WET STEAM.*

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The second annual report of the Inspector of Boilers of the city of Philadelphia states that, out of 56 men who presented themselves during the year 1870 for inspection and license as engineers and boiler-tenders, only 4 were considered first-class. Out of 39 who sought examination for a renewal of their licenses, only 9 were first-class. A large proportion were only third-class. I am not aware what the standard of classification adopted in Philadelphia is, but it is probably none too rigid. It is, probably, also fair to suppose that those who sought examination were better than the average of those employed to take charge of boilers; since there is in that city no penalty imposed for the employment of unlicensed engineers or boiler-tenders. I deem it, therefore, extremely probable that the 4 receiving first-class certificates, out of the 56 examined, represent even a larger proportion of thoroughly qualified men than would be shown if a general system of examination and license were legally enforced.

In view of the general incompetence of those placed in charge of boilers not only in Philadelphia, but throughout the country, the use of boilers not only safe with good care and treatment, but safe even under neglect, has been gradually growing in favor, notwithstanding most of the boilers justly regarded as being incapable of exploding disastrously do not compete in point of economy with others which, unskilfully attended, are liable at any moment to explode with destructive violence.

The year 1870 has a most appalling record of death and destruction from boiler explosions, and it is time that the question of safety *versus* economy in the use of boilers should be definitively settled. The first step towards settling this question is the accurate determination of the real ratio of economy, in boilers admittedly safe under all circumstances, to those admittedly unsafe except when used with the best skill and fullest knowledge.

The safe boilers are those known as "sectional," in which very great strength in proportion to rupturing strain is attainable, and which—even if, under enormous pressure, they explode—cannot explode as a whole, but can only burst some minute portion of their structure. These boilers could, some of them, make a fair showing of evaporative power in proportion to consumption of fuel without forcing; but in trials made to ascertain their steam-producing capacity, their exhibitors are apt to force them until they prime, and thus the amount of water passed through them becomes no index of their economical value as steam-generators. These boilers also present such an enormous heating surface in proportion to the water they carry, that in practical use they may be caused to prime by slight overfiring; and with the ordinary care they get, it is little to be wondered at that it is an exception to find one of them delivering dry steam.

Any boiler has a limit of steam generation beyond which it cannot be pushed without priming; and, on the other hand, any boiler has a limit of steam-producing capacity below which it will deliver perfectly dry steam. The amount of dry steam per pound of fuel actually burned that boilers will produce from water at 212 deg. Fahr. is the accepted standard of comparison as to their working economy. Experiments made by myself have, however, shown that, in very few cases where boilers are thus tested, absolutely dry steam is delivered; the amount of water contained in the steam being in one case, which I now call to mind, certainly not less than 40 per cent. of the entire weight of mixed steam and water issuing from the boiler. This was, of course, an extreme case, in which the boiler was specially contrived, it would seem, to prime as much as possible. The evaporative power claimed for it by its sanguine inventor was 13 lbs. of water per lb. of coal consumed. All the way from this extreme up to absolutely dry steam, you may find boilers working if you will look for them. Boilers priming to the extent named, or even much less than that, are really unfit for service to supply engines with steam, and, I need

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not say, are scarcely ever used for that purpose. But boilers often prime to a much greater extent than is suspected, in the absence of means to detect the exact amount of water mechanically carried over.

A common method of testing the quality of steam is to pass the hand through the jet of steam escaping—a method so rúde that it is really a disgrace to the science which has taught us that, with steam as a motor, everything may be reduced to mathematical certainty. I have known the estimate made by good judges to be 10 per cent. from the truth in making this test. The appearance and feeling of steam differ with the hygrometric condition of the atmosphere into which it rushes. On a clear, bright day, steam appears different from the same quality educted on a moist, foggy, and obscure day.

The method I have employed for testing the quality of steam, and the instrument devised for the purpose, is based upon the fact that steam at 212 deg. always contains 1,178 heat units per lb. and water at 212 deg., 212 units of heat per lb. It follows that, knowing the amount of heat issuing from a boiler in a lb. of mixed steam and water, the proportions of water and steam in the lb. can be easily determined. For, if x be used to represent the water in lbs., and y the steam in lbs., a the quantity of mixed water and steam educted in lbs., and b the total number of units of heat carried out in the mixed water and steam, we may form the equations

$$x + y = a$$
$$212\,x + 1178\,y = b.$$

from which we find the value of x to be $x = [1178a - b] \div 966$; or, to drop algebraic language, the amount of water contained in a given amount of mixed steam and water will be, in lbs., 1,178 times the weight of mixed steam and water, minus the number of units of heat it contains, divided by 966, the number of units of heat required to convert a lb. of water at 212 deg. Fahr. into steam at the same temperature.

To determine the amount of heat carried out by the mixed steam and water, I devised the following apparatus. A scale-beam with a platform, and a thickly felted water-chamber at one end, and a counterpoise at the other, has upon it a sliding weight, indicating lbs. and ½ lbs. The walls of the water-chamber are made of thin tinned sheet-copper; there being 2 shells, between which felting, 1½ in. thick, is placed. A felted cover is also provided, through which is inserted a standard thermometer, having a large bulb and easily read in 5ths of degs. A finely-perforated coiled copper pipe rests upon the inner floor, and passes out at the lower part of the side wall of the chamber. This is the steam-induction pipe. The bottom of the chamber is obtusely funnel-shaped; and from the lower part of the funnel is led out an escape-pipe. Both pipes are provided with cocks. A small funnel in the cover, also provided with a cock, completes the apparatus.

To use it, 5 lbs. of water are placed in the chamber through the funnel in the cover. The water is then raised to 80 deg. Fahr. by allowing a jet of steam—conveyed through a felted pipe—to enter through the coiled induction-pipe. The surplus water thus added is drawn off through the escape-pipe at the bottom of the chamber, leaving in the chamber 5 lbs. of water at 80 deg., containing 400 units of heat. The sliding weight is then set along into the 5½ lb. notch, and the steam to be tested is then allowed to flow in till the scale-beam balances. Then the influx of steam is stopped, the thermometer is read, and the experiment is complete.

Suppose, now, the resulting thermometrical reading to be 180 deg. We then have 960 units of heat in the chamber, not counting in the amount absorbed by the thin copper lining—a very small amount indeed, and only noticeable theoretically; the general result is scarcely affected by its neglect. It follows that the amount of heat conveyed into the chamber in the lb. of mixed steam and water is 960—400 = 560 heat units. Substituting this value for b in the above formula, we have (the value of a now being ½) $[1178 - 560] \div [966 \times 2]$ which, reduced to hundreds, gives $31\frac{1908}{1932}$ per cent. of water.

This instrument, for want of a better term, I have called the "steam hygrometer."

The standard quantity of water in the chamber, 5 lbs., the standard temperature, 80 deg., and the standard quantity of steam admitted in the experiment, ½ lb., are chosen merely as matters of convenience. It is evident that, for any system of standards, tho percentages for different resulting temperatures, between the minimum and maximum limits inclusive, may be computed and tabulated, so that, in testing boilers, no calculation need be made; the percentage for any resulting temperature being taken at once from the table.