INVESTIGATION

Of the Conditions Governing the Choice of a Proper Quality Standard for Artificial Gas

with Conclusion and Recommendation of the

JOINT COMMITTEE ON CALORIMETRY

of the

PUBLIC SERVICE COMMISSION

and

GAS CORPORATIONS

in the

SECOND PUBLIC SERVICE DISTRICT

NEW YORK STATE

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March 6, 1913.

Honorable F. W. STEVENS, Chairman,
Public Service Commission,
Second District,
Albany, New York.

Sir:

On December 8, 1909, your Honorable Commission issued a circular to corporations engaged in furnishing or distributing coal gas, water gas and mixed gas within your jurisdiction, and appointed February 1, 1910, as a date for conference to interchange views on the necessity for a calorific standard and all questions necessary and incidental thereto.

On February 1, 1910, the representatives attending appointed a committee to co-operate with the Commission in the consideration of these questions, and thereupon your Honorable Commission appointed representatives to meet with this Committee. After a preliminary meeting on the same date, the representatives of the companies and of the Commission organized as a "Joint Committee on Calorimetry."

Since that date the investigation of this subject has continued and the history of the work and matters relating thereto will be found in the report transmitted herewith.

In accordance with our instructions: "If there is anything in your conclusion that requires the action of this Commission in any way, we shall expect that it shall be reported to us, and we will take it into consideration as to whether it is the proper thing for the Commission to do," we would respectfully direct your attention to paragraphs 12, 26, 35, 37 and 41, of the report herewith.

We have the honor to be,

Very respectfully yours,

W. R. ADDICKS, Chairman.
T. R. BEAL,
M. J. BRAYTON,
H. H. CROWELL,
J. C. DeLONG,
A. H. ELLIOTT,
J. B. KLUMPP,
C. F. LEONARD,
WM. McCLELLAN,
W. T. MORRIS,
R. M. SEARLE,
C. H. STONE,

C. H. B. CHAPIN, Secretary.

REPORT OF JOINT COMMITTEE ON CALORIMETRY.

1. The first commercial distribution of artificial gas for illumination was in open luminous flames and quite naturally its quality was stated in terms of the most convenient unit at hand—the candle. With the introduction of the much more efficient mantle burner, and the increasing use of heating devices, the heating value of the gas became important. As a result, scientific men in both Europe and America have recognized that to continue the use of the candle power (illuminating) standard was, for modern conditions, illogical and unsatisfactory, and in lieu thereof have advocated the adoption of a heat unit standard. More than four years ago the Public Service Commission of the Second District of the State of New York noted the trend of development, and started an investigation of the actual conditions existing throughout the Second District. This led to the appointment of a Joint Committee on Calorimetry, composed of representatives of the Commission and of the Gas Corporations of the State.

2. This Committee, after three years of continuous research and investigation, having had the assistance of the laboratories of the Commission and of tests made at sixteen gas plants in the State, and the results of numerous experiments conducted elsewhere to aid it in its conclusions, now makes its report.

3. The object constantly in mind has been the selection of a standard for artificial gas which will enable the consumer to obtain the most value for the least money, and will enable the Company to obtain its profit at the smallest expense to the consumer. The interests of the consumer and the Company are one. This one interest demands a standard which will fit in with present economic conditions, which will permit the most efficient use of modern invention and which will conserve resources instead of wasting them.

4. The yielding of the open flame burner, the only device requiring the gas to have an illuminating value, is the first reason for suggesting a standard based on the heating value. The mantle burner is from four to eight times as efficient as the open flame burner, and its use reduces the cost of lighting to the consumer. As is well known, the light is obtained by heating a mantle of rare earths to incandescence. The gas needs only heating value because the burner is merely a heater for the mantle.

5. As in all heating devices the burner is adjusted so that the gas is completely burned and shows a blue or almost colorless flame. Consumers, if properly informed, would substitute mantle burners for open flames in practically every case. In addition to the greater economy there is greater safety in many cases and more effective illumination always.

6. In addition to modern gas lighting devices which require heating value only in the gas, there is a rapidly growing demand for gas for cooking and heating purposes. Artificial gas is being supplied in increased amounts for melting, tempering, metal finishing, drying, gas engines and hundreds of other industrial uses. Inventors are actively at work designing apparatus which will greatly increase this use. Heat storage furnaces for heating buildings economically with gas are proposed. Indeed it seems to be true that it only needs the design of proper gas-using apparatus to make gas the most economic means of transporting the heat content of coal. Under such

circumstances to give artificial gas an expensive and unnecessary illuminating value is illogical and indefensibly wasteful.

7. The illuminating quality in gas, which, with the disappearance of the open flame burner becomes unnecessary, may become a costly feature if it must be added to the gas by a special process of enrichment. This enrichment is usually made by means of a petroleum oil which for a number of years was worthless for anything else and consequently was very cheap. But the enormous growth in the demand for gasoline for automobiles and motor boats has stimulated chemists to invent processes by which the enriching oils heretofore used by gas companies can be turned into light oils suitable for internal combustion engines.

8. Inventors of oil engines are perfecting their devices rapidly, which results in much more extended direct use of oil for power generation. Oil used in this way commands a higher price than when used for gas enrichment. The United States and other governments are resorting to increased use of oil fuel for war vessels, and their needs are so paramount that price is not a critical factor. (Reference: "The Production of Petroleum in 1911," U. S. Geological Survey, 1912.)

9. This sudden demand for enriching oil products by the people for pleasure and industrial purposes, and by governments for power purposes, and the consequent rise in the selling prices, has within a year increased the cost of manufacturing water gas from 10 to 15 cents per thousand cubic feet. In addition there is every reason to believe that the present price of oil is by no means the maximum, so that cost may operate in the future to require that enrichment be kept to a minimum. It was the presence of a large and cheap supply of enriching oil that made water gas commercial after the manufacturing apparatus had been made practical from 1877 to 1882. It is probable that the high price of enriching oils will make carburetted water gas useful chiefly for peak demands and as a reserve to retort gas and oven gas, which need no enrichment if heating value only be required.

10. The present rise in the price of oil would result in a condition seriously affecting the price of gas to the consumer if it were necessary for artificial gas to continue to have the present high illuminating value. Fortunately the availability of the mantle burner modifies the seriousness of the situation. It may be argued that gas oil has risen in price before and afterward dropped. It must be added, however, that the price never returns to its previous low figure. Moreover, as shown above, the present rise is due to plainly apparent and quite natural causes, and it does not appear that these causes will abate in force.

11. In passing it may be stated that water gas must be enriched to be practical for community use. Retort gas (so-called "coal gas") has ample heating value and illuminating value to be distributed without enrichment to the community. Run of oven gas (by-product from coke ovens) has a large heating value without enrichment, but in candle power is materially lower than retort gas.

12. It should also be noted that whatever reasons there may have been in the past for different standards for coal gas, mixed gas and carburetted water gas (16, 18 and 20 candle power in New York State, Second District), they certainly are without force now, and only one standard is necessary or desirable.

13. Mere increased cost, though important and almost compelling, is not alone the cause for a change from a candle power to a heat unit standard. As a matter of fact, when this Committee was appointed this feature could not have been in any degree a reason for changing the standard. The present standard actually retards the extension of gas service and as a direct consequence retards the development of communities.

14. Present development in gas distribution falls into two classes—first, distribution in comparatively densely populated large territories such as cities, with closely attached suburbs; and second, distribution of gas from one large central plant to a number of more or less distant communities with intervening territory in which there is little or no demand for gas supply. In either case the present candle power standard is a burden. This is for the reason that because of temperature and pressure changes and friction in mains a part of the enrichment added to a gas to give it illuminating power drops out during transmission, and the loss becomes more and more serious as the distance of transmission increases. Higher pressures are necessary if the gas is to be transmitted economically for a long distance and it is impossible to avoid some exposure to low temperature. As a result either the gas must be given excessive candle power at the plant, or it must be enriched after transmission so that the gas distributed after transmission may be up to standard. In either case it is sometimes difficult to make the operation of the system satisfactory and the cost increases to an amount which makes such distribution often commercially impracticable.

15. Within single areas or communities, extension of service is possible so far as the present law is concerned which requires inspections to be made about a mile from the works. This does not mean, however, that the same quality of gas can be supplied economically at the center and on the outskirts. The company undertaking to give standard service at all points must of necessity spend much more on its manufacturing and distribution cost because the average candle power must be higher in order to make up the loss.

16. In the case of one large central plant distributing gas to a number of more or less distant and separate communities, the burden is especially heavy, for but one quality of gas can be ordinarily distributed from the plant. The long distribution system with its higher pressure and exposure to low temperature entails a very great loss in candle power during transmission. In addition, the operation is likely to be difficult, because the enriching oils which condense in the system must be taken care of in larger pipes, traps and other devices and the labor cost of operation is increased on account of the maintenance and operation of these extra devices. With the increased cost of enriching oil it is probable that such extended distributions will not be possible without a serious increase in the selling price.

17. Too small a community cannot support a gas plant of its own, if first-class service is to be given, ample financial support secured and adequate business and engineering superintendence supplied. For a long time the same conditions obtained in the supply of electricity but the problem of supplying the smaller community has been solved by the development of high-tension, long-distance transmission of power. By this means any number of small communities and intervening farm territory can be served from one large central station. High-pressure gas distribution bears the same relation to the gas industry as high-tension transmission bears to the electric industry.

18. As shown later, the loss in heat units in transmission due to pressure or low temperature is very much less than the loss in candle power. A heat unit standard not very different from the heat unit value of gas at present supplied would permit gas distribution over long distances under pressure at a loss which would be in no sense burdensome. Such a result would permit, as soon as development could take place, gas service to many small villages and towns which it is quite impossible to supply under present conditions.

19. A further reason why a change from a candle power standard to a heat unit standard is desirable rests on a broad economic policy. Even though oil were not increasing in price the present standard spells waste. It is a waste of resources and it is wasteful of money. Conservation of resources

would demand that there should be no unnecessary resort to the use of oil for gas enrichment. It is wasteful to maintain a standard beyond what is required for efficiency and when the standard means an unnecessarily high cost. The public wants the best gas for the least money and it is to the business advantage of the Company to supply the demand. The present standards, under existing conditions, do not assist in attaining this desirable end.

20. Summarizing then, the movement toward a heat unit standard is based on three important factors:

1. Modern appliances for the use of gas require that it have heating value only. The open flame burner is rapidly disappearing on account of its inefficiency and expense.
2. The present candle power standard seriously impedes desirable distribution in extended communities and for long distances, and as a consequence retards community development. The rising price of enriching oils adds to the difficulty.
3. The present standards are wasteful of resources and unduly burdensome on the consumer and the Company.

21. In order to obtain accurate information on which to base the choice of a proper standard, particularly with reference to the needs of New York State, the Committee turned to a number of gas corporations of the State for assistance. Laboratories for calorimetrical measurements were established at sixteen different plants of the State and regular daily tests started. The instruments were checked first at the laboratory of the Public Service Commission at Albany. The cost of the apparatus and the expense of the tests were all carried as operating expenses of the plants where the tests were made. Constant attention had to be given by the Company's officers and their employees to the investigation, and the expenditure of time and money was not small. Results of this work make up the most valuable data that the Committee has in this report. In Appendix B will be found tabulations and curves showing the results obtained by the various Companies with comments and discussion in considerable detail (see also Appendix C). The monthly reports of the Companies summarizing their daily tests when received by the Committee were scrutinized closely for errors and critical features. Every effort possible has been made by the Committee to make sure that the work was being done with uniformity and accuracy. The co-operation of the traveling gas inspectors of the Commission was of marked assistance in this respect. As a final test on this point, a demonstration was held at Amsterdam, N. Y., at which all the calorimeter operators of the various Companies making tests were present. This gave an opportunity for a further demonstration in regard to uniformity and accuracy. The Committee feels confident that the results are accurate within one per cent.

22. Certain other important facts demonstrated by this experimental work should be mentioned.

23. It is known that a calorimetrical laboratory can be established at comparatively small expense.

24. Calorimetric measurements can be made with great accuracy by men with no special scientific training except experience in and attention to proper operating directions.

25. The calorimeter as a practical instrument is more accurate than the photometer. There is no uncertain feature in connection with its use as there is with the type of burner and standard unit of light used with the photometer.

26. From the test results no law could be discovered showing a relation between the candle power and the heat unit value of artificial gas. The Com-

mission's preliminary investigation indicated this, but the results, involving 6,738 calorimetric and 9,167 photometric observations, obtained by the Committee make it a demonstrated fact.* For this reason it would be very difficult indeed to state the heat value of artificial gas of a quality equal to the State standard for candle power inasmuch as the Companies generally distributed gas above the legal standard, in some cases as much as 17 per cent. For the information of the Committee, however, two plants were operated close to the State standard. As the results in Appendix B show, gas meeting the State standard of candle power would have approximately a monthly average of 585 B. t. u.** The question immediately arises as to whether this value should not be taken for the heating value standard of gas to be distributed in New York State. The several steps in the reasoning necessary to properly answer this question are important.

27. It is desirable that a new standard shall not differ greatly from the heating value of gas of the present legal standard. To have it materially less would require the distribution and use of a larger volume of gas in order to get the same useful effect. This in turn would necessitate radical changes in the selling price annoying to both consumers and Companies without benefit to either.

28. To meet a heat unit standard of 585 B. t. u. means that most Companies must enrich the product during a portion of each twelve months.

29. There are a variety of combination methods of making artificial gas from gas coal, anthracite coal, bituminous coal and oil, which are discussed in Appendix C.

30. Any enrichment is expensive and it has been shown above that it is becoming more and more so with the increasing price of oil. It is safe to predict that if the present price of oil continues, carburetted water gas will no longer occupy the important position that it has for some years past in the gas industry. Indeed, the idea is now taking firm hold that, owing to the oil situation, with the practically inexhaustible supply of gas coal now in sight, the gas industry must depend upon coal gas of some sort for the bulk of its output and use water gas as a reserve. In any case excessive enrichment is useless and unsatisfactory, especially in connection with modern gas appliances. Gas unnecessarily enriched interferes with manufacturing processes, and when distributed to the consumer deposits carbon in burners and mantles and, as heretofore stated, the illuminants drop out in transmission, especially under pressure and at low temperature. Other things being equal, it will be to the advantage of consumers and manufacturers if enrichment is reduced to a minimum.

31. As shown later, with the most modern horizontal retort settings and machine stoking, coal gas from high-grade gas coals and with high yields of gas per ton of coal, without enrichment, varies in heat units from approximately 550 to 600 B. t. u. monthly average. If the general use of carburetted water gas as a staple product becomes impossible on account of the very high price of enriching oils, and must be replaced by retort or oven gas, and if the heat unit standard is set at such a point that the manufacturer will need the highest grades of coal in order to meet this standard or else be compelled to use high-priced enriching oils, it is obvious that the price of these higher grade coals will rise so that the very object of the change

*** Note Chart Appendix B, pages 40-41.**

** B. t. u. is the accepted abbreviation for the British thermal unit, which is the amount of heat required to raise the temperature of one pound (avoidupois) of pure water from 39.1° F. to 40.1° F. The variation in the quantity of heat necessary to raise the temperature of a pound of water one degree F. is so slight for any temperature between 32° and 212°, that in general the B. t. u. may be safely taken as the amount of heat necessary to raise the temperature of one pound (avoidupois) of water one degree F.

will be defeated. It is interesting to quote here from Bulletin 6 of the Bureau of Mines of the United States, published in 1911:

> "In a consideration of the various means whereby more economical and more efficient use may be made of the fuels in the United States, the possibility of obtaining for the production of illuminating gas other and cheaper fuels than the Pennsylvania coals demands attention. For the Government, as well as for private corporations and the householder, there can be no more economical and efficient way of using some coals than through the medium of illuminating gas. In the stove, gas reduces the labor cost of heat production and lessens the drudgery of the kitchen; burned in the Welsbach mantle, it is an excellent and cheap illuminant. In addition, the coke that remains after the gas has been recovered furnishes a smokeless fuel that has about the same heating value as anthracite. Hence any investigations that will indicate how local coals through proper treatment may be substituted for the higher priced and rapidly vanishing Pennsylvania gas coals will bring about lower prices for both gas and coke, and will also aid to conserve for use in metallurgical processes the coking coals of Pennsylvania and of other States.
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> * * * * * * *
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> "There are few well-developed coal fields in this country that furnish coal satisfying all the requirements of illuminating-gas manufacture. Most of the coal used hitherto has come from Western Pennsylvania, the quantity supplied by other fields being relatively small. The introduction of gas-coals from new or little-known districts, because of the lack of necessary testing stations and of scientific study of the complex process of gas manufacture, has been difficult."

32. We must, therefore, think that it would be inadvisable to set the standard for artificial gas so high that the best coals only could be used. The standard should be placed so that average coals may be used without enrichment, and thus give the very greatest economic value to the consumer at the lowest cost.

33. Certain methods of operation are now being discussed that may be desirable, or even become compulsory under conditions which seem to be approaching. The disposition of the coke resulting from the manufacturing of coal gas has been in the past a serious problem to some Companies, and at a time when coke was used in cooking ranges since discarded for more desirable gas ranges. For this and other reasons it may be desirable in the future to manufacture a mixed coal and carburetted water gas, using substantially all of the coke as fuel in the water gas sets. If this becomes a general practice it may be desirable to lower the standard. Coke oven gas in which the coal is carbonized primarily to obtain coke for industrial purposes and the gas a by-product is also being considered in many places. Run-of-oven gas would require excessive enrichment if the present standard was in force. It is quite probable that should this coke oven gas be distributed in larger quantities it would be desirable to reduce the standard. Present data from these various processes show that it might be necessary to fix the standard at 525 B. t. u. or even lower.

34. It is difficult indeed, in view of the uncertainty as to just how fast certain changes in the conditions governing gas manufacture and distribution will take place, and as to what the final situation will be, to determine the proper value at which to set the standard. It has been shown that some time in the future the standard may have to be 525 units or lower. It has also been shown that, at present, the monthly average, even with the best coals and highest grade plants, may be as low as 550 units. All plants, of various sizes and locations, cannot become highest grade plants, at least immediately, and

the smaller plants never. The best coals are not available to all, and if the demand is increased the price will rise. Notwithstanding these facts it is believed that the standard adopted must be close to the heat unit value of the present standard gas.

35. Taking all these conflicting factors into consideration, it is the judgment of the Committee that a total heat value not exceeding 570 British thermal units monthly average measured at the point where the gas leaves the manufacturing plant, corrected to a temperature of 60° F., and to a pressure of 30 inches of mercury, as measured by the rules of the Committee accompanying this report, is the standard which will best serve the interest of the people of New York State.

36. The standard suggested above is referred to the standard atmospheric cubic foot, i. e., at 30 inches barometer and 60° F. It will be perceived that the only time a consumer would get the standard number of heat units would be when his meter was at 60° F. and the barometer was at 30 inches. Such conditions cannot obtain, however, with localities at different heights above sea level and with meters located in all kinds of places giving different and varying temperatures. Therefore, some average conditions must be chosen. These might be the average annual barometer and temperature if they could be obtained for each locality and a "local cubic foot" might be fixed on these terms. All such "local cubic feet" could then be required to have the standard number of heat units. This would be possible for a group of localities not varying too much from a certain average altitude. It would be very inconvenient however. A certain mass of coal gives a certain mass of gas at best economic yield, and the volume of the gas is solely dependent upon pressure and temperature. Therefore, if a "local cubic foot" is used, operators would operate differently at different altitudes and temperatures, even though using the same coals, oils and machinery. A comparison of detail methods of operation, the study of proper amounts of oil and steam, temperature of various parts of the sets or benches and other features, are sufficiently complex now without making them more so by introducing accidental atmospheric conditions. There could not be even a mere comparison of results by State authorities and others interested, in order to increase efficiency, until the results were brought to a common basis. In a State having largely different altitudes several standards might be required owing to the impossibility of making a uniform commercial gas in all cases. The operators would still have to observe the daily barometer and temperature, and make corrections to the "local cubic foot." The only suggested advantage discernible is that the consumers everywhere throughout the region or State in question would get the same number of heat units in the yearly average "local cubic foot." What they get from day to day will vary by the same amounts under any system. All features considered, it will be much more satisfactory to fix the requirement in terms of the atmospheric standard cubic foot, i. e., at 30 inches barometer and 60° F. The average "local cubic foot" sold will then contain slightly different numbers of heat units according to the height of the locality above the sea and to the climatic conditions. In New York State these differences are unimportant.

37. The conditions governing the use of the standard are important. Gas manufacture is not an exact science but is a complex operation including a number of distinct processes. Quality of coal, methods of firing, temperature of retorts, the human factor, the failure or breakdown of parts of the plant, and other factors not easily controlled, make it impossible for a Gas Company to deliver an absolutely uniform product. This points to the necessity of applying the standard as an average for a reasonable length of time. A month has been adopted elsewhere and is recommended for New York State. If a Company falls below the standard for a few days it

will then be necessary for it to produce above the standard, at an economic loss, in order to have its monthly average satisfactory. In order to protect the public against improper management by which there would be wide departures from the standard, should a minimum value be set? It is not necessary that this minimum be set too close to the monthly average, as there is a financial loss to a Company if it departs too far from it. The cheapest and best operation for both Company and consumer will obtain by a close adherence to the standard. A wide departure due to careless operating means an increase in operating cost which will not be to the Company's profit. A 5 per cent. deviation for not exceeding three consecutive days would be adequate protection to the consumer. In extraordinary conditions due to failure to obtain supplies or to accident in the plant, the Commission might properly suspend the operation of the standard in its discretion.

38. As a matter of fact even a properly fixed minimum is of little practical importance. Well-managed companies would never reach it except under circumstances absolutely beyond their control. The saving and satisfaction in operating close to the monthly average is very great and induces good management. A management continually inefficient and incompetent would be exposed in so many ways that a change would eventually come through reorganization or new ownership.

39. Penalties have been used in an attempt to compel good management, but as a rule, experience has shown them to be ineffective. The difficulties of placing the blame on the proper persons and conditions, of proper legal phrasing, of collecting the penalties, of fixing equitable penalties and penalties that are real, the fact that through carelessness they so frequently fall into disuse, the opportunity that exists for abuse and persecution—all operate against the effectiveness of a penalty system. Continual and broad publicity is very much better. The greatest force in the country to-day is public opinion. No company could ignore or withstand the effect of frequently published statements that its product was not up to a prescribed standard. A weekly publication of tests, for example, would keep the public informed, would keep the company active in good management, would prevent careless and irresponsible complaints, and would prevent abuse and criticism.

40. It is reasonable to ask what disadvantage there will be, if any, to persons using flat flame burners if a standard is fixed according to heating value only. It is fair to exclude from consideration all persons who continue to use flat flame burners through indifference to their own interests. That a smaller and smaller number of people are doing this is evident from the results reported by Gas Companies in regard to the reduction in the number of consumers using open flames. Mantle burners have become so cheap and the saving is so great that in a short time no one will use open flame burners except for some peculiar reason. The cases will be remarkably few where open flame burners will be thought desirable, but for those who feel that they must use them it may be stated positively that any artificial gas having the heating value recommended in the above standard would have sufficient illuminating power, though at times lower than at present, to make the gas useful in locations suitable to open flame burners. The use of a very small percentage of the gas for such a purpose should not prevail against the general usefulness of the whole product.

41. The Committee recommends, therefore, that no candle-power standards be considered in connection with the heat unit standard heretofore recommended.

APPENDIX A

HISTORY OF COMMITTEE AND ITS WORK

1. In August, 1908, an investigation was started by the Public Service Commission, Second District, N. Y., through its Division of Light, Heat and Power "into the subject of the calorific power and illuminating power of the coal gas, carburetted water gas, and mixed coal and carburetted water gas supplied." (Page 21, Third Annual Report.)

2. This examination, as stated in the Third Annual Report of the Commission, was of a preliminary nature, and was completed in October, 1909, and the data embodied in a report by the Chief of Division of Light, Heat and Power.

3. On December 8, 1909, notice was sent by the Commission to all the gas companies operating in the Second Public Service District of a conference to be held on February 1, 1910, in reference to this subject.

4. In December, 1909, following the receipt of this notice and report, the Empire State Gas and Electric Association appointed a Committee to investigate the matter as thoroughly as might be done prior to the hearing of February first. This Committee held a number of meetings, discussed the matter contained in the report and such other data as was available, but was unable to arrive at any definite conclusion in the very limited time at its disposal.

5. At the hearing on February 1, 1910, after some general discussion, a vote was taken on the question as to whether or not the investigation started by the Commission should be continued. The result of the vote being in the affirmative, the Chairman of the Commission suggested the appointment by the representatives of the gas companies present, of a Committee to co-operate with the Commission's representatives. This suggestion having met with the approval of all those present, a recess was declared, during which the companies held a meeting and elected as their representatives:

W. R. Addicks,
T. R. Beal,
J. C. DeLong,
W. T. Morris,
M. W. Offutt,
R. M. Searle.

6. Upon the continuation of the conference the Chairman of the Commission named as its representatives:

H. C. Hazzard,
H. H. Crowell,
C. H. Stone.

The persons above named convened after adjournment of the hearing and voted to hold the first regular meeting in the Capitol, Albany, on Friday, February 11.

7. On February 11, 1910, the Committee appointed as above outlined, met and elected H. C. Hazzard, Chairman, and C. H. B. Chapin, Secretary. It was voted that the Committee should be known as the Joint Committee on Calorimetry.

8. Since its original appointment, the personnel of the Committee has undergone some changes. The Commission has appointed William McClellan and C. F. Leonard as its representatives, H. H. Crowell and C. H. Stone having severed their connection with it. H. H. Crowell continued to serve upon the committee, and C. H. Stone resigned, but by unanimous invitation continued to sit with the committee and was later re-elected a member. M. W. Offutt resigned as a member of the Committee and M. J. Brayton was elected in his place. Dr. A. H. Elliott and J. B. Klumpp were elected additional members of the Committee. H. C. Hazzard having resigned from the service of the Commission, thereupon resigned from the Committee, and W. R. Addicks was elected Chairman.

9. At the commencement of the investigation, the Committee deemed it desirable to secure the co-operation of Companies in different parts of the State and operating under different conditions of manufacture and distribution of gas. Ten Companies decided to purchase calorimeters and make such tests as the Committee desired. Before the conclusion of the investigation additional Companies joined in the work, so that the Committee had results from sixteen plants located in widely separated parts of the State to aid it in its conclusions.

10. Statistics are given in Table I showing the kind of gas made by these Companies, the magnitude of the daily output, and the date of beginning of tests. Companies are designated by number instead of by name throughout the report. (For further information regarding the different Companies see Appendix B.)

TABLE I.

Company Number.	Class.	Kind of Gas.	Tests Started.
1	A	Coal gas, enriched.	Oct. 1, 1911.
2	D	Coal gas, enriched.	Aug. 1, 1911.
3	A	Carburetted water gas.	Aug. 1, 1911.
4	A	Carburetted water gas.	Aug. 1, 1911.
5	C	Carburetted water gas.	Aug. 1, 1911.*
6	B	Carburetted water gas.	Aug. 1, 1911.
7	B	Carburetted water gas.	Aug. 1, 1911.
8	C	Carburetted water gas.	Aug. 1, 1911.
9	A	Carburetted water gas.	Aug. 1, 1911.
10	B	Carburetted water gas.	Oct. 1, 1911.
11	A	Mixed coal and carb'd water gas.	Aug. 1, 1911.
12	A	Mixed coal and carb'd water gas.	Aug. 1, 1911.
13	C	Mixed coal and carb'd water gas.	Aug. 1, 1911.
14	C	Mixed coal and carb'd water gas.	Apr. 1, 1912.
15	A	Carburetted water gas.	Oct. 1, 1912.
16	B	Carburetted water gas.	Feb. 1, 1912.

*Tests discontinued November 30, 1911, and calorimeter moved to another plant.

Class A—Companies having a maximum daily send-out of over 1,000,000 cubic feet.

Class B—Companies having a maximum daily send-out from 500,000 to 1,000,000 cubic feet.

Class C—Companies having a maximum daily send-out from 100,000 to 500,000 cubic feet.

Class D—Companies having a maximum daily send-out of under 100,000 cubic feet.

11. At the meeting of the Committee in February, 1910, it was deemed advisable to prepare specifications for calorimeter installations and rules for their operation. This work, which was done by a sub-committee, was completed and adopted by the full Committee on May 6, 1910, and printed for distribution under the title "Calorimetric Rules, Regulations and Specifications." Copies were furnished to all Gas Companies operating in New York State.

This pamphlet is divided into six general sections as follows:

I. Heating Value of Gas (Definition).*

II. Primary Standard—To be maintained at the laboratory of Commission at Albany (Specifications).

III. Secondary Standard—To be used in checking Calorimeters of Gas Companies in situ (Specifications).

IV. General Specifications and Recommendations for Calorimeter Installations by Gas Companies.

V. Directions for Operating Calorimeter.

VI. Suggestion of Several Types of Calorimeters Suitable to Use when Checked by the Primary Standard Adopted.

12. Following the adoption of these specifications, the Public Service Commission, Second District, purchased necessary instruments and equipped a laboratory where the instruments of the different Companies could be calibrated.

13. The delays in delivery of instruments were considerable, so that the calibration of the companies' calorimeters at the State laboratory was not completed until early in 1911. It was deemed wise by the Committee to allow a preliminary period after the instruments were finally installed for the companies' operators to become acquainted with the methods of testing before asking that the results be submitted to it for inspection.

14. During this preliminary period forms were prepared to be used by the companies in recording their daily readings and in submitting the results each month to the Committee.

15. Observations of the results obtained during the first few months of testing prompted the Committee to prepare a second pamphlet which was printed under the title "Plan of Calorimetric Investigation and Explanation of Test and Report Forms." A copy of this pamphlet was furnished each company engaged in the investigation. Amended forms for recording and reporting daily readings and works data were also prepared.

16. This second pamphlet, which was tentatively adopted January 6, 1912, treated in further detail the following subjects:

1. The making of daily calorimetric tests and the recording daily of certain works data.
2. The submitting to the Committee monthly the results of the daily tests and of monthly averages and details of works data.
3. The furnishing to the Committee of information regarding operating conditions, and apparatus and methods in use.

17. Beginning with August 1, 1911, and ending October 31, 1912, a period of fifteen months, reports have been regularly received by the Committee and each month tabulated by the Secretary so that copies could be in the hands of each member of the Committee for individual study. During this period 6,738 calorimetric tests and 9,167 photometric tests were reported as shown in Tables II and III respectively.

* The definition of the heating value of gas adopted by the Committee for the purposes of this report and the investigations conducted is as follows:

"The heating value of a gas is the total heating effect produced by the complete combustion of a unit volume of the gas, measured at a temperature of 60 degrees Fahrenheit, and a pressure of 30 inches of mercury, with air of the same temperature and pressure, the products of combustion also being brought to this temperature.

"In America the unit of volume is the cubic foot and we recommend that the heating value be stated in terms of British Thermal Units per cubic foot of gas."

TABLE II.
CALORIMETRIC TESTS

Company	August, 1911	September	October	November	December	January, 1912	February	March	April	May	June	July	August	September	October	Total	
No. 1			25	25	22	6	1	7	26	25	25	16	26	23	25	252	
No. 2	31	30	31	30	25	25	24	25	25	26	23	22	25	23	22	387	
No. 3	24	23	26	25	25	27	25	25		25	26	25	27	24	27	354	
No. 4	29	28	29	28	31	29	32	26	28	32	29	24	24	17	14	400	
No. 5	27	25	26	25												103	
No. 6	29	27	28	28	29	31	29	28	30	30	30	31	30	27	26	433	Works
" "						20	15	26	30	30	30	31	28	26	31	267	Outlying Station
No. 7	27	30	31	27	26	26	26	26	26	27	25	26	25	21	7	376	
No. 8	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Inst. A at Works
" "	27	25	27	24	24	26	23	26	26	26	25	26	25	26	26	382	Inst. B at Works
" "	27	25	27	24	24	24	23	26	26	26	25	26	25	26	26	380	Inst. C at Office
No. 9	31	30	31	25	24	26	24	26	26	25	25	26	26	25	27	397	
No. 10			26	25	22	26	22	26	24	24	25	26	27	23	26	322	
No. 11	26	24	26	25	24	25	24	26	26	26	24	24	27	23	26	376	Coal Gas
" "	26	24	26	25	24	26	24	26	26	26	24	24	27	22	26	376	Water Gas
" "	26	24	26	25	24	26	25	26	26	25	25	24	27	23	26	378	Mixed Gas
No. 12	26	20	26	25	21	20	21	21	19	12	18	26	19	19	21	314	
No. 13	26	25	26	25	25	24	25	26	26	26	25	26	27	15	27	374	
No. 14									28	31	30	31	31	30	29	210	
No. 15														23	27	50	Works
" "															23	23	Outlying Station
No. 16							19	26	26	13	13	27	27	24	26	201	
Total	409	385	464	435	394	414	405	444	470	481	472	487	498	466	514	6,738	

TABLE III.
PHOTOMETRIC TESTS

Company	August, 1911	September	October	November	December	January, 1912	February	March	April	May	June	July	August	September	October	Total	
No. 1			26	25	25	26	1	7	26	26	25	16	26	24	25	278	Works
No. 3	31	30	31	30	30	31	29	25		25	25	26	31	30	31	406	Works
" "	27	25	26	24	25	26	24	26		25	23	26	26	23	27	351	Office
No. 4	31	30	30	30	31	31	32	29	29	32	29	24	24	17	15	414	Works
No. 5	27	25	26	25												103	Meter Shop
No. 6	31	30	31	30	31	31	29	31	30	31	30	31	31	30	31	458	Works
" "						31	29	31	30	31	30	31	31	30	31	305	Outlying Station
No. 7	27	30	31	28	26	24	26	28	27	27	25	26	24	22	25	396	Works
" "	23	22	26	25	25	26	25	24	26	26	22	24	26	24	26	370	Office
No. 8	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Works
" "	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Works
" "	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Office
" "	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Office
No. 9	31	30	31	30	31	31	29	31	30	31	30	31	31	29	31	457	Works
" "	31	30	31	27	24	27	25	26	26	25	25	26	26	26	27	402	Office
" "	31	30	31	27	24	27	25	26	26	25	25	26	26	26	27	402	Office
No. 10			26	25	24	26	23	25	24	25	25	25	27	23	26	324	Office
No. 11	27	25	26	25	25	24	24	25	26	25	24	24	27	23	26	376	Coal Gas
" "	27	25	26	25	25	26	24	25	26	26	24	24	27	22	26	378	Water Gas
" "	27	30	26	25	25	31	25	26	26	26	25	24	27	23	26	392	Mixed Gas
No. 12	31	30	31	30	31	31	29	31	30	31	30	26	19	19	21	420	Works
" "	26	23	26	25	25	20	22	26	26	26	25					270	Office
No. 13	26	25	26	25	25	26	25	26	26	26	25	26	27	24	27	385	Office
No. 14									30	30	30	31	31	30	31	213	Works
" "									29	31	30	31	31	30	29	211	Office
No. 15														25	27	50	Works
" "														25	23	48	Outlying Station
No. 16							19	26	26	26	25	27	27	24	26	226	Meter Shop
Total	562	538	615	577	548	603	557	598	623	680	653	629	645	651	688	9,167	

18. In May, 1912, a meeting of the Committee was held at Amsterdam which was attended by the men operating the calorimeters in the several plants. At this time a general conference was held and a discussion of the work, with particular reference to uniformity and accuracy, took place.

19. Sub-committees have taken up in detail matters that were considered of enough importance to require special study. Frequent meetings of the Committee have been held during the past two years and the work constantly reviewed with an endeavor to consider every phase of the question. An analysis of the work, the results of the tests and the conclusions drawn therefrom, will be found elsewhere in the report.

INTRODUCTORY OBSERVATIONS RELATING TO THE STUDY OF APPENDIX B.

1. Laboratory accuracy cannot be applied in commercial gas production. The engineer cannot predict from day to day the quality of gas that will be produced, not only because of the uncertainties in the character of the raw material, but also because of climatic conditions. It will be observed therefore that, owing chiefly to atmospheric changes, an excess candle power exceeding 10% at the plants is frequently not realized at official testing station, even though the minimum realized meets the State candle power requirements. This necessary condition tends to the serving of an irregular product which the charts clearly disclose.

2. Similarly, when operating under a heat unit standard, the engineer must continue to make his product in excess of the standard adopted. The information derived by the test indicates that the consumer will receive a much more uniform and satisfactory product which should work for greater efficiency in its use at the point of consumption when compared with operating under the candle power standard where, even with uniform pressure, the essential readjustment of air supply is neglected; this is wasteful in use of gas and through carbonization (a too familiar sight with over-enriched gas) is destructive of gas mantles. This condition would be eliminated under the proposed heat unit standard and the present economic losses and annoyance in the use of gas due to this neglect in readjustment of air supply will be eliminated.

3. The adoption of the proposed standard will be a conservation of resources through the elimination of unnecessary wastes in production and distribution without loss in effectiveness of the product when compared with all elements of waste resulting from pursuing present methods.

4. It should be noted that a percentage variation from a standard by, for example, 5% is but 1 unit in the case of 20 as used in candle power, while the same accuracy when dealing with the larger heat unit figure becomes 29 units (nearly) when dealing with heat unit standards, yet both 1 and 29 are figures that show equal percentage accuracy.

5. It should be kept in mind that a difference in reading by two observers of the same gas might reasonably be even .5 of a candle or nearly 3% in candle power. It is probable that the variation in B. t. u. observation by the same observers would be less than 1%. The following table may be found useful. It shows, for example, that a 5% variation from 20 candle power is 1 or 21 candle power; for 18 candle power is .9 or 18.9 candle power; from 16 candle power is .8 or 16.8; while from 570 B. t. u. it is 28.50 or 599 (nearly).

TABLE SHOWING RESULTANT ILLUMINATING OR HEATING VALUE FOR VARIATIONS IN THE QUALITY OF THE GAS, ABOVE STANDARD, OF FROM 1 TO 13 PER CENT.

Standard	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%
20 C. P.	20.2	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.0	22.2	22.4	22.6
18 C. P.	18.2	18.4	18.5	18.7	18.9	19.1	19.3	19.4	19.6	19.8	20.0	20.2	20.3
16 C. P.	16.2	16.3	16.5	16.6	16.8	17.0	17.1	17.3	17.4	17.6	17.8	17.9	18.1
570 B. t. u.	576	581	587	593	599	604	610	616	621	627	633	638	644

APPENDIX B

1. As already noted in Appendix A, page —, there have been 6,738 calorimetric tests and 9,167 photometric tests reported to the Committee during the period August 1, 1911, to October 31, 1912. It has seemed unnecessary to include all of these tests in detail in this report, but the monthly averages are given in Table IV. These averages are in all cases based on the actual number of tests made during the month. The table also gives the minimum monthly average of heating value for each Company and the average illuminating value for the month during which the minimum average heating value occurred.

TABLE IV.

CARBURETTED WATER GAS

STANDARD CANDLE POWER REQUIRED AT TESTING STATION 20

Month	Company No. 3 At Works Average		Company No. 4 At Works Average		Company No. 5 At Meter Shop Average		Company No. 6 At Works Average		Company No. 6 Testing Station Average		Company No. 7 At Works Average	
	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.
August, 1911	621	22.8	642	23.3	624	20.7	613	23.8			605	20.7
September	631	22.5	644	23.7	616	21.1	613	24.9			615	20.7
October	636	22.9	632	22.5	635	20.6	612	23.4			617	20.5
November	657	22.5	635	22.1	634	19.6	615	22.9			623	21.1
December	661	22.4	627	21.9			637	23.1			625	22.6
January, 1912	669	21.8	622	20.5			631	22.8	619	19.9	635	25.1
February	650	23.1	645	22.0			634	23.2	618	20.4	631	25.6
March	643	24.1	631	22.4			624	22.8	620	20.4	630	25.6
April			626	22.1			627	23.3	617	20.2	628	25.5
May	628	23.3	634	23.5			638	23.2	621	20.5	621	22.5
June	622	22.1	630	22.7			643	23.2	636	20.7	610	21.7
July	622	21.3	644	22.4			646	23.1	639	21.1	607	21.1
August	619	20.6	643	22.3			636	23.1	631	20.7	613	21.5
September	624	21.3	644	22.5			630	22.9	616	20.2	619	21.5
October	630	20.7	652	22.3			638	23.4	626	20.4	629	21.6
Min. Ave. B t. u. and C. P. same month	619	20.6	622	20.5	616	21.1	612	23.4	616	20.2	605	20.7

Month	Company No. 8 At Works Average		Company No. 8 At Office Average		Company No. 9 Testing Station Average		Company No. 10 At Office Average		Company No. 15 At Works Average		Company No. 15 Outlying Station Average		Company No. 16 At Meter Shop Average	
	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.
August, 1911	617	19.1	613	20.0	589	20.8								
September	610	18.9	605	19.6	597	20.6								
October	594	18.7	584	19.3	619	21.2	625	21.2						
November	633	19.7	622	19.9	625	20.4	632	21.2						
December	645	22.5	642	20.9	638	20.7	626	20.7						
January, 1912	653	22.4	643	21.1	631	20.9	626	20.5						
February	650	22.6	631	20.6	621	20.7	634	20.6					625	20.5
March	621	20.3	607	19.8	610	20.7	618	20.4					619	20.8
April	602	18.7	591	20.4	600	20.2	620	20.6					620	20.6
May	592	19.5	590	19.9	589	20.6	629	20.9					621	21.2
June	592	19.3	596	20.7	595	20.6	624	21.2					631	21.0
July	584	17.9	586	20.6	597	20.6	619	21.2					639	20.7
August	592	19.3	591	20.1	588	20.5	633	21.9					626	21.2
September	607	19.7	605	21.0	592	20.2	615	20.8	627	20.9			626	20.7
October	615	20.4	618	20.5	597	20.6	605	20.4	629	22.2	606	17.6	622	21.1
Min. Ave. B t. u. and C. P. same month	584	17.9	584	19.3	588	20.5	605	20.4	627	20.9	606	17.6	619	20.8

Month	Mixed Coal and Carburetted Water Gas								Coal Gas Enriched				Coal Gas Unenriched	
	Company No. 11 At Works Average		Company No. 12 At Works Average		Company No. 13 At Office Average		Compnny No. 14 At Office Average		Company No. 1 At Works Average		Company No. 2 At Office Average		Company No. 11 At Works Average	
	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.	B t. u.	C. P.
August, 1911	626	20.0	590	21.3	611	18.2					660		602	14.9
September	640	20.4	592	21.3	623	18.3					654		616	15.3
October	628	20.6	596	21.5	661	18.7			683	18.7	654		611	13.5
November	643	20.9	611	21.9	624	18.6			674	18.0	651		607	13.8
December	649	20.5	615	21.9	633	18.4			667	17.7	647		621	14.2
January, 1912	672	20.5	635	21.6	632	18.5			653	17.5	630		628	13.7
February	656	21.4	645	21.5	641	18.4					636		614	13.7
March	646	20.4	647	21.1	626	18.3			626	16.5	616		612	14.9
April	636	20.8	647	20.9	626	18.6	605	18.6	641	16.4	637	Not Reported	612	13.5
May	628	21.5	642	20.8	633	18.4	634	19.4	656	16.9	651		601	14.7
June	624	19.7	631	20.6	620	18.4	623	18.5	642	16.6	662		610	15.3
July	610	19.9	617	20.3	635	18.6	618	18.6	638	17.0	646		593	14.3
August	614	19.7	628	20.4	627	18.4	618	18.9	645	16.8	644		591	13.7
September	612	19.8	622	20.5	621	18.4	611	18.7	653	17.0	646		595	14.2
October	623	20.4	633	20.5	625	18.5	603	18.4	650	17.8	618		592	13.1
Min. Ave. B t. u. and C. P. same month	610	19.9	590	21.3	611	18.2	603	18.4	626	16.5	616		591	13.7

2. The results of the tests throughout the entire period are shown graphically in the following pages. Data in regard to the works and operation of the various Companies are also given.

3. The charts were prepared to show the variations in the quality of gas, both daily and from month to month. There are separate diagrams for the heating value and the illuminating value.

4. The zero line represents the average for a complete year, except when tests did not cover so long a period. In each case the actual figure represented by the zero line is given, and the months included in the average are stated. The average for each month is shown by a heavy line indicating the percentage of variation above or below the yearly average. The cross-sectioning represents the extreme high and low variation of any daily readings during such month in percentage of the monthly average.

5. The illuminating values and their variations from the yearly and monthly average are shown according to the same method in the second diagram.

6. A careful study of these diagrams indicates that the percentages of variation in heating values from day to day and from month to month are considerably less than the percentages of variation in illuminating values, that the variations in monthly averages for the two measures of quality do not parallel one another and that there is no definite relation between them.

COMPANY NO. 1

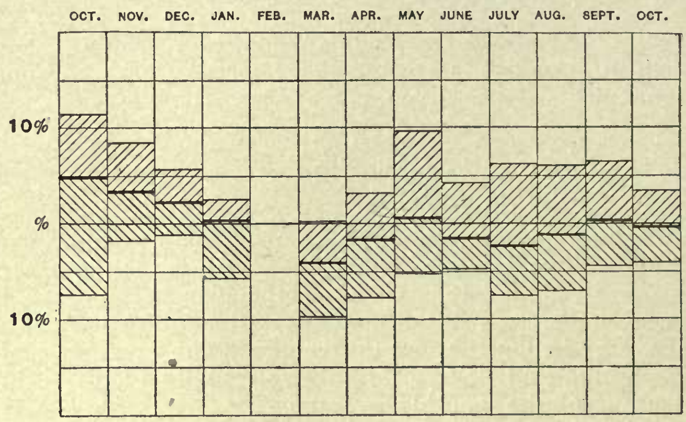
Works Kind of coal—¾ screened Pennsylvania gas coal.
Class A—Table I. Page 16.
Duration of charge—4 hours.

Operation Coal gas plant with water gas auxiliary, not in use daily.
One holder housed, six exposed.
Yield per lb. coal—4.79 to 4.94 cu. ft. (cor.)

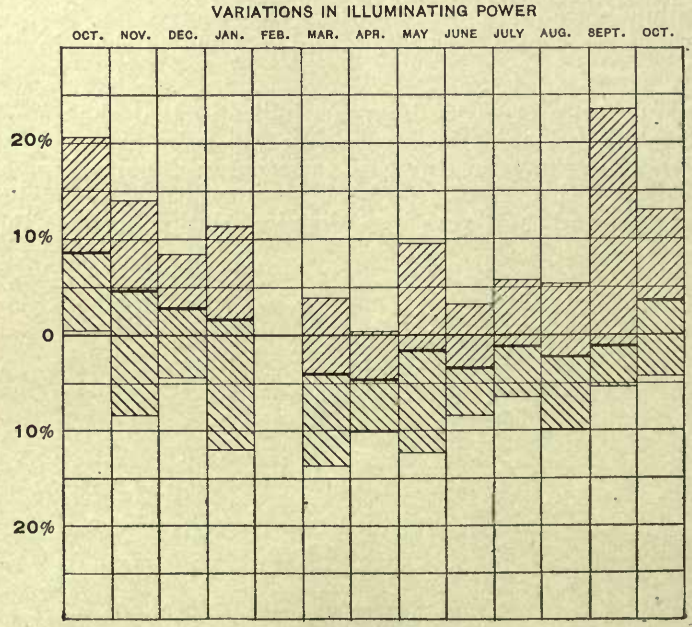
Tests Tests made at works.
Coal gas enriched with oil gas.
Type of calorimeter—Junkers—American Meter Co.
Temperature of atmosphere not reported each month, probable range during period of tests from 0° to 100° F.

Curves Zero lines represent average heating power or illuminating power for period October 1, 1911, to September 30, 1912, excepting February, 1912, for which month no tests were reported.
Average heating power=652 B. t. u.
Average illuminating power=17.2 C. P.

VARIATIONS IN HEATING POWER



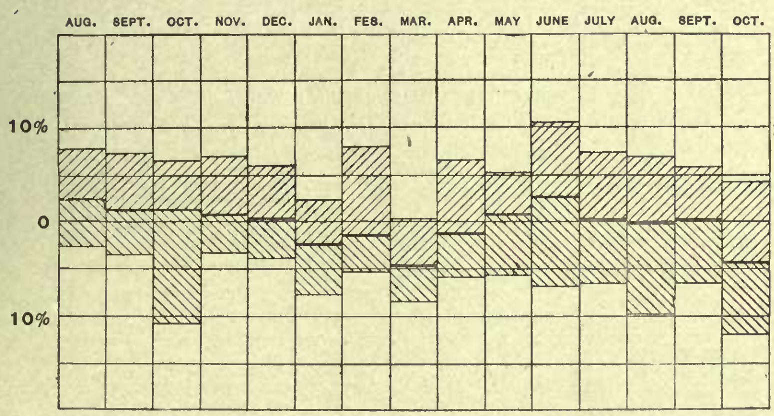
VARIATIONS IN ILLUMINATING POWER



COMPANY NO. 2

Works	Coal gas plant.
	Class D—Table I. Page 16.
	Holders exposed.
	Horizontal retorts.
	One-half depth furnace.
Operation	Enricher—cannel coal—8.57 to 9.23 lbs. per 100 lbs. coal carbonized.
	Kind of coal—Pennsylvania.
	Duration of charge—from 5 hrs. 35 min. to 7 hrs. 26 min.
	Yield per lb. coal—December to July—4.78 to 5.25 cu. ft. (cor.)
Tests	Tests made at office.
	Type of calorimeter—Junkers.
	No photometric tests reported.
	Temperature of atmosphere ranged from — 10° to 102° F.
Curves	Zero line represents average heating power for 12 months—August 1, 1911, to July 31, 1912.
	Average heating power=645 B. t. u.

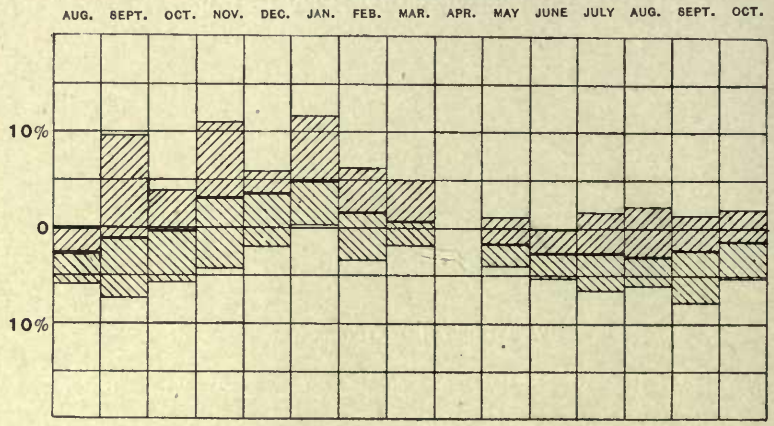
VARIATIONS IN HEATING POWER



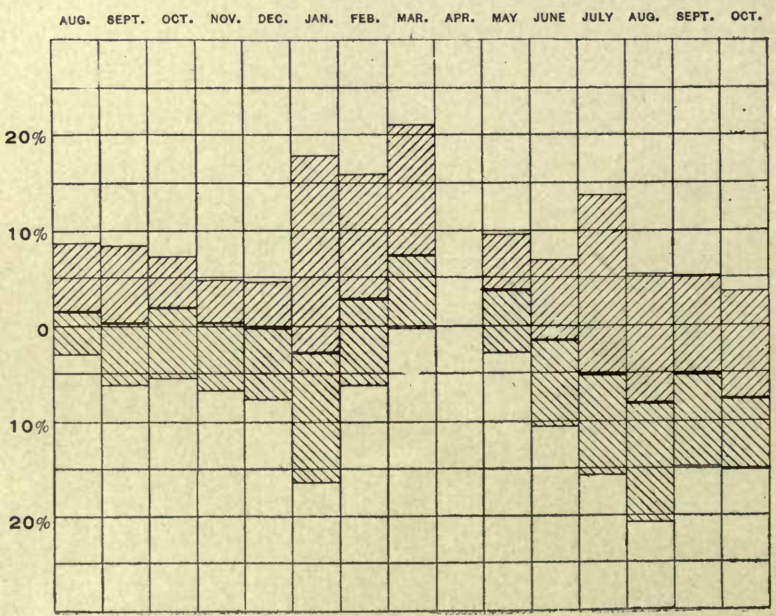
COMPANY NO. 3

Works	Carburetted water gas plant. Class A—Table I. Page 16. Holders exposed. Generators—7′ 6″ and 12′ sets.
Operation	Enricher—34° to 35° B. gas oil—3.68 to 4.48 gals. per M. (cor.) Kind of fuel—Anthracite grate coal. Generator fuel per M. (cor.)—31.55 to 37.44 lbs. Hours per day works operation—from 10 to 24.
Tests	Tests made at works. Type of calorimeter—Junkers. Temperature of atmosphere ranged from — 16° to 98° F.
Curves	Zero lines represent average heating power or illuminating power for period August 1, 1911, to July 31, 1912, excepting April, 1912, for which month no tests were reported. Average heating power=640 B. t. u. Average illuminating power=22.6 C. P.

VARIATIONS IN HEATING POWER

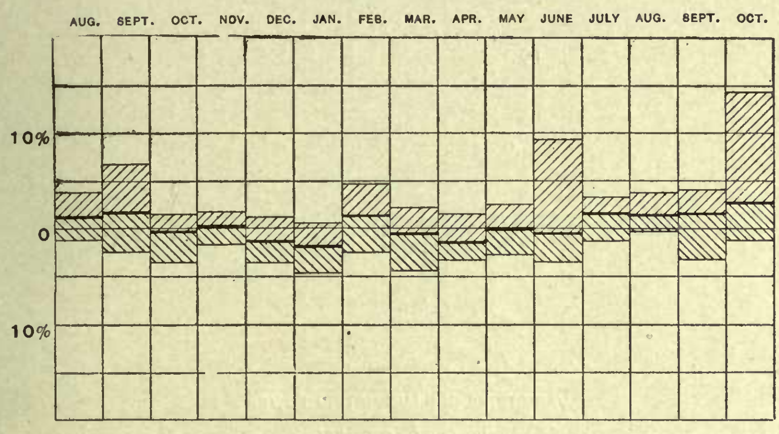


VARIATIONS IN ILLUMINATING POWER

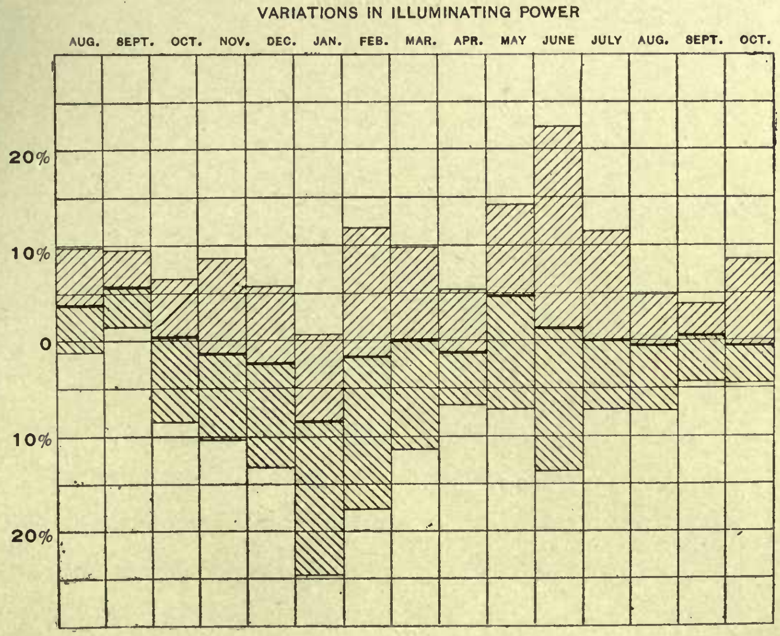


Works	Carburetted water gas plant. Class A—Table I. Page 16. Holders exposed. Generators—U. G. I. Improved Lowe—up and down steam, 7′ 6″ and 8′ 6″ sets. Air and steam meters.
Operation	Enricher—Gas oil—3.80 to 4.19 gals. per M. (cor.) Kind of fuel—Broken anthracite. Generator fuel per M. (cor.)—29.7 to 35.7 lbs. Hours per day works operation from 4.5 to 23.8.
Tests	Tests are made at works laboratory. Samples of gas taken from outlet of street main governor. Gas has been exposed to atmospheric temperature in storage holder and relief holder. Type of calorimeter—Junkers, 1910—American Meter Co. Type of photometer—U. G. I. 60″ Bar. Edgerton Standard. No. 7 Bray burner. Temperature of atmosphere ranged from — 4° to 97° F.
Curves	Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power=634 B. t. u. Average illuminating power=22.4 C. P.

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



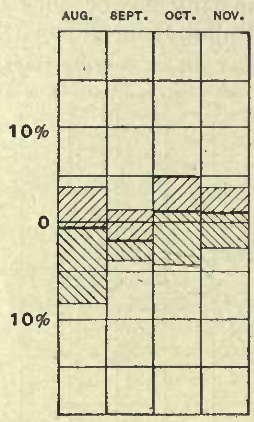
COMPANY NO. 5

Works Carburetted water gas plant.
Class C—Table I. Page 16.
Relief holder housed.

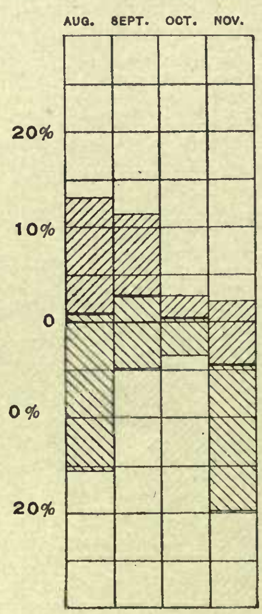
Tests Tests made at a test station one-half mile from works.
Type of calorimeter—Sargent.
Temperature of atmosphere ranged from 27° to 97° F. during period of tests.
Note.—This calorimeter was moved during December and January to plant of Company No. 16.

Curves Zero lines represent average heating power or illuminating power for four months—August 1, 1911, to November 30, 1911.
Average heating power=627 B. t. u.
Average illuminating power=20.5 C. P.

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER

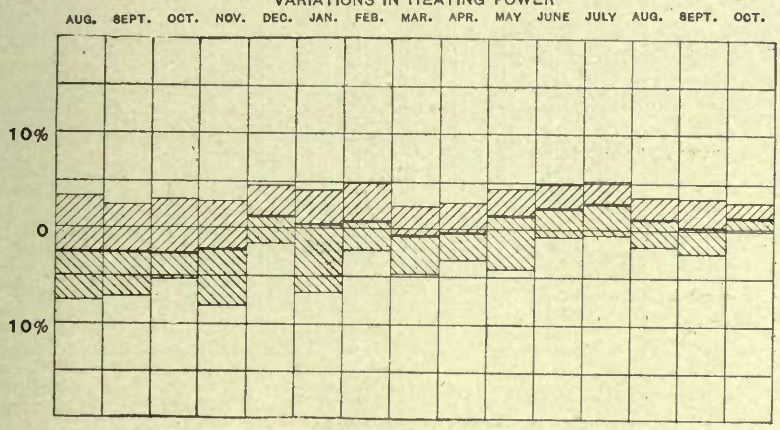


COMPANY NO. 6

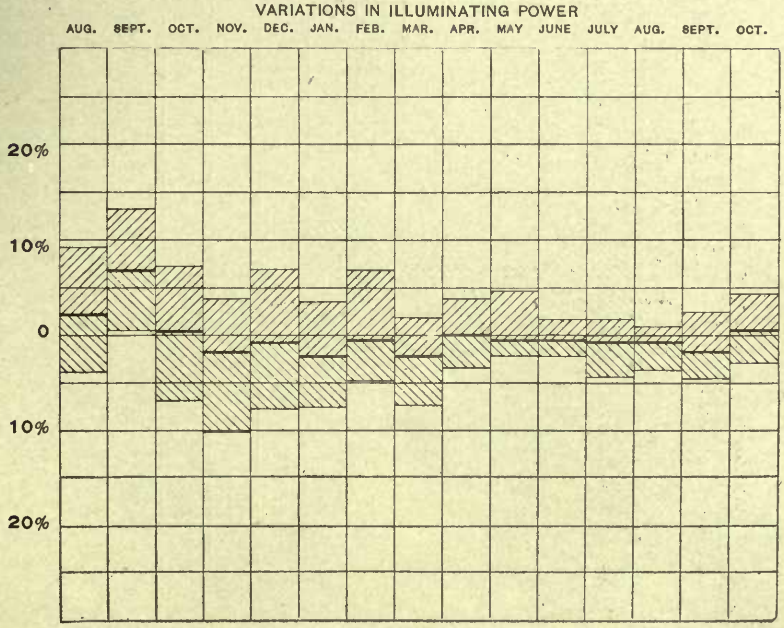
Works	Carburetted water gas plant.
	Class B—Table I. Page 16.
	Holders—1 housed, 1 exposed, Works A; 1 exposed, Station B.
	Generators—U. G. I. Standard—up and down steam, 6′ sets.
Operation	Enricher—Gas oil—3.59 to 4.11 gals. per M. (cor.)
	Kind of fuel—Anthracite grate.
	Generator fuel per M. (cor.)—27.31 to 30.48 lbs.
	Hours per day works operation from 9.18 to 22.45.
	Tests are made at works (A).
Tests	Tests are also made at outlying station (B). See next page.
	Samples of gas, works A, taken at outlet of station governor.
	Type of calorimeter—Junkers.
	Type of photometer—U. G. I. Standard 60″ Bar. Edgerton Standard checked by Pentane lamp. No. 7 lava tip burner.
	Temperature of atmosphere ranged from — 20° to 108° F.
Curves	Zero lines represent the average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
	Average heating power=628 B. t. u.
	Average illuminating power=23.3 C. P.

TESTS AT WORKS

VARIATIONS IN HEATING POWER



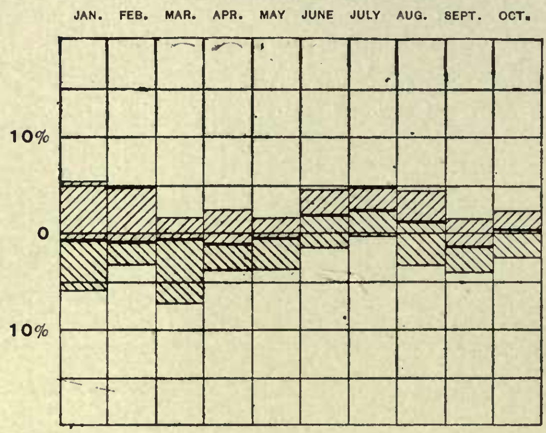
VARIATIONS IN ILLUMINATING POWER



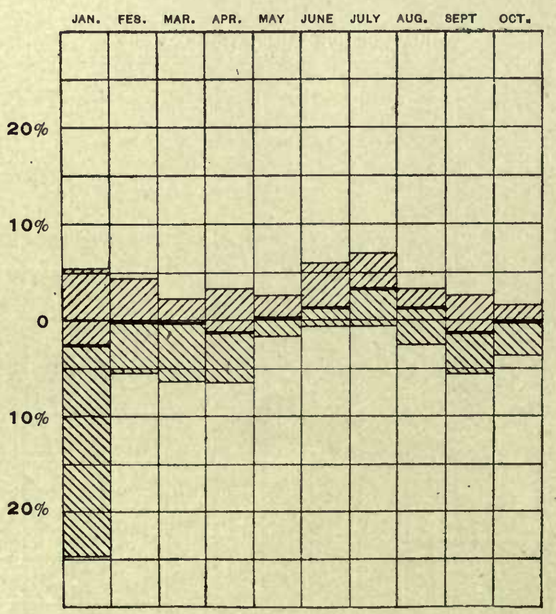
Tests Works and operating data given on preceding page.
Tests made at outlying testing station (B).
Samples of gas taken from inlet side of the governor on the outlet of exposed storage holder.
For course of gas from works see map on page 48.
Type of calorimeter—Junkers—American Meter Co.
Type of photometer—U. G. I. Standard 60″ Bar. Pentane lamp—standard. No. 7 lava tip burner.

Curves Zero lines represent average heating power or illuminating power for 10 months—January 1 to October 31, 1912.
Average heating power=624 B. t. u.
Average illuminating power=20.5 C. P.
For further information see Appendix C, page 49.

TESTS AT OUTLYING STATION
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



COMPANY NO. 7.

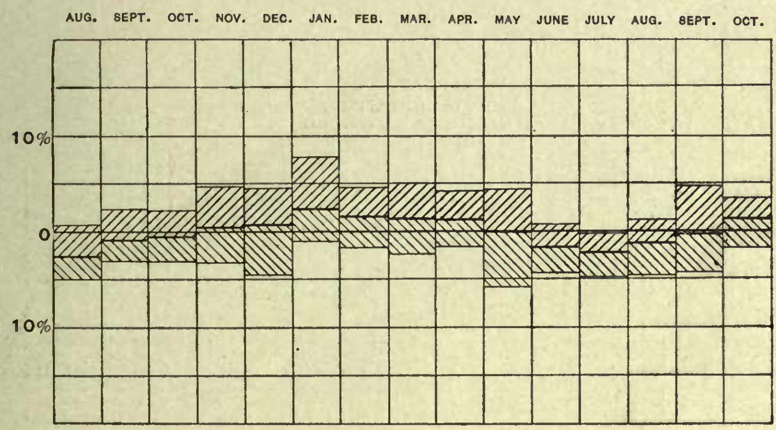
Works Carburetted water gas plant.
Class B—Table I. Page 16.
Holders exposed.
Generators—Western Gas Const. Co., 7′ 6″ sets.

Operation Enricher—34° B. gas oil—3.06 to 3.84 gals. per M. (cor.)
Kind of fuel—Anthracite coal.
Generator fuel per M. (cor.)—31.7 to 35.4 lbs.
Hours per day works operation from 7.5 to 20.7.

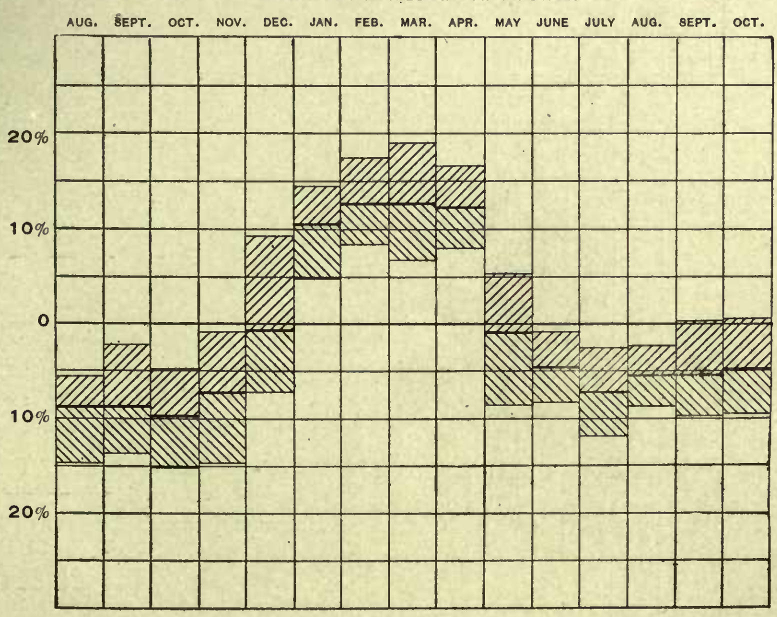
Tests Tests are made at works.
Samples of gas taken from outlet of station governor.
Gas has been exposed to atmospheric temperature in city holder.
Type of calorimeter—Junkers.
Type of photometer—Suggs-Letherby open type. Standard—Hefner lamp burning imported Amylacetate. Burner—Argand F.
Temperature of atmosphere ranged from — 20° to 95° F.

Curves Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power=621 B. t. u.
Average illuminating power=22.7 C. P.

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



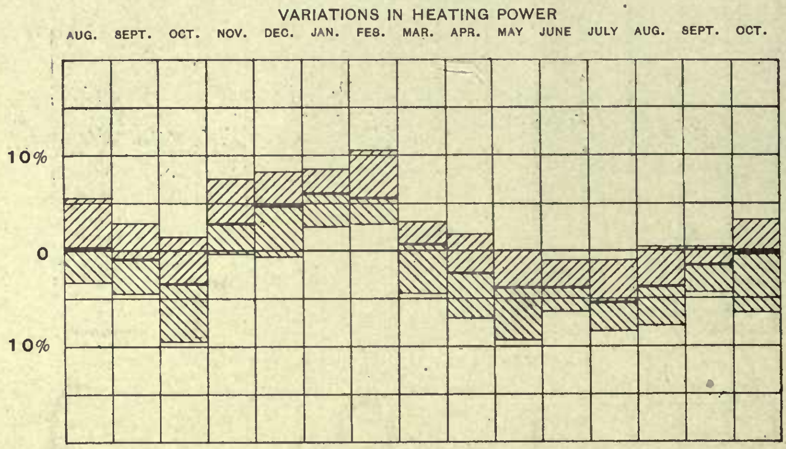
Works Carburetted water gas plant.
Class C—Table I. Page 16.
Holders exposed.
Generators—5′ and 7′ 6″ sets. Pyrometers on sets.

Operation Enricher—28° B. oil—3.5 to 4.65 gals. per M. (cor.)
Kind of fuel—Broken anthracite and from 80 to 89% anthracite remainder gas house coke during March, April, May and June.
Generator fuel per M. (cor.)—35.90 to 40.8 lbs.
Hours per day works operation from 8 to 23.8.

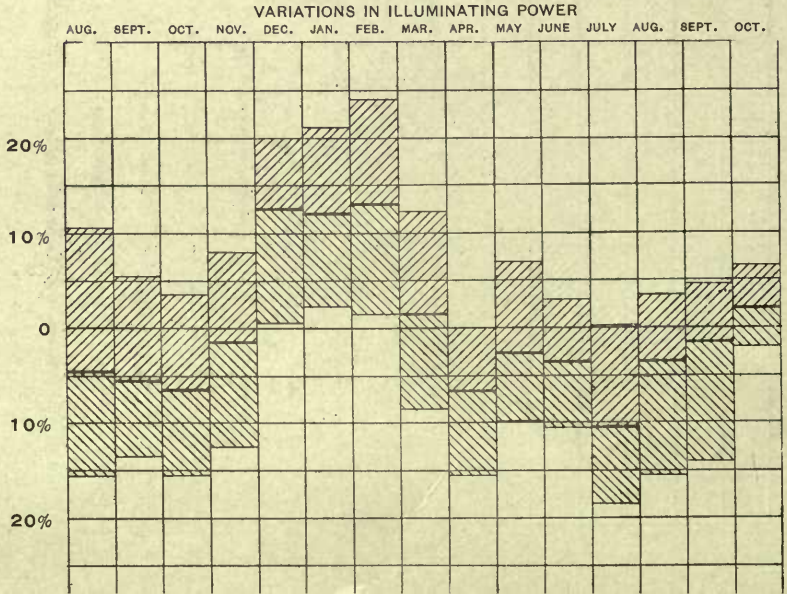
Tests Tests are made at works (A) and also made at testing station (B). See next page.
Samples of gas at works (A) taken from distribution main governor inlet.
Type of calorimeter—Junkers and Sargent. (Although results of tests with Sargent calorimeter were reported, they have not been used in connection with accompanying curves to avoid duplicating curves unnecessarily.)
Type of photometer—60″ Open Bar. U. G. I. Standard—Genuine English Spermaceti candles weighing 6 to the pound.
Burner—No. 7 L. P. Slit Union Bray and "New F" Argand Sugg pattern.
Temperature of atmosphere ranged from — 3° to 100° F.

Curves Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power*=616 B. t. u.
Average illuminating power=20 C. P.
N. B.—Average heating power Sargent same period, 616 B. t. u.
* See also Appendix C, page 56.

TESTS AT WORKS
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



COMPANY NO. 8.—(Continued.)

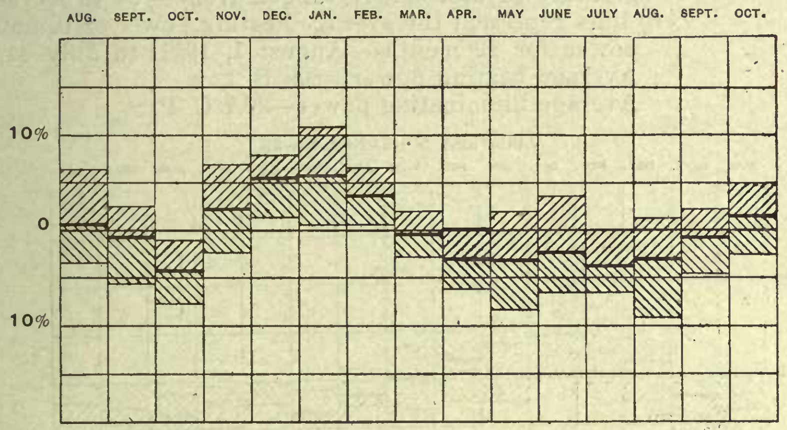
Works and operating data given on preceding page.

Tests Tests made at testing station (B).
Samples of gas are taken direct from service entering building from street main.
Type of calorimeter—Junkers.
Type of photometer—60″ open Bar. American Meter Co. Standard—Genuine English Spermaceti candles weighing 6 to the pound. Burner—No. 7 L. P. Slit Union Bray and "New F" Argand Sugg pattern.

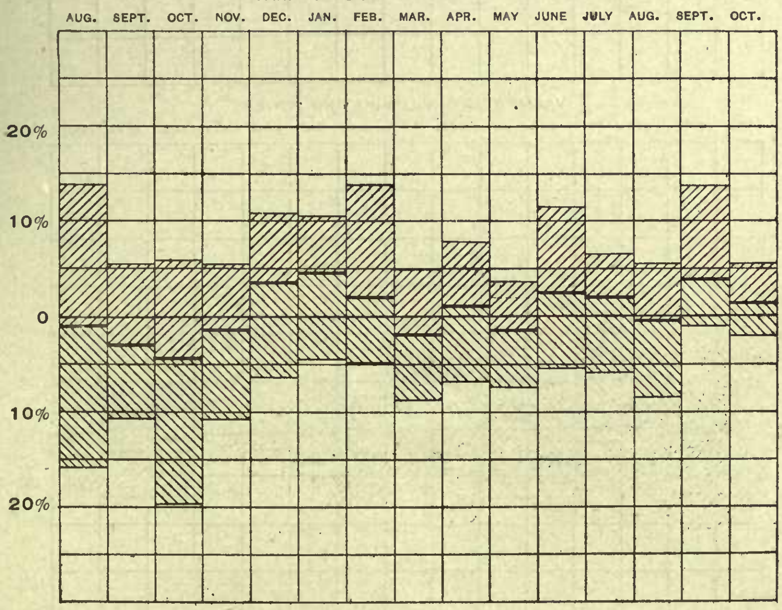
Curves Zero lines represent average heating power of illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power=609 B. t. u.
Average illuminating power=20.2 C. P.

TESTS AT TESTING STATION

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



COMPANY NO. 9.

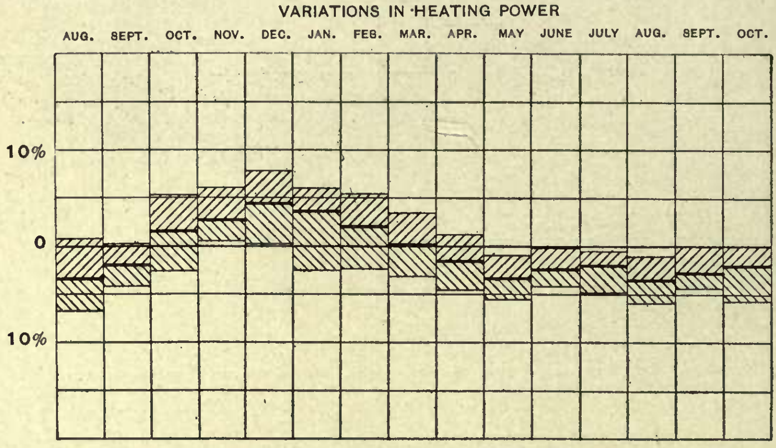
Works Carburetted water gas plant.
Class A—Table I. Page 16.
Holders exposed.
Generators—11'x16' 7" and 12'x16' 7" Lowe reverse steam sets.
Indicating and Recording Pyrometers.

Operation Enricher—28° B. gas oil—3.41 to 4.34 gals. per M. (cor.)
Kind of fuel—Anthracite.
Generator fuel per M. (cor.)—30.45 to 32.67 lbs.
Hours per day works operation—continuous running.

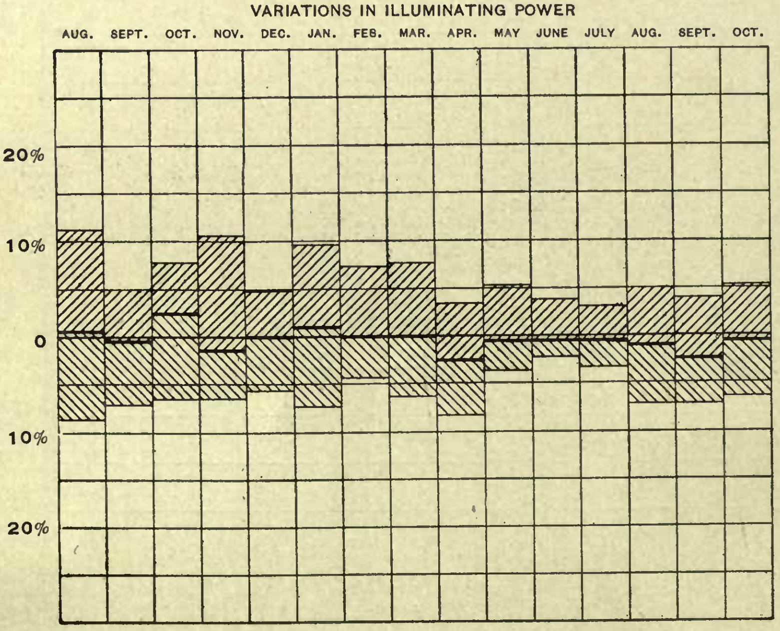
Tests Tests are made at testing station exceeding 1 mile from works.
Samples of gas taken directly from service entering building from the street main.
Gas has been exposed to atmospheric temperature in holders and ground temperatures in mains.
Type of calorimeter—Junkers.
Type of photometer—60" open Bar, American Meter Co. Standard—Genuine English Spermaceti candles weighing 6 to the pound. Burners—No. 7 L. P. Slit Union Bray and "New F" Argand Sugg pattern.
Temperature of atmosphere ranged from — 2° to 98° F.

Curves Zero lines represent the average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power=609 B. t. u.
Average illuminating power—20.7 C. P.

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER

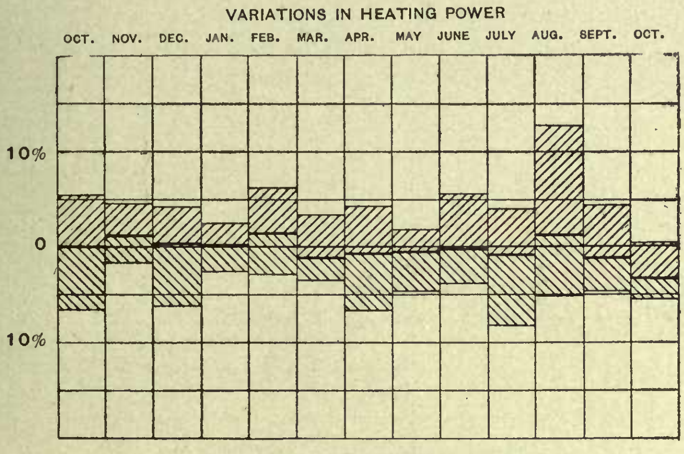


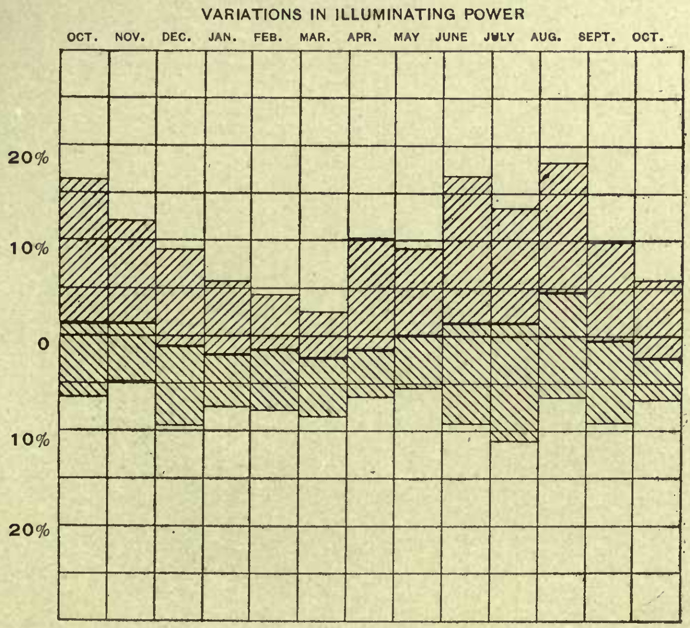
Works Carburetted water gas plant.
Class B—Table I. Page 16.
Storage holder exposed. Relief holder housed.
Generators—5′ Western Gas Const. Co. sets, one with no down-run valve, one with down-run valve.

Operation Enricher—28° to 34° B. gas oil—3.91 to 4.47 gals. per M. (cor.)
Kind of fuel—Anthracite grate.
Generator fuel per M. (cor.)—38.3 to 46.9 lbs.
Hours per day works operation—3 1/7 to 15½.

Tests Tests are made about ¼ mile from works.
Samples of gas taken direct from regular service into the building.
Gas has been exposed to atmospheric temperatures in holder and to ground temperature in mains.
Type of calorimeter—Sargent.
Type of photometer—80″ closed Bar. American Meter Co. Standard—Candles. Burner—Either "New F" Argand or No. 7 Slit Union Bray.
Temperature of atmosphere not reported.

Curves Zero lines represent the average heating power or illuminating power for 12 months—October 1, 1911, to September 30, 1912.
Average heating power=626 B. t. u.
Average illuminating power=21 C. P.





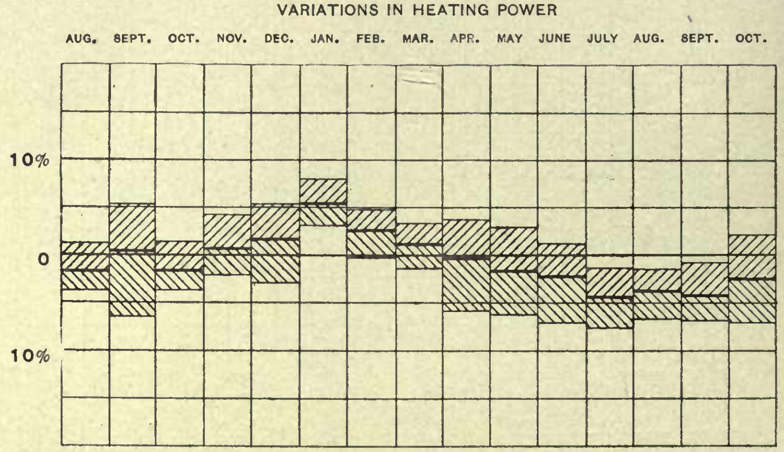
Works Mixed coal and carburetted water gas plant.
Class A—Table I. Page 16.
Holders exposed.
Generators—8′ 6″, 10′ 0″, 10′ 0″ Twin Gen., U. G. I. sets.
Benches—10 Parker & Russell 9s.

Operation Water gas—Enricher—35° to 37° B. gas oil—3.77 to 4.48 gals. per M. (cor.)
Kind of fuel—Anthracite coal, retort coke and oven coke.
Generator fuel per M. (cor.)—32.27 to 36.19 lbs.
Hours per day works operation—continuous running.
Coal gas—Kind of coal—Pennsylvania gas coal.
Yield per lb. coal cor. gas—4.71 to 4.96 cu. ft.
Duration of charge—4 hours.
Mixed gas—Mixture from 16.4% coal gas and 83.6% water gas to 24.7% coal gas and 75.3% water gas.

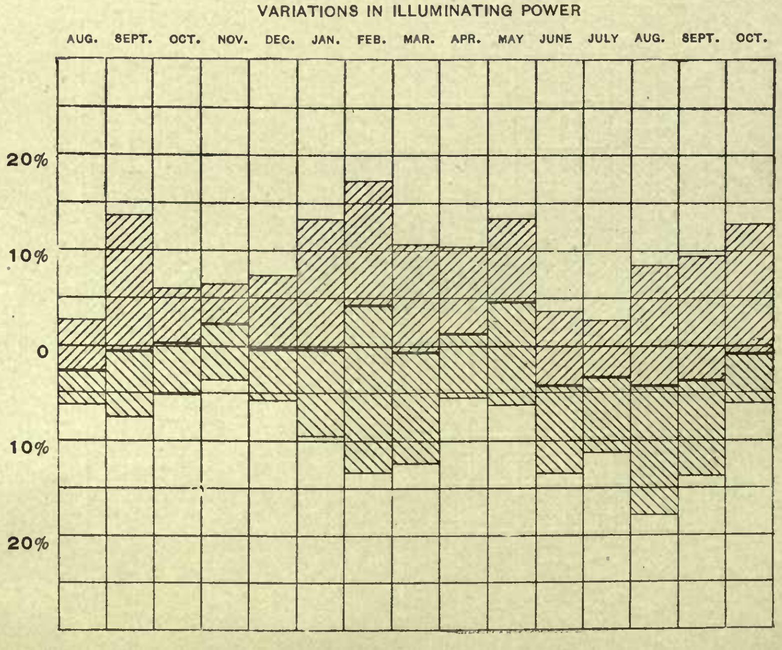
Tests Tests are made at works.
Tests were made of the carburetted water gas, of the coal gas and also of the mixed gas.
Type of calorimeter—Junkers—American Meter Co.
Type of photometer—not reported. Burner—No. 7 Bray Slit Union.
Temperature of atmosphere ranged from —4° to 94° F.

Curves The curves given below are for the mixed-coal and carburetted water gas. (Curves for straight coal gas are on following page.)
Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power=638 B. t. u.
Average illuminating power=20.6 C. P.

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



COMPANY NO. 11.—(Continued.)

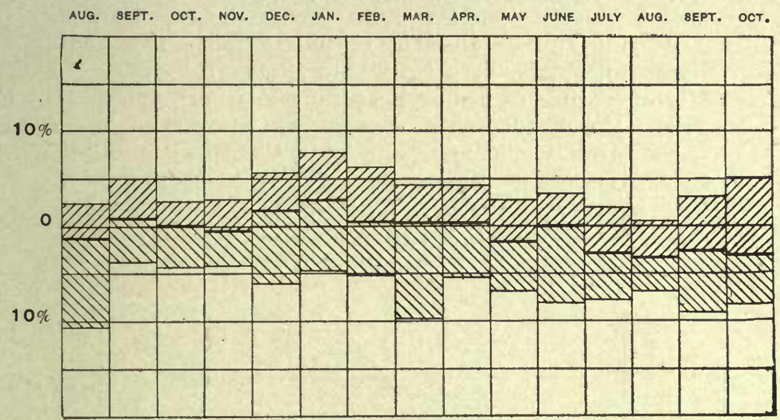
Unenriched coal gas.

Data regarding works, operation and tests are given on preceding page.

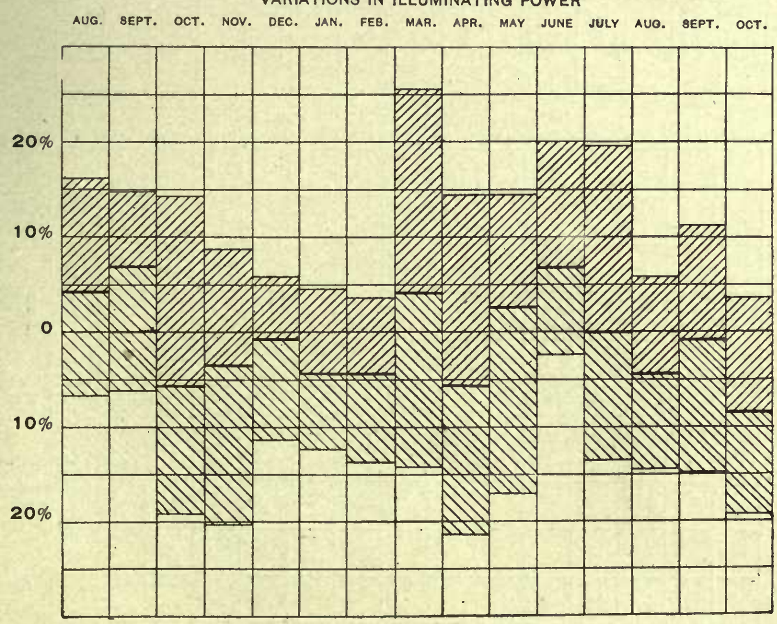
Curves Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power=611 B. t. u.
Average illuminating power=14.3 C. P.

UNENRICHED COAL GAS

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



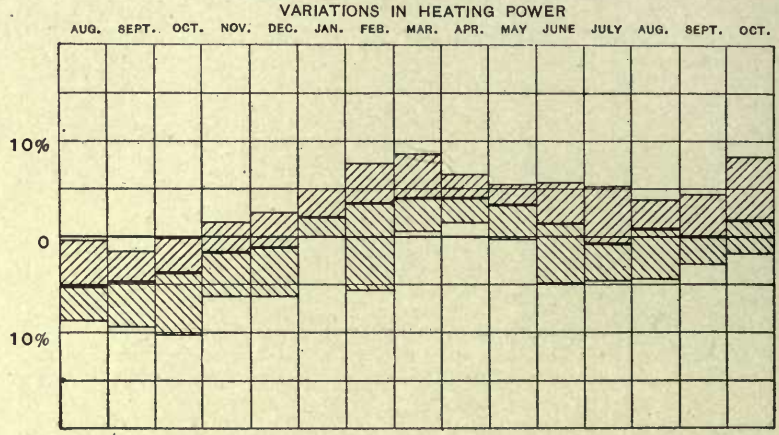
Works Mixed coal and carburetted water gas plant.
Class A—Table I. Page 16.
One holder exposed, others housed.
Generators—7′ 6″ H. & G. and 8′ 6″ U. G. I.
Benches—½ depth horizontal.

Operation Water gas—Enricher—35° B. gas oil—3.52 to 4.33 gals. per M. (cor.)
Kind of fuel—Retort house coke.
Generator fuel per M. (cor.)—27.96 to 33.45 lbs.
Hours per day works operation—continuous running.
Coal gas—Kind of coal—Pennsylvania gas coal.
Yield per lb. coal (cor.) gas—4.55 to 5.22 cu. ft.
Duration of charge—4 hours.
Mixed gas—Mixture from 19.21% coal gas and 80.79% water gas to 26.8% coal gas and 73.2% water gas.

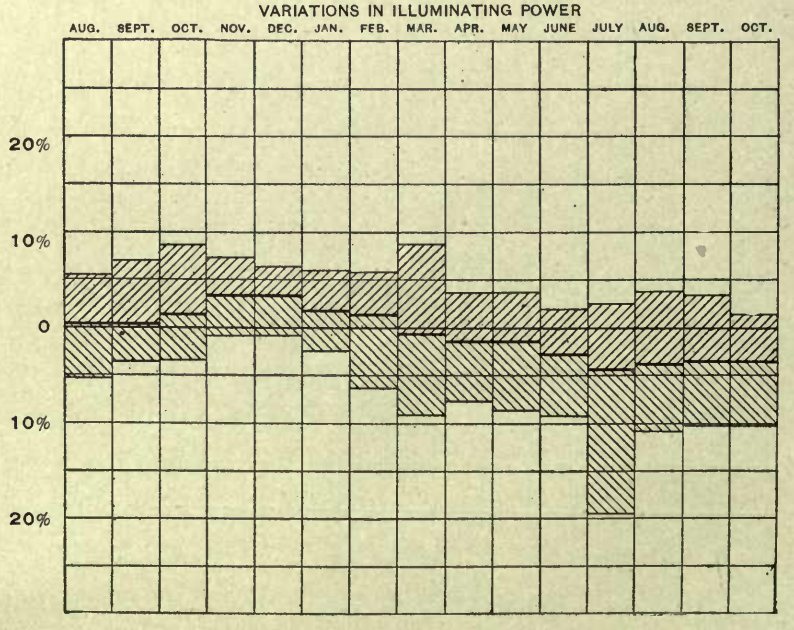
Tests Tests are made at works.
Samples of gas taken at inlet to works governor.
Type of calorimeter—Junkers.
Type of photometer—60″ Standard U. G. I. Bar. Standard—Edgerton standard checked daily by Pentane lamp. Burner—7′ lava tip burner.
Temperature of atmosphere ranged from — 8° to 116° F.

Curves Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power=622 B. t. u.
Average illuminating power=21.2 C. P.

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



COMPANY NO. 13

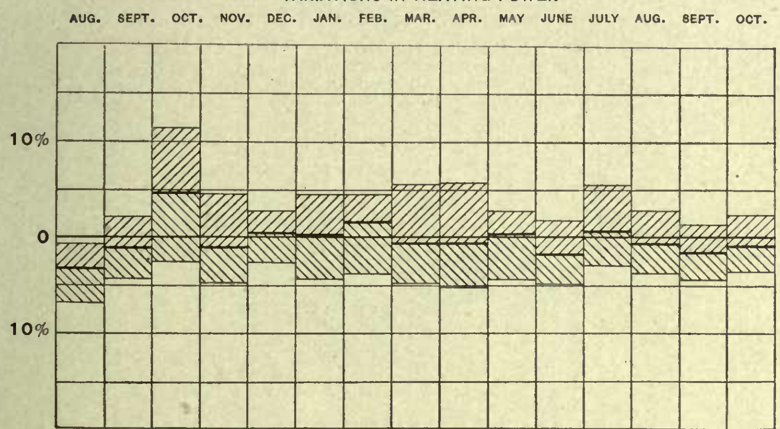
Works Mixed coal and carburetted water gas plant.
Class C—Table I. Page 16.
Holders housed.
Generator—6′ Lowe set.

Operation Water gas—Enricher—gas oil—3.4 to 4.3 gals. per M. (cor.)
Kind of fuel—Coke.
Generator fuel per M. (cor.)—41.09 to 48 lbs.
Hours per day works operation from 2 hrs. 43 min. to 12 hrs. 45 min.
Coal gas—Kind of coal—Pennsylvania.
Yield per lb. coal (cor.)—4.75 to 5.5 cu. ft.
Duration of charge—from 4 hrs. to 6 hrs. 20 min.
Mixed gas—Mixture from 53% coal gas and 47% water gas to 68% coal gas and 32% water gas.

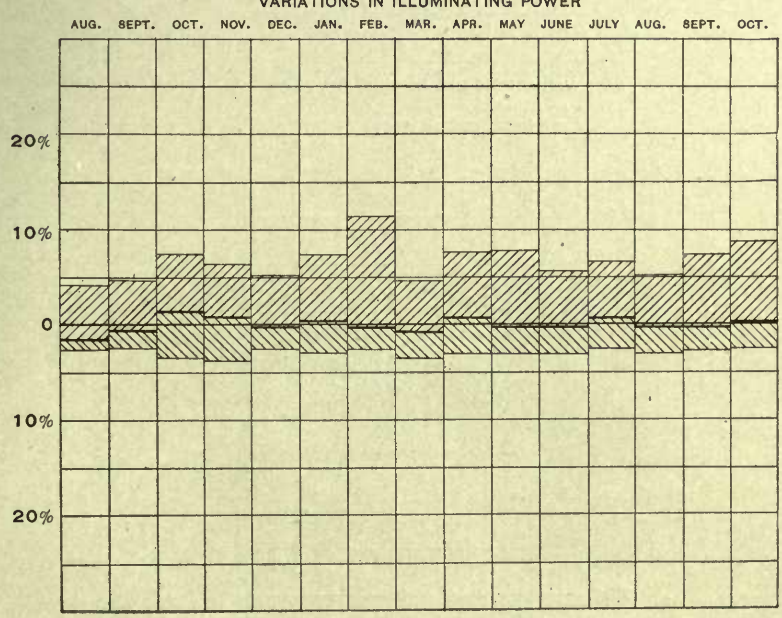
Tests Tests are made at office.
Type of calorimeter—Junkers.
Temperature of atmosphere not reported regularly—from — 10° to probable 100° F.

Curves Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912.
Average heating power=630 B. t. u.
Average illuminating power=18.5 C. P.

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER

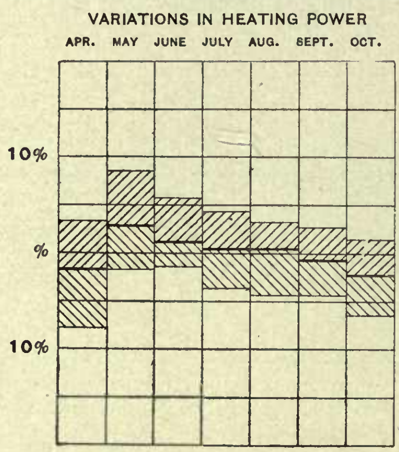


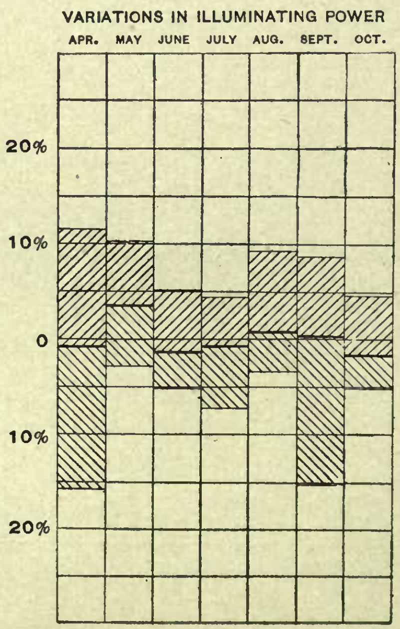
Works Mixed coal and carburetted water gas plant.
Class C—Table I. Page 16.
Holders—at works, exposed. Outlying, housed.
Generators—5′ double superheater, Lowe set, U. G. I. pattern with down-run connections.
Benches—½ depth benches of 6s by Improved Equipment Co.

Operation Water gas—Enricher—gas oil—3.93 to 4.63 gals. per M. (cor.)
Kind of fuel—Gas coke.
Generator fuel per M. (cor.)—34.37 to 39.28 lbs.
Hours per day works operation from 5 hrs. 38 min. to 17 hrs. 15 min.
Coal gas—Kind of coal—Pennsylvania.
Yield per lb. coal (cor.)—4.29 to 4.96 cu. ft.
Duration of charge—4 hours.
Mixed gas—Mixture from 31.18% coal gas and 68.82% water gas to 54% coal gas and 46% water gas.

Tests Tests made at office 3½ miles from works.
Samples of gas taken from regular distribution main through service entering building.
Type of calorimeter—Junkers—American Meter Co.
Type of photometer—60″ open Bar. U. G. I. Standard—Double candles. Burner—Sugg F or occasionally Sugg D or Bray special.
Temperature of atmosphere ranged from 22° to 84° F.

Curves Zero lines represent average heating power or illuminating power for 7 months—April 1 to October 31, 1912.
Average heating power=616 B. t. u.
Average illuminating power—18.7 C. P.





COMPANY NO. 15

Works Carburetted water gas plant.
Class A—Table I. Page 16.
Holders exposed.
Generators—9′ and 12′ Williamson.

Operation Enricher—34.1° B. gas oil.
Kind of fuel—Anthracite coal and coke.
Hours per day works operation—12 to 18 hours.
For information regarding transmission, see map, page 51, and explanation of tests, page 49.
Tests not having been started until September 1, 1912, no diagram has been made of the results.

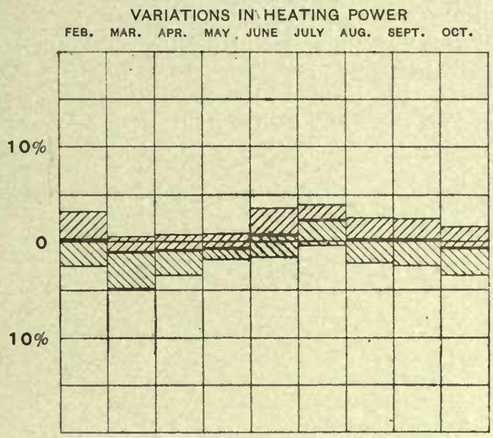
COMPANY NO. 16

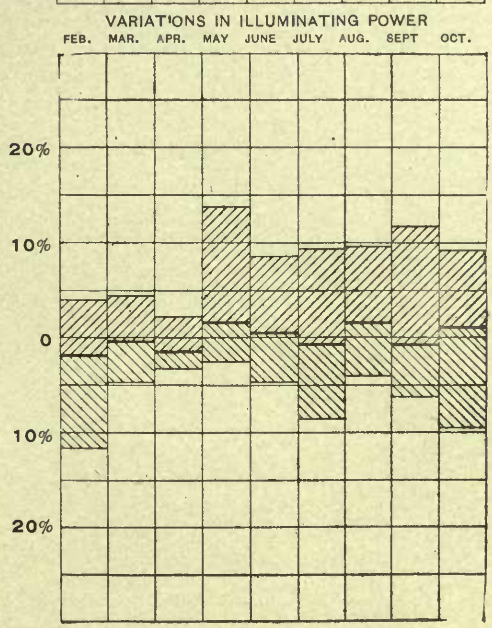
Works Carburetted water gas plant.
Class B—Table I. Page 16.
Holders exposed.

Operation Enricher—Gas oil—3.60 to 4.21 gals. per M. (cor.)
Kind of fuel—Anthracite.
Generator fuel per M. (cor.)—33.82 to 41 lbs.
Hours per day works operation from 6.24 to 14.4.

Tests Tests are made at testing station, 1½ miles from works.
Type of calorimeter—Sargent.
Temperature of atmosphere ranged from 2° to 102° F.

Curves Zero lines represent average heating power or illuminating power for 9 months—February 1 to October 31, 1912.
Average heating power=625 B. t. u.
Average illuminating power=20.9 C. P.





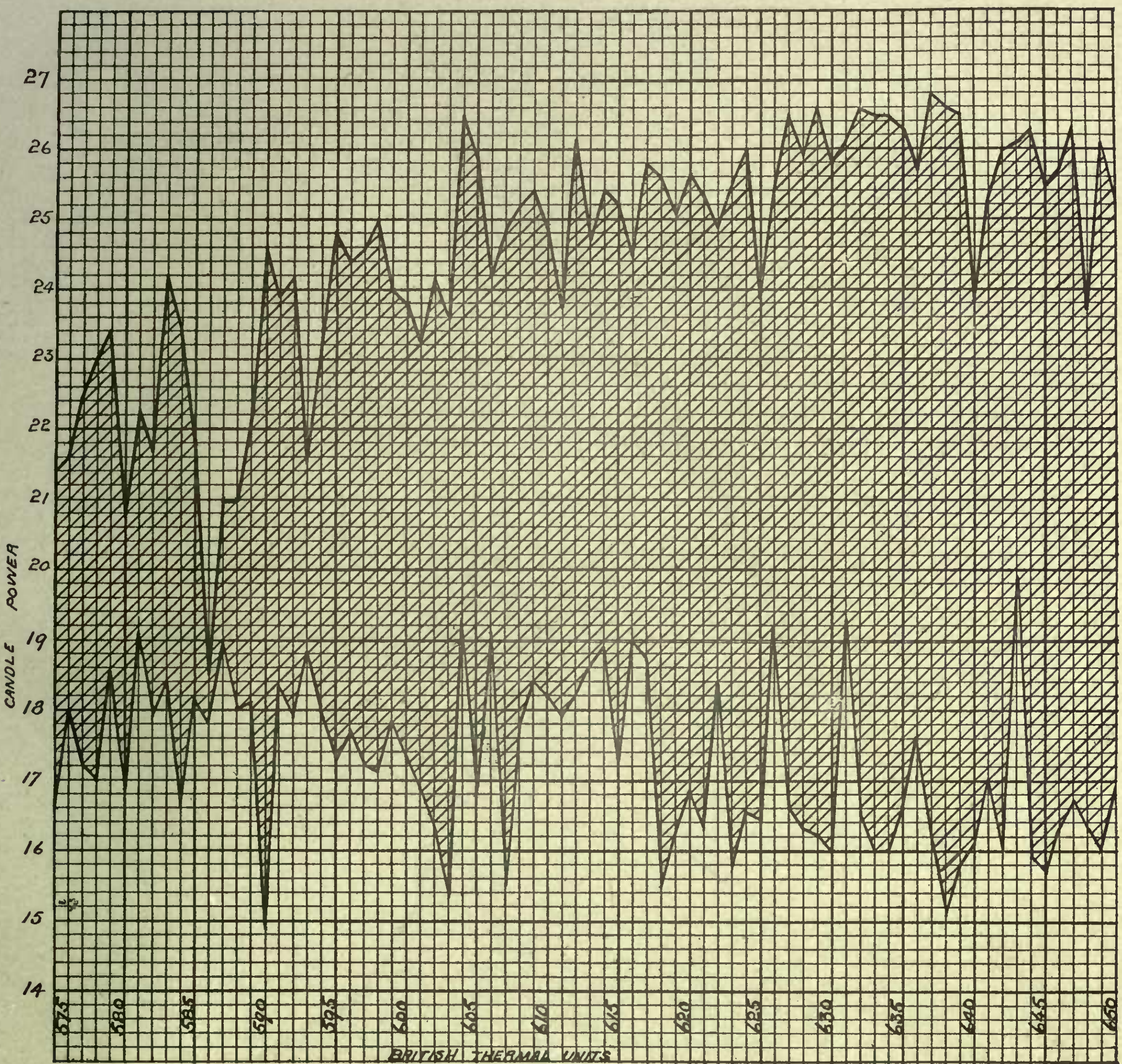
7. The accompanying diagram has been prepared for the purpose of demonstrating the fallacy of the impression which still exists in some quarters that there is a definite relation between the illuminating power and the heating power of the gas. The results of all tests, made at the works, of coal gas, carburetted water gas, and mixed coal and carburetted water gas, have been considered in the preparation of this diagram with the exception of tests of unenriched coal gas. Tests showing a heating power below 575 or above 650 have also been excluded, as they were exceptional and as they were doubtless due to some extraordinary conditions.

8. With the exceptions noted, all of the results obtained during the fifteen months covered by the tests when plotted fall within the shaded portion of the diagram. In other words, gas having a heating power of 575 B. t. u. has been shown to have an illuminating power anywhere between the limits of 16.6 and 21.4 candle power. Similarly, gas of 620 B. t. u. is shown to have an illuminating power anywhere between the limits of 16.8 and 25.6 candle power.

9. It might have been expected that the limits would be fairly wide apart in all cases, but that the tendency of the shaded portion of the diagram would follow a direction corresponding to higher candle power for higher heating values. Possibly if all of the tests were plotted and the values weighed a tendency of this character would be noted. It is, however, a fact that the minimum candle power, reported at any time 14.9 candle power, was found when the gas had a heating power of 590 B. t. u. and that the next lowest candle power, 15.1 candle power, was found when the gas had a heating power of 638 B. t. u. Similarly, the highest candle power reported, 26.8 candle power, occurred when the gas had a heating power of 634 B. t. u.; the next highest candle power, 26.6 candle power, occurred when the gas had a heating power of 629 and 632; the third highest candle power, 26.5 candle power, occurred on five occasions, the gas having heating power of 603, 627, 633, 634 and 639.

(See Diagram on opposite page.)

Range in candle power, at works, of gas having heating values of from 575 to 650 B t. u.



APPENDIX C

Manufacture and Distribution with Reference to Illuminating Value and Heating Value

UNENRICHED COAL GAS

1. Only one Company (No. 11) participating in the investigation reported the illuminating value and heating value of straight unenriched coal gas. From the reports submitted it has been found that the average illuminating value of this coal gas, for a full year, as read at the manufacturing plant, is 14.3 candle power, with a maximum individual daily reading of 18.1 and a minimum of 11.4—on a No. 7 Bray special burner. This gas is reported to be made from the best gas coal obtainable, and generated under good average conditions in horizontal retorts, with yields of only 4.71 to 4.96 cu. ft.

2. The present State requirements demand at the testing station a 16 candle power coal gas. It will be seen that under these requirements, the manufacture and sale of straight coal gas, without enrichment, is not permissable. To meet the requirements a coal gas must be enriched the greater part of the year with either gas made from cannel coal or gas made from oil.

3. Should a coal gas be enriched by mixing with a carburetted water gas, the gas would then be classified as a mixed gas and the present requirements would demand 18 candle power. To obtain this result would mean a large percentage of a high candle power water gas—from 22 to 25 candle power—to bring the mixture up to the required quality, an increasingly difficult process with the deterioration in the quality of oil obtainable.

4. The enrichment of coal gas with a gas made from cannel coal is not generally practiced. The coke made from this coal is of little value as a by-product, and if mixed with the coke obtained from gas coal, reduces the value of the entire product, thus increasing the cost of manufacture without compensating results in the quality of gas thus obtained. The supply of a good grade of cannel coal is limited, and if generally used, it is doubtful whether an adequate supply could be obtained. This method of enrichment is used only under peculiar and unusual conditions.

5. Enrichment with heavy oil by generating oil gas in coal gas retorts has been considered generally inefficient and expensive; and light oils are no longer available. It is a practice that, where possible, has been abandoned by nearly all coal gas companies; but some method of enrichment is compulsory under the present requirements of this State.

6. Benzol enrichment, so-called, consists of adding light oil vapors in the shape of benzol and toluol to the gas in the form of a spray, to increase its illuminating value. This increase is only effective under certain favorable conditions and is lost, to some extent, when the gas is further subjected to low temperatures or high pressures. (See pages 45 and 46, paragraphs 25, 26 and 27.)

7. In enriching coal gas by making a mixed gas, the present standards demand an illuminating value two candles higher than required for coal gas. This method of manufacture was employed by Companies 11, 12, 13 and 14, but only one of these Companies (11) reported the illuminating value and heating value of the two gases separately, and it will be seen from the following

table, which is a summary of its results, that a corresponding increase in the heating value was not obtained in the effort to bring the illuminating value of the mixed gas up to the required standard. It is seen that while the illuminating value of the coal gas is increased about 45 per cent., the heating value is only increased 5 per cent. It should also be noted that the coal gas is mixed with three to four times its own volume of carburetted water gas of high illuminating value.

	Coal Gas.	Carburetted Water Gas.	Mixed Gas.
Illuminating value	14.3 C. P.	22.5 C. P.	20.6 C. P.
Calorific value	609 B. t. u.	647 B. t. u.	639 B. t. u.

8. The results of the entire fifteen months' readings by this Company, as reported to the Committee, on the illuminating value and the heating value of the straight coal gas, are shown below.

9. This gas was made from Pennsylvania gas coal in stop end retorts and is straight coal gas without enrichment; the illuminating value being determined on a No. 7 Bray special burner. The minimum day's reading for each month and the average for the month, are shown, as well as the average for the entire fifteen months. (See also Appendix B, pages 34 and 35.)

Company No. 11—Straight Unenriched Coal Gas:

Month—1911.	Candle Power. Min.	Candle Power. Avg.	B. t. u. Min.	B. t. u. Avg.
August	13.3	14.9	546	602
September	13.3	15.3	587	616
October	11.7	13.5	584	611
November	11.5	13.8	586	607
December	12.7	14.2	573	621
1912.				
January	12.4	13.7	580	628
February	12.4	13.7	579	614
March	12.2	14.9	550	612
April	11.4	13.5	578	612
May	12.6	14.7	570	601
June	13.9	15.3	561	610
July	12.5	14.3	565	593
August	12.3	13.7	569	591
September	12.2	14.2	557	595
October	11.7	13.1	562	592
Minimum..................		13.1		591

10. The following figures (Par. 11) show the result from a coal gas plant —not participating in the investigation—using coal with a volatile constituent of 36 per cent., by weight, and producing a straight unenriched coal gas.

11. The generators and settings are designed to give a maximum yield of gas per pound of coal. The retorts are set horizontally and machine stoked. All results are corrected as to temperature and pressure. The burner is the new Sugg F, Argand. The heat unit averages are the result of ten calorimetric tests per month. A year's results are as follows:

Month.	Average Heating Value of Gas. B. t. u.	Average Illuminating Value of Gas. Candle Power.	Yield Per Lb. Coal. Cu. Ft.
January	556.1	14.54	5.36
February	567.3	14.79	5.17
March	573.7	14.79	5.26
April	568.3	14.32	5.21
May	594.2	14.82	5.25
June	600.5	14.74	5.24
July	600.9	14.16	5.19
August	602.3	14.32	5.28

September	596.6	14.34	5.21
October	599.6	14.30	5.19
November	589.1	14.14	5.20
December	583.0	14.64	5.17
Minimum	556.1	14.14	5.17

12. For the purpose of confirming the above results, we submit the average candle power of straight unenriched coal gas manufactured by two large gas plants, for each month covering a period of two years.

13. These values, which are the averages of hourly readings, are indicative of the illuminating value that may be obtained in an efficiently managed plant, using the best West Virginia gas coal, in horizontal retorts. Candle power readings were made each hour of the twenty-four, on a No. 7 flat flame burner against a pentane lamp. Candle power variations are due largely to changes from freshly mined coal to stored coal. Yield slightly in excess of 5 feet per pound.

	Plant 1. Candle Power		Plant 2. Candle Power	
	1910.	1911.	1910.	1911.
January	12.61	11.44	12.65	11.97
February	12.40	12.20	13.34	13.28
March	12.00	13.01	13.50	12.63
April	12.69	12.46	12.91	12.11
May	11.65	13.00	12.03	13.08
June	11.96	12.68	11.84	13.22
July	11.44	13.11	11.40	13.11
August	11.25	12.20	12.07	11.82
September	11.39	13.30	12.27	13.10
October	11.11	13.62	13.38	12.83
November	12.60	13.34	11.96	12.37
December	12.59	12.80	12.54	13.99
Average	11.97	12.76	12.49	12.79

RECENT DEVELOPMENTS IN COAL GAS MANUFACTURE

14. Recent developments in connection with the manufacture of coal gas have appeared in the form of vertical gas retorts and chamber ovens. Among the features of these types of installation have been improvements in the methods of handling materials and by-products. The character of construction of these retorts has permitted the adoption of devices for charging coal and discharging coke that have eliminated much of the heavy work of stoking labor, which is particularly arduous during the hot summer months.

15. The installation of these types of retorts has been of benefit in the saving of ground space occupied and in some instances in overcoming the ventilation retort house problems during the time of charging and discharging.

16. Gasifying coal in bulk in relatively large units has allowed a longer time for carbonization of the charge, and has been somewhat effectual in increasing the total yield of gas from an equal quantity of coal, with, however, a slight reduction in the heating value and illuminating value per thousand.

17. Lengthening the carbonizing time has been helpful in increasing the total heat in resultant gas, per ton of coal carbonized, thereby producing a general economic saving.

18. Developments along this line are showing rapid improvements at the present time and it seems advisable that the quality requirements of a gas should be so placed as to allow the adoption and use of these more recent methods in the manufacture of coal gas throughout this State.

COKE OVEN GAS

19. During the past decade a large number of coke oven plants have been erected throughout the United States. Many of these plants were installed in connection with industrial undertakings, requiring coke for their operation, and where they have been compelled to seek a market for the by-product gas.

20. In many instances the coals used by these coke ovens were selected for their ability to produce a good metallurgical coke and often these ovens were not operated to handle by-product gas most efficiently. But in later years the methods of operating coke ovens have been somewhat modified, with the result that the quality of the gas has been much improved. With a selection of coals better suited for gas-making purposes, a better quality of gas may be expected from the coke ovens. But where these ovens are operated for the purpose of producing a high-grade furnace coke, and not primarily for the production of gas, the so-called best gas coals cannot be used to the best advantage, and, therefore, we probably will not see the highest quality of coal gas made in coke oven plants.

21. A number of instances have already arisen where such by-product coke oven gas could have been utilized to advantage. The heating value approached that of unenriched retort coal gas, and could have been made to equal it by enrichment, or mixture with carburetted water gas. The illuminating value, however, could not be brought up to the present requirements, except by enriching costs that were commercially prohibitive, or by using too large a percentage of carburetted water gas, and therefore the supply could not be availed of. To permit the utilization of this gas by proper standards would prevent this useless waste, and would constitute a great economic saving.

22. It seems probable that such situations will occur more frequently in the future than in the past and it would appear to be good public policy to permit the use of such gas for general distribution.

23. Coke oven gas has been used by many gas companies in other States, in whole or in part, for distribution to general consumers.

24. The treatment of this gas, in a number of instances, by manufacturing companies, however, is quite different from that of ordinary coal gas produced by gas companies, in that the operators of the coke ovens scrub the gas and remove the light oil vapors, consisting of benzol, toluol and xylol, reducing to a considerable extent its illuminating value, at the same time reducing in a slight degree only its heating value.

25. In a number of cases where coke oven gas has been purchased by the gas companies, its illuminating value has been restored by the addition of refined benzol to a value even greater than that of the gas before it was first scrubbed.

26. This method of increasing the low illuminating value of this gas has been the result of a requirement for a higher illuminating value, which has been obtained without a corresponding increase in heating value. And the addition of this increase in illuminating value may not be considered at all

times to be permanent. Under certain conditions where the unfixed hydro carbon vapors have been removed in a previous washing and scrubbing of the gas, the imparted enrichment from benzol is more effective, as the gas is in a condition to absorb these vaporous hydro-carbons having such a relatively low percentage of saturation. Under these conditions the increased illuminating value will stand with rather severe changes in temperature and pressure, and the gas may be considered suitable for general consumption where the illuminating requirements are low, but where a normal heating value is demanded.

27. But, as a general rule, the enrichment or increase in illuminating value of any gas, by the addition of benzol, may not be considered permanent and its addition has a tendency to create a gas variable in quality when delivered to the consumer and objectionable because of carbon deposit in burners and mantles.

28. Carburetted water gas has been used as an enricher for coke oven gas, and its use may be successfully employed where the requirements do not demand an illuminating value above that of unenriched retort coal gas, but otherwise the quantity of carburetted water gas necessary for this enrichment results in too great a proportion of the total amount of gas supplied.

29. Carburetted water gas may be used to advantage to provide any deficiency in supply and to take care of the peak loads where the coke oven gas is produced at a uniform rate from day to day, and provide reserve in times of a depressed market for furnace coke.

CARBURETTED WATER GAS

30. An analysis of the records of the Companies manufacturing carburetted water gas, and reporting their results, shows a great variation in both illuminating value and heating value, and proves conclusively that there is no positive relation between illuminating value and heating value.

31. It has been proven, however, that in general the carburetted water gas of the highest average illuminating value has had the highest heating value, as the illumination imparted to the open flame is a function of the quantity as well as the quality of oil used, considering the manufacturing apparatus is operated with equal efficiency. It has also been demonstrated that the heating value is a factor of the quantity of oil used, but there are limits to the quantity of oil that can be efficiently handled and turned into a constituent gas.

32. Therefore gases of equal illuminating value do not necessarily have equal heating value and vice versa. This is true of the gas when manufactured, without introducing any of the uncertain elements of distribution. Such a condition is due more particularly to the variation in oil efficiencies obtained in producing illuminating value, and which are occasioned by different types of generating apparatus and different methods and constituents of operation, as well as the quality of the oil available. These economies or efficiencies are greatly influenced by climatic and temperature conditions, which cause extreme variations between the warm summer months and the cold winter months. And the economic results obtained by scientifically operated plants cannot be expected of all plants throughout an entire State.

33. In the plants of the reporting Companies, the conditions of gas manufacture vary greatly and some variation in the results obtained was, therefore, to be expected. At the same time, the location of the testing station, whether at the works or at some remote point in the distribution system, introduced factors that had to be considered in making an analysis of the results obtained.

We believe, however, that the reports indicate what may be considered as good practice, representing fair and average conditions of operation, and that the conclusions drawn are based on representative data.

34. As regulatory requirements have frequently been based on monthly averages, an analysis has been made of the results obtained by months, and from these results have been calculated the heating value imparted to the carburetted water gas per gallon of oil employed in manufacture.

35. From the tests made by six of the Companies the heating value of the gas, as read at the works, for a whole year, averaged 162 heat units per cubic foot, per gallon of oil used per thousand cubic feet; while the average obtained in the summer months was 168 and in the winter months 157. The minimum monthly average for all plants was 151 heat units. These same tests show that in one plant the average for an entire month was only 141 heat units per gallon of oil used. The indications are that a yearly average of 150 heat units per gallon, per thousand cubic feet, can be obtained with good operating conditions.

36. It is evident from the reports made by four of the Companies, testing at a point some distance from the works, that the heating value delivered would be somewhat below this figure. These plants show a yearly average of 154 heat units per gallon of oil used, with an average of 167 during the summer months, and an average of 146 heat units during the winter months. The minimum for all plants for any month occurred during January, when 142 heat units per gallon of oil was delivered, with an individual plant average in any month of 139 heat units per gallon.

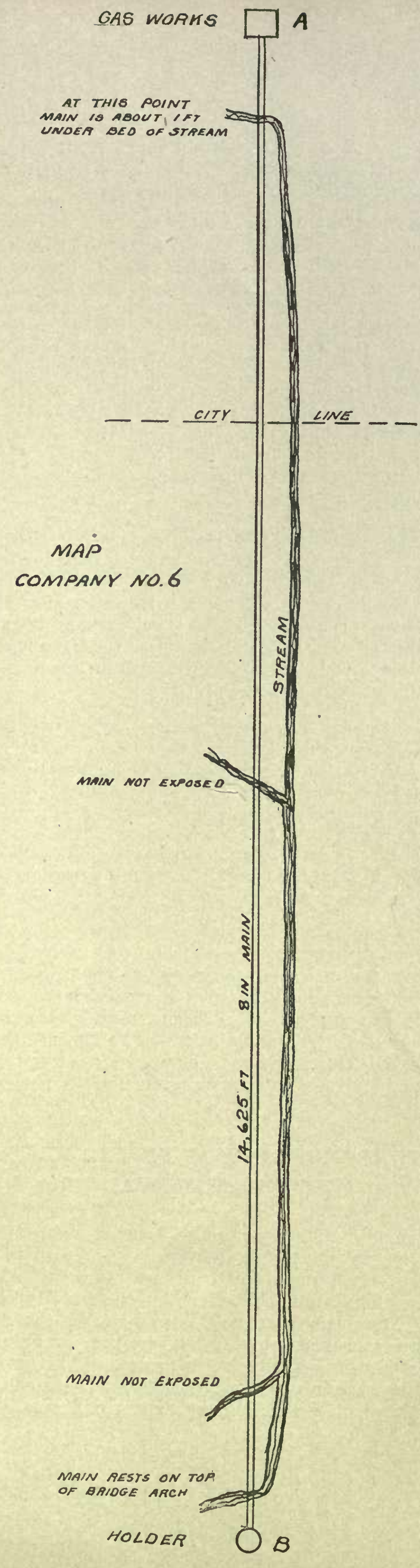
37. The above figures indicate that, on the basis of the average quantity of oil used in these ten plants during twelve months, at least 150 heat units per gallon of oil during the winter months may be expected when measurements are taken at the works, or 140 heat units per gallon of oil when measured at a point some distance from the works.

38. The quantity of oil used as an average by all the Companies was about 3.9 gallons, and if this is considered as a normal quantity to be used, then the average heating value for any one month, of a gas, as read at the works, would be 3.9x150 or 585 heat units.

39. The average quantity of oil used in the above deduction represents the conditions when manufacturing gas to meet the present illuminating standard. To meet such a standard requires the manufacture of a gas having an illuminating value of from 6 to 8 per cent. higher than that specified in the standard, on account of the impossibility of manufacturing gas of an exact illuminating value and the necessity for an excess in quality to allow for variable losses due to handling, to transmission and to changes in temperature.

EFFECT OF DISTRIBUTION ON THE HEATING AND ILLUMINATING VALUES

40. In addition to determining the heating value and the illuminating value of gas as generated at and delivered from various gas plants, it was deemed essential by the Committee to discover—as far as the present operating conditions would permit—the effect on the quality of the gas of transmission through distribution systems. It was known that losses in the quality of a gas occur during transmission, caused by the scrubbing action on the gas in passing through the mains, which is aggravated by a reduction in temperature and by any increase in pressure. Readings, therefore, were taken, where opportunity permitted, to determine the extent of losses due to these factors.


GAS WORKS
A
AT THIS POINT
MAIN IS ABOUT 1 FT
UNDER BED OF STREAM
CITY LINE
MAP
COMPANY NO. 6
STREAM
MAIN NOT EXPOSED
14,625 FT 8 IN MAIN
MAIN NOT EXPOSED
MAIN RESTS ON TOP
OF BRIDGE ARCH
HOLDER
B

41. At the beginning of the investigation there was little authoritative data available relating to this question. At the suggestion of the Committee, however, some experiments were undertaken to determine the effect of distribution under varying conditions.

42. During a period of eleven months, beginning January, 1912, readings were taken by one of the participating Companies (No. 6) of the illuminating value and heating value of carburetted water gas as manufactured, and again as delivered in an outlying district three miles distant, at the end of a pumping main; the initial pressures being from eight to fifteen inches water pressure. These readings were made daily—with some few exceptions—and include some 294 individual tests for both heating and illuminating value. (See tables II. and III., Appendix A, page 18.)

The location of the works and the testing stations are shown on the map, on opposite page, and it will be seen that at some few points the main is exposed to temperatures of the streams that are crossed, and at other points to atmospheric temperature. The gas was further subjected to atmospheric temperature in an outlying storage holder. Results of these tests indicate the losses in heating value and illuminating value that may be expected at various seasons of the year for gas delivered under similar conditions. The average loss in heating value is 1.4 per cent. and the average loss in illuminating value is 12.8 per cent.

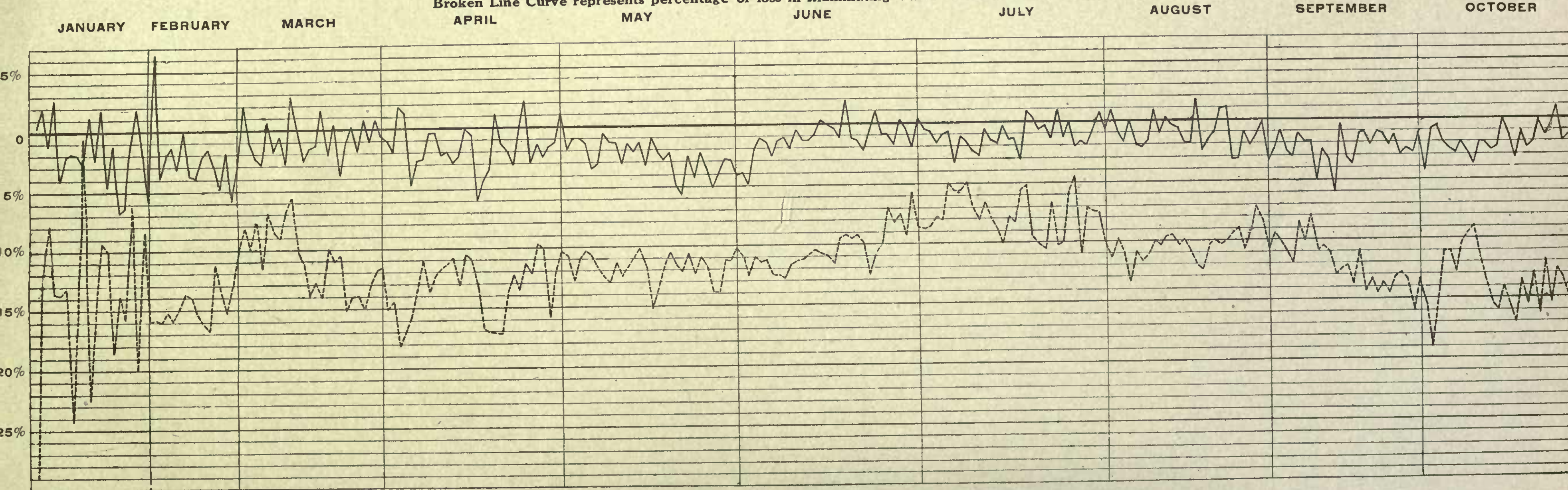
Month.	No. Tests	Loss in Illuminating Value Candles.	Per Cent.	Loss in Heating Value B. t. u.	Per Cent.
January	20	3.2	14.0	11	1.75
February	16	3.2	13.8	13	2.06
March	26	2.7	11.7	4	.64
April	30	3.4	14.4	4	.64
May	31	2.7	11.6	17	2.66
June	30	2.5	10.8	7	1.09
July	31	2.3	9.8	8	1.24
August	29	2.6	11.2	5	.79
September	27	3.0	12.9	14	2.22
October	26	3.0	12.8	12	1.88
November	28	4.6	18.3	5	.77
Average			12.8		1.4

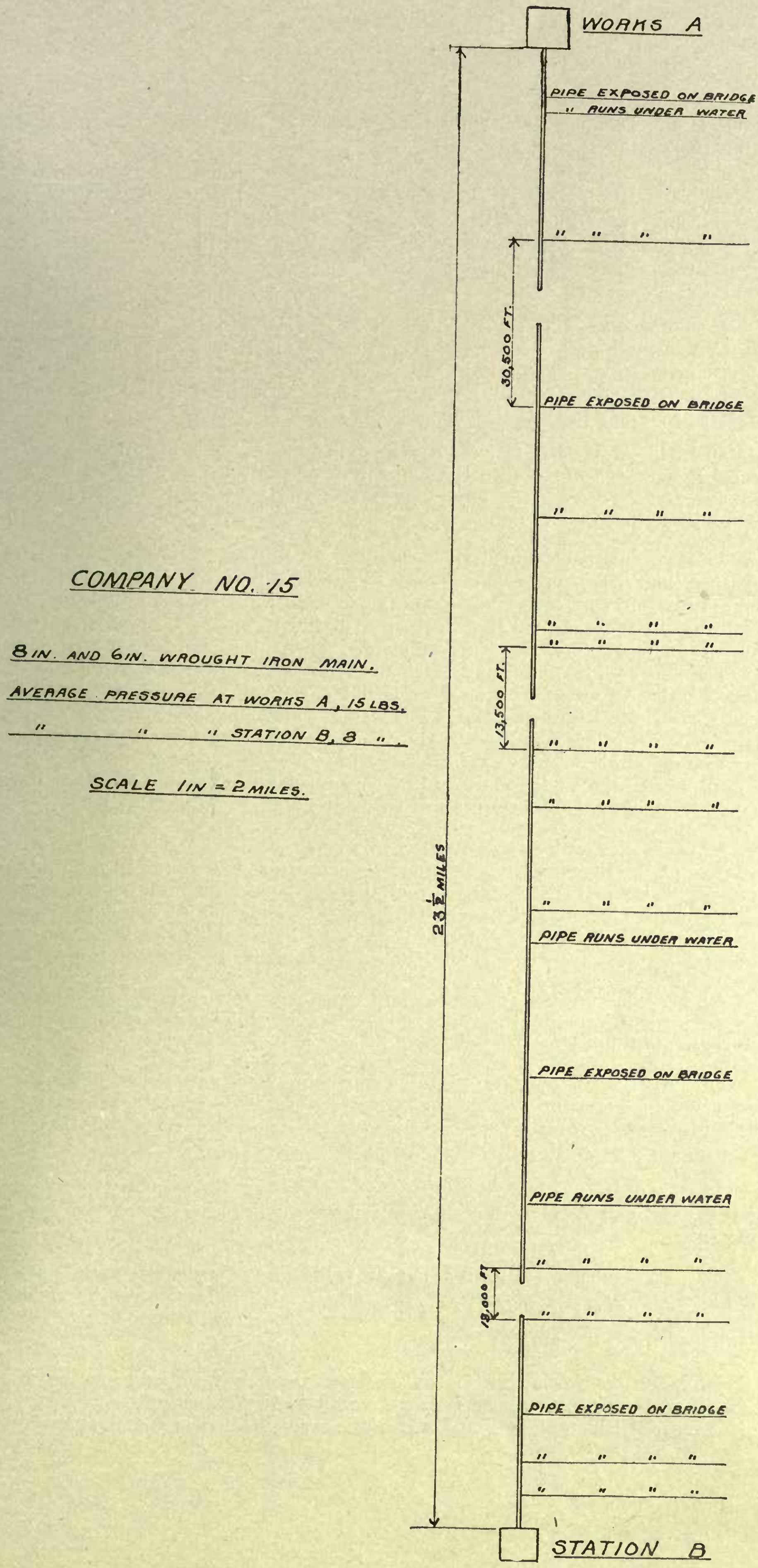
43. The daily variations in heating value and illuminating value between Stations A and B are shown by diagrams (page 50). The zero line represents the heating value or illuminating value at A. The solid line curve shows the heating value at B in percentage of the heating values at A. The broken line curve similarly shows the illuminating value at B.

44. Another Company (No. 15) made observations of the loss in heating value and illuminating value of gas when pumped under the relative high pressure of fifteen pounds, for a distance of about twenty-three miles. These results cover daily observations for the months of October and November, 1912, consisting of about sixty individual tests. They indicate what may be expected under similar conditions. The readings were made when the ground temperature was about 50° F., and, therefore, do not show the extreme conditions that will be met during the winter months when the temperature of the ground is 32° F. Plate III shows how the main is exposed both to atmospheric and stream temperatures. (See page 51.)

45. The readings made on this high pressure line are summarized below, and it will be seen that the loss due to transmission of gas under these condi-

Zero Line represents Heating Value or Illuminating Value of Gas as measured by Company No. 6 at Station A
Solid Line represents percentage of loss in Heating Value as measured at Station B
Broken Line Curve represents percentage of loss in Illuminating Value as measured at Station B




WORKS A
PIPE EXPOSED ON BRIDGE
" RUNS UNDER WATER
" " " "
30,500 FT.
PIPE EXPOSED ON BRIDGE
" " " "
" " " "
" " " "
13,500 FT.
" " " "
" " " "
" " " "
PIPE RUNS UNDER WATER
PIPE EXPOSED ON BRIDGE
PIPE RUNS UNDER WATER
" " " "
13,000 FT
" " " "
PIPE EXPOSED ON BRIDGE
" " " "
" " " "
STATION B
23½ MILES
COMPANY NO. 15
8 IN. AND 6 IN. WROUGHT IRON MAIN.
AVERAGE PRESSURE AT WORKS A, 15 LBS.
" " " STATION B, 8 " .
SCALE 1 IN = 2 MILES.

tions is much more in illuminating value (20.7%) than it is in heating value (6.05%).

October—1912.	Heating Value, B. t. u.	Illuminating Value, C. P.
Uncompressed gas	629	22.2
Compressed gas	619	...
Delivered gas—23½ miles	607	17.6
Loss—per cent.	3.5	20.7
November.		
Uncompressed gas	631	21.3
Compressed gas	627	...
Delivered gas—23½ miles	577	16.9
Loss—per cent.	8.6	20.7
Average loss—per cent.	6.05	20.7

46. This is in accordance with the expectations, as it is apparent that the decrease in quality is due to the deposition of the unfixed or light oil vapors that are removed from the gas by pressure, and by the low temperature and scrubbing action of the mains.

47. To further confirm these results, at the request of the Committee, investigations were also made under the direct supervision of one of its members, on carburetted water gas, manufactured in a large city, in another State, compressed—pressure varying from ten to twenty pounds—and delivered to several outlying districts. These districts consisted of two smaller cities, several small boroughs and small settlements on both sides of a large river. A large portion of this territory is so situated that the inhabitants would have been unable to obtain gas under any other conditions. The high pressure is reduced and the gas supplied to the two cities through low pressure distribution systems, but the boroughs and small settlements are directly supplied by high pressure which is reduced on the consumers' premises. An outline map—page 53—shows the general plan of the system.

48. The gas as manufactured at A averaged about 22 candle power. At the time of the investigation the gas was compressed to about 16 to 20 pounds pressure, as shown in the tables, and then delivered through a high pressure system, consisting of 9,700 feet of 6″ and 1,875 feet of 4″ main, to a second testing station, B. From this point the 4″ high pressure main is continued across the river for a distance of 16,625 feet, to a third testing station, C.

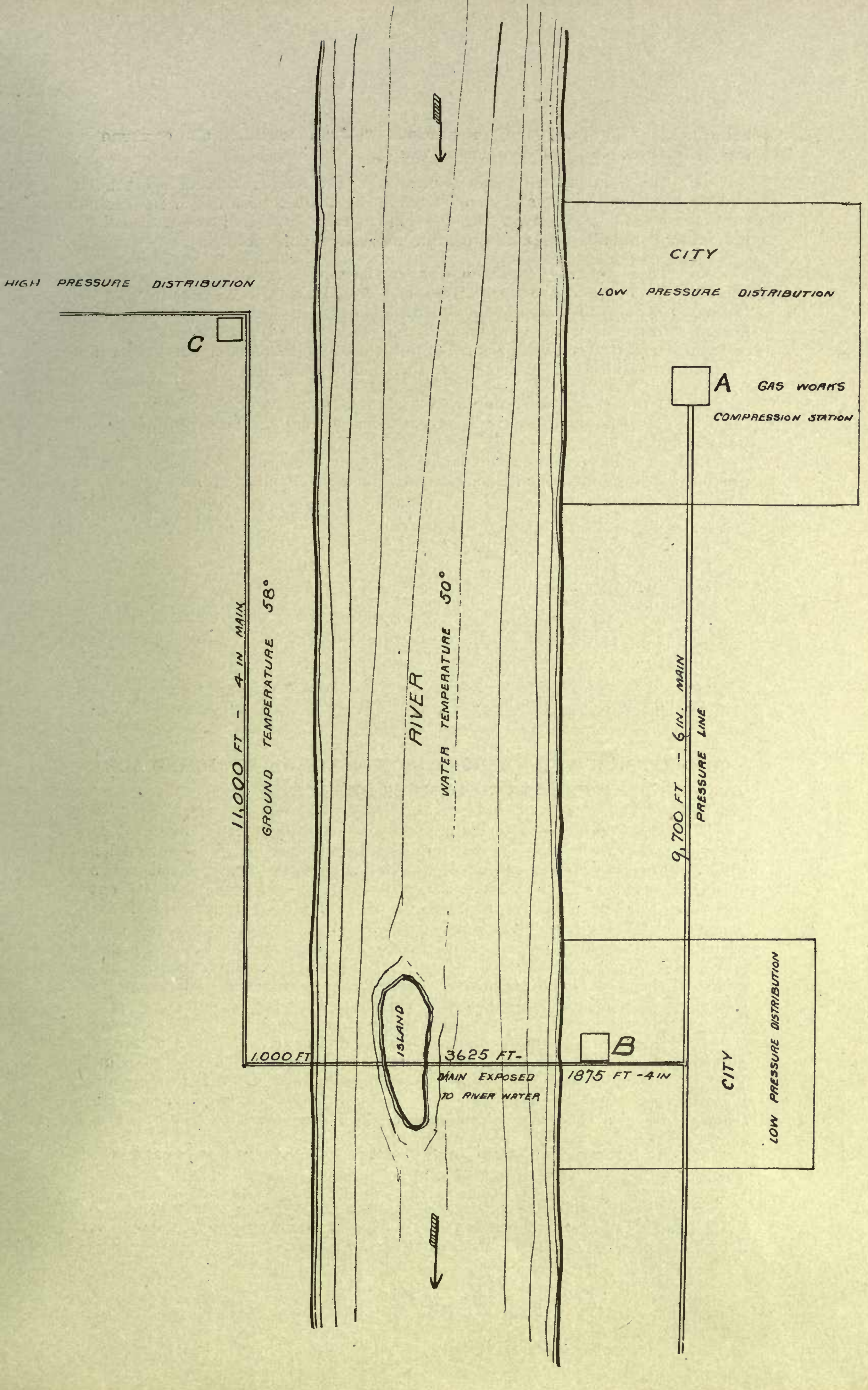
49. In crossing the river the main is exposed for a considerable distance, and acquires the temperature of the river water, which at the time of the test approximated 50° F.

50. At Station A, where the gas was compressed, tests were made before and after compression. At Station B tests were made on the gas direct from the high pressure lines before entering the low pressure system. At Station C the gas was tested directly from the high pressure lines.

51. In order to obtain samples of the same gas, the capacity of the mains and the estimated rate of consumption was determined, and the lag was calculated.

52. To determine the illuminating value of the gas, tests were made on standard 60″ bar photometers at Stations A and B, and on a 60″ portable photometer at Station C, ten candle power pentane lamps being used as standards.

53. The heating value of the gas was read on new calorimeters of the American Meter Company, which were compared with each other just previous to testing. All instruments and accessories were tested and calibrated before


HIGH PRESSURE DISTRIBUTION
C
CITY
LOW PRESSURE DISTRIBUTION
A
GAS WORKS
COMPRESSION STATION
11,000 FT - 4 IN MAIN
GROUND TEMPERATURE 58°
RIVER
WATER TEMPERATURE 50°
9,700 FT - 6 IN. MAIN
PRESSURE LINE
ISLAND
B
1,000 FT
3625 FT-
MAIN EXPOSED TO RIVER WATER
1875 FT - 4 IN
CITY
LOW PRESSURE DISTRIBUTION

being used. The humidity of the atmosphere was determined and corresponding corrections made in the calorific values.

54. The temperature of the atmosphere, the temperature of the ground and the dew point of the gas were determined. The temperature of the ground ran from 56° to 58° F., while the dew point gave indications as low as 30° F., indicating combined effect due to the compression and cooling.

55. These readings were made over the period from October 31 to November 14, 1912, and the results obtained from day to day, as shown by the following table, substantiate the conclusions presented above—that the illuminating value cannot be maintained if the gas is to be transmitted to outlying districts at relatively high pressures; but that under the same conditions it is possible to maintain the heating value with only slight loss.

56. If these tests were duplicated in the extreme cold weather months of the winter, we might expect even greater losses in illuminating value at Stations B and C.

Loss in illuminating and heating value of carburetted water gas, compressed to 16 pounds and transmitted distances of 2.2 and 5.1 miles:

	Illuminating Value, C. P.	Per Cent. Loss.	Heating Value, B. t. u.	Per Cent. Loss.
Initial gas	21.69	...	630	...
Loss due to compression	2.66	12.3	8	1.27
Loss due to transmission—of 2.2 miles	.74	3.4	2	.32
Total loss	3.40	15.7	10	1.57
Initial gas	21.69	...	630	...
Loss in compression and transmission—of 5.1 miles	6.68	30.8	11	1.75

COMPRESSION AND TRANSMISSION TESTS ON ENRICHED COKE OVEN GAS, NOVEMBER-DECEMBER, 1912.

57. The Committee also made some investigation of the effects of compression and transmission on the illuminating and heating values of enriched coke oven gas. As there was no such installation in the State, permission was obtained elsewhere to make such a test on a plant consisting of forty ovens and having a capacity for carbonizing three hundred tons of coal daily. A good grade of Pennsylvania gas coal was used, with an average coking period of twenty-two hours. Run-of-oven gas, enriched to about 16 candle power, flat flame, was obtained, using a 90 per cent. benzol enricher. During a part of the test a small amount of high candle power carburetted water gas was made to help out the deficiency in the make from the coke ovens. In both cases, after enrichment at "A," the gas was compressed at "A-1" to between 30 and 40 pounds per square inch, and then delivered to "B," a distance of nine miles. The terminal pressure at "B" was between 26 and 36 pounds. This high terminal pressure was necessary because of distribution to surrounding territory. After compression the gas was cooled to about atmospheric temperature in a condenser, the condensate being removed.

58. At the terminus of the high pressure line the gas was expanded into a holder and distributed at low pressure.

59. The illuminating value and the heating value of the gas at "A," "A-1" and "B" is shown in the tables. These tables also give the losses both actual and in per cent. of original quality of the gas.

60. The ground temperature at "A" was about 47° F. and at "B" it was 49° F. The dew point at "A-1" was 31° F. and at "B" it was 12° F. The average outside air temperature was 39° F.

61. The tests were made with improved American Meter Company calorimeters of the Junker type, and standard 60" bar photometers. All candle power readings are flat flame value against a standard 10 candle power pentane lamp. All apparatus was tested and checked for accuracy.

Loss in illuminating and heating value of enriched run-of-oven coke oven gas, due to a compression of 30 pounds and a transmission of nine miles:

	Illuminating Value, C. P.	Per Cent. Loss.	Heating Value, B. t. u.	Per Cent. Loss.
Initial gas	16.2	...	598	...
Loss due to compression—30 lbs.	1.8	11.1	20	3.34
Loss due to transmission—9 miles	4.0	24.7	21	3.51
Total loss	5.8	35.8	41	6.85

Run-of-oven coke oven gas with an addition of 15 per cent. carburetted water gas:

	Illuminating Value, C. P.	Per Cent. Loss.	Heating Value, B. t. u.	Per Cent. Loss.
Initial gas	16.9	...	597	...
Loss due to compression—40 lbs.	2.7	16.0	18	3.02
Loss due to transmission—9 miles	5.1	30.2	23	3.85
Total loss	7.8	46.2	41	6.87

62. A previous test had been made on the same system, by one of the Committee, in March and April, 1907; and while at that time no determinations in loss of heating value were made, the loss in illuminating value was determined.

63. In addition to the effect of compression and transmission, a test was made on the effect of low temperature by passing the gas through a freezing coil.

64. The following tables give a summary of the results obtained on these tests.

65. The first table shows the effect of freezing on the candle power of low pressure coke oven gas, carburetted water gas and mixed coke oven gas and carburetted water gas.

	Enriched Coke Oven Gas.	Carburetted Water Gas.	Enriched Coke Oven Gas and 20% Carburetted Water Gas.
Initial candle power	15.92	19.15	16.32
Loss due to compression and freezing to 32° F.	2.89	2.63	2.43
Loss in per cent. of initial candle power	18.2	13.7	17.5

66. The second table shows the effect of compressing to pressures approximating 30 pounds and transmitting through a distributing system 11.5 miles. The first test was on run-of-oven coke oven gas, benzol enriched, and the second test was made on this same gas with a mixture of carburetted water gas, equalling 27 per cent. of the total volume.

67. Hygrometer readings indicated a dew point of 18° F. on the compressed and delivered gas.

	Enriched Coke Oven Gas.	Enriched Coke Oven Gas Mixed With 27% Carburetted Water Gas.
Initial candle power	17.45	17.0
Loss due to compression of 30 pounds and delivered 11.5 miles at high pressure..	6.02	4.82
Loss in per cent. of initial candle power....	24.5	28.4

LABORATORY EXPERIMENTS TO DETERMINE THE EFFECT OF COMPRESSION AND FREEZING ON CARBURETTED WATER GAS.

68. To determine further the effect upon the illuminating value and heating value of the gas, certain laboratory experiments were carried on under the supervision of the Committee, with the following results:

69. Carburetted water gas of 23.5 candle power and 654 B. t. u. heating value, was compressed first to low pressures of three and ten inches of water and then in stages of five pounds each to a total of thirty pounds gauge pressure, and while under compression reduced to a temperature of 35° F. The condensation formed, due to compression and cooling, was removed, and the gas, when expanded again, showed a dew point of 15° F. No serious losses in heating value were found to take place in pressures up to ten inches of water. Such losses, however, became evident as soon as the pressure had reached five pounds and over. At thirty pounds' compression the illuminating value had dropped 32.4 per cent., while the heating value dropped 6.8 per cent. It was noted that the gravity of the gas changed but very little, as shown by a test on an effusion apparatus. The illuminating value seemed to drop uniformly with the compression, while the heating value dropped 30 heat units or the first ten pounds and only twelve additional heat units for the next twenty pounds. The results are shown in detail below:

Pressure.	Candle Power	B. t. u. Gross.	Loss Per Cent. Candle Power	Loss Per Cent. B. t. u.
3 inches, before cooling..	23.5	654	...	...
3 inches	20.2	656	...	...
10 inches	20.3	654	...	...
5 pounds	18.1	631	10.6	3.5
10 pounds	16.3	621	19.5	5.0
15 pounds	15.6	624	23.0	4.6
20 pounds	14.95	615	26.2	6.0
25 pounds	14.2	617	29.9	5.6
30 pounds	13.7	609	32.4	6.8

Note.—Original gas passed through 70° F. coil. Compressed gas passed through 35° F. coil.

HEATING VALUE CALCULATED BY ANALYSIS

70. One Company, No. 8, ran its plant (Class C, Table I.) to determine as nearly as may be the heat unit equivalent to the present standard of candle power. This plant was equipped with a Junker automatic continuous registering calorimeter, which was destroyed by fire before the completion of the full year's test. In addition tests were made daily on both a Sargent and on a Junker calorimeter. Samples of gas were taken and analysis of gas

made and recorded. The candle power was likewise determined on a 60″ U. G. I. open bar, using No. 7 L. P. Slit Union Bray and new F Argand Sugg pattern gas burners against candles in accordance with New York legal requirement.

71. Not until the completion of the year's test was any use made of the gas analysis so that the calculated heat units therefrom have special interest as a check.

72. The daily heat unit readings therefore were checked by an automatic instrument self recording and finally by the calculated B. t. u. from the gas analysis. The gas manufactured was carburetted water gas. The gas generating apparatus, 5′ and 7′ 6″ sets, have up and down steam connections and automatic continuously registering pyrometers on superheater. As the plant is a small one the running was intermittent, varying from 8 hours to 23.8 hours. Gas oil was used, "28° B." which had been contracted for prior to beginning of test. Anthracite broken coal was used, with some gas-house coke at times for experimental purposes. Oil corrected varied from 3.5 to 4.65 gallons per thousand. Fuel per 1,000, corrected, varied from 37.62 to 40.76.

73. The equivalents used in calculating the B. t. u. from gas analysis were:

Illuminants	2350.0	B. t. u. per cu. ft.
Co	323.5	" "
H2	326.2	" "
CH4	1009.0	" "

The results were as follows:

COMPANY NO. 8.

Average Monthly Results at Works—B. t. u.

	Candle Power.	B t. u. Junkers	B. t. u. Sargent.	Calculated from Analysis.
1911.				
August	19.1	617	613	606
September	18.9	610	607	605
October	18.7	594	591	589
November	19.7	633	628	626
December	22.5	645	651	651
1912.				
January	22.4	653*	656*	658*
February	22.6*	650	653	636
March	20.3	621	625	614
April	18.7	602	601	585
May	19.5	592	593	569†
June	19.3	592	591	582
July	17.9†	584†	584†	580

* Maximum. † Minimum.

74. The official testing station of this Company was equipped with a Junker calorimeter and 60″ American Meter Company open bar photometer using similar burners and candles. Gas was analyzed as at plant and B. t. u. calculated with the following results:

Monthly Averages.

	Candle Power.	B. t. u. Junker.	B. t. u. Calculated from Analysis.
1911.			
August	20.0	613	608
September	19.6	605	602
October	19.3†	584†	581†
November	19.9	622	618
December	20.9	642	645
1912.			
January	21.1*	643*	655*
February	20.6	631	634
March	19.8	607	610
April	20.4	591	582
May	19.9	590	568
June	20.7	596	586
July	20.6	586	577

* Maximum. † Minimum.

75. The Gas Inspector of the State tested the candle power for the State record twelve times during the period of testing, finding candle power averaging 20.1. The Company's test for the same days averaged 20.0 candle power.

76. It will be observed that the B. t. u. calculated from analysis varies from the actual readings made by calorimeters in different seasons. The effect of temperature affects the character of the illuminants remaining in the gas at different seasons. The following calculations were made as a matter of interest. The values of B. t. u. per cubic foot of C O of H_2 and C H_4 were taken as stated heretofore and the actual B. t. u. observed in the Junker calorimeter was assumed in each case as the B. t. u. value of the gas. From these figures the B. t. u. value of the illuminants was calculated with the following results:

Monthly Averages.
Plant.

Date.	Plant		Testing Station	
	B. t. u. Junkers.	Cal. Val. of Illuminants.	B. t. u. Junkers.	Cal. Val. of Illuminants.
1911.				
August	617	2458	613	2399
September	610	2400	605	2377
October	594	2404	584†	2378
November	633	2410	622	2385
December	645	2304†	642	2321
1912.				
January	653	2311	643*	2251†
February	650*	2465	631	2320
March	621	2408	607	2325
April	602	2450	591	2429
May	592	2582*	590	2576*
June	592	2449	596	2454
July	584†	2396	586	2336

* Maximum. † Minimum.

The above results clearly indicate the uncertainty of chemical analysis as a means of accuracy determining the calorific value of manufactured gas.

Comparison of Continuous and Intermittant Operations.

77. The manufacture of gas by Company No. 9 was under the same engineering superintendence as Company No. 8. Tests in this case were made only at the testing station over a mile from the manufacturing plant. This plant (Class A, Table I.) runs continually night and day manufacturing carburetted water gas; generators 11′ and 12′ reverse steam Lowe type with indicating and recording pyrometers. Gas oil 28° B. using (corrected) 3.41 to 4.34 gallons per 1,000 cu. ft. Anthracite fuel (corrected) 30.45 to 32.67 pounds per 1,000. Calorimeter used Junkers. Candle power determined by American Meter Company, 60″ open bar photometer; burners No. 7 L. P. Slit Union Bray and New F Argand. Analysis of gas was made only occasionally. The results follow:

Monthly Averages.

	Candle Power	B. t. u. Junker,
1911.		
August	20.8	589
September	20.6	597
October	21.2	619
November	20.4	625
December	20.7	638
1912.		
January	20.9	631
February	20.7	621
March	20.7	610
April	20.2	600
May	20.6	589
June	20.6	595
July	20.6	597

78. A comparison of the Company's candle power reading taken at the time B. t. u. results were taken on thirty days when the State Inspector tested the gas of the Company shows 20.4 candle power average by State test and 20.8 candle power by Company's observer.

Comparison of Efficiency of Open Flame and Mantle Burners.

79. In replacing the flat flame burner with the mantle burner, it is a matter of importance to determine the relative efficiency of these burners when using the same quality of manufactured gas. It is also important to inquire if similar results are obtained when using mantle burners with unenriched coal gas and the present 20 candle power water gas. The State Commission, Second District, requires that five cubic feet of carburetted water gas shall give 20 candle power when burned in the burner best adapted to it, and applicable for general use, when compared with the light of two standard English sperm candles. The candle power obtained with the normal mantle burner is uniformly greater than obtained in the flame burner even when using only three cubic feet of the same gas. It is customary to state the efficiency of the gas mantle in terms of candle power per cubic foot of gas used.

80. Under the supervision of a member of the Joint Committee mantles costing at retail 10 cents, 15 cents, and 35 cents, mantle burners costing 10 cents and 50 cents, and chimneys at a uniform cost of 10 cents were purchased at shops patronized by the general public.

81. These mantles and mantle burners were tested using carburetted water gas from 19.4 candle power to 21.8 candle power at burner pressures, varying from one to three inches water. The B. t. u. varied from 603 to 622. Sixty-five separate illuminating power tests were made with the mantles

when using this gas. The average candle power per cubic foot of gas when used in the flame burner was 4.15 candles, while the same gas developed 13 to 21.7 candles per cubic foot when used in the mantle burner. The 13 candle power test was obtained with gas giving 4.12 candles per cu. ft. in the flame burner, yet the same type mantles gave 16.4, 19.1 and 19.9 candles per cu. ft. with gas of lower candle power than 4.12 candles.

82. Seventeen tests, with 2.5 inch burner pressure, were made with these mantle burners and the same type mantles, but using a 14.38 candle power, unenriched coal gas, equivalent to an efficiency of 2.87 candles per cubic foot of gas when used in the flame burner. The heat units of this coal gas varied from 601 to 607 B. t. u. When this gas was used in the mantle burners from 13.7 to 21.4 candles per cubic foot of gas was obtained.

83. It will be observed that the efficiency of the mantle burner was equally good with either 20 candle power carburetted water gas or with 14.38 candle power in enriched coal gas. It will also be noted that the mantle burner is many times more efficient than the flame burner. In some caess the flame burner shows only 13.4 per cent. relative efficiency when compared with the mantle burner using the same gas or as one is to eight nearly.

84. A mantle burner ordinarily consumes three cubic feet of gas per hour and with 16 candles per foot gives 48 candle power. To obtain this candle power with a twenty candle gas in an open flame burner would require twelve cubic feet of gas. This is an hourly saving in gas bills of nine cubic feet. Assuming one thousand hours' burning per annum there is a saving of 9,000 cubic feet of gas, which represents a cash saving of from $8 to $18, depending upon the price of gas. Four mantles per annum would be a fair average for this number of hours' use at an annual cost of from 40 cents to $1.40; as stated, a burner which should give good service for many years costs from 10c. to 50c., and the chimneys 10c. each. Smaller mantles consuming but one foot to one and one-half feet per hour, where less illumination is required, would show a corresponding saving.

APPENDIX D

STANDARDS IN OTHER PLACES

1. Up to 1906 practically all standards for gas, both in this country and abroad, prescribed a certain illuminating value but contained no requirements as to heating value. As early as 1894, however, gas engineers had begun to recognize the inadequacy of a photometric standard and the necessity for determining a calorific value.

2. The earliest date of a calorific standard being established was 1906. Since that time this measure of the quality of gas has been adopted quite generally abroad and in a considerable number of instances in this country.

3. Generally speaking we find no scientific reasons for the figures which have been adopted, and in few cases does there appear to have been any preliminary investigation made along the lines of practical operating experience under varying conditions.

4. Wisconsin, which was the pioneer in the establishment of a state standard of heating value, did, through the Wisconsin Railroad Commission, conduct a series of tests before the adoption of the requirement now in force. These tests, however, did not cover a sufficient period of time or a wide enough variety of conditions to be conclusive. It should also be remembered that long strides have been made in the science of calorimetry during the last year or two, and manufacturing conditions have undergone important changes.

5. At the present time heating value requirements are in force in five states and in some thirty-one cities. A list of the states and cities with their respective requirements follows:

States.

Wisconsin	Monthly average 600 gross B. t. u.	Minimum 550
New Jersey	Monthly average 600 gross B. t. u.	Minimum 550
Nevada	Monthly average 550 gross B. t. u.	Minimum 500
Washington	Monthly average 600 total.	Minimum 550
Indiana	600 B. t. u.	

Cities.

Aurora, Ill.	600 gross	Elkhart. Ind.	600
Birmingham, Ala.	575 gross	Elyria, O.	600 "heat units"
Cedar Rapids, Ia.	600	Freeport, Ill.	Monthly ave. 600
Chicago, Ill.	600 gross	Freeport, Ill.	Minimum 550
Dallas, Tex.	650	Helena, Mont.	500
Detroit, Mich.	600 gross	Kankakee, Ill.	600 "heat units"
Elgin, Ill.	600 net	Ottawa, Ill.	600
Ft. Wayne, Ind.	550	Sault St. Marie, Mich.	500
Indianapolis, Ind.	600	Port Huron, Mich.	600 gross
Jackson, Mich.	600	Stockton, Cal.	600 gross Mo. ave.
Joliet, Ill.	600 "heat units"	Minneapolis, Minn.	600
Kalamazoo, Mich.	600 gross	Minneapolis, Minn.	Daily min. 550
Lansing, Mich.	600 (low value)	Oakland, Cal.	600
Lincoln, Neb.	625	Omaha, Neb.	600 net
Los Angeles, Cal.	600 gross	San Francisco, Cal.	600
Milwaukee, Wis.	635 gross	Springfield, Ill.	650
Adrian, Mich.	Average of 600		

6. In 1906 the calorific standard was adopted for Tottenham, the first place in England to have such a standard. This standard was fixed by agreement, but the Gas Light and Coke Company of London was the first to have the heat unit test statutorily applied to town gas. This was accomplished through the Parliamentary Committee of the London County Council advised by Dr. Frankland, Charles Hunt and Dr. Clowes, the figures being set at approximately 500 net B. t. u., with a minimum of 450 B. t. u.

7. In Europe Paris has adopted a calorific standard of 528 net B. t. u. and abandoned photometric requirements. The same standard holds in Rheimes. Marseilles has adopted 551 B. t. u. and Milan, Italy, 573 B. t. u.

8. In 1909 German chemists concluded that they ought to have a calorific test, and that the figures should be set at 543 gross B. t. u. with a minimum of 522, these results to apply to tests made at the works. There is even yet no generally accepted standard of calorific value in Germany, although tests have been regularly made in Berlin, Magdeburg, Bonn and Breslau for at least seven years. Zurich was also testing for calorific value at least five years ago.

9. A member of the Committee from personal observation ascertained that many continental cities do not even maintain photometric apparatus for testing gas. Included in this number are Paris, Brussels, Ghent, Bruges, Nuremberg, Stettin, Berlin, Charlottenburg, Warsaw and Zurich. No attention is paid to candle power. Another authority from personal inquiry and observation confirms this tendency by information derived within six months that the same conditions may be found in Austria and Austria-Hungary as well as Germany and other continental countries.

10. It should be noted that in Continental countries, it is customary to correct the gas volume to 0°C (32° F.) and 760 M. M. (30" Barometer). The correction to 32° F. instead of 60° used in the United States and by this Committee, means that the standard abroad is actually over 5% lower than the figures quoted above would indicate. For example, a German gas consumer receiving 543 gross B. t. u. per cubic foot is actually receiving not more than 51.6 when United States methods of measurements are followed.

11. In South America Colombo has had a heat unit standard of 400 B. t. u. for about five years, and in Buenos Ayres it is required that the net B. t. u. shall not be less than 539.

12. It will be seen from the preceding figures that the calorific power requirements in Great Britain, on the Continent and in South America are generally lower than those in the United States, due to a recognition of the economic advantages of permitting the use of unenriched coal gas manufactured from such grades of coal as were available.

13. The standards which have been adopted in this country in the past are in most cases in excess of what should be required. They were usually set arbitrarily and without thorough investigation. It is inconceivable that they would have been so fixed with present available raw materials. Reference to Table IV., page 20, shows monthly averages of heating power of gas, enriched to meet the present illuminating power standards as low as 584 B. t. u. and the table in Appendix C, page 43, shows monthly averages of heating power of unenriched coal gas, manufactured, however, from the highest grades of coal, as low as 556 B. t. u. These are not individual readings, but are averages for entire months.

APPENDIX E

CALORIMETRY AND PHOTOMETRY

Calorimetry

1. Assuming that a suitable calorimeter is employed, that the operator has had reasonable experience and proper instruction, and that the accepted rules of procedure are followed, it is proper to inquire as to the consistency of the readings and the accuracy of the results that will be obtained.

2. One of the smaller Companies participating in the investigations has had check tests made on practically every working day during the entire period and with three observers, of whom two were no more than high school graduates, only 5 per cent. of the time was there a difference of 3 B. t. u. between the tests, while on 88 per cent. of the days the difference was 2 B. t. u. or less. The determinations came out exactly the same, decimals being of course excluded during 32 per cent. of the time.

3. Such results can, however, only be secured by an absolute conformity to operating instructions. The great danger with calorimetric determinations, as in photometric work, is that the operator will drop into the habit of regarding this or that minor detail as unimportant and consequently will finally disregard it altogether. To illustrate, some operators only read their outlet water thermometers to tenths of a degree F., yet an error of 0.1° F. means an error of about 4 B. t. u. in the result.

4. The pressure at which the gas is metered is an important factor, although by some it is considered only a negligible quantity and is left out of consideration. If this is not corrected for, and the gas is delivered to the meter at 3 inches water pressure, the final result will be about 4 B. t. u. too high.

5. The rules as laid down by this Committee in its two pamphlets are not difficult to follow and every point emphasized has a practical value and is necessary to successful determinations. If this is borne in mind there should be no difficulty, under ordinary conditions, in obtaining consistency of results.

6. The accuracy of results, however, assuming that the test has been carefully and correctly carried out in every particular, is a different question and demands separate treatment. We shall assume that the operator is endeavoring to obtain the total heat value, or as near thereto as is practically possible, and that he has made all of the usual corrections, i. e., for thermometer error and stem exposure, temperature and pressure under which the gas is measured, and efficiency of instrument. If the inlet water were of the room temperature, and the products of combustion left the instrument also at room temperature, there is still a correction to be applied for the humidity of the air entering the calorimeter. This can be obtained by the use of a psychrometer, the correction then being found in the table furnished by the National Bureau of Standards and published in the Proceedings of the American Gas Institute for 1912. This table, however, consists of two parts: (a) Where seven volumes of air are used per volume of gas, and (b) where nine volumes of air are used. Since there is at present no practical method of measuring the air passing through the calorimeter, it would seem as if there were an insuperable difficulty at the outset. But if we examine the two tables we find that for ordinary

working conditions the differences are not large, as will be seen from the following which have been compiled by taking the difference in B. t. u. between the corrections in the two tables for the same temperature and humidity:

Humidity in P.C. Room Temp.	65°	70°	75°	80°	85°	90°
10	1.9	2.2	2.5	2.9	3.3	4.0
20	1.7	1.9	2.3	2.5	3.0	3.5
30	1.5	1.6	2.1	2.2	2.6	3.1
40	1.2	1.5	1.8	1.9	2.2	2.6
50	1.0	1.2	1.5	1.5	1.9	2.2
60	0.7	0.9	1.2	1.2	1.5	1.7
70	0.6	0.6	1.0	1.0	1.1	1.3
80	0.3	0.4	0.6	0.6	0.7	0.8
90	0.1	0.2	0.4	0.4	0.4	0.5
100	0.0	0.0	0.0	0.0	0.0	0.0

In every case the corrections in Table B are algebraically the greater, but it must be remembered that the low ranges of humidity, as well as the excessive room temperatures, are comparatively rare, at least in this part of the country, and moreover, these extreme conditions do not, as a rule, occur at the same time. If, therefore, the ordinary working conditions are considered, such as a room temperature between 65° and 80°, and a humidity over 30 per cent., it will be seen that the maximum error likely to occur from use of the wrong table is only 1.5 B. t. u. or about one-fourth of 1 per cent. But there is another factor which still further tends to diminish the chances of error from this source. With the exhaust damper set properly and with the air mixer on the burner so adjusted as to give the most perfect combustion (a condition easily judged by the color and general appearance of the flame) the excess of air admitted to the calorimeter is a constant within reasonably close limits, and the seven volumes of air per volume of gas will ordinarily be the mixture employed. Thus it will be seen that, with the aid of the correction table and a humidity determination, the error due to humidity will never be over 4 B. t. u., and, under working conditions, will probably average about 1.5 B. t. u. The application of surface combustion may well be studied with the object of minimizing the quantity of air used in the calorimeter.

7. Another factor which is intentionally disregarded in practical work is the specific heat of the water. Since the custom of weighing the water is now almost universally adopted, any error from this source has usually been considered so small as to be unworthy of attention. In a study of this matter by Leo Loeb, in March, 1911, he states that, in gas calorimetry, the possible variations due to this cause are from 0.13 to 0.25 per cent. This would mean a maximum error of about 1.4 B. t. u.

8. An error which cannot be readily computed is introduced through the fact that the gas is not saturated with moisture as it enters the burner. It has always been assumed that gas after passing a wet meter would be very nearly saturated with water vapor, one author stating as the result of his experiments that the saturation was over 98 per cent. Recent investigations seem to render so high a result questionable, but it is the consensus of opinion that the error due to this cause is so small as to be negligible in practical work; it will probably be less than 0.5 B. t. u.

9. One other factor affecting the accuracy of results remains to be considered, and this is loss from radiation. This matter has received considerable attention from the National Bureau of Standards, which has found that if proper baffle plates are placed on the burner, radiation losses may be reduced to about 0.3 per cent., or about 1.75 B. t. u.

10. If we now combine all of these errors, and assume them to be all in the same direction (which is not true) we should have a total maximum error of about 5.5 B. t. u., or less than 1 per cent. The error due to radiation, how-

ever, tends to make the observed result too low, while the fact that the gas is not saturated makes the observed result higher than the true figure. The error introduced by the specific heat of water makes the observed result too high, while that due to the unknown volume of excess air admitted may be either a positive or a negative correction. Combining these algebraically, we get a possible error of +1.5 B. t. u., or about 0.25 per cent.

Photometry

11. Even with the most complete photometric outfit it is not possible to secure results which are accurate within less than 1 or 2 per cent. This is due to a number of factors which are variable and cannot be corrected for: the personal equation, atmospheric conditions, quality of pentane, deterioration of standards lamps and of discs, varying water line in the meter and inaccuracy of the latter, etc. If this be true of the best type of apparatus, how much more true it is of photometers as generally employed, with candles as standards and burners which do not begin to develop the full illuminating power of the gas.

12. In New York State candles have been made the official standard, principally for the reason that it did not seem practical to employ either a pentane or a Hefner lamp in connection with the portable photometer which the Commission's inspectors are obliged to use in a large number of places.

13. It appears to have been conclusively established that the candle as a standard is unreliable. Instead of attempting to take up this subject ourselves, we refer to the following as being among the most notable discussions to be found in the voluminous literature dealing with this question—Dutch Photometric Committee, 1894, C. O. Bond's paper on Working Standards of Light, American Gas Institute Proceedings, 1907; Dr. Love's paper on Standard Candles, and the recent work by C. E. Crittenden on the variations in illuminating value of candles.

14. To cite the last authority only, Mr. Crittenden publishes curves showing fluctuations from minute to minute of over 10 per cent. while the average approached closely 2.1 candle power per pair. If to this be added the errors inherent in a portable photometer, the inaccuracies of a dry meter for photometric work, the troubles furnished by the candle-balance and the use of improper burners, the result obtained is most unsatisfactory. The last item, however, is one of the most important and should receive special consideration.

15. In this country the two states which have given the most thorough study to photometric work have adopted the practice of employing the burner best adapted to the gas to be tested; the burners selected would be either a slit union Bray, a Suggs table top or one of the various styles of Argand burners. The result of this is that, in order to make a satisfactory test, several burners must be tried.

16. While, as a rule, the new style F Argand will give the best results from a water gas of between 17 and 21 candle power, it very frequently happens that, even under these conditions, the Bray burner is superior, and therefore both burners must be tried in every case if a correct result is to be assured.

17. With a coal gas the matter is still worse, for there are at least five styles of Argand burners which may be tried, each adapted to a little different quality of gas and each liable to give the best result on a gas of unknown candle power.

18. After all of these have been used, and the maximum result secured. is this the candle power of the gas? No; for there is at least one other burner which might be employed, the Metropolitan No. 2, which would give a much higher candle power than any of the above.

19. This latter burner has been adopted as official by the London Referees and is recognized by Parliament. It has not met with favor in this country for two reasons: First, its initial cost, which places it beyond the reach of most consumers; and, second, the fact that it gives so much greater candle power than the burners now used. Neither of these is a scientific reason, for science is not concerned with cost and is concerned with securing as nearly a theoretically correct result as possible.

20. It has been argued that the illuminating value of gas as measured in candle power is not a definite scientific quantity and in this respect differs from the calorific value. This does not nullify the argument that the manufacturer is entitled to a judgment of his product based upon the best that can be attained therefrom using the most accurate scientific instruments.

21. It is also sometimes urged that illuminating value should be measured with an open flame burner, because the results thus obtained would more nearly represent the value of the gas to the consumer. Such a method would not measure the illuminating value of the gas, but rather the efficiency of the burner used. There are a number of types of open flame burners in general use whose efficiency varies from 50 to 90 per cent.

22. If to test the gas the Metropolitan No. 2 burner is used, the consumer will be getting the gas of a certain fixed illuminating value and the measure of light which he will obtain from a given quantity of gas will depend entirely upon the efficiency of his burner.

23. From the above discussion it is evident that a calorimetric test measures much more accurately the heating value of the gas than a photometric test measures the illuminating value. In the test itself, even eliminating the question of burners, the percentage of probable error is much less in a calorimetric test than in a photometric test. It will also be seen that calorimetric tests may be made with sufficient accuracy by other than highly technical men as long as the prescribed rules of procedure are followed.

INSTRUMENTS USED IN INVESTIGATION AND CALIBRATION WORK OF PUBLIC SERVICE COMMISSION.

24. The selection of those calorimeters that assure accuracy in determining the heating value of the gas, and yet are simple in operation, received considerable attention from the Committee. For this purpose the work that had been done on the subject of gas calorimetry was reviewed. A study was made of the reports of the Calorimetry Committee of the American Gas Institute made in the years 1908, 1909 and 1912, and in addition consultations were held with the members of the staff of the National Bureau of Standards, Washington, who have had this subject under investigation.

25. It was found that at the present time there are a number of instruments in use and on the market designed to measure the heating value of gas, but employing different underlying principles in their operation. After giving the matter much consideration, it was found advisable to employ calorimeters for this investigation of the water heater type, and only those that expressed directly the heating value of the gas, when burning a known quantity of gas and imparting the heat developed to a known quantity of water.

26. Of the calorimeters approved by the Committee, only three have been used by the reporting Companies during this investigation. They are the Junkers, the American Meter Company and the Sargent. These instruments have all been calibrated and checked for accuracy at the Commission's laboratory at Albany and in their operation have proved satisfactory.

27. It is interesting to note in this connection the variation in efficiency of instruments after a period of continuous operation for one or two years. We have received figures from the laboratory of the Commission for one instrument tested on November 23, 1910, and again on October 15, 1912. The efficiency in the first case was 99.6 per cent., and in the second case 99.5 per cent. Another instrument was tested on January 27, 1911, and again on November 25, 1912, the efficiency at the first test showing 99.8 per cent. efficiency and in the second case 99.4 per cent. efficiency. Another instrument tested November 18, 1910, and having an efficiency at that time of 99.5 per cent., was tested again on December 16, 1912, about two years, and showed an efficiency of 99 per cent.

28. The photometrical measurements were made in the usual way and in accordance with the State requirements.

29. The Primary Standard was tested by the Bureau of Standards at Washington by means of an electrical burner, with the following results:

October 22, 1910 .... Efficiency 99.5%
April 22, 1912 .... Efficiency 99.8%

30. All wet meters were calibrated prior to the investigation. The calibration of calorimeter thermometers showed that those used in the investigation were of high class, the corrections applicable being very small.

31. In the table following the efficiencies of the calorimeters of the participating companies are given. Column I. shows the efficiencies as determined against the Primary Standard in the laboratory of the Commission at Albany, before the companies began to report to the Committee. Column IV. gives the results against the Primary Standard after the companies ceased reporting. There is thus an interval of at least fifteen months between the results in Column I. and IV. in nearly every instance, and in some cases over two years. The efficiencies given in Columns II. and III. were determined by the use of the Secondary Standard at the plants of the companies by traveling gas inspectors of the Commission and at intervals of several months.

EFFICIENCIES OF CALORIMETERS DETERMINED BY PUBLIC SERVICE COMMISSION

Company Number	Column I. vs Primary Standard	Column II. vs Secondary Standard	Column III. vs Secondary Standard	Column IV. vs Primary Standard
1	99.8		99.6	99.3
2	99.3	98.8	99.2	99.4
3	99.8	98.5	99.6	99.4
4	99.5	99.7	99.0	99.0
5*	99.3			
6	99.2	97.7	99.6	98.4
"	99.7		98.9	99.1
7	99.5	99.6		99.3
8	99.4	99.4	99.4	99.6
"	99.5	98.8	99.5	99.2
"	99.1	99.4	98.7	99.3
"	99.6			99.5
9	99.3			99.6

Company Number	Column I. vs Primary Standard	Column II. vs Secondary Standard	Column III. vs Secondary Standard	Column IV. vs Primary Standard
10	99.3	99.1		
11	99.6	99.9	99.8	99.8
12	99.3	99.0	99.5	98.7
13	98.2	99.2	97.6	99.0
14	99.3			99.0
15	99.8			
16*		99.0	99.2	99.3

* Same instrument.

32. These tests not only indicate that the variation in efficiency of a calorimeter is slight, but also that a more satisfactory result is obtained when this calibration is performed in the laboratory of the Commission, which has been especially equipped for just such work.

APPENDIX F.

REPRINT OF CALORIMETRIC RULES, REGULATIONS AND SPECIFICATIONS.

Adopted May 6, 1910, by the Joint Committee on Calorimetry, representing the Public Service Commission and Gas Corporations in the Second Public Service District, New York State.

INTRODUCTORY NOTES.

(1) A preliminary inquiry into the heat units of gas supplied in New York State was made in 1908 and 1909 by the Division of Light, Heat and Power of the Public Service Commission, Second District, by direction of the Commission. The inquiry was conducted under the immediate supervision of Mr. Charles H. Stone, the Chief Inspector of Gas.

(2) The results of the determinations were submitted to the Commission in a report by the Chief of the Division, Mr. Henry C. Hazzard, under date of October 29, 1909.

(3) Under date of December 8, 1909, the Commission addressed the following communication to each gas corporation:

"Albany, December 8, 1909.

"To Corporations Engaged in Furnishing or Distributing Coal Gas, Water "Gas, or Mixed Gas:

"By resolution duly adopted, this Commission has appointed February 1, 1910, as the date for a conference with representatives of gas companies on the subject of standards for the measurement of the value of gas.

"The particular object of the conference is to obtain an interchange of views on the necessity for a calorific standard, and on all questions necessarily incidental thereto.

"A preliminary inquiry into the subject has been completed, the results of which are embodied in a report by the Chief of Division of Light, Heat and Power. For your information therein we are sending you under separate cover a printed copy of this report.

"The conference will begin at 2 p. m., in the hearing room of this Commission, at the Capitol, Albany, on the above mentioned date, and if necessary will be continued the following day. You are respectfully requested to have a representative present.

"Very truly yours,

"J. S. KENNEDY,
"Secretary."

(4) The conference on February 1, 1910, decided upon the desirability of establishing a joint committee under whose immediate charge and direction, subject to the approval of the Commission, the inquiry should be concluded.

(5) The Commission appointed to serve on such committee:

Messrs. Henry C. Hazzard, Chief of Division of Light, Heat and Power.

Howard H. Crowell, Engineer of Division of Light, Heat and Power.

Charles H. Stone, Chief Inspector of Gas, Division of Light, Heat and Power.

The gas corporations represented at the conference appointed to serve on such committee:

Messrs. R. M. Searle, Rochester Railway and Light Company.

W. R. Addicks, Westchester Lighting Company.

T. R. Beal, Poughkeepsie and Newburgh Light, Heat and Power Companies.

J. C. DeLong, Syracuse Lighting Company.

W. T. Morris, United States Gas and Electric Company.

M. W. Offutt, Mohawk Gas Company.

(6) This Joint Committee, of which Mr. Henry C. Hazzard was elected Chairman on February 11, 1910, appointed a sub-committee of three, consisting of Messrs. W. R. Addicks, James C. DeLong and Charles H. Stone. The sub-committee in the discharge of its duties submitted the following report, which was duly adopted by the Joint Committee at a meeting held March 11, 1910, and revised May 6, 1910, and ordered printed for the guidance of those participating in the inquiry:

REPORT OF A SUB-COMMITTEE OF THE JOINT COMMITTEE OF NINE

REPRESENTING THE NEW YORK PUBLIC SERVICE COMMISSION, SECOND DISTRICT, AND REPRESENTATIVES ELECTED AT A MEETING OF GAS COMPANIES IN ALBANY, FEBRUARY 1, 1910.

At a meeting of the Joint Committee held in Albany February 11, 1910, resolutions were adopted providing for the appointment of a sub-committee consisting of Mr. Addicks, Mr. DeLong and Mr. Stone to prepare and submit to the Joint Committee:

(1) Specifications for a primary standard calorimeter;

(2) Rules and regulations for the installation and operation of calorimeters at plants of gas corporations;

(3) Suggestions as to suitable types of calorimeters for use, when checked against the primary standard, at gas plants.

In accordance with the above, your sub-committee begs leave to report as follows:

I.

HEATING VALUE OF GAS.

(1) The definition of the heating value of gas adopted by your sub-committee for the purposes of this report and the investigations to be hereafter conducted is that given by the American Gas Institute, Vol. III., 1908, page 383, as follows:

> "The heating value of a gas is the total heating effect produced by the complete combustion of a unit volume of the gas, measured at a temperature of 60 degrees Fahrenheit, and a pressure of 30 inches of mercury, with air of the same temperature and pressure, the products of combustion also being brought to this temperature.
>
> "In America the unit of volume is the cubic foot and we recommend that the heating value be stated in terms of British Thermal Units per cubic foot of gas."

II.

PRIMARY STANDARD—TO BE MAINTAINED AT LABORATORY OF THE COMMISSION AT ALBANY.

1. The Primary Standard shall be a new instrument, and shall consist of the calorimeter proper, as manufactured by Junkers & Company, Dessau, Germany, and as illustrated by Instrument No. 1221, now in possession of the Public Service Commission of the Second District, State of New York.

2. The meter for measuring the gas shall be a wet meter, having a drum capacity of 1/10 of a cubic foot for each revolution, and with an outside gauge glass for indicating the water level. The dial shall read in tenths, hundredths and thousandths of a cubic foot. This meter shall be of the size and pattern supplied by the American Meter Company, fulfilling the above requirement.

3. The thermometers for use in determining the temperature of the water entering and leaving the calorimeter shall be of the design recommended by the Calorimetry Committee of the American Gas Institute. They

shall have a range of from 60 to 110 degrees F., shall be subdivided to read 1/10 of one degree, and shall have an auxiliary division at 32 degrees F. for checking the ice point. They shall be calibrated throughout their entire range.

4. The thermometers for reading the temperatures of the gas, the atmosphere and the exhaust products shall be graduated in degrees F., shall be accurate to within one-half (½) of one degree, and shall be calibrated throughout their entire range.

5. Gas used for standardizing purposes shall be stored in a holder of not less than 50 cu. ft. capacity.

6. The gas pressure at the inlet of the meter shall approximate existing normal distribution pressure supplied to consumers of artificial gas, and this pressure shall be added to the barometric pressure and taken into account when making the barometric corrections as indicated hereafter.

7. The gas governor placed between the meter and the burner shall be of the float type now supplied with the Junkers Calorimeter.

8. Arrangements shall be made for accurately weighing the water passing through the calorimeter, and the balance employed shall have a capacity of ten (10) pounds avoirdupois, and give the correct weight at that capacity to within 0.001 of one pound.

9. The calorimeter, balance, weights and thermometers shall be carried to Washington and there standardized and calibrated by the National Bureau of Standards. The gas meter shall be tested against a cubic foot bottle bearing the seal of the said National Bureau of Standards.

10. The water supply to the calorimeter shall be filtered, and so arranged that the water entering the calorimeter shall be of a uniform pressure and temperature, and that temperature shall be within two (2) degrees of the temperature of the atmosphere surrounding the calorimeter, and of the exhaust products leaving the calorimeter.

11. The gas as metered and entering the calorimeter shall have approximately the room temperature, and shall be corrected to 60° F. and 30″ barometric pressure, the latter to be read from U. S. Signal Service type of barometer.

12. The calorimeters shall be operated with the minimum quantity of air to effect complete combustion of the gas, which shall be burned at a rate giving the maximum calorific efficiency.

13. Corrections shall be made for atmospheric humidity.

14. The entire apparatus shall be installed in a proper room of the Laboratory of the Public Service Commission, Second District, in Albany.

III.

SECONDARY STANDARD—TO BE USED IN CHECKING THE CALORIMETERS OF THE GAS COMPANIES IN SITU.

1. The Secondary Standards used by the Public Service Commission, Second District, New York, shall consist of calorimeters and accessories which with the operating methods employed shall give, within 2%, the heating value of the gas, as determined by the Primary Standard heretofore recommended.

2. The Secondary Standards shall be checked against the Primary Standard at such intervals as will maintain the calorimeters and accessory apparatus in condition to fulfill the said 2% requirement, and the results of such tests shall be recorded and filed.

3. The Secondary Standards shall be used for checking the calorimeters of the companies engaged in experimental work relating to the heating value of artificial gas; said checking should be made not oftener than once in thirty (30) days, and shall be made at least once in ninety (90) days.

IV.

GENERAL SPECIFICATIONS AND RECOMMENDATIONS FOR CALORIMETER INSTALLATIONS BY GAS COMPANIES

1. We recommend the adoption of a calorimeter of the water heater type (see ¶ 2), which when new shall be tested against the State's Primary Standard, and we feel that an instrument should be required to have an efficiency within 2% of the Primary Standard (see page 71).

In determining the calorific value of the gas we recommend:

(a) The measuring of the gas in cubic feet (see ¶ 9).

(b) Taking all temperatures of air, gas and water with Fahrenheit thermometers (see ¶ 22).

(c) Weighing or measuring the water in pounds and hundredths of a pound (see ¶ 30).

(d) Correction of the volume of the gas to standard volume, as expressed when measured at a temperature of sixty (60) degrees Fahrenheit, and barometric pressure of thirty (30) inches of mercury (see ¶ 29).

(e) Expressing the result of all calorific determinations in British Thermal Units (B. t. u.'s) [see page 71].

(f) That at this time, with the information before us, we believe that a calorimeter in commercial use may be expected to give results with an efficiency within 3% of the Primary Standard, in which case it should be held to be commercially correct. A record should be kept of the periodic tests made by the State's Inspector with the Secondary Standard.

Calorimeter Proper.

2. The calorimeter proper shall be an instrument that transmits directly the heat evolved by the burning gas to a quantity of water: it shall at this writing be of a design operating on the principle as illustrated by that of the Junkers Gas Calorimeter. This calorimeter shall be accompanied by accessories that shall measure definitely the gas burned; the water heated and the temperatures of the gas, water, air and exhaust products.

3. The apparatus should be designed to give a constant head of water on the Calorimeter. This head should be maintained by having a weir overflow on the inlet at some distance above the top of the calorimeter, and a weir overflow at the outlet. The rate of flow through the calorimeter should be regulated at the inlet by means of a cock with graduated scale.

4. The calorimeter should be so built that the water will circulate freely, and will be equally distributed throughout the apparatus. Baffle plates should be so arranged that the water will be thoroughly mixed before coming in contact with the bulb of the outlet thermometer, insuring a correct average reading. The design should be such that air pockets cannot form in the water space of the calorimeter.

5. The calorimeter should be made of bright polished metal, air jacketed in all its parts.

6. There should be a damper in the exhaust gas flue which can be easily adjusted, and which cannot be moved by a slight jar.

7. The calorimeter should be mounted at a height sufficient to make it easy to put the burner in place, and on legs with a spread great enough to insure a firm base.

8. It may prove desirable in practice to have water thermometers on the same level, to facilitate readings, as recommended by the Calorimetry Committee of the American Gas Institute. The openings for thermometers should be large enough to take a No. 4 rubber stopper.

Meters.

9. For a meter, we recommend a wet meter, and one registering 1/10 cubic foot per revolution.

10. The large dial should be divided into 100 equal parts, with every tenth part distinctly marked to facilitate reading. In addition to the large dial, there should be a smaller dial to register the number of revolutions of the large hand; this dial should register tens, units and tenths of a cubic foot.

11. The face of the meter should be enameled and no glass used on the front, thereby preventing error due to parallax. The face of the meter should be easily removable, in order to get at the shaft and the stuffing box on the shaft. This stuffing box should be of a size large enough to be easily packed.

12. The large hand of the meter should be well pointed, and not extend to the outer end of graduations of the meter dial. The meter should have leveling screws.

13. Two leveling tubes, placed at right angles to each other, should be securely fastened to the top of the meter.

14. The meter should have an outside gauge glass showing the water level. This glass should not be less than 3/8-inch, nor more than 3/4-inch, inside diameter, as it is necessary to have the glass large enough to be readily cleaned, and small enough that the meniscus formed by the water can be accurately read. The openings from the gauge to the meter should be unobstructed, and of a size to correspond with the size of the gauge glass. A fixed point to show the correct water level, reading to the bottom of the meniscus, should be put on the outside of all water level gauge glasses.

15. For convenience, a standard 3-light meter union should be used on all meters, and hose nipples for 3/8-inch hose should be furnished with the unions.

16. The meter should be provided with an opening for the addition of water when needed. This can be done by using a pet cock, with a small covered funnel mounted on top, connected to the top of the gauge glass support.

17. An opening must be left for a thermometer in or near the gas outlet. This thermometer should have a metal case and read to one degree Fahrenheit, with a range of from about 50 to 100 degrees, and accurate to within ½ degree.

18. An opening with a plug connection should be left on the bottom of the meter to drain it when so desired.

19. The number of joints liable to cause leakage should be reduced to a minimum.

Gas Pressure Regulator.

20. The pressure of the gas when burning in the calorimeter should be absolutely uniform to obtain correct results, and any small regulator that will maintain this uniform pressure will be satisfactory. We recommend the use of a small wet governor, similar to the one supplied with the Junkers Calorimeter. This will give excellent regulation, and will operate without chattering. Such a regulator should be constructed so as to be readily weighted for altering the delivered pressure.

Burners.

21. The burner should be a long tube Bunsen, having a spreader on top, and adjustable air mixer which can be easily reached when burner is in position in the calorimeter. The burner should be provided with a stop-cock. The burner should be attached to the calorimeter in such a way that the gas flame cannot impinge on the interior body of the calorimeter, and when the burner is set at its correct position it should be so fastened that it cannot be accidentally shifted. The condition of the flame should be observable by the operator, either directly or by means of a reflecting mirror.

Thermometers.

22. Accurate thermometers are the most important accessories to correct calorimetry.

23. The thermometers for reading water temperatures should be of high-grade quality, and should read accurately within 1/10 of a degree Fahrenheit.

24. The thermometers should be graduated from 60 to 110 degrees Fahrenheit, each degree to be divided into tenths, with short, distinct graduations. The thermometers should be so accurately made that in ordinary commercial work corrections may be neglected. With each thermometer should be provided a calibration curve, which should enable very accurate results to be obtained whenever it was deemed necessary to make these corrections.

25. This matter of high-grade thermometers for calorimetry work has been taken up with several thermometer makers by the American Gas Institute's Calorimetry Committee, which reported that Messrs. Hohmann & Maurer, of Rochester, N. Y., are now delivering a thermometer that has been built according to its recommendations. The thermometers have a range of from 60 to 110° F., and graduated to 1/10 degree, having an auxiliary division at 32° F., which is convenient for carefully checking the ice point. These thermometers are carefully made and have a bore that is exceedingly uniform and accurate. This Committee hopes that other makers will place on the market similar instruments.

26. The error of 1/10° above mentioned may seem to be a small matter, and it is in most measures of temperature, but when the calorific value of an artificial gas is determined with a rise in the water temperature of 15° F., a difference of 1/10° means an error of 1/150 of the total heat of the gas, or about four (4) B. t. u.'s.

27. When doubt arises as to correctness of thermometers, we recommend their calibration by the National Bureau of Standards at Washington.

28. Telescopic sights for reading thermometers should be provided, as much more accurate readings can be obtained in this way.

Barometer.

29. Corrections for variation in barometric pressure should be made in measuring the volume of the gas. This pressure should either be obtained by means of a mercury column barometer or by a recently calibrated aneroid barometer. Where it is possible barometer readings should be checked occasionally with readings of the Government Weather Bureau of the city in which the readings are made. Where no barometer is available, it may be possible to get fairly accurate figures on pressure by obtaining from the local Weather Bureau the barometer readings for the day, and correcting for variations in elevation.

Water Supply and Measurement.

30. The control of the temperature of the water supply is very important in calorimetry, and this temperature should be approximately that of the room in which the observations are being made. Water obtained from an ordinary house piping system is apt to be variable in pressure and temperature, due to the uneven consumption in other parts of the building, and possible exposure of the water main to the extreme temperatures of the ground or atmosphere. This control of temperature or pressure may be readily obtained by providing a permanent water supply tank in the upper part of the calorimeter room, that will contain enough water to enable the readings for the day to be made. A flat tank of large horizontal area is preferable to a deep vertical tank. The exposed surface allows the water to come to the temperature of the room more readily, while the shallow depth has less effect on the head as the water is being used.

31. Should a number of continuous readings be made that will require more water than is contained in the overhead tank, a simple coil gas water heater may be employed to raise the temperature of the water supply to the overhead tank, so that it will enter this tank at approximately the temperature of the room. The tank will then act as an equalizer and assist in maintaining a uniform temperature and pressure of water entering the calorimeter.

32. Water may be collected and weighed in thin sheet metal containers, holding about nine (9) pounds of water. This size container will hold all the water required in burning 0.2 of a cubic foot of ordinary illuminating gas, with a range of about fifteen (15) degrees Fahrenheit in temperature between the inlet and outlet water. The scales, or balance, employed should have a capacity of at least ten pounds, should read to 1/100 of a pound, and should be calibrated and certified to as being correct by proper authorities.

33. Should it be desired to measure the water volumetrically, instead of weighing it, graduated vessels may be employed that will read accurately the water passed through the calorimeter to within 1/100 of a pound. Such vessels, however, shall be approved by the Commission and calibrated (by State or National authority) at 60° F. and accompanied by a curve to correct for other temperatures.

Gas Piping and Tubing.

34. Gas connections for a calorimeter should consist of metallic piping or tubing where possible; rubber tubing is not advisable, but when necessary, the lengths used in conducting the gas should be as short as possible, and they should be thoroughly saturated with gas before a test is made.

Humidity.

35. It may be desirable to have the state of the humidity of the atmosphere during the test, in which case percentage readings may be made from wet and dry bulb thermometers. For accurate work these wet and dry bulb thermometers should be arranged so that the average humidity of the room may be obtained. This may be done by having a whirling wet thermometer, or having a constant current of air impinging upon the wet bulb from an electric fan; or, a more perfect instrument in the form of an Assman Psychrometer may be obtained. These humidity readings of the atmosphere will not be found ordinarily necessary in commercial calorimetry, but may be useful if it is desired to make corrections for heat absorbed in saturating the products of combustion.

Calorimeter Cabinet.

36. To facilitate the operation of the calorimeters at the various gas plants, the calorimeters should preferably be installed in a cabinet, similar to that recommended in the Report of the Calorimetry Committee of the American Gas Institute, as contained in the American Gas Institute Proceedings, Vol. IV., 1909, pages 205 and 206. This sketch represents a typical cabinet, suitable for use in some convenient building, either at the gas works or gas office, and of such a design that when the calorimeter is once placed and connected up, it may be kept clean, protected and ready for use at all times.

37. In construction, the cabinet should be made as dust tight as practicable. Where there is not enough head room for a vertical sliding door, horizontal sliding or folding doors may be substituted. This cabinet should provide for an overhead water tank, and may be most conveniently located adjacent to a sink and water supply.

38. The gas supply line to the calorimeter should have a purging connection. All cocks controlling the gas and water supply should be inside of the cabinet, and the cabinet should be kept closed and locked when not in service.

39. This cabinet shall not be near any gas flame, register or other object radiating heat; direct sunlight shall not be allowed to strike upon it, but the thermometers and meter shall receive sufficient reflected artificial light to enable them to be easily read. Since drafts must be rigorously excluded, it is better, wherever possible, to set aside a room solely for the use of the calorimetric outfit.

40. The adoption of such an installation will enable a calorific reading of the gas to be made in a very short time, and will warrant the best of care being taken of the calorimeter and of its accessories.

41. After installation and before undertaking investigations involving experimental data, the above equipment should be inspected by the Chief Inspector of Gas of the State Commission and have the approval of the Commission.

V.

DIRECTIONS FOR OPERATING A CALORIMETER.

1. On unpacking the Calorimeter, see that it is cleaned inside and out, and free of packing material.

2. Study carefully the erecting directions and cuts and see that all parts are included.

3. Handle the thermometers with the **greatest of care.**

4. The Calorimeter should be set up in a quiet, light and well-ventilated room or cabinet, which is free from draughts and in which the temperature can be maintained constant at not less than sixty degrees Fahrenheit. The room should be provided with a sink and with a good supply of running water. It is advisable to have a large shallow overhead covered tank, from which the water supply can be taken. Should the tank capacity be small and not hold enough water for a prolonged series of readings, a small gas water heater may be employed as already noted to bring the water to approximately the room temperature. It is desirable to use water in the Calorimeter that is clear and free from suspended matter, therefore, a filter should be installed in the water supply line before it enters the overhead tank.

5. If only a single test is desired, gas may be taken from the house piping, but if an average value is required, a small gas holder, or averaging tank, should be used, and the gas flowing into the holder adjusted to a rate of flow to just fill it in the time during which the sample is to be taken. Care should be taken to have a short service to this holder in order that an average sample of gas may be obtained, and if the sample be taken from a line on which there is no considerable consumption, see that this line is thoroughly purged before sampling. It is recommended that the gas be metered at a pressure not to exceed 2 inches of water; if this is not obtainable, it is advisable to insert a holder or diaphragm governor in the supply line to reduce the pressure to within this limit.

6. Set up the calorimeter so that the overflow and outlet water can be easily led to the sink. Make water connections with rubber tubing, being careful not to cramp the tubing. To avoid air currents caused by the movement of the observer's body, set up the calorimeter so that the water supply and waste may be easily adjusted and that all temperatures may be readily observed. Lead the outlet water to a waste funnel supported a little above the top of the copper or glass container used in collecting the water, so that the water can be shifted from the funnel to the container and back without spilling.

7. Set up the gas meter facing the observer and level it carefully. Then adjust the water level of the meter, both inlet and outlet being open to the air. To do this, remove the plug from the dry well, open the funnel cock and disconnect the tubing on the outlet of the meter. With one finger over the dry well turn on the gas a little and by removing and replacing the finger see that there is no water in the dry well. If water be found therein it must be blown out by gas pressure. Notice whether the water in the gauge glass moves freely, as, if it does not, the meter is out of order. Now remove the finger from the dry well and add or remove water (through the funnel or by the cock under the gauge glass) until the lowest edge of the meniscus just touches the scratch on the gauge glass, or is even with the fixed pointer. Replace the plug in the dry well, close the funnel valve and connect the governor. If the meter has been filled with fresh water the gas must be allowed to burn at least two hours before making a test. When the water in the meter is saturated with gas, twenty minutes should be sufficient.

8. Fill pressure regulator with water, then connect it to the calorimeter burner. Metallic tubing is preferable, but when rubber tubing is used to connect meter, pressure regulator and burner, connections should be as short as possible, and should be saturated with the gas.

9. Turn on gas and allow it to burn for 5 or 10 minutes with the burner on the table. Shut off gas at burner and watch hand on meter for leakage. Be sure that all leaks are stopped before attempting to make a test. Start water running through the calorimeter at a rate of about three pounds per minute. Then regulate the gas to flow at the rate of 4 to 7 feet an hour, as may be found by experiment to give the highest result with the gas to be tested, admitting enough air through the burner so that the flame shows a faint luminous tip, then insert the burner at the proper height in the calorimeter and observe again the condition of the flame to see that it is all right, using a mirror.

10. The excess of air passing through the calorimeter is controlled somewhat by the position of the damper in the exhaust port, and the best results are obtained by having the excess air as low as possible and still maintaining complete combustion of the gas. Such position has heretofore been found to be about one-fourth open with those calorimeters already investigated; care must be exercised to determine this for each calorimeter.

11. Water should be regulated so that there is a difference between the inlet and outlet temperatures of about 15 degrees Fahrenheit. The temperature of the inlet water should vary but little when an overhead tank is used and the water maintained at room temperature. Be sure that both overflows are running.

12. Before making the test the barometer, temperature of the gas at the meter, temperature of room and temperature of exhaust products should be recorded. It is desirable to have the temperature of the inlet water and temperature of exhaust products as nearly as possible at room temperature, in order to establish more nearly a thermal balance; the difference in these temperatures should never exceed five degrees.

13. Next allow the gas to burn in the calorimeter until a thermal balance is established, or until there is the least change in the inlet and outlet waters.

14. The test may now be started by shifting the outlet water from the funnel to the container just as the large hand on the meter passes the zero point. Readings are then made of inlet and outlet thermometers, making the readings as rapidly as the observer is able to record them during the consumption, preferably of 2/10 of a cubic foot of gas. At least ten readings should be made of both inlet and outlet water temperatures. Water is again shifted from the container to the waste funnel as the hand passes the zero point the second time. Water is then weighed, or measured. The uncorrected heating value per cubic foot is obtained by multiplying the difference of the averages of inlet and outlet temperatures, by the number of pounds of water and dividing by two-tenths. This quantity is divided by the correction factor for barometer and temperature, obtainable from tables, to give the heating value at 30 inches pressure and 60 degrees Fahrenheit. The weight or contents of container should be obtained while the inside is wet. This may be done by filling it with water, emptying and shaking for about five seconds in an inverted position. This will do away with any correction where several consecutive tests are required with same container.

15. A second, and perhaps a third test is advisable, and these should be made without disturbing the existing conditions, provided all readings are within the above prescribed limits. In practice the operator should get consecutive results on the same holder of gas within ten (10) B. t. u's. Under such conditions an average of the results may safely be taken.

Results as Obtained by Calculation.

16. The method of calculating the calorific value of the gas from the observations indicated is very simple when all readings are made in English units, as recommended, and entered in some form conveniently arranged. A simple record sheet is illustrated in the American Gas Institute Proceedings, Vol. III., 1908, page 320.

17. The averages of the inlet and outlet water temperatures are made and any correction for thermometer error allowed for. The difference in these averages should give the rise in temperature of the water. This rise in temperature of the water is then multiplied by the number of pounds of water passed through the calorimeter during the test. The product of these two is then divided by the quantity of gas burned, either 0.1 or 0.2 of a cubic foot as may be. This quotient will give the heating value of one cubic foot of gas in B. t. u's. at the indicated temperature and barometric pressure. To correct this to 60° F. and 30″ pressure, divide by the "Correction Factor" for the indicated temperature and pressure as obtained from some standard table, a copy of which may be found opposite page 373 of the Proceedings of the American Gas Institute, Vol. III., 1908. The final result will be corrected heating value of the gas tested, in B. t. u's.

18. Expressing the above in a formula we have:

$$\text{B. t. u's. per cubic foot} = \frac{G}{W \times T}$$

W = Weight, in pounds, of water passed.

T = the average difference in temperature, in degrees Fahrenheit, between inlet and outlet water.

G = corrected volume of gas burned, in cubic feet.

Use of Computer.

19. The labor of making the calculations for determining the heating value from observations of a calorimeter may be lessened by the use of a heating value computer. The computer consists of a circular slide rule, with divisions corresponding to the readings made on the calorimeter. This computer gives the corrected heating value of a cubic foot of gas in B. t. u's, having the barometer and temperature of the metered gas, and the difference in temperature between the inlet and outlet water and the pounds of water passed. This computer is designed to operate within the limits of from 300 to 800 B. t. u's. Should a gas of a lower or higher heating value be measured, the computer can still be used by dividing or multiplying one or the other of the factors in its computation. A cut of this computer may be found on page 373, Vol. III., Proceedings of the American Gas Institute.

Care of Instruments.

20. The calorimeter, being a delicate and sensitive instrument, should be very carefully cared for when not in use. If the instrument is set up permanently, provision should be made that it be not disturbed by anybody except the operator. If the instrument is not erected permanently, when dismantled it should be carefully cleaned inside and out and the thermometers removed and carefully packed in cotton.

21. It seems hardly necessary that instruction should be given for the care of such an instrument, but certain precautions should be noted.

Precautions—"Don'ts".

22. Don't place lighted burner in calorimeter when water is not running through the calorimeter.

Don't shut off water while gas is burning, but if water is accidentally shut off, then shut off the gas quickly, to avoid breaking thermometers.

Don't move suddenly near instrument during test. Slight drafts thus caused will vary outlet readings and vitiate test.

Don't fail to check daily the water level in the gas meter.

Don't forget to test meter and all connections daily for leakages.

Don't erect the calorimeter too close to any heating or lighting appliances, where radiant heat might affect the readings.

Don't make the test with the inlet water temperature over 5 degrees above or below the temperature of the room.

Don't fail to fill the overhead tank with water when through testing so that it will be ready for the next test.

Note:

23. That an error of 1/10° F. in water temperature means an error of about four B. t. u's. in the gas.

That an error of 1/100 of a pound of water when burning .2 of a cubic foot of gas in the test means an error of about .9 B. t. u's. in the gas.

That an error of one degree in the temperature of the gas means an error of about 1.8 B. t. u's.

That an error of 1/10 of an inch in Barometer reading means an error of about 2 B. t. u's.

That when metering the gas, each additional inch of water pressure to which the gas is subjected means an error of about 1.5 B. t. u's.

VI.

SUGGESTION OF SEVERAL TYPES OF CALORIMETERS SUITABLE TO USE WHEN CHECKED BY THE PRIMARY STANDARD ADOPTED.

The Committee believes that any calorimeter of the water heater type, when fitted with the accessories as provided in the recommendations of the Committee, that, when new, will test with the Primary Standard within two per cent. would be suitable for commercial use by any company.

From the information available, the Junkers, the Improved Sargent, or American Meter Company calorimeters are types of instruments which seem to be available for immediate use by the Companies, but they must in each case be equipped with the accessories as provided in the recommendations of the Committee. Any instrument of the above mentioned types must pass the prescribed test against the Primary Standard.

We believe that all makers of instruments of the water heater type prescribed should be encouraged to place their instruments in use.

Dr. Arthur H. Elliott, Ph. D., of New York, and J. B. Klumpp, M. E., of Philadelphia, met with the Committee; they entered into its discussions, aided in the determinations and join in the conclusions of the Committee.

W. R. ADDICKS, Chairman,
JAMES C. DE LONG,
CHAS. H. STONE.

February 25, 1910.

APPENDIX G.

REPRINT OF PLAN OF CALORIMETRIC INVESTIGATION AND EXPLANATION OF TEST AND REPORT FORMS.

Tentatively adopted January 26, 1912, by the Joint Committee on Calorimetry, representing the Public Service Commission and Gas Corporations in the Second Public Service District, New York State.

INTRODUCTORY.

On May 6, 1910, this Committee adopted certain Calorimetric Rules, Regulations and Specifications which were printed and a copy sent to each gas company operating in the second public service district in New York State. References made hereafter to "Calorimetric Rules, Regulations and Specifications" refer to this pamphlet. (See Appendix F, page 69.)

A number of companies at once purchased and installed instruments in accordance with these specifications and started daily tests to determine the calorific value of their gas for the assistance of the Committee in its investigation.

As other companies are becoming interested in the investigation and are deciding to participate, it has become necessary to devise a definite plan for the investigation in order that the results obtained in different localities and under different conditions may be analyzed intelligently, and correct conclusions drawn therefrom.

The Committee is making a very comprehensive study of this entire subject and the plan formulated is therefore more elaborate than would be the case if merely the calorific values, without reference to operating conditions, were desired.

PLAN OF INVESTIGATION.

The plan formulated comprises:

1. The making of daily calorimetric tests and the recording daily of certain works data. Form A is to be used for this purpose. (See page 93.)

2. The submitting to the Committee monthly of the results of the daily tests and of monthly averages and totals of works data. Form B is to be used for this purpose. (See page 94.)

3. The furnishing to the Committee of information regarding operating conditions, and apparatus and methods in use. A map or sketch with an accompanying letter of explanation and description is to be used for this purpose. (See page 88.)

EXPLANATION OF TEST AND REPORT FORMS.

FORM A.

Apparatus in Use—

1. Each piece of apparatus will be given a designating letter or number (see page 89, paragraph 6f), and this letter or number may be used in noting the apparatus in use each day.

Send Out—

2. The maximum, minimum and average daily send out will be reported monthly and the figures will be obtained from these daily entries.

Works Started (First Blast On) at—
Works Shut Down (Last Run Off) at—
Duration Intermediate Shut Down—
Total Works Operation—

3. The maximum, minimum and average hours per day of works operation will be reported monthly and the figures will be obtained from these daily entries.

Yield Per Lb. Coal—
Oil Per M.—
Generator Fuel Per M.—

4. In many instances it would be extremely difficult to determine these figures with any degree of accuracy on a daily run and in such cases it need not be attempted. On the other hand, if it is the practice to make these calculations, the figures should be entered for comparison with the monthly measurements. (See page 87, paragraph 5.)

Enricher Per 100 Lbs. Coal Carbonized—

5. The unit of "100 lbs. coal carbonized" has been adopted as a fair basis for comparison.

The calculation should be made and the figures entered daily.

Kind of Enricher—

6. If cannel coal is used, the grade of this coal should be given, or if oil, the kind of oil. The practice in regard to this subject should be explained in considerable detail in the letter. (See page 89, paragraph 61.)

Duration of Charge—

7. The duration of charge each day should be noted so that the average daily duration of charge for the month can be obtained.

NOTE—The term "Corrected Gas" means that the quantity of gas, as measured by a meter, has been corrected to a standard of volume as represented when measured at a temperature of 60° Fahrenheit and a barometric pressure of 30 inches. The figure for corrected gas is obtained by multiplying the volume of uncorrected gas by a factor corresponding to the temperature and pressure at which the gas has been measured. A table of "Correction Factors" is given in Appendix A. This is copied with the permission of the author, from the table given in "Practical Testing of Gas and Gas Meters," by C. H. Stone.

Mixed Gas
Coal Gas —%, Water Gas —%

8. This is self-explanatory.

Time of Test—

9. A calorimetric test consists of one or more sets of readings taken continuously. On the form, three columns are provided for three sets of readings. For convenience they are headed Test 1, Test 2, Test 3. It should be understood that the three sets of readings or "tests" taken together and the results checked or averaged, constitute one test. The time of starting this test should be given. (See Calorimetric Rules, Regulations and Specifications, page 74, paragraph 15.) Should two or more tests be made at different hours of the same day, a separate sheet should be used for each test.

Barometer—

10. Refer to Calorimetric Rules, Regulations and Specifications, page 76, paragraph 29.

The mercury column barometer specified in the reference should have an adjustable zero and a vernier for reading. If the participating company is relying on barometric readings taken by the local weather bureau, the reading taken at a time nearest to the time of test should be used. Otherwise a reading should be taken as a part of the test.

Room Temperature—

11. The temperature of the room at the time of the test should be stated in degrees Fahrenheit.

Candle Power—

12. Two spaces are provided for candle power so that in case two types of burners are used the results obtained with each can be entered separately. Spaces are also provided in which the type of burner should be noted directly above the candle power obtained with it. The result of this one photometric test only is to be noted on this form. The results of other photometric tests made during the day will be disregarded so far as this investigation is concerned. (See page 88, paragraph 14.)

Pressure
Meter Inlet— Burner Inlet—

13. These readings should be taken at the time of starting the test. (See Calorimetric Rules, Regulations and Specifications, page 78, paragraph 5.)

Minimum Temperature to Which Gas Has
Been Subjected Before Test—

14. This temperature may be obtained by the use of an hygrometer. (See Proceedings American Gas Institute, Vol I., 1906, pages 601 and 602.)

Rate of Combustion Per Hour—

15. See Calorimetric Rules, Regulations and Specifications, page 78, paragraph 9.

Exhaust Temperature—
Gas Temperature—

16. See Calorimetric Rules, Regulations and Specifications, page 79, paragraph 12.

Total Pressure Correction—

17. This means that the water pressure, at meter outlet, in inches, is calculated to inches of mercury and added to the barometric reading. It is desired to correct the pressure of the gas to 30 inches of mercury, from the combination of the barometric pressure and the inches of mercury calculated from the water pressure at which the gas is burned.

Correction Factor—

18. See Table, pages 90 and 91.

Uncorrected Gas Used in Test—
Corrected Gas Used in Test—

19. (See footnote, page 83.)

Weight, Water and Pail—
Weight, Pail Empty—
Weight, Water—

20. See Calorimetric Rules, Regulations and Specifications, page 76, paragraph 32; also page 79, paragraph 14.

Temperature of Water—

21. Readings 1-20. See Calorimetric Rules, Regulations and Specifications, page 79, paragraph 14.

Average Temperature—

22. The average temperatures will, of course, be obtained by adding all the temperatures taken and dividing by the number of readings. Space is provided for this calculation.

Thermometer Correction—

23. This figure will be obtained from the calibration curve. See Calorimetric Rules, Regulations and Specifications, page 75, paragraph 24; also paragraphs 22, 23, 24 and 26.

Stem Correction—

24. See page 92.

Corrected Average Temperature—

25. This means the average temperature after the two corrections, thermometer and stem, have been applied.

Rise in Temperature—

26. The rise in temperature equals the corrected average outlet temperature minus the corrected average inlet temperature.

Calculation—

27. The general formula is:

$$\text{B. t. u. per cu. ft.} = \frac{W \times T}{G \times e}$$

W = Weight of water.

T = Rise in temperature of water.

G = Corrected gas used in test.

e = Efficiency of instruments in tenths of 1%. This figure is obtained from the most recent comparison of the instrument with the State standard.

In the blank formula as stated on the form, the numerator contains the figure 1,000, so that the efficiency can be stated in whole numbers and decimals thus avoided.

A computer may be used in making the calculation after the blank formula has been filled out, but if this is done the correction for efficiency will have to be made separately. (See Calorimetric Rules, Regulations and Specifications, page 80, paragraph 19.)

Average = —— B. t. u.

28. The results obtained with the different sets of readings should check within 10 B. t. u's. Under such conditions the average of these results should be obtained and this figure will be the one transferred to the Monthly Summary, Form B. (See Calorimetric Rules, Regulations and Specifications, page 79, paragraph 15.)

FORM B

Coal Gas Made—
Carburetted Water Gas Made—
Mixed Gas Made—

1. This refers to the gas made during the calendar month. Whether the figures are for uncorrected or corrected gas should always be indicated.

Daily Send Out, Maximum—
Daily Send Out, Minimum—
Daily Send Out, Average—

2. These figures will be obtained from the entries for "Send Out" on Form A.

Gas Enriched (Yes or No)—
Gas Enriched (How)—

3. This subject will be reported on fully in the letter. (See page 89, paragraph 61) but should also be reported on briefly opposite these headings. (See also "Average Enricher" and "Kind of Enricher," page 87, paragraphs 7 and 8.)

Hours Per Day Works Operation, Maximum—
Hours Per Day Works Operation, Minimum—
Hours Per Day Works Operation, Average—

4. These figures will be obtained from the entries on Form A for "Total Works Operation."

Average Yield Per Lb. Coal—
Average Oil Per M.—
Average Generator Fuel Per M.—

5. These figures should be based on measurements of the coal, oil or fuel on hand at the beginning and end of the month and not on the averages of the entries on Form A. (See page 83, paragraph 4.)

Kind of Coal—

6. The information desired is the commercial name of the coal used and the mine from which it comes, if this is known.

Average Enricher Per 100 Lbs. Coal Carbonized—

7. This figure will be the average of the daily entries on Form A.

Kind of Enricher—

8. (See page 83, paragraph 6.)

Average Duration of Charge—

9. This figure will be the average of the daily entries on Form A.

Kind of Oil—

10. This entry should give the "kind of oil," the district where the oil is produced, if definitely known, and the specific gravity in degrees Beaumé, if this figure is available. If the companies have any distillation test figures, they should be given.

Kind of Fuel—

11. This entry should state whether coal or coke is used, and if the latter, whether retort or oven.

Mixed Gas.
Coal Gas —%, Water Gas —%.

12. These figures will be the average of the corresponding entries on Form A.

Calorific Values—

13. As explained, page 84, paragraph 9, a test consists of one, two or three sets of readings. This form provides space for only one test per day at works and one at office, or some other location. If more tests are made, additional sheets should be used.

The figure to be entered will be taken from Form A, "Average B. t. u.," but the nearest whole number should be given and decimals eliminated.

Candle Power—

14. The candle power figures to be entered here should be taken from Form A, "Candle Power." The entry should **not** represent the average of all photometric tests made during the day, but should be the candle power at the time the calorimetric test is made. The candle power should be stated with only one decimal.

Minimum Temperature Gas—

15. As explained in the note on the form, this refers to the minimum temperature to which the gas has been subjected before test. The figures should be taken from the corresponding entries on Form A.

Temperature of Atmosphere—

16. The maximum and minimum temperature of atmosphere should be stated in degrees Fahrenheit. As no space is left for them on Form A they may be entered daily on Form B.

Maximum—
Minimum—

17. Refers to figures in columns above.

Note—

18. When calorimetric or photometric tests are made at both works and office or some other location, the tests at the two places should be made simultaneously.

MAP AND LETTER

1. A detailed map, or if this is not possible, a sketch, on paper 8½" x 14" should be submitted.

2. This map or sketch should show the relative location of the works and holders and should indicate the points at which the tests are made.

3. If these tests are made at a distance from the works, this distance following the course taken by the gas should be accurately shown. Also if any exposed bridges have been crossed, or if the line runs under water, these points should be made clear.

4. Such map or sketch will be asked for but once unless changes are made, and it should therefore contain information regarding all matters which are liable to affect the results obtained in the tests.

5. The map or sketch should be accompanied by a letter, also on paper 8½" x 14", containing a general description of the apparatus and methods employed.

6. Such letter should state:
   (a) Kind of gas made.
   (b) Manufacturing capacity of plant, giving figures for coal gas and water gas separately.
   (c) Gas holder capacity at plant.

(d) Gas holder capacity outlying.

(e) Holders housed or exposed.

(f) List of generator apparatus with type and capacity of each piece of apparatus. The different pieces of apparatus may be designated by a letter or number for future reference.

(g) Type and make of calorimeter.

(h) Type and make of photometer.

(i) Type of standard and burner used in photometer test.

(j) General description of the methods used and conditions under which the tests are made. For example, such a description might be that the calorific and candle power values are taken at office located at works, that the gas is taken from inlet of the street governor and has been in the storage holder, and that, as this holder is exposed, the probabilities are that the gas has been subjected to the extreme temperatures of the atmosphere.

Or, for another example, that the tests are made at the company's office, located a mile from the works, that the gas is taken from the house piping or that it is taken from an individual service; if this service is any way exposed to the temperature of the atmosphere, it should be mentioned; that the gas has passed over an exposed bridge as shown on the map, etc.

(k) Concise statement of how the gas is stored and exposed before it is delivered to the street mains.

(l) Concise statement of methods employed in enriching.

WM. McCLELLAN, Chairman.
A. H. ELLIOTT,
J. B. KLUMPP,
C. F. LEONARD,
C. H. STONE.

January 26, 1912.

CORRECTION FACTORS FOR TEMPERATURE AND BAROMETRIC PRESSURE FROM PRACTICAL TESTING OF GAS AND GAS METERS

By C. H. STONE

	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
107	.816	.820	.823	.826	.829	.832	.835	.838	.841	.844	.847	.851	.854	.857	.860	.864	.867	.870	.874	.877
106	.820	.823	.826	.829	.832	.835	.838	.841	.844	.847	.851	.854	.857	.860	.863	.867	.870	.874	.878	.881
105	.823	.827	.830	.833	.836	.839	.842	.845	.848	.851	.855	.858	.861	.864	.867	.871	.874	.878	.881	.884
104	.827	.830	.833	.836	.839	.842	.845	.848	.851	.854	.858	.861	.864	.867	.871	.874	.878	.881	.884	.887
103	.830	.834	.837	.840	.843	.847	.849	.852	.855	.858	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891
102	.834	.837	.840	.843	.847	.850	.853	.856	.859	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891	.894
101	.837	.840	.843	.846	.850	.853	.856	.859	.862	.865	.868	.872	.875	.878	.882	.885	.888	.891	.895	.898
100	.840	.843	.846	.849	.853	.856	.859	.862	.865	.868	.872	.875	.878	.881	.885	.888	.891	.895	.898	.901
99	.844	.847	.850	.853	.857	.860	.863	.866	.869	.872	.876	.879	.882	.885	.889	.892	.895	.898	.902	.905
98	.847	.850	.853	.856	.860	.863	.866	.869	.872	.875	.879	.882	.885	.888	.892	.895	.898	.902	.905	.908
97	.850	.853	.856	.859	.863	.866	.870	.873	.876	.879	.882	.885	.888	.891	.894	.898	.901	.905	.908	.911
96	.854	.857	.860	.863	.867	.870	.873	.876	.879	.882	.886	.889	.892	.895	.898	.901	.904	.908	.911	.914
95	.857	.860	.863	.866	.870	.873	.876	.879	.882	.885	.889	.892	.895	.898	.901	.904	.908	.911	.914	.918
94	.860	.863	.866	.869	.873	.876	.879	.882	.885	.888	.892	.895	.898	.901	.904	.907	.911	.914	.918	.921
93	.863	.866	.869	.872	.876	.879	.883	.886	.889	.891	.895	.898	.901	.904	.907	.910	.914	.918	.921	.924
92	.866	.869	.872	.875	.879	.882	.885	.889	.892	.894	.898	.902	.904	.907	.910	.914	.917	.921	.924	.928
91	.869	.872	.875	.879	.882	.885	.889	.892	.895	.898	.902	.905	.908	.911	.914	.917	.921	.924	.928	.931
90	.872	.875	.878	.881	.885	.888	.892	.895	.898	.901	.905	.908	.911	.914	.917	.920	.924	.927	.931	.934
89	.875	.878	.882	.885	.889	.892	.895	.898	.901	.904	.907	.910	.914	.917	.920	.923	.927	.931	.934	.937
88	.878	.881	.885	.888	.892	.895	.898	.901	.904	.907	.910	.913	.917	.920	.923	.926	.930	.934	.937	.940
87	.881	.884	.888	.891	.895	.898	.901	.904	.907	.910	.913	.916	.920	.923	.926	.929	.933	.937	.940	.943
86	.884	.887	.890	.894	.898	.901	.904	.907	.910	.913	.916	.919	.923	.926	.929	.932	.936	.940	.943	.946
85	.887	.890	.893	.896	.900	.903	.906	.909	.913	.916	.919	.922	.926	.929	.932	.936	.939	.943	.946	.949
84	.889	.893	.896	.899	.903	.906	.909	.912	.915	.919	.922	.925	.928	.932	.935	.939	.942	.946	.949	.952
83	.892	.895	.899	.902	.906	.909	.912	.915	.918	.921	.924	.928	.931	.935	.938	.942	.945	.949	.952	.955
82	.895	.898	.901	.905	.908	.911	.914	.918	.921	.924	.927	.931	.934	.937	.941	.945	.948	.951	.954	.958
81	.898	.901	.905	.908	.911	.914	.917	.921	.924	.927	.930	.934	.937	.940	.944	.948	.951	.954	.957	.960
80	.901	.904	.907	.910	.914	.917	.920	.923	.927	.930	.933	.937	.940	.943	.946	.950	.954	.957	.960	.963
79	.904	.907	.910	.914	.917	.920	.923	.926	.930	.933	.936	.939	.943	.946	.949	.953	.956	.960	.963	.967
78	.906	.909	.913	.916	.919	.923	.926	.929	.932	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.969
77	.909	.912	.915	.919	.922	.925	.928	.931	.935	.938	.942	.945	.948	.951	.955	.958	.962	.965	.968	.972

76	.911	.915	.918	.921	.925	.928	.931	.935	.938	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.975
75	.914	.917	.921	.924	.928	.931	.934	.937	.940	.943	.947	.950	.954	.957	.960	.963	.967	.971	.974	.978
74	.917	.920	.924	.927	.930	.933	.937	.940	.943	.947	.950	.953	.957	.960	.963	.966	.970	.973	.977	.980
73	.920	.923	.926	.930	.933	.936	.940	.943	.946	.949	.953	.956	.960	.963	.966	.969	.972	.976	.980	.983
72	.922	.925	.929	.932	.935	.939	.942	.945	.949	.952	.955	.959	.962	.965	.968	.972	.975	.979	.982	.986
71	.925	.928	.931	.935	.938	.941	.945	.948	.951	.954	.958	.961	.965	.968	.971	.975	.978	.981	.985	.989
70	.927	.931	.934	.937	.941	.944	.947	.950	.954	.957	.960	.964	.967	.970	.974	.977	.980	.984	.988	.991
69	.930	.933	.937	.940	.944	.947	.950	.953	.957	.960	.963	.967	.970	.973	.977	.980	.983	.987	.990	.994
68	.932	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.969	.972	.976	.979	.983	.986	.989	.993	.997
67	.935	.938	.942	.945	.949	.952	.955	.959	.962	.965	.968	.972	.975	.979	.982	.985	.989	.992	.996	1.000
66	.938	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.974	.978	.981	.985	.988	.992	.995	.998	1.002
65	.941	.944	.947	.950	.954	.957	.960	.963	.967	.970	.973	.977	.980	.984	.987	.991	.994	.997	1.001	1.005
64	.943	.946	.949	.953	.956	.959	.963	.966	.969	.973	.976	.980	.983	.986	.990	.994	.997	1.000	1.004	1.008
63	.945	.949	.952	.955	.959	.962	.965	.969	.972	.975	.979	.982	.985	.989	.993	.996	1.000	1.003	1.006	1.010
62	.947	.951	.954	.958	.961	.964	.968	.971	.975	.978	.981	.985	.988	.991	.995	.999	1.002	1.005	1.009	1.013
61	.950	.954	.957	.961	.964	.967	.971	.974	.977	.981	.984	.987	.991	.994	.998	1.001	1.005	1.008	1.011	1.015
60	.952	.956	.959	.963	.966	.969	.973	.976	.980	.983	.986	.990	.993	.997	1.000	1.004	1.007	1.010	1.014	1.017
59	.955	.959	.962	.966	.969	.972	.976	.979	.983	.986	.989	.992	.995	.999	1.003	1.006	1.010	1.013	1.016	1.020
58	.957	.961	.964	.968	.971	.975	.978	.981	.985	.988	.992	.995	.998	1.002	1.005	1.009	1.012	1.016	1.019	1.023
57	.960	.963	.967	.970	.974	.977	.980	.984	.988	.991	.994	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025
56	.962	.966	.969	.973	.976	.979	.982	.986	.990	.993	.996	1.000	1.003	1.007	1.010	1.014	1.017	1.021	1.024	1.028
55	.965	.968	.972	.975	.979	.982	.985	.989	.993	.996	.999	1.002	1.006	1.009	1.013	1.016	1.020	1.023	1.027	1.030
54	.967	.970	.974	.977	.981	.984	.988	.991	.995	.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033
53	.969	.973	.976	.980	.983	.986	.990	.993	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.031	1.035
52	.971	.975	.978	.982	.985	.989	.992	.996	.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038
51	.974	.977	.981	.984	.988	.991	.995	.998	1.002	1.005	1.009	1.012	1.016	1.019	1.023	1.026	1.030	1.033	1.037	1.040
50	.976	.980	.983	.987	.990	.994	.997	1.001	1.004	1.008	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043
49	.979	.982	.986	.989	.993	.996	1.000	1.003	1.007	1.010	1.014	1.017	1.021	1.024	1.028	1.031	1.035	1.038	1.042	1.045
48	.981	.985	.988	.992	.995	.999	1.002	1.006	1.009	1.013	1.016	1.020	1.023	1.027	1.030	1.034	1.037	1.041	1.044	1.048
47	.984	.987	.991	.994	.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033	1.036	1.040	1.043	1.047	1.050
46	.986	.990	.993	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.032	1.035	1.039	1.042	1.046	1.049	1.053
45	.989	.992	.996	.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038	1.041	1.045	1.048	1.052	1.056
44	.991	.994	.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033	1.036	1.040	1.043	1.047	1.050	1.054	1.058
43	.993	.997	1.001	1.004	1.008	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043	1.046	1.050	1.053	1.057	1.060
42	.995	.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038	1.041	1.045	1.048	1.052	1.055	1.059	1.063
41	.998	1.001	1.005	1.009	1.012	1.016	1.019	1.023	1.026	1.030	1.034	1.037	1.041	1.044	1.048	1.051	1.055	1.058	1.062	1.065
40	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.032	1.036	1.039	1.043	1.046	1.050	1.053	1.057	1.060	1.064	1.068
39	1.002	1.006	1.010	1.013	1.017	1.020	1.024	1.028	1.031	1.035	1.038	1.042	1.045	1.049	1.052	1.056	1.059	1.063	1.066	1.070

STEM CORRECTION

In general, all corrections are determined for total immersion, i. e., for the condition where both bulb and stem of the thermometer are at the same temperature. If, however, the stem is emergent into space, either hotter or colder than the temperature of the bulb, a stem correction must be applied to the observed reading.

This so-called stem correction may be considerable if the number of degrees emergent and the difference of temperature between the bath and the space above it are large. It may amount to more than 68° F. for measurements made with a mercury thermometer at 752° F.

For the glass of which this thermometer is made the stem correction may be computed from the following formula:

Stem correction=0.000088 x n (T°—t°).

n=number of degrees emergent from the bath.

T=temperature of bath.

t=mean temperature of the emergent stem.

The mean temperature, t°, may be approximately measured by means of a small auxiliary thermometer suspended near the emergent stem, or by surrounding the latter with a small water jacket and taking the temperature of the water with the auxiliary thermometer, or, more accurately, in the way suggested by Guillaume, by exposing an exactly similar stem and capillary mercury thread beside the emergent stem, and thus measuring its mean temperature.

This is also conveniently carried out with the "thread Thermometer" (Fadenthermometer) of Mahlke, in which the expansion of the mercury in the capillary tube (bulb) is measured on a still finer capillary stem.

Example—

Suppose that the observed temperature was 85° and the thermometer was immersed to the 32° mark on the scale, so that 53° of the mercury column projected out into the air, and the mean temperature of the emergent column was found to be 70° F., then—

Stem correction= .000088 x 53 (85—70).

=0.07°

As the stem was at a lower temperature than the bulb, the thermometer read too low, so that this correction must be added to the observed reading to find the reading corresponding to total immersion, i. e., 85.00° + 0.07° = 85.07° F.

This correction must be considered in addition to any correction shown by the certificate accompanying the thermometer.

For further information in regard to this subject see "The Correction for Emergent Stem of the Mercurial Thermometer," published by the U. S. Bureau of Standards as Reprint No. 170.

FORM A

RE JOINT COMMITTEE ON CALORIMETRY—2ND P. S. C. DIST. N. Y.

....
(NAME OF COMPANY)

Day.. Date...

GAS MAKING RECORDS

Apparatus in use.. Works started (1st blast on) at.................................. a. m. p. m.

Send out ....cu. ft. uncorrected Works shut down (last run of) at.................................. a. m. p. m.

" " ...." " corrected Duration intermediate shut downs..................................hrs.

Total works operation..................................hrs.

COAL GAS

Yeild per lb. coal uncorrected gas..cu. ft. Enricher per 100 lbs. coal carbonized.............................lbs.....................gals.

" " " corrected "..." Kind of enricher..

Duration of charge...

WATER GAS

Oil per M uncorrected gas..gal. Generator fuel per M uncorrected gas.......................................lbs.

" " corrected gas.." " " " corrected gas.."

MIXED GAS

Coal Gas.......................................% Water Gas.......................................%

CALORIMETER TESTS

TIME OF TEST	BAROMETER	ROOM TEMP.
a. m. / a. m.	in	°

CANDLE POWER		PRESSURE	
		Meter Inlet	Burner Inlet
C. P.	C. P.	in.	in.

Minimum Temperature to which Gas has been subjected before Test °

	TEST 1	TEST 2	TEST 3
Rate of combustion per hr......	........cu. ft.	........cu. ft.	........cu. ft.
Exhaust temperature...........	°	°	°
Gas "	°	°	°
Total pressuse correction.......	........in.	........in.	........in.
Correction factor..................			
Uncorrected gas used in test...	........cu. ft.	........cu. ft.	........cu. ft.
Corrected " " " (G)	........"	........"	........"
Weight water and pail.........	........lbs.	........lbs.	........lbs.
" pail empty	........"	........"	........"
" water...............(W)	........"	........"	........"

TEST 1 ....x........................x..1000= ....B. t. u.

TEST 2 ....x........................x..1000= ....B. t. u.

TEST 3 ....x........................x..1000= ....B. t. u.

.......................AVERAGE.......................= ....B. t. u.

	TEMPERATURE OF WATER					
	TEST 1		TEST 2		TEST 3	
	Inlet Water	Outlet Water	Inlet Water	Outlet Water	Inlet Water	Outlet Water
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Average temperature..........						
Thermometer correction........						
Stem correction..............						
Corrected average temperature....						
Rise in temperature (T).........						

NOTE. For explanation of use of this form see "Plan of Calorimetric Investigation and Explanation of Test and Report Forms," Joint Committee on Calorimetry, Jan. 26, 1912.

REMARKS..

....

....

Signed...Approved...

The actual size of this Form is 8½″ x 11″

FORM B

RE JOINT COMMITTEE ON CALORIMETRY—2ND P. S. C. DIST. N. Y.

____
(NAME OF COMPANY)

SUMMARY MONTH OF..

GAS MAKING RECORDS

Coal Gas Made..cu. ft. { Uncorrected / Corrected

Carburetted Water Gas Made .... " { Uncorrected / Corrected

Mixed Gas Made.. " { Uncorrected / Corrected

Gas enriched (yes or no) ....

" " (how) ....

....

Daily Send Out, Maximum ....cu. ft { Uncorrected / Corrected

" " " Minimum .... " { Uncorrected / Corrected

" " " Average.............................. " { Uncorrected / Corrected

Hours per day works operation, maximum..............................hours

" " " " minimum.............................. "

" " " " average.............................. "

COAL GAS

Ave. yield per lb. coal uncorrected gas..............................cu. ft.

" " " corrected gas.............................. "

Kind of coal..

Ave. enricher per 100 lbs. coal cardonized............lbs............gals.

Kind of enricher..

Ave. duration of charge..

WATER GAS

Ave. oil per M uncorrected gas.......................................gals.

" " corrected gas....................................... "

Kind of oil..

Ave. generator fuel per M uncorrected gas..............................lbs.

" " " " corrected gas.............................. "

Kind of fuel ....

MIXED GAS

Coal Gas..............................% Water Gas..............................%

RESULTS OF TESTS

DAY	AT WORKS					AT					TEMP. OF ATMOSPHERE	
	Min. Temp Gas*	B. T. U.	Readings	C. P.	Readings	Min. Temp. Gas*	B. T. U.	Readings	C. P.	Readings	Maximum	Minimum
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
Maximum												
Minimum												
Average												

*MINIMUM TEMPERATURE TO WHICH GAS HAS BEEN SUBJECTED BEFORE TEST

NOTE:—For explanation of use of this form see "Plan of Calorimetric Investigation and Explanation of Test and Report Forms," Joint Committee on Calorimetry, Jan. 26, 1912

Remarks..

....

Signed..Approved..

The actual size of this Form is 8½″ x 11″

ERRATA

Contents—"Classification of Companies Making Tests" under Appendix A is given in Table I not Table 2 16

Insert "Introductory Observations Relation to the Study of Appendix B" 19

Page 19—paragraph 2, second sentence, reading "The information derived by the test * * *" should read "The information derived from the test."

Page 19—paragraph 4, reading "It should be noted that a percentage variation from a standard by, for example," etc. should read "It should be noted that a percentage variation from a standard of, for example," etc.

Page 20—paragraph 1, reference in first line is to page 18.

Page 21—In connection with table, note that the present standard for mixed coal and carburetted water gas is 18 candle power and for enriched coal gas 16 candle power.

Page 22—Diagram showing th variations in heating power, symbol at left of centre line of diagram should be "O" instead of "%".

Page 38—In diagram "Variations in heating power"—same correction.

Page 40—paragraph 9, second sentence, reading "Possibly if all the tests were plotted and the values weighed," etc., should read, "Possibly if all the tests were plotted and the values weighted."

Page 49—paragraph 44, reading "Plate III shows how the main is exposed," should read, "Drawing on page 51 shows how main is exposed," etc. The words "(See Page 51)" at the end of this paragraph should be omitted.

Page 52—The page opposite Page 52 with drawing should be numbered 53.

Page 56—paragraph 69, third sentence reading "No serious losses in heating value were found to take place in pressures up to ten inches of water" should read, "No serious losses in heating value were found to take place with pressures up to ten inches of water."

Page 57—paragraph 73, the symbol for carbon monoxide should be "CO" not "Co". H2 should be H_2 and CH4 should be CH_4

Page 58—paragraph 76, last line of page reading "as a means of accuracy determining," etc.,should read, "as a means of accurately determining."

Page 59—paragraph 81, second line, the comma at the end of the line should be stricken out and a comma inserted before the word "at".

Page 60—paragraph 83, first sentence reading "It will be observed that the efficiency of the mantle burner was equally good with either 20 candle power carburetted water gas or with 14.38 candle power in enriched coal gas," should read, "It will be observed that the efficiency of the mantle burner was equally good with either 20 candle power carburetted water gas or with 14.38 candle power unenriched coal gas."

Page 61—The standard in Dallas, Texas, is 633 at 32° F, not 650.
The standard in Milwaukee, Wis. is 600 gross and not 635 gross.

Page 62—paragraph 10, last line, figure "51.6" should be "516."

Page 63—paragraph 2, in the fourth line there should be a semi-colon instead of a comma after the word "graduates" and in the last line there should be a comma after the word "excluded".

Page 64—paragraph 6, the first line after the table, reading "In every case the corrections in Table B," etc., should read, "In every case the corrections in part b of the table."

Page 67—paragraph 27, the word "later" should be inserted after the words "two year," in next to the last line.

Page 67—Table—The three tests opposite Company No. 8 showing accuracies 99.4, 99.4, 99.4, were made September, 1912, February, 1912 and July, 1912, respectively.

Page 82—references to Calorimetric Rules, Regulations and Specifications througout Appendix G should all be accompanied by a reference to Appendix F, the reprint of this pamphlet.

Page 83—title, opposite the words "Form A" should be a reference to page 93, where there is a cut of this form.

Page 83—Foot-note, third from the last line, the reference to Appendix A should be to pages 90 and 91, making this sentence read "A table of correction factors is given on pages 90 and 91."

Page 86—Opposite words "Form B" should be a reference to page 94 where there is a cut of this form.