

## THE RELATION OF SULPHUR IN LIGHTING-GAS TO AIR VITIATION.

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It is matter of common observation that air which is much vitiated by combustion of lighting-gas is distinctly oppressive, apart altogether from the rise of temperature which is always associated with the vitiation. This effect is always very evident if the proportion of  $\text{CO}_2$  in the air of a room has been raised to 30 or 40 volumes per 10,000 by combustion of gas. Air to which pure carbonic acid has been added in the same proportion has no such effect, however, and is practically indistinguishable from pure air. Deficiency of oxygen to such an extent as occurs in the air of a room is also without sensible effect. In coal-mines, where the air is commonly vitiated to a considerable extent by slow oxidation in the strata, it is, for instance, quite impossible to distinguish by the senses pure air from air containing an excess of 50 or even 100 volumes per 10,000 of  $\text{CO}_2$ , with a correspondingly large deficiency of oxygen. The unpleasantness of air vitiated by combustion of lighting-gas is therefore not due to excess of carbonic or deficiency of oxygen.

In a recent paper in this Journal<sup>1</sup> I remarked that the sulphur present in gas is probably the cause of the unpleasantness. The quantity of sulphur in ordinary lighting-gas is, however, so small that this hypothesis may at first sight seem improbable. As a rule English gas contains less than 20 grains (1·3 grammes) of sulphur per 100 cubic feet, or 0·46 grammes per cubic metre. Hence, as gas forms in burning about half its volume of  $\text{CO}_2$ , the products of combustion would contain

<sup>1</sup> Vol. II. p. 424, 1902.

less than 0.5 grammes of sulphur to 500 litres of  $\text{CO}_2$ . If the sulphur were oxidised to  $\text{SO}_2$ , this would correspond to about one gramme or 0.33 litres of the latter to 500 litres of  $\text{CO}_2$ , or one volume of  $\text{SO}_2$  to 1500 of  $\text{CO}_2$ . Hence air vitiated by combustion of gas to the extent of 30 volumes of  $\text{CO}_2$  per 10,000, would usually contain less than  $\frac{30}{1500} = 0.02$  volumes of  $\text{SO}_2$  per 10,000 of air, or about one part in 500,000. This is a very small proportion; but not very much less than what Lehmann<sup>1</sup> found to produce perceptible irritation of the nose and throat. He showed that this effect occurred with air containing about one part in 200,000 of air. He records no experiments with smaller proportions.

There is no doubt, however, that the sulphur is partly, at least, present as sulphuric acid and in a particulate form. My attention was first drawn to this fact by an observation related to me by the manager of a weaving shed in a small country town. He informed me that occasionally a fog had occurred in the shed when the gas was lit, and that at the same time the air became most unpleasant and irritating. This was clearly due to the purification of the gas being occasionally worse than usual, so that a considerable proportion of  $\text{H}_2\text{S}$  passed through the purifiers. The quantity of sulphuric acid formed was thus so great that although the ventilation was especially good the air of the shed became foggy from the condensation of moisture on minute drops of sulphuric acid in the air. As will be shown below, it is easy to produce evident fog in a room by burning gas containing an extra proportion of sulphur. Sulphuric acid suspended in a particulate form has not the same specific taste as sulphurous acid, but is extremely irritating and unpleasant.

The sulphur contained in crude unpurified lighting-gas is present chiefly as sulphuretted hydrogen, about a tenth being present in other forms, chiefly as carbon bisulphide. In the process of purification the  $\text{H}_2\text{S}$  is easily removed by quicklime, hydrated oxide of iron, or manganese dioxide ("Weldon mud"). The sulphur in other forms amounts usually to about 30 to 40 grains (2 to 2.7 grammes) per 100 cubic feet (2.8 cubic metres) of gas. When, as is usually the case in England and America, the  $\text{CS}_2$  is also removed, this is effected by passing the gas through a purifier charged with sulphide of lime, which has the property of absorbing  $\text{CS}_2$ . The purified gas contains only about 0.5 gramme (6 or 8 grains) of sulphur per 100 cubic feet when the sulphide purifier is working perfectly. If, as is sometimes the case even in large towns, sulphide of lime purification is not used, the gas which is distributed

<sup>1</sup> *Archiv für Hygiene*, xviii. p. 180.

may contain 2 to 2.7 grammes (30 to 40 grains) of sulphur per 100 cubic feet. The averages of the daily official tests of the gas of the three London companies for 1902 were 11.1, 12.2, and 9.2 grains of sulphur per 100 cubic feet.

The large gas companies in England are usually legally bound to supply gas containing less than a certain maximum amount (about 20 grains) of sulphur per 100 cubic feet. For London the maximum is at present 17 grains in summer and 22 grains in winter. The importance of keeping the proportion of sulphur in gas as low as possible is thus very generally recognised, although less attention has been given to the physiological action of the products of combustion of sulphur than to their destructive action on the bindings of books and on other fabrics. In many of the smaller English towns, and certain of the larger ones, including Birmingham, gas containing as much as 30 grains of sulphur per 100 cubic feet is, however, regularly distributed.

In order to investigate the relation between the proportion of sulphur in lighting-gas and the unpleasantness of air vitiated by the products of combustion I employed the following method. In one of two rooms the ordinary Oxford gas (which contained about 8 or 9 grains of sulphur per 100 cubic feet) was burnt. In the other room gas was used to which any required proportion of CS<sub>2</sub> vapour had been added. The carbonic acid was determined at intervals in the two rooms, so that the degree of admixture of the products of combustion with the air was known.

The CS<sub>2</sub> vapour was added to the gas by the following method. By means of a three-way junction the stream of gas passing to the burner was divided into two portions, one of which passed over liquid CS<sub>2</sub> contained in a wide test-tube. The relative quantities of gas passing in each portion were regulated by means of taps. The two streams were afterwards re-united by a second three-way junction, and then proceeded to the burner. By regulating the taps the proportion of CS<sub>2</sub> vapour in the united stream could be regulated at will. The stream passing over the carbon disulphide was relatively very small, and in order to facilitate its regulation the gas was allowed to bubble through about half-an-inch of water in a test-tube before passing to the CS<sub>2</sub>. By counting the bubbles it was easy to regulate the stream to about the proper amount, and any variation could be detected at once.

The sulphur in the gas was estimated by Harcourt's method<sup>1</sup>. This method depends on the fact that in presence of hot platinised pumice

<sup>1</sup> Fully described in Butterfield's *Gas Manufacture*, p. 218.

$\text{CS}_2$  in gas is broken up with formation of  $\text{H}_2\text{S}$ , which is estimated by passing the gas in a slow stream of small bubbles through lead acetate solution, until the colour becomes equal to that in a standard tube containing a perfectly stable brown solution. As a small portion (about 6 or 8 grains of S per 100 cubic feet of gas) of the sulphur in gas is not affected by this platinised pumice, it is necessary to add to the result obtained about 6 to 8 grains (0.5 gramme) in order to get a true result. The small stream of gas required for the test was taken off just before the mixed stream of gas reached the burner. Frequent determinations were made during the experiments. The ordinary Oxford gas was found to show only from 1 to 2 grains of S by Harcourt's test, and was therefore taken to contain 8 to 9 grains in all. The  $\text{CO}_2$  in the air was determined by the rapid method which I described in this Journal, Vol. I. p. 109, and Vol. II. p. 415.

The effects produced by the air in the two rooms, with varying percentages of  $\text{CO}_2$  in the air and of S in the gas burnt, were observed at intervals by myself and others, and noted at the time. The impure gas was burnt in Room 1, and the ordinary Oxford gas in Room 2. Several experiments were made on different days. The burners employed were the ordinary ones (Bray's fishtail burners) used in the two rooms.

The following are the notes of an experiment.

- Gas lit at 12.45 p.m. Stream of gas passing over  $\text{CS}_2$  in Room 1 adjusted to 32 bubbles per minute. Sulphur=34 grains per 100 cubic feet.
- 1.15 p.m. Room 1.  $\text{CO}_2$ =18.5 volumes per 10,000. 30 bubbles per minute. Air markedly unpleasant, causing perceptible irritation of the air-passages, and having a slight taste of sulphurous acid.
- 1.30 p.m. Room 2.  $\text{CO}_2$ =20.5 volumes. Air not appreciably unpleasant.
- 1.45 p.m. Room 1.  $\text{CO}_2$ =25 volumes. 38 bubbles per minute. Sulphur=46 grains per 100 cubic feet. Air very unpleasant. Distinct irritation of air-passages, and slight irritation of the eyes. Acid taste.
- 2.50 p.m. Room 1.  $\text{CO}_2$ =20 volumes. Sulphur=41 grains per 100 cubic feet. Air irritating and unpleasant. Temperature 20° C.
- 3.5 p.m. Room 2.  $\text{CO}_2$ =36 volumes. Air slightly unpleasant, but much less so than in Room 1. Temperature 20° C. No acid taste perceptible.
- 4.0 p.m. Sulphur in ordinary gas=8.7 grains per 100 cubic feet.

The same experiment was repeated on several days, with slight variations. With 40 grains of sulphur per 100 cubic feet of gas a taste of sulphurous acid and slight irritation of the air-passages were distinctly noticed at about 13 volumes of  $\text{CO}_2$  per 10,000. With only 9 or 10

grains of sulphur, on the other hand, similar irritation of the air-passages was not noticed until the  $\text{CO}_2$  rose to about 35 or 40 volumes; and even at this point no acid taste could be detected—possibly because any sulphurous acid formed had been almost entirely oxidised to sulphuric acid. It was thus evident that the unpleasantness of the air varied in proportion to the amount of sulphuric and sulphurous acid present.

With 51 grains of sulphur in the gas, and 39 volumes of  $\text{CO}_2$  in the air, distinct fog was observed in the room, although no moisture had condensed on the windows, and the air was only 81% saturated with moisture, as shown by the readings of dry and wet bulb thermometers ( $23.5^\circ$  and  $21.5^\circ$ ). The air was extremely unpleasant. The fog was more evident when with the same gas burning and the air 82% saturated with moisture, the  $\text{CO}_2$  had risen to 48 volumes. When the air contained about the same proportions of moisture and  $\text{CO}_2$ , with only the ordinary gas burning, no distinct fog could be seen.

Several other individuals besides myself compared the air in the two rooms, and all agreed that the air was far more unpleasant in Room No. 1 than in Room No. 2. They easily perceived the acid taste and unpleasantness of the air in Room No. 1. In one individual, sneezing was produced on going into Room 1 with 35 volumes of  $\text{CO}_2$  in the air, and 36 grains of sulphur in the gas. Two others complained of slight headache after a few minutes. From the results as a whole there could be no doubt whatever as to the great superiority from the standpoint of comfort and health, of gas properly purified by sulphide over gas from which the carbon bisulphide is not removed.

Unfortunately no process is known by which the whole of the sulphur can be removed from lighting-gas. Were it possible to remove the whole there would apparently be no objection whatever to using gas perfectly freely for both heating and illuminating purposes in any ordinary room, and allowing the products of combustion to escape into the room. With a clean paraffin lamp, burning good oil, I found that the air of a room was not noticeably unpleasant, apart from the heat, even when the  $\text{CO}_2$  had risen to 75 volumes per 10,000. With the Oxford gas, on the other hand, the air was distinctly unpleasant when vitiated to the extent of 30 to 40 volumes of  $\text{CO}_2$ , and very unpleasant when vitiated to 60 volumes. The small quantity (8 or 9 grains per 100 cubic feet) of sulphur in the gas was evidently responsible for the difference.

In judging of the hygienic importance of varying proportions of

sulphur in lighting-gas it is of course necessary to take into consideration the illuminating power of the gas. To take an example, the gas now distributed in London south of the River has with ordinary burners only about half the illuminating power of the gas distributed in several towns in Scotland, and about two-thirds of the illuminating power of Liverpool gas. To obtain the same light with a good flat-flame burner it is thus necessary to burn about 100% more gas in London south of the River than in the Scotch towns, and 50% more than in Liverpool. A given percentage of sulphur is therefore correspondingly more important with the poorer than the richer gas if flat-flame burners are used. With Welsbach burners the difference is much less important.

#### CHIEF CONCLUSIONS.

1. The unpleasantness of air vitiated by the products of combustion of lighting-gas is due to the presence of sulphur in the gas, and varies in proportion to the amount of sulphur.

2. Gas which is purified from carbon bi-sulphide is greatly superior from the hygienic standpoint to gas which is only purified from sulphuretted hydrogen.