are more frequent and more fatal in their consequences than ever. It is a sad condition of things that this much needed and much used force should be so little within our control. Must these mines of destruction, placed in our cities and towns, under our feet as we tread the side-walk, and all around us, threatening at every moment our very households with destruction, still hold their pent-up wrath by so frail a thread? Is there no way to safely clip the hair, and thus let the sword now hanging over our heads, fall harmless at our feet, there to lie harmless forever? I think there is a way to do this. If this can be shown, then let no one say hereafter that steam-boiler explosions cannot be prevented. Says Mr. Wm. Fairbairn, whom we again quote: "Instead of working two hundred pounds pressure to the square inch, I think we shall reach five hundred pounds." In *Engineering Facts and Figures*, for 1863, in treating of the great need of improvement in marine boilers, we find the following: "The answer is obvious,—no further economy can be obtained in steam-power without the use of *high pressure* and expansion." Ocean steamers, twenty-five years ago, used three or four pounds pressure to the square inch. Now the Cunard steamers use twelve or fifteen. Our North River and Sound steamers, the pioneers in using much higher pressure condensing engines, carry thirty or forty, and even fifty pounds to the square inch. Common consent, if not necessity, demands higher pressure, and it behooves the engineering profession to look to it, that we do not continue the present imperfect and most dangerous system, if there is any way to avoid it. It is a sad story of disaster in the past. It is meet and necessary, that the long-time reproach should be removed. Enough, we think, has been said to convince the most prejudiced that a good, safe and durable steam-boiler *cannot be made of wrought iron.* Assuming this to be proved, in what direction must we then look to find a better and more reliable material for the purpose,—one not possessing the many inherent and insuperable defects of wrought iron, one that can be readily made into such forms as will most conduce to the safety, durability and economy of a steam-boiler.

Turn we now to cast iron,—early used, but heretofore and even now, generally supposed inferior material for steam-boilers. On the subject of cast iron, a writer in the *London Mechanics' Magazine*, for May 2d,

1864, uses the following language: "There is a French proverb which says, that we always return to our first love, and it is by no means unlikely that this will be verified in boiler engineering. At one period it is beyond question that cast iron boilers were habitually used for very high pressures, and they were used because the material possessed constructive advantages which were not then believed to reside in wrought iron, and if these advantages reside in it still, under a principle of construction modified to meet existing demands, there is no good reason why it should not be habitually employed. Cast iron is far better adapted to meet the ordeal of fire and water to which a boiler is exposed than the best wrought iron plates ever manufactured. As to strength, we all know, or ought to know, that that is a matter of proportion quite as much as a matter of material. There is nothing like practical illustration to bring such truths home to the mind. Let us suppose, then, the case of two boilers, one made of plates half an inch thick, and the other one quarter of an inch thick. If each of these boilers is, say, six feet in diameter, the first one will possess, as nearly as may be, double the strength of the other. To render both of equal strength it is only necessary to reduce the diameter of the thinnest one to half the diameter of the thickest." "In the same way, it is certain that a cast iron tube, of a given diameter, may be made quite as strong as one of wrought iron of the same thickness, provided the diameters are proportioned the one to the other, in the ratio of their tensile strength. That the arguments adduced against the use of cast iron, are many and powerful, we do not pretend to deny; but that they are invariably applicable, or that it is, in other words, impossible to devise a boiler that shall elude these objections, is false." "We daily see cast iron used to carry enormous pressures with the utmost confidence. Its tensile strength may always be brought, in one sense, up to wrought iron by using enough of it. It has thus beaten wrought iron, in the form of guns, many times. There are two ways of increasing the strength of any vessel; the one in increasing the thickness, the other in reducing the diameter of the globe or cylinder to be tested. It is obvious that cast iron can only be used in small tubes or chambers, inasmuch as larger vessels must necessarily be of such a thickness that heat would pass through it very slowly indeed. But this fact in no way militates against the safety, economy or efficiency of a generator. Perhaps the present system of employing wrought iron boilers of colossal dimensions in our every-day practice, has been productive

of more injury to life and property, than can be laid at the door of the engineer on any other ground."

In a leading article in the *Engineer*, for 1864, it is said: "It has been so long the custom to consider cast iron as a brittle material, hardly to be trusted under pressure, that it requires some amount of reflection to perceive wherein it possesses manifest advantages over wrought iron. The resisting strength of a properly made cast iron boiler is calculable, and a good *a priori* case, could have been made out in its favor, long ago." What if the very brittleness of cast iron, when used in a steam-boiler, should prove an element of safety?

In an article in the *American Artisan*, for November 22d, 1865, in answer to an assertion made in that journal, referring to the Harrison boiler, that, "cast iron was not to be recommended for steam-boilers," because it "was liable to be strained from inequality of temperature," I have said, "Many years of experience in the use of this boiler has taught me that as a material for steam-boilers, cast iron is far preferable to wrought iron, and for a reason that can be very easily understood. Cast iron is *not* liable to be strained 'by inequality of temperature;' it is liable to *break* from such cause, and will give out at once if badly proportioned or improperly used. Wrought iron in steam-boilers *is* liable to be strained by 'inequality of temperature,' and not fracturing at once, goes on straining until its structure is destroyed, and the parts thus strained inevitably give way, death and destruction too often following. Put cast iron in such form as will prevent harm in case of rupture, and it becomes the *very best* material for steam-boilers, and one of its best qualities is in giving out when badly treated, a warning not to treat it so again. Not so wrought iron; its very tenacity begetting a false security which might lead to disaster at any moment." It certainly appears strange at a first glance, that such a seeming bad quality as brittleness in any material, should make it more reliable than a more tenacious one, for purposes needing strength. It would appear more strange, if this should prove true, in a material for steam-boilers.

(To be continued.)