

*Further remarks, on suggestions, by Mr. Perkins, in regard to the Explosion of Steam Boilers. By a CORRESPONDENT.*

In the June number of this Journal,\* I commenced an examination of certain suggestions in regard to the explosion of steam boilers, by our countryman Mr. Perkins. The examination was made by the light of *direct experiments* by the Committee of the Franklin Institute, on the explosion of steam boilers. It was there shown that the following suggestions of Mr. Perkins are erroneous, viz: First, that the gradual increase of pressure within a steam boiler, cannot produce all the effects of the most violent explosions. Second, that the projection of water into hot and unsaturated steam, can produce highly elastic, or explosive steam.

I now propose to apply the experiments of the Committee above referred to, to test the further suggestions contained in the article under examination.

It has been seen in the preceding essay that Mr. Perkins assigns as one cause of explosion, that water gets too low in a boiler. Then according to him, the metal becoming heated forms unsaturated steam which rises, and water being thrown into it, is flashed into explosive steam.

In justice to the very direct experiments of the Committee on explosions, I ought to have inquired whether surcharged steam could exist in a boiler containing water. Whether such steam would not take up water and become, in a greater or less degree, saturated. But as the answer would have been favorable to the statement, that unsaturated steam might so exist, I passed on, taking the circumstances to be as stated by Mr. Perkins. The reader will, however, find this point fully settled in the answer to the fourth inquiry of the Committee.† A fire being made upon the top of a boiler, while the quantity of water within was kept at about 308° Fah., the steam became highly surcharged, so as to attain a temperature of 533° Fah. This surcharged steam remained above the water, which varied from three inches to .9 of an inch in depth, more than two hours, its pressure not rising above seven atmospheres; while saturated steam of the same temperature would have had a pressure of more than *sixty atmospheres*. These experiments stood a severe test, now to be described. Setting out with steam of 308½° Fah., the pressure of which is 5.2 atmospheres, if heat be applied to expand it as a gas, supposing no water to be taken up, the steam will have, by calculation upon the known rate of expansion, a pressure of 6.75 atmospheres.‡ As satisfactory a coincidence, with the pressure actually measured, and which is stated above, as could be desired.

Though this hot steam may exist in a boiler, there seems no occasion to guard against its remaining, or to look for a method to indicate its existence, since it is proved that the projection of water into it will diminish, not increase, its pressure.

I proceed next to examine the effect of water thrown upon hot metal, and it will be seen that Mr. Perkins is fully borne out, in assuming this as a source of *very great danger*; that he should, in fact, have looked entirely, to the heated metal itself, as the cause of explosion, and not to the surcharged steam which it may produce. The committee on explosions took the course, involving assuredly some personal danger, of making a di-

\* See page 369, vol. XVII.

† p. 73, vol. XVII. Jour. Frank. Inst.

‡ Ibid. p. 74.

rect experiment on this point.\* The bottom of the experimental boiler being heated to a red heat, water was injected by the forcing pump, and the pressure obtained ascertained by a gauge. In every case the pressure rose very rapidly.

"In the last experiment, the glass window at the fire end of the boiler, blew out with a quick, sharp report, as loud as that of a musket; the fragments of glass, from a hole in the centre of the plate, were projected through a window, about three feet from the boiler, and could not be found. The number for twelve atmospheres is placed opposite to this experiment, as being an approximate result. In the act of observing the gauge, the glass window burst, and the mercury at once fell: the number of inches at which the mercury had certainly risen, and above which it was, by an undetermined quantity, not however very considerable, was noted; and from this the pressure given in the table is calculated. Here explosive steam is generated by the injection of water upon red hot iron, and in a time not exceeding one or two minutes at the most, the interval between the last stroke of the pump and the explosion, not having been sufficient to note the height of the gauge; the experimenter being at the pump, which was adjacent to the gauge."

The glass window referred to, we are elsewhere told, was three-eighths of an inch thick, and its dimensions were two and a half by one and three quarter inches.

Here then, by the injection of a limited quantity of water, which it is stated was not sufficient to cool the metal to the temperature at which it would have produced steam most rapidly, a bursting pressure of eleven atmospheres was rapidly produced.

Some experiments originally made by Klaproth, and repeated by Mr. Perkins, seemed to show that water thrown upon very hot metal, was so entirely repelled by it as to generate but little steam. Indeed, this has been regarded as a stumbling block in the way of the theory, which assigns to the hot metal so important a part, in producing explosions. It was this, probably, which led Mr. Perkins to abandon the idea that heated metal is the source of danger, in favour of the hot and unsaturated steam. It was the consideration of such results, that induced Mons. Arago† to say, that in order to complete this theory, which he attributes to Marestier, it must be shown why the water in a boiler acts differently when thrown upon hot metal from the small drops in the iron spoon, in Klaproth's experiments. The committee of the Franklin Institute, have not only proved the fact to be that explosive steam may be produced by throwing water on red hot metal, but have supplied an answer to the difficulty just referred to, by an elaborate series of experiments‡ on the vaporization of different quantities of water in metallic vessels of different materials, thicknesses, states of surface, &c. and have pointed out the influence of all these circumstances on the rapidity with which water is converted into steam. The effect of pressure in modifying the results was appreciated in their first experiment.

The direct experiment before referred to, being sufficient to meet Mr. Perkins' views, I pass on for the present, intending to recur to these other experiments, for information quite as important as the fact under review.

If then the water in a steam boiler should fall below its proper level, the portion of fire surface exposed without water, could become unduly heated as in the experiments of the committee. But how are we to find the water to be thrown upon the hot metal? Mr. Perkins answers this question, by

\* Ibid, p. p. 14, 15.

† *Annuaire du bureau des Long.* 1830, p. 191.

‡ *Jour. Frank. Inst.* vol. XVII. p. p. 90, 91, &c.

supposing the safety valve to be "suddenly raised, the water will [then] be relieved from the steam pressure," and rush up, and "that part of a boiler which has been raised in temperature, giving off its heat to the water so elevated, steam is generated in an instant, &c."

Is it the fact, as here asserted, that water when relieved from pressure, does rise into foam? Again, when that foam is thrown upon the sides of the boiler, does it generate more steam than is sufficient to compensate for the loss of steam which produced the diminution of pressure and thence the foaming?

When M. Arago wrote his essay on the explosion of steam boilers, he could not decide the first of these questions; he brought general analogy to bear in favour of the probability that this foaming was produced. The experiments of the committee on explosions have supplied, completely, the desired information. They examined the question in its bearing "upon the apparatus designed to show the level of the water within the boiler," and also upon the question now before the reader.\*

"The first experiments on the effect of relieving water in ebullition from pressure were made in a glass boiler: here the fire was under the whole length of the boiler, which was a cylinder of fourteen and a quarter inches in length, and seven and a half inches in diameter. The steam within, being at a pressure of less than two atmospheres, by opening a cock at the end of the boiler, or the safety valve, also at the end, large bubbles were formed through the whole extent of the boiler.

The inquiry was prosecuted in the iron boiler already described, a distinct view of the interior being had through the glass windows placed in the heads. The greatest intensity of the fire was in front of the middle of the boiler, and extended through about one-third of its length: the part immediately near the flue, was next to this band in temperature. With this boiler experiments were made, which showed, that on making an opening in the boiler, even when the pressure did not exceed two atmospheres, a local foaming commenced at the point of escape, followed soon by a general foaming throughout the boiler, the more violent in proportion as the opening was increased. This small boiler was completely filled with foam by opening the safety valve, (nearly two-tenths of an inch in area) which was placed on the middle of the top, and the water violently discharged through the opening of the valve. The area of the valve bears to the horizontal section of the boiler, at the water line, the ratio of one to two thousand and fifty-five nearly. The boiler was half full of water in these experiments."

To show the extent to which this foaming may take place, I quote an experiment in point.

"The steam in the boiler being not higher than two atmospheres, the following experiment was made. The level of the water was reduced until it stood just below the lowest gauge-cock. On opening this cock, steam at first flowed out, then water and steam; on opening the second cock, in addition, water flowed freely from the lowest, which was above the hydrostatic level; the foaming within the boiler, which was produced by thus relieving the pressure, was distinctly seen through the glass windows. On opening the third cock, steam and water issued from the second, which was two inches above the water level; and on partially raising the safety valve, water flowed freely from the second cock. A further rise of the valve filled the boiler with foam, water flowed freely out of the third cock, more than three inches and three quarters above the water level, and finally through the opening of the safety valve itself. In these experiments, an opening of .03 of a square inch in area, the lowest cock, which, to the area of the water surface, was as one to thirteen thousand seven hundred, caused water and steam to issue through a cock, below which the water was known to be. A further opening of .03 of a square inch, making, with the first, .06 inch, or one six thousand eight hundred and fiftieth the area of the water surface, brought water from the lowest cock; a total opening of .09 inch, (one four thousand five hundred and sixty-seventh of the area of the water surface) brought water and steam from the middle

\* Jour. Frank. Inst. vol. XVII. p. p. 8, 9, &c.

cock, indicating that the level of the water was nearly two inches higher than it really was.

A first apparatus, which was contrived for applying fusible plates to the boiler, suddenly opened an aperture of .95ths of an inch in diameter. Even at low pressures, the scalding contents of the boiler were violently discharged through this opening, against the roof of the experiment house."

But after all, will the steam produced by this foam coming in contact with the heated sides of a boiler, be greater in quantity than the escape steam which produces the foaming? M. Arago says, that in experiments which he made on the effect of opening a safety valve, the pressure was always diminished. But he remarks that the boilers on which he experimented had their full supply of water. His results do not therefore, decide the question. Indeed, the question being one of degree, is a difficult one. The Committee of the Franklin Institute endeavored to imitate the circumstances to be found in a boiler in which the water is low. Having allowed the water to waste, the bottom of the boiler above the water level became heated; openings of different sizes were made in succession, so as to produce different degrees of foaming. In every case an opening produced a diminished elasticity of steam.\*

M. M. Tabareau and Rey of Lyons,† found a different result by surrounding a small high pressure boiler with flame, allowing the water to become low, then opening a large stop cock. The pressure was increased.

These results do not contradict each other, they show that an increase of pressure may or may not be produced, *according to the quantity of hot metal present*. No one would probably venture upon making an opening under circumstances in which it was a mere question of degree whether the boiler would burst or not. At the same time the experiments of the committee led us to look further for causes to produce explosion from heated metal, by a sudden access of water. The choking of a forcing pump and the sudden removal, by the action, of the pump of the obstruction, the sudden introduction of water when it has been found very low, without putting out the fires, are occurrences which would produce a certain result. The last is entirely within the control of the engineer. In connected boilers occupying the breadth of a boat, the careening of the boat will cause just such a state of things. If continued long enough it cannot fail to produce an explosion.

Wherever there is unduly heated metal there is danger, and that danger may be actually increased by making an opening into a boiler, is the inference from this examination. Before leaving this subject, and after differing in the former essay entirely from Mr. Perkins, I am so well pleased to find some part of his suggestions well founded, that I am disposed to dwell upon it, I propose to examine whether the danger of explosion from hot metal will probably increase with the temperature, or not.

Finding that drops of water are repelled from heated metal at quite moderate elevations of temperature, the result has hitherto been assumed, as applying to the case of a steam boiler, of which the metal is unduly heated. Reflection will show that this is not the case, the heated metal is cooled by the very act of generating steam. The rapidity of the supply of heat is also to be taken into account. If the metal is directly above the fire receiving heat, the result will be very different from what would take place, were the heat derived from conduction, through the medium of other heated

\* See Jour. Inst. p. 14.

†Ibid, p. 13.

parts of the boiler. The problem is in some sort indeterminate. This has been pointed out in the report of the committee on explosions, and experiments have been devised by using different modes of applying heat, to give an idea of the true state of the case.\*

They began by showing the early development of a repulsion in the heated metal, tending to diminish the vaporization of water, taking place when the quantity of water is too small to cool down the metal, at a lower temperature in copper than in iron, in a clean surface of metal than in one which is oxidated. This repulsion, preventing the effect of the increased difference of temperature in the metal, and the water to be vaporized produces a maximum in the vaporizing power of the metal. The vaporizing power of different metals at their maximum is different, being greater in copper than in iron, nearly in the ratio of the conducting powers of the metals. An important practical conclusion where the heat of the metal is kept up, as the temperature of greatest vaporization lies below that of our high pressure engines.†

By increasing the water, from drops to as great a quantity as the bowls, used in the experiments, would contain, and varying the circumstances by communicating heat to the metal through oil, and through tin, the Committee proceeded to examine the question now before us. While the quantities of water were small, great regularity appeared in the results, permitting a calculation of the temperature of greatest vaporization from results below that temperature.‡ The general conclusions are stated briefly thus:§

1st. The vaporizing power of copper, when supplied with heat, by a bad conductor or circulator, such as oil, increases with great regularity as the temperature increases, up to a certain point, the water being supposed thrown upon the copper surface, in small quantities. Copper flues, heated by air passing through them, would be in this condition if left bare of water, and then suddenly wet. This holds with copper one-sixteenth of an inch thick, without indication that a limit will be attained by a much more considerable thickness. The temperature at which the metal will have the greatest vaporizing power, is about 570° Fah., or about 230° below redness, according to Daniell.

The law of vaporization of small quantities of water, by a given thickness of copper, is represented with singular closeness by an ellipse, of which the temperatures represent the abscissæ, and the times of vaporization the difference between a constant quantity and the ordinates.

2d. The same power in thin iron, .04 inch thick, increased regularly, and was at a maximum, probably, at 510°. With thicker metal the power increases more rapidly at the lower temperatures, and varies very little, comparatively, above 380°, with thicknesses exceeding one-eighth, and less than one-fourth of an inch; attaining a maximum at about 507° Fah., when the quantities are small; rising to 550°, and much above, as the quantity of water is increased relatively to the surface of the metal which is exposed. Quadrupling the quantity of water, the entire amount being still small, nearly tripled the time of vaporization at the maximum.

3d. When copper of one-sixteenth of an inch in thickness, was supplied with heat by melted tin, a worse conductor, and having a lower specific heat than copper itself, the time of vaporization, in a spherical bowl, of quantities varying from one-sixteenth to one-half of the entire capacity of the bowl, increased but three-fold, and the temperature of greatest evaporation was raised by 56°, or from 470° to 526°. When the bowl had half of the portion which was exposed to heat filled, the weight of the water was about one and one-tenth of that of the metal.

4th. The times of vaporization of different quantities of water, varying from one-eighth of an ounce to two ounces, in an iron bowl one-fourth of an inch thick, and supplied with heat by the tin bath, were sensibly, as the square roots of the quantities, at the temperatures of maximum vaporization for each quantity.

\* Jour. Frank. Inst. vol. XVII. p. 152.

† Ibid. p. p. 152, 153, &c. and plates 5 and 6.

‡ Ibid. See p. p. 150, 151.

§ Ibid. p. p. 162-3.