

(*Paper No. 2225.*)

## “Gas-Power Compared with Steam-Power.”

By JOSEPH EMERSON DOWSON, M. Inst. C.E.

IN the series of lectures delivered at this Institution in the Session 1883-84, on “Heat in its Mechanical Applications,” there was one, by the late Professor Fleeming Jenkin, “On Gas- and Caloric-Engines.” In this most interesting and instructive lecture, he dealt with several kinds of efficiency in various types of heat-engines, but he purposely avoided the consideration of their mechanical efficiency. By this term should be understood the difference between the gross indicated power developed in the cylinder, and the effective power given off on the brake. Often some confusion arises, owing to the different meanings rather loosely attached to the word efficiency, and the lecturer was careful to give precise definitions. The absolute efficiency is the ratio between the indicated HP. and the total quantity of heat generated by the fuel per minute; and, in referring to this, the lecturer reminded his audience that heat has done all that can be expected of it when it has given the power shown by the indicator-diagram. After that it is a question, not of heat efficiency, but of mechanical efficiency, of what the ratio may be between the indicated power and the actual brake-power.

To understand the principles on which the absolute efficiency of a gas-engine depends, no better authority can be consulted than Professor Jenkin’s lecture. If, however, information is desired as to its mechanical efficiency, or as to its working cost, the actual results obtained in different places where such engines have been tried must be examined. At present there is no complete record to refer to, and this is hardly to be wondered at, seeing that gas-engines have been used for so short a time. The Author has, however, had occasion to study this subject closely, and thinks that some of the information he has collected may be of use to others. At all events, he trusts that the statements now made will be examined critically, and that the outcome may be a fuller appreciation of the merits and demerits of gas-power, compared with steam-power. Professor Jenkin has shown that, although the gas-engine is a comparatively new invention, 24 per cent. of

the heat actually generated in it is converted into work in the cylinder. This absolute efficiency is about double that admitted by competent authorities to have been obtained by the best steam-engine; and an endeavour will now be made to see how far this superiority holds good in practical work.

Usually gas-engines are designed to work with gas, such as is distributed in all towns of importance. This heat-giving agent is ready to hand, and, by simply turning a cock, a moderate-sized engine can be started or stopped at a moment's notice. In this respect the gas-engine has a distinct advantage over the steam-engine, which requires a boiler to produce the steam. When the gas-engine is worked with town gas, there are no ashes to remove, no smoke nuisance, and no need of constant attendance. The space required is small, no chimney is necessary, and the repairs are inconsiderable. In fact, for any power under 4 HP. effective, it is now generally conceded that a good gas-engine is much more convenient and more economical than a steam-engine and boiler, whether for regular or for intermittent work. In certain special cases it may be desirable to use a steam-engine rather than a gas-engine for 4 HP. and under; but the Author considers it unnecessary to enter into a detailed comparison of such small engines, and therefore passes on to the higher powers.

With a steam-engine and boiler the fuel consumption per HP. is less, and consequently the working cost is less, as the power of the engine is increased. With a gas-engine the consumption of gas per HP. is also slightly reduced as the power of the engine is raised. When, however, town gas is used for regular work with the larger sizes of engines, its cost soon exceeds that of the fuel required for the steam-engine. Therefore, the case of a gas-engine worked with cheap-fuel gas, made specially for it in a separate apparatus, should also be considered. Here there will be a close analogy between the steam-engine and boiler, and the gas-engine and gas-making plant.

The largest gas-engine working in this country is at the mill of Messrs. E. Butterworth and Co., Manchester, and is a twin-cylinder Otto engine, capable of indicating about 80 HP. A single-cylinder vertical engine, indicating about 100 HP., has recently been made by Messrs. Crossley Brothers, but it is not yet working regularly. The other sizes of gas-engines made in England (above 4 HP.), have indicated powers of about 6, 8, 12, 14, 15, 18, 25, 33, 40, and 50 HP. respectively. To make the comparison exact, cases

of steam-engines of about the same indicated power should therefore be taken.

In Appendix I the results are given of careful trials made in 1872, by Sir F. J. Bramwell and Mr. W. Menelaus, of ten portable steam-engines exhibited at the Royal Agricultural Society's Show at Cardiff.<sup>1</sup> The judges remark:—"The consumption of the most economical engine tried at this show, of which successful indicator-diagrams were obtained . . . was as low as 2·377 lbs. per indicated horse-power per hour; a consumption which will bear favourable comparison with the best modern marine engines, when it is remembered that those engines condense their steam, and are of large size." The coal was of good quality, Welsh (Llangennech), and the fires were nursed in the most careful way. In fact, the judges point out that, "During the trials" men were employed "who exhibit the highest skill and diligence in attending to the firing. In order to preserve uniformity, they fire from thirty to forty-five times in the hour, but clearly in practice no man could so attend to a fire." Such firing is allowable in a competitive trial lasting a few hours, when all the competitors do alike; but in regular practical work such results as the above are not attainable. It should also be remembered that the consumption of fuel per HP. will be greater when the load is variable, as in ordinary working.

In Appendix II returns are given which have been extracted from the Report for November 1880 of the Manchester Steam User's Association. They comprise all the engines indicating under 100 HP., for which the net fuel consumption is given. An average of these shows a fuel consumption of 7 lbs. per indicated HP. per hour, but if an average be taken of the five engines, each indicating under 20 HP., the fuel-consumption will be over 11 lbs. per indicated HP. per hour.

In his Address in January 1885, as President of this Institution, Sir Frederick Bramwell made the following statement with regard to the fuel-consumption of steam-engines in actual work: "In an investigation instituted last year by the Corporation of Birmingham, when considering whether they should approve of a proposal to lay down power-distributing mains throughout their streets, it was found, on indicating some six non-condensing steam-engines, taken indiscriminately from among users of power, and ranging from five nominal HP. up to thirty nominal HP., that the

---

<sup>1</sup> The Journal of the Royal Agricultural Society, vol. ix. p. 51.

consumption in one instance was as high as 27·5 lbs., while it never fell below 9·6 lbs., and the average of the whole was as much as 18·1 lbs.”<sup>1</sup> per indicated HP. per hour.

Many other instances could be given, but as the working of steam-engines is more or less familiar to all engineers, those already mentioned will probably be considered sufficient for the purpose of determining the fuel consumption. In Appendix I it has been shown that the best result obtained during a short trial under exceptionally favourable conditions was 2·37 lbs. per indicated HP. per hour. Appendix II shows a general average of 7 lbs., and an average for engines under 20 HP. of 11 lbs. per indicated HP. per hour. The Birmingham average is 18 lbs.

As regards the mechanical efficiency of steam-engines, most of the recorded tests have reference to larger engines than those now under consideration. It has, however, been shown in Appendix I that, in those of the portable type, the average ratio of the brake HP. to the indicated HP. is 0·825. In a high-class compound condensing-engine, accurately tested for a prize award by a committee of experts appointed by La Société Industrielle de Mulhouse, in 1879,<sup>2</sup> the average gross indicated power was 74·7 HP., while the ratio of the average brake to the indicated HP. was 0·868. These results were obtained under the most favourable conditions possible, and, without entering further into details, it may be assumed that in ordinary practice the ratio of the brake to the gross indicated power is not higher than 0·85 for non-condensing, and 0·80 for condensing engines.

In Appendix III returns, of recent date, are given of the working of several gas-engines developing over 4 HP. From these it will be seen that the average mechanical efficiency of all the Otto engines is 0·839, while only one engine is as low as 0·744. A still higher mechanical efficiency is given for the 8 HP. Delamare-Debouteville engine, tested by Professor Witz; but as the Author has reason to believe that the indicator diagrams taken during this trial were irregular, owing to varying conditions in the cylinder, he cannot but think that the indicated powers deduced from them, and consequently the mechanical efficiency given, should not be taken as final. These remarks have no reference to the brake-power developed and the gas consumption per brake HP., as these were, doubtless, measured accurately.

---

<sup>1</sup> Minutes of Proceedings Inst. C.E. vol. lxxx. p. 23.

<sup>2</sup> “Engineering,” vol. xxx. p. 311.

The ratios given in Appendix III are important, as they show that the mechanical efficiency of gas-engines as now made is as high as that of the best non-condensing steam-engines, and considerably higher than that of condensing-engines. It should also be mentioned that this efficiency can now be maintained more easily than formerly, because the area of the slide-valves has been much reduced, and consequently their wear and tear has been lessened. Formerly in the Otto engines the gas and air were passed through ports in the slides; but in the larger engines of this type the slide-valves are now only used for igniting the charge.

As already mentioned, the gas consumption is rather less per HP. as the size of the engine is increased, owing to the total power developed being greater in proportion to the total friction. This is best seen by referring to the results obtained at the Otto engine works in Germany, where all the tests were made with lighting gas of fairly uniform quality, and where the excellent practice is followed of testing every engine with a brake before it leaves the works. The tests made with lighting gas in England and Scotland show rather higher results, as they were made with gas of 20 to 26 candle-power, whereas at Deutz the candle-power is only about 11. When the Author's gas<sup>1</sup> is used for driving an engine, it is generally consumed as quickly as it is made, and as it is not thoroughly cooled, it is at a higher temperature than ordinary lighting gas, which is stored for some hours in a holder, and afterwards travels long distances in pipes underground. To make the comparison more exact, the volume of Dowson gas given in Appendix III is, therefore, the volume actually used, reduced to the temperature of the lighting gas with which it is compared.

To determine the working cost, the more simple and direct way of comparing a steam-engine with a gas-engine driven by Dowson gas is to take in each case the weight of fuel used per HP. per hour. To compare the relative cost, it is no more necessary to determine the volume of gas consumed than it is to know the volume of steam used. In Appendix IV examples are, therefore, given of several engines, which for some time have been working regularly with Dowson gas, and for which the weight of fuel consumed has been ascertained.

It should be explained that example No. 1 includes the different engines used at Messrs. Crossley's works, there being one engine for

---

<sup>1</sup> Minutes of Proceedings Inst. C.E. vol. lxxiii. p. 311.

each department,<sup>1</sup> and that the 150 HP. mentioned is the average aggregate power used. No. 3 engine has twin cylinders, and is seldom worked up to more than one-half its maximum power. This is probably the reason why its fuel consumption is rather higher than that of the other engines. The average fuel consumption in Appendix IV is under 1·4 lb. per indicated HP. per hour, and as this result has been obtained with several engines working independently in different places, it may be accepted as reliable. As examples, in Plate 9, Figs. 1, 2, and 3 represent indicator diagrams taken on engines Nos. 2, 5, and 7 in Appendix IV, and Figs. 4 and 5 are copies of diagrams taken on engine No. 2 in Appendix III.

A few special remarks may be made with reference to the last two engines on the list. In testing these, the gas generator was in each case placed on a Pooley weighing machine, which was free to move up or down, as a loose water-joint was provided in the vertical pipe which conveyed gas to the engine. The engine was kept fully loaded at a regular speed, the actual number of revolutions during the trial being taken with a counter. Readings of the weight on the machine, and indicator diagrams on the engine, were also taken at frequent intervals. In this way there was not only a record of the total fuel consumed during the trial, but also a determination of the weight of fuel converted into mechanical work at stated times. The first of these trials was carried out in March 1884, with gas made from Garnant anthracite. The average indicated HP. was 32·6, and the consumption of fuel, including that used for the steam superheater, and for getting up the fires at starting, was at the rate of only 1·2 lb. per indicated HP. per hour. The last trial was made in November 1886, with gas produced from ordinary gas coke, costing 5s. 6d. per ton. The average indicated HP. was 32, and the total fuel consumed, including that used for the production of superheated steam, and for getting up the fires at starting, was 1·4 lb. per indicated HP. per hour. It may be added that immediately before the trial was made with coke-gas, the engine was worked with anthracite-gas, so that a direct comparison of the power developed might be instituted. Fig. 6 is an indicator diagram taken with the anthracite-gas, and Fig. 7 with the coke-gas (the same indicator being used), and it will be seen that the two diagrams are almost identical. Nothing was done to favour

---

<sup>1</sup> "Engineering," vol. lxxxvii. p. 136.

the results unduly, and both these trials may be compared directly with those of the steam-engines given in Appendix I.

Hitherto the Author has been obliged to use anthracite for producing gas in his apparatus; but now that he has succeeded in working with ordinary gas-coke, which is usually much cheaper, and which can be readily procured in nearly all towns, he considers that a further move in the right direction has been effected.

With the above information it is now possible to estimate the comparative working cost of steam-engines in regular work, and of gas-engines driven by lighting gas and Dowson gas. To make the comparison exact, the engines referred to in Appendixes V, VI and VII, are assumed to be indicating the same average power, and the number of working hours for a year is in each case taken at two thousand five hundred (fifty weeks of fifty hours each).

The estimates show clearly that, however well ordinary lighting-gas, at 3s. per 1,000 cubic feet, may suit small engines, it is much too expensive a fuel for engines working regularly with an indicated power of 25 HP. and upwards. There is, however, a marked economy compared with steam, when the gas-engine is driven by cheap-fuel gas such as that made in the Author's apparatus. The saving with the latter combination is no less than 25 per cent. for the 25 HP., and about 30 per cent. for the 50 and 100 HP. For the purpose of this comparison, it has been assumed that the coke will cost as much as the coal, but in many places it is much cheaper. In Manchester, Birmingham, Bristol, Leeds, Newcastle, and many other towns, the price of ordinary gas-coke ranges from 5s. to 7s. a ton.

It is, no doubt, seldom that an engine has to work with a constant load, and usually the average power may be taken as about one-third or one-half less than the maximum. With steam it is hardly possible to prevent some loss on this account, as the boiler fire cannot be regulated precisely for a varying amount of work; also the loss of heat by radiation from the boiler is about the same, whether the engine is fully loaded or not. With a gas-engine, when there is a varying load, the governor admits only the quantity of gas necessary for the actual power required, and in this respect it is more economical than a steam-engine. It must not, however, be forgotten that the friction of the engine is constant, and that the heat lost in various ways is nearly constant; therefore, when the power required is less than the maximum, the consumption of gas per brake HP. per hour is proportionally

increased. The trials of Messrs. Brooks and Steward with an Otto engine, having a maximum brake power of about 7·5 HP., show the following results :—<sup>1</sup>

Brake HP. . . . .	2·73	4·5	5·3	6·3	7·6
Gas consumption per cubic feet	46·1	38·4	37·4	33·0	32·7
brake HP. per hour litres	1,310	1,090	1,060	940	930

When the Author's gas-making plant is used, the production of gas in the generator is governed automatically to suit the varying rate of consumption; moreover, the results given in Appendix IV represent the average consumption per HP. per hour in engines working under varying loads in ordinary work. The loss of heat by radiation from the generator is about the same whether the engine is fully loaded or not, but its surface is small compared with that of a steam-boiler.

A point in favour of gas, which is not taken account of in the foregoing estimates, is that it can be conveyed to any part of the works without appreciable condensation, and separate engines can be used with advantage for different lines of shafting. On the other hand, it must be allowed that with steam there is the practical advantage of being able to increase the power of the engine to a certain extent in an emergency by raising the steam-pressure. With a gas-engine it is impossible to admit more than a certain maximum proportion of gas, or there will be imperfect combustion; there is, in fact, an absolute limit to the power obtainable. It is, therefore, important in all cases to allow fully for the power required.

It is estimated that the total number of Otto engines now in use in all countries is over twenty thousand. About nine thousand are in great Britain, and of these a large proportion is for small powers; but there are seven hundred and fifty of about 15 indicated HP.; three hundred and ninety of about 24 HP.; and one hundred and sixty of about 40 HP. each. In Germany more has been done with large installations than in any other country, of which the examples given in Appendix VIII may be cited. The Gasmotoren Fabrik of Deutz has kindly sent the Author drawings of several of these installations, and, as typical examples, he has selected the pumping-station of the Coblenz Waterworks

<sup>1</sup> Van Nostrand's Engineering Magazine, vol. xxx. 1884, p. 93.



and of the gas-engines used for electric lighting at Prague, shown in Plate 9.

In conclusion the Author would point out that he has endeavoured to confine himself to a statement of facts, and that they certainly show a very rapid extension in the use of gas-power. He is not prepared to admit that present gas-engines are incapable of improvement; but seeing that their general use dates from Dr. Otto's patent of 1876, it is not a little surprising that such rapid strides have been made in so short a time. This is largely due to the sound principles followed by the inventor, and to his mechanical skill, but also in a great measure to the enterprize and ability of the makers in this country and in Germany.

Professor Jenkin has shown that the absolute efficiency of a gas-engine is already greatly superior to that of the steam-engine when both are treated as heat-engines. The mechanical efficiency of the gas-engines now made has been shown to be quite as high as that of steam-engines, and further, that when gas-engines are worked with cheap-fuel gas, their working cost is considerably less than that of steam-engines of equal power. If, therefore, so much has been accomplished in about ten years, what may not be expected in the near future, now that the principles on which success depends have been learnt, and that so many persons are seeking improved means of applying them?

The Paper is accompanied by several diagrams from which Plate 9 has been prepared.

## APPENDICES.

## APPENDIX I.

Name of Exhibitor.	Makers' Nominal HP.	Mean Indicated HP. during Trial.	Ratio of Brake HP. to Indicated HP.	Coal Consumed.	
				Per Indicated HP. per Hour in lbs.	Per Brake HP. per Hour in lbs.
1. Marshall and Co. . . .	8	18·0	0·797	2·62	3·30
2. Clayton and Shuttleworth	8	13·97	..	..	2·79
3. Hayes, E. . . . .	8	9·1	0·823	8·30	10·0
4. Davey, Paxman and Co.	8	13·6	0·878	2·85	3·25
5. Brown and May. . . .	8	10·1	0·92	3·02	3·29
6. Tasker and Sons . . .	8	14·0	0·88	4·36	4·94
7. Reading Iron Works . .	8	20·32	0·826	2·37	2·88
8. Turner, E. and F. . . .	8	24·8	0·803	2·90	3·63
9. Barrows and Stewart . .	8	13·8	0·84	4·87	5·78
10. Ashby and Co. . . . .	8	12·6	0·66	4·94	7·47
Averages . . . . .	..	..	0·825	4·02	4·73

## APPENDIX II.

Description of Boiler.	Description of Engine.	Total Indicated HP.	Coal Consumed per Indicated HP. per Hour.	Description of Coal.
1. Lancashire	Single-cylinder condensing .	83	4·6	{Trencherbone slack.
2. " "	Compound " .	73	5·6	{Mold slack.
3. " "	Single-cylinder " .	79	5·6	{ " "
4. Cornish .	" " non-condensing	24	6·27	{Wrexham slack.
5. " "	" " condensing .	12	14·6	{Barnsley.
6. Lancashire	Compound " .	93	2·87	{Bestwood ; good round coal.
7. " "	" " " .	52	6·16	{Barnsley nuts.
8. " "	Single-cylinder " .	49	4·42	{Staffordshire.
9. " "	" " non-condensing	79	4·26	{Good round coal.
10. Cornish .	" " " .	13	10·36	{Writhlington.
11. Lancashire	" " " .	72	{ 6·73 } exclusive of coke.	{Best hard steam coal, and coke.
12. Cornish .	" " " .	14	8·55	{Broad Oak.
13. Lancashire	" " condensing .	61	6·31	{Tawd Vale, &c.
14. " "	" " non-condensing	9	11·79	{Baddesley; good slack.
15. Cornish .	" " " .	17	10·36	{Rhosddn ; fair slack.
16. Lancashire	" " " .	38	8·53	{Bristol.
17. " "	Compound " .	88	4·97	{Ince Hall ; good slack.
18. Galloway .	" " " .	57	5·7	{Bridgwater.
19. Lancashire	Single-cylinder " .	54	5·73	{Bury.

## APPEN

Number and Type of Engine.	Name of Maker.	Commercial Nominal HP.	Indicated HP. during Trial.	Brake HP. during Trial.	Ratio of Brake HP. to Indicated HP.
1. Otto, single-cylinder	{Crossley Brothers, Limited . . . }	8	11.5	9.0	0.782
2. " "	" "	9	18.2	..	..
3. " "	" "	{ same } { engine }	18.0	..	..
4. " "	" "	9	18.5	15.9	0.859
5. " "	" "	12	22.9	19.2	0.838
6. " "	" "	16	32.6	26.6	0.816
7. " "	{C <sup>o</sup> Française des Moteurs à Gaz, Paris . . . }	4	5.26	3.94	0.744
8. " "	{Schleicher-Schumm and Co., Philadelphia . . . }	8	9.1	7.4	0.813
9. " "	{Gasmotoren-Fabrik, Deutz . . . }	4	5.04	4.4	0.873
10. " "	" "	12	..	12.2	..
11. " "	" "	12	16.0	13.4	0.838
12. " "	" "	{ same } { engine }	16.8	13.7	0.825
13. " double-cylinder	" "	50	57.1	50.1	0.877
14. " "	" "	50	57.9	50.9	0.879
15. " "	" "	50	57.6	50.6	0.878
16. " single-cylinder	" "	6	..	..	} 0.84
17. " "	" "	8	..	..	
18. " "	" "	10	..	..	
19. " "	" "	12	..	..	
20. " "	" "	16	..	..	} 0.85
21. " "	" "	20	..	..	
22. " "	" "	25	..	..	
23. " "	" "	30	..	..	
24. " double-cylinder	" "	30	..	..	} 0.87
25. " "	" "	40	..	..	
26. " "	" "	50	..	..	
27. " "	" "	60	..	..	
28. Clerk . . . .	{L. Sterne and Co., Glasgow . . . }	12	29.3	23.2	0.757
29. Delamare-Deboutville .	{Thomas Powell, Rouen . . . }	8	9.10	8.79	0.966
30. " "	" "	{ same } { engine }	8.10	7.22	0.891

## DIX III.

Gas Consumed.				Description of Gas used.	Authority.
Per Indicated HP. per Hour.		Per Brake HP. per Hour.			
Cub. ft.	Litres.	Cub. ft.	Litres.		
22.0	623	28.0	793	{Glasgow gas, about 26 candle-power . }	{Jury Report of Glasgow Exhibition, 1882.
19.4	550	..	..	{Openshaw gas, about 20 candle-power. Temp. 13° C. . }	{Crossley Brothers, Limited, May 1886.
81.7	2,315	..	..	{Dowson gas, reduced to same temp. . }	{Trial for Jury of Liverpool Exhibition, July 1886.
20.3	575	23.8	672	{Liverpool gas, about 20 candle-power . }	{Crossley Brothers, Limited, April 1884.
21.0	595	25.0	708	{Openshaw gas, about 20 candle-power . }	{Crossley Brothers, and J. E. Dowson, March 1884.
(See Appendix IV.)				Dowson gas . .	{Mr. Tresca and others, for Jury of Exposition d'Electricité, 1881.
23.8	672	31.7	897	{Paris gas, about 14 candle-power . . }	{Brook and Steward, Stevens Institute, U.S.
24.5	694	30.1	853	{Hoboken lighting gas, about 14 candle-power. Temp. 24°C. }	{Dr. Slaby, Berlin. Inst. C.E. Lectures, vol. ii. Appendix IV.
27.9	790	32.0	906	{Deutz gas, about 11 candle-power . . }	{Prof. E. A. Brauer, May 1886.
..	..	28.9	816	{Deutz gas, 10.8 candle-power. Temp. 12° C. . . . }	{Gasmotoren Fabrik, Deutz, March 1886.
23.7	670	28.3	800	{Deutz gas, about 11 candle-power. Temp. 15° C. . }	{Ditto, and J. E. Dowson, May 1886.
83.7	2,371	102.7	2,908	{Dowson gas, reduced to same temp. . }	{E. Grahn, Engineer of Coblenz Water Works, 1886.
23.3	660	26.6	753	{Deutz gas, about 11 candle-power . . }	" "
24.5	694	27.9	790	" "	" "
23.4	662	26.6	754	" "	" "
..	..	32.9	930	" "	{Gasmotoren Fabrik, Deutz, 1886.
..	..	31.1	880	" "	" "
..	..	31.8	900	" "	" "
..	..	31.1	880	" "	" "
..	..	27.9	790	" "	" "
..	..	27.6	780	" "	" "
..	..	27.6	780	" "	" "
..	..	27.2	770	" "	" "
..	..	29.0	820	" "	" "
..	..	27.8	785	" "	" "
..	..	27.8	785	" "	" "
..	..	25.4	720	" "	" "
19.1	541	24.1	683	{Glasgow gas, about 26 candle-power . }	{L. Sterne and Co., Dec. 1885.
19.7	557	20.3	577	{Rouen gas, about 14 candle-power. Temp. 10° C. . }	{Prof. A. Witz, November 1885.
85.9	2,432	89.0	2,518	{Dowson gas; same temperature . . }	" "

## APPENDIX IV.

Number and Type of Engine.	Locality.	Work done by Engine.	Maximum Indicated HP.	Fuel Consumed per Indicated HP. per Hour.	Remarks.
1. Otto, single-cylinder	Openshaw . .	Driving tools and machinery . . . .	150	Lb. 1·3	{ Result of 35 weeks' trial. Fuel includes 5 cwt. consumed each Sunday, without work.
2. " "	Bristol . . .	Grinding materials for paints . . . .	36	1·25	
3. " double "	Manchester .	Pressing bales, &c. . . . .	80	1·5	
4. " single "	Farningham .	Driving 3 pairs of stones and flour-machines	35	1·4	{ Each pair of stones grinds 5½ bushels of corn per hour.
5. " " "	Chippenham .	" 3 " " "	35	1·4	
6. " " "	Ewell . . .	" 2 " " "	20	1·25	{ Result of 10 weeks' trial, engines working day and night.
7. " " "	Eastbourne .	" 2 " " "	40	1·4	
8. " " "	Elstree . . .	Electric lighting and driving farm-machines	16	1·4	
9. " " "	Adelaide . .	Driving printing-presses, &c. . . .	30	1·3	Approximate estimate.
10. " " "	Brisbane . .	" " " " " " " " " " " "	30	1·3	" "
11. " " "	Marseilles . .	" roller-mills for grinding corn .	25	1·25	{ Gas-generator on Pooley weighing machine during trial.
12. " " "	Openshaw . .	" foundry blower . . . . .	33	1·2	{ Gas made from anthracite.
13. " " "	" . . .	Experimental . . . . .	33	1·4	{ Ditto. Gas made from small gas coke.

## APPENDIX V.

## STEAM-ENGINE.

—	Average of 25 Indicated HP.	Average of 50 Indicated HP.	Average of 100 Indicated HP.
	£. s. d.	£. s. d.	£. s. d.
Coal = 25 HP. $\times$ 6 lb. $\times$ 2,500 hours = 167½ tons at 10s. }	83 15 0	..	..
„ = 50 „ $\times$ 5 „ $\times$ „ „ = 279 „	..	139 10 0	..
„ = 100 „ $\times$ 4 „ $\times$ „ „ = 446½ „	..	..	223 5 0
Water at 2 gallons per indicated HP. per hour at 9d. per 1,000 gallons . . . }	4 13 9	9 7 6	18 15 0
Oil and waste at 4s., 6s. and 8s. per week .	10 0 0	15 0 0	20 0 0
Wages of fireman at 24s. a week . . . .	60 0 0	60 0 0	60 0 0
Repairs and insurance at 5 per cent. on prices erected¹ . . . . . }	21 10 0	27 10 0	39 10 0
Depreciation at 10 per cent. on prices erected	43 0 0	55 0 0	79 0 0
Total . . . . .	222 18 9	306 7 6	440 10 0
= per HP. per annum . .	8 18 4	6 2 6	4 8 1

¹ These prices include brick-setting and chimneys.

## APPENDIX VI.

## GAS-ENGINE WORKED WITH ORDINARY LIGHTING GAS.

—	Average of 25 Indicated HP.	Average of 50 Indicated HP.
	£. s. d.	£. s. d.
Gas = 25 HP. $\times$ 21 cub. feet $\times$ 2,500 hours at 3s. per 1,000 cub. feet }	196 17 6	..
„ = 50 „ $\times$ 20 „ $\times$ „ „	..	375 0 0
Water for cooling engine . . . . . say	1 10 0	2 0 0
Oil and waste at 5s., 7s. and 10s. a week .	12 10 0	17 10 0
Wages of attendant at 6s. a week . . . .	15 0 0	15 0 0
Repairs and insurance at 2½ per cent. on prices erected . . . . . }	8 12 6	11 17 6
Depreciation at 10 per cent. on prices erected	34 10 0	47 10 0
Total . . . . .	269 0 0	468 17 6
= per HP. per annum . .	10 15 2	9 7 6

## APPENDIX VII.

## GAS-ENGINE WORKED WITH DOWSON GAS.

	Average of 25 Indicated HP.	Average of 50 Indicated HP.	Average of 100 Indicated HP.
	£. s. d.	£. s. d.	£. s. d.
Coke=25 HP. $\times 1\frac{1}{2}$ lb. $\times 2,500$ hours = 41·8 tons at 10s. }	20 18 0	..	..
„ =50 „ $\times$ „ $\times$ „ „ =83·7 „	..	41 17 0	..
„ =100 „ $\times$ „ $\times$ „ „ =167·4 „	..	..	83 14 0
Water for making gas . . . . . say	0 10 0	0 15 0	1 0 0
„ cooling engine . . . . . „	1 10 0	2 0 0	3 0 0
Oil and waste at 5s., 7s. and 10s. per week .	12 10 0	17 10 0	25 0 0
Wages of fireman at 24s. a week . . . . .	60 0 0	60 0 0	60 0 0
Repairs and insurance at 3 per cent. on prices erected . . . . . }	16 1 0	20 17 0	31 10 0
Depreciation at 10 per cent. on prices erected	53 10 0	69 10 0	105 0 0
Total . . . . .	164 19 0	212 9 0	309 4 0
= per HP. per annum . . .	6 11 11	4 4 11	3 1 10

## APPENDIX VIII.

Name of User.	Locality.	Number of Engines.	Aggregate Brake- power.
1. Grills, W. . . . .	Oberhausen . . .	10	HP. 244
2. Iron Works . . . . .	Mechernich . . .	7	174
3. Russian Powder Co. . . .	Schlüsselberg . .	17	194
4. Wilkens and Son . . . .	Hemelingen . . .	3	77
5. Pfeifer and Langen . . . .	Elsdorf . . . . .	6	191
6. Oil Works . . . . .	Mannheim . . . .	4	125
7. Sugar Works . . . . .	Sampierdarena . .	2	100
8. Water Works . . . . .	Coblenz . . . . .	3	150
9. „ „ . . . . .	Düren . . . . .	2	80
10. Electric lighting of Pleasure Gardens . . . . . }	Prague . . . . .	3	150
11. „ „ of Opera House	Frankfort . . . .	2	100
12. „ „ of Theatre .	Karlsbad . . . .	2	60

