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GAS QUESTION:

Economic and Sanitary.

BY

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L.R.C.S.E., F.F.P.S.G.,

Late Examiner in Chemistry, Fac. Phys. & Surg., Glasg.

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FROM THE AUTHOR.

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PREFATORY NOTE.—The following pages appeared in the *Glasgow Herald* of February, 1882, as my contribution to the discussion of a question much exciting the public mind. A Committee of the City Council, opposed by an influential minority, had recommended that Parliamentary powers should be obtained for lowering the illuminating quality of Glasgow gas from its present standard of 25 to 20 candle power. Among other assertions and reasons—chiefly the former—it was urged, in favour of the proposed change—*First*, that the present gas being of high quality *necessarily vitiated the air more than gas of lower quality*, and, therefore, a change was necessary, or at least advisable, as a measure of Public Health—*Second*, that *gas of the proposed lower quality will be equally effective* for private and public use through improved methods of combustion—*Third*, that *the proposed quality of gas will be lower in price* than the present—*Fourth*, that *the proposed change will not involve the re-construction or alteration of gas mains, works, or other public gas plant or compel the private consumer to substitute new gas fittings for those in present use.*

These assertions I have shown to be erroneous and mischeviously misleading, the facts alleged in their support to be fallacious, and the results if carried out to be disastrous for the public interest. Having kept myself well informed in all that relates to Coal and Gas since 1854, when at the Torbanhill Mineral Trial, I gave evidence based on original researches into the structure and properties of Coal; and having subsequently been much associated with eminent *confrères*, as joint investigator, as literary contributor, and as co-witness in connection with coal and gas questions, I have fair warrant to speak on this gas question. If the facts on which I base my conclusions are not controverted—and I assume they are in substance incontrovertible—my readers will give judgment by default against the advocates of the proposed change.

Many individuals, here and at a distance, since the publication of my views, have urged a reprint in the connected form of a pamphlet, as well to remind them of details that are too little known, and that too readily pass from the memory, as also to aid the enquiries of others who are now qualifying themselves for an intelligent judgment on the gas question as it has been laid before the Glasgow public.

I have accordingly revised this reprint, made necessary corrections, interpolated important fresh matter, and reserved some copies for the booksellers.

The proposed change in the character of the gas supply for Glasgow has affected the public mind with the suddenness of a shock, more especially the minds of those individuals whose information enables them to appreciate the consequences which will follow so great an economic revolution. Those who are doubtful, and at same time ill-informed, are perplexed in the extreme by conflicting statements, some of which show very clearly that imperfect information exists regarding very simple matters of fact, the diffusion of which is misleading the judgment that the public must ultimately form. I cite one illustration. It is publicly stated that the standard of candle power of Birmingham is 12 candles, of Newcastle 14, of London 16, and of Liverpool just 20. But the facts regarding these localities are very different. The actual standard of Birmingham is 17·3 candles, of Newcastle 16, of London 20, and of Liverpool 21½. When errors of this kind are made regarding the merest matters of fact, open to the easiest reference and verification by the initiated, although difficult of detection by the general reader, it is unlikely that matters of scientific deduction will be better elucidated, and on this head I cite another illustration. At a recent public meeting, the chemistry and mechanics of gas combustion were expounded; the chairman agreed with all that the principal speaker said, and the meeting memorialised in accordance. It was stated that many consumers do not receive a light of more than 12 or 15 candles at the most, because that their jets, instead of allowing a consumption of five cubic feet per hour, "the standard measurement," only permitted a consumption of from one to two and a-half cubic feet per hour. This reference to "the standard measurement" has been made under a misconception of the meaning of that phrase and of the conditions under which it is to be applied. It is merely *a measure or rule of comparison* used by the chemist or gas analyst in his laboratory, by which he compares and appraises the value of different gases, although in the actual experiments these gases may have been a little higher or lower in quality; and the rule is only applied under the conditions that the gas during the time of the experiment is burned at a certain pressure. In one locality, or with one kind of burner, this pressure may be half an inch or only one-hundredth of an inch. But the natural inference drawn by the audience would assuredly be that, unless a burner allowed a consumption of five cubic feet per hour the full lighting value of the gas could not be obtained. This is so far from being the case that with burners in general use an illuminating power equal to 25 or 26 candles may be obtained by burning little more than three cubic feet per hour. It is the *pressure* at which the gas is burned that forms the most important factor. A very common and cheap burner will give fullest value at a certain pressure, but will waste gas greatly at another pressure. But the almost unavoidable variations in pressure at the mains makes those common cheap burners very costly. On the other hand, a good burner—a Brönner's burner, for example, or an improved Bray's burner of the latest make—is constructed to regulate the pressure and prevent the blowing away of gas without yielding up its lighting power. I repeat that it is not the quantity of five cubic feet per hour, whether of Glasgow or of any other gas, that regulates the value obtainable by the consumer. Indeed, it is questionable if burners that will consume five cubic feet per hour are in use in Scotland, unless in very exceptional circumstances, In an altogether admirable report, laid before the meeting of the British Association for 1878, on the best means for the development of light from coal-gas of different qualities by a Committee consisting of Dr. W. Wallace, Professor Dittmar, and Mr. Thomas Wills, F.C.S., F.I.C., drawn up by Dr. Wallace, it is shown that with burners suited to deliver five cubic feet per hour the light yielded at ½ inch pressure was 28½ candles nearly, while at 1½ inch pressure the light from an equally good burner barely exceeded 21 candles, those numbers being in the proportion of

100 to 74. In those instances the quantities of gas were the same (five cubic feet per hour). But with smaller quantities of gas the results, *calculated to five feet*, were still more startling. A Bray's burner which at 1½ inch pressure burned 2 cubic feet per hour gave a light barely equal for five cubic feet per hour to 9 candles; while another Bray's burner which at 1 inch pressure consumed seven cubic feet per hour gave a light for five cubic feet equal to 32 candles. Between ordinary working limits of pressure, and with equally good burners, we have therefore a measured quantity of gas (five cubic feet per hour) giving in the one case 32 candles and in the other barely 9, or in the proportion of 100 to 27½. These experiments were with Cannel or good quality gas. The loss of light with common or low quality gas, under similar conditions of pressure, is in still greater proportion. The reference to a "standard measurement" was therefore misleading, and it would be as correct to state that the purchaser of a yard of flannel could not obtain honest measurement if the draper measured it with a two-foot rule.

The same speaker referred to the loss of illuminating power that was incurred by the use of imperfect gas burners, and said that, "taking into consideration the pressure of the gas sent to such jets" —I quote the newspaper report—"a considerable portion of it was unconsumed, passing off into the atmosphere of a room in deleterious *products of imperfect combustion—carbonic acid* and carbon mon-oxide"— . . . and in continuation explained that certain precautions as "an *increase* of the initial pressure at the works, combined with the use of better burners, . . . *would prevent any greater generation of carbonic acid gas*, and any further vitiation of a room atmosphere." Now, to include carbonic acid among the products of "*imperfect*" combustion is an extraordinary error. Carbonic acid, on the contrary, is the product of *perfect* combustion, and its formation is the true and only proof that combustion has been perfect, and that the fullest value has been obtained from the gas. And any arrangement for the combustion of gas* which *prevents* "the further generation of carbonic acid gas" is equivalent to a proportional loss—*and a very great loss*—of the lighting or of the heating power of which the gas is capable. The formation of carbonic acid gas in the fullest quantity that the gas is capable of producing, is *a necessary evil that always must accompany the fullest utilisation* *of gas*, and it is because of this unavoidable attribute of gas combustion that I deprecate any change of gas supply that *by increasing the volume of gas consumed increases the quantity of a very deleterious agent* to mingle with the atmosphere of our dwelling apartments. It will be well that the public should bear carefully in mind the fact I have stated, together with its great importance. And I adjure the earnest inquirer to give no credence whatever to any assurances, however specious, that any contrivance, any cunning device, chemical or mechanical, is at present *in retentis*, in the knowledge of our local officials or legislators, that can prevent or lessen by one iota the gross amount of the deleterious products of the perfect, or of the imperfect, combustion of coal gas. The proportions which these deleterious products bear to each other may be altered and that is all.

I will not make further reference to the special illustrations I have cited, which are made in all courtesy and altogether impersonal, neither will I proceed with additional illustrations I could cite of the erroneous teachings that may now be influencing the public mind. But, impelled by my own reflections on such illustrations, I propose to contribute some observations that may enable others less informed than myself to separate the wheat from the chaff that is being offered for their digestion, and aid them in the progress of the inquiry which every citizen is directly and largely interested in making. The question is a great question—too large for being thoroughly thrashed out in a few newspaper paragraphs. It is, indeed, with me a matter of doubt whether the proposed purification of the Clyde through a River Conservancy Commission, together with a comprehensive sewage scheme, involves greater consequences, immediate and remote, monetary or sanitary, than are involved in the realisation of the modest seeming *permissive* clause, which "may" change the character of the gas supply of Glasgow.

Among the inducements held out to the public by the promoters of the proposed change there are comprised two very important assurances. The assurance—*of belief*—is given that gas will be sold to the public at a substantially lower price per 1000 cubic feet than hitherto. Upon this assurance I will venture some comments, but with the previous admission that it is not a branch of the question with which I am so competent to deal, because it involves mercantile transactions, contracts, financing, &c. Another assurance—of belief—is given that with a substantially lower *nominal price* per 1000 cubic feet there will be accorded greater actual value in lighting and heating power, with no contingent additional expenditure involving the consumer, and with no increase of the sanitary and economic drawbacks that are unavoidably attendant on the use of coal gas. These assurances I will now discuss *seriatim*.

Is it the fact that 20 candle gas can be sold at a lower price per 1000 cubic feet than the present Glasgow price of 3s. 8d.? I willingly concede that it is so, for there is good reason to believe that Glasgow, being its own customer, might have its present gas at a still lower price. Be this as it may, the probable cost of 20 candle gas supplied for Glasgow, must be conjectural within certain limits, and based in a large measure on the assumption that the new coal supplies together with such changes in manufacturing details as may be effected, will be effected under as favourable conditions, and be attended with as favourable results, as obtain in those localities where gas of low illuminating power is the rule. Throughout England coal gas is made of low candle power, and has been so since the earliest introduction of the invention. In this respect the English have been thoroughly conservative, and in the literature of gas managers' meetings I occasionally recognise the sturdy "practical man," who "makes no pretence of being wiser than his father," and who refers to "the good old honest English 16 candle gas" much in the affectionate spirit that I can imagine him gloating over "the roast beef of Old England," or with which in *bygone times* he would triumphantly toast the "*wooden* walls" of Old England.

From officially authenticated returns of the last three years, corrected by comparison with the latest information,* regarding about 2,000 localities in Great Britain and Ireland, I have collated and "boiled down" the statistics of 285 localities. These statistics show the number of tons of coal "carbonised" in the manufacture of coal gas, the approximate quantity in cubic feet of gas manufactured, the candle power of the gas, and the price per 1,000 cubic feet to the consumer, together with other details. In some localities the coals carbonised in a year are under 100 tons, and from such places no safe deduction can be drawn. But 1,000 tons of coal represents a large quantity

* Gas Engineers' Diary and Text-Book for 1882. Birmingham: J. Wright & Co

of gas — a larger quantity than is produced by such centres of population as Peebles, Gourock, Maybole, Morpeth, etc. Excluding, then, the smaller localities, I find that above 285 places throughout the Kingdom carbonise above 1,000 tons of coal annually in the manufacture of gas. I subjoin a list of thirty-four towns as an example of the materials from which I have framed a digest of the larger number, premising that in some districts there is a difference in the rates charged for suburban supplies, and that in these instances I have averaged the cost :—

Localities.	Candle Power.	Tons of Coal Carbonised.	Price of Gas per 1000 Cubic Ft.	Cub. Ft. of Gas annually. Millions
Aberdeen,	30	23,503	4s. 2d.	243
Accrington, Lancashire,	18	11,470	3s. 7½d.	116
Belfast,	17·3	54,340	3s. 4d.	563
Birmingham,	17·3	312,000	2s. 9d.	2,840
Cambridge,	16	15,000	3s. 6d.	146
Chester,	17	12,000	3s. 11½d.	120
Cork,	14	22,000	4s. 2d.	200
Dublin,	17	111,000	3s. 11d.	1,120
Edinburgh,	28	27,700	3s. 10d.	287
Fleetwood,	16	1,200	5s. 0d.	11
Glasgow,	27	199,266	3s. 8d.	1,961
Greenock,	29	17,400	4s. 2d.	170
Hampton Court, Middlesex,	14	6,000	4s. 6d.	60
Harrowgate,	15	5,000	4s. 7d.	45
King's Lynn,	14	4,000	4s. 0d.	40
Lancaster,	19	4,900	3s. 7½d.	51
London Gas Light and Coke Co.,	{20 / 16	1,206,217	{4s. 2d. / 3s. 4d.	12,479¼
Do., Commercial, Ratcliffe, S. Metrop., Surrey, & Phœnix Cos.,	16	549,587	3s. 0½d.	5,567
Do., Crystal Palace, Lea Bridge Dis., West Ham. Cos.,	14	80,909	4s. 1d.	801½
Do., Gas Light Co.,	12	155,467	3s. 3d.	1,560¼
Liverpool,	21·5	234,000	3s. 1d.	2,295
Do., Birkenhead,	20·5	23,724	3s. 4½d.	251½
Manchester, Salford,	21·7	76,026	3s. 6d.	732¼
Do., Stretford,	20·5	7,134	3s. 2d.	73¾
Maryport,	17	1,871	4s. 0d.	16½
Newcastle-on-Tyne,	16	92,000	2s. 0d½.	1,000
Northampton,	14	20,000	3s. 2d.	185
Peterborough,	14	5,000	4s. 0d.	55
Rochdale,	18	26,023	3s. 4½d.	265¾
Scarborough	14	12,400	4s. 0d.	129
Tottenham, Middlesex,	15	16,500	4s. 0d.	164
Tynemouth,	14	12,000	3s. 0s.	126
Windsor,	16	5,700	4s. 3d.	63
Yarmouth,	12	7,900	3s. 6d.	84

The 34 localities just enumerated seem to me a sufficiently numerous haphazard selection from which an inquirer may draw rough inferences. The following table gives a digest of the same details in 285 places, all of which carbonise above 1,000 tons of coals yearly :—

	Under	From	From
Quality of gas in candle power............	20 cand.	20 to 25 cand.	25 to 30 cand.
No. of localities..................................	233	16	36
Candle power ranges from..................	12 to 19·5	20 to 21·7	26 to 30
Candle power averages........................	15·3	21·1	28·25
Price per 1,000 cubic feet ranges from	1/10 to 6/	3/1 to 5/10	3/4 to 7/6
Price for 1,000 cubic feet averages.......	4/	4/1¼	4/8¾

The gases of 26 candle power and upwards, referred to in this table are exclusively Scotch. All under 26 candle power are exclusively English and Irish, and of the latter only a few are embraced in the table. Of the large towns in England which show a candle power of 20 candles there are only three—viz., London, Liverpool, and Manchester, and of these the average candle power is 20·8, and the average price per 1,000 cubic feet is 3s. 4½d. In the case of these towns, all the elements seem to be present which can affect, in the way of lowering, the price of gas. An enormous output facilitates large contracts for supply, and long experience in a special manufacture reduces the cost of production. And yet, in the case of London, with a manufacture of 1,206,217 tons of coals carbonised by one Company alone, amounting to six times that of Glasgow, and above 43 times that of Edinburgh, the consumer of London pays a higher price for his 20 candle gas than is paid by the consumer in Glasgow and Edinburgh for 26 and 28 candle gas. It may be shown by the promoters of the proposed change that contracts for large supplies can be effected more cheaply by Glasgow officials, that labour may be conducted more economically, and the entire question may be so handled, and cleared up, or muddled, in the explanation of details as to convince, or at least to silence, those who believe that a bad exchange is threatening the community. But it seems to me that such facts as I have presented are not to be lightly put aside and are sufficient to induce scepticism even with reference to the promise of a substantial reduction in the mere nominal price. I have no scepticism as to the actual bad value of the exchange, and have satisfied myself that although a large reduction in price was offered and guaranteed, the citizens of Glasgow would do well to reject the proffer on the score that they will not receive equal value with what they enjoy at the present moment. This consideration leads me to the next branch of my contention.

It is asserted that lowering the quality of Glasgow gas to 20 candle power will not necessarily, or at least substantially, lower the lighting and heating value, which will still be equally great with that obtainable at present from our 26 candle gas; because, it is said, the equal value can be obtained by employing better methods of combustion than are now in use. This is certainly true, but it is a truism that applies at all times to any coal gas whatever the value. The suggestion cuts both ways. 20 candle gas, by means of a careful adjustment of the pressure at which it is delivered, and by the use of burners of good construction, will give the light usually obtainable from 26 candle gas. But if these precautions are not employed, then 20 candle gas will only give the light of 10 candles, and 30 candle gas will only give the light of 20 candles. Moreover, the lowering of the present quality of gas does not insure the employment of improved methods of combustion. Ignorant and wasteful consumers will always be with us; and whatever the quality of gas, there will always be a liability to wasteful practices. The lower the nominal price, the greater the waste—*videlicet*, pins, matches, and steel pens. A wasteful consumer will no more amend his ways through demonstration that he is wasting his gas, and might and ought to do better, than will a confirmed drunkard through admonition and conviction that he is wasting his health, money, and business. But granting that by the use of automatic pressure governors the distribution of gas was equalised—instead of being delivered from full supply pipes at the Broomielaw at 5-10ths of an inch pressure and at Park Quadrant at 26-10ths pressure, as I have verified—-and that individual consumers employed the best burners, I would, despite the desirable improvement, not be reconciled to the lowering of the present quality of gas. Neither 20 nor 26 candle gas are standards of excellence at which, when attained, we should rest and be thankful. The consumer who believes, as I believe, that we cannot have too much light at command, as well for social comfort as for many other uses, should not willingly accept a supply of inferior gas. On this point I quote the observations of Dr. Wallace,* our City Analyst.

"It cannot be doubted," he says, "that a supply of gas of

* On the Economic Combustion of Coal Gas.—Phil. Soc. Trans., 1874.

comparatively high illuminating power is a most desirable thing, independent altogether of the consideration of cost. Cannel gas gives very little more carbonic acid and other products of combustion than common gas, while it yields in ordinary practice twice as much light. In other words, if we wish in an apartment a certain amount of light, we must vitiate the air to nearly double the extent if we employ common gas, such as that used in Birmingham and London [Manchester and Liverpool], that we require to do with Glasgow or other gas, with a corresponding increase of temperature. As regards sulphur, it is even worse; for in common gas the average is about 30 grains per 100 cubic feet, while with our gas it certainly does not exceed 15 grains; so that for equal quantities of light about four times as much sulphurous acid is produced in burning common gas as compared with cannel gas. This is a very serious evil, and accounts to a large extent for the comparatively limited use of gas in the better class of houses in London and other English towns. Then again, all our gas fittings are adapted for cannel gas, and are often deficient even for it, and a change to gas made from common coal would necessitate a complete revolution in gas-fitting arrangements. I think you will agree with me, therefore, that we should retain our cannel gas as long as we can; and my own impression is, that by a judicious use of a mixture of splint or caking coal with oil shales, together with a limited use of cannel coal, a supply of 25 to 28 candles may be kept up for very many years."

I agree *in totalibus* with these thoroughly accurate and usefully suggestive observations. The case I am presenting could not be better argued, and I commend the moral to the thoughtful consideration of our citizens. I go further, and urge that instead of lowering the quality of Glasgow gas it should be raised—raised to the 28 candle gas that was supplied in Glasgow before the Town Council obtained the control—raised to the level of the other chief towns of Scotland, instead of being almost exceptionally the lowest—raised to the level of 28 candles, as supplied in Edinburgh, or to 30 candles, as in Aberdeen. And it may even be in this time of progress that, when the consumer who thinks with me has obtained his desire, he might still crave more light, even the electric light. Indeed, it has just occurred to me that if some great speculative project was hatching for the introduction of the electric light on the largest scale, and if it was felt desirable to pave the way, no surer way could be devised than that of lowering the quality of the gas. Meanwhile I suggest that the consumer who feels the present price of gas too high, needs no Act of Parliament, seeing that he can regulate his gas bill by lessening the amount of light he uses, and with that the amount of money he pays, to the standard of his requirements. He has it in his option to use only as much light as would be furnished him under a regime of 20 candle gas. But under a compulsory restriction to 20 candle gas, he can never obtain an extra amount of light should he find that desirable, unless coupled with serious drawbacks, some of which have been already indicated and will afterwards be further referred to. The suggestion of improved appliances for the combustion of gas is good, and good at all times; but at the present juncture, when applied as an argument and inducement to reconcile the consumer to the acceptance of a lower quality of gas, it is only a delusion and a snare—a mere red herring drawn across the trail of informed public opinion to lead wakeful inquirers off the true scent. At the risk of repetition, I affirm that of the appliances which will insure to the consumer the full value of gas, whatever the candle power may be, there are only three that are practically available—viz., automatic governors that will equalise the pressure in the gas mains to the fullest working efficiency—which may be taken at 12 or 14-10ths of an inch pressure—throughout the high and low levels of the Glasgow gas district; similar pressure regulators for individual dwellings, or warehouses, or public buildings as prompted by individual convictions of the advantages of these adjuncts, and gas burners of a construction that will harmonise with the standard pressure that is adopted. To those provisions might be added official inspection of dwelling-house gas-fittings in like manner as the Corporation Water Inspectors look after dwelling-house water-fittings. Failing these appliances, all the seductive blandishments and promissory bills drawn on hopeful expectations should be, by all whom I can influence, relegated to the land of Utopia.

It is asserted by some advocates of the proposed change that it will not involve an alteration of gas pipes and other gas appliances. Such a statement will not, however, be ventured upon by any person of information, official or otherwise, who could be made personally responsible. A knowledge, although slight, of the composition of coal gas will prove their safeguard, and it would be well for the public if this knowledge was a little more general than seems to be the case when men of presumed special education, and of a position that gives influence, are found to utter or to sit in silent approval, or without protest, while utterance is given before them to such matter as found acceptance at a recent public meeting. Let me endeavour to make this point clear. The mixture of gases and vapours that goes by the name of coal gas is substantially composed of carbon in a gaseous condition, and of hydrogen, which exists naturally as a gas. All the lighting power, and three-fourths of the heating power of coal gas, is due to the carbon. None of the lighting power, and only one-fourth of the heating power is due to the hydrogen. The hydrogen is chiefly a dilutent that carries the carbon just as water in the teapot carries the essential constituents of the tea. The less water the stronger the tea, and the less hydrogen the stronger the coal gas. But hydrogen, although forming more than three-fourths of the bulk of coal gas, constitutes only about one-fifth, or 20 per cent., of the weight. It is the lightest substance known, being a little less than one-fifteenth of the weight of atmospheric air, and, while 1 lb. of air measures 12 cubic feet, 1 lb. of hydrogen measures 179 cubic feet. Carbon, on the other hand, even in the gaseous condition, is heavy, and constitutes about 70 per cent. of the entire weight of coal gas. Many persons will be surprised when told that of 100 cubic feet of 20 candle coal gas there are only about 6½ cubic feet that give the light obtainable from that gas, and that about 93½ cubic feet give no light whatever. The question naturally arises—Cannot coal gas be manufactured without its bulk being non-illuminating? The answer is—No! it is impossible. Water is necessary to infuse our cup of tea, and hydrogen is necessary to carry the carbon in our coal gas. We can only put more tea in the tea-pot if we wish it stronger, and put more carbon in our coal gas if we wish it stronger. And this is exactly what is done when we mix the more plentiful, rich, volatile carbon compounds obtainable from cannel coals with the poor hydrogenous gas that is distilled from common coals. Coal gas made from common coal, subsidised by the richer products of cannel coal, may therefore, for popular comprehension, be described as thicker, and stronger, and heavier than common coal gas. The proportion of hydrogen entering into the composition of coal gases does not vary materially with the quality of the gas, but the proportion of carbon differs very considerably. I request particular attention to this point, as it bears with great importance on the entire "Gas Question," and to illustrate it I have selected three coal gases analysed by three chemists of the very foremost class in all that relates to the chemistry of gas—viz., the late Dr. Letheby, Professor Bunsen, and Dr. Frankland. I have carefully calculated from their analyses the relative proportions of the essential constituents, and otherwise extracted and fashioned in a form easily understood the most important facts deducible. These facts I will present in two tables, the first of which deals with the weight of material contained in the bulk of one cubic foot of gas.

In each cubic foot of the gases as under there were :—

Candle power.	Grains weight of Carbon.	Grains weight of Hydrogen.
18	129	51
20	147	51
30	246	68

Here it is at once made apparent that carbon is the prime constituent. But it is not mere quantity as carbon that makes it the factor of chief value in coal gas. It is the number and manner in which the molecules of carbon are proportioned and held together in various groups, and associated with the molecules of hydrogen, that is most material. The molecules are not close together, but according to their manner of arrangement they are compressed at one time to one-half or one-fourth of the bulk they occupy at another. Thus, while stone and lime may be combined to form a mere sheepfold, they may also be put together to form a temple or a fortress, and with like analogy the molecules of carbon and hydrogen may be—or, I should rather say, are—grouped in a number and manner undetermined, each group possessing a distinct value as a factor in generating heat and light.

These facts I merely refer to in this place, as the consideration which is properly their due would lead me into a disquisition far beyond the apprehension of a popular audience, and beyond the actual necessities of my argument. For present purposes it will suffice to state that the carbon compounds of highest value are more abundant in cannel than in common coal. Meanwhile it is shown in the foregoing table that a cubic foot of one gas may contain 180 grains weight of heat and light generating material;

a cubic foot of another 198 grains; and a cubic foot of a still different quality 314 grains. And these variations occur throughout the wide range of qualities of coal gas. From this it is evident that the practice of selling gas by the 1000 cubic feet, although commercially convenient, affords no indication of value. To the masses coal gas is simply coal gas, and nothing more, and to many the measure of 1000 cubic feet as it meets their glance in a gas bill is merely equivalent to the summation of loaves of bread in a baker's bill—the price of the loaf may have varied, but the numbers seem to be all right. Such parties will better realise the importance to them of the "Gas Question" if in their imagination they can picture the cubic feet of 26 candle gas as representing full-weight *half*-loaves, and the cubic feet of 20 candle gas as representing "halfpenny scones." The contrast is exaggerated, but it suggests the truth.

The actual value—impurities apart—consists in the weight of the gas, and it is on this character that the analyst bases his estimate. The volume of coal gas is nothing unless in conjunction with its weight, as will be easily understood by the second table, which I have constructed from the analyses of gases referred to in the last table, which deals with the volume and weight of *a cubic foot only*. I now show the proportions of the essential ingredients, the number of cubic feet, and the standard units of heat * contained in 1 lb., by weight of the three gases already specified :—

	12 candle power.	20 candle power.	30 candle power.
Grains of Carbon	4,128	3,969	4,920
Grains of Hydrogen,..........	1,632	1,377	1,360
Cubic Feet,...........	**32**	**27**	**20**
Units of Heat..................	22,777	20,736	22,238

A careful consideration of this table teaches that to obtain lighting and heating power from the 20 candle gas equal to what is obtainable from the 30 candle gas, we must burn a larger quantity of the former. And a simple arithmetical calculation shows what this additional quantity will be. Assuming that 1,000 cubic feet of the 30 candle gas is consumed, it will require 1,456 cubic feet of the 20 candle gas to yield the same amount of heat; and a similar rule of three operation shows that 1,500 cubic feet of 20 candle gas is required to yield the amount of light derivable from 1,000 cubic feet of 30 candle gas.

* A unit of heat is the quantity required to raise the temperature of 1 lb. of water 1° Fahr.

These results are not matter of conjecture, because practical tests, even when roughly applied, establish with approximate nearness the theoretic estimates. I could furnish many illustrations from my own experiments, but the circumstances of the present communication make it preferable that I should draw my examples from sources beyond cavil. And I will, therefore, take two sets of practical experiments, devised and conducted by two able observers—viz., the late Mr. Evans, a name well and honourably known in the annals of gas literature, and Dr. Wallace, our excellent local gas analyst, who has done more, according to my reading and inquiries, than any other, in teaching, by numerous and well-devised experiments, elucidated by sensible commentaries, the practical mechanics of gas combustion in their applications to lighting for domestic and street use.

Mr. Evans ("Ronalds & Richards's Chemical Technology, 1855") employed three gases, which I estimate were as near as may be, of 12, 20, and 33 candle-power, and he tested the quantity of water in 10ths of 1 lb., which was boiled off by the burning of 1 cubic foot of each gas. I have calculated the units of heat which were utilised in each test :—

Candle Power.	1lb. Water.	Utilised. Units of Heat
1 cubic foot of 12 boiled off, ...	4-10ths	386·4
Do. 20 do.	5-10ths	433·0
Do. 33 do.	7-10ths	675·2

Dr. Wallace also selected three gases, and his tests consisted in raising 1 gallon of water from 60° F. to 160° F., and measuring the gas consumed in the operation. I have calculated the units of heat that were utilised per cubic foot of gas :—

Candle-power.	Cubic Feet burned.	Unit heat Utilised per cubic foot.
14·7	2·9	347
26·2	2·2	455
33	1·9	522

The apparatus employed in both sets of experiments did not admit of absolute, but only of comparative results, and Dr. Wallace conjectures that he obtained about 55 per cent. of the heat which the gases were capable of generating. Both sets of experiments are mutually corroborative, and illustrate in a conclusive manner the superior commercial values of the better qualities of coal gas. Dr. Wallace in connection with the experiments conducted by himself, has estimated the relative values of the three gases as employed for lighting and for heating. Taking Glasgow gas of 26·2 candles as his standard, and assuming it to be of the value at which it was then selling—viz., 3s. 10d. per 1000 cubic feet, he shows that if 26·2 candle gas was worth 3s. 10d. for lighting, and 3s. 10d. for heating, then 33 candle gas was worth 4s. 10d. for lighting, and 4s. 5d. for heating, and 14·7 candle gas was worth 2s. 2d. for lighting, and 2s. 11½d. for heating.

The examples I have already given should be sufficient to establish my argument that an increased bulk of inferior gas is required to do the same work that is done by a smaller bulk of superior gas, and that, therefore, increased storage accommodation, mains, and service pipes, &c., will become necessary for the production and distribution of as much of the proposed new gas as will be equivalent to the work of which our present supply is capable. I think I have clearly shown that this is not a matter of inference. But I will bring the argument nearer home, as I am not content to leave in any doubt what I have at hand the means of demonstrating as a fact. In my paper "On the Heating Power of Coal Gas," read at Birmingham, June, 1881, before the British Association of Gas Managers, I stated :—"There is not, I regret to make the acknowledgment, a single analysis of any of our Scotch gases. . . . It is my hope that when Scottish chemists are roused to remove what is at present an opprobrium, their investigations will show the quantities of the heavy hydrocarbons in which Scotch cannel coals are admittedly very rich, and also show . . a much higher thermal power than has been suspected." That reproach is no longer applicable, and it is with peculiar pleasure I record that the first complete analysis of a Scotch gas has been made in our own city, and for Glasgow gas. Dr. Mills, of the Young Chair of Technical Chemistry, has made this analysis, and I am indebted to him for a copy of the same. To myself the information has been specially grateful, because enabling me to confirm in Theoretical estimates the results I had substantially and conclusively obtained throughout an extensive series of practical tests of the heating power of Glasgow gas. These results I placed in the hands of several parties long before I obtained the scientific data from Dr. Mills that confirmed the substantial accuracy of my own practical investigations. This by the way; but meanwhile I may state that 1lb. of Glasgow gas measures 21 cubic feet, and generates—by theoretic estimate—22,345 standard units of heat. From this data I estimate that if the proposed new gas of 20 candle power, produced under the drawback of a new manufacture, should be equal in quality to the 20 candle gas as produced in Manchester under all the advantages of long and familiar experience, the total supply required for Glasgow, to be equally effective with the present supply, must be increased in bulk at least 25 per cent.—that is, 1250 cubic feet of the new gas will be required to do the work that is now done by 1000 cubic feet of gas. To bring the price of the new gas to correspond in value, 1000 cubic feet must be charged 2s. 11¼d., which will seem to many an actual instead of a mere nominal reduction. There are considerations which, to prevent complicating a clear presentment of my estimate, I for the present hold back, but which will show that a still greater reduction in price will be necessary to make the value in work to correspond. With this increased bulk of gas supplied, and at this reduced cost per 1000 cubic feet, the consumer will receive—subject to several serious evils—an equivalent in working value for the present gas, but he will receive it in a form analogous with that in which milk consumers sometimes receive their milk, viz., plus so much water.

This increase of at least 25 per cent. in the actual quantity of gas manufactured and distributed may therefore be accepted as a certain result of the decrease in quality. But as the new gas will be nominally much cheaper, and must be much cheaper as well to fulfil promises as to meet popular expectations, there will naturally be a still larger demand and production. It will be well to consider in anticipation some of the further consequences to which this increased distribution will lead. Even with gas of the present quality, the quantity is at present often insufficient for very common requirements, and larger mains and larger service pipes are in some localities already desirable. To continue the distribution through the present service pipes and mains would be possible only under enormous pressure, and as 20 candle gas is of lower gravity than the present cannel gas the amount of loss by leakage, always so considerable under ordinary pressure, would be enormously increased, and economic combustion by the consumer would be simply impossible. The alternative of larger mains and branch supply pipes would become a necessity, and inasmuch as the mains cost from one-third to one-half of the whole gas plant, it follows that the interest on the extra expenditure would have to be paid by one-third of the gas made. So at least it seems to me, and so the question has presented itself under analogous conditions to the minds of eminent gas engineers, who have discussed the problem in its hypothetical application to other localities. Enlarged mains or duplicate mains involve a reconstruction of the causeway of our streets, enlarged supply pipes involve the breaking up and replacing of side pavements, enlarged service pipes within dwelling-houses, shops, factories, and public buildings follow with necessary sequence, and with such prospects of a good time coming for contractors in navvy labour, for manufacturers of gas mains, &c.; for plumbers, gas-fitters, joiners, plasterers, &c., there is little likelihood for some years of any emigration of these classes of citizens from Glasgow to better gold diggings than will be found in the public rates and in the pockets of all dwelling-house proprietors.

How the change will affect the pockets and wealth and trade interests of private consumers comes next to be considered.

To enable my readers to realise the consequences of substituting *quantity* of coal gas for *quality*, and of adding fully 25 per cent. to the bulk that must traverse the street mains before it can be burned by the consumer, it will be necessary for me to discuss more fully a matter that I have already touched upon, viz., the influence of pressure upon the economic combustion of coal gas. The assertion is made that the consumer does not get the full value of his gas supply because of the use of insufficient gas burners. But the cause lies deeper.

There are pressures and pressures. There is the pressure at which the gas is driven through the mains and delivered to the consumer, and that pressure must in practice be, or ought to be, not less than 1 inch and not more than 1½ inches. There is the pressure at which the gas should circulate through the supply pipes of the consumer, and that pressure should not exceed 1 inch; and there is the pressure at which the gas actually issues from the burner, and that pressure should average 5-10ths of an inch. At these pressures, whatever the quality of the gas, there will be economic combustion. It has, however, been long the practice, and the practice is only being slowly overcome, of burning gas at a high pressure, *i.e.*, of passing it through the burners at a pressure ranging from one to two inches and upwards. This has not been within the choice, and the consequences have not been within the comprehension of the consumer. It has been mainly the result of ignorance, in which the chief blame attaches to gas managers or other allied managers, whether honorary or paid, who distribute a material the nature and properties of which it is their peculiar duty and province to study and understand, but who, whatever their information, have left the consumer to deal with that material according to his own uninstructed devices. For, with a few creditable exceptions, these officials have restricted their energies to the mere manufacture or to the mere delivery of the gas, and these objects effected, their obligations, according to their conceptions of duty, begin and end.

To furnish a supply of gas is comparatively easy, but to ensure its delivery under conditions that enable the consumer to make the most of his supply requires efficient gas engineering. For the difficulties are great, as I will endeavour to show. Gas mains and supply pipes are liable to leak at the joints, and where the gas travels many miles of pipes this leakage is considerable, increasing as the pressure increases, and greater in the case of common than of cannel gas, because of the lower gravity of the former. On the other hand, if the pressure is feeble and the pipes not fairly filled, air enters at the joints, and mixing with the gas, injures its quality, particularly in the case of common gas, which has a narrower margin admitting of any lowering influence. A sample of gas at the works differs very materially from a sample taken from the mains during an early hour of the day, when the mains are less fairly filled; and in such circumstances the sample may be nearly as deficient for illuminating purposes as the flame of a Bunsen burner. I have, indeed, been assured by an able chemist, very familiar with the qualities of the common low power London gas, that he has seen samples drawn from the mains during the earlier hours of the morning where the illuminating property was such as to leave little choice between a blow-pipe flame and that of the street gas. With a high pressure anywhere there is an over supply, an increased difficulty in applying an efficient check, and therefore a great waste; and with a low pressure in the mains there is deterioration of quality, and often an insufficient supply. The differences in the quality of gas during the hours of the morning arise chiefly from an admixture of air that has *leaked in*—I should rather say been pressed in—at the joints during the night when little gas is being used, and when the initial pressure at the works is at the lowest. For the initial pressure under which the gas is forced from the gasholders at the works into the distributing mains is necessarily varied throughout the twenty-four hours, increasing with the coming on of the dark hours, the lighting up of shops, public works, and dwellings, and decreasing as the time approaches for turning off lights at the same places. In illustration, I have seen a service pipe which, at the low level of Buchanan Street, at twelve o'clock mid-day, delivered only eighteen cubic feet of gas per hour; but which, at eight o'clock evening, passed thirty feet per hour. This difference was owing to the increased initial pressure at the works during the evening. The pressure is therefore never the same, either at the works or in the same locality of the city during different hours of the 24, and this variation, which is considerable, taxes the performance of the very best possible construction of gas burner. The pressure at the burner varies from another cause. Gas is elastic, and its molecules can be crowded together and packed into smaller compass, and being at the same time much lighter than air it ascends wherever it has freedom. Owing to these inherent properties gas arises from the lower levels of the city to the mains and supply pipes of the upper levels, where it accumulates, and becoming more closely packed it springs from the burner with an elastic force that may be three or five times greater than at the lower levels, where the mains at the same moment may be comparatively empty. I have frequently found at the low level of the Broomielaw that the pressure of gas delivered from a ¾-inch service pipe scarcely exceeded 5-10ths of an inch, and was barely sufficient to lift the valve of *a volume regulator* constructed to work at a pressure of 7-10ths; while within the same hour I have found at Cambridge Street—about 100 feet of a higher level—that the pressure was 17-10ths, and the valve of the same regulator and also the valve of *a pressure regulator* were so forced as to deliver gas much beyond the stipulated quantity for which the instruments were registered. High pressure, as I have defined it, means therefore great waste, whether that high pressure occurs at the point of delivery from the mains into the service pipes of the consumer or at the burners of the consumer. Under high pressure the gas issues from an ordinary gas burner with great velocity, "blows" and burns with a flaring or flickering flame. Gas molecules dart through the flame not only unconsumed, but barely scorched—as I may express it for popular comprehension—and there is a corresponding waste of gas and absence of light. To ensure the generating of the fullest quantity of light of which the gas is capable, the molecules of the gas ought to pass through the flame with sufficient slowness to permit of them becoming incandescent and rising to a white heat. After this stage of combustion, if the molecules as they are leaving the visible portion of the ignited gas meet a proper modicum of air the combustion is complete; all the carbon is converted into carbonic acid, and all the hydrogen into watery vapour.

Facts of this kind illustrate the difficulties with which the gas engineer has to contend, whether in regulating the public delivery or in controlling the domestic supply. The mechanical remedies that have been recommended, and in great measure tested, are legion, but no one contrivance meets completely even the first and most essential desideratum of equalising pressure over a large area of varying levels. It has not been done in Glasgow with our present gas supply, and there is nothing in the properties of the proposed gas of lower quality that removes by one iota the difficulties. Remedies that mitigate the evils are, however, obtainable, and these are more effective for domestic consumption than for public supply. These, so far as the consumer is concerned, consist mainly of a pressure regulator fitted on a full-sized service pipe at the point where the gas enters his premises, and the valve of the same regulated to an average pressure of 1 inch. If that average pressure can be ensured, there is then no difficulty in obtaining excellent gas burners that will harmonise with this pressure and deliver the ignited gas at the pressure which has been found to give the best value—viz., 5-10ths of an inch. In obtaining, and in the right application of these remedial agents, an official adviser might do much good service. For it is not one in ten, nor even in one hundred of master tradesmen or of their employés, dealing and working in gas-fittings, who can intelligently advise the consumer. It may be from instinctive knowledge of this fact that the consumer so often delivers himself over to the operations of some mere plumber, whose capacity goes little beyond the bending or soldering of a gas pipe, or the attaching of a gasalier. Knowing no better, the consumer usually commits the first great error of selecting the smallest because the lowest-priced service pipe; and this pipe, being from the first insufficient to give the supply that is often expected, becomes afterwards more insufficient because of the unskilful bends at right angles which flatten and diminish the calibre of the tube, and because of clumsy workmanship at couplings and other connections, whereby lumps of solder or grease still farther obstruct the gas channels. If such arrangements are completed by the selection haphazard of some burner that under the pressure existing at the moment of trial may give a desirable flame, the consumer is thereafter the plaything of the public delivery—at one hour grieved by a feeble, smoky, wasteful flame; at another by a flaring, wasteful flame, and rarely enjoying the comfort of a bright, full and steady light. These details may be to many somewhat tedious, but I think them relevant and necessary, because they meet and correct the ignorant expectations, and the vague, plausible, but altogether non-responsible, suggestions of those who may be reconciled to, or who are advocating the proposed change. And to such individuals these details should suggest the consideration that, whatever the excellence in quality of a coal gas, there must always be discounted from it a loss of possible value through causes which the masses are unable to remedy. Obviously, therefore the larger the margin of excellence that remains after this unavoidable loss the smaller is the deprivation on those who cannot obtain their full value, and the greater is the gain in comfort and usefulness to those who do obtain the fullest value.

I cannot leave this question of pressure without reference to one of the specious but hollow arguments with which this gas question is being obscured. Among other debatable, and to my mind easily controvertible, matter with which the report abounds that is now under consideration of the Town Council, it is stated " that with a high quality it is necessary to deliver the gas at the burner under a high pressure to prevent smoking, while with a lower quality a low pressure is more advantageous." So far as I have proceeded I have furnished, as I trust, sufficient material to enable any person, however little previously informed, to put aside this very feebel, altogether inapplicable, but dangerously intended suggestion. For what is here meant by "high pressure?" In the light of explanations I have given it is evidently a very intangible phrase, vague and shifty in the extreme. The nearest analogy it suggests is that indicated in the answer given to a frequently-pressed question by a much badgered witness, who replied that the size of the object referred to was "about as big as a lump of chalk." For what is the pressure that can be *ensured* and will prove effective with the proposed low quality of gas and at the same time *objectionable* with the present gas, or gas of still better quality? In words often familiarly quoted—I pause for a reply. And I pledge the entire value of my argument that the pause—so far as any intelligible, reliable, or conclusive answer can be given—will last to the time that our coalfields are exhausted. Still pressing this straw dummy of an argument, it may be asked if it is the fact that gas of high quality—*i.e.*, Glasgow gas—requires to be delivered at the gas burner under a high pressure to prevent smoking. This question has been very ably handled by Dr. Wallace *(op. cit.)* and his experiments on this point are numerous, exhaustive, and thoroughly conclusive. In public demonstrations, while admitting that in every-day practice it is impracticable to obtain *the most perfect results that can be obtained by perfect testing appliances*, he nevertheless "had no hesitation in stating that *without difficulty* from 20 to 23 candle-power might be obtained in every-day life from 26 candle gas," and that very fair values can be obtained even with very small burners "provided the pressure is reduced sufficiently low to allow the gas to pass very gently into the air." With a No. 4 Bray's burner at only half-inch pressure, and burning only 2·4 cubic feet per hour, he got 23 candle illuminating power, and with a No. 8 jet consuming 4·7 cubic feet per hour he got 28 candle illuminating value—the full illuminating power of the gas with which he experimented. At a pressure not exceeding 1 inch, and with an extensive series of Brönner's burners, consuming from 1·2 to 4·3 cubic feet per hour, the average illuminating power was 25·7 candles, or nearly 26. And he lays it down as a rider or general axiom, while discussing high-quality gas averaging 28 candles, that "the lower the pressure the better is the result." In like manner, Mr. Stewart, of the Greenock Gas Works, experimenting with a very high quality of gas, burning only 2 cubic feet per hour, and at a pressure of *less than 5-10ths*, obtained an illuminating value of of 31·25 candles. It is with a high pressure that the very poorest results are obtained, and the facts have been established by many observers, while the axiom I have quoted has since been endorsed by the special committee of able chemists formerly referred to. The pressure at which gas of high quality can be burned without smoking at the burners is therefore not a high pressure, as has been asserted, but a low pressure—lower than any pressure that in practice can fill the gas mains, whether the gas is of high or low quality; and the statement I am combating is not only incorrect, but is, together with its dangerously intended inference, in no way applicable to existing or to any probable future conditions. I may add that what is true of gas of high quality is equally true of common gas—viz., the lower the pressure at which it is burned the better the results.

Leaving the question of pressure, I come to that of price, which is alleged to be needlessly high, and "all for an idea"—a preposterous, erroneous idea—an "idea" for which the Glasgow citizens have paid dearly in the past, and may pay more dearly in the future. It has not been characteristic of Glasgow citizens to imitate our French neighbours, who, according to Napoleon III., are "the only people who will go to war for an idea." But this is no mere idea that now lies waiting the decision of the community. Glasgow citizens have known very well how to "flourish" in the past—know very well on which side their bread is buttered—and they will have altered very much from the time when they rose against, and successfully withstood, the fanatics bent on destroying our chiefest ornament, the Cathedral, if they do not now rise and withstand the modern gas iconoclasts, who are bent on depriving the city of—what Bailie Finlay truly designates—our beautiful Scotch gas. It may be that gas is needlessly high in price, and may in the future be still higher, although in the present era of wonderful appliances it may with equal reliance be predicted that it will be lower. But in the worser event, in the words of an old proverb, "It is time enough to bid the Devil good morning when you meet him." The most prominent advocate for the proposed change has reminded us that many years back the price of gas was above 5s. per 1000 cubic ft. That was one of the exceptional times that characterise the ordinary cycle of human events, for trading operations were at fever pressure and competition for labour power excessive, and what had a special bearing on the gas question of that day was the fact that coal miners were able to indulge a predilection for riding to champagne pic-nics in a landau and pair, and were in evident belief that their time had come for

> "Six hours for work, six hours for play,
> Twelve hours for bed, and eight shillings a day."

But even at that exceptional time Glasgow had good value for its money. In 1874, when the price of Glasgow 26 candle gas was 5s. per 1,000 cubic feet, the price of Manchester 20 candle gas was 3s. 8d. to 4s. 2d., and of Birmingham 15 candle gas was 3s. to 3s. 6d. Dr. Wallace at that time, before meetings of intelligent spectators and deeply interested audiences, exhibited illustrations of the numerous experiments through which he had himself reached the most definite conclusions. Using identical meters and burners and qualities of gas with the same used in London, Birmingham, and other large towns that were then, as now, being held up for our imitation, he made his results strictly comparative and what were his conclusions? He showed that in comparison of value with Glasgow gas at 5s. that of Manchester was only worth 3s. 10d., and that of Birmingham 2s. 10½d. per 1,000 cubic feet, and he urged that these facts should reconcile Glasgow citizens "to the paying of a price, which, although much larger than we have been accustomed to, is moderate when compared with other towns when quality is taken into account." And, referring to the unavoidable loss that takes place in the management of gas combustion, he added—"We who use cannel gas have an immense advantage over those who consume gas from common coal, for the loss of light in their case is even greater than ours, and is probably not usually less than 50 per cent." In the face of such teachings never disavowed, and important facts in social economics never better demonstrated than here and elsewhere, and never controverted anywhere, it is to me perfectly astounding how the proposed change to a lower quality of gas can find any acceptance amongst us.

The effects of gas combustion in vitiating the air in dwelling-houses and warerooms is an important factor in dealing with the gas question. So many of these evils are so unavoidable and altogether undeniable that it only remains to reduce them to a minimum. The Gas Committee propose to aid this laudable object by reducing the quality of the gas from a higher to a lower, and their very foremost proposition is: "The higher the quality of the gas, the greater is the quantity of air required for its perfect combustion, and *consequently* the greater is the amount of air vitiated *per cubic foot* burned." (The italics are mine.) Why "consequently?" in the words of Hamlet—

"Be thou a spirit of health, or goblin damn'd,
Thou com'st in such questionable shape,
That I will speak to thee."

High quality gas *uses* more air and therefore *vitiates* more air—that is the proposition. Glasgow gas is high quality gas, and should be discarded—that is the Gas Committee's consequent recommendation. Granting, with a reservation which will be soon apparent, that the first part of the proposition is true, the corollary is by no means a necessary sequence. Setting aside impurities, the constituents of gas, whether of high or low quality, are precisely the same, and the amount of deleterious products of combustion depends entirely on *the quantity of material* that is consumed. That material can use no more and no less of air than what is necessary for combustion, and the resultant products can be no more and no less than the combustion of these materials can produce, whether that material is packed into 20 cubic feet or diffused over 30 cubic feet. The combustion is effected for a useful purpose, and if more gas is employed than necessary for the desired use—an event more likely with insufficient low quality gas than with good gas—there is corresponding waste and an increase of the evils arising from the burnt gases. The question is therefore narrowed to this point—Is more air necessary for combustion and more air vitiated through the use of gas of high quality in comparison with gas of low quality in effecting a given value? That is substantially the question, not as formulated, but honestly, as earnest inquirers would desire to understand it. But the proposition in its entirety is one to be dealt with by a chemist, and better still, by a chemist combining the knowledge of an all-accomplished medical man. It has been dealt with by the late Dr. Letheby, Medical Officer of Health for London, Chemical Analyst for the Corporation, Lecturer on Toxicology, and well known and esteemed by leading gas officials. He read a communication before the British Association of Gas Managers, which will be found in the *Chemical News* for July 6, 1856, and among other matters discussed the point now in question. The following is a portion of a table constructed by him showing "Heating and vitiating effects of different illuminating agents when burning so as to give the light of 12 sperm candles":—

	Oxygen consumed. Cub. Ft.		Carbonic acid produced. Cub. Ft.		Air vitiated. Cub. Ft.
Cannel gas,.........	3·30	....	2·01	....	50·2
Common gas,......	5·45	....	3·21	....	80·2

"The vitiating effect," says Dr. Letheby, "is calculated on the actual loss of oxygen, and on the power which 4 per cent. of carbonic acid has on the vital qualities of the atmosphere."

Through Dr. Letheby's most conclusive evidence, the erroneous corollary to the proposition that I have challenged is, therefore, easily and most effectively refuted. It will make this point better understood if the composition of the air through which combustion is effected is kept in view. Air is a mechanical mixture of 23 parts of oxygen and 77 of nitrogen, and of these components oxygen is the only constituent that is affected by combustion, whilst the nitrogen is not in any way affected. The fallacy embodied in the proposition of the Gas Committee seems to have arisen from some hazy notion or uninformed conviction that all the air used in combustion is converted into deleterious products. But only one-fifth part—viz., the oxygen—is so converted, and the nitrogen, constituting four-fifths, passes through the flame, still retaining its original harmless properties, and re-enters its parent atmosphere to unite with fresh oxygen, which is supplied through ever active natural agencies. Another cause of fallacy consists in the erroneous practice of speaking of, referring to, and I fear thinking of, gas by the cubic foot—simply the cubic foot—without taking into account the very great differences in weight of material contained in a cubic foot of one gas and a cubic foot of another gas. The materials of composition as well as of the products of combustion are much the same—impurities apart—whether the gas is of high or of low quality. But when a given amount of light is required, then the gas of low quality, having less material per cubic foot, must be burned in greater quantity, and the deleterious products are thrown into the atmosphere with corresponding rapidity and amount. This should require little explanation to make it apparent. The following illustration should remove all difficulty. In the heat-testing experiment referred to, Dr. Wallace desired to obtain as much heat as would raise the temperature of a gallon of water from 60° to 160° F., and he employed three gases of different qualities in three experiments. The durability of one cubic foot of each gas was tested by burning it with a flame five inches high.

1 cubic foot of lowest quality	burned for	39	minutes	35	seconds.
1 do.	medium do.	,,	54	,,	40	,,
1 do.	best do.	,,	64	,,	45	,,

In previous references I have shown how great may be the differences in weights of material in one cubic foot as contrasted with a cubic foot of different gas, and also how great may be the difference in heating effect; and we have now a comparison of the durability of the flame illustrated. From so many examples it should be apparent to persons of very ordinary intelligence, that no comparisons or inferences should be based on the expression, "cubic foot of gas," without some qualification such as I have indicated. I will assume that I have sufficiently resolved any doubts that have reference to the comparative vitiating properties of high and low qualities of gas, and demonstrated that low quality gas has the largest vitiating property; and I may now, therefore, refer to a contamination of the atmosphere arising from gas combustion that is more immediately hurtful and more evidently the cause of discomfort than the other waste products. It is nevertheless very rarely taken into account, and the discomforts and other injurous effects which it occasions are rarely connected with the true cause. Water is generated in large quantity from the combustion of coal gas. Every grain of low quality gas that is burned produces 2 grains of watery vapour, and the quantity thus generated will much surprise individuals to whom this is a new fact, or who have not sufficiently realised its importance At all times the atmosphere contains moisture in an invisible form, and when the air is calm and "muggy," as it is sometimes termed, there are few individuals who are not sensible of the depressing influence. This is the condition that gas burning engenders, aggravated, of course, by the heat and the want of sufficient ventilation, which too often characterise gas lighted apartments. Any of my readers who may wish to realise visibly and tangibly this phenomenon of the production of water from gas may do so by a very simple experiment. If a cool glass shade—a large tumbler will do, although not so well—is inverted over the flame of a gas burner for a few seconds only, they will see watery vapour rapidly condensing on the inside. If the experiment is prolonged, the condensed water again becomes vapourised, is absorbed by the air, and ceases to be visible. Many individuals who feel listless and non-energetic in gas lighted apartments are more apt to blame the heat or the carbonic acid, and but few think of the condition of atmosphere that is impeding the functions of the skin and the action of the lungs. Dr. Letheby has not overlooked this important feature of gas combustion, although he has not illustrated it, as I propose to do, by showing the actual amount of water generated from given quantities of gas. In his table already quoted he demonstrates that sperm oil, wax and tallow candles, &c., cause a greater loss of oxygen, generate more carbonic acid, and vitiate the air to three or four times the extent of coal gas; but although these results, he says, "indicate that there should be less discomfort in a room lighted with coal gas than with any other illuminating agent, yet common experience is altogether in the opposite direction." The explanation of this is to be found not only in the fact that *gas is used more lavishly* than other agents, but also that in burning it produces a larger proportion of aqueous vapour, which, becoming diffused into the surrounding atmosphere, occasions great discomfort. Professor Tyndall has shown that the molecules of aqueous vapour are endowed with a remarkable power of absorbing the radiant heat of burning gas, and by thus becoming warm they create a sense of oppression; and, again, when the warm atmosphere of a room is overcharged with moisture, it checks the action of vaporous or insensible perspiration, and this also causes distress. In all cases, therefore, where gas is largely used in rooms, provision should be made for the quick removal of the products of combustion.

I now exhibit a table that shows in a measureable form the quantities of air required for the combustion of high-quality gas as contrasted with low-quality gas. It likewise gives comparison of bulk, of illuminating, and of heating power. The actual quantities of air used in combustion *in the production of equal value* are also shown, making it clearly evident that there is no greater amount of air consumed by high-quality gas than by low-quality gas in the production of equal values for lighting or heating. I may add that if, in this investigation, it had resulted that more air was necessary—even twice as much—the extra supply might have been submitted to with equanamity. Air is not sold by the meter. I have added a demonstration of the evil hitherto so little considered, of an unwholesome moist atmosphere produced by the combustion of any quality of coal gas, but in a greater degree following the use of low-quality gas.

A	London.	London.	Manchester.	London (Cannel).	Glasgow (Cannel).
Calculations based on Analyses of	Dr. Letheby.	T. Wills, F.C.S.	Professor Bunsen.	Dr. Letheby.	Dr Mills.
Candle Power of Gas..................	12	16	20	22·5	26
Cubic feet in 1 lb. of Gas............	32·1	28·6	27	24·5	21
Units of Heat in constituents of 1 cubic foot of Gas..................	709	729	765	931	1059
Cubic feet of Air required for Combustion of 100 cubic feet gas....	584	584·5	612·1	781·2	897·6
Cubic feet of Watery Vapour from burning of 100 cubic feet gas...	132·6	129·8	134	153·7	170·5
Weight of Water Condensed from combustion of 100 cubic feet gas	lb. oz. gr. 6 10 23	lb. oz. gr 6 8 117	lb. oz. gr. 7 2 215	lb. oz. gr. 7 11 201	lb. oz. gr. 8 8 417
B.					
Cubic feet Gas *equal* to 100 cubic feet of Glasgow Gas	**149·3**	**145·2**	**138·4**	**113·7**	100
Cubic feet Air required for equivalent value of other Gas..........	871·9	848·7	847	887·9	897·6
Cubic ft. Watery Vapour generated from equival't value of other gas	197·9	183·4	185·4	174·7	170·5
Weight of Condensed Water from equivalent value of other gas	lb. oz. gr. 9 14 422	lb. oz. gr. 9 7 145	lb. oz. gr. 9 4 404	lb. oz. gr. 8 12 134	lb. oz. gr. 8 8 417

This is in every respect a strictly comparative table, comprising much illustrative data that should be interesting and useful to all who desire a better knowledge of "the gas question." The lessons it inculcates are in accordance with the teachings of the most advanced sanitary authorities, who have dealt with the subject of gas combustion for domestic use. For corroborative testimony recorded by able chemists, I again refer to and quote their report as laid before the British Association :—

"It is not only on the score of economy that it is desirable to burn gas in such a manner as to afford the greatest possible amount of light. The burning of a moderate-sized jet of gas produces as much carbonic acid as the breathing of two grown-up men, and as in an ordinary apartment we have usually from three to six of these, the air becomes vitiated with remarkable rapidity. It is therefore desirable in relation to health to obtain the illumination we require with the least possible expenditure of gas. The sulphur in gas is a very serious drawback to its use. In burning, it is no doubt converted chiefly, if not entirely, into sulphurous acid; but it is soon converted into sulphuric acid, which attacks with avidity all the more readily destructible articles in the apartment. So far back as 40 years since the effects of the sulphuric acid arising from the combustion of gas upon the binding of books and many articles of furniture was noted, and recent experiments have shown that leather, paper, &c., in ill-ventilated apartments exposed to the emanations from burning gas for a series of years contain very large quantities of sulphuric acid. One of us has had occasion recently to investigate the action of burning gas upon cotton goods stored in warehouses in London, Manchester, and other cities and towns, and found that in some cases a few months are sufficient to affect certain colours; while within a year enough sulphuric acid is absorbed to seriously injure the strength of the fabrics. No doubt the true remedy for this evil is to ventilate the warehouses; but it is obvious that if the gas was burned in an advantageous manner *and the quantity reduced to one-half or one-third*, the damaging effect, would be proportionately lowered."

There remains for consideration the impurities inseparable from the manufacture and ordinary use of coal gas, and of these the constituent of sulphur referred to in the foregoing quotation is the only impurity that is seriously operative. And here the measurement by *cubic feet* tells powerfully against the use of low quality gas. As a rule *cannel gas*, or high quality gas, contains little sulphur, although *cannel coal* may. The coke of cannel coal is porous and bulky and absorbs and retains much of the sulphur, but in common coal the coke is less porous or capable of absorbing and a very much larger percentage of the contained sulphur is volatilised, escapes absorption and passes into the gas. Common coal gàs admittedly contains about twice as much sulphur as cannel gas *in each cubic foot*, and as a greater number of cubic feet are required to do equal work, the question of a greater quantity of sulphur *per cubic foot* and the larger number of cubic feet necessary to do the required work I leave to be estimated by others, or to the common-sense appreciation of tradesmen who suffer so much in deterioration of shop and warehouse goods. That the amount of loss and of injury through this cause is considerable may be inferred from a statement made to me by a merchant in hosiery, to the effect that in the single article of kid gloves that loss sometimes amounts to £1000 in a year's business. Shopkeepers very quickly learn the lesson that if bright colours and delicate fabrics are exposed in their windows above the level of the gas there is certain injury. Jewellers, silversmiths, &c., find that close-fitting glass cases are no sufficient protection against the tarnishing effects of the sulphur, and often regret the injury done to fine chasings and frosted work by the frequent cleansing operations made necessary for the presentation of their goods in a saleable condition. Collectors of luxurious editions of books, of plates, and of photographs, &c., are often mortified and puzzled to account for the blotches of discoloured paper, faded and spotted engravings, speckled bindings, &c., which occur so mysteriously in prized articles, carefully enshrined in close-fitting glass cases. But sulphur is a subtle enemy, and in the vaporous form of sulphurous acid finds easy access to localities that are not freely ventilated. Aided by the watery vapour that hastens a transformation into liquid sulphuric acid, the corrosive fluid sticks wherever it touches, and leaves a regretful record of its action. Within the past few weeks I suffered personally by this energetic product of gas combustion, and the incident is worth mentioning as an instructive warning. On each side of my dining-room mantelpiece I had two small-sized oil paintings, much valued for more reasons than that of their being among the best specimens from the brush of the late J. Milne Donald. I have an Arnott's ventilator placed close to the ceiling, and entering the chimney a little to one side of the mantelpiece. This ventilator carries off the vitiated air of the apartment, which, of course, consists largely of the waste products of gas combustion. Unluckily, in a re-arrangement of the pictures, the hanging cord of one came very close to the ventilator, and consequently was continuously exposed to the current of burnt gases. A startling crash was the first intimation that the cord of this picture had given way, the frame and protecting plate-glass were shivered, the picture itself impaled on one of the hearth fire-irons, and it is now in the hands of a skilled artist to undergo a doubtful attempt at restoration. The cord was found corroded and as friable as touchwood, while the cord of the companion painting retains the original strength that would fit it for the use of Marwood's "ten-foot drop."

The apprehensions of a suspicious public have been so far allayed by assurances that the promoters—or certain of them—don't intend, and never intended, to use the powers asked for—

that they deprecate, and would themselves oppose the change if attempted—that the ostensible reasons put forth by or for them, are mere stalking horses, under cover of which they may gain a position of vantage in dealing with the coal owners—and that it is hard upon them "to have their hands forced." If this, as the real and only object, had been honestly stated from the first—and I cannot conceive why so laudable an object should require any roundabout cunning policy — it seems to me that no voice would have been raised in opposition. But if it is not really believed that the present quality of gas is pernicious for the public health, "because so good;" and if it is really not believed that a change will be profitable for the consumers, with no reservation throughout the range of the persuasive inducements advanced, then the wheedling policy is disingenuous, and deserves no respectful consideration. For my part, I do not suspect the promoters of any such double dealing. I take them at their word, and assume that they believe what they are trying to make the public believe; and I think it only too probable that they will act up to their belief if they get the chance. As regards promises that at least no immediate change is contemplated, I would willingly accept the individual assurance of any member of the Town Council, but never that of the impersonal thing called a "corporation," or a "standing committee." *That* has "no pocket to fine or flesh to pine." This distrust, which I share with the general public, is protested against as unfair; and it is pointed out that in other places—Edinburgh for example—where the parliamentary standard is very low, lower still than 20 candles, the actual standard supplied by gas directors is high, and the citizens are asked to credit the Gas Committee with equal solicitude for the public interest. But such references are unwise, because in Edinburgh, with a compulsory standard of only 18 candles, the high practical standard of 28 candles has been preserved, while Glasgow has a contrary experience. The Glasgow Corporation obtained control of the gas supply under the assurance given to Parliament, that the object was "to supply gas of the greatest purity and *the brightest illuminating power which may be obtainable.*" How has that assurance and that duty been fulfilled? Glasgow is now worse served than by the old companies, who were supplanted. When the Corporation obtained control, the actual illuminating power of Glasgow gas averaged 30 candles, was rarely under 28, and was frequently 34 candles. But very soon the illuminating power was lowered; and it is now the lowest of any considerable town in Scotland. Shaving the line as close as may be to the compulsory standard of 25 candles, (occasionally considerably below it, as I have reason to know; *verb. sap.!)* there has been no indication of a desire to obtain "the brightest illuminating power obtainable," or even to *maintain* the bright illuminating power *that did obtain under the Old Companies.* In 1870 the actual management of the Corporation may be said to have commenced; and for a year thereafter matters remained much in the old way, but about this time a change took place. Up till June, 1871, there had appeared weekly reports in the *Herald* on the average quality of Glasgow gas, which until this date was certified as near as may be at 28 candles. But after this date and for a long interval, I cannot trace a continuance of the customary reports. About this period, by a strange coincidence, in the words of our greatest statesman, the aggregate consumpt of gas "increased by leaps and bounds." Our older citizens will recollect, as the quality was gradually being lowered, how frequent were the complaints, of which the newspapers of the day preserve the record. Gas bills went up mysteriously; but meters were tested, and, being found to register correctly, there seemed no legitimate cause for complaint. In fact the public did not understand, neither, as I believe, did the Gas Committee understand, nor do either party as yet understand, what I am so solicitous to point out—viz., that an increased number of cubic feet of gas have now become necessary to maintain the actual amount of light formerly realised and still required. The Gas Committee did not seem in any degree to understand this essential principle that underlies the gas question; and they have gone on lowering the quality to the extremest point they dared, and farther than they can *safely* dare, educating the consumer to an acceptance of, or resignation to, a lower standard. Meanwhile they have expended their energies in distributing an increased quantity, laying the flattering unction to their soul that they are actually lowering the cost of equal value to the consumer, while they are only lowering the price per 1,000 cubic feet, and, at same time, compelling the unconscious victims of their ignorant procedure to pay for such a larger number of cubic feet, as will be found through experience, equivalent in value to the old supply. Setting fractions aside—

CORRECTION *at page 37. Owing to an accidental omission when copying manuscript for the printer, the following correction of the first five lines at top of page is necessary.*

In the year ending June, 1870 the consumpt was 1010 millions cubic feet—

					an increase of	3%
Do.	1871	"	1116	"	"	9%
Do.	1872	"	1227	"	"	10%
Do.	1873	"	1310	"	"	6·7%

or nearly 26 per cent. of aggregate increase within three years, or an annual increase of 8·5 per cent., while the population &c.

In the year ending June, 1871	the consumpt was	1116 millions cubic feet.			
Do.	1872	,,	1227 ,,	an increase of	10%
Do.	1873	,,	1310 ,,	,,	6·7%

or nearly 17 per cent. within two years while the population was only increasing as we now have learned from the shrewd and instructive commentary of Dr. Russell, in a ratio of *less than one* per annum, or only 4 per cent. for the entire decade commencing 1871. This extraordinary increased consumpt did not therefore occur because of the wants of an increased population. Neither did it occur because of temptations to extravagance resulting from cheap gas, because this was the very exceptional time of dear coal and of dear gas. It occurred through the inevitable craving on the part of the consumer for more light; for that amount of light to which he had been accustomed, or that was necessary for his wants. In 1874 the point of equivalent in light through increased quantity, seems to have been reached, for the consumpt now fell off some 4½ millions. The increasing cost of gas bills began to tell; and in 1875 there was only an increase of 2 per cent. For several years, therefore, and up till the present moment, the Glasgow public has been paying for so many millions cubic feet of gas in excess of what would be necessary if the illuminating value had been maintained by the Gas Committee at its original standard. Quantity has been substituted for Quality, and it has been in every respect a costly exchange.

I have endeavoured to impress by various modes of demonstration the great essential fact that price "per 1,000 cubic feet of gas" is not the measure by which either the Gas Committee or the equally uninformed consumer should estimate the value he is obtaining. I will try to clench home this truth by another illustration, taken from the principle of averages, and with that conclude my argument. What is meant by the principle of averages?—Let me premise.

Although an occasional giant and an occasional dwarf show that an exceptional and even an extreme range exists in the stature of individuals of any country, it is nevertheless certain that an *average stature* prevails throughout the population of that country. This principle of average will be found to obtain in respect to the time allotted for sleep, to the amount of solid food consumed within twenty-four hours, and to many other conditions of social life, little suspected or considered. I have no doubt the principle extends to the amount of artificial light employed by Town Centres of Population throughout England and Scotland, although

Scotland, being more northerly in latitude, and having longer hours of darkness, may probably use a larger ratio of artificial light. In applying this hypothesis to the gas question, I have reached some curious and interesting results, confirmatory in a remarkable degree of conclusions reached through other methods of demonstration.

I have formed three groups, each consisting of twelve towns, the aggregate population of each group, as given in the recent Census, being a little above 650,000. For each town I have collated from authentic returns the tons of coal carbonised for last year, the approximate manufacture of gas, the candle-power, and the cost per 1,000 cubic feet of gas. The first group, A, consists of 12 Scotch towns, having an average candle-power of 28·6; the second group, B, consists of 12 English towns, having a candle-power of 20·3; and the third group, C, also consisting of 12 English towns, has an average candle-power of 15. These three groups may be held to represent, High, Medium, and Low quality gas, and should give a fair idea of the comparative value and comparative cost to the community which uses one of the three qualities of gas specified. The subjoined Tables give the details; and it will be seen at a glance that precisely in the ratio of a lowered quality of gas there is a corresponding increase in quantity.

SCOTTISH TOWNS.	Population of District Supplied.	Illuminating Power Candles.	Tons of Coal Carbonised Annually.	Approximate Annual make of Gas, Cubic Feet, Millions.	Price per 1000 Cub. Ft. s. d.
Aberdeen	88,125	30	23,503	243	4 2
Airdrie	18,000	28	2,400	27½	3 9
Broughty Ferry	8,009	28	1,928	19¾	4 2
Dunfermline	22,000	28	38,000	38½	3 10
Edinburgh	300,000	28	27,000	287	3 10
Forfar	15,000	28	2,200	23	5 5
Galashiels	16,000	29	4,088	41¾	3 4
Greenock	70,000	29	17,400	170	4 2
Hamilton	18,000	28	4,000	35	3 9
Hawick	17,000	30	2,965	30½	3 6½
Kilmarnock	25,000	28·3	4,716	45½	4 2
Paisley	55,000	28·7	15,000	154	3 9
	652,134	average 28·6	143,200	1,115¼	average 3 11^{591}

ENGLISH TOWNS.	Population of Districts Supplied.	Illuminating Power Candles.	Tons of Coal Carbonised Annually.	Approximate Annual make of Gas, Cubic Feet, Millions.	Price per 1000 Cub. Ft. S. D.
Altrincham, Cheshire..	11,249	20	6,400	64	3 7
Barrow-in-Furness......	47,111	20	8,600	89	4 0
Birkenhead	83,324	20·5	23,724	251⅛	3 4½
Carlisle............	45,000	19	14,500	146	2 6
Eton, Bucks...............	3,466	20	1,360	12	5 6
Huddersfield..............	87,146	20	30,000	300	2 9
Lytham......................	5,000	20	1,300	13	4 6
New Mills, Derby	6,552	20	1,200	12	4 6
Oakengates, Salop	6,800	20	1,026	10	4 9
Manchester (Salford)...	300,000	21·7	76,026	732¼	3 6
Do., (Stretford)	19,025	20·5	7,134	73¾	3 2
Southport..................	40,000	22	17,000	175	4 3
	654,673	average 20·3	188,270	1878⅛	average 3 4^{822}

ENGLISH TOWNS.	Population of District Supplied.	Illuminating Power Candles.	Tons Coal Carbonised Annually.	Approximate Annual make of Gas, Cubic Feet, Millions.	Price per 1000 Cub. Ft. S. D.
Barnstaple.................	12,283	14	2,500	25	4 3
Bridgewater.............	14,000	15	3,300	31¼	3 3
Bromley....................	15,153	14	8,000	80	4 2
Boston.......................	14,932	16	5,000	50	4 0
Crewe	24,000	14	8,000	75	4 2
Chipping Norton........	5,000	16	1,000	10	5 3
Dover........................	30,000	15	11,300	130	3 4
Fleetwood..................	6,513	16	1,200	11	5 0
Newcastle..................	300,000	16	92,000	1,000	2 0½
Plymouth..................	85,000	14	32,600	352¼	2 0
Sunderland	110,000	16	36,000	360	2 2
Tynemouth................	40,000	14	12,000	126	3 0
	656,881	average 15	212,900	2,250½	average 2 5^{621}

The bearing of quantity *versus* quality, upon the point of economy, as shown in the aggregate cost to each community, is brought out in the following summary which, as being a purely monetary, purely commercial aspect of the gas question, should carry conviction to the minds of those who are distrustful of their powers to "tackle the Carbon and Hydrogen mystery," as a private correspondent ruefully admitted to me a few days back, was his predicament.

Comparative Values of High, of Medium, and of Low Quality Gas.	A 12 Scotch Towns.	B 12 English Towns.	C 12 English Towns.
1. Average Candle-power of Gas.........	28·6	20·3	15
2. Aggregate Population	652,134	654,673	656,881
3. Tons of Coal annually Carbonised....	148,200	188,270	212,900
4. Approximate Annual Make of Gas, Millions of Cubic Feet,................	1,115¼	1,873⅜	2,250⅓
5. Cost to Consumer pr. 1000 cub. ft. Gas,	3s. 11^{591}d.	3s. 4^{822}d.	2s. 5^{321}d.
6. Aggregate cost to the community.....	£221,149	£319,461	£274,945
7. Extra cost to community for extra quantity as an equivalent in value to A..	—	£98,312	£53,796

My reader will draw his own inferences. The Corporation Gas Committee is entitled to point to item No. 5, showing comparative lower price per 1,000 cubic feet paid by consumers of groups B and C. On the other hand, I point to every item throughout the range of groups. I have not thought it needful to estimate the extra cost to the consumers of groups B and C, in the form of vitiated air. That is a big calculation, which I leave for the imagination to dwell upon.

I think I have dealt with the "gas question" in all the more important aspects that affect the interests of the general public, although it may be that in some respects these require further elucidation. This remains to be ascertained, and I therefore reserve further communications which may yet be found expedient or necessary.

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