

ANALYSIS REPORT
ON THE
GRANGER WATER GAS

BY
DR. GIDEON E. MOORE,
ANALYTICAL CHEMIST,
NEW YORK.

TOGETHER WITH A BRIEF
DESCRIPTION OF THE PROCESS AND
APPARATUS.



A. O. GRANGER & CO.,
22 AND 24 N. FOURTH ST., AND 400, 402 AND 404 COMMERCE ST.,
PHILADELPHIA.

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INDEX.

DESCRIPTION OF THE WORKS AND METHOD OF OPERATING,	7
Chief point of superiority,	13
Cost of the Gas,	15

REPORT OF DR. GIDEON E. MOORE, .	17
Principle upon which the Granger system is based,	18
Method of analyses and apparatus employed, .	19
I. COMPOSITION OF THE GAS,	20
Preliminary analysis of non-luminous Gas at Worcester,	21
Preliminary analysis of Holder Gas, Worcester and Lake,	22
DETERMINATION OF CHARACTER OF HEAVY HYDRO-CARBONS,	23
1st. Examination of Tar,	24
2d. Examination of products obtained by action of Bromine on Water Gas,	24
3d. Examination of products obtained by solu- tion in absolute Alcohol,	26
Results of above determination,	26

QUANTITATIVE PROPORTIONS OF ILLUMINATING HYDRO-CARBONS IN GAS FROM CONDENSER AT LAKE,	27
A. Preliminary analysis,	27
B. Eudometric analysis,	28
C. Complete analysis,	29
Complete analysis of Holder Gas at Worcester and Lake,	29
Analysis of Coal Gas for comparison with above,	30
II. CALORIFIC VALUE OF THE GAS,	31
CALORIFIC EQUIVALENT. DEFINITION OF THE TERM,	31
Method of determination,	32
Table of Calorific Equivalents of Constituents of Illuminating Gas,	33
Calorific Equivalent of Granger Gas at Worcester,	33
Calorific Equivalent of Granger Gas at Lake,	35
Calorific Equivalent of Coal Gas at Heidelberg,	36
Results compared,	37
FLAME-TEMPERATURE. DEFINITION OF THE TERM,	37
Manner of investigating,	39
Flame-Temperature of Granger Gas at Worcester,	40
Flame-Temperature of Granger Gas at Lake,	41
Flame-Temperature of Coal Gas at Heidelberg,	43
Comparison of results,	44
III. PHOTOMETRY OF THE GAS,	45
Candle power of the Gas at Worcester,	46
Candle power of the Gas at Lake,	46
Candle power regulated at will,	46

Quality of the light,	46
INFLUENCE OF EXTREME COLD ON ILLUMI- NATING POWER,	46
Freezing test, Granger Gas at Worcester,	48
Freezing test, Coal Gas at Worcester,	48
Reasons why Water Gas should resist cold better than Coal Gas,	49
RELATIONS OF CHEMICAL COMPOSITION TO ILLUMINATING POWER,	49
IV. DENSITY OF THE GAS,	55
Water Gas at Worcester,	55
Water Gas at Lake,	55
Coal Gas at Heidelberg,	55
V. PURITY OF THE GAS,	56
Quantitative determination of impurities, . . .	56
The Granger Gas of the highest degree of purity,	57
VI. SUMMARY OF RESULTS,	57
Uniformity in composition as compared with Coal Gas,	58
It will not stratify in the Holder,	59
Distinctive feature of the Granger process, . .	60
Table II. Results of analysis of Granger Gas at Worcester and Lake, and of Coal Gas at Heidelberg,	63
Table I. Analyses of the Coal Gas of 27 English and Scotch companies,	64-65

THE cut at the back of this pamphlet gives a very fair idea of the appearance of our improved Water Gas apparatus, and the following brief description of the method of operating the works is given to make clear the subject in connection with Dr. Moore's report on the Analysis of the Gas.

How the works are operated.

A fire of anthracite coal or coke being started in Generator A, an air blast from the Blower B is admitted below the grate bars of the Generator, by opening the valve C, and the products of partial combustion, (Carbonic Oxide and Nitrogen) pass to the Superheater D

Blowing up the heat.

through the flue E, and meet another blast of air by opening the valve F. Complete combustion takes place, and the heat evolved is absorbed by the fire brick with which the Superheater D is filled, and the products of complete combustion (Carbonic Acid and Nitrogen) pass off to the open air through the Stack-valve G.

Ready to
make Gas.

When the Superheater is hot enough, which can be seen by looking through the sight cock H, the air valves F and C are closed, and the lever I is pulled downwards, with the simultaneous effect of closing the stack-valve G, at top of Superheater, and removing to the left the hood seal J, thus uncovering the upper end of the gas pipe K, which extends into the seal chamber Y.

Steam
turned on.

Steam is now admitted under the grate bars of the Generator, by turning the index lever L, which controls the steam valve below. The steam in passing through the bed of coal is decomposed, forming Hydrogen and Carbonic Oxide, which gases burn with great heat, but no luminosity.

Naphtha or crude petroleum is now sprayed Oil admitted. in the form of a mist into the base of the Superheater D, through the spraying injector M, being first forced through the oil heater N, by the plunger steam pump O. A very thorough incorporation of the particles of oil with the hot Water Gas, as it comes through the flue E, takes place and the oil in this finely divided state is vaporized by the heat of the Gas from the Generator, and the mixture passes upwards through the hot fire brick in the Superheater D, with the result of producing a perfectly fixed Illuminating Gas, which passes off through the pipe P, into the seal chamber Y, and downwards from it through the pipe K into the Scrubber Q, where it passes through wrought iron perforated plates, placed both vertically and at an angle, over which warm water from the Condenser flows, and is thus thoroughly scrubbed. The Gas then passes through the pipe R, to the Condenser, and downwards through the tubes S, which are surrounded with water, and off to the lime purifiers through the exit pipe T.

Time blowing and making Gas.

The process of blowing up the heat takes from six to ten minutes, and the time of making a run of Gas, *i. e.*, with steam and oil on, from ten to fifteen minutes. The process is thus an alternate one, although several runs are made from one coaling of the Generator.

Short runs the best.

We prefer short runs, and make our bed of Coal in the Generator of large area and shallow depth to accomplish this purpose, as we thus make all our Gas at high heats, and avoid the deleterious products resulting from long runs and low heats.

Checker brick work condemned.

The usual practice is to fill the Superheater or fixing chamber D, with checker brick work, but experience shows that the flat surfaces presented by each layer of bricks afford a lodging place for cinders, etc., coming from the Generator, and these cinders are soon burned into a slag, and in a short time the Superheater is clogged up and the bricks require to be taken out and others put in their places, and this is often a difficult job, as the bricks, cinders, etc., are found run together in a solid mass.

Our form of fire brick filling is that of a cylinder about 6 inches high, with a conical hole through it, larger at the upper end than at the lower. These bricks are placed one on top of the other, as shown in the cut, forming a series of straight holes from top to bottom, and yet the Gas in passing through these bricks, by reason of the conical shape of the interior hole, is given a whirling or eddying motion, thus bringing it into contact with the hot surfaces and perfectly fixing the Gas and yet preserving a straight hole from top to bottom, and offering no flat surface anywhere for the lodgment of cinders or other matter mechanically suspended in the Gas. While being in every way as effective as the old form, we claim that our conical bricks will last many years longer than the best form of checker brick work ever devised.

Improved conical filling bricks for Superheater.

We call attention to our Seal Chamber Y, in which the Hood Seal J effectually seals the pipe K, while blowing up the heat, and when making Gas permits the Gas to pass to the Scrubber without being forced through a body

Improved open seal.

of water, which latter is the cause of producing considerable tar, and also of increasing the back pressure on the works, and of causing the Gas to be delivered in a pulsating movement with the effect of blowing out the seals in various parts of the works. Our Gas is delivered at a nearly uniform pressure, and entirely avoids these objectionable features.

Piping of
Condensers.

Cold water is admitted to the bottom of the Condenser, and the warm water overflows from the top to the Scrubber and Seal Chamber; the Gas thus comes in contact first with the warmest part of the Condenser, and leaves it at the coolest part, and no matter how many Condensers are used, we pipe them in the same way, so that there is a gradual and uniform reduction of the temperature of the Gas.

The Pressure Gauges X give a convenient index of the pressure in various parts of the works.

Shaking
Grate for
Generator.

We have a very complete shaking grate operated from the working floor by the lever U, and the ashes fall into the inverted conical bottom V, where they may be allowed to col-

lect, and only require dumping once or twice a day, when the lid W is opened by operating a convenient lever and the ashes dropped into the buggy, where they are sprinkled with water and removed with but little of the ordinary labor and dirt attendant upon cleaning a Generator fire.

While making strong claims as to the convenience in operating our works, and their mechanical appearance and durability, yet we have also studied simplicity, and on this important point claim to be without any rival.

Simplicity.

That our Gas is perfectly fixed, and has ability to resist cold without condensing, far in excess of that of the best Coal Gas, is clearly shown by the freezing tests to which the Gas was submitted by Dr. Moore, as detailed on pages 46, 47 and 48.

Fixed Gas.

The main point upon which we base our claim of superiority, is our method of Carburetting the Gas. Where the Oil is allowed to run in as a liquid on top of the bed of Coal, it is apparent that, if the Coal is too hot, lamp black will be the immediate result, and if it is

Superiority
of Spraying
the Oil.

not hot enough, the Oil will not only not be vaporized, but will actually run through the fire, and be found as free Oil in the ash pit, and will produce considerable tar. In either case, a loss of material is the result, besides annoying stoppages in the works. We spray the hot Oil through the Injector M in the form of a very fine mist, right into the hot Water Gas, as it issues from the Generator through the flue E, and it is completely vaporized by the heat of the Gas, without the formation of either lamp black or tar, and we can produce the maximum result, no matter whether the top of the bed of Coal in the Generator be perfectly black, or at an intense white heat. We thus utilize all the Oil, and attain the highest degree of economy, and the candle power of the Gas is under perfect control of the Gas maker, so that anything from a blue light to 30 candle power, can easily be produced at will.

We have many minor improvements of value that have suggested themselves in the course of long years of experience, gained in building

over 70 sets of Water Gas works, and we may add that, in our largest size works, we can produce 18 to 20 candle power Gas from 45 lbs. of Coal and 3.75 galls. naphtha per thousand feet, and over 100,000 feet per day per man.

Cost of the
Gas.

We believe in *Water Gas on its merits*, and solicit correspondence.

A. O. GRANGER & CO., ENGINEERS,
Patentees and Builders,
22 AND 24 NORTH FOURTH ST.,
PHILADELPHIA, PA.

A. O. GRANGER.

JOS. H. COLLINS, JR.

ANALYTICAL LABORATORY OF
DR. GIDEON E. MOORE,
69 Liberty Street,
NEW YORK, June 20th, 1885.

Messrs. A. O. GRANGER & Co.,
Engineers and Contractors,
22 and 24 North Fourth St.,
Philadelphia.

GENTLEMEN :

I have the honor to submit the following report of the results of my analyses of the Gas made in your Water Gas apparatus at the works at Lake (Chicago), Ill., and Worcester, Mass.

Permit me, in this place, to express my grateful appreciation of the unvarying kindness and courtesy with which Mr. J. H. Rollins, Agent of the Worcester Co., and Mr. H. D. Bannister, Superintendent of the Lake Co., have extended every assistance and facility in their power during the progress of the work.

Very respectfully,

GIDEON E. MOORE, Ph. D.

REPORT.

The principle upon which the Granger system of manufacture of Illuminating Water Gas is based consists, first, in generating ordinary "Water Gas" by passing steam through incandescent anthracite coal or coke, then diffusing through the hot Gas as it issues from the Generator petroleum naphtha or other hydro-carbon substances by spraying them under mechanical pressure, and finally causing the mixture to pass through a Superheater previously heated to redness, wherein by the heat of the incandescent fire-brick work, with which the Superheater is filled, the hydro-carbon vapors are converted into permanent Gases and the transformation of the Water Gas into Illuminating Gas is completed. From the Superheater the Gas then passes through the Scrubber where it is washed with a spray of warm water, and then through the Condenser, wherein the Gas is cooled and any liquid or solid impurities that it may contain are removed; finally it passes through the lime purifiers, wherein the purifi-

cation is completed and the Gas made ready for delivery into the holder and for distribution.

The material for the following analyses was collected by myself at the works at Lake, Cook Co., Ill., and at Worcester, Mass. At the Lake works the older form of the Granger plant was in use. In this case the hydro-carbon (naphtha at 72° Bé) was sprayed under mechanical pressure into the base of the Superheater, meeting there the current of hot Gases from the Generator and being vaporized by the heat of the latter passed therewith as vapor into the Superheater proper. In the works at Worcester the naphtha was forced under pressure through a large coil heated by steam to about 350° F., and was then sprayed into the base of the Superheater. Except in the particulars above mentioned, the Gas at both places was made under similar conditions and from similar materials.

The samples illustrating the composition of the Gas were collected by causing the Gas to pass in a rapid current through a series of glass tubes, drawn out at each end and connected

by short pieces of rubber tubing, until the air had been expelled, and then sealing each of the tubes by melting the ends together with the blow-pipe flame.

The analyses were made in this laboratory, chiefly in the apparatus of Prof. Walther Hempel* for Gas analysis *over mercury*, although some of the more important determinations were made by the methods of Bunsen, and in the case of duplicates invariably with closely accordant results. The photometric tests were made with a very exact and complete Bunsen-Letheby standard 60 inch photometer, made by W. W. Goodwin & Co., of Philadelphia. The density determinations were made by means of a Bunsen-Schilling diffusion apparatus by the same makers.

I. COMPOSITION OF THE GAS.

The constituents of all Illuminating Gases may be arranged in three classes, namely:

* Neue methode zur analyse der Gase von Dr. Walther Hempel
—Braunschweig—F. Vieweg u. Sohn, 1880. S. 127.

1. Heavy hydro-carbons or illuminants proper.

2. Combustible diluents.

3. Incombustible diluents or impurities.

The quality of the Gas as a source of light or heat is closely dependent upon the nature and relative proportions of the individual members of the two classes first named. The proportion of the constituents of the third class should of course be reduced as far as possible.

In my study of the composition of the Granger Gas I have first determined the proportion of the heavy hydro-carbons in each sample, together with the qualitative nature and proportional amount of the several combustible and incombustible diluents, restricting the determinations of the nature and amount of the individual heavy hydro-carbons to the complete analysis of the purified holder Gas.

The results of the analyses were as follows, viz. :

Gas from Generator, Worcester, Mass.

The composition of the non-luminous Water Gas from the Generator of the Granger appa-

ratus is shown in the following analysis, which was made on a sample taken at the commencement of the run.

Nitrogen	4.69
Carbonic Acid	3.47
Oxygen	0.00
Heavy Hydro-Carbons	0.00
Carbonic Oxide	36.80
Marsh Gas	2.16
Hydrogen	52.88
	<hr/>
	100.00

Gas from Holder.

	WORCESTER. LAKE.	
Nitrogen	2.64	3.85
Carbonic Acid	0.14	0.30
Oxygen	0.06	0.01
Heavy Hydro-Carbons	12.82	15.43
Carbonic Oxide	28.26	23.58
Marsh Gas	18.88	20.95
Hydrogen	37.20	35.88
	<hr/>	<hr/>
	100.00	100.00

From the foregoing analyses it will be seen that the combustible diluents in the Granger Gas contain, besides the usual constituents of the ordinary non-luminous Water Gas a large proportion of Marsh Gas (Methane) and it is interesting to note that the ratio of the percentage of the heavy hydro-carbons to that of

the Marsh Gas is in both the Worcester and the Lake samples approximately as 2 : 3.

Determination of the Character of the Heavy Hydro-Carbons.

In the foregoing analyses I have stated the whole amount of the heavy hydro-carbons, as such, without entering into the details of the character and relative amounts of the different hydro-carbons of this class contained in the Gas. The specific nature of these must always be determined by special tests before the methods of eudiometric analysis can be applied for their quantitative determination.

The methods of investigation applied for the determination of this question were as follows :

- 1st. Examination of the Tar,
- 2d. Examination of the products obtained by the action of bromine on the Gas.
- 3d. Examination of the products dissolved from the Gas on passing the latter through absolute alcohol.

Examination of the Tar.

Owing to the small amount of the tar formed in the Granger process, great difficulty was experienced in obtaining sufficient for examination. A sample of about half a pint of thin liquid tar was finally obtained and subjected to a fractional distillation. By repeated fractionation a product boiling between 80° and 85° Centigrade and amounting to 36.32 per cent. of the weight of the tar was finally obtained. This product was found to consist chiefly of Benzole $C_6 H_6$. Other products were also obtained corresponding in their boiling points to the higher homologues of Benzole. Lack of time, however, and the small size of the sample prevented a more thorough study of the last-named products. But 12 per cent. of the tar possessed a higher boiling point than 311 . Fah.

Examination of products obtained by the action of Bromine on Water Gas.

Illuminating Water Gas, prepared as in the Granger process by passing a mixture of naphtha vapor and non-illuminating Water Gas

through a hot Superheater, was passed in a slow current through Bromine contained in a Pettenkofer's tube, until the Bromine had become of a light yellowish or brownish color. The product was washed with dilute caustic potash solution, dried over fused chloride of calcium and submitted to fractional distillation. It yielded to this treatment 80 per cent. of Bromide of Ethylene, $C_2 H_4 Br_2$, a small proportion of Bromide of Methylene (due to the action of Bromine on Marsh Gas) and about 12 per cent. of a residue that was not volatile without decomposition but when heated evolved hydrobromic acid, and on cooling deposited crystals, which, after purification by pressure between absorbent paper and recrystallization from boiling naphtha, yielded a product consisting of colorless needles and which, on examination proved to be Tetra-bromide of Naphthaline. The pure product thus obtained amounted to about 1 per cent. of the weight of the mixed Bromides. None of the higher members of the Ethylene series (Propylene,

Butylene, etc.) were present in recognizable proportions.

Examination of products obtained by solution in absolute alcohol.

A slow current of the dry Gas was allowed to pass through absolute alcohol, several weeks being consumed in the operation. On mixing the alcohol with an excess of water a yellowish mobile liquid separated, which after being collected, dried over fused calcium chloride and subjected to a series of fractional distillations, yielded a product boiling between 90° and 100° C., and amounting to about 70 per cent. of the weight originally taken. This substance was found to consist chiefly of Benzole ($C_6 H_6$).

The foregoing results show that the heavy hydro-carbons produced by subjecting naphtha vapor mixed with non-illuminating Water Gas to high temperatures, as in the Granger process, consist essentially of Ethylene and Benzole vapor, with a small proportion of naphthaline vapor, the latter being too insignificant in

quantity to materially affect the character of the Gas.

In the study of the quantitative proportions in which these illuminating hydro-carbons occur in the Granger Gas, I have commenced with a sample taken from the Condenser at Lake near the close of the run, and hence exceptionally rich in heavy hydro-carbons. The preliminary analysis of this sample shows the composition to be:

Nitrogen,	4.03
Carbonic Acid,	2.66
Oxygen,	0.00
Heavy Hydro-Carbons,	20.36
Carbonic Oxide,	17.31
Marsh Gas,	26.73
Hydrogen,	28.91
	<hr/>
	100.00

This Gas was subjected to eudiometric analysis both before and after removing the heavy hydro-carbons by absorption with fuming sulphuric acid. The figures for the contraction by explosion, volume of Carbonic Acid formed, and volume of aqueous vapor, due to the heavy

hydro-carbons were determined in the usual manner by deducting the results of the last-named analysis from those of the one first mentioned.

The data so obtained were as follows:

Volume of Heavy Hydro-Carbons,	20.36
Contraction on exploding with Oxygen and Air.	40 40
Carbonic Acid formed,	45.40
Aqueous Vapor formed	41.92

These data in connection with the results of the qualitative examination above mentioned lead to the following figures for the composition of the heavy hydrocarbons in question.

Ethylene,	19.19 vols.
Benzole Vapor,	1.17 "
	—————
	20.36 vols.

The theoretical volumes of contraction, Carbonic Acid, and Aqueous Vapor, resulting from the explosion of a Gas of this composition would be:

Original Volume,	20.36
Contraction,	41.30
Carbonic Acid,	45.40
Aqueous Vapor,	41.89

The close accordance of these figures with those obtained in practice confirm the conclusions as to the qualitative nature of the

heavy hydro-carbons based upon the experiments for their isolation and identification previously described.

We have therefore for the composition of the Gas in question the following figures:

Gas from Condenser at Lake.

Nitrogen,	4.03
Carbonic Acid,	2.66
Oxygen,	0.00
Ethylene,	19.19
Benzole Vapor,	1.17
Carbonic Oxide,	17.31
Marsh Gas,	26.73
Hydrogen,	28.91
	100.00

By similar methods of investigation the composition of the Gas from the holders at Worcester and Lake was found to be as follows:

Gas from Holder.

	WORCESTER.	LAKE.
Nitrogen,	2.64	3.85
Carbonic Acid,	0.14	0.30
Oxygen,	0.06	0.01
Ethylene,	11.29	12.80
Benzole Vapor,	1.53	2.63
Carbonic Oxide,	28.26	23.58
Marsh Gas,	18.88	20.95
Hydrogen,	37.20	35.88
	100.00	100.00

For the purpose of comparison I append the following analysis of the Coal Gas of the town of Heidelberg, Germany, made at the laboratory of Bunsen, by Messrs. Kinnicutt and Treadwell :*

Heidelberg Coal Gas.

Nitrogen,	2.15
Carbonic Acid,	3.01
Oxygen,	0.65
Ethylene,	2.55
Propylene,	1.21
Benzole Vapor,	1.33
Carbonic Oxide,	8.88
Marsh Gas,	34.02
Hydrogen,	46.20
	100.00

On comparing this analysis of what may be accepted as a typical Coal Gas with the Granger Gas it will be seen that the latter contains ethylene as the sole representative of the olefiant series. In other respects the only difference is in the relative proportions of the other constituents contained therein.

*Gasometrische Methoden, von R. Bunsen, 2te Aufl. S. 142.

II. CALORIFIC VALUE OF THE GAS.

1. Calorific equivalent.

The theoretical calorific equivalent or heating power of combustibles is the amount of heat evolved by the combustion of the unit of weight or volume thereof, expressed by the number of units of weight of water which can thereby be raised in temperature one degree on the thermometric scale.

In this country the units of weight and volume are respectively the avoirdupois pound and the cubic foot, and the measure of temperature the Fahrenheit thermometer. One unit of heat therefore, is that quantity of heat which will raise the temperature of one pound of water one degree on the Fahrenheit scale, and n units of heat the amount that would be required to raise n pounds of water one degree Fahrenheit in temperature, or one pound of water n degrees.

In the case of a compound combustible or, more properly, a mixture of several combusti-

bles like the Granger Gas, the theoretical calorific equivalent is obtained by multiplying the weights of the different constituents, expressed in decimals of a pound, by their several calorific equivalents as previously determined by experiment. The sum of the numbers so obtained expresses the theoretical calorific equivalent of the mixture.

The quantity of heat realized by the combustion of the unit of weight of any combustible containing Hydrogen, will vary according to whether the water vapor formed during the combustion is allowed to escape uncondensed, or is condensed to liquid water. In the first instance the specific heat of vaporization of water must be subtracted from the total amount of heat resulting from the combustion.

The most recent and trustworthy determinations of the heat evolved during the combustion of the several constituents of Illuminating Gas are given in the following table:

*Calorific Equivalents of Constituents of
Illuminating Gas.**

HEAT UNITS FROM 1 LB.

	WATER LIQUID.	WATER VAPOR.
Ethylene,	21524.4	20134.8
Propylene,	21222.0	19834.2
Benzole Vapor,	18594.0	17847.0
Carbonic Oxide,	4395.6	4395.6
Marsh Gas,	24021.0	21592.8
Hydrogen,	61524.0	51804.0

Proceeding in the manner indicated we obtain the following calorific equivalents:

*Calorific Equivalent of the Granger Gas at
Worcester, Mass.*

COMPOSITION IN DECIMALS OF 1 LB.		MULTIPLIERS.		CALORIFIC EQUIVALENT.	
		WATER LIQUID	WATER VAPOR	WATER LIQUID	WATER VAPOR
Nitrogen, . . .	0.04402	0.0	0.0	0.0	0.0
Carbonic Acid	0.00365	0.0	0.0	0.0	0.0
Oxygen, . . .	0.00114	0.0	0.0	0.0	0.0
Ethylene, . . .	0.18759	21524.4	20134.8	4038.5	3777.7
Benzole Vapor,	0.07077	18594.0	17847.0	1315.8	1263.0
Carbonic Oxide	0.46934	4395.6	4395.6	2063.0	2063.0
Marsh Gas, . .	0.17928	24021.0	21592.8	4306.4	3871.1
Hydrogen, . . .	0.04421	61524.0	51804.0	2720.0	2290.3
	1.00000			14443.7	13265.1

*Computed from results of J. Thomsen, in A. Naumann's "Die ziele Hungsfrage," Gissen, 1882, S. 61.

The total amount of heat evolved on burning one pound of the Granger Gas at Worcester, Mass., is therefore 14,443.7 units, while if the steam produced in the said combustion be allowed to escape uncondensed the amount of heat will be 13,265.1 units. Under the conditions under which Gas is usually burned for heating purposes the latter figure represents the calorific equivalent of the Gas:

The density of the Gas as determined by experiment is 0.5915, whence one cubic foot would, at 62° Fahrenheit and 29.92 inch barometer, weigh 0.04501 pounds, avoirdupois, hence the calorific value of one cubic foot is as follows:

	WATER LIQ.	WATER VAP.
Calorific Equivalent of one cubic foot, . . .	650.1 units	597.0 units.

*Calorific Equivalent of Granger Gas, at
Lake, Ill.*

COMPOSITION IN DECIMALS OF 1 LB.	MULTIPLIERS.		CALORIFIC EQUIVALENT.	
	WATER LIQUID.	WATER VAPOR.	WATER LIQUID.	WATER VAPOR.
Nitrogen, . . .	0.06175	0.0	0.0	0.0
Carbonic Acid,	0.00753	0.0	0.0	0.0
Oxygen, . . .	0.00018	0.0	0.0	0.0
Ethylene, . . .	0.20454	21524.4	20134.8	4402.6
Benzole Vapor	0.11700	18594.0	17847.0	2175.5
Carbonic Oxide	0.37664	4395.6	4395.6	1655.6
Marsh Gas, . .	0.19133	24021.0	21592.8	4345.9
Hydrogen, . . .	0.04103	61524.0	51804.0	2524.3
	1.00000			15103.9
				14119.0

The total amount of heat evolved on burning one pound of Granger Gas at Lake, Ill., is therefore 15,103.9 units, while if the steam produced in the combustion be allowed to escape uncondensed the amount of heat will be 14,119.0 units.

The density of the Gas being, as determined by experiment 0.6018, one cubic foot would weigh at 62° Fahrenheit and 29.92 inches barometer 0.04579 lb. whence we have :

	WATER LIQ.	WATER VAP.
Calorific Equivalent of one cubic foot . . .	688.7 units.	646.6 units.

*Calorific Equivalent of Coal Gas at
Heidelberg.*

COMPOSITION IN DECIMALS OF 1 LB.		MULTIPLIERS.		CALORIFIC EQUIVALENT.	
		WATER LIQUID.	WATER VAPOR	WATER LIQUID.	WATER VAPOR.
Nitrogen, . .	0.04559	0.0	0.0	0.0	0.0
Carbonic Acid	0.09992	0.0	0.0	0.0	0.0
Oxygen, . .	0.01569	0.0	0.0	0.0	0.0
Ethylene, . .	0.05389	21524.4	20134.8	1160.0	1085.1
Propylene, . .	0.03834	21222.0	19834.2	813.6	760.4
Benzole Vapor	0.07825	18954.0	17847.0	1455.0	1396.5
CarbonicOxide	0.18758	4395.6	4395.6	824.5	824.5
Marsh Gas, . .	0.41087	24021.0	21592.8	9869.5	8871.8
Hydrogen, . .	0.06987	61524.0	51804.0	4298.7	3619.6
	1.00000			18421.3	16557.9

The total amount of heat evolved on burning one pound of this Gas is therefore 18,421.3 units, while if the steam produced in the combustion be allowed to escape uncondensed the amount of heat will be 16,557.9 units.

The theoretical density of the Gas as calculated from the analysis is 0.4580, whence at 62° Fahrenheit and 29.92 inches barometer one cubic foot would weigh 0.03485 pounds.

The calorific equivalent of one cubic foot of the Heidelberg Coal Gas is therefore

	WATER LIQ.	WATER VAP.
Calorific Equivalent of one cubic foot, . . .	642.0 units.	577.0 units.

The calorific equivalents of one cubic foot of each of the three Gases in question are therefore as follows :

	WATER LIQ.	WATER VAP.
Granger Gas, Worcester,	650.1	597.0
Granger Gas, Lake:	688.7	646.6
Coal Gas, Heidelberg,	642.0	577.0

From the foregoing results it will be seen that the Granger Gas has a considerably higher value as a source of heat than Coal Gas when compared by volume.

2. *Flame-Temperature.*

By the term flame-temperature is understood the temperature prevailing in the interior of a burning mixture of Gases. The theoretical flame-temperature may be computed from the calorific equivalents when the specific heats of the products of combustion are known. The result is very different, according to whether the mixture burns under constant pressure or with constant volume. When, namely, the pressure is constant, and hence the Gas can

expand freely as the temperature rises, a certain amount of the heat evolved from the combustion is consumed or transformed into mechanical energy in performing the work of expansion. When, however, the Gas is prevented from expanding during the act of combustion, there is no *work* of expansion to be performed, hence the temperature attained by the gaseous mixture is higher than in the first instance. The increase of flame-temperature caused by the use of pressure as in the compound blow-pipe or Gas blast, is an illustration of the effects of approximating the conditions for combustion with constant volume.

Under ordinary conditions the flame-temperature under constant pressure, i. e. that of the free-burning Gas flame, is the only one with which we have to do, and this may be calculated as follows:

The calorific equivalent of the unit of weight of a mixture of the Gas with just sufficient air for its perfect combustion represents the quantity of heat required to raise the unit of weight of water so many degrees on the thermomet-

ric scale, but this heat instead of being considered as utilized in heating *water* is here utilized solely in heating the gaseous products of combustion of this mixture. But much less heat is required to raise one pound of Gas one degree in temperature than one pound of water. Thus, if we call the amount of heat required to raise one pound of water one degree Fahrenheit 1.000, the amounts of heat required to raise one pound of Nitrogen, Carbonic Acid or Aqueous Vapor one degree will be respectively 0.2440, 0.2164 and 0.4750 when the Gas is allowed to expand freely on heating, and these figures are called the *specific heats, under constant pressure*, of the Gases in question.

The temperature to which the products of combustion of a free-burning mixture of Gases may be raised by the heat evolved during this combustion, or the "*flame-temperature*," is therefore found by dividing the calorific equivalent of the mixture of combustible Gases and air, expressed in *heat units*, by the specific heat of the collective products of combustion of the same.

Proceeding in the manner above indicated, we obtain the following figures for the theoretical flame-temperatures of the Gases under consideration.

Flame-Temperature of the Granger Gas at Worcester, Mass.

At 62° Fah. and 29.92 inches barometer, one cubic foot of the Worcester Gas weighs 0.04501 lbs., requires for its perfect combustion 5.5236 cubic feet of air and furnishes 6.2040 cubic feet of products of combustion, including aqueous vapor. The calorific equivalent of one pound of the mixture of Air and Gas in the above proportions would be as follows :

COMPOSITION OF COMBUSTIBLE MIX- TURE IN DECIMALS OF 1 LB.		CALORIFIC EQUIVALENT.
Nitrogen, 0.69904	×	0.0 = 0.0
Carbonic Acid, . . 0.00035	×	0.0 = 0.0
Oxygen, 0.20983	×	0.0 = 0.0
Ethylene, 0.01790	×	21524.4 = 385.3
Benzole Vapor, . . 0.00675	×	18594.0 = 125.5
Carbonic Oxide, . . 0.04479	×	4395.6 = 196.9
Marsh Gas, 0.01712	×	24021.0 = 411.2
Hydrogen, 0.00422	×	61524.0 = 259.6
		<hr/>
		1.00000
		<hr/>
		1378.5

The specific heat of the products of combustion results from the following computation.

COMPOSITION OF PRODUCTS OF COM- BUSTION IN DECIMALS OF 1 LB.	SPECIFIC HEAT.
Nitrogen, 0.69904	$\times 0.2440 = 0.17056$
Carbonic Acid, 0.19686	$\times 0.2164 = 0.04260$
Aqueous Vapor, 0.10410	$\times 0.4750 = 0.04945$
1.00000	0.26261

Dividing the calorific equivalent by the specific heat of the products of combustion, we have:

$$1378.5 \div 0.26261 = 5249.2^{\circ} \text{Fah.}$$

The theoretical elevation of temperature above the initial temperature of the gaseous mixture is therefore $5249.2^{\circ} \text{Fah.}$ If this initial temperature be 62°Fah. we have as the theoretical flame-temperature of this Gas

$$5249.2 + 62^{\circ} = 5311.2^{\circ} \text{Fah.}$$

*Flame-Temperature of the Granger Gas at
Lake, Illinois.*

At 62°Fah. and 29.92 inches barometer one cubic foot of the Lake Gas weighs 0.04579 lbs., requires for its perfect combustion 6.1901 cubic feet of air and furnishes 6.9060 cubic feet of products of combustion, including Aqueous

Vapor. The calorific equivalent of one pound of the combustible mixture is :

COMPOSITION OF COMBUSTIBLE MIX- TURE IN DECIMALS OF 1 LB.	CALORIFIC EQUIVALENT.	
Nitrogen, 0.70516	×	0.0 = 0.0
Carbonic Acid, 0.00067	×	0.0 = 0.0
Oxygen, 0.21120	×	0.0 = 0.0
Ethylene, 0.01824	×	21524.4 = 392.6
Benzole Vapor, 0.01043	×	18594.0 = 193.9
Carbonic Oxide, 0.03358	×	4395.6 = 147.0
Marsh Gas, 0.01706	×	24021.0 = 409.8
Hydrogen, 0.00366	×	62524.0 = 225.2
<hr/>		<hr/>
1.00000		1368.5

The specific heat of the products of combustion is :

COMPOSITION OF PRODUCTS OF COM- BUSTION IN DECIMALS OF 1 LB.	SPECIFIC HEAT.	
Nitrogen, 0.70516	×	0.2440 = 0.17206
Carbonic Acid, 0.19294	×	0.2164 = 0.04175
Aqueous Vapor, 0.10190	×	0.4750 = 0.04840
<hr/>		<hr/>
1.00000		0.26221

Dividing the calorific equivalent of the mixture by the specific heat of the products of combustion, we have :

$$1368.5 \div 0.26221 = 5219.1^{\circ} \text{Fah.}$$

as the theoretical elevation of temperature above the initial temperature of the combustible mixture. If the initial temperature be

62° Fah. we have as the theoretical flame-temperature of this Gas :

$$5219.1 + 62^\circ = 5281.1^\circ \text{ Fah.}$$

Flame-Temperature of Heidelberg Coal Gas.

From the density calculated from the analysis above cited, viz. : 0.4580, one cubic foot of Heidelberg Gas weighs, at 62° Fah. and 29.92 inches barometer. 0.03485 lbs., requires for its complete combustion 5.6298 cubic feet of air and furnishes 6.3671 cubic feet of products of combustion, including Aqueous Vapor. The calorific equivalent of one pound of the combustible mixture is as follows :

COMPOSITION OF COMBUSTIBLE MIX- TURE IN DECIMALS OF 1 LB.	CALORIFIC EQUIVALENT.
Nitrogen, 0.7138 ×	0.0 = 0.0
Carbonic Acid, . . 0.0075 ×	0.0 = 0.0
Oxygen, 0.2156 ×	0.0 = 0.0
Ethylene, 0.0041 ×	21524.4 = 87.4
Propylene, 0.0029 ×	21222.0 = 61.1
Benzole Vapor, . . 0.0059 ×	18594.0 = 109.5
Carbonic Oxide, . . 0.0141 ×	4395.6 = 62.0
Marsh Gas, 0.0309 ×	24021.0 = 742.7
Hydrogen, 0.0052 ×	61524.0 = 323.6
1.0000	1386.3

The specific heat of the products of combustion is :

COMPOSITION OF PRODUCTS OF COM- BUSTION IN DECIMALS OF 1 LB.	SPECIFIC HEAT.
Nitrogen, 0.71376 × 0.2440 =	0.17416
Carbonic Acid, 0.15644 × 0.2164 =	0.03385
Aqueous Vapor, 0.12980 × 0.4750 =	0.06165
1.00000	0.26966

Dividing the calorific equivalent by the specific heat of the products of combustion, we have :

$$1386.3 \div 0.26966 = 5140.9^{\circ} \text{ Fah.}$$

as the theoretical elevation of temperature above the initial temperature ; if the latter be 62° Fah., we have :

$$5140.9 + 62 = 5202.9^{\circ} \text{ Fah.}$$

as the theoretical flame-temperature of Coal Gas.

The flame-temperatures of the three Gases in question are therefore

Granger Gas, Worcester.	5311.2° Fah.
Granger Gas, Lake,	5281.2° “
Coal Gas, Heidelberg,	5202.9° “

These temperatures all lie beyond the point at which dissociation commences, and hence would never be attained in practice. Bunsen,*

*Poggendorff's Annalen, CXXXI, 171.

namely, has shown that the percentage of dissociation increases from the point at which it commences through the higher temperatures being, for instance, in the case of a mixture in equivalent proportions of Hydrogen or Carbonic Oxide and Oxygen, 50 per cent. at 2000° Centigrade= 3632° Fahrenheit, and $66\frac{2}{3}$ per cent. at 3000 Centigrade= 5432° Fahrenheit. The same investigator has also shown that the extreme temperature which may be attained by the Oxy-hydrogen blast will not exceed 5432° Fahrenheit. While therefore, the temperatures above noted are beyond the limit that may be attained in practice the practical results will be proportional, in the case of similar gases, to the theoretical flame-temperatures, and it may be safely assumed that the temperature of the flame of the Granger Gas will at least equal and may possibly exceed that of the flame of Coal Gas.

III. PHOTOMETRY OF THE GAS.

Average Illuminating Power.

The results of the photometric tests made at Worcester and Lake, on Gas of average charac-

ter from the holders, using a pressure of $\frac{1}{2}$ inch, and corrected for the temperature of 62° Fahrenheit, barometric pressure of 30 inches, candle consumption of 120 grains of spermaceti per hour, and meter rate of 5 cubic feet per hour, were as follows :

Granger Gas, Worcester,	22.06 Candles.
Granger Gas, Lake,	26.31 “

During my sojourn at Lake I had the opportunity to convince myself that the candle-power of the Gas produced may be regulated at the pleasure of the person in charge of the apparatus; the range of candle-power being from 20 to 29 candles, according to the manipulation employed.

In the matter of *quality* the light furnished by the Gas both at Lake and at Worcester, was of the purest white and yet remarkably soft and agreeable to the eye, being in this respect greatly superior to Coal Gas.

Influence of Extreme Cold on Illuminating Power.

The capacity for resisting low temperatures

is an important requisite for Illuminating Gas intended for use in this climate. To test the capacity of the Granger Gas in this respect the following experiments were tried :

A length of thirty feet of $\frac{3}{8}$ -inch lead pipe was bent into two communicating coils about eight inches in diameter. The coils were placed in separate tubs and one end of the pipe was connected with the service pipe, the other end being attached to the photometer pipe. The tub next to the photometer was filled with water at the temperature of the photometer room and the Gas turned on. After the air had been entirely displaced from the pipe and the photometer readings had become constant, the candle-power of the Gas was carefully determined. The tub adjoining the service pipe was then filled with a mixture of snow, salt and sal-ammoniac. The Gas was allowed to burn at the photometer burner at the rate of about five cubic feet per hour until the expiration of one hour after the freezing mixture had been applied. The indications of the photometer fell gradually from the time of the

application of the freezing mixture, but were in each case stationary for some time previous to the final observations of the candle-power. The final readings were taken one hour after adding the freezing mixture and the temperature of the coil noted at the same time.

For comparison a similar experiment was made on the Coal Gas at Worcester, Mass. In each case the coils employed were made of new lead pipe purchased for that purpose.

The results of the foregoing experiments reduced to standard temperatures and pressures etc., are given in the following table:

KIND OF GAS.	TEMPERATURE OF COIL.	CANDLE POWER.		LOSS IN CANDLES.	PERCENTAGE OF LOSS.
		BEFORE COOLING.	AFTER COOLING.		
Granger, Worcester, . .	-7.8 F	22.06	17.36	4.70	21.30
Coal Gas, " . .	-7.6 F	18.41	11.33	7.08	38.40

These figures show that the Granger Gas possesses greater power of resistance to the extreme degree of cold employed than Coal Gas

of much lower candle-power. That this should be the case will also appear from a comparison of the analyses of the different gases. In the Granger Gas the only illuminating ingredient susceptible of condensation by cold is the Benzole vapor, and in the Worcester Gas this constitutes 11.93 per cent. of the total illuminating hydro-carbons, while in the Heidelberg Gas it constitutes 26.13 per cent. The illuminating power of Benzole vapor is, however, according to Frankland,* when diffused through Coal Gas previously deprived of its illuminating hydro-carbons by treatment with Bromine, nearly six times that of Ethylene similarly employed. Simple cold will not, of course, condense all of the Benzole vapor from a state of admixture with gaseous substances.

Relations of Chemical Composition to Illuminating Power.

The luminosity of the flame of Illuminating Gas is due to the decomposition by heat of the heavy hydro-carbons into lighter hydro-carbons

*Journal of the Society of Chemical Industry, III, p. 274.

and Carbon, the latter being separated in a state of extreme subdivision. By the heat of the flame this separated Carbon is heated to intense whiteness and the illuminating effect of the flame is due to the light of incandescence of the particles of Carbon.

The attainment of the highest degree of luminosity of the flame depends upon the proper adjustment of the proportion of the heavy hydro-carbons (with due regard to their individual character), to the nature of the diluent mixed therewith. The question of the flame temperature of the diluent is here of special importance. If the proportion of the heavy hydro-carbons be too great in view of their density, the heat of combustion will be insufficient to raise the whole of the separated carbon to a sufficient degree of incandescence to permit the attainment of the maximum illuminating effect, and the light of that portion which is in fact fully incandescent, is, in part, intercepted by the less strongly incandescent particles. The light emitted will therefore be less than should be obtained from the same

quantity of heavy hydro carbons burned under more suitable conditions. If the excess of heavy hydro-carbons be still more marked, in proportion to their density, the separated Carbon will, in part, escape combustion and appear as smoke or lampblack outside of the flame.

It is evident from the foregoing that the luminosity of the flame will largely depend upon its temperature, for this determines not only the decomposition of the heavy hydro-carbons, but also the degree of incandescence of the separated Carbon. The higher the degree of incandescence the purer and whiter will be the light furnished from a given proportion of heavy hydro-carbons. Other things being equal, the higher the temperature of the flame of the combustible diluent the larger will be the amount of light furnished by a given quantity of heavy hydro-carbons. The character of the combustible diluent is therefore only second in importance to that of the heavy hydro-carbons in its influence on the luminosity of the flame.

But there is yet another condition which has a material effect on the degree of luminosity, namely, the question whether the combustible diluent itself is capable of affording a more or less luminous flame. All of the Carbon that separates in a flame as such does not remain unburned long enough to become incandescent and thus add to the luminosity of the flame. On the contrary, a certain amount is burned at once and has therefore no luminous effect. Thus it follows, from the investigations of Percy F. Frankland,* that mixtures of Ethylene and Hydrogen cease to have any luminous effect when the proportion of Ethylene does not exceed 10 per cent. of the whole. Mixtures of Ethylene and Carbonic Oxide cease to have any luminous effect when the proportion of the former does not exceed 20 per cent., while all mixtures of Ethylene and Marsh Gas have more or less luminous effect. The luminosity of a mixture of 10 per cent. Ethylene and 90 per cent. Marsh Gas being equal to about 18 candles, and that of one of 20 per cent. Ethylene and 80 per

* Loc. cit., p. 271, et seq.

cent. Marsh Gas about 25 candles. The illuminating effect of Marsh Gas alone, when burned in an argand burner, is by no means inconsiderable,* although this substance has hitherto been held to be non-luminous in character.

As far, therefore, as the object to be obtained is the production of the maximum of light from the smallest proportion of Ethylene, Marsh Gas is unquestionably the best diluent, and that this is also true of other hydro-carbons than Ethylene is evident from the experiments of Frankland and Thorne with Benzole vapor. Hence in the case of Coal Gas wherein the proportion of Illuminants is restricted by the conditions of the manufacture, a large proportion of Marsh Gas is beneficial. On the other hand, in the case of Water Gas wherein the proportion of Ethylene may be increased at pleasure, an excessive proportion of Marsh Gas is not only useless, but in the case of Gas of high candle power may even prove prejudicial on account of the fact that that substance re-

* L. Wright, *Journal of the Chemical Society (English)*. 1885. I., 200-202.

quires for its combustion a far larger proportion of Oxygen than either Hydrogen or Carbonic Oxide, and that the presence of relatively large amounts in Gases of high candle power increases the danger of imperfect combustion, and the attendant evil of a smoky flame, which is one of the chief defects of high candle power Coal Gas. In the Granger Gas the constituents of the combustible diluent are so proportioned that with the high illuminating effect of 26 candles, as in the case of the Lake Gas, the flame is of a pure white color, and entirely free from tendency to smoke.

But the highest degree of luminosity from a given proportion of illuminants is not the sole object to be attained. The amount of heat evolved from the flame and the tendency to vitiate the air of the rooms in which the gas is burned, must also be taken into account in the case of Gas intended for illuminating purposes. Marsh Gas consumes four times as much Oxygen as the same volume of Hydrogen, produces three times as much heat and furnishes its own volume of Carbonic Acid.

Of the incombustible diluents, Carbonic Acid is the most prejudicial. Nitrogen acts only by reason of its specific heat in lowering the temperature of the flame and is a much less objectionable impurity than Carbonic Acid.

IV. DENSITY OF THE GAS.

In the following table are given the densities obtained by experiment in the cases of the Granger Gas at Worcester and Lake, and for comparison, the densities calculated from the analyses of these Gases and the Heidelberg Coal Gas.

	DENSITY.	
	FOUND.	CALCULATED.
Worcester, Mass.	0.5915	0.5825
Lake, Ill.	0.6018	0.6057
Heidelberg Coal Gas	0.4580

The agreement between the theoretical and experimental densities in the two first named Gases is as close as the processes of determination would justify us in expecting, and affords a satisfactory confirmation of the correctness of the analytical results previously given.

V. PURITY OF THE GAS.

The tests and quantitative determinations of impurities in the Granger Gas from the holders gave the following results :

1. *Total Sulphur*.—The determination of total Sulphur in the Gas was made by the London Referee's method. The result showed the Gas to contain but 5.11 grains of Sulphur to the 100 cubic feet.

2. *Sulphuretted Hydrogen*.—The Gas was free from any appreciable amount of Sulphuretted Hydrogen.

3. *Ammonia*.—The Ammonia determination showed the presence of but 0.38 grains to the 100 cubic feet of Gas.

4. *Carbonic Acid*.—The before-mentioned complete analyses of the purified holder Gas showed the presence of but 0.14 to 0.30 per cent. of Carbonic Acid.

5. *Tar*.—The Gas was conducted for 28 hours in a moderately rapid current through a glass tube loosely packed with pure white jeweler's cotton. At the expiration of the time men-

tioned the cotton was not discolored nor had any appreciable quantity of tarry substances condensed thereon.

The foregoing results show the Gas made in the Granger apparatus to be of the highest degree of purity and in all respects comparable with the best results heretofore attained in the technology of Gas making. The London Gas Referees, whose requirements are especially strict, allow a maximum of 20 grains of Sulphur and 5 grains of Ammonia to 100 cubic feet.

SUMMARY OF RESULTS.

The results of the foregoing investigation show that the Gas manufactured by the Granger process is, as far as concerns the nature of the constituents of which it is composed, identical with Coal Gas, except in the fact that Ethylene is the only representative of the Olefiant series present therein. In other respects the Granger Gas differs from Coal Gas solely in the relative proportion of its various constituents, and it is to this difference that the great superiority of the Granger Gas over Coal Gas in regard to

illuminating effect, purity of light, calorific power and density is to be ascribed.

This similarity in composition involves as a necessary result, that in its general properties the Granger Gas differs from ordinary Coal Gas simply as a rich and dense Coal Gas differs from one relatively poor and light in character.

The analysis of the Holder Gas at Worcester and at Lake show a remarkable uniformity in composition in the finished product; the differences between these two samples being no greater in amount or character than those which are usually to be found between the products furnished by different Coal Gas works working on the same variety of coal and using the same process of manufacture, while they are vastly less than those obtaining between works using different varieties of coal and different methods of treatment. Witness the enormous variations in composition among the various English and Scotch Coal Gases shown in Table II, pages 64 and 65.

This uniformity in composition is an effective answer to the absurd statements that have been made in various quarters that, being a mixture of several Gases, Illuminating Water Gas must necessarily develop "a tendency to stratify in the holder" and that the product must vary greatly in composition and properties. All Gases diffuse through each other as they do in a vacuum and however heterogeneous may be the constituents of any given mixture of Gases, they become diffused to a perfectly uniform mixture in an exceedingly brief interval of time. The samples above mentioned were taken from the holders while the operation of Gas making was actively in progress, and the outlet and inlet pipes of the holder were placed near together, so that the gas from the one could readily enter the other. The time consumed in taking the samples was, in each case longer than the duration of a single run, and yet the contents of the several sample tubes of the Gas from the holder showed no difference in composition.

The same remark applies to the photometric tests, which were entirely uniform throughout the whole series of observations.

Concerning the distinctive feature of the Granger process, viz. : the employment of mechanical pressure to spray the oil at the base of the Superheater where it is volatilized by the heat of the Gas from the Generator, instead of spraying it by a steam jet or introducing it into the Generator, I would state as my opinion that the Granger process is a very important improvement on the systems that have preceded it, and especially the processes last named.

The method of spraying the oil by means of a steam jet is objectionable for the reason that, at the temperature that prevails in the interior of the Superheater, the steam will react upon the oil, or, properly speaking, upon the products of the action of heat on the oil, and notably on the illuminating hydro-carbons of the Gas, with the natural result of either reducing the illuminating power or increasing the consumption of oil required for the production of Gas of a given candle-power.

The method of introducing the oil directly into the Generator is open to two objections, namely: *first*, that the admixture of the vaporized oil with the Gas is less perfect, whereby the danger of irregular and imperfect gasification, with the attendant inconveniences of the formation of tar and lamp black is increased; and *second*, that the heat abstracted from the Generator for the vaporization and partial gasification of the oil, tends greatly to reduce the temperature of the former and hence to increase the amount of Carbonic Acid produced therein. It is, namely, a fact that the question whether incandescent coal, when subjected to the action of steam, is to furnish Carbonic Oxide or Carbonic Acid in admixture with Hydrogen is, other things being equal, chiefly one of temperature. The lower the temperature the larger will be the proportion of Carbonic Acid formed. And the formation of any considerable proportion of Carbonic Acid is a disadvantage, for the reasons that in the Superheater it tends more or less to react upon and destroy the heavy hydro-carbons, while what escapes

this reaction adds to the difficulty and expense of purification.

For purposes of comparison there is given in the following table (Table I.) the results of the analyses of the Granger Gas from the holders at Lake and Worcester, together with the analysis of the Heidelberg Coal Gas before mentioned.

TABLE I.

		GRANGER GAS.		COAL GAS.
		WORCESTER	LAKE.	HEIDEL- BERG.
Nitrogen		2.64	3.85	2.15
Carbonic Acid		0.14	0.30	3.01
Oxygen		0.06	0.01	0.65
Ethylene		11.29	12.80	2.55
Propylene		0.00	0.00	1.21
Benzole Vapor		1.53	2.63	1.33
Carbonic Oxide		28.26	23.58	8.88
Marsh Gas		18.88	20.95	34.02
Hydrogen		37.20	35.88	46.20
		100.00	100.00	100.00
Density.	Theory,	0.5825	0.6057	0.4580
	Practice,	0.5915	0.6018	. . .
Heat units from 1 cub. ft.	Water Liquid,	650.1	688.7	642.0
	Water Vapor,	597.0	646.6	577.0
Flame-temperature.		5,311.2°F.	5281.1°F.	5202.9°F.
Av. Candle Power.		22.06	26.31	. . .

TABLE
COMPOSITION OF ENGLISH AND SCOTCH
HUMPIDGE AND E.

(Journal of the Society of

GAS WORKS.	DATE.	CARBONIC ACID.
London—City Co.,	1851	0.53
“ Great Central Co.,	“	0.28
“ Western Co.,	“	0.13
“ Imperial Co.,	“	0.29
“ Chartered Co.,	“	0.00
“ Imperial Co.,	1876	0.00
“ Chartered Co.,	“	0.00
“ Houses of Parliament,	“	0.00
“ Gas Light and Coke Co.,	1882-84	0.00
“ South Metropolitan Co.,	“	0.09
Redhill,	“	0.74
Gloucester,	“	0.03
Newcastle-on-Tyne,	“	0.28
Brighton,	“	0.03
Southampton,	“	0.07
Ipswich,	“	0.06
Norwich,	“	0.27
Edinburgh,	“	0.35
Glasgow,	“	0.29
St. Andrews,	“	2.73
Liverpool,	“	1.70
Preston,	“	0.84
Nottingham,	“	0.81
Leeds,	“	0.34
Sheffield,	“	0.24
Birmingham,	“	1.50
Bristol,	“	0.00

II.

COAL GASES, FROM THE ANALYSES OF
AND P. F. FRANKLAND.

Chemical Industry, III, 272-73.)

NITROGEN.	OXYGEN.	HEAVY HYDRO- CARBONS.	HYDROGEN	MARSH GAS.	CARBONIC OXIDE.
.....	3.05	47.60	41.50	7.32
1.80	0.44	3.56	51.24	35.28	7.40
1.51	0.43	13.06	25.82	51.20	7.85
5.10	1.20	3.67	41.15	40.66	8.02
0.38	0.08	3.53	51.81	35.25	8.95
9.73	1.91	4.18	40.82	36.57	6.79
3.48	trace.	4.41	50.59	38.39	3.13
2.71	0.00	8.72	41.72	41.88	4.98
5.95	0.26	4.41	47.99	37.64	3.75
3.19	0.00	2.92	53.14	36.55	4.11
3.37	0.49	4.40	48.18	39.41	3.41
2.73	0.51	4.95	48.89	38.25	4.64
5.29	0.23	3.62	50.50	36.71	3.37
2.07	0.23	3.76	51.62	38.15	4.14
2.53	0.39	3.09	53.59	36.74	3.59
10.84	0.12	4.53	43.26	38.73	2.46
3.03	0.14	3.26	53.79	36.11	3.40
3.64	1.00	12.23	33.24	42.93	6.61
3.07	0.06	10.00	39.18	40.26	7.14
2.83	0.48	10.04	36.63	42.13	5.16
6.10	0.19	7.90	36.44	44.28	3.39
4.79	0.25	6.22	43.95	39.33	4.62
2.51	0.24	5.63	45.52	39.66	5.63
4.32	0.07	7.28	40.23	42.74	5.02
2.56	0.10	6.28	43.05	43.05	4.72
10.10	0.36	4.76	40.23	39.00	4.05
5.11	0.27	4.58	44.57	40.70	4.77

THE GRANGER WATER GAS CO.,

Owners of the Patents,
PHILADELPHIA, PENNA.

OFFICERS :

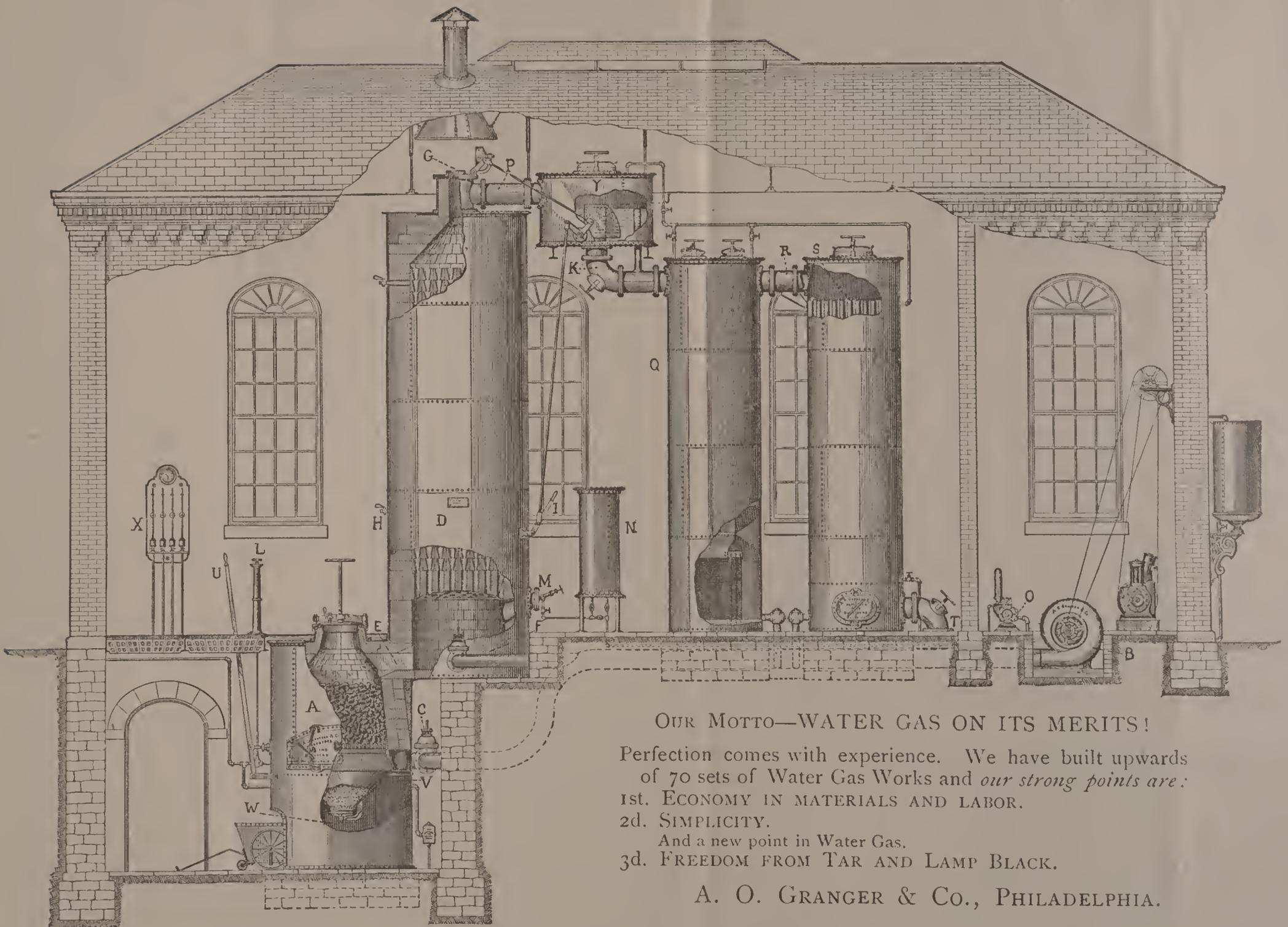
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JOSEPH H. COLLINS, JR.,
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JOSEPH H. COLLINS, JR., " "
ARTHUR O. GRANGER, " "

We refer to the following Works under our Improved Process, in operation or now building :

New Brunswick,	New Jersey.	Changed from Lowe Process.
Jersey City (People's Co.),	"	
Binghamton,	New York.	
Cohoes,	"	
Coney Island,	"	Changed from Lowe Process.
Port Jervis,	"	Changed from Lowe Process.
Starin's, Glen Island, . . .	"	
Utica,	"	
Bloomington,	Illinois.	
Chicago (Consumers' Co.),	"	
Lake (Cook County), . . .	"	
Peoria,	"	
Quincy,	"	
Honesdale,	Pennsylvania.	Changed from Lowe Process.
Mauch Chunk,	"	Changed from Lowe Process.
Wilkes Barre,	"	Changed from Lowe Process.
York,	"	
Athol,	Massachusetts.	
Lynn,	"	
Worcester,	"	
Marshall,	Michigan.	
Burlington,	Iowa.	
Washington,	D. C.	
Sherbrooke,	Quebec,	Changed from Lowe Process.
St. Hyacinthe,	Quebec.	
Norfolk,	Virginia.	Changed from Lowe Process.



OUR MOTTO—WATER GAS ON ITS MERITS!

Perfection comes with experience. We have built upwards of 70 sets of Water Gas Works and *our strong points are:*

- 1st. ECONOMY IN MATERIALS AND LABOR.
- 2d. SIMPLICITY.
- 3d. FREEDOM FROM TAR AND LAMP BLACK.

And a new point in Water Gas.

A. O. GRANGER & CO., PHILADELPHIA.

