ON THE RELATIVE PHOTOGENIC OR ILLUMINATING VALUE OF VEGETABLE, ANIMAL, AND MINERAL OILS, AND COAL GAS.

BY

STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S.,

LECTURER ON CHEMISTRY.

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ON THE

ILLUMINATING VALUE OF VEGETABLE, ANIMAL, AND MINERAL OILS, AND COAL GAS.*

The communication which I have now the pleasure of bringing before the Society, has special reference to the light-giving power and relative cost of the illuminating agents in common use, and will include the results of a large number of experiments made upon the subject during the last ten years. Considering, however, that great fluctuations occur from time to time in the quality and cost of materials, I have repeated every experiment during the last few months, and have made great additions thereto.

The observations included common dip or tallow, composite, and paraffin candles; sperm, rape, and whale oils; paraffin and petroleum oils; and coal gas.

The illuminating standard of intensity of light was the sperm candle, burning 120 grains per hour; and the relative photogenic power of the flames, as contrasted with the said candle, was determined by Bunsen's photometer. The sperm candles were of the best quality, and burned generally between 120 and 122 grains per hour, and in no case was the trial considered as conclusive where the standard candle burned more than 125 or less than 117 grains per hour. The candle was weighed immediately before and after each experiment, and the requisite calculations were made to bring the light to the standard of 120 grains per hour. The room in which the experiments were conducted was kept at an uniform temperature of 60° F.

Considering that the various illuminating agents employed in these trials were of such different qualities and natures as candles, oils, and gas, sold and purchased respectively by the pound, gallon, and 1000 cubic feet, it appeared desirable, after determining the illuminating or photogenic

* Read before the Society, and illustrated by diagrams and experiments, on 27th November 1871.

power according to the pound, gallon, or cubic feet, that the light evolved in each case should be calculated into its equivalent in lbs. of sperm. Such a plan of recording the results enables the observer to see more clearly the relative illuminating power of the candles, oils, and gas. And, lastly, the photometric results were contrasted by calculating the light-giving value of each source of light yielded for a given price—say, a pennyworth of the material. In making the calculations, it was necessary to fix on a unit, and it was found best to take the standard sperm candle for one hour as *the unit of a candle hour*, and to reckon any light as equal to a given number of candle hours for 1d., indicating that the light evolved was equivalent to that given by a standard sperm candle for the stated period.

Common Tallow or Dip Candles.—Three sizes of these candles were experimented upon, viz., 6, 8, and 12 to the lb., and the price was 6d. per lb., so that the respective candles cost 1d., ¾d., and ½d. each. The average weights of the candles were 1118, 849, and 611 grains each. The size of the wicks was about the same in each sort, and, when burning, the candles lost in 1½ hours :—

1st, or largest size,	299 grains,	and	giving an average of close upon 200 grains per hour.
2d, or medium „	297 „		
3d, or smallest „	300 „		

The consumpt of tallow, therefore, in each size of candle was practically the same, and the illuminating value of the light evolved from each was equal to 1·25 standard sperm candles burning during the hour. Calculating that if 200 grains of tallow consumed during the hour were equal to 1·25 candle or 150 grains of sperm burned during the same period, what would 1 lb. of the tallow candles be equal to? The following results were obtained :—

$$200 : 7000 : : 150 : : 5250 \text{ grains of sperm};$$

or 1 lb. of tallow, consumed in common dip candles, evolves a light equal to that capable of being obtained from 75 lbs. of sperm, burned in standard sperm candles of 120 grains per hour.

Composite Candles.—These candles were obtained in three sizes, viz., 4, 6, and 8 to the lb., and respectively weighing 1758, 1165, and 851 grains each on the average. The price was 8d. per lb., so that each candle cost respectively 2d., 1½d., and 1d. During burning for 1½ hours, the loss in weight was as follows:—

1st, or largest size,	260	grains	Average consumpt per hour, 154 grains.
2d, or medium ,,	232	,,	
3d, or smallest ,,	199	,,	

The light evolved during the combustion of the composite candles was in accordance with the relative consumpt, and the average illuminating power was equal to 1·1 standard sperm candle, or 132 grain of sperm. Calculating these figures into 1 lb. of composite candles, and its equivalent in sperm, we obtain the following results:—

154 : 7000 : : 132 : : 6000 grains of sperm ;

or 1 lb. of composite candles yields a light which is equivalent to that evolved from ·85 lb. of sperm consumed in standard sperm candles.

Paraffin Candles.—These candles were also in three sizes, viz., 6, 8, and 12 to the lb., and cost 1s. per lb., so that the price of each candle was respectively 2d., 1½d., and 1d., whilst the average weight of each size was 1117, 848, and 567 grains. The loss in weight during 1½ hours consumpt was as follows:—

1st, or largest size,	215	grains	Being an average consumpt of 137 grains per hour.
2d, or medium ,,	206	,,	
3d, or smallest ,,	195	,,	

The light evolved during the combustion of these candles was greater than that given by the tallow and composite candles, being equal to 1·494 standard sperm candles, or 179·28 grains of sperm. This result, calculated into lbs. of paraffin and sperm, gives the following:—

137 : 7000 : : 179·28 : : 9160 grains of sperm ;

or 1 lb. of paraffin burned in candles evolves a light equal to that capable of being yielded by 1·3083 lbs. of sperm when consumed in standard sperm candles.*

* This amount of light yielded by solid paraffin in candles is theoretically much less than what ought to be obtained from the paraffin, and indicates

These experimental results on the candles may be shortly stated thus:—

1 lb. of tallow candles	is equal in light-giving power to	·75 lb. of sperm candles.
1 lb. of composite „	„	·85 lb. of „ „
1 lb. of paraffin „	„	1·3083 lb. of „ „

Considering, however, the relative cost of the tallow, composite, and paraffin candles, it follows that, value for value, these results require to be amended according to the purchase price of the materials. A lb. or 7000 grains of the standard sperm candle, consuming 120 grains per hour, will necessarily give

120) 7000 (58·33 candle hours.

One lb. of tallow candles is equal to ·75 lb. of sperm, and costs 6d., hence—

1·00 : ·75 : : 58·33 : : 43·74 candle hours from 1 lb.

6d.) 43·74
7·29 candle hours for 1d.

One lb. of composite candles is equivalent to ·85 lb. of sperm, and costs 8d., therefore—

1·00 : ·85 : : 58·33 : : 49·58 candle hours from 1 lb.

8d.) 49·58
6·19 candle hours for 1d.

One lb. of paraffin candles, costing 1s., is equal to 1·3083 lb. of sperm, hence—

1·00 : 1·31 : : 58·33 : : 76·41 candle hours from 1 lb.

12d.) 76·41
6·36 candle hours for 1d.

Sperm, Rape, and Whale Oils.—These oils were burned in two kinds of lamps, viz., 1*st*, a common flat wick lamp, such as is used in kitchens and country cottages; and 2*d*, an inch Argand lamp with glass chimney, such as is employed in larger rooms. The oils were of excellent quality of their class, and cost at retail prices, sperm oil, 9s. per gallon; colza or rape oil, 5s. per gallon; and whale oil, 4s. per gallon.

Sperm Oil in Flat Wick Lamps.—The consumpt of oil in 10 hours was 4·12 oz., which gives ·412 oz. per hour; and the

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that there is great room for improvement either in the manufacture or mode of combustion of these candles.

average light evolved was equal to 1·306 of standard sperm candles, or 156·72 grains of sperm. Calculating these results into one gallon of the sperm oil, viz., 160 oz., the following results were obtained :—

·412 : 160·000 : : 156·72 : : 60861 grains of sperm ;

or one gallon of sperm oil, consumed in the flat wick lamp, is equal to 60861 grains (8·69 lbs.) of sperm candles burned each at the rate of 120 grains per hour.

Rape Oil in Flat Wick Lamps.—In 10 hours 3·90 oz. of oil were consumed, and this quantity is equal to ·39 oz. per hour. The light yielded was equal to 1·05 standard sperm candles, or 126 grains of sperm. Carrying on these calculations to the gallon of rape oil, we get as follows :—

·39 : 160·00 : : 126 : : 51693 grains of sperm ;

or one gallon of the rape oil, burned in the flat wick lamp, evolves a light equal to that yielded by 51693 grains (7·39 lbs.) of sperm consumed in standard sperm candles.

Whale Oil in Flat Wick Lamp.—This oil burned at the rate of 3·50 oz. in 10 hours, which gives the hourly consumpt as ·35 oz. The light was equal to ·9 standard sperm candles, or 108 grains of sperm, and calculating this into the gallon of oil,

·35 : 160·00 : : 108 : : 49371 grains of sperm ;

or one gallon of the whale oil, consumed in the flat wick lamp, is equal to 49371 grains (7·05 lbs.) of sperm burned in standard sperm candles.

Sperm Oil in Argand Lamps.—The quantity of oil consumed in the Argand lamps was 2·30 oz. per hour, being fully five times the amount capable of being burned in the flat wick lamp. The light evolved was equal to 13 standard sperm candles, or 1560 grains of sperm consumed during the hour. Calculating into the gallon of oil, the following results were obtained :—

2·3 : 160·0 : : 1560 : : 108522 grains, or 15·5 lbs. of sperm.

The great increase in light when the sperm oil is consumed in Argand lamps, as compared with that obtained when the same oil is burned in flat wick lamps is due to the greater body of oil which is consumed at the same time, and the consequent larger flame yielded by the oil, which enable the oil gas to resist more completely the deleterious effects of the oxygen of the air in intermingling with, and attenuating down, the luminosity of the flame. The practical result is, therefore, that the greater the body of oil which can be consumed in a lamp at one and the same time, the higher the illuminating power which is obtained from a given volume of the oil. The same observation applies to other oils, such as rape and whale oils. These remarks will explain why it is that a gallon of sperm oil, weighing less than 9 lbs., can evolve a light in the Argand lamp, which is equal to that given by 15½ lbs. of sperm burned in candles consuming each only 120 grains per hour. The sperm oil is burning at the rate of 2·3 oz., or 1006·25 grains per hour, whilst the standard candle is only consuming 120 grains, or slightly more than ¼ oz. of sperm per hour.

Rape Oil in Argand Lamps.—The consumpt of oil was 2·133 oz. per hour, and the light evolved was equal to 11·33 standard sperm candles, or 1360 grains, which, when calculated into the gallon of the oil, gave

2·133 : 160·000 : : 1360 : : 102016 grains, or 14·57 lbs. of sperm.

Whale Oil in Argand Lamps.—This oil burned at the rate of 1·95 oz. per hour, and yielded the light of 9·8 standard sperm candles, or 1176 grains of sperm, and the results, calculated for the gallon of whale oil, yielded

1·95 : 160·00 : : 1176 : : 96492 grains, or 12·69 lbs. of sperm.

The photogenic results of the combustion of the fatty oils in flat wick and Argand lamps may be contrasted as follows :—

Flat Wick Lamps.

1 gallon of sperm oil	is equal in light-giving power to	8·69 lbs. of sperm candles.
1 „ rape „	„	7·39 „ „ „
1 „ whale „	„	7·05 „ „ „

Argand Lamps.

1 gallon of sperm oil	is equal in light-giving power to	15·5 lbs. of sperm candles.
1 " rape "	"	14·57 " " "
1 " whale "	"	12·69 " " "

These results may be calculated for the price of oil as well as for the quantity consumed, and may, as in the case of the candles, be reduced to the common standard of candle units for 1d.

Flat Wick Lamps.

A gallon of sperm oil costs 9s., and evolves a light equal to 8·69 lbs. of sperm; and each lb. of sperm candles, burning at the standard rate of 120 grains per hour for each candle, gives 58·33 candle hours; consequently,

Sperm Oil at 9s. per gallon.

$$\frac{58{\cdot}33 \times 8{\cdot}69}{108} = 4{\cdot}69 \text{ candle hours for 1d.}$$

A gallon of rape oil = 7·39 lbs. of sperm candles; therefore,

Rape Oil at 5s. per gallon.

$$\frac{58{\cdot}33 \times 7{\cdot}39}{60} = 7{\cdot}18 \text{ candle hours for 1d.}$$

A gallon of whale oil = 7·05 lbs. of sperm candles; therefore,

Whale Oil at 4s. per gallon.

$$\frac{58{\cdot}33 \times 7{\cdot}05}{48} = 8{\cdot}56 \text{ candle hours for 1d.}$$

Argand Lamps.

A gallon of sperm oil = 15·5 lbs. of sperm candles; therefore,

Sperm Oil at 9s. per gallon.

$$\frac{58{\cdot}33 \times 15{\cdot}5}{108} \quad 8{\cdot}99 \text{ candle hours for 1d.}$$

A gallon of rape oil = 14·57 lbs. of sperm candles; therefore,

Rape Oil at 5s. per gallon.

$$\frac{58{\cdot}33 \times 14{\cdot}57}{60} = 14{\cdot}17 \text{ candle hours for 1d.}$$

A gallon of whale oil = 12·69 lbs. of sperm candles; therefore,

Whale Oil at 4s. per gallon.

$$\frac{58{\cdot}33 \times 12{\cdot}69}{48} = 15{\cdot}42 \text{ candle hours for 1d.}$$

The following table will show at a glance the respective cost of the candles and the fatty oils, and the relative value of the light obtainable from a given price of each.

Tallow candles gives a light equal to	7·29	candle hours	for	1d.
Composite „ „ „	6·19	„	„	1d.
Paraffin „ „ „	6·36	„	„	1d.

Flat Wick Lamps.

Sperm oil gives a light equal to	4·69	candle hours	for	1d.
Rape „ „ „	7·18	„	„	1d.
Whale „ „ „	8·56	„	„	1d.

Argand Lamps.

Sperm oil gives a light equal to	8·99	candle hours	for	1d.
Rape „ „ „	14·17	„	„	1d.
Whale „ „ „	15·42	„	„	1d.

Paraffin Oil.—Five different lamps were employed in the experiments upon the illuminating power of paraffin oil, viz. :—

Small sized flat wick or cottage lamps.
Medium „ „ parlour lamps.
Large „ „ dining-room lamps.
Small Argand lamp with $\frac{3}{4}$-inch wick, and
Doty's Argand lamp with 1-inch wick.

The oils employed were manufactured by the Uphall Mineral Oil Co., and Young's Paraffin Oil Co., and were of excellent quality. The retail price was 2s. per gallon.

Small or Cottage Lamp.—The consumpt of oil in this lamp was $\frac{3}{4}$ oz. per hour, and the light evolved was equal to 6 standard sperm candles of 120 grains per hour, or 720 grains of sperm, which, calculated into the gallon of the paraffin oil, viz., 160 oz., gave the following results :—

·75 : 160·00 : : 720 : : 153600 grains, or 21·943 lbs. of sperm.

Medium or Parlour Lamp.—Consumed $1\frac{1}{8}$ oz. of paraffin oil per hour, and yielded a light equal to 9 standard sperm candles, or 1080 grains of sperm ; consequently, the photogenic value of one gallon of the oil was,

1·125 : 160·000 : : 1080 : : 153600 grains, or 21·943 lbs. of sperm.

Large or Dining-room Lamp.—Burned $1\frac{1}{2}$ oz. of paraffin oil per hour, with the illuminating value of 12 standard sperm candles, or 1440 grains of sperm, so that the gallon of oil was equal to

1·5 : 160·0 : : 1440 : : 153600 grains, or 21·943 lbs. of sperm.

Small Argand Lamp.—Consumed $1\frac{1}{8}$ oz. of paraffin oil every hour, and the illuminating power of the light evolved was equal to that obtained from 9 standard sperm candles, or 1080 grains of sperm, which, calculated into the gallon of oil, gave as follows:—

1·125 : 160·000 : : 1080 : : 153600 grains, or 21·943 lbs. of sperm.

Doty's Argand Lamp.—Burned a little more than 2 oz. (2·004) of paraffin oil per hour, and yielded a light equal to 19·83 standard sperm candles, or 2380 grains of sperm, which, when calculated for the gallon of oil, gave the following results:—

2·004 : 160·000 : : 2380 : : 190400 grains, or 27·2 lbs. of sperm.

The foregoing experimental observations demonstrate that the paraffin oil, when consumed in any of the flat wick lamps, or in the small Argand lamps, evolves the same amount of light from the gallon of the oil; and in this respect the paraffin oil differs materially from the vegetable and animal oils, which, as noticed previously, evolve proportionally more light when they are consumed in larger lamps, and in greater quantities at a time. On the other hand, the paraffin oil, when burned in the cottage lamp with a 6-candle power, yields as much light from the gallon as when consumed in larger lamps with a 9 or 12 candle power,—in other words, two 6-candle power paraffin lamps are equal in light-giving power to one 12-candle power lamp, and will consume exactly the same quantity of oil. The same remark applies to the small Argand lamp, which burns with a 9-candle power, and where for the consumpt of oil the light obtained from a given volume of the oil is neither greater nor less than what is yielded from any of the sizes of flat wick lamps. Employing, therefore, any of the common constructions or sizes of paraffin lamps, the oil evolves a light strictly proportionate to the amount of oil consumed at the time.

The Doty lamp, however, from the superiority of its construction, and the more perfect combustion of the oil, yields a higher photogenic value from the paraffin oil, in the proportion of $27\frac{1}{5}$ lbs. of sperm to 22 lbs. obtained as equivalent of light in the more common lamps.

The experimental results yielded by paraffin oil may be more readily contrasted with those obtained from candles and the animal and vegetable oils, by reducing the light evolved to the common standard of candle units for 1d., and which was adopted in the previous parts of this paper. Thus—

A gallon of the paraffin oil consumed in the cottage, parlour, or dining-room flat wick lamps, or in the small Argand lamp, yields a light equal to that capable of being obtained from 21·943 lbs. of sperm burned in standard candles at the rate of 120 grains per hour; and as each lb. of sperm candles gives 58·33 candle hours or units, it follows that the ordinary lamps yield with

Paraffin Oil at 2s. per gallon.

$$\frac{58{\cdot}33 \times 21{\cdot}943}{24} = 53{\cdot}33 \text{ candle hours for 1d.};$$

whilst if the paraffin oil is purchased at 1s. 6d. per gallon,

Paraffin Oil at 1s. 6d. per gallon.

$$\frac{58{\cdot}33 \times 21{\cdot}943}{18} = 71{\cdot}11 \text{ candle hours for 1d.}$$

When the results in the Doty lamps are worked out in the same way, it is found that—

Paraffin Oil at 2s. per gallon.

$$\frac{58{\cdot}33 \times 27{\cdot}2}{24} = 66{\cdot}10 \text{ candle hours for 1d.}$$

And when paraffin oil may be purchased at 1s. 6d. per gallon, the Doty results yield—

Paraffin Oil at 1s. 6d. per gallon.

$$\frac{58{\cdot}33 \times 27{\cdot}2}{18} = 88{\cdot}13 \text{ candle hours for 1d.}$$

The foregoing results show at once the great superiority and relative cheapness of paraffin oil as an illuminating agent over any vegetable or animal oils or fats consumed in candles or in lamps. The highest photogenic value obtainable from candles was from the common dip or tallow, which gave 7·29 candle hours for 1d., and the greatest illuminating power of the oils, considering the cost, was given by whale oil, which yielded 8·56 candle hours for 1d., when consumed in common lamps, and 15·42 candle hours for 1d., when burned in the best Argand lamps. With paraffin oil, however, even when consumed in the common flat wick lamps, there is a return of 53·33 candle hours for 1d.; and when burned in the Doty lamp, 66·10 candle hours for 1d.—the oil being taken at 2s. per gallon, or 71·11 candle hours for 1d., and 88·13 candle hours for 1d. when the oil is 1s. 6d. per gallon. But reckoning the paraffin oil at the higher price, there is a sudden passage from candles giving 7¼ candle hours for 1d., and fatty oils giving in common lamps 8½ candle hours for 1d., or in improved Argand lamps 15½ candle hours for 1d., to paraffin oil in common lamps yielding 53⅓ candle hours for 1d., and in Doty's improved lamp 66 candle hours for 1d. Paraffin oil, therefore, is from four to eight times cheaper as an illuminating agent than any of the candles or vegetable and animal oils employed for light-giving purposes.

Petroleum Oil.—Experiments were made with petroleum oil in the flat wick, Argand, and Doty lamps, and the results, taking cost into consideration, were on the average one-twelth less than those yielded by paraffin oil.

Coal Gas.—In fixing the illuminating value and cost of the coal gas, the comparatively low average price of 5s. per 1000 cubic feet was taken, and the photogenic power of the gas was based upon 28 standard sperm candles. There are many places in Scotland where the price of the gas is higher than 5s., and some towns where it is lower; and there are few towns where the standard of 28 candles is exceeded, whilst there are a number of places where it is less. The adoption of the standard of 28-candle gas at 5s. per 1000 cubic feet, is within rather than above the average cost of gas.

Knowing well that the form and size of burner employed in the consumption of the gas had a most material bearing upon the illuminating or photogenic power of such, it was arranged that all the trials should be made with the union or fish-tail burner (which yields a higher photogenic return with 28-candle gas, than any other form of burner), whilst the sizes of the burners were Nos. 5, 4, 3, 2, 1, and ·5. Care was taken to regulate the pressure, so that each burner should consume as nearly as possible the exact amount of gas in cubic feet, which the respective number indicated. Thus, No. 5 burner passed 5 cubic feet, No. 4 consumed 4 cubic feet, &c. The following short table gives the experimental results obtained in these trials :—

Jet.	Consumpt. of gas per hour.	Evolved light equal to
No. 5, . .	5 cubic feet.	28 standard sperm candles.
No. 4, . .	4 ,,	20·8 ,, ,,
No. 3, . .	3 ,,	13·8 ,, ,,
No. 2, . .	2 ,,	7·8 ,, ,,
No. 1, . .	1 ,,	3 ,, ,,
No. 0·5, . .	½ ,,	1 ,, ,,

In glancing at these results, there is manifestly a great loss of light as the size of the jet is diminished, and probably the difference will be better observed if the data given above be calculated into the light in standard sperm candles, capable of being obtained from a given volume—say, 5 cubic feet—of the gas transmitted through the various sized burners. Thus, 5 cubic feet of gas consumed at a

No. 5 jet	evolves	a light equal to	28	standard	sperm candles.
No. 4	,,	,,	26	,,	,,
No. 3	,,	,,	23	,,	,,
No. 2	,,	,,	19½	,,	,,
No. 1	,,	,,	15	,,	,,
No. 0·5	,,	,,	10	,,	,,

So that we lose 2 candles going from No. 5 to No. 4, or one-fourteenth of the whole light; and between No. 5 and No. 2, there is a loss of one-third of the illuminating power; whilst between No. 5 and No. 0·5, there is a disappearance of nearly two-thirds of the whole light.

The results given were the best which could be obtained during the consumption of the 28-candle gas in the various jets, with well regulated pressure, and they are higher than those given in other trials, where the pressure was purposely allowed to be excessive. Indeed, the loss in illuminating power when the gas is burned with undue pressure is large, and may be observed from the following experimental data, calculated for 5 cubic feet of gas.

Fish-tail or union jet.	Under full pressure. Consumpt. in cubic ft.	Under full pressure. Candle power for 5 cubic ft.	Under reduced pressure. Consumpt. in cubic ft.	Under reduced pressure. Candle power for 5 cubic ft.
No. 5, . .	4·99	28·14	4·99	28·14
No. 4, . .	4·94	24·02	4	25·98
No. 3, . .	4·36	20·48	3	22·89
No. 2, . .	3·14	15·16	2	19·46
No. 1, . .	2·49	10·94	1	14·95
No. 0·5, . .	1·68	7·04	0·5	10·12

It will thus be observed, that there is a serious loss of illuminating power when the gas is consumed under undue pressure; there being in the case of No. 2 burner, which is the more common size used in households, a difference of fully 4-candle power between the light obtained from 5 cubic feet burned at the proper pressure, and that given under excessive pressure.

Taking, however, the best results obtained from the 28-candle coal gas during its combustion from the various sized jets under proper pressures, and calculating the light evolved from such jet, for every 5 cubic feet consumed, into standard candle hours or units for 1d., the following results are obtained:—

No. 5 *jet* consumes 5 cubic feet per hour, and evolves a light equal to 28 standard sperm candles; consequently, the gas, in being burned from this jet, gives

Coal Gas, at 5s. per 1000 cubic feet.

5)1000
200
28
60)5600
93·33 candle hours for 1d.

No. 4 *jet* consumes 4 cubic feet per hour, and gives a light equal to 26 standard sperm candles for every 5 cubic feet consumed; consequently,

Coal Gas, at 5s. per 1000 cubic feet.

5)1000
200
26
60)5200
86·66 candle hours for 1d.

No. 3 *jet* burns 3 cubic feet per hour, and yields a light equal to 23-candle power for every 5 cubic feet consumed; therefore,

Coal Gas, at 5s. per 1000 cubic feet.

$$\begin{array}{r} 5\overline{)1000} \\ \hline 200 \\ 23 \\ \hline 60\overline{)4600} \\ \hline 76{\cdot}66 \end{array}$$ candle hours for 1d.

No. 2 *jet* consumes 2 cubic feet of gas, and evolves a light equal to 19½ standard sperm candles for every 5 cubic feet burned; hence,

Coal Gas, at 5s. per 1000 cubit feet.

$$\begin{array}{r} 5\overline{)1000} \\ \hline 200 \\ 19\tfrac{1}{2} \\ \hline 60\overline{)3900} \\ \hline 65 \end{array}$$ candle hours for 1d.

No. 1 *jet* burns 1 cubic foot per hour, with the photogenic power of 15 standard sperm candles for every 5 cubic feet consumed; therefore,

Coal Gas, at 5s. per 1000 cubic feet.

$$\begin{array}{r} 5\overline{)1000} \\ \hline 200 \\ 15 \\ \hline 60\overline{)3000} \\ \hline 50 \end{array}$$ candle hours for 1d.

No. 0·5 *jet,* with a consumpt of half a cubic foot per hour, evolves a light equal to 10-candle power for every 5 cubic feet; consequently,

Coal Gas, at 5s. per 1000 cubic feet.

$$\begin{array}{r} 5\overline{)1000} \\ \hline 200 \\ 10 \\ \hline 60\overline{)2000} \\ \hline 33{\cdot}33 \end{array}$$ candle hours for 1d.

These results may be tabulated as follows:—

For every 5 cubic feet of Gas consumed.

No. 5	jet	gives a light equal to	93·33	candle hours	for	1d.
No. 4	,,	,,	86·66	,,	,,	1d.
No. 3	,,	,,	76·66	,,	,,	1d.
No. 2	,,	,,	65	,,	,,	1d.
No. 1	,,	,,	50	,,	,,	1d.
No. 0·5	,,	,,	33·33	,,	,,	1d.

The foregoing experimental data prove that where much light is required, coal gas is the cheapest of all the illuminants, provided the gas can be obtained of the quality of 28 candles, and at a cost not exceeding 5s. per 1000 cubic feet, and is burned from the larger sized jets. Under these circumstances, and paraffin oil at 2s. per gallon, the gas gives 93⅓ candle hours in No. 5 jet, 81⅔ candle hours in No. 4 jet, and 76⅔ candle hours or units in No. 3 jet; whilst the paraffin oil in Doty's lamp yields 66 candle hours or units for the 1d.; but the gas only gives 65 candle hours in No. 2 jet, 50 candle hours in No. 1 jet, and 33⅓ candle hours in No. 0·5 jet for the 1d. Consequently, whilst the gas is a cheaper illuminating agent in the three larger sized burners or jets, the paraffin oil is cheaper when the gas is consumed in the three smaller jets.

Summary of Results.

The following table will exhibit at a glance the relative illuminating power and photogenic value of the different luminants, taking each as they were burned:—

½d. dip or tallow candle	gives	3	hours of	1¼	candle power	for	½d.
¾d. „ „	„	4½	„	1¼	„	„	¾d.
1d. „ „	„	6	„	1¼	„	„	1d.
Composite candle (average)	„	5½	„	1·1	„	„	1d.
Paraffin candle (average)	„	4·27	„	1·49	„	„	1d.

Common Flat Wick Lamps.

Sperm oil	gives	3·59	hours of	1·306	candle power	for	1d.
Rape oil	„	6·84	„	1·05	„	„	1d.
Whale oil	„	9·5	„	·9	„	„	1d.

Argand Lamps.

Sperm oil	gives	·69	hours of	13	candle power	for	1d.
Rape oil	„	1·25	„	11·33	„	„	1d.
Whale oil	„	1·57	„	9·8	„	„	1d.

Cottage Lamp.

Paraffin oil, at 2s. per gallon, gives 9 hours of 6-candle power for 1d.

Parlour Lamp.

Paraffin oil, at 2s. per gallon, gives 6 hours of 9-candle power for 1d.

Dining-Room Lamp.

Paraffin oil, at 2s. per gallon, gives 4½ hours of 12-candle power for 1d.

$\frac{3}{4}$-inch Argand Lamp.

Paraffin oil, at 2s. per gallon, gives 6 hours of 9-candle power for 1d.

Doty's Lamp.

Paraffin oil, at 2s. per gallon, gives 6 hours of $11\frac{1}{3}$-candle power for 1d.

No. 5 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives $3\frac{1}{3}$ hours of 28-candle power for 1d.

No. 4 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 4·16 hours of 20·8-candle power for 1d.

No. 3 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 5·55 hours of 13·8-candle power for 1d.

No. 2 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 8·33 hours of 7·8-candle power for 1d.

No. 1 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 16·66 hours of 3-candle power for 1d.

No. 0·5 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives $33\frac{1}{3}$ hours of 1-candle power for 1d.

Cottage Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 12 hours of 6-candle power for 1d.

Parlour Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 8 hours of 9-candle power for 1d.

Dining-Room Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 6 hours of 12-candle power for 1d.

$\frac{3}{4}$-inch Argand Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 8 hours of 9-candle power for 1d.

Doty's Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 8 hours of $11\frac{1}{3}$-candle power for 1d.

From the foregoing table it follows, that a cottager will consume a 1d. tallow candle in 6 hours, and will only get $1\frac{1}{4}$-candle power of light; whilst, if he purchases paraffin oil at 2s. per gallon, he will obtain, for every pennyworth of paraffin oil consumed in a common small lamp, 9 hours light of 6 candle power. The most economical of candles, therefore, is beat by paraffin oil so completely, that the latter will burn half again as long a time and give nearly five times the amount of light during the whole period. A similar remark applies to whale oil which is the most economical fatty oil, and a 1d. worth of which will burn for 9½ hours with less than a candle power, whilst the small paraffin lamp will practically burn as long and give six times the light for the same sum of money. Not only so, but if the cottager is content with the light of a single candle, and will reduce the size of the flame of the paraffin lamp by simply screwing down the wick, he may burn the paraffin oil with a single candle power, and spread his 1d. worth of oil over 54 hours, whereas his 1d. candle will burn out in 6 hours, and he cannot stop the rapidity of its combustion.

In contrasting the paraffin oil with coal gas, it will be found that paraffin oil is cheaper than gas in the No. 0·5 jet, as the following calculations will show:—

Paraffin cottage lamp,—9 hours of 6 candles, equal to reduced flame of 54 hours of 1 candle.	No. 0·5 jet coal gas gives 33⅓ hours of 1 candle.

The same remark applies to No. 1 jet, where

Paraffin cottage lamp,—9 hours of 6 candles, equal to reduced flame of 18 hours of 3 candles.	No. 1 jet coal gas gives 16·66 hours of 3 candles.

When the gas is burned from No. 2 jet, and the paraffin oil is consumed in a common parlour lamp, the gas beats the paraffin, for

Paraffin parlour lamp,—6 hours of 9 candles, equal to reduced flame of 6·92 hours of 7·8 candles.	No. 2 jet coal gas gives 8·33 hours of 7·8 candles.

But when the paraffin oil is consumed in Doty's lamps the two luminants are practically equal, for

Paraffin Doty's lamp,—6 hours of 11⅓ candles, equal to reduced flame, of 8·71 hours of 7·8 candles.	No. 2 jet coal gas gives 8·33 hours of 7·8 candles.

With coal gas at 5s. per 1000 cubic feet and 28 candle power the gas is cheaper than paraffin oil when the gas is consumed in the No. 3 jet, but if the gas cost 5s. 8d. per 1000 cubic feet, the two illuminating agents are equal; thus—

2 reduced Doty lamps will yield 4·92 hours of 13·8 candles.	No. 3 jet coal gas gives 5·55 hours of 13·8 candles (at 5s.), but 4·90 hours of 13·8 candles, when the gas costs 5s. 8d. per 1000 cubic feet.

The paraffin oil, and gas from No. 4 jet only become equal when the gas costs 6s. 6d. per 1000 cubic feet; thus—

2 reduced Doty lamps afford the light of 3·26 hours of 20·8 candles.	No. 4 jet coal gas gives 4·16 hours of 20·8 candles (at 5s.), but 3·20 hours of 20·8 candles when the gas costs 6s. 6d. per 1000 cubic feet.

The gas is superior to paraffin when the No. 5 jet is used, until the price of the gas reaches 7s. per 1000 cubic feet; thus—

3 reduced Doty lamps afford the light of 2·42 hours of 28 candles.	No. 5 jet coal gas gives $3\frac{1}{3}$ hours of 28 candles (at 5s.), but 3·28 hours of 28 candles when the gas costs 7s. per 1000 cubic feet.

The above comparisons are drawn out on the basis of the photogenic value of the gas and paraffin oil for 1d., and on the assumption that the coal gas is of 28 candle power when consumed at the rate of 5 cubic feet per hour from a No. 5 fishtail or union burner; but in many places the gas does not come up to this standard, and granting that the gas can be purchased at 5s. per 1000 cubic feet, and the paraffin oil at 2s. per gallon, both luminants will still remain equal when the larger gas-jets are used if the quality of the gas comes below 28 candles. Thus, paraffin oil is as cheap as gas, when the latter is consumed at No. 3 jet, if the gas cost 5s. per 1000 cubic feet, and is of 24·70 candle power, or at No. 4 jet, when the same priced gas is of 21·53 candle power, or at No. 5 jet, when the 5s. gas is of 20 candle power.

The great convenience attendant on the use of coal gas, and the trouble connected with oil lamps, must always commend the gas for general use, wherever it can be obtained at reasonable cost, but where the charge is exorbitant, the paraffin oil will be found useful and serviceable in the illumination of not only small but of large apartments.

These two luminants are not antagonistic to each other in their chemical construction, or in the economical and photogenic results obtained during their combustion; and considering that the refined paraffin oil, costing 2s. per gallon, becomes almost equal to gas when the ordinary sized jets are used, the question may be asked, if it be not possible to experiment with the crude paraffin oil in our gas retorts, so as to get cheap illuminating gas from it. I know that great difficulties are in the way of obtaining permanent gas from paraffin oil, but considering that crude paraffin oil can be purchased at a sixth of the price of the refined oil, it appears probable that if some method of distinctive distillation could be devised and followed out, where the crude oil could be broken up into gas which would not condense in the gasometers or pipes, a great and important step would be taken in the advancement of the manufacture of coal gas. Cannel coals are not so cheap as they were, and the shale beds are of vast extent and extremely prolific of oil; so that I cannot resist the thought that the future of gas making will lie in the discovery of a practical process for transmitting crude shale oil into our gas retorts, and obtaining therefrom a permanent gas of high photogenic or illuminating power.