

T H E S I S

A CONTINUOUS AUTOMATIC CARBON DIOXIDE

INDICATOR FOR CHIMNEY GAS.

by

Truman Hopkins

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Prof. R. L. Wales.

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It is a well known fact, that the fuel supply in this country is rapidly being exhausted. This is partially due to our increased industries, but much more to our careless and wasteful use of our natural resources. Space can not be given here to say how much fuel annually might be saved by an economical and intelligent development of our water resources, for it is not in my field. It is the duty of the Mechanical engineer to put an end to the wasteful use of our fuel supply, and this end can be accomplished only by careful study of the most economical way to burn coal.

It is evident from the reports on boiler efficiency, that there is a great waste of fuel, which can be accredited to three causes.

First. To poor boiler and furnace design. As a general rule, one will find reasonably good design and poor construction. A study of boiler and furnace efficiency shows that poor construction of the boiler and furnace settings is one great cause of low efficiency, as the air vents in the settings let in large quantities of cold air. Now this inleaking air produces the same ^{effect} as if it were let in at the ash pit doors. The reason is easily seen. The inleaking air has the same cooling effect on the gases of combustion as the same amount of excess cold air mixed in with the gases in the combustion chamber.

Second. To poor regulation of the air supply. Statistics on boiler and furnace efficiency show very clearly, that the greatest loss in fuel economy is due to the fact that a large excess of air is

used in burning coal. At the present time, it is found that about twenty pounds of air per pounds of coal, give the best efficiency. This excess air^{is} necessary on account of the fact that the gases in the combustion chamber can not be mixed completely. One will find the greatest wastefulness in small plants and even the large manufacturing and power companies are not as careful as they should be, because it is not only a waste of fuel, but a waste of money. It seems perfectly possible to regulate the air supply if the boiler and furnace settings are air tight and the air passages fitted with practical dampers.

Third. To poor firemen. Much depends on the fireman, as he is the means for regulating all the furnace devices. The boiler efficiency can be increased to a great extent, in many plants by judicial firing. The fireman can not judge with any certainty the amount of air he is using. Hence, the necessity of an accurate indicator of the amount of air being used in the furnace.

Now a study of boiler economy and air supply will lead up to the fact that the boiler efficiency depends on the amount of air supplied, and that both of these bear a relation to the amount of carbon dioxide in the chimney gas. This last fact is the foundation upon which the present investigation depends. Knowing the boiler efficiency can be measured by the amount of carbon dioxide in chimney gas, the problem was to find a way to indicate continuously the amount of carbon dioxide in flue gas. Before presenting the above method, it would be well to speak of the present methods of determining the

amount of carbon dioxide in flue gas, with comments on the advantages and disadvantages of each method.

Hempel Method. The Hempel apparatus absorbs the gases in chimney gas in the following order. Carbon dioxide in the caustic potash pipette, Oxygen in the pyrogalllic acid pipette, and Carbon monoxide in the cupreous chloride pipette. The nitrogen is found by calculation from the amount of other gases in chimney gas. The Hempel method has two great disadvantages. First the determination is not continuous; Second, it requires a skilled man to handle the apparatus. The second disadvantage alone prevents its commercial use and hence it adds very little to the general boiler efficiency.

Orsat Method. The Orsat method is the same in principle as the Hempel. The Orsat apparatus is much more convenient in construction for general use than the Hempel apparatus, but the Orsat method has the same disadvantages as the Hempel method.

Fig. 1. Plate I shows an absorption apparatus which in theory ought to prove useful. Parts: 1. & 2 small orifices of exactly the same size, 3 absorption bulb, 4 ejector, 5 manometer, 6 Intake from chimney, 7 calibrated scale to read percent of carbon dioxide in gas directly. Operation. The chimney gas was drawn by means of ejector (4), first through Orifice (1), then through the absorption bulb, where the carbon dioxide is taken into the solution, and then finally through orifice (2). The manometer (5) indicates the difference in pressure between the two orifices. Then the manometer reading can be calibrated to read percent of carbon dioxide in chimney gas.

Gravimetric Method. The fact that air is lighter than chimney gas containing carbon dioxide, gave ground for investigation on gravimetric method. Several apparatus of this type were constructed and gave fairly good determinations, but the great trouble with instruments of this type was in the ease of getting out of adjustment.

Orifice Method. It is a known fact that gases have a volumetric rate of flow, which varies inversely as the square root of the densities. This law only holds true, when the orifices are very minute. A study of the composition of flue gas will show that the rate of flow is indirectly proportional to the amount of carbon dioxide present. This is evident from the composition of flue gas.

Composition of Chimney Gas. Chimney gas is a mixture of nitrogen, oxygen, and carbon dioxide with an addition of small quantities of water vapor, carbon monoxide and sulphur dioxide.

Nitrogen. Nitrogen constitutes the greater part of flue gas, being about eighty percent of the whole. It has a density fourteen times that of hydrogen.

Oxygen. Oxygen should never be higher than eight or ten percent and has a density of sixteen.

Carbon Dioxide. is found in varying amounts, and has a density of twenty two.

Water Vapor. As for water vapor present in chimney gas, it is always condensed out before the analysis is made. The percent of water vapor in flue gas depends for its value on the amount of moisture present in the atmosphere and in the coal, also on the amount of hydrogen present in the coal.

Carbon Monoxide. As a general rule carbon monoxide is found in very small quantities in flue gas. In most cases it is not found at all. It has a density of fourteen.

Sulphur Dioxide. All bituminous coals contain more or less sulphur, varying in amounts from a few tenths of one percent to about two percent for ordinary coals. Now this sulphur when burned in the furnaces, forms sulphur dioxide, which has a density of thirty two.

Now it is readily seen from the above statements, that all the gases in chimney gas except carbon dioxide and sulphur dioxide, have an average density of about 14.2. See table below.

Nitrogen	Density 14	Percent 80.0
Oxygen	" 16	" 10.0
Carbon dioxide	" 22	" 10.0
Water vapor	" 9	" 0.0
Sulphur dioxide	" 32	" 0.0
Carbon monoxide	" 14	" 0.0

Rate of Flow. Now that it has been shown that the average density of all the gases in flue gas with the exception of carbon dioxide, is very near 14.2 and that the density of carbon dioxide is 2.20. Hence the rate of flow depends primarily on the amount of carbon dioxide present.

Proposed Scheme. Since the rate of flow of flue gas bears a definite relation to the amount of carbon dioxide present, it was thought that an apparatus, based on this fact could be constructed. The operation is as follows. The flue gas is to be drawn continuous-

ly through the very small orifices by an ejector. Now the vacuum maintained by the ejector depends on the amount of leakage into the vacuum chamber. If the rate of flow of the gas changes the vacuum will be ^{changed} ~~increased~~, When the rate of flow of the gas decreases, ^{the vacuum will be increased} and vice versa.

Design, Construction and Operation.

Construction of Orifice. The orifices were made as follows. A piece of thin copper foil was pricked through with a very fine needle point, then the foil was hammered flat and these fine holes were again opened on the opposite side with the same fine needle point. The holes were treated thus to round out the holes on both sides of the copper foil. Then the foil was carefully hammered in order to reduce the holes to the required size. Four orifices were made, but the first and second were unsatisfactory and were discarded. The third was used and the results of the experiments on it are given in the table below, also the time of flow as calculated according to the law of flow already stated, assuming the time of flow for carbon dioxide as correct.

Gas	Volume	Time by Exp.	Time Cal.
C O ₂	30 C.C.	50 sec.	50.0 sec.
$\frac{1}{2}$ C O ₂ + $\frac{1}{2}$ air	30 C.C.	46 sec.	45.5 sec.
$\frac{1}{4}$ C O ₂ + $\frac{3}{4}$ air	30 C.C.	43 sec.	
air	30 C.C.	33 sec.	40.5 sec.

From the results given in above table, there is a large discrepancy in the time of flow as calculated and as found by experiment.

Let V = volume of gas to be passed through an orifice

" D = density of gas

" T = Time required for volume V . to pass through the orifice.

" A = Area of the orifices

Then $T = f(A, V, D^n)$

Ejector. An ejector was used to draw the gas through the orifice. The construction and operation of the ejector needs no explanation here. The ejector was supplied with water from a small stand pipe made of $1\frac{1}{4}$ gas pipe. See Fig. 2. Plate II for details.

Test on Orifice No. 4. After making orifice No. 4 and the ejector with stand pipe for water supply, several tests were made. See Plate III for arrangement. It was found the orifice let in air at such a rate that very little vacuum was produced by the ejector, that the water manometer showed very little increase in pressure when carbon dioxide was passed through the orifice under the same atmospheric conditions. However, when some of the holes in orifice No. 4 were stopped, it was found that the water manometer showed several inches vacuum for air and a much higher reading for carbon dioxide, mixed with air in some unknown proportion..

Conclusion.

It is my candid belief that a suitable orifice, ejector, and a vacuum indicator not affected by the changes in temperature and pressure of the atmosphere would make the apparatus perfectly possible and the one great advantage in its favor would be its continuous and automatic action.

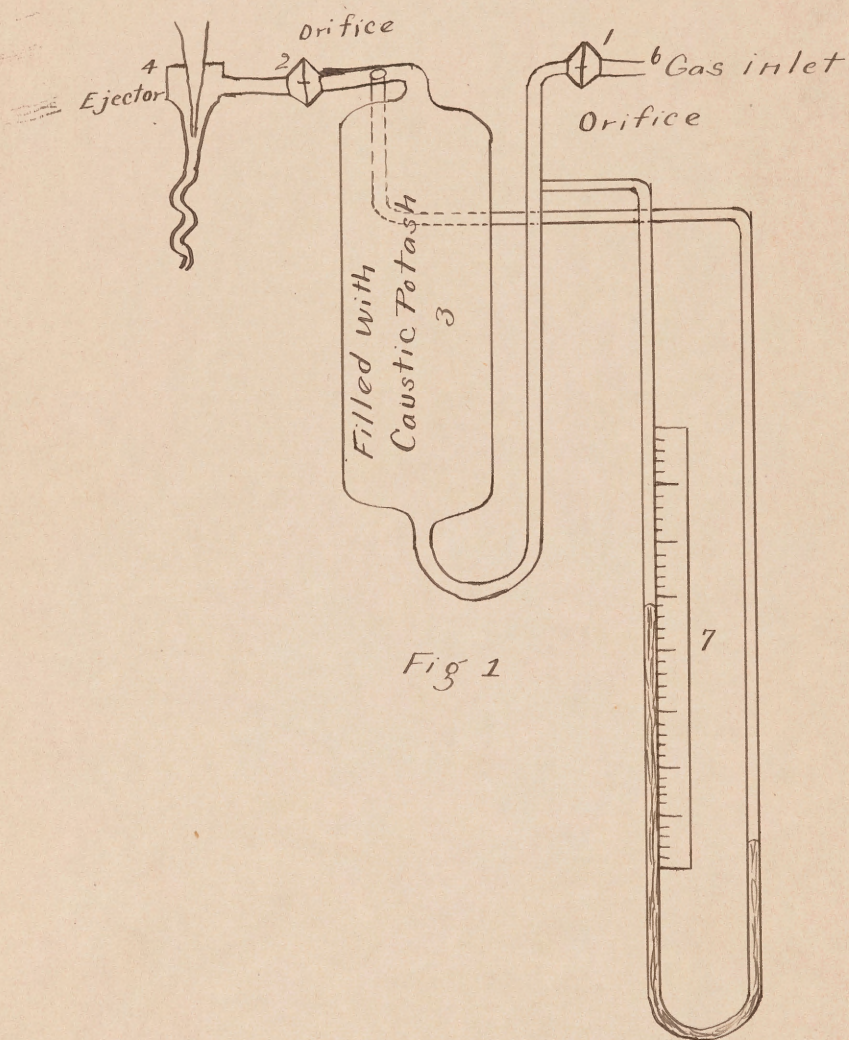


Fig 1

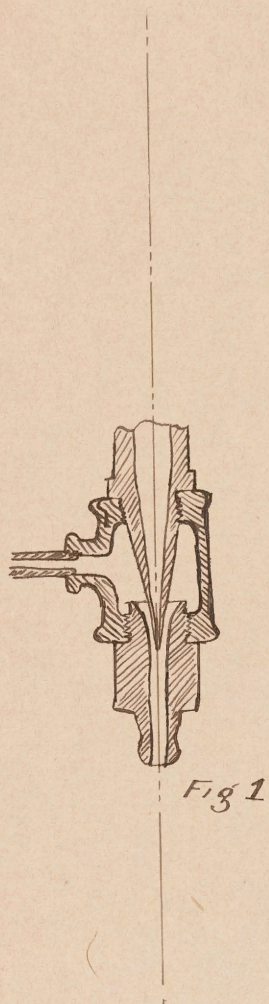


Fig 1

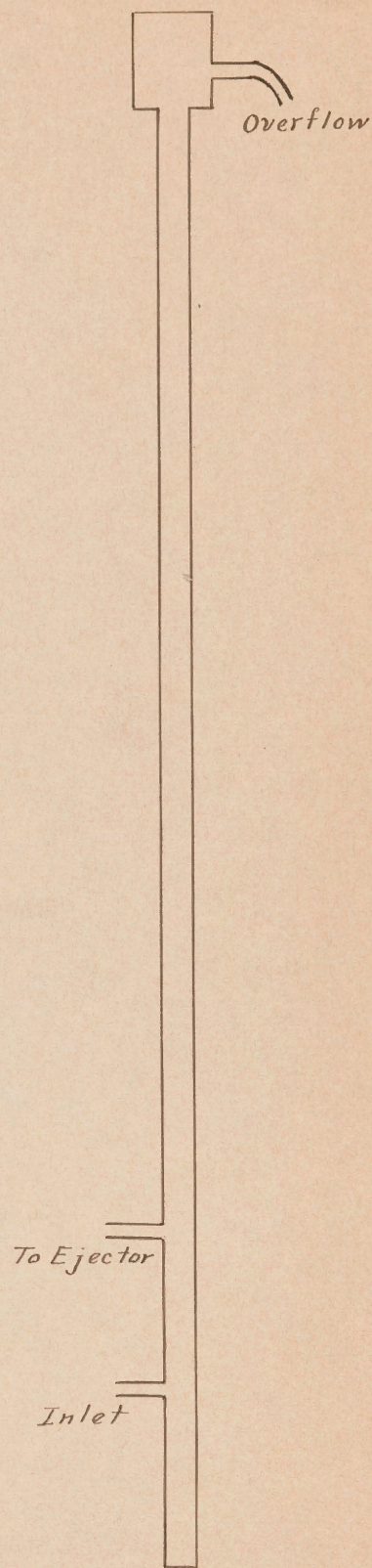


Fig 2

