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ON THE USE OF CONCENTRATED SOLUTIONS OF SODA FOR GENERATING STEAM.

BY C. WAGEMANN, C.E.

SOME two years ago the attention of the engineering world was attracted by a discovery made by Mr. Moritz Honigmann, the proprietor of a large soda factory at Aix-la-Chapelle (Germany), and since that time the patented inventions based upon that discovery have not only been tested by a great number of trials, but have been set into practical working, and two years' experience has shown that we have to add a new chapter to the science of engineering. Mr. Honigmann's invention will, no doubt, revolutionise the present mode of generating steam in all cases where steam is required in large quantities, or steam-power is to be transmitted from its source to either stationary or moving working-places, or where a high degree of safety is required.

Before entering into the matter it may be advisable to recall to memory a few physical laws.

It is well known that the various liquids have different boiling points. That of water (under mean atmospheric pressure) lies at 212° F. At this temperature the water is expanded to such an extent that a further addition of heat introduces a power sufficient to neutralise the pressure of the atmospheric air, to decompose the globules of water and to transform them into steam. If the water is exposed to more than the common atmospheric pressure, say to that of 2 atm., steam-making begins at a temperature of 2768 F., under a pressure of 3 atm., a temperature of 291° F. is required, and a temperature of 365° F. is corresponding to 10 atm. pressure. A reduction of the atmospheric pressure lowers the temperature for evaporating, In a partial vacuum of $\frac{1}{2}$ atm., a temperature of 180° F., and in that of 1-10th atm., a temperature of 115° F. is sufficient to raise steam.

The boiling-point of solutions of caustic soda (Na O. HO.) in water depends on the degree of concentration. The following table shows the boiling-points of a few soda-brines (under mean atmospheric pressure), and the pressure of steam (generated from water) of the same temperature :—

If the soda-brine consists of:					The boiling point is:		The pressure of steam of equal heat is :
100	parts soda	and	400	parts water	224·6	deg. F.	0·3 atm.
100	,,	,,	300	,,	230·6	,,	0·4 ,,
100	,,	,,	200	,,	248	,,	0 95 ,,
100	,,	,,	120	,,	276	,,	2 ,,
100	,,	,,	100	,,	291	,,	3 ,,
100	,,	,,	80	,,	309	,,	4·2 ,,
100	,,	,,	70	,,	319·1	,,	5·1 ,,
100	,,	,,	60	,,	330·8	,,	6·1 ,,
100	,,	,,	50	,,	338·9	,,	7 ,,
100	,,	,,	40	,,	365·9	,,	10·2 ,,
100	,,	,,	35	,,	378·5	,,	12·1 ,,
100	,,	,,	20	,,	428·9	,,	
100	,,	,,	10	,,	492·8	,,	

It is evident that the boiling-points of the various solutions must become of higher or lower temperature if a higher or lower pressure is acting on the brine.

As only a small quantity of caustic soda is soluble in cold water, but large quantities are readily dissolved in hot water, the preparation of highly concentrated solutions is executed by heating a low-graded brine and thereby evaporating a portion of the water. One part of the heat thus introduced into the brine escapes with the evaporated water, another one serves to raise the temperature of the brine, and the (very considerable) remainder is bound in the brine as latent heat. By again diluting the concentrated brine the latent heat is set free, and (so far as it is not used for raising the temperature of the diluting water) it forms a stock of heat ready for any heating purpose.

Suppose a common vertical boiler, partially filled with water of about 210° F., be inserted in an open vessel containing a heated soda-brine which is composed of 100 parts soda and 20 parts water (boiling-point 428.9° F.), a certain amount of heat will be transmitted from the brine into the boiler, and its contents will generate steam. By adding water to the brine a new quantity of heat i generated, and the pressure in the boiler must rise, or (if the steam is allowed to escape from the boiler) fresh steam will be generated therein.

This process can be continued until the dilution of the brine is so far advanced that its boiling-point does not sufficiently surpass the temperature of the steam which is to be generated. For a further continuation of steam-making, either the diluted brine must be exchanged against concentrated one, or it must be admitted that the steam may leave the boiler under lower pressure than during the first period of the process. Such an apparatus could be used in cases where steam is to be generated in places where the use of fire is absolutely prohibited (for instance, in powder-mills), but it needs no special calculation to show that the price of power generated and transmitted in such manner is too high for extensive practical use. The missing link, for making the above combination, a superior boiler was added by Mr. Honigmann, who observed that soda-brine absorbs without any noise, and condenses instantaneously and completely large quantities of steam introduced into it, provided the temperature of the steam remains below the boiling-point of the soda-brine.

The addition to the above apparatus of a pipe conducting the waste-steam of an engine (instead of water) into the soda-brine, alters the whole aspect. All heat stored in the brine is now utilised, and what is not converted into labor in the cylinders of the engine is returned to the brine, and (as the quantity of heat generated by the dilution of the brine is greater than that which is converted into labor) the pressure in the boiler must rise. In fact, the boiler must be supplied with water during the working of the engine, if a constant pressure shall be maintained.

It appears quite unnecessary to enter into calculations for demonstrating the enormous saving of fuel by this process. Suffice it to point out that the latent heat of the waste steam—which, fos instance, represents in steam of 1½ atm. pressure 528 calories (centigs.) out of 630 calories total heat—is completely saved.

On the other hand, inquiries must be made as to the *quantity of fuel used for evaporating the water* from the diluted brine. This, of course, depends upon the construction of the concentrating appliances. For the tramway motors at Aix-la-Chapelle the concentration is executed in a vessel of the shape of a Cornwall boiler, wherefrom the evaporated water escapes into the open air. By careful observations, it is stated that one pound of common Westphalian coal (which is able to convert, in a well-constructed boiler, 6 to 8 lbs. water into steam) is able to concentrate such a quantity of brine as is required for making 7·1 pounds of steam in the boiler of a tramway engine. This is, so far, a very satisfactory result, as it shows that with a most inferior concentrating apparatus the Honigmann boiler possesses a steam-making capability per pound of fuel at least equal, if not superior, to that of any good boiler. The reason why the useful effect is not higher must be found in the loss of heat carried in that steam which is evaporated from the concentrating vessel. And here Mr. Honigmann succeeded to reduce it, by aid of a very ingenious arrangement, to nearly *nil.* Instead of allowing the steam from the concentrating vessel to escape into the open air, he carries it through a number of pipes which are crossing a tank filled with diluted cool brine; thereby the steam is condensed, and the condensed water forms the best material for feeding the boilers. At the same time the diluted brine in the tank is heated and some water evaporated. The latter operation is supported by a small vacuum-pump, which makes a partial vacuum (of $\frac{1}{4}$ to $\frac{1}{10}$ atm.) in the (closed) tank, and thereby raises the temperature of the brine therein to 122° and 176° F. respectively. The waste steam of the vacuum-pump is also conducted through the pipes crossing the tank, and assists heating the brine, consequently nearly no heat of any steam generated is lost. The Cornwall boiler (destined for concentrating the brine to the degree finally required) is fed from the brine-tank, which is placed about 24 feet high. The latter feeds itself automatically through a pipe which leads to the bottom of a reservoir standing so much below the said tank that the vacuum generated in the latter is sufficient to suck up the diluted brine. This apparatus (with three large Cornwall boilers) has been in use for a long time at Mr. Honigmann's factory for making concentrated soda-brine; and on the 23rd April, 1885, Mr. Gutermuth (Assistant at the Royal

Technical Academy at Aix-la-Chapelle) has ascertained that the quantity of water evaporated from the Cornwall boilers was 776 cubic feet, and that the quantity of water evaporated by the vacuum-pump was also 776 cubic feet, which shows a saving of 50 per cent. Considering all possible losses, and the heat used for driving the vacuum-pump, the saving of fuel in the Honigmann process must be at least 40 per cent., and the quantity of steam generated by one pound of common Westphalian coal must be 11·9 lbs.

An important question is that of the *influence of soda-brine on the boiler material.* A series of experiments has proved that soda-brine does not attack iron at temperatures below 313° F. If, therefore, steam of low pressure (4 atm.) is used, boilers and soda-vessels can be made of iron. If steam of higher temperature is required, the soda-vessels must be made of copper or brass, which stand the influence of soda-brine at any temperature. Fortunately the brine-vessel can be very light, as it is exposed to a slight pressure. The boiler is comparatively small, and its heating-surface can be obtained by using field-tubes made of brass.

If the soda-boiler is used on locomotives, it is essential to ascertain *the quantity of brine which must be carried* on it to enable it to work for a certain length of time without a renewal. Suppose the waste steam be below 2 atm., the corresponding heat is 276° F. A soda-brine with boiling-point of this temperature consists of 100 parts (by weight) soda and 120 parts water, its specific gravity is 1·41 (1 cb. ft. = 88·8 lbs.), and 220 lbs. are measuring 2·5 cb. ft. If for the condensation of this steam a soda-brine shall be used, with boiling-point of 492° F., viz., a mixture of 100 parts soda and 10 parts water (spec. gr. 1·89; 1 cb. ft. = 117·9 lbs.), 110 lbs. of *this* brine measures 0·93 cb, ft. The difference between these two cubical contents, viz., 2·5—0·93 = 1·57 cb. ft. must represent the quantity of water to be introduced into the concentrated brine for diluting it to such a degree that it cannot condense any longer steam of 2 atm. pressure. Or 1 cb. ft. brine of 492° F. boiling-point is able to absorb 1·7 cb. ft. of water *if the process is going on under atmospheric pressure.*

It is already mentioned that with all liquids the boiling-point rises if the liquid is exposed to higher pressure, and Mr. Honigmann found that the capability of absorbing steam increases considerably if soda-brine is exposed to pressure. For instance, in the above case, the quantity of water which can be absorbed by brine which is exposed to $\frac{1}{2}$ atm. pressure is $1\frac{3}{4}$ times, and if exposed to 1 atm. pressure it is 3 times that which can be absorbed in an open vessel, viz. :—

1 cb. ft.	of said brine	absorbs	in an open vessel	1·7	cb. ft.	water.
1	,,	,,	,, under $\frac{1}{2}$ atm. pressure	2·975	,,	,,
1	,,	,,	,, ,, 1 atm. pressure	5·1	,,	,,

Of course these maximum pressures do not appear but at the end of the operation, and the average becomes very low if another highly interesting invention of Mr. Honigmann is made use of, who adds to the soda-brine (in the soda vessel of the locomotive) a quantity of protoxide of iron. During the time the concentrated brine is running into the brine vessel, a cock on top of the latter is opened to allow the air to escape, and when the charging of the brine vessel is completed and the air-cock closed, a partial vacuum (of 1-10th to $\frac{1}{4}$ atm.) is generated in the brine vessel by the protoxide of iron (Fe O) absorbing oxygen from the air (remaining over the brine) and being converted into peroxide of iron ($Fe_2 O_3$). This vacuum lasts about one hour, and at the end of a $4\frac{1}{2}$ hours' trip the gauge shows a pressure in the brine vessel which amounts in the locomotives used at the Aix-la-Chapelle tramway to 1-5th atm. Mr. Honigmann estimates the loss of power caused by the average back pressure on the piston to less than what is required in fired locomotives for the steam-jet which gives the artificial draft.

Consequently by allowing at the end of the operation a small amount of back pressure, the duration of the process, with one charge, can be multiplied, or, for a given duration, the quantity of brine carried can be reduced at the same ratio.

Moreover, the presence of protoxide of iron in the brine vessel and the absorbtion of oxygen by it prevents oxydising of the copper.

The *capacity of the soda boiler to generate steam is very great.* In February, 1885, trials were made with one of the Aix-la-Chapelle tramway engines, in the presence of Professor Wullner (Rector of the Royal Technical Academy, Aix-la-Chapelle) and other prominent engineers to decide upon this question. The vertical boiler of the said engine is about 20 inch high, and of 4 feet diameter; it has 120 field tubes of 1·6 inch diameter. The boiler is screwed on top of the brine vessel of the same diameter and 55 inch-high. The weight of the boiler and soda vessel, including water and brine, is 3 tons. During the trials the engine and one carriage (with hand-break put on) were going at a very high speed, and as even then the maximum capability of steam-making could by far not be utilised, *a part of the steam was (without passing the engine) directly conducted into the brine* and condensed. The quantity of steam was in one case 2,400 lbs., in another 2,700 lbs. per hour. During the trials the heated surface (field tubes surrounded by brine) was on an average 107 square feet, the difference in the temperatures of brine and water was 12° F. The 107 sq. ft. surface generated on an average 2,500 lbs. steam per hour, or *one* sq. ft. made 23 *lbs. steam*, whilst one sq. ft. in a common stationary boiler raises from 3 to 7 lbs., and in a locomotive boiler 8 to 10 lbs. steam per hour.

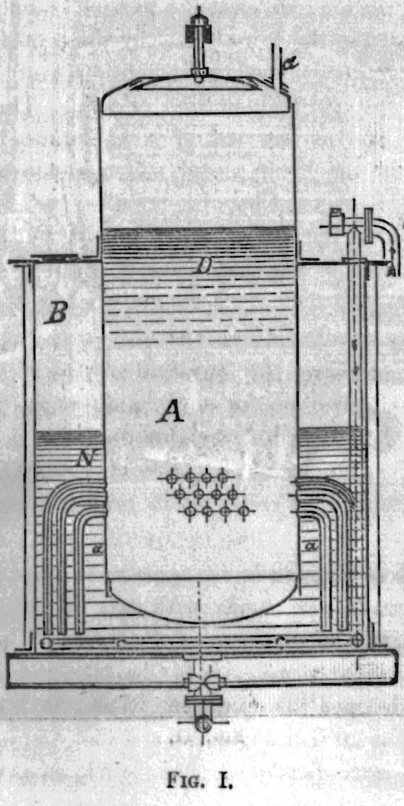

FIG. I.