EXPERIMENTS ON SUPERHEATING AS A CAUSE OF BOILER EXPLOSION.

On the 9th of April, 1883, Commandant Treve laid before the Academy of Sciences a note upon the different means proper to prevent the explosion of steam generators, and, in the course of his paper, attributed a large number of explosions to a peculiar state of the water called *superheating.*

First Series of Experiments.—The object that these had in view was a study of ebullition in ordinary glass vessels. It was desired to ascertain what importance the long preparation which physicists cause their vessels to undergo may have from the standpoint of superheating.

Balloons of good, clear glass and small dimensions were selected, and pure water and dilute aqueous solutions of three degrees. The ebullition was accompanied with violent movements of the vessel. When vaporization was excited by one of the means indicated for superheated water, there was at times a violent ebullition accompanied with projections.

Second Series of Experiments.—These experiments were performed at the shops of the Orleans Railway, in France,

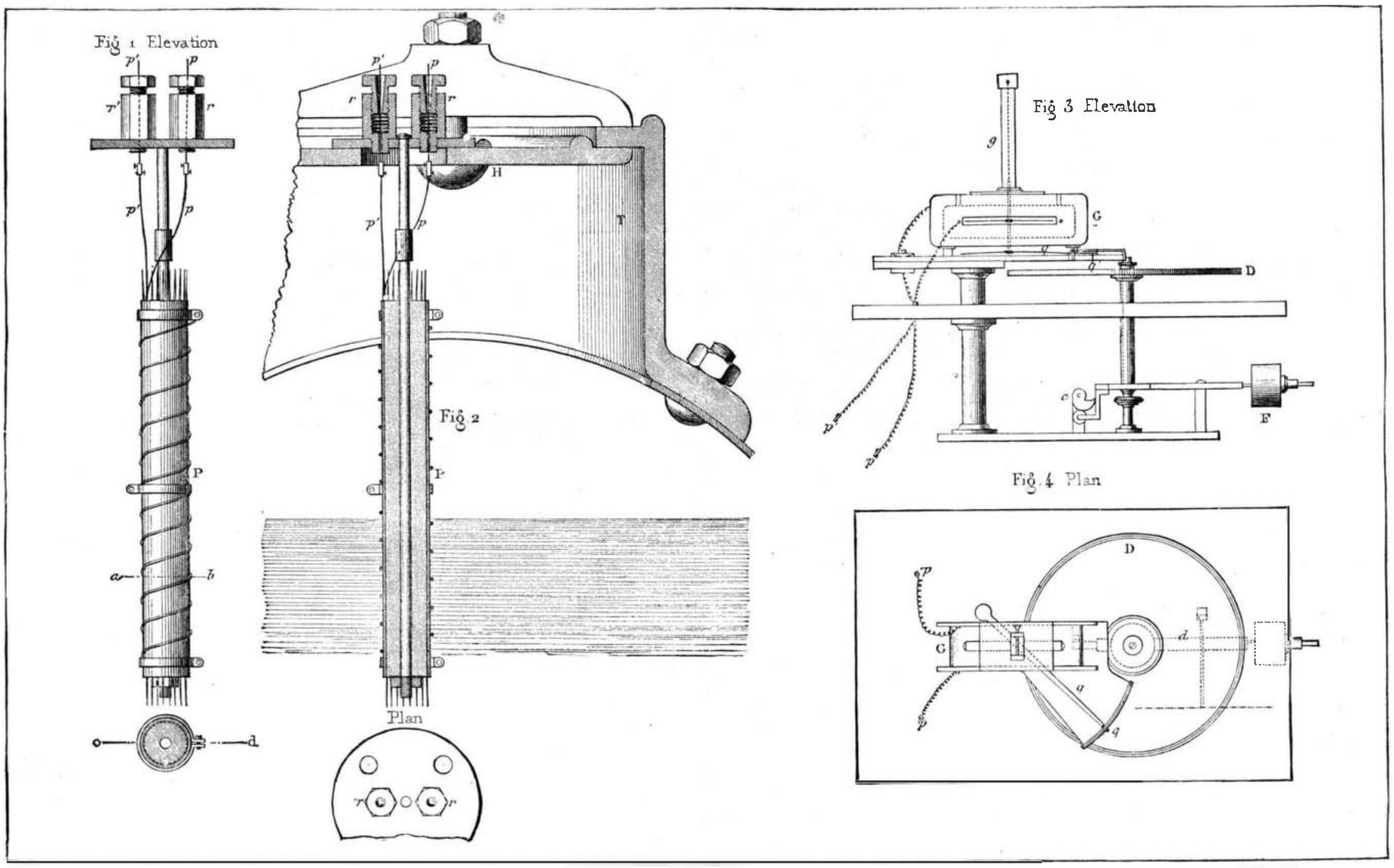

Fig 1.—Elevation. Fig. 2.—Section through *c d.* Fig. 3.—Elevation. Fig. 4.—Plan (Scale ¼).

Plate I.—EXPERIMENTS AT THE CONSERVATORY.

The Minister of Public Works having invited the Central Committee on Steam Engines to examine the processes proposed by Commandant Treve, a number of experiments were made by that body, and a report was drawn up, from which we extract the following:

Not finding in the industrial facts that have been observed up to the present any decisive proof in favor of M. Treve's theory, the sub-committee endeavored to enlighten itself through experiments, as follows:

various materials were boiled therein. The heat was obtained from a Bunsen burner, the flame of which was spread out by means of wire cloth. The temperature was given by a thermometer which dipped into the liquid. The ebullition of the pure water and of the saline and alkaline solutions gave rise to but a few insignificant movements, even when it was prolonged for some time.

Slightly acidulated water gave rise to very marked superheating, which, however, did not exceed more than two or upon the saw mill boiler, and the object of them was as follows:

It results from the experiments of physicists that superheating is in all cases favored by a stagnation of water during a more or less prolonged stoppage, having for effect the expulsion of the imprisoned air. Let but a slightly energetic action occur on the superheated liquid, and evaporation will take place and a large quantity of steam will be

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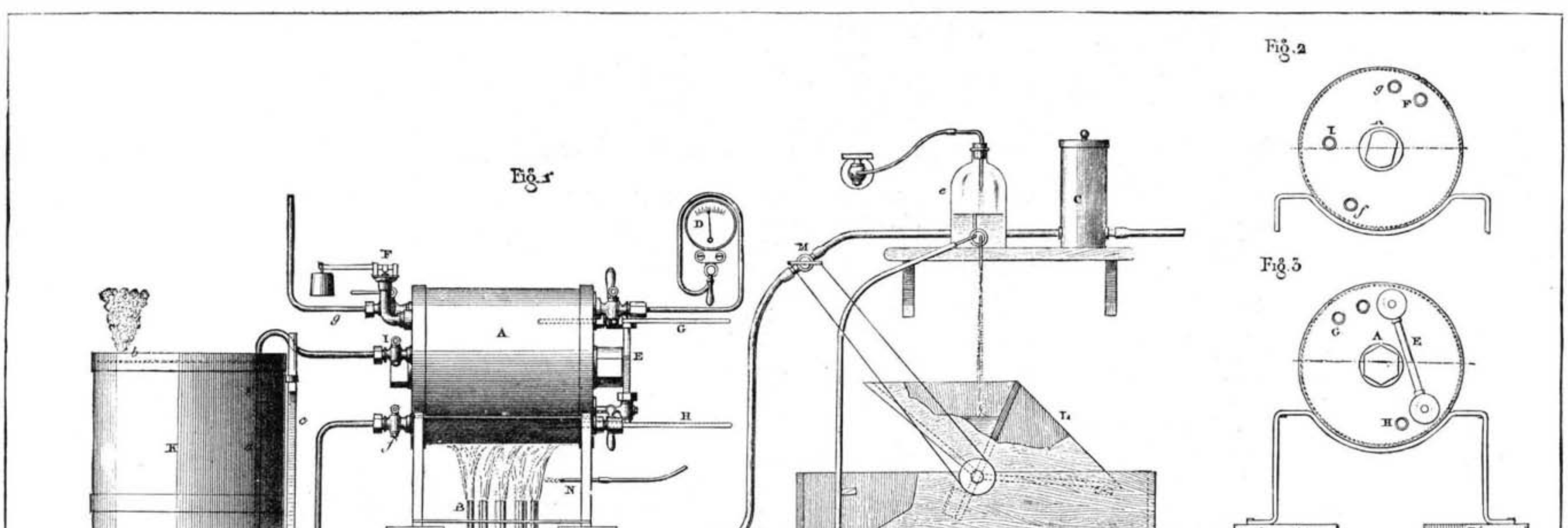

Fig. 1.—General Arrangement of Boiler and Accessories. Fig. 2.—Elevation of Boiler Front. Fig. 3.—Elevation of Rear End.

Plate II.—EXPERIMENTS AT THE TROCADERO.

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quickly emitted. Such a thing occurs at the moment of starting a generator that has slowly cooled during an entire night, with register and ash box closed, and with a fire covered uniformly with cinders. It was of interest, then, to ascertain whether, under such circumstances, the opening of the steam port, by causing an ebullition, would not bring about a sudden forward motion of the pressure gauge.

The boiler experimented upon was a tubular one, having the shape of that of a locomotive, and the following dimensions: Heating surface, 65·4 square meters; capacity of the water reservoir, 3,130 liters; capacity of the steam reservoir, 1,089 liters.

During its normal operation this boiler vaporized about 425 liters of water per hour. It was heated by wood.

Observations were made on the 22d and 23d of June, 1883, and were resumed on the 11th of July, and continued every day till the 1st of August. In the morning, at the moment of setting the boiler in operation, and while the steam port was being opened, an observer had his eyes fixed upon the pressure gauge. But these observations showed absolutely nothing abnormal in the movements of the gauge. If the fire was quick at the moment of starting, the pressure continued to rise until the engine had acquired its normal speed; and, when the fire was covered, the pressure slowly lowered.

Third Series of Experiments.—In a boiler in normal operation the temperature of the steam is the same as that of the water. If, at a given moment, the water becomes superheated (to take that particular state in which it ceases to vaporize), the tension of the steam becomes independent of the temperature of the water, and there must, therefore, occur a difference between the temperature of the two. An endeavor was made to seize differences of such a nature, and, with this end in view, a series of experiments was planned in which the differences of the temperature of the steam and water of a boiler should register themselves for a long time.

The arrangement adopted for taking the temperature is shown in Plate I., Figs. 1 to 4.

The boiler experimented upon was that of the Conservatoire des Arts et Metiers. It was a cylindrical one, having four lateral feed-water heaters, a heating surface of 13 square meters, and a grate surface of 27·5 square decimeters.

A thermo-electric pile was constructed for suspension in the boiler in such a way that a series of solderings should dip into the water, while others of equal number should remain in the steam. This pile, which was 45 centimeters in length, consisted of 15 iron wires and 15 German silver ones, 1·5 millimeters in diameter, soldered successively by their extremities. These wires were arranged according to the generatrices of a boxwood cylinder, 40 millimeters in diameter, having an aperture running through it lengthwise for the passage of the copper wire by which the pile was suspended vertically from the self-closing cover of the manhole of the boiler.

The ends of contrary polarity, which remained free, were connected with a galvanometer needle, whose deflections were registered every quarter of an hour upon a sheet of paper by means of a puncture made by a vertical point fixed to the needle's extremity. This registering apparatus, with clockwork movement, was the same as had been successfully employed by Gen. Morin for measuring at the different points of a ventilating chimney, the excess of internal temperature over that of the surrounding air.

Each positive experiment included the registering, every twenty-four hours, of the position of the galvanometer needle, before firing up and until the boiler was under pressure, at the time the engine was set running, and while the latter was operating under nearly a constant pressure, and finally during the period of cooling, up to the next day or day after. Then the paper was changed in order to obtain a new diagram corresponding to the firing up again, before or after a new feed, until the pressure had risen to the normal one of five atmospheres, and had permitted the engine to run regularly.

No notable deviation was exhibited in the position of the galvanometer needle during all these alternations, or during the whole duration of the observations, which were greatly prolonged.

It resulted from an examination of the diagrams that the temperature of the steam pole was in general not quite so high; but the difference was always below 2°. This is explained by the proximity of the sides of the boiler, the temperature of which was naturally lower than that of the steam, and which radiated against the steam pole.

During the night of August 26–27, the galvanometer needle became strongly disturbed, as shown by the tracings. What was the cause of it? We do not know; but, at any event, the form of the tracing does not permit it to be attributed to superheating, seeing that the movements occurred between half-past one and six o'clock in the morning, that is to say, during the period of cooling. Further, the diagram shows that the deflections of the needle occurred suddenly and disappeared slowly, while the contrary would have taken place had superheating been the cause of the movements.

It is thus established by direct experiment that no appreciable difference is shown between the temperature of the water and that of the steam during any of the periods comprised in the observations, either during the running or during firing up or cooling.

Fourth Series of Experiments.—Finally, it was desired to ascertain whether, by depriving water entirely of the air in solution, by means of an extremely prolonged ebullition, the phenomenon of superheating could not be obtained in a metallic boiler.

The experiments were performed at the laboratory of the Ecole des Ponts et Chaussees, at the Trocadero.

The boiler, A, used (see Plate II., Figs. 1 to 3) consisted of an iron cylinder provided with strong cast iron heads. This was tested to a pressure of 15 kilogrammes per square centimeter. Its capacity was about 21 liters, and it was heated by a large Bunsen burner, B, having two crowns, one of them carrying 6, and the other 12 jets. The gas pipe was provided with a pressure regulator, C. By varying either the number of jets or the pressure of the gas, the conditions of heating could be modified within wide limits. The boiler was provided with the following accessories: A good Bourdon pressure gauge, D, divided into quarter kilogrammes; a water gauge, E; a safety valve, F; and various cocks. It was also provided with two horizontal mercurial thermometers that passed through stuffing boxes, G and H, and the bulbs of which entered, one of them, the water, and the other the steam. Their tubes were external to the boiler.

The arrangements made for obtaining a prolonged ebullition were as follows: From one of the cocks, I, which debouched a little over the center of the boiler, branched a tube that bent so as to run nearly to the bottom of a vertical cylindrical vessel of water, K, made of galvanized iron. The water in this reservoir had been previously boiled, and the same was the case with that which was to be added from time to time to replace the water which had evaporated. The capacity of this vessel was 50 liters.

The boiler being heated, the steam produced bubbled up through the water in the vessel, K, and kept it at a boiling point. As the cover of K had but two narrow apertures, one of them for the passage of the steam pipe, and the other for the exit of the excess of steam, it will be seen that there always existed at the surface of the ever hot water in K an atmosphere of steam, and that the water could not dissolve any air.

The operation was as follows: The boiler was heated for about an hour and a half, and then the gas was shut off. Through the condensation of the steam by cooling, the boiler became completely filled with water drawn from K. In half an hour, heat was again turned on, when there flowed through the feed pipe, first, water, and next steam. For alternately admitting and cutting off the gas, a small apparatus was used that consisted of a hydraulic working beam, L, which maneuvered the gas cock, M.

The boiler had been cleaned with caustic potash, and then washed with a large quantity of water. The apparatus was set running January 4, 1884, at 3 o'clock P. M. The experiments, properly so-called, began January 15. The water had therefore boiled, before the first experiment, for eleven days, night and day, with an interruption of half an hour every two hours, corresponding to about 200 hours of continuous ebullition. It may be admitted that on the 15th of January the boiler and water were absolutely devoid of air.

During this entire period the two thermometers were observed from time to time, and were always found to agree within about one or two degrees. Such difference we have already explained in our account of the Conservatoire experiments.

The experiments, properly so called, were performed on the 15th of January and the days succeeding, and were as follows:

All the cocks were closed, and the boiler being submitted to the action of heat, the temperature and pressure consequently rose. At intervals, simultaneous observations were made of the thermometer which dipped into the water, of the one which was in the steam, and of the pressure gauge.

Finally, the conditions of heating were varied, so as now to cause the temperature to rise 50° in half an hour, and then to rise only 28° in six hours and a half.

The last experiments were performed after the boiler had been kept closed, and slightly heated for nearly fifteen hours, and the result of them may be summed up as follows:

The two thermometers were constantly in accord; the difference, which was always less than 2°, as in the Conservatoire experiments, is very naturally explained by a few small variations in the construction of the instruments and the action of pressure upon their bulbs, and especially by the unequal effect of radiation from the sides of the boiler. It was remarked, in fact, that the thermometer in the steam gave lower indications than the other when the pressure rose, and, on the contrary, higher indications when it lowered. At the moment of opening the escapement no abnormal movement in the needle of the pressure gauge was ever seen.

Conclusions.—In conclusion, the committee believes that it has in no wise been demonstrated, up to the present, that the superheating of water has caused any boiler explosion, nor that superheating has ever occurred in generators used in the industries. If it does occur, it is only in extremely rare cases, and through the concurrence of exceptional circumstances that are up to the present neither defined nor known. There is, therefore, no need for the moment of examining the remedies that have been proposed for preventing the superheating of water in generators.

DESCRIPTION OF PLATE I.—P, thermo-electric pile; *pp'*, wires for connecting the poles of the pile and the galvanometer, G; Q, needle of the galvanometer, G, that moves around the axis of the suspension wire, *g*; *c*, cam of the registering apparatus, moved by clockwork and allowing the disk, D, to rise every 15 minutes under the action of the weight, F; T, man-hole, closed by the cover, H, which latter is provided with two stuffing boxes, *r*, *r'*.

PLATE II.—A, boiler; B, Bunsen burner; C, pressure regulator; D, Bourdon pressure gauge; E, water gauge; F, safety valve; G, thermometer in steam; H, thermometer in water; I, feed cock; K, freed water tank; *b*, steam eduction aperture; *c*, water gauge; *d*, blow-off cock; L, hydraulic working beam fed by the bottle, *e*; M, gascock; N, lighter; *f*, blow-off cock of the boiler; *g*, escape pipe.—*Abstract from Annales des Ponts et Chaussees.*

Acetate of Soda Heaters.

For the last two years experiments have been making toward the warming of cars by means of a heat giving fluid, which continues for several hours to throw out heat with approximate regularity, for a time depending upon the original degree of heat imparted to the liquid. The cars of the De Kalb Avenue line in Brooklyn, seventy in number, have been heated by this system during the last winter to the satisfaction of the company, and presumably to that of the public.

A large iron pipe containing the compound passes under each seat of the car; through the center of the pipe runs a smaller pipe, through which steam is passed when it is desired to heat the compound. When heat is applied to the pipes from a steam boiler in the station, the crystals in the acetate of soda used are liquefied, and remain so until the temperature begins to fall perceptibly. Then the crystals begin to form, and the liquid throws out an increased heat. A thermometer taking the temperature of a pipe of the heated compound shows that during the first hour or two there is a slight fall in the temperature, then a sharp rise while crystallization takes place, and then a gradual fall.

A record of the temperature of one car kept during twenty days showed that after each run of sixteen miles, the temperature of the car was upon an average less than one degree lower when the car returned to the station than when it started out. The cost of heating cars by this system is said, by the company which controls the patents, to be not more than for stoves, while the heat is pleasanter and the atmosphere is free from gas and smoke. The compound in the pipes will last for an indefinite number of years, for all that is known to the contrary, being hermetically sealed.

This company now propose to introduce the same system as an improvement on heating by ordinary steam radiation. Steam coils often heat too violently in small rooms, and either give too little or too much heat. By using the steam to heat a reservoir of the compound liquid, the steam can be turned off when the room is sufficiently warm, and the reservoir will continue to throw out a constant amount of warmth for several hours. A small pipe full of the compound, 3 feet long and 4 inches in diameter, is made for heating private carriages.

Earth Worms.

An interesting paper on the habits of earth worms in New Zealand is contributed to the New Zealand Institute by Mr. A. T. Urquhart. The species are not named, but with such wonderful opportunities as Mr. Urquhart possesses for making a collection of these, may we hope that, in addition to his following out his painstaking observations as to their habits, he will also advance science by making a careful collection of the forms and placing them in the hands of some of the able naturalists of the Auckland Institute for description? It will be remembered that Darwin assumes that in old pastures there may be 26,886 worms per acre, and that Henson gives 53,767 worms per acre for garden ground and about half that number in corn fields. Mr. Urquhart gives, as the result of his investigations of an acre of pasture land near Auckland, the large number of 348,480 worms as found therein. It being suggested to him that in his selection of the spots for examination he may have unconsciously selected the richest, the experiment was again tried in a field seventeen years in grass. A piece was laid out into squares of 120 feet, and a square foot of soil was taken out of each corner; worms hanging to the side walls of the holes were not counted, and in one hole, where the return of worms was a blank, the walls were crowded with worms. As a result there was an average of 18 worms per square foot, or 784,080 per acre. Although this average is very striking when compared with that of Henson, it is worthy of note that the difference between the actual weight of the worms is not so marked. According to Henson, his average of 53,767 worms would weigh 356 pounds, while Mr. Urquhart finds that the average weight of the number found by him came to 612 pounds 9 ounces.

Indelible Stamping Ink.

E. Johanson, of St. Petersburg, gives the formula for a convenient ink for marking clothing by means of a stamp: 22 parts of carbonate of soda are dissolved in 85 parts of glycerine, and triturated with 20 parts of gum arabic. In a small flask are dissolved 11 parts of nitrate of silver in 20 parts of officinal water of ammonia. The two solutions are then mixed and heated to boiling. After the liquid has acquired a dark color, 10 parts Venetian turpentine are stirred into it. The quantity of glycerine may be varied to suit the size of the letters. After stamping, expose to the sun or apply a hot iron.—*Pharm. Rec.*