

conditions observed in constructing and working the engine, a continuous run made by it will be long or short. We may consider these conditions *seriatim*. One of the first and most important is, that the crank shaft shall be made of the best metal and be very lightly loaded. It is not as generally known as it ought to be that there is no such thing as a bar of metal which will not yield to a small stress imposed on it. A railway axle 4 in. in diameter can be bent by an amount which it is possible to measure, by weight of 100 lb. hung in the middle. A crank shaft therefore, especially of the double-web type, will be bent through a sensible amount at each revolution; and it has been shown over and over again that the duration of a crank shaft, say, in a locomotive engine, depends, other things being equal, on the amount to which it is bent at each revolution, the quality of its material, and the number of bendings. The process by which fracture is ultimately brought about is in its nature precisely the same as that by which we break a bit of wire or tin by bending either backward and forward between our fingers. Now the crank shaft of the Westinghouse engine at the Pittsburg gas works must have been bent first one way and then the other no less than 466,000,000 of times; and that it should endure this manipulation it is essential that the stress on it should be very small, so that the bendings should be trifling. We are told that the engine is 10 horse power, but we are not told what it was indicating. Assuming that the stroke was 6 in., the piston speed would be about 250 ft. per minute, and there are two pistons, the engine being compound; this gives an average pressure of 660 lb. on each piston for 10 horse power. But the stress at the beginning of each stroke must have been much greater than this—probably three times as much—quite enough to produce an easily measurable bending of a 2½ in. shaft. Therefore we can only say that the piece of steel which endured nearly five hundred millions of contrary deflections is of exceptional quality and worthy of all praise. What holds good of the crank shaft may also be said of the connecting rods, and even of the framing of the engine to a certain extent.

We come next to the question of wear and tear in an engine. Assuming that it is made with pistons all through, no slide valves being used, it is entirely a matter of workmanship and material how long the engine will run, always presupposing that the steam is quite clean, and the lubrication uniformly efficient. In an engine intended to make long runs, the pistons and insides of the cylinders must be got up with elaborate care, and the springs of the piston rings must be so adjusted that these last shall press as lightly as will suffice to keep them steam-tight against the cylinder. Theoretically, a solid block piston got up dead steam-tight by scraping would run forever without wear and tear, provided grit and dust were kept out of the cylinder. In practice, however, it is essential that the piston shall be in some measure elastic, and this means that there must be friction. In marine work it is known that tail rods are of much value in saving both piston and cylinder from wear. English engineers have something yet to learn concerning cylinders and pistons from such men as Vanden Kerchove of Ghent, concerning whose admirable work we wrote fully at the time of the last Antwerp exhibition. All things considered, we hold that it is more easy to make pistons and piston valves and cylinders endure through tremendously long runs than any other portion of the engine. It is, however, quite possible to make a mistake in fitting up these parts of an engine, less in degree, but somewhat similar in kind, to the blunder of a sea-going engineer in the old low-pressure days, who set out his piston rings so tight that, as tradition goes, his engines stopped dead when he was 100 miles out of port, because the metal scraped by the rings off the cylinder had accumulated to such an extent on the lower cylinder cover that the crank could not turn the center. The crank shaft and connecting-rod brasses offer a far more perplexing problem. They constitute, after all, the crux for the engineer. It would not, indeed, be too much to say that if they could be kept all right, an engine might be run until it broke its crank shaft. But no one has succeeded in producing a double-acting engine yet of which this can be said. Many years have now elapsed since we pointed out that if a high speed steam engine was to be a success, it must be single-acting. At that time no single-acting engines were being made. By a coincidence, a very short time after the appearance of our proposition, single-acting high-speed engines made their appearance, and their success justifies our argument. It is possible to run a single-acting engine with slack brasses, for the very obvious reason that the stress is always exerted in one direction. But it is not possible to run a double-acting engine unless the brasses are just the right fit, neither too slack nor too loose, and unfortunately what is a splendid adjustment when cold may be an adjustment anything but splendid if the crank pin heats a very little. In our own experience we once met with an engine indicating about 200 horse power, the main shaft of which would always run cool if the engine room door—which was close to it—were kept open, but it always heated when the door was shut. Lastly, we have to consider the effects of impact. If the engine is properly made and has sufficient lead, there will be no knocking or thumping so long as the brasses are in good condition and a proper fit; but the moment knock begins to make itself heard, we feel that we are approaching the moment when the engine must be stopped that the big ends may be adjusted. In large engines the effect of knock may be to crack the brasses, and in any case to hammer them out of shape by degrees; and in small engines much the same results may ensue, only they will be longer coming about.

To sum up, we may say that the destructive forces tending to render a long run difficult or impossible can all be fought against to a greater or less degree. That is to say, it is not impossible to build and work a steam engine, which can run day and night without ceasing for months, or even for years; but to secure such a result unusual precautions must be taken in selecting the design and materials, and to secure perfect workmanship. It is a mistake often made that nothing more is wanted than plenty of surface. Too much surface, if badly fitted and badly lubricated, may be much worse than too little surface. We could name a pair of large stationary engines built to drive electric light plant, and provided with enormous surface, which gave for the first couple of months of their ex-

istence constant trouble. They have long since been superseded by much smaller engines of a different type, which give no trouble at all. The large engines are kept as reserves. A notable case occurred in the United States navy some years ago. In order to provide plenty of bearing surface, the crank shaft was carried in brasses 4 ft. long, the shaft being about 13 in. in diameter; all the resources of the engine room could not keep these bearings cool, and they had ultimately to be reduced in length one-half. It is not given to every engineer to be able to build an engine which can make very long runs without stopping for adjustment, and it is questionable after all whether such an engine is worth the trouble and labor spent on it. But the fact that the Westinghouse engine company has contrived to produce such an engine as that at the Pittsburg gas works ought to act as a stimulus to our own builders of high-speed engines, who will certainly have to look to their laurels in the face of a continuous run of 233,000,000 of revolutions.—*The Engineer*.

#### SIBLEY COLLEGE LECTURES.—1887-88.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

#### IV.—DETERIORATION OF STEAM BOILERS—WEAR AND TEAR.

By J. M. ALLEN, M.E., Hartford, Conn.

WHEN a boiler is completed and set to work, destructive forces more or less severe become active, and they must be carefully watched, or the working age of the boiler will be materially shortened. The forces

whether shorter boilers of a different type may not be used with safety and equal economy. Another form of cylinder boiler from twenty-eight to thirty feet long is used in connection with reheating furnaces in iron works, the gases being utilized for fuel. These boilers are often supported by resting simply on walls at each end. When the metal is being run off, the furnace doors are thrown wide open and a current of cold air is allowed to flow into the furnace and along the bottom of the boiler. The walls are very hot, and the temperature of the steam and water in the boiler is that due to the pressure. The sudden cooling of the fire sheets causes contraction, and a severe strain is brought, especially on the girth seams. These not unfrequently crack from rivet hole to rivet hole, and in a number of cases I have known the boiler to break into two parts, each part flying off in opposite directions. Fig. 1.

A current of cold air should never be allowed to strike, for any length of time, the fire sheets of a hot boiler, and such boilers should always have rods not less than one inch sectional area, running from head to head, sufficient in number to hold the boiler together under such circumstances. With this provision for safety, if a leak was noticed at any girth seam, the boiler could be put out of use and the extent of the fracture ascertained and suitable repairs made, thus preventing what otherwise might cause a serious accident.

Internally fired and fire box boilers have their weak points as well. There are narrow passages for the collection of sediment and formation of scale, and in these narrow passages the circulation is very imperfect, and wasting and corrosion is very liable to take place. I

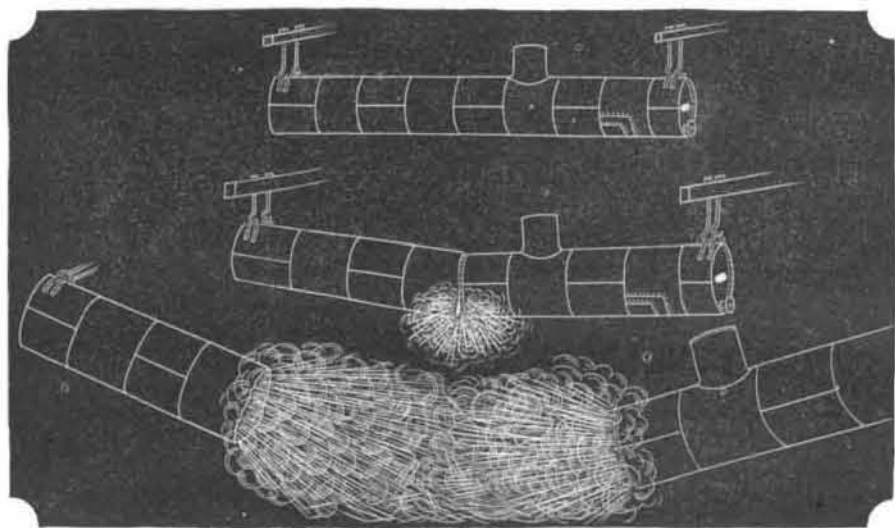


FIG. 1.

may be mechanical or chemical, or both. The mechanical forces are those usually arising from bad design, bad workmanship in construction, with the exercise of little judgment in the matter of setting. A boiler should be so designed, constructed, and supported, that under the conditions of use the strains will be as uniformly distributed as the conditions will allow. In externally fired boilers it is well known that the bottom or fire sheets are more expanded than the top sheets. Hence it becomes necessary to have such arrangements made in the setting or support that the boiler shall rest easy and have opportunity to adjust itself to these conditions. In long cylinder boilers this strain often becomes quite severe, and if the boiler is tightly bound up in brickwork, fractures are very liable to occur. To compensate for this, various plans for supporting long boilers have been devised. In some cases the brackets or beams supporting the boilers have rested on volute springs, in other cases equalizing beams or bars are used. In some cases quite elaborate apparatus has been devised. The point to be attained is to so support the boiler that the load will be properly distributed under the changes of form to which the boiler may be liable under heat. Were it not for the elasticity of the metal, these long boilers could not adjust themselves to this severe strain, but when well constructed and properly set, they have stood the test for many years. Usually these long boilers, from forty to sixty feet in length, are used in iron works, and are heated by the waste gases from the smelting furnaces. The gas enters the boiler furnace under more or less pressure, and when ignited will present one continuous sheet of flame from the furnace to the rear end of the boiler. In order to fully utilize these gases, the long boilers are used. It is a question

will, however, say that this type of boiler is very much used, and with economical results. There is economy of space also, which is often an important consideration. But boilers with water legs and narrow water passages should be frequently examined, so that the difficulty, if such exists, can be discovered and remedied before the progress of deterioration has gone to a dangerous extent. Boilers with narrow water passages, whether vertical or of the horizontal type, should be supplied with a sufficient number of hand holes to make the work of cleaning out sediment comparatively easy. The following illustrations (Figs. 2 and 3) will show how vertical boilers are often constructed, also how they should be constructed to overcome the difficulties mentioned.

Another important, yes, all important, matter is good workmanship in construction. If a boiler is bunglingly put together there will be several strains that under the conditions of use will be greatly aggravated. If the parts of the boiler do not fit well, and are brought into place by severe hammering and wrenching, what can we expect of such a boiler when put into use under a pressure of eighty or ninety pounds to the square inch? It will leak and give any amount of trouble to the user, and it will be fortunate if it does not burst or explode, carrying death and destruction in its flight. The "drift pin" seems to be one of the great evils in a boiler shop, although few boiler makers will admit that they use it, except to keep the plates in place while they are being riveted together. But I sometimes step into a boiler shop, unknown and unannounced, and I have seen the cruel use of the drift pin. Work has been poorly laid out, and the rivet holes which have been punched do not come into place, so that the holes in the different places are not coinci-

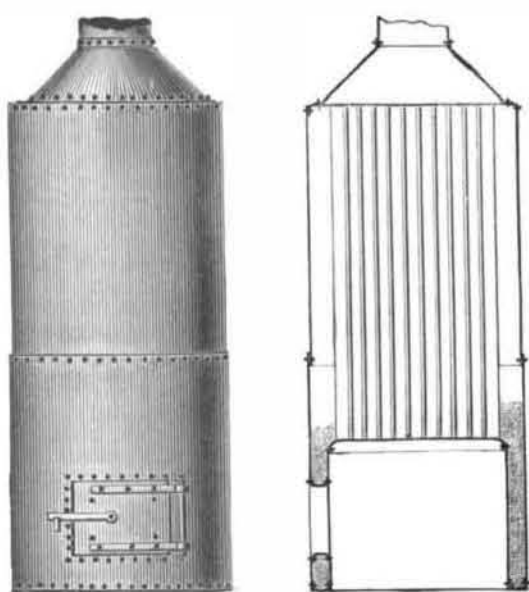


FIG. 2.—AS BOILERS ARE OFTEN BUILT.

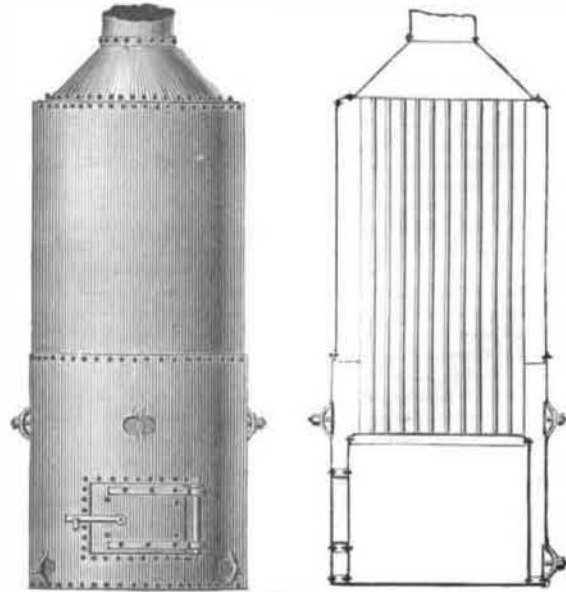


FIG. 3.—AS THEY SHOULD BE BUILT.



dent, one will ride over the other, and instead of using a reamer to cut away the intruding metal, the drift pin is resorted to, and strong men with hammers or sledges of eight pounds weight will drive the drift pin until one hole is elongated to a third or half greater than its original diameter. The rivet is driven and its expanded head covers the defect, and the exterior appearance of the boiler is very fair, but who can tell what strains and weaknesses have been caused, which, when the boiler is put into use, will develop into troublesome and possible dangerous defects? I am sometimes surprised that men will allow such work to go out of their shops. There is a moral responsibility connected with this business that should rest more heavily on some at least of the boiler makers in the country than their work would indicate, and in this connection allow me to say that a man's work is a pretty good indication of his character. Honesty and truthfulness lie at the very foundation of character, and these qualities show themselves in a man's life and work quite as much, yes, more, than in his words. Another potent cause of

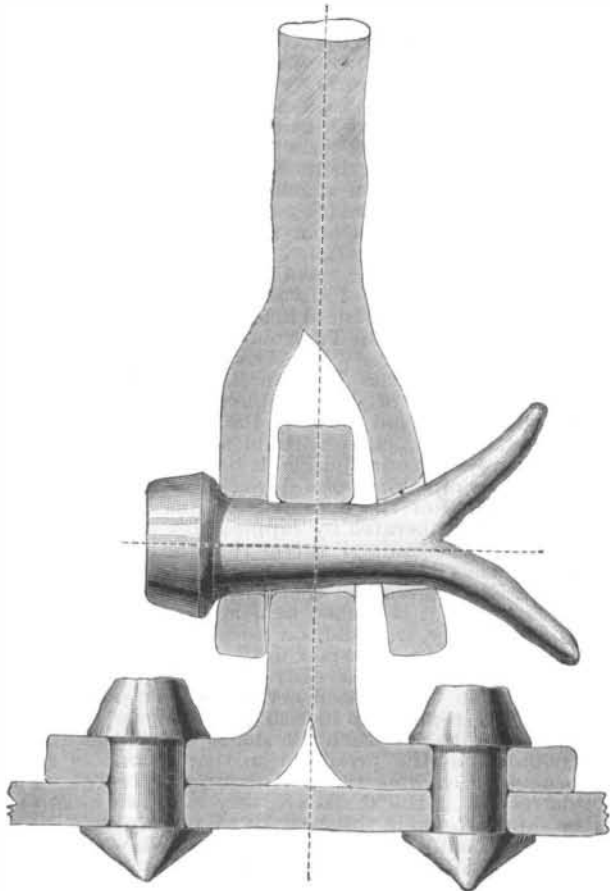


FIG. 4.—SHOWS A BRACE FASTENING TO HEAD OF BOILER AS THEY ARE SOMETIMES MADE. (This is no exaggeration.)

the deterioration of boilers is the water which is used causing deposits of sediment, formation of scale, and often having corrosive tendencies. We have a great variety of waters in this country, chemically speaking. In many sections of this country we find the underlying strata to be largely sulphate and carbonate of lime. This formation is of wider extent than any other. Then there are also chalybeate waters, magnesia, alumina, silicate, and waters carrying more or less organic matter. All of these waters give more or less trouble. In carbonate waters, the carbonate of lime and magnesia are frequently thrown down in the form of a fine powder, which settles along the joints at the lap; this often causes leaks. Another practice which aggravates these cases is returning the exhaust from the engine to the boiler. The oil thus carried into the boiler in combination with the impurities in the water makes a pasty substance that adheres to the plates, keeps the water from contact, causing overheating and often rupture. In fire box boilers where there are water legs and narrow water passages, this deposit often becomes a serious matter. Open heaters should not be used for collecting drips, if there is any oil used, but where the drips come from slashers or drying rooms, there will be no trouble. To utilize the heat in the exhaust from the engine, a pipe or coil heater should always be used. By such an apparatus all danger is avoided. I have mentioned above some qualities of water which are found in different sections of the country. In many cases the water is so bad that it is not fit to be used in boilers, and would not be used if a better supply could be found. Some very difficult problems come up for solution in connection with the water supply for boilers. Our rule is first to analyze the water, and then, knowing what impurities are carried in solution, we are better able to decide what the remedy must be. If the impurity is mainly carbonate of lime or magnesia, it is usually thrown down in the form of a fine powder. Frequent blowing is necessary, that is, blow down two gauges of water two or three times a day. This should be done in the morning before the mill or manufactory is started up, the impurities having had time to settle during the night. Then, again, after the dinner hour, just before starting the engine. This practice faithfully carried out will greatly relieve the difficulty. But in addition to this, there should be a good pipe or coil heater, and the sediment from that should be blown out often. It sometimes occurs that the impurities do not readily settle on to the bottom of the boilers, especially if the boilers are hard worked, and circulation is rapid. In such cases a surface blow is desirable and important; the object being to remove, as far as possible, the impurities from the water. To give you a correct impression of the character of some waters used in boilers, I copied the following from our laboratory records: In a spring water from Nashville, Tenn., we found in 100,000 parts, insoluble and sparingly soluble solids 17.6 parts, readily soluble solid matter 35.2, or a total of 52.8 parts, or 30.32 grains to a United States gallon. In

another case, water from a mill at a chemical works in Eastern New York, we found in 100,000 parts, insoluble and sparingly soluble solids 25.6, readily soluble solids 71.2, total 96.8 parts, or 56.52 grains in a United States gallon. In another case not far from Hartford, water from an artesian well, we found in 100,000 parts:

Insoluble and sparingly soluble.....	12.4
Readily soluble.....	32.4
Total 44.8 parts, or 26.15 grains in a U. S. gallon.	

Similar waters have been found in artesian wells in different parts of the Connecticut Valley. This valley was once an ancient sea, long before the sandstone formation, and in boring deep wells strata are struck containing chloride of soda, sulphate of soda, carbonate of lime, also nitrate of potash. In some cases beds of Glauber's salt are struck, a sort of neutral sulphate of soda and very cathartic. This water, with care, could be used in a boiler, but frequent blowing would be imperative, also thorough cleaning at stated periods of at least once in two or three weeks.

We had occasion to analyze some water from a mine in Illinois, and found in 100,000 parts:

Insoluble and sparingly soluble.....	28.1 parts.
Readily soluble.....	83.5 "
Total in 100,000 parts, 111.6, or 65.17 grains in a U. S. gallon.	

This water had in addition to sulphuric and carbonate acids, and sulphureted hydrogen and nitric acids

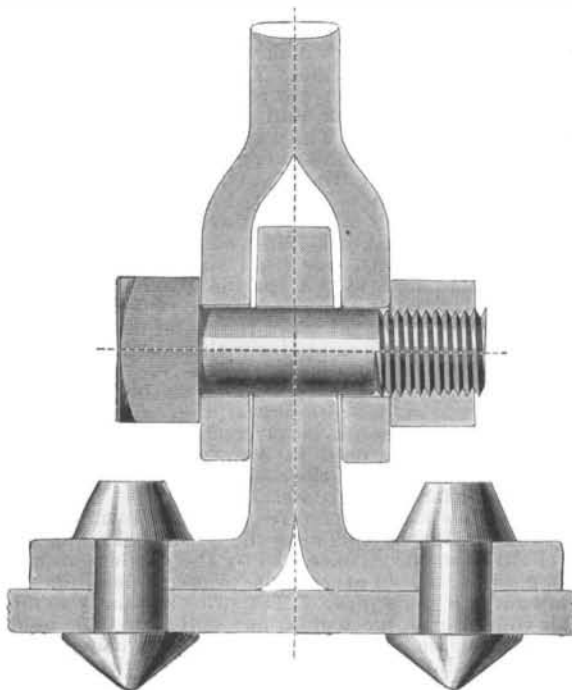


FIG. 5.—BRACE FASTENING AS IT SHOULD BE.

combined, chloride of soda, sulphate of soda, carbonate of lime, carbonate of soda, carbonate of potash, and carbonate of iron. It was wholly and utterly unfit for use in boilers. It would not only make a hard scale, but it was corrosive and would rapidly eat away the iron. An artesian well was bored in the vicinity of this mine, and was even worse than the mine water. Analysis showed:

Insoluble and sparingly soluble....	26.4 parts.
Readily soluble.....	231.2 "
Total in 100,000 parts, 257.6 parts.	

This water, if used in a 60 horse power boiler, would deposit at least 250 pounds of sediment a week. It could not be safely used. I might continue this record over many pages, but it is sufficient to show the quality of some of the worst waters we have to deal with. You will very naturally inquire, What do you advise to be done in these cases of bad water? It is often a very puzzling question. If carbonate or sulphate of lime predominate, a very good antidote is carbonate of soda. Especially is this good in case of carbonate of lime. It prevents it from readily forming a scale, and if attention is given to blowing and cleaning, the difficulty can be easily overcome. We usually recommend from eight to ten pounds of soda ash dissolved in warm water to be

cases we use one part, by weight, of catechu to two parts soda ash. Tannin works well in some cases, and a solution made from boiling the leaves of the eucalyptus tree has found much favor on the Pacific coast, and is being introduced in this part of the country. There is no grand panacea that will cure all these maladies. We must know something about the case before we can remove the disturbing cause. It will be readily seen that if attention is not given to these cases, the result will be not only annoying, but dangerous. Hard scale will accumulate on the fire plates of the boiler, resulting in overheating, and greatly weakening the boiler. The question of the waste of fuel is also an important one, for steam cannot be economically generated in a boiler where the plates are covered with scale. We all know that scale is a very slow conductor of heat, hence, in addition to the loss here, the plates are worn away and become greatly weakened. The question of corrosion is a serious one in some cases, and is difficult to manage. Water from swamp lands often has corrosive tendencies (Fig. 6), and in rivers and streams on which a number of manufactories are located, discharging their spent dyes and refuse, becomes very much contaminated, and gives serious trouble to the mills located down the stream. Law suits not unfrequently grow out of river contamination, and we have been summoned into court in a number of such cases. Our advice has always been for the parties to combine and lay a water main from the pond of the upper dam to the mill lowest down, of sufficient capacity to supply them all with good water. Another difficulty which is often encountered, and which at first seems paradoxical, is corrosion or pitting from pure water. Corrosion in boilers in the absence of free mineral acids can proceed from three principal causes:

1. The purity of the water.

Water is an almost universal solvent, and dissolves most substances to some extent. In the absence of substances in solution to prevent that action, even pure water would attack iron and corrode it, but except in the case of distilled (condensed) water returned to a boiler with the return pipe coming near the shell, this condition can hardly be said to exist, as even rain water contains from one to three parts per 100,000 of impurities.

2. The presence of air and dissolved gases in the water.

This is in all probability the most fruitful source of corrosion (except the acid decomposition of grease, oil, etc.). Water, unless recently boiled, contains varying amounts of dissolved gases, which are expelled at boiling temperatures. It has the peculiarity of holding a larger proportion of oxygen in solution than air has, usually about 33 per cent. more in water free from oxidizable matter. This under proper conditions would combine with the iron, rusting it rapidly, and when oxidation had once begun, forming a rust spot, heat and moisture would rapidly continue the work.

Water also contains varying and sometimes large amounts of carbonic acid gas. This by some authorities is equally injurious with the oxygen, but as when existing in large amounts it is almost invariably associated with lime and alkalies, which have been found to prevent corrosive action, in practice it is probably not especially harmful.

Oxygen and nitric acid occur in rain water and newly fallen snow, and the purer and more aerated a water is, as for example rain water, snow water, and water from uncultivated upland and quick slopes, the more dissolved oxygen it is likely to contain.

3. Substances in the water causing corrosion.

A water containing more than ten parts per 100,000 of solid matter usually contains considerable lime as carbonates, some soda and potash salts, and is alkaline. Such a water is not likely to corrode a boiler. A water with only four or five parts of solid matter (though it may contain also considerable dissolved oxygen, etc.) may be almost, if not quite, neutral, or even slightly acid. This acidity may come from dissolved organic matter, which if from fields or woody districts, the water is likely to carry in considerable amount. This woody extractive matter is easily decomposable, and some of the complex acids, so called humic, crenic, apocrenic, oxalic, etc., present, or formed under the action of decomposition, act very unfavorably on the iron of the boiler. This woody or especially peaty matter also contains tannic acid and gums in many cases, and has been observed to so varnish the inside of boilers in some places as effectually to prevent corrosion where otherwise it would be expected.

The presence of certain salts in solution has a very injurious effect on boilers, even in small amounts. Waters containing nitrates, and especially ammonia salts, as ammonia chloride, seem to be especially bad.

Water, therefore, exposed to the leaching from vaults, etc., is especially undesirable, even though a water

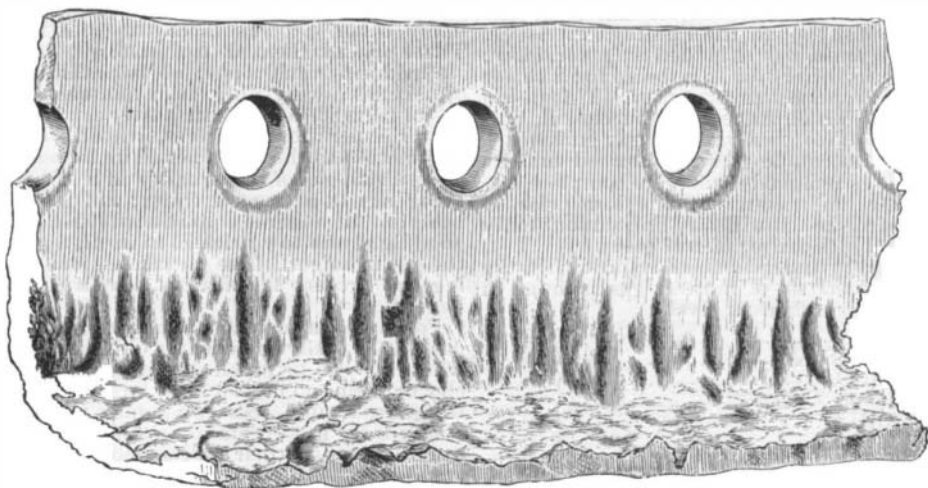


FIG. 6.—PART OF A HEAD OF A BOILER BADLY CORRODED AND PITTED BY WATER FROM A SWAMP.

introduced into the boiler about once or twice a week. This can be done by putting a branch into the suction pipe of the pump and connecting this branch by a hose to the pail or vessel containing the solution. In some

strong in salt and alkalies from a common sewer might not be harmful to the boiler. The action of oil and tallow, etc., decomposing to oleic and margaric acid in the boiler, in the absence of alkalies, and especially

with a coating of sulphate scale to prevent free circulation of the water at the corroding points, is well established.

It occurs, perhaps frequently, that a water at some seasons of the year making quite a scale is, at others, quite soft and charged with air and gases and partly dissolves that scale. This may go on indefinitely, until an unusually wet season, or a very clean or new boiler with the water quite pure, may suddenly develop injurious pitting from the absence of matter to counteract the effect.

FROM ROWAN—PART OF A TABLE BY WAGNER.

*Iron, loss of weight in per cent. in water.*

	One week.	Six weeks.
Distilled water (flask half filled)....	0.44	2.46
Distilled water (l. e., more air).....	1.01	5.18
With magnesiachloride .....	1.31	3.05
With soda and potash chlorides... ..	0.84	3.41
With ammonium chloride .....	1.15	4.16
With potash.....	0	0
With soda carbonate.....	0	0

I have now given you some of the causes that result in the wear and tear and deterioration of boilers. The subject is an important one, and the young consulting engineer will often find himself greatly puzzled to ascertain the true cause of the difficulty. He must not only be familiar with the true principles of construction and setting of boilers, so that wear and tear shall not result from unnecessary and undue strains, but he must know something of the sources of the water supply. A general knowledge of the geology of the country will be helpful. I believe that the broader a man's culture is, the more valuable his services will be. While technical education is all important, and without it the great problems which are so intimately connected with our growing industries could not be solved, a man need not be always in a rut. Another point. We have been considering the question of wear and tear as applied to steam boilers. The ambitious and industrious young engineer is in danger of being so absorbed in his profession as to forget himself, I mean his physical condition, his health. In testing metals we learn that there is a point known as the limit of elasticity. Beyond that is the permanent set, from which there is no recovery. Bear in mind that human fiber may be subjected to a strain that exceeds the elastic limit. Hence, I repeat, take good care of your health.

I trust it will not be out of place if I say in closing, let your work, quite as much as your words, indicate that truth lies at the foundation of every undertaking.

#### NATURAL GAS, AND ITS EFFECTS ON THE CONSUMPTION OF COAL GAS.\*

By E. B. PHILIPP, Findlay, O.

MR. PRESIDENT AND GENTLEMEN: At the second annual meeting of the Ohio Gas Light Association, held at Springfield, March, 1886, in a paper on "Natural Gas as a Competitor of Coal Gas," I gave the result of practical experience in the use of natural gas, in its crude state, as an illuminant. Much time had been spent in solving this problem, not only in regard to the practicability of its employment from a strictly photometrical standpoint, but also as to its use so far as health, convenience, and comfort were concerned. The various photometrical tests, given in detail in this paper, with the best and most approved kind of burners, showed its illuminating quality to be between 12 and 13 candles; but with this illuminating value seemingly against its use, and in competition with coal gas of from 16 to 18 candle power, nevertheless, on account of the remarkable cheapness at which it was furnished, it succeeded in successfully competing with coal gas; and, finally, to have superseded the latter entirely.

At this time effort had been made to increase the candle power by mechanical enriching, and also to purify it. These processes, however, were never continued, as the increased expense at that time would not warrant so doing. Since the time referred to in that paper, natural gas in its crude state has continued to be used in Findlay. On account of the great difference in its cost, and by using burners specially adapted to its consumption, it has, in the main, given general satisfaction. An experience of three years in its use in Findlay and in other places has shown conclusively that by using it in the proper way, and by obtaining it at a low price, it will successfully compete with any other illuminant. The question as to whether it can be used in its natural state, or without enriching, has been practically proved at Findlay. The gas celebration and public illumination at Findlay last June showed the extent and the satisfaction given by such use.

The fact of its practical use as an illuminant being undisputed, the problem and its solution as to how it can best be used will form the subject matter of this paper. As has been shown in the Findlay experience, satisfaction in the main has attended its general use; yet in Findlay, as in other towns, a desire for a better illuminant at a fair price has prevailed. This desire led to experiments, which have been successful, and which conclusively prove that natural gas enriched—or, in other words, its candle power increased and its detrimental qualities removed—will give complete satisfaction. Further, on account of the low price at which it can be furnished, it will, and has, undoubtedly become a successful competitor of coal gas.

In order to plainly understand and show this, the following chemical analysis of natural gas as found in the Western natural gas fields is given:

Ammonia (NH <sub>3</sub> ).....	0.00
Sulph. hydrogen (SH <sub>2</sub> ).....	0.88
Carbonic acid (CO <sub>2</sub> ).....	0.88
Bisulphide carbon (CS <sub>2</sub> ).....	0.00
Illuminants (C <sub>2</sub> H <sub>4</sub> ).....	0.50
Oxygen (O).....	0.00
Carb. oxide (CO).....	2.00
Marsh gas (CH <sub>4</sub> ).....	95.74
Total.....	100.00
Specific gravity .....	0.57

The detrimental qualities of natural gas which tend to make its use in its crude state unsatisfactory are its heavy specific gravity and the excess of sulphureted hydrogen, carbonic acid, and carbonic oxide which it

contains. Its heavy specific gravity makes the light flicker and unsteady, when subject to draughts or currents of air; and the excess of sulphureted hydrogen makes its use unpleasant, on account of the formation of sulphurous acid in burning. Now, in removing these detrimental qualities, and in increasing its candle power, it will successfully compete with any other illuminant, not only from a photometrical standpoint, but also on account of the low price at which it can be furnished. There are two practical methods of treating natural gas and of removing its detrimental qualities; one of which is by passing it through a complete coal process, from the retorts through scrubbers, washers, condensers, and purifiers, into the holder, and enriching it by using oil or naphtha in the retorts; while another method is to put it through a water gas process. The latter, on account of its being the cheapest and best, is to be preferred. This process is now being used in Fostoria, Fremont, and Tiffin, in this State, and in a number of cities and towns in the East, very successfully. In using the water gas process no change is made whatever in the construction of the apparatus. The only real difference in the process is that instead of using anthracite coal and steam to make water gas, natural gas is passed through the apparatus, and simply enriched and purified. The use of the cupola in the water gas process is to make, from anthracite coal and steam, carbonic oxide gas and free hydrogen, which together form water gas; and also to carburet or enrich the same by vaporized oil. The use of the cupola in the natural gas process is merely to carburet or enrich the crude natural gas by vaporized oil. By this process of carbureting its specific gravity is changed from 0.57 to 0.40, which makes it of about the same specific gravity as coal gas. The rest of the machinery belonging to the water gas process proper, consisting of the washer, scrubber, and purifiers, is also used in treating natural gas. The washer removes principally a black, clayey substance, very similar to lamp black, the scrubber removes the oily, condensable vapors; the purifiers remove the sulphureted hydrogen and carbonic acid. The result of this method of treating natural gas gives a merchantable, high candle power, non-condensable illuminant, free from sulphureted hydrogen and carbonic acid, with a specific gravity of 0.40, and with an illuminating power of from 22 to 24 candles, and which at a low price per thousand cubic feet completely and signally competes with and supersedes coal gas or any other illuminant.

A water gas plant, with cupola, washer, scrubbers, purifiers, and engine and blower, of a capacity of 75,000 cubic feet per 24 hours, costs (complete) between \$5,000 and \$6,000. This, used in connection with purifiers, holders, and mains of the coal plant, will make a complete plant for the purpose.

Now a few facts and figures in regard to natural gas treated in this way. The crude natural gas, unless the wells are owned or controlled by the parties interested themselves, is sold at various prices, depending upon how far the gas is piped. The price is usually so much per thousand cubic feet of gas sent into the holder. This can be metered through the station meter, or calculated by holder measurement. The price will average from 10 to 20 cents per thousand cubic feet. The material used, as in making water gas, is substantially the same. Anthracite coal is not used, for it is not needed. Coke is used in "blowing up the heat." Connellsville is the best, weighing 42 lb. to the bushel. Ordinary crude oil, the same as is obtained from the Findlay or Lima field, is used for enriching. The present price of coke delivered in this part of the country is \$4.50 per ton, and the present price of crude oil is about 1.35 cents per gallon.

In treating from 15,000 to 30,000 cubic feet of gas, three runs are usually made. In some places where the supply of natural gas is deficient, or in other words where the gas is not furnished fast enough, it takes, as a matter of course, longer to make the runs. Three runs, of 35 minutes each in the average case, treat from 15,000 to 17,000 cubic feet of gas. In other places where the supply is better, from 27,000 to 30,000 cubic feet of gas can be treated in about two hours. The average amount of oil used per thousand cubic feet is from 2¼ to 2½ gallons. The average amount of coke used is from 20 to 25 lb. per thousand cubic feet. A works whose output is from 15,000 to 30,000 cubic feet per day can send into the holder all the gas in less than three hours.

Now, without going farther into financial details, I will simply state that natural gas can be metered and sold at \$1 per thousand and realize a very satisfactory profit. The difference in the labor account between the old coal process and the natural gas process is fully one-half in favor of the latter; the difference in purification is about one-quarter in favor of the latter, and the wear and tear and renewal to plant is about one-fourth as much as in the coal process. In addition to the greater profit in furnishing carbureted natural gas, many other circumstances are greatly in its favor. There are no heated up, smoky retort houses; no stopped up stand-pipes; no naphthalene; no renewal of benches; everything clean and neat. The fact that gas of from 22 to 24 candle power can be furnished at a low price per thousand gives, in itself, very good general satisfaction to the consumer. The increase in consumption, which gas of this quality at a low price is sure to bring about, is a good thing; and above all, the satisfaction, in a general business sense, of furnishing a good light at a low price is, in itself, a great comfort to the gas manager. The cleanliness and comfort attending the process is certainly, also, a great object and benefit.

For these reasons then, in natural gas territory, where gas can be easily and cheaply obtained, and in territory where gas can be piped and furnished at a fair price, no city or town, no matter how large or small, can afford to ignore its use. Gas companies, where thus circumstanced, are most certainly standing in their own light in not changing their process, not only from a financial standpoint, but also from a good, general business standpoint; for the profit is certainly greater, the satisfaction in doing business with the consumer is much greater, and the satisfaction in the cleanliness and comfort of the process is certainly much greater. In case the supply of natural gas should fail, there is no loss on account of the investment in the plant, for the same plant can be used either for making water gas or a cheap fuel gas; so that no risk whatever is run on account of wasted or useless machinery. For these reasons natural gas has entered and will, wherever it

can be obtained, most positively enter into competition with and take the place of coal gas; not only so, but it will also most effectually compete with and take the place of any other illuminant.

A few practical remarks on the longevity or life of gas wells, although in some degree foreign to the subject matter of this paper, may not be here amiss. The only durable supply of natural gas obtained in the Northwestern gas territory is found in the Trenton limestone. It is true that gas in considerable quantities is found in the shales above the Trenton; but this is not of continuance, being generally accumulated in pockets, which soon give out. The difference between a good gas well, or gusher, and a small well is due to the porosity or density of the Trenton limestone. I have here three samples of Trenton rock. This one, as you will observe, is very porous, of a spongy character, similar very much to a piece of pumice stone. This specimen came from the Karg well, at Findlay, the capacity of which is 12,600,000 cubic feet per twenty-four hours. The other specimen is also porous, but not so much as the piece from the Karg. This sample came from the Heck well, near Findlay, the capacity of which is between 5,000,000 and 6,000,000 cubic feet. The third specimen here shown is from a well in the eastern Findlay territory, which scarcely shows any sign of porosity, and, in fact, is very dense and close. The capacity of this well is about 500,000 cubic feet per day. These specimens show very accurately the comparative difference in the porosity and density of Trenton rock, on account of which the difference in the flow or production of the wells exactly to the same degree is attributed. There are many theories in regard to the manner in which natural gas is made or produced by nature. The two leading theories, and those which have the greatest number of advocates among experts, are that it is made or produced in the Trenton rock, or that it is made far below the Trenton. At best it is all theory and not a proved fact. It is, however, our theory that it is not made in the Trenton limestone, for the immense quantities of gas that have already been used or wasted could not actually have been made in the Trenton, as the rock area could not produce it. The Trenton rock, in our opinion, is but an enormous passageway or pipe line, so to speak, for the distribution or conveyance of the enormous volumes of gas which the drill has liberated by tapping this passageway or pipe line. Presuming it is true that the gas is generated far below the Trenton, it can easily be supposed, for it is all imagination, that with the enormous pressure at which it is packed or compressed in the place of manufacture, it would, on this account, find its way through the various strata until it reached the Trenton, and here becomes distributed. The shales and slates above the Trenton act almost completely as a barrier or stoppage to its rising farther; and when in some cases it does reach the shales above, this fact is attributed to the presumption that it reaches these pockets or cavities through fissures or breaks. For this reason, as the shales are very close and compact, the supply found in these pockets is not lasting. Now, as far as the life of a gas well is concerned, we can only theorize. All that we are able to learn concerning this important phase of the natural gas problem is from actual experience and knowledge, and from that limited knowledge form our conclusion. We know the flow of gas wells does diminish—not to such an alarming extent, however, as to discourage the investment of many millions of dollars in the business; for the natural gas territory of this country is of such enormous area that, should the life of the first wells drilled be comparatively short, others may be drilled in other parts of the territory, and (comparatively) the same amount of gas can be obtained. This has been demonstrated to be a fact as far as our present experience teaches us, and for this reason, if the average life of the wells should be of from five to ten years, as has been claimed, the supply can be kept up by farther use of the drill in adjacent territory not yet depleted. These facts and experiences from which we derive our conclusions are so numerous, and the ground to be covered in the consideration of this great problem so vast, that we can in this paper only mention, in a comparatively limited and concise way, some of the principal points or arguments in the matter.

#### ANCIENT MATERIALS FOR PAPER MAKING.

It has been generally believed that linen rags have been used in the manufacture of paper only since the fourteenth century, and that previously to that the writing materials of the East were chiefly made from unmanufactured materials. This view must be considerably modified in consequence of a careful microscopical examination, made by Dr. Julius Wiesner, of the paper from El Faijum preserved in the Austrian Museum at Vienna in the collection known as "Papyrus Erzherzog Rainer." Many of these papers extend to the ninth, and some are even as old as the eighth century. The papers are all "clayed" like modern papers.

Dr. Wiesner's examination gave the unexpected result that these papers were all manufactured from rags. The fiber is mainly linen, among which are traces of cotton, hemp, and of some animal fiber; well preserved yarn threads are of very frequent occurrence. The manufacture of paper out of rags is not, therefore, as has hitherto been supposed, either a German or an Italian invention, but is an Eastern one. In addition to the Faijum papers, he examined also more than five hundred Oriental and Eastern specimens from the ninth to the fifteenth century, not a single one of which was a raw cotton paper; all were manufactured from rags, the chief ingredient being linen.

The examination of the substance used for "claying" gave equally unexpected results. In all the Faijum papers this was found to be starch paste, a substance which had been supposed not to have been used for this purpose before the present century; animal substances do not appear to have been employed for "claying" before the fourteenth or fifteenth century. In some instances well preserved starch grains were mingled with the paste; these agreed, in the form and size of the grains, with wheat starch, and were evidently prepared starch separated from the meal. In two papers, belonging to the tenth and eleventh centuries, buckwheat starch was found, and the cultivation of this substance must, therefore, be dated back to the tenth century. The object of the "claying" was apparently to increase the whiteness of the paper.

\* A paper lately read before the Ohio Gas Light Association.—*Amer. Gas Light Journal*.