WALTER JONES of JONES & ATTWOOD

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Walter Jones was the 2nd President of the Institution of Heating & Ventilating Engineers in 1899

CHAPTER XXXII.

EXPLOSION OF THEORIES, SAID TO HAVE BEEN THE CAUSE OF BOILER EXPLOSIONS.

In dealing with explosions the matter is of such importance that I propose to devote to its consideration one or more chapters, to which I invite the special attention of the reader. So much has been said and written on this subject that is erroneous and misleading that it cannot be too widely known what is the cause of explosions, and how they may be prevented. In a catalogue of a well-known firm of range manufacturers appears the following :—"Each winter we get the newspaper reports. Fearful boiler explosions! Several lives lost! People then realise that an ordinary range boiler can in times of severe frost develop a power of destruction that is simply enormous, shattering the buildings, and causing most disastrous, and frequently fatal accidents. The cause of these explosions is generally either the freezing of the flow and return pipes, or the failure of the water supply, *thus the boiler is allowed to get red-hot; then a sudden inrush of water raises steam so rapidly, that if there is no relief from a valve, bursting must ensue.*"

Note the Italics, because this theory is given by many writers in ignorance of the actual cause. Explosions are invariably brought about from a different cause; it would appear quite reasonable to suppose that cold water suddenly introduced into a red hot boiler would cause explosion, but as a matter of fact, explosions are not thus brought about. There are three theories freely urged as being the cause of explosions, none of which are substantiated by facts.

First. The theory advanced by Professor Tyndall and others of the spheroidal conditions of water has been freely advocated as one cause. In a paper on "Explosions of Boilers and other Vessels," read by Mr. E. B. Martin, before the Institute of Mining and Mechanical Engineers

on April 14th, 1883, when he exhibited drawings and models illustrating the subject, he refers to the spheroidal condition of water as follows:—"The spheroid can be made to stand over the heated part of the plate, but will burst into steam on the cooler part. It is believed by some that this may happen with the overheated side of a boiler; this must not be confounded with the effect produced by the concentration of intense heat on a small surface of plate, thus causing a volume of steam that prevents the water from coming in contact with the boiler plate."

Second. The theory that an unknown and highly explosive gas is generated which creates the mischief. Both these theories may be made subjects for scientific argument, but no proof has been adduced to shew that a single explosion has been thus caused. Nevertheless, gas can be generated from water that is hermetically sealed, and then subjected to high temperatures. In a high pressure apparatus worked under heavy pressure, and at temperatures of 400° to 700° Fah., when cooled down, and the plug or cap removed, a gas is emitted that will, when ignited, burn with a blue flame for several minutes. The following description may appear incredible, but it was substantiated by reliable witnesses, and I can vouch for its accuracy. The pipes ($\frac{7}{8}$-inch bore) of a high pressure apparatus used in an enamelling stove, where the temperature was maintained at 250° Fah., were, after several months' working, disconnected and emptied of water. The day following, one of my fitters blew up one end of the coil of tubes, another fitter held a lighted candle at the other end to see if the tube was quite clear and free from stoppage, the gas expelled was ignited, and emitted a pale blue flame; this was repeated time after time for about 10 minutes, and so long as the blowing continued, the gas would be relit, until they tired of the exercise; this happened, strange to say, 15 to 20 hours after the emptying of the apparatus.

The same thing occurs with steam pipes passed through a muffle for super-heating, to raise the temperature of the steam, gas is emitted that will show a pale blue flame when a cap or plug is removed. In a book on the "Explosions of Boilers," March 22nd, 1884 (by E. B. Martin, Esq., C.E.), it says: "Other experiments shewn included the decomposition of steam by passing it through a tube containing red hot iron shavings or filings, when the oxygen was absorbed by the iron and the hydrogen passed on, and was lighted at the other end of the tube."

On Feb. 10th, 1903, I received a letter from a gentleman who had observed that the air (gas) emitted from radiators in a low pressure apparatus could be ignited, and wrote as follows:—

"I am rather interested in finding out the cause of the formation of hydrogen gas in the pipes, and shall be obliged if you can give me any information respecting it."

I replied as follows :—

Dear Sir,

In reply to your letter of the 9th, the air-locking is caused, first, by air bubbles in the water when apparatus is filled; second, by ebullition when the water approaches boiling point; third, by generation of steam; fourth, when water is drawn from apparatus.

The air accumulates at the highest parts of the apparatus above the water level. The gas you refer to is caused by the separation of the oxygen and hydrogen. The former has an affinity for iron, and when attacking it, forms oxide of iron (or rust) on the inner surfaces of pipes or radiators, and thus releases the hydrogen which accumulates above the water level in radiator commonly called air-lock. These gases are formed principally when steam is generated through the boiler being over its work, and are rarely met with unless the water reaches boiling point, they are more commonly found in steam plants, super heaters, and high pressure apparatus.

The best way to prevent the accumulation of air is by putting air pipes instead of air cocks on the apparatus, whenever this is practicable.

Yours faithfully.

Third. The theory that explosions are caused by the admission of water into red-hot boilers appears more feasible, and has been frequently advocated in leading Journals, and by practical and intelligent men. Nevertheless, I am prepared to prove that this is not the cause of explosions, and further to demonstrate that, although a red-hot boiler may be *ruptured* by the admission of cold water, it is improbable, if not impossible, for a disastrous *explosion* to be thus brought about.

First. A boiler must be drained or emptied of water before it can get red hot.

Second. The draw-off taps are invariably put on the flow pipe, and this is taken from the top of the boiler, so that if the pipes were drained the boiler would still contain water.

Third. If the circulating pipes were blocked with ice or scurf, and the boiler had a drain pipe connected at the bottom, the water would not run out unless forced out by atmospheric or steam pressure. Again, if any outlet existed that would drain the boiler, the same outlet would liberate the steam if generated.

Fourth. If boilers were liable to run dry from shortness of water, this would occur more frequently in summer than in winter, from intermittent supply in times of drought, from cutting off the supply when new services are connected, during repairs to mains, or in elevated positions where the pressure is insufficient to keep up a constant supply. If the theory of cold water on hot plates is correct, explosions should be more frequent in summer than in winter. What are the facts? After careful investigation of the records for the past 50 years, I have traced 6 explosions only of range boilers during the summer months, viz. :—

October,	1868,	caused	by	Taps	closed,	hence	over-pressure.	
August,	1869,	,,	,,	,,	,,	,,	,,	,,
May,	1873,	,,	,,	,,	,,	,,	,,	,,
October,	1874,	,,	,,	,,	,,	,,	,,	,,
July,	1886,	,,	,,	,,	,,	,,	,,	,,
July,	1895,	,,	,,	,,	,,	,,	,,	,,

The one that occurred in July, 1886, had taps on the circulating pipes, these were closed, there was no safety valve or escape pipe, the steam pressure accumulated until the boiler could no longer withstand the strain, and explosion was inevitable, killing one person and injuring another.

The explosion in 1895 occurred (such is the irony of fate) at the house of an experienced boiler maker, near Wolverhampton, on July 2nd, 1895. The following particulars are extracted from the *Midland Evening News*, July 3rd, 1895. "Two months ago a new cooking range was put in; as a precautionary measure stop taps were put in connection with the old range in the front kitchen, and the new range in the back kitchen; a few days later a leakage was discovered and the workmen were called in to remedy the defect. The range in the front kitchen was not used until yesterday, when it was brought into requisition for the purpose of heating irons for the laundress. Her attention was attracted by a fizzing noise; fearing something was wrong she called the cook, and while they endeavoured to trace whence the sound proceeded a terrific explosion occurred, three persons were injured, a valuable spaniel dog killed, considerable damage done to property, and some wearing apparel set on fire."

This case is very similar to the preceding one, with the exception that there were two boilers connected by circulating pipes to one system. The cause of explosion was self evident, there was no necessity for speculation, and both would have been prevented had the boilers been fitted with reliable safety valves.

I wish the reader to distinguish clearly the difference between a *rupture* and an *explosion*, because it has a most important bearing on this subject. A boiler may be split or ruptured by excessive pressure with cold water, or by expansion when water is converted into ice, but there would be no violent explosion calculated to cause damage to property, or loss of life.

The effects produced by the bursting of a boiler depend, not upon the force exerted in lbs. pressure, but upon the amount of *heat energy* stored or pent up within the boiler.

The *volume* of steam at 60 lbs. pressure is about 350 times more than that of water at an equal temperature; the amount of heat or *stored* up *energy* is in an inverse ratio, being greater in water than in steam. The heat energy contained in one cubic foot of boiling water at 60 lbs. pressure is 350 times greater than that contained in one cubic foot of steam, at an equal temperature and pressure. The force or heat energy of one cubic foot of steam, at 60 lbs. pressure, is about 850 foot-pounds, and in water, at the same temperature and pressure, about 300,000 foot-pounds, or 350 times greater than that of an equal *volume* of steam only. The sudden liberation of this pent-up force will account for the fatalities, injuries to individuals, and wreckage of property, when an explosion occurs; whereas if a boiler contained steam only, the result would be rupture only, with a probability of scalding, should any person be standing near at the time of the accident.

From the researches of Rankine, Joulle, and Airy, one cubic foot of water, heated to the temperature of steam at 60 lbs. pressure per square inch, would develop, when suddenly liberated from pressure, as much force as 1 lb. or 2 lbs. of gunpowder.

The proportion of *heat-energy* contained in a given quantity of water or steam varies enormously, according to the pressure and temperature. At 10 lbs. pressure it is 996 times greater in water than in steam; at 20 lbs. pressure, 726 times greater; at 50 lbs. pressure, 405 times greater; and at 100 lbs. pressure, 237 times greater in one cubic foot of water than in one cubic foot of steam.

The boiling point of water varies also with the pressure or feet head. At atmospheric pressure, i.e., in an open vessel, water boils at 212 degrees, at 20-lbs. pressure = 46 head it boils at 259 degrees, at 50-lbs. pressure = 115 feet head it boils at 298 degrees Fah. I have referred to these points at some length, because these are potent factors in the *cause* and in the *effects* of all explosions, whether in steam or hot water boilers, and whilst many heating engineers are in absolute ignorance of the facts, by others they are frequently lost sight of or not taken into consideration.

TABLE XLV.

A.	B.	C.	D.	E.	F.	G.
Lbs. pressure of steam exclusive of Atmosphere as shewn on pressure gauge.	Equivalent in feet head of water.	Water boils at.	Units of heat in 1-lb. of steam.	Volume of 1-lb. of steam.	Weight of 1 cubic foot steam.	Volume of steam from 1 cubic foot of water.
Lbs. pressure	Feet head.	Faht. Degs.	Units.	Cubic Feet.	Lbs.	Cubic Feet.
Atmospheric.	—	212°	1177	26·36	·038	1644
5	11·5	228°	1182	19·72	·050	1229
10	23·1	240°	1186	15·89	·062	996
15	34·6	250°	1189	13·46	·074	838
20	46·2	259°	1192	11·65	·085	726
25	57·7	267°	1194	10·27	·097	640
30	69·3	274°	1197	9·18	·108	572
35	80·8	281°	1199	8 31	·120	518
40	92·4	287°	1201	7·61	·131	474
45	103·9	292°	1202	7·01	·142	437
50	115·5	298°	1204	6·49	·153	405
55	127·0	302°	1205	6·07	·164	378
60	138·6	307°	1207	5·68	·175	353
65	150·1	312°	1208	5·35	·186	333
70	161·7	318°	1209	5·05	·198	314
75	173·2	320°	1211	4·79	·208	298
80	184·8	324°	1212	4·55	·219	283
85	196·3	327°	1213	4·33	·230	270
90	207 9	331°	1214	4·14	·241	257
95	219·4	334°	1215	3·97	·252	247
100	231·0	338°	1216	3·80	·262	237

To get the equivalent in feet head (Column B), for any given pressure in lbs. (Column A)

Lbs. pressure per square inch × 2·31 = feet head of water.

Feet head of water × ·433 = lbs. pressure per square inch.

From the foregoing remarks it will be evident that the effect produced by the sudden admission of water into a red-hot boiler, would be the sudden generation of steam, of a pressure sufficient to force back the water up the supply pipe, or to rupture the boiler, but not sufficient to cause a violent explosion; the liberated steam may alarm or even scald a person standing near, but serious damage or wreckage would not result. These statements will be verified in Chapter XXXIV. which describes experiments with red-hot boilers.

I now give extracts from the *Ironmonger*, January 24th, 1903, on the kitchen boiler explosion at Gotherington.

"The explosion of a kitchen boiler is usually accompanied by loss of life. The accident which happened near Cheltenham on January 16th is the worst which has taken place for some time. Two lives were lost and three persons are in a critical condition.

"Recognising the seriousness of this latest case we at once sent a representative to make enquiries on the spot, and one result of his work is to throw some light on a disputed question. Experiments were made a few years ago with the view to prove that water flowing into an empty red-hot boiler would not cause an explosion provided the boiler had an aperture of 1-inch clear. The experiment has even been tried with a boiler having a ½-inch aperture, yet no explosion resulted, but notwithstanding this we have always considered that the result of the experiments has not put the question altogether beyond doubt, because none of the tests were made under quite normal conditions. In the Gotherington accident there are two circumstances that go to weaken the '1-inch aperture' safety theory. One is that here we had a boiler and piping system of which the taps were but rarely used; the second that the explosion took place at 4.35 P.M. when the fire had been alight about nine hours. A quite full boiler without a clear expansion pipe would have been ruptured several hours before this time, while an explosion due to the water in a partially-filled boiler being converted into steam, which could not get away but grew in force, would also have taken place in much less time. The only conclusion, therefore, which we can draw is that the contents of the boiler had evaporated that day, and that, at the critical moment, it was red-hot. Whether on account of a sudden change of temperature outdoors, or to the probability that on the occasion of the little family gathering the fire was larger than usual, water came down into the boiler from a frozen pipe. We have no desire to throw doubt on the value of practical experiments, but the doubt which we

have entertained with regard to the particular tests alluded to have been strengthened by what has occurred at Gotherington."

I commend the enterprise of the Editor of the *Ironmonger*, and the spirit that prompted a close inspection of the cause of this calamitous explosion, but feeling that the opinion expressed may be misleading, I sent the following letter, which was inserted in their issue of Feb. 7th.

The Kitchen-boiler Explosion at Gotherington.

Sir,—I have read your report of the sad accident caused through the kitchen-boiler explosion at Gotherington, and the Editorial remarks on page 169 of your issue of January 24th.

I am decidedly of opinion that your conclusion "that the contents of the boiler had evaporated, and at the critical moment it was red-hot, &c.," is quite erroneous, because I believe that it is practically impossible to burst a boiler in that way so as to cause such serious mischief.

I have experimented with similar boilers by turning cold water into them whilst red-hot; the steam generated has always forced the water back again before sufficient pressure could be generated to cause any explosion.

If the plates had been examined after the explosion they would bear unmistakable traces if they had been red-hot, and if they have not yet been interfered with would probably do so still. I hope this point will be cleared up by the Board of Trade.

From your description I think the probable cause was that the 2-inch pipes running along the top of the greenhouse were blocked with ice, and the water in the boiler hermetically sealed, it would then be only a question of the size of the fire, and the time required to cause an explosion, because,

1. The boiler was large, and it is highly probable that the front only, or a small flue under, was exposed to the fire.

2. If "the people seldom or never used the water" it is clear that it rarely got hot.

3. With a large surface of the boiler encased in brickwork or exposed to the air, and a small portion only exposed to the fire, it would take several hours to generate sufficient steam, so that the afternoon would be a likely time for an explosion.

4. The force of the explosion proves that the heat energy was considerable, which indicates that the boiler was full of water at high temperature, the heat energy of a cubic foot of water at 60 lbs. pressure being 350 times greater than that stored in a cubic foot of steam.

5. If water could get into the boiler whether from ½-inch, or from a 2-inch bore-pipe, it would be readily expelled through the same pipe by the steam generated if the boiler-plates were hot.

I am certainly of opinion that if any expert had examined the wreckage after the explosion he would have found that the pipes had been blocked with ice, and that the boiler-plates bore no indications that they had been red-hot.

Yours truly.

The Editor promptly followed up this matter, and sent a representative for a further inspection, which was duly reported in their issue of February 14th with an illustration of the manner in which the apparatus had been erected. I give the following extract, which certainly points to the fact that the explosion had not been due to a red-hot boiler, but from the apparatus becoming sealed by ice in the pipes.

"The scene after the explosion has already been described. The boiler lay on a heap of débris some 2 feet from its original setting. Every inch of welding had been torn open, and one of the ends of the boiler had been blown clean away. On carefully examining the several parts our representative found *nothing to indicate that the boiler had been red-hot*. There was a suspicion of crystallisation at the weld on the side which had been blown away; but this may have existed from the time the boiler was made. The interior of the boiler was free from scale, and was quite black. There was no bulge in any part. The side which was blown away was bent in an approximately vertical direction to an angle of about 45°, the apex of the angle being on the outside of the plate. This was possibly caused after the explosion by impact, for the side appears to have struck an angle in the chimney-breast in its flight, and carried away with it several feet of solid masonry. One of the bricks dislodged in this way was shot clean across the kitchen, a distance of 16 feet, and striking the opposite wall left a perfect impression in the plaster nearly ¼-inch deep. The hand-hole of the boiler was intact, although probably owing to the bending of the plate some of the packing material was missing."