West Virginia Natural Gas Association

Eliminating Waste of Natural Gas in Industrial Plants

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K. HUESSENER, Pres.

Duquesne Burner Service Co., Pittsburgh, Pa.

To be presented at the Annual Meeting of The West Virginia Natural Gas Association at Huntington, W. Va., July 24th and 25th, 1918

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NATURAL GAS IN INDUSTRIAL PLANTS

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The necessity of preserving the country's fuel supply is to-day in everybody's mind, and it is just as important to prevent waste of natural gas as it is to economize in the use of coal. We all know that the cases where the natural gas is utilized as efficiently as possible are the exception and not as they ought to be, the rule. There is a certain amount of avoidable waste going on nearly everywhere where natural gas is used. From the home where cooking and lighting are done by means of this fuel, and where only a few hundred cubic feet of gas are used per day, up to the large industrial user whose gas consumption is counted by millions of cubic feet every day, we find this waste.

While we cannot hope to reach every domestic user and educate him to the necessity of stopping this waste, except by united efforts of all the gas companies, as well as the press, and by long and wearisome work, it ought to be much easier to induce the industrial user to exert himself and take the necessary measures in order to avoid all unnecessary waste because he feels this waste in his pocketbook and knows that any saving he can effect is really worth while and will not only benefit him in a financial way, but will also help to improve the already serious fuel situation.

Natural Gas for industrial purposes is used in three different methods of combustion:

FIRST. The gas is burned with pre-heated air in regenerative furnaces.

SECOND. The combustion air is supplied by blowers under pressure.

THIRD. The combustion air is supplied by aspiration and chimney draft.

The first method of burning gas is without any doubt the most economical, as the heat in the products of combustion is utilized for the purpose of pre-heating the combustion air, with the result that not only are very much higher flame temperatures obtained but the waste heat is also to a certain extent recovered and utilized to advantage. This method of burning natural gas, however, is for a number of reasons practically confined to large regenerative furnaces, and an increase in efficiency with this method of combustion is not easy to obtain, as in order to do so it would be necessary to change their entire design because a mixture of gas and air before ignition is for many reasons not practicable.

The second method of burning natural gas with the combustion air under pressure undoubtedly offers a good many advantages, but owing to the fact that very large volumes of air have to be compressed it will not be extensively utilized except in cases where no chimney draft is available, or where the available chimney draft is not sufficient to allow combustion of the necessary quantity of gas. One disadvantage of using this system is that owing to the blow-pipe effect of the flame under pressure, difficulties will frequently be encountered in getting the brick work of the combustion chamber to stand up, and where boilers are concerned, even small quantities of scale in boiler tubes will, with this method of combustion, be sufficient to result in local overheating.

The third method of burning natural gas with the combustion air supplied by either aspiration or chimney draft is the one with which we wish to deal particularly in this paper. This kind of combustion embraces all steam boilers and evaporation vessels, as well as a large variety of furnaces which are not adapted to the regenerative system, or the use of compressed air. Hundreds of millions of cubic feet of natural gas are consumed every day for these purposes, and if we could succeed in inducing the industrial user to take the necessary steps to utilize gas to best advantage the natural gas situation would be considerably improved.

If, however, we are to do any successful mission work (with industrial gas consumers), we should surely first see to it that the offense for which we blame them is not committed by ourselves. Many of the gas companies here represented are operating drilling boilers where the steam is generated by means of gas.

We understand that when gas was used at high pressures under these boilers, it was not unusual to consume as much as 110 thousand cu. ft. of gas in 24 hours under a single boiler, but are also glad to note that at present some of the drillers, by using lower gas pressures and improved appliances, have reduced this extravagant amount to as low as 35 M. C. F. per 24 hours. However, from information we have been able to obtain, it appears that as a rule the daily gas consumption of the drilling boiler will vary between forty and fifty thousand cubic feet. On this basis from 160,000,000 to 200,000,000 cubic feet of gas are used daily for the purpose of drilling wells. This figure, although not large, compared to the total production of natural gas, is yet well worth our attention. With suitable improvement over the present method of burning gas in these boilers there is hardly any doubt that this figure could easily be cut down by twenty per cent., which would mean a daily saving of thirty to forty million cubic feet of gas; and we can all appreciate the importance of saving this amount of fuel for other uses.

Having given due attention to the wastefulness within our gates, let us step without and see what can be done there. Some time ago we had an opportunity of investigating the conditions of one of the electric power stations in one of our western gas fields. We found that the average load for twenty-four hours was a little short of 3000 B. H. P., and that the daily gas consumption amounted to about 3,700,000 cubic feet. We found that by making certain changes in the equipment of the burners and the method of operating the plant, there would be no difficulty in reducing this gas consumption by 700,000 cubic feet every day, equivalent to nearly twenty-eight tons of coal per day, so that this individual user might save heat equivalent to ten thousand tons of coal per year; and there are hundreds, if not thousands, of cases where similar savings can be effected without the expenditure of a prohibitive amount of money or attention.

The few examples cited above are sufficient to convince us that the field is large and worthy of our most earnest attention. The chief difficulty, however, that we will encounter in efforts to induce the industrial user to look into the question of possible gas economy, is that there are only a few of these users who realize that they are actually wasting part of their gas. Very possibly they will have bought a burner equipment that had the name of being the most efficient gas burner on the market, and for a time followed the instructions of the makers of such gas burner equipment and attended to the necessary regulation. As such regulation is usually very troublesome and requires more skill on the part of the boiler tender than can be expected from that class of men, the regulation of the burner has in many cases fallen into abeyance with resutling inefficient and wasteful combustion conditions.

Every gas user knows from his monthly gas bill just how much gas he is consuming, but he usually has only a very hazy idea of what he is getting in return from his gas.

In the case of heating furnaces, glass pot furnaces, and all other industrial furnaces it is very hard to ascertain the returns obtained from the gas, but in the case of steam boilers it is very much easier to get reliable figures by means of measuring the feed water as well as the gas. As, however, nearly all the industrial users are operating their boilers with preheated water, the ordinary water meters, which are fairly accurate in measuring cold water, cannot be employed, and water measuring instruments that record the velocity of the water rather than its weight, by means of the Venturi principle, have to be used. This type of meter, whilst fairly accurate in expert hands, has a tendency to go wrong if it is not scrupulously kept clean. When out of order it will record very much more water than it actually passes, and we have found instances where a meter of that type was out by ten to as much as one hundred per cent. This shows that even the velocity water meter is not an instrument to be relied upon, apart from the fact that it is only to be found in a minority of plants.

In order to start the industrial gas user on the road to fuel economy, the first thing to be done is to teach him how to ascertain the combustion efficiency by flue gas tests. Every Gas Company should impress on its industrial users the necessity of not only owning, but also regularly using, a gas testing instrument. For this purpose an instrument which analyzes for carbon dioxide, oxygen and carbon monoxide will fully answer.

In addition to that the industrial user should be impressed with the importance of having every one of his chimneys equipped with, preferably, a recording thermometer, in any case an indicating thermometer. He should further not only be supplied with an exact average analysis of the gas he uses, but also be informed of the theoretical composition of the combustion gases after complete combustion without excess of air.

The Gas Company should supply him with a table or record showing the percentage losses through flue gas at its varying compositions for a range of temperatures in the stack.

As the highest theoretical CO_2 is about 12%, by ascertaining the composition of the flue gas the percentage of CO_2 in the flue gas will give an exact indication of the volume of the same per cubic foot of gas. The following curve, Figure 1, shows the percentage losses through flue gas for every 100° rise of chimney temperature over boiler house temperature for the various percentages of CO_2 in the flue gas for complete combustion.

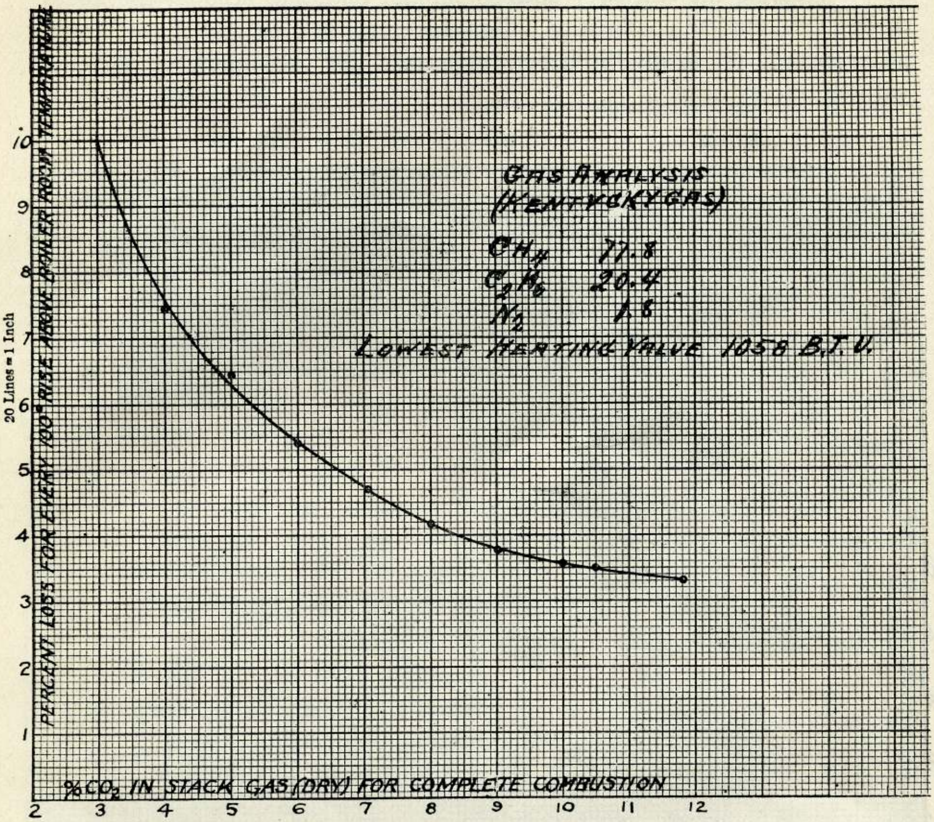

Fig. 1.

Example No. 1. Flue Gas Analysis is:

10% CO_2 (Carbon Dioxide)
1% O_2 (Oxygen)
— CO (Carbon Monoxide)

Stack Temperature 450° F; Boiler House Temperature 80° F.
Curve, Figure No. 1, gives a loss of 3.6% for 10% CO_2 which must be multiplied by $\frac{(450-80)}{100} = 3.7$. The total stack loss in this case is therefore $3.7 \times 3.6 = 13.32\%$.

We would recommend that a curve as shown in Figure No. 1 be sent to every industrial gas user. It will be noticed that this method of ascertaining the efficiency does so far not take into account the losses through incomplete combustion. For this purpose a second curve should be prepared, as we give it here in Figure 2 for incomplete combustion without excess of air.

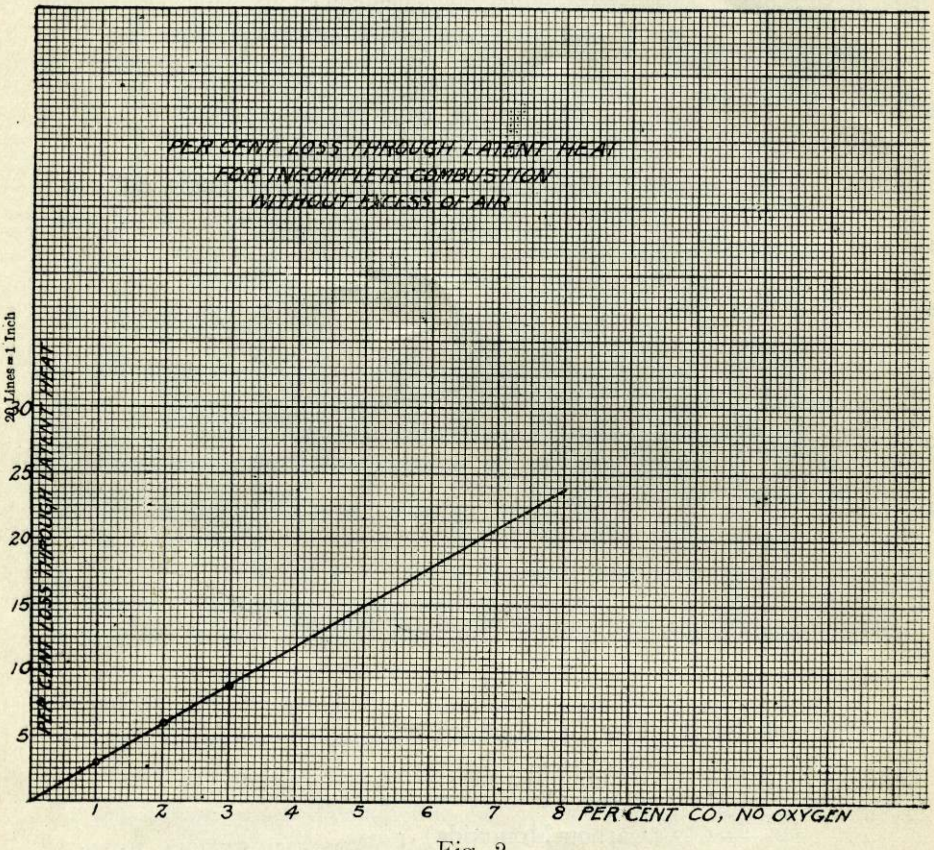

Fig. 2.

Example No. 2. Flue Gas Analysis:

7% CO_2
4% CO
O_2

Stack Temperature 550° F; Boiler House Temperature 80° F.
In order to find the sensible heat losses we add CO_2 and CO and find

from Figure No. 1 a loss of 3.35% under 11% CO_2. This we multiply by $\frac{(550-80)}{100} = 4.7$ and find that the sensible heat losses are 15.74%. In addition to this we have to find the losses through latent heat on account of the unburnt CO. Table No. 2 gives us 13.5%. The total losses are therefore 29.24%.

The industrial gas user should be informed that when his total losses through chimney gases exceed 20% of the heat in the gas his conditions are open to improvement and immediate steps to procure such improvements should be taken.

It will also be very important to disabuse the industrial consumer's mind from the idea that eye-sight observation of the appearance of the flame is an infallible method of judging the efficiency obtained. On account of the fact that most of the domestic burners will give their best results with a clear blue flame the majority of gas users have formed the erroneous idea that such blue flame will give the best possible results and should be tried for at all costs. A blue flame is always a proof that the burning gas is for some reason or other cooled down very much below the theoretical flame temperature and allows in nearly all cases of the conclusions that the gas is burning with a considerable amount of excessive air.

If natural gas is burnt at a velocity below its critical mixing velocity, with a low excess of air, the combustion is a gradual one in so far as the hydro-carbons are first burned into water and monoxide and afterwards the monoxide into dioxide. The first combustion takes place with a slightly smokey flame of bright orange color; the second combustion is colorless and cannot be observed.

After we have shown the industrial user how he can ascertain his wastage we surely should show him also how to abolish it. In order to do so the industrial consumer requires not only an efficient burner, but also expert services in order to establish in his boiler house or at his furnaces those conditions which are indispensable for obtaining continuously satisfactory results. The industrial gas user is not often benefited by having a few pieces of cast iron under the name of "Patent Gas Burner" put into his plant with a few lines of instructions on "How to Install and Regulate." Nearly every kind of gas firing installation offers its own individual difficulties, dependent on the variation in the load carried, the amount of draft available, and the class of men operating the plant.

In a few large establishments where the yearly fuel bill runs into hundreds of thousands of dollars, it will pay to have a special Efficiency Department that will give all its time to these problems and such gas consumers may perhaps not be in need of outside services. The average industrial gas user will, however, rarely be in a position to afford the luxury of a Combustion Expert, and he will have to call on outside services.

If services are available, the equipment of the plant must of course be such that really good results can be obtained. There are quite a number of burners in use at the present moment for which varying claims are made.

But as a matter of fact most of the gas burners now on the market have certain marked disadvantages which render it impossible to get completely satisfactory results. Mr. J. C. Hobbs of the Duquesne Light Company of Pittsburgh, enumerates these disadvantages in his paper on "An Efficient Gas Fired Boiler Installation," read before the Engineers Society of Western Pennsylvania, as follows:*

> "1st. The air and gas could not be easily controlled with any degree of certainty.
>
> "2nd. At low ratings or with low gas pressure, trouble from burning back was experienced.
>
> "3rd. When the burners are shut off, all of the air could not be shut off, most of the burners having a secondary supply of air to prevent the end of the burner from being burnt. This excess air could not be shut off.
>
> "4th. The secondary air principle is wrong, and tests of the mixing feature of the burners themselves by the use of smoke and bridge wall temperature investigations, showed that the air through the center of the burner was really a cold core and the stream lines were not broken up."

Very efficient results have however been obtained in a new design of burner in which an endeavor was made to overcome all of the above objections, and up-to-date results have shown that the new design is a success. The most valuable feature of the new burner which we have named the "Duquesne Combustion Unit" is the absolute control of the quantities of gas and air. Another of almost equal importance is the

*See proceedings of Engineers Society of Western Pennsylvania, Vol. 33, No. 7.

thoroughness of mixing before entering the furnace, without allowing the burner to flare back.

This Combustion Unit is made in four different types, two of which are shown in Figures 3 and 4. It will be seen that both the gas and air are absolutely under the operator's control, and further, that although the gas and air are kept separate up to within a few inches of the combustion chamber a mixture with a very fine subdivision is made. Each unit consists of a gas box carrying a number of gas nozzles which discharge their gas into a special tile having one hole for each noozle. The whole unit is fully enclosed by a steel sheet air box fitted with an air slide.

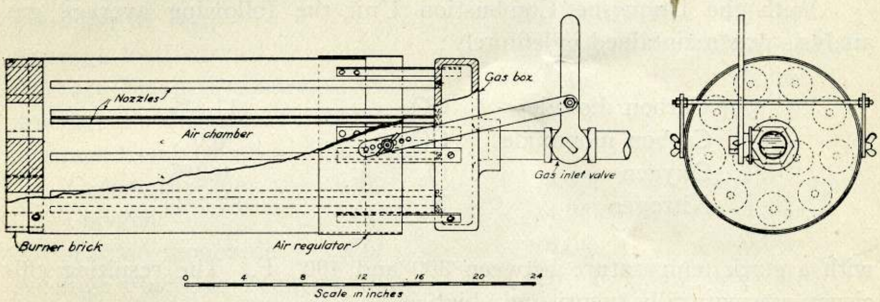

Fig. 3.

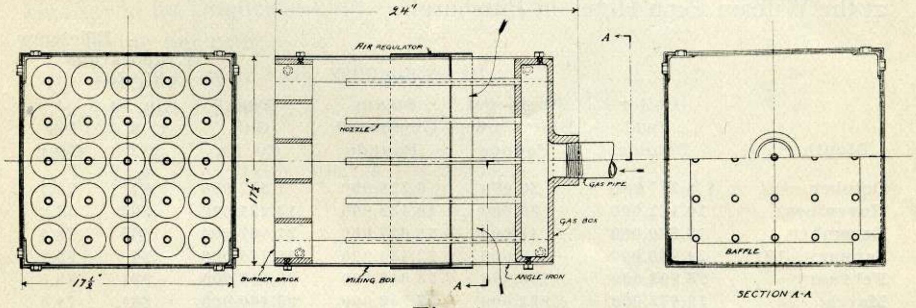

Fig. 4.

The three types of units above illustrated differ only in their mechanical design, the principle followed being the same in every case. The air slides which regulate the admission of the whole of the combustion air are graduated for the various gas pressures indicated on a gas pressure gauge, which forms part of each Unit, so that the regulation is not only extremely simple but always positive and correct. When one or more units are not in use they are closed air-tight so that no false air can enter the boiler and reduce the efficiency of the other units in use.

One chief advantage of this type of burner is that it burns the gas completely with a very little excess of air so that the chimney draft can be kept very low indeed. Whilst most of the burners at present in use require three to four-tenths of an inch draft in the combustion chamber in order to operate the boiler at all, the Duquesne Combustion Unit will work perfectly with a chimney draft of one-tenth to twelve-hundredths of an inch, which renders it possible to overload the boilers to a very much larger extent.

With the Duquesne Combustion Unit the following average gas analysis was maintained indefinitely:

Carbon dioxide	CO_2	11.4%
Carbon monoxide	CO	0.0
Oxygen	O_2	0.9%
Nitrogen	N_2	87.7%

with a stack temperature between 300 and 400° F. The resulting efficiency was naturally surprisingly high.

Table, Figure No. 7, gives results obtained over a number of months at the William Penn Hotel, in Pittsburgh.

Month	Boiler Feed Pounds	Drain and Blow-Down Pounds	Net Steam Generated Pounds	Fuel Gas Cu. Ft.	Efficiency Evaporation Lbs. Per Cu. Ft. F. & A. 212°	Efficiency Per Cent.
October,	6,257,000	29,000	6,228,000	7,977,000	.87	78.9
November,	10,171,000	33,000	10,138,000	13,251,000	.852	77.2
December,	16,660,000	43,000	10,617,000	21,867,000	.865	78.4
January, 1917,	24,240,000	816,000	23,424,000	28,728,000	.94	85.2
February,	23,803,000	763,000	23,040,000	28,917,000	.921	83.5
March,	19,675,000	1,922,000	17,753,000	23,460,000	.861	78.0
April,	15,257,000	776,000	14,481,000	18,563,000	.863	78.2

In connection with the above results it has to be kept in mind that these are operating and not test figures, and that they have been taken with such exceptional care that even allowances have been made for the drain and blow-down water. The large variation in efficiency is due to the fact that the load was very low except during the months of December, January and February, when the boilers were operated on a load of 100—120%.

At the time of writing this paper only one comparative test of sufficient duration has been made with one of the chief burners at present in use, i. e. the Gwynn Burner. The test was conducted for four weeks in each case, first with the Gwynn Burners and afterwards with the Duquesne Combustion Unit, on a 150 H. P. Erie Return Tubular Boiler, and we have tabulated below the results obtained:

		Gwynn Burner	Duquesne Combustion Unit
Duration of test,		220 hours	220 hours
Average load carried,		137.5 B.H.P.	137.5 B.H.P.
Average Steam Pressure,		95 lbs.	95 lbs.
Average Feed Water Temperature,		190° F.	195° F.
Average Composition of Flue Gas,			
Carbon dioxide	CO_2	3.4%	9.6%
Oxygen	O_2	14.0%	3.5%
Carbon monoxide	CO	0.0%	0.0%
Average Flue Gas Temperature,		420° F.	410° F.
Average Losses through Flue Gas,		30.8%	11%
Total Gas Consumption for Whole Test,		1,479,000 cu. ft.	1,124,000 cu. ft.
Gas saved by Duquesne Unit,			355,000 cu. ft.
Gas saving per cent.			24%
Approximate over all efficiency of Boiler and Furnace,		64.2%	84%

The above table speaks for itself.

COMBUSTION UNIT FOR DRILLING BOILERS.

Figure 5 shows a Drilling Boiler equipped with the Duquesne Combustion Unit.

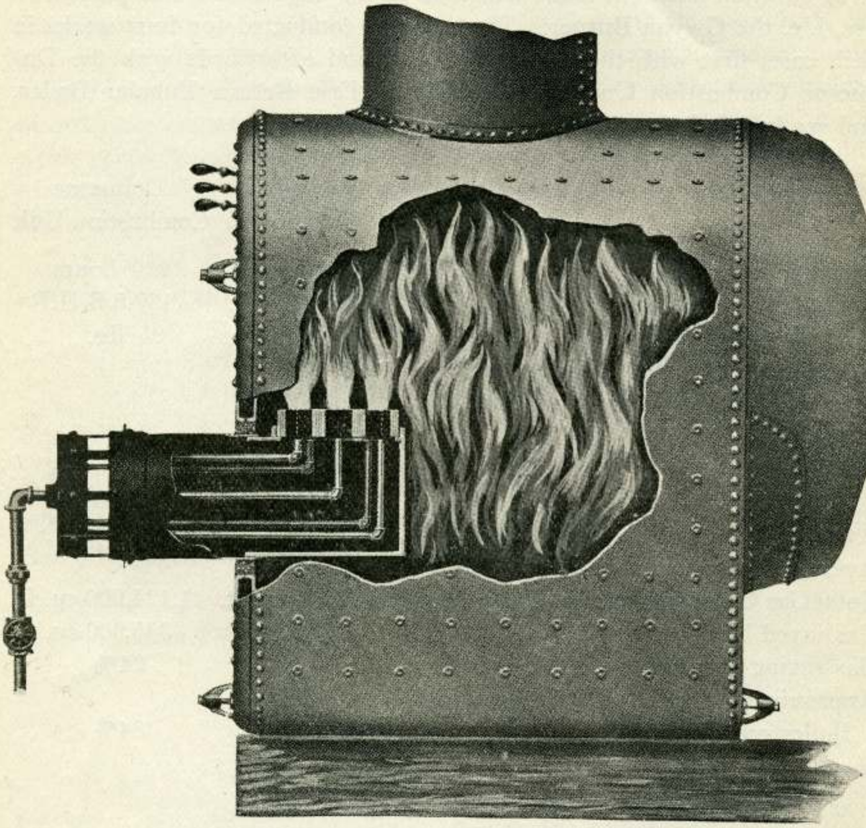

Fig. 5.

It will be noticed that the Unit is L shaped, and that the flame shoots upwards, playing direct on the crown sheet and side plates of the firing box. One particular feature of this Unit is that the mixture of gas and air receives a violently revolving motion in the firebox itself, so that the combustion is absolutely completed before the gas enters the fire tubes. This Unit, which is primarily designed for the standard 25 H. P. drilling boiler, will deal with considerably varying quantities of gas, depending on the amount of chimney draft and gas pressure. If the boiler is equipped with a 12 foot stack, the maximum is approximately 4,000 cubic feet of gas per hour. This quantity will hardly ever be required except in cases of very sudden high loads. The gas consumption for this unit at various gas pressures is as follows:

1 oz. or 1¾″ water, 1250 cu. ft. per hour
2.35 oz. or 4″ water, 1875 cu. ft. per hour
4.1 oz. or 7″ water pressure, 2500 cu. ft. per hour
10.6 oz. or 18″ water pressure, 4000 cu. ft. per hour

In order to utilize this burner and to always have at a moment's notice all the steam which the boiler can possibly generate, a gas pressure of 11 oz. should be available at all times. If it is desired to work at a lower pressure, the same unit can be so designed that it consumes 30% more gas, in which case the maximum gas pressure required will be 6 oz. or 10 inches W. G.

In designing this unit we had to keep in mind that sufficient space had to be provided in the fire door so that any gas that might be found during drilling could be utilized side by side with the gas under pressure. This unit is therefore of such size that without disturbing its operation, a two inch gas pipe can be pushed through the fire door.

Same as in all other boilers, a very essential feature of gas economy is the exclusion of false air from the combustion chamber. We therefore recommend not only that the grate be covered with slabs and earth, or, still better, with brick and fire clay, but also that the space between the fire box and the ground be filled so as to prevent any air infiltration. The space around the combustion unit in the fire door should also be completely filled in and when using casing gas, only a sufficient opening for an additional two inch pipe should be made.

General Conclusions—

1. A tremendous waste of gas almost everywhere where natural gas is used is an established fact.
2. The Gas Consumers must be educated to see this waste and to take steps to stop it.
3. The first essential for good gas economy is an efficient gas burning device making high efficiencies possible.
4. The second essential are expert services to procure the general combustion conditions which are indispensable for economical gas consumption.
5. A close cooperation between the distributing gas companies and the combustion engineer is highly desirable, not only for the benefit of gas consumers but also in the interests of fuel economy.