U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

STANDARDS FOR GAS SERVICE

CIRCULAR OF THE NATIONAL BUREAU OF STANDARDS, No. 405

U.S. DEPARTMENT OF COMMERCE
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FOREWORD

Four earlier editions of this circular (previously designated Circular C32) were issued in 1912, 1913, 1915, and 1920, respectively, and met with a demand large enough to indicate a real need for a publication of this kind. Economic conditions, gas-making practice, and the manner in which gas is used change from time to time with the development of the industry; and with such changes should come changes in the various State and city regulations. To be of value, therefore, a publication such as this must be revised from time to time to take cognizance of these new conditions.

Within the past 10 or 12 years the changes which have taken place in the fuel-gas industry have been more varied and probably more important than during any previous period of equal length. Probably the most fundamental change of all has been a psychological rather than a physical or economic one and may be stated as the recognition that the fuel-gas industry must be guided by facts rather than by tradition. The tangible evidence of this change is to be found in the establishment of the laboratory of the American Gas Association, in the development of schools of gas engineering in several universities, and in the extensive research programs of recent years. Although it is too soon to experience the full benefits of these activities, the available knowledge regarding the technical aspects of satisfactory service with fuel gas is far more complete than it was when the last edition of Circular C32 was published.

To take account of recent changes and advancing knowledge it has been necessary to rewrite the greater part of the earlier circular. The discussion of and the recommendations made with respect to standards of heating value, the testing of meters, and the control and testing of pressure conditions have all been radically changed. Natural gas, which was almost ignored in the earlier circular, has been given equal consideration with manufactured gas. The extension of mains and rules for the installation and maintenance of service pipes are fully discussed. The résumé of existing regulations has been entirely altered. In the earlier circular the principal State and municipal rules were merely summarized in tabular form. The increased diversity of the rules and the variety of subjects treated have made a satisfactory tabulation of present rules extremely difficult. The tabular summary has, therefore, been replaced by direct quotation of the more important provisions of the rules so arranged as to bring together a practically complete statement of all requirements in effect which relate to a single subject.

The circular is intended to serve, to a certain extent, as a manual of recognized "good practice" for the use of gas companies themselves. Indeed, it is hoped that it will find its greatest usefulness in this field rather than through its effect upon the formal provisions of future regulations and franchises. Some discussion is therefore

given to topics, the recommendations with respect to which it might not be desirable to incorporate into formal regulations. A new section has been added which is devoted to a summary of existing company "standards" as revealed by a questionnaire mailed to all gas companies which serve one thousand or more customers. This section should enable one company to make interesting comparisons of its practice with that of other companies.

Although the more important phases of standards for gas service are rather fully discussed in this circular, it has been impossible to include all questions and subjects of interest which arise within the field. Upon request of public officials, representatives of gas companies, or others interested in any subject related to standards of service, the Bureau is glad to furnish available information by correspondence or conference, to examine proposed ordinances or rules for service, or to participate in any proper way in the improvement of gas service, in the adjustment of misunderstandings, or in the clarification of uncertain technical points which lie within its field of activity. In such work, it should be clearly understood as the wish of the Bureau that its suggestions and recommendations be received as only advisory in nature, for the Bureau has no authority and does not desire to assume responsibility either in fixing requirements of this kind or in their enforcement. It is serving solely as a disinterested and impartial agency which holds itself in readiness to assist when desired. Its effort is to serve as a clearing house and medium of cooperation among those who are interested in gas service standards because of their position in local or State agencies or connection with the public-utility companies.

A careful consideration of existing regulations, and of prevalent practice not directly resulting from formal regulation, has furnished much valuable information as to the probable success of one or another standard. Such practice has thus been a guide in the preparation of this circular, but at the same time summarized data of this character have been used with caution. In every case, an effort has been made to ascertain definitely why one or another standard is to be preferred rather than to recommend anything because it is the usual practice or represents the consensus of opinion of any group whatever.

The Bureau has received and gratefully acknowledges help in the form of information, advice, suggestions, and criticism from many sources, the most important of which are the committee on gas standards and service of the American Gas Association under the chairmanship of Walter C. Beckjord, and a small group of engineers of State commissions who have individually given the Bureau much help in this work. The assistance given by the committee and the individuals mentioned does not imply any indorsement of the views expressed in this publication, the responsibility for which rests entirely with the Bureau.

The recommendations made in this circular are by no means final or unalterable, and the Bureau will be glad to receive from any reader information or suggestions which may be useful in the preparation of future publications or in dealing with the current problems which the Bureau may have occasion to discuss.

Lyman J. Briggs,
Director, National Bureau of Standards.

June 18, 1934.

STANDARDS FOR GAS SERVICE

I. INTRODUCTION

1. MEANING OF STANDARDS FOR GAS SERVICE

A city gas supply is a supply of energy in a form that is always available, easily controlled, and easily conveyed to a desired point and there converted into heat. It can be nothing more and should be nothing less than this. The conditions which are essential to good service are therefore easily defined. They consist merely in making the supply of energy available in sufficient quantity at all times to all parts of the territory served by the company under conditions which permit its satisfactory control; in correctly measuring the energy sold to each customer; and in giving the customer such information and assistance as will enable him to use the supply with safety and satisfaction. To describe and discuss these conditions in detail is the purpose of this circular.

The gas should, of course, be sold at a reasonable price, but one sufficient to permit the company to maintain its equipment in a high state of efficiency and to earn a fair return on the investment. The determination of the price at which the energy is sold is outside the scope of this circular and will be mentioned only when necessary to make the discussion of other subjects clear and complete. However, the probable effect of various requirements on the cost and selling price of energy must be carefully considered, for, in general, any increase in the cost of manufacturing or supplying energy falls ultimately upon the consumer. Therefore, only those rules and regulations should be made which really improve the service enough to justify the cost of meeting them.

The requirements of good service will now be stated in other and more familiar terms. The rendering of service "to all parts of the territory served" involves a fair policy of extension of mains to serve new customers. To make the gas supply "available in sufficient quantity at all times" involves the construction and proper maintenance of an adequate plant for the production of manufactured gas, the provision of a sufficient amount of reserve capacity in wells and transmission mains for natural gas, and the installation and maintenance in good condition of an ample distributing system for either gas. The minimum pressure in any part of the system is the principal criterion by which "sufficient quantity" may be specified or determined. "Conditions which permit the satisfactory control" of the energy used are uniform and not excessive pressures, and uniformity of composition of the gas supplied. The measurement of the energy sold involves equally the problems of metering the volume of gas used, and the maintenance and determination of its heating value. The "information and assistance" which will enable the

customer to use the gas with safety and satisfaction are included with the mutual rights, duties, and responsibilities of the company and its customers in the commonly used term "public relations."

Every company which distributes gas to the public for use as a fuel must conduct its business in accordance with certain decisions as to the practice by which these "requirements of good service" shall be met. The decisions may be made by a State commission or other public authority; they may take the form of an agreement with the city and be embodied in a franchise, or they may be only the voluntary policy of the company. In any case, a decision which affects the character of the service received and paid for by the company's customers may be regarded as a "standard of service" in effect in that locality at that time.

Because many gas companies are now operating without official regulation and without franchise provisions in regard to important service conditions, as well as because many companies find it desirable to provide more liberal service than is required of them, some attention will be given to the voluntary or "company standards" of good service.

However, public regulation or formal agreements constitute by far the more important part of existing standards for service. Such regulations or agreements are to be preferred to voluntary standards and should contain explicit provisions concerning the various elements of good service.

In the formulation of service rules and in the enforcement of such requirements, it should always be borne in mind that these regulations are really a technical specification covering the quality of the commodity and service to be supplied under a franchise which is in effect a contract with the people. These specifications should not be looked upon as police regulations of the State or the city, but rather as a part of a business arrangement between purveyor and users of gas; and if properly drawn they will protect the interests of both parties to the contract. To do this, they must not only be fair and equitable, but also clear and comprehensive, defining precisely and without ambiguity all the important conditions which it is expected the gas company shall meet in furnishing gas service. The fact that the company is likely without requirement to fulfill certain important conditions is not sufficient reason for the omission of these conditions from the rules or ordinance. And, on the other hand, it is not reasonable or fair to the gas company to omit rules which afford it protection against unreasonable demands or unjust criticism.

2. APPLICATION OF STANDARDS PROPOSED

The discussion and recommendations in this circular are intended to meet the needs of public utilities which supply fuel gas of any kind to customers through a system of piping laid in the streets. It does not apply to "bottled gas" service, the supplying and storage of propane and butane for industrial use, etc. In general, the suggested rules and service standards are in a form suitable for use in regulation of privately owned gas companies operating as public utilities, but they are equally applicable as a guide to the operation of publicly owned and operated gas properties.

As pointed out in the preface, the rules proposed in this circular are not intended to be binding in any locality, but are simply recommendations for the guidance or use of State and municipal officials who may have local administrative or legislative authority, and for the information of officers and employees of gas companies who are responsible for the maintenance of good service.

II. HEATING VALUE

The ability of gas to give off heat when it is burned is the single characteristic upon which its present-day usefulness depends. Cooking, mantle-lighting, and the operation of gas engines depend entirely upon the heating quality of the gas, as is more obviously the case with water heating, house heating, and most of its industrial uses. It is because gas affords a convenient, economical, easily controllable, and ever-ready supply of heat which can be made available wherever needed that it is used so generally and in such great quantity.

Probably without exception at the present time, all city gas supplies consist of mixtures of a number of individual chemical substances. Natural gas is usually mainly methane with some ethane, propane, butane, etc., all of which are fuels, and some nitrogen and at times other constituents which are not fuels. Manufactured gas usually contains as important combustible constituents hydrogen and carbon monoxide, methane, ethylene, and minor amounts of other hydrocarbons (compounds of the elements hydrogen and carbon). Inert nitrogen and carbon dioxide are also present. Given quantities of each of the combustible constituents produce perfectly definite but very different amounts of heat when burned, and any mixture of them produces an amount of heat equal to the sum of the heat available from the individual constituents of the mixture. Consequently, a measured quantity of gas may have any heating value within a wide range, depending upon the proportions in which the various constituents of the mixture are present.

1. DEFINITION OF HEATING VALUE AND OF THE UNITS USED IN ITS MEASUREMENT

The heating value of a gas is the amount of heat which is given off when a unit quantity of the gas is burned. In this country, the British thermal unit (abbreviated Btu) is generally used in the expression of the heating value. It represents the quantity of heat necessary to raise 1 pound of water 1° F. The specific heat of water varies slightly with temperature, and this fact must be taken into account in the most precise work, but for regulatory and commercial purposes the difference at different temperatures between the amounts of heat required to raise the temperature of the water one degree may be, and in practice almost always is, neglected.

The unit quantity of gas used in expressing heating value is the cubic foot measured under certain conditions which are specified in the more exact definition of heating value which follows.

The heating value of gas in the United States is usually expressed in Btu per cubic foot. For this purpose a quantity called the "total heating value" is used. The following definition of this term is sufficiently precise for purposes of industrial and engineering tests:

The *total heating value* of a gas, expressed in the English system of units, is the number of Btu produced by the combustion, at constant pressure, of the amount of the gas which would occupy a volume of 1 cubic foot at a temperature of 60° F if saturated with water vapor and under a pressure equivalent to that of 30 in. of mercury at 32° F and under standard gravitational force (acceleration 980.665 cm per sec) with air of the same temperature and pressure as the gas, when the products of combustion are cooled to the initial temperature of gas and air, and *when the water formed by combustion is condensed to the liquid state.*

The net heating value of a gas differs from the total heating value in that the water formed during combustion remains in the state of vapor. The net heating value accordingly is less than the total heating value by an amount equal to the heat of vaporization, at the initial temperature of the gas and air, of the water formed in the combustion of the gas. From the observed heating value, as defined below, one can obtain the net heating value by making a correction depending upon the amount of water condensed in the calorimeter.

In addition to the terms "total heating value" and "net heating value", the term "observed heating value" may be used as a matter of convenience in discussing experimental data. The observed heating value for a flow calorimeter may be understood to be the value obtained by multiplying the mass of water which flowed through the calorimeter during the test by the corrected increase of the temperature of the water and dividing by the volume of gas burned, the latter being referred to the standard conditions of 60° F and 30 in. pressure, saturated with water vapor. While the observed heating value is sometimes regarded as identical with the total heating value, this practice is not permissible if an accuracy greater than 2 or 3 percent is required. However, by the application of a correction, which can be taken from a table of corrections when the atmospheric humidity and the room temperature are known, it is practicable to correct this observed value to the total. In routine testing under average conditions this correction is frequently ignored, but when accurate results are desired it can easily be applied. Since the observed heating value is almost invariably lower than the total heating value, neglect to apply this correction simply results in reporting a little lower heating value for the gas than it has.

The term "gross heating value", sometimes used instead of total and sometimes instead of observed heating value, should be discontinued because of its ambiguity.

The conditions specified in the definition of heating value are sometimes a source of curiosity and possibly of confusion. The water formed during combustion is seldom condensed under conditions which make its latent heat useful, hence, the net heating value of gas, not the total, actually represents the energy available from combustion in practice. Although with the most used type of modern equipment it is as easy to determine accurately one heating value as the other, this was not true before the invention of the flow calorimeter for gases, and it is still not true for solid or liquid fuels, which are rated in terms of total heating value. The total rather than the net heating value was therefore generally adopted for use in connection with service standards because it was the one

originally employed and because it placed gaseous fuels on the same basis as solids and liquid ones. These reasons still apply; an additional reason for continuing the practice is that the continuous calorimeters, which are coming into general use, record the total rather than the net value.

Although the net heating value represents much more closely the heat actually available for use than does the total value, it is possible to express the standard in terms of total heating value with fairness to everyone, in most cases, because the ratio of the net value to the total is nearly the same for all mixtures of gases commonly supplied commercially. Roughly, the net heating value is usually about 90 percent of the total. Data relating to the 4 principal constituents of fuel gases and to 4 mixtures, selected somewhat at random as representative of different types of commercial gases and given in table 1, show that this is true. Usually, the change in ratio between the two heating values can be ignored, but there are some cases in which it should be given consideration, particularly that of a proposed change from a carburetted water gas to a coal gas of the same nominal heating value without reconsideration of rates.

TABLE 1.—*Comparison of total and net heating values of some pure gases and typical gas mixtures*

Gas	Composition by conventional methods of analysis							Heating value		Ratio of net to total
	H_2	CO	CH_4	C_2H_6	C_2H_4	Other illuminants	Inerts	Total	Net	
								Btu/ft^3	*Btu/ft*^{3}	*Per-cent*
Hydrogen	100							318.5	269.2	84.5
Carbon monoxide		100						316.1	316.1	100.0
Methane			100					994.1	895.2	90.1
Ethane				100				1,757.0	1,607.	91.4
Ethylene					100			1,572.	1,472.	93.7
"Theoretical" water gas	50	50						317.8	293.0	92.3
Carburetted water gas	34.8	30.6	15.0		9.5	2.0	8.1	585.4	540.6	92.4
Coal gas	51.0	11.0	23.7		2.0	1.1	11.2	508.7	456.2	89.7
Natural gas			84.2	14.8			1.0	1,098.3	992.6	90.4

The designation of 60° F as the temperature to which the volume of gas will be reduced is an inheritance from the past, and represents the assumed average temperature at the places of installation of gas meters in Great Britain. It is a temperature base used only in connection with the public supply of fuel gas and has nothing to recommend it except its traditional and general use for this purpose. The correction of the observed barometric column to standard gravitational force and a temperature of 32° F simply places the measurement of pressure on the basis employed in other technical work.

Since the heating value of gas is now specified, for purposes of sale in the United States, exclusively or almost so in terms of total heating value as above defined, it is desirable to avoid any other practice because of the confusion that would result from local differences in practice.

2. DEVELOPMENT OF SPECIFICATIONS OF "QUALITY" FOR GAS

During approximately two-thirds of the time since it was first commercially distributed, gas was used almost exclusively for the purpose of illumination with open-flame burners. Naturally, the earlier specifications for gas were based upon the property which made it useful, which was the brilliance or candlepower of its open flame. In order to make the measurement of candlepower significant, it was necessary to specify exactly the conditions under which the measurement was made, including the burner and the rate at which the gas was burned. The same quantity of the same gas burned with burners which were not substantially identical in construction did not give the same amount of light. The same gas burned at different rates with the same burner did not give amounts of light bearing any simple relation to the amount of gas burned. It was impossible to compute the candle power of a mixture of gases from the candlepower of the components. Because of this entire lack of recognized quantitative relationships involving candlepower, the user of gas, although his payment to the gas company was essentially for the purchase of illumination, could not know in quantitative terms how much illumination he would get for his money. The only practicable way in which the transaction could be regarded was as the purchase of a quantity (volume) of gas of specified quality; and candlepower was commonly referred to as the "quality" of the gas.

As the use of gas for open-flame illumination declined and its use as a source of heat for a multitude of purposes developed, candlepower specifications were gradually replaced by specifications for heating value; but the idea persisted that the specification was one of quality and was essentially unrelated to the quantity of the commodity purchased. This was unfortunate because it served to obscure the simple fact, which is not generally recognized by the public even today, and has been accepted only slowly and with apparent reluctance by the gas industry itself, that the modern user of gas is merely purchasing energy, to be made available as heat, and that he is not concerned with the heating value of the gas or the price per cubic foot as separate factors, but only with the cost of energy (per heat unit) delivered.

The quantitative significance of heating value stands in sharp contrast to the vague relationships of candlepower. The same amount of the same gas liberates the same amount of heat in any appliance and, as will be shown in the next section, the useful application of the heat is, with minor exceptions, independent of the kind of gas which supplies it.

3. ADJUSTMENT AND OPERATION OF GAS-BURNING APPLIANCES

It may be useful at this point to discuss briefly the adjustment and performance of gas appliances. This will serve not only as a preparation for the consideration of standards of heating value but will be helpful in the later discussion of pressure, of the inspection and adjustment of appliances by the gas company, and of variations of composition of the gas supply which do not result in changes of heating value.

All modern gas appliances are designed by their manufacturers to have a definite "input rating" expressed in Btu per hour. This rating is usually permanently indicated on the appliance except in the case of ranges, the rating of each burner of which practically always conforms to the standard "requirement" of the American Gas Association. The input rating usually indicates nearly the highest rate at which heat can be liberated within the appliance and still give service that is safe and satisfactory in all respects. If the heat of combustion of the gas supplied to the appliance is very much less than the rating, too much time is required for heating operations, or the desired temperatures of rooms, ovens, etc., cannot be maintained; if it is very much greater than the rating, trouble is encountered from incomplete combustion or from the overheating of the appliance or its surroundings. In the majority of cases, the factor which limits the rating is the danger of incomplete combustion and the consequent liberation of the poisonous gas, carbon monoxide, usually attended by disagreeable odors and sometimes by soot.

There is, of course, a reasonably wide range of heat supply on either side of the rating within which the appliance will ordinarily give satisfaction, but this range is needed because of the changes of pressure and sometimes of composition which take place in almost every city's gas supply, the exact magnitude of which cannot be predicted. To take advantage of the protection against unusual conditions which this range of satisfactory operation provides, it is necessary that every appliance be adjusted to take very nearly its manufacturer's rating under normal conditions. With the exception noted in the following paragraph, the performance of a given appliance depends almost entirely upon only two elementary factors, the rate at which energy is supplied to it (the number of Btu per hour) and the rate at which air enters the burners of the appliance as primary air. Gas enters the burner through a small opening called the orifice, and it is immaterial, so far as the performance of the appliance is concerned, whether a given number of Btu per hour is delivered through a small orifice as gas of high heating value at high pressure or whether it is deliverd through a large orifice as gas of low heating value at low pressure, provided the amount of air which accompanies the gas into the burner is the same in both cases. Usually, the amount of air entrained is controlled by means of an "air shutter." Fixing the size of openings of orifice and air shutter to supply gas and air at the desirable rates are the essential operations in the adjustment of all appliances.

The important exception to the general rule that one gas can replace another under the conditions outlined in the last paragraph, without affecting the performance of the appliance, results from the fact that the initial stage of combustion takes place much more readily with some gases than with others, and that this determines whether or not the flame will be stable, that is, whether it will continue to burn at the "burner ports" or will either "blow off" (lift from) the burner or "backfire" (flash back) into it. The rule that performance is unaffected by a change of gas applies, of course, only when the flames are stable with both supplies. The stability of the flames depends upon the composition of the gas supplied, and

trouble from instability may arise from changes of composition which do not alter the heating value, as well as from those which do.

In most cases the serious danger which attends unstable flames can be avoided by adjusting an appliance to take less than the amount of primary air which would otherwise give the best result, and at the same time reducing the number of Btu per hour supplied to it. However, some of the appliances in use cannot be satisfactorily adjusted for gases of every composition which it might otherwise be desirable to distribute. If a gas outside the range of adjustment of an appliance is to be supplied, the burners must be replaced by more suitable ones. Uncarburetted or " blue " water-gas, for example, has never been distributed successfully because there are few appliances in use or immediately obtainable which could be adjusted for its use; it would without doubt give excellent service in appliances designed for it.

Because this subject is so frequently misunderstood, something more should be said of the efficiency with which the heat of combustion of the gas is utilized. In this discussion and throughout the circular, the term efficiency will be used in the sense that two gases are used with equal efficiency if the same number of Btu (not the same number of cubic feet) produce the same useful result.

In the majority of appliances, an increased rate of supply of energy, whether it is the result of higher pressure or higher heating value, does not result in its less efficient application. Hence, no more Btu are used for a given purpose when the appliance is adjusted to take more than when it is adjusted to take less than its manufacturer's rating. Indeed, the majority of gas ranges, including both cooking tops and ovens, and the majority of water heaters and house heating furnaces show increasing efficiency as the rate of gas supply is increased, until incomplete combustion results and the deposition of carbon or the contamination of the atmosphere becomes intolerable.

It should be understood that the adjustment of appliances to the manufacturer's rating takes place with all cocks and valves open. To permit broiling or the rapid preliminary heating of the oven, and for the occasional use of utensils of large capacity such as wash boilers and dishpans, all the burners of a gas range have such large ratings that they cannot be used at full capacity, except in the preliminary stages, for ordinary cooking in utensils of moderate size. Therefore, all such burners are controlled in almost every case of actual usage, either manually or by thermostats, to give heat at the desired rate; and since this is less than the full rate and is judged by the effect produced, neither the character or pressure of the gas supplied nor the adjustment of the appliance has much to do with the amount of heat used.

Some use is made of constantly burning flames for pilot lights, and sometimes where gas is cheap, for nonautomatic water heaters. Such flames, if not readjusted, will show an unnecessary increase in the amount of heat taken if heating value or pressure is increased. Some types of instantaneous water heaters are affected in much the same way. The heating coils of an instantaneous heater contain a considerable volume of water. When the spigot is opened these coils become filled with hot water, which rapidly loses heat after

the spigot is closed. Unless the supply of gas to the heater is controlled by a thermostat as well as by the flow of water, an increase in the heating value or pressure of the gas results in an increase of temperature of the water in the coils, and accordingly in the amount of heat which is lost after the water is turned off.

Gas is still used to a limited extent for illumination. Burners for lighting, whether of the open-flame or mantle type, usually lack ready means for adjusting the gas rate and are likely to be entirely neglected when the orifices of major appliances are changed. It is necessary, in order to get good efficiency from mantle lights, to have the burner and mantle so designed and adjusted that the mantle will nearly coincide with the outer cone, or zone of reaction with secondary air. Changes which result in the relative displacement of mantle and combustion zone greatly affect the light-producing efficiency of the lamp.

Slow-burning gases, such as natural gas, cannot be used as satisfactorily as a rapidly burning gas in appliances of the type of the "blow torch" or even the laboratory burners used by the chemist for igniting crucibles, etc., but the number of such appliances is relatively small and their use is almost confined to laboratories and industrial plants.

These exceptions to the rule that the amount of heat used in an appliance even without readjustment is independent of the heating value and pressure of the gas supplied are of minor importance. They are partly, if not entirely, offset by the general tendency of increasing rates of heating to result in greater efficiency of utilization of the heat, and by the effect of increased pressure (higher pressures are usually employed for natural than for manufactured gas) on the volume occupied by a given quantity of gas in the meter. The last statement must not be interpreted to mean that it is unnecessary to adjust appliances after a change of heating value. On the contrary, every considerable change of composition, whether it alters the heating value or not, and every material change of pressure will affect the operation of many appliances to such an extent that they should be readjusted. Readjustment is needed, however, to prevent unstable flames, incomplete combustion, or service that is unsatisfactory in other respects, and not primarily or usually for the sake of economy.

4. SIGNIFICANCE OF HEATING VALUE

The discussion in the preceding section has shown that, if we leave out of consideration gases which will not burn with stable flames in the appliances in use and, perhaps, mixtures containing so much "inert" [1] that efficiency is materially diminished, all fuel gases give the same result in service per Btu supplied. Since the user obtains the same service from a heat unit whether it comes to him as 400, 600, 1,200, or even 2,500 Btu gas, the standard of heating value makes little difference in the number of heat units "demanded" by a customer for the same purposes. This fact has been amply confirmed by the results of many statistical studies of the effects of changes of

[1] Inert gases, i.e., gases which take no part in the chemical process of combustion, are commonly spoken of as "inert" or "inerts".

heating value on the volume of gas used by chosen communities or groups of customers. When the groups considered have been large enough, and when care has been taken to eliminate so far as possible the effect of other variable conditions by intercomparisons between suitable groups, etc., the demand for heat by domestic customers, at least, has been shown to be independent of the heating value of the gas within an extremely small margin of uncertainty.

Significant comparisons of the results of the large changes from manufactured to natural gas are unfortunately hard to obtain because such changes have nearly always been accompanied by reductions in the cost per Btu, which resulted in largely increased use. However, the immediate effect of such changes, before the additional market could develop, has usually been such a reduction in the volume of gas used that the amount of heat taken was substantially the same as before the change.

The significance of heating value is now clearly established. It is simply 1 of 2 factors which together measure the amount of the useful commodity which the gas company is selling to its customers. The other factor is, of course, the volume of the gas sold. Neither factor alone is of direct concern to the purchaser of the fuel; only their product is significant. When gas is sold, as usual, at a certain rate per unit of volume, the specification of the heating value of the gas has exactly the same importance as the determination of the price per thousand cubic feet. When gas is sold by the therm (100,000 Btu) or other unit of energy, it is of little importance whether the heating value is high or low provided it is correctly measured. In either case, the accuracy of the maintenance and measurement of heating value has for each customer exactly the same significance as the accuracy of his meter.

These facts are fundamental to the discussion which follows, and may be accepted without hesitation or qualification in the consideration of changes of heating value made without changing the general character of the mixture supplied. They will apply accurately, for example, to variations from 450 to 620 Btu in gas manufactured by any of the usual methods, or to variations of natural gas from 900 to 1,200 Btu. In making a change from manufactured to natural gas or the even more difficult change from natural to manufactured gas, so many appliances require replacement or expensive alteration that questions of efficiency of utilization tend to be obscured by the difficulties of the change-over. In such cases the difference in the cost of supplying the gas is usually a compelling reason both for changing the source of supply and for an entire readjustment of the rate schedule. The exact equivalence, in service-value, of heat units from one or the other gas, therefore, usually becomes unimportant, and it is only necessary to recognize their equivalence as a good approximation.

5. VARIOUS METHODS OF TREATING STANDARDS OF HEATING VALUE

If potatoes are quoted at a dollar per sack the statement is significant only to one who understands whether a sack holding 10, 50, or 100 pounds is meant. Just so, the volumetric rate (the price per hundred or per thousand cubic feet) at which gas is sold means nothing unless the heating value of the gas is specified or understood.

Standards of heating value and volumetric rates are thus so intimately associated that a discussion of the policy relating to one necessarily involves the other. The various methods of dealing with these related subjects may be grouped conveniently in the following way:

1. The volumetric rate may be determined by agreement or by a regulatory authority and the heating value left to the decision of the gas company, subject to existing limitations as to sources of supply or methods of production and to the company's desire to retain or develop its business against competition with other sources of energy.

2. Gas may be sold at specified rates per unit of volume under a State-wide standard of heating value or under one fixed by franchise or other arrangement which does not permit the heating value to be changed except at long intervals and after the negotiation of a new agreement or other difficult procedure.

3. The standard of heating value and the volumetric rate may be treated alike as subject to determination to meet local conditions and to revision by a regulatory authority whenever conditions warrant, but without any recognized relationship between the standard and the volumetric rate.

4. The standard of heating value may be left to the option of the company and treated as a "part of the rate schedule", but as in the preceding case without recognition of a definite relationship between heating value and volumetric rate. This is the prevailing practice in States permitting "selective standards."

5. The gas may be sold at a definite rate per unit of energy instead of a definite rate per unit of volume, and the heating value left to the judgment of the utility's management. Under this system customers may be billed either in therms (or other units of energy) or in cubic feet at rates per cubic foot which are varied automatically in proportion to any change of heating value.

6. STATE-WIDE AND LOCAL STANDARDS

The first system, under which the company is permitted to operate without restriction or agreement as to heating value has been employed mainly but not exclusively in the sale of natural gas, and a discussion of it will be reserved for the section on standards for that material.

A State-wide standard of heating value has much to recommend it. In combination with the volumetric rate it provides a definite, relatively permanent, and easily understood basis for the transaction of business between the gas company and its customers. The operations of gas companies under the jurisdiction of the same regulatory body can be controlled with a minimum of difficulty. Comparisons are possible between the results obtained in different manufacturing plants and between the rates for service in different localities and are of assistance in the discovery of unsatisfactory conditions and undesirable practices. Since supplies of gas of the same heating value are likely to be more alike in composition and in characteristics which affect the operation of appliances than are those of different heating values, the gas-burning equipment used in

one locality can be removed to another with less danger of giving unsatisfactory service in the new location. When the same design and nearly the same adjustment of appliances are required throughout the State, the distribution of new appliances is facilitated, especially of types that are given fixed adjustments at the factory. The interconnection and consolidation of neighboring systems, where desirable, can be accomplished without disturbing rate schedules and usually without readjusting appliances.

Despite these advantages of a State-wide standard, many commissions, probably a majority of them, have recognized in recent years the desirability of making exceptions to State-wide rules in certain cases. Although in most of these States such exceptions made to otherwise general rules have been few, the fact that they are made at all must be regarded as a recognition that local conditions largely determine what heating value is desirable. If this principle were applied generally, it would lead to the determination of the proper standard individually for each locality.

The choice between State-wide standards and those determined individually for each system depends, of course, upon the importance of local differences in the conditions encountered. In some States a single standard may be equally satisfactory for all localities, within the degree of certainty with which the fact can be determined. This is not improbable in States in which water gas or oil gas is made in fairly well standardized units almost to the exclusion of gases of other types, and in which the same considerations with respect to cost and availability of fuels, investment in plant, etc., apply without much modification to all gas properties.

Generally speaking, however, the engineering and economical factors differ from plant to plant in such a way that they should receive individual consideration. In some cases, byproduct gases or limited supplies of natural gas can be obtained at less than the cost per heat unit at which gas can be manufactured by the utility. Clearly the heating-value standard should permit the use of these gases. In other cases the relative availability of various fuels, development of new processes, age and condition of the existing equipment, market for byproducts, magnitude of the demand, character of the load curve, and perhaps even the ability of the company to finance improvements will affect the economy of various processes and methods of operation and in consequence change the economical standard of heating value.

It may be useful to list a few representative problems of the kind presented by these ever-changing conditions. Natural gas, coke-oven gas, or an oil refinery's byproduct may be locally available. Should it be distributed as received or mixed or "reformed", i.e., treated as raw fuel and converted into a gas of lower heating value by partial combustion, by reaction with steam, by decomposition in contact with incandescent solid material, or by a combination of these processes? If it is to be mixed, then with what and in what proportions? Is the mixture to be constant throughout the year or to vary with peak loads? If reforming is to be practiced, to what extent should it be carried and by which of several available methods? Should a coke plant heat its ovens with the "lean" gases from the end of the coking process, or with producer gas; should it introduce steam into the retorts at the end of the coking process as is done in

many European plants; or should it go still further and use surplus coke to make water gas in separate generators and thus increase the relative quantity of gas available for sale? Obviously the answer will depend upon the construction of the existing plant and the market available to the utility for the two products, gas and coke. Two coals may be available for carbonization, the more expensive of which may yield more gas of higher heating value and coke of better quality than the other. Which should be purchased? How long should coal be carbonized and at what temperature, operating costs, and fixed charges, as well as yields and heating value being considered? At what price for oil should the heating value of water gas be changed and how much? If fuel costs more for a plant operated at high capacity, to what extent should this expense be incurred to prevent the necessity of occasionally operating additional shifts or starting idle equipment? At what stage are the economies of using the blow-run offset by the cost of distributing the useless inerts? A process superior to the one in use may become available; the existing plant may be relatively modern and capable of continuing to render good service or it may be inadequate, in bad repair, and ready for replacement, which the gas company may or may not be in position readily to finance. What should be done in each combination of circumstances? The most economical product for a large system may be coke-oven gas; for a small one air carbureted with butane or an oil-producer gas. Each company will have a totally different problem in determining economical operation. Economy of materials and independence of the byproduct market favor "complete gasification" and low heating values; investment costs and ability to meet economically a changing demand favor in varying degrees oil gas, water gas, unmixed coal gas or mixed gases of higher heating value than can be produced by complete gasification. Which process should be adopted in a given case?

These questions or others like them are faced by every gas company. Every one of them involves conditions which vary from time to time and place to place, and in every one the heating value of the gas is an essential factor. Each of these questions and many more of the same kind ought to be answered for each gas property only after a thorough consideration of local conditions.

Under a State-wide or other fixed standard of heating value, there is little opportunity for the regulatory body or even the local gas company to determine how its operations shall be conducted. Whatever economic or technical problem it may be necessary to solve, the answer must come out so that the heating value will be equal to a standard which was probably fixed without reference to the local situation, perhaps at a time when economic conditions were essentially different, and which may have been based originally on tradition or temporary policy rather than on an investigation of technical facts.

If State-wide standards are not maintained but heating values are subject to change locally, and if there is no predetermined policy as to the effect of a change of standard on volumetric rates, every technical and managerial decision that involves heating value becomes actually, if not nominally, a rate case. The technical and economic merits of the change, which alone ought to be considered, are invariably complicated and frequently almost entirely obscured by

questions as to the effect upon the gas company's income and the consumers' expenditure, the fairness of existing rates, the company's motives in proposing the change and frequently by lengthy and fruitless arguments regarding efficiency of utilization and related subjects. The procedure is likely to involve all the trouble, delay, uncertainty, and expense associated with rate hearings; indeed, it may be much worse than a rate hearing because it involves every complication of the latter and in addition a whole field of technology with which those accustomed to dealing with rate cases are usually unfamiliar.

For a regulatory body to permit a change of standard without a reconsideration of volumetric rates is simply to abandon its rate-making authority. It is in addition a particularly unfair procedure, because proposed changes of volumetric rates for gas of uniform properties are clearly understood by the public and provision is usually made for an adequate representation of the consumers' interests in cases involving such rates; on the contrary, proposals to make equivalent changes in the cost of service through changes of heating value frequently fail to come to the attention of the public at all and are vaguely understood at best.

Even when these cases are given formal hearings, the two interested parties are by no means placed on an equal footing. The agencies which act for consumers are often dependent upon voluntary contributions, are seldom well informed with respect to technical matters, are usually unable to obtain competent "expert" witnesses, and because of these conditions are almost never in position to collect data and present their cases adequately. They are at very great disadvantage as compared with the utilities which have most of the pertinent data at hand in usable form, whose employees are usually the only persons available who are adequately informed regarding both the technology of the gas industry and the economic and legal aspects of rate making, and whose expenditures in connection with such cases are usually allowed as operating expenses and, theoretically at least, by affecting the rate allowed, are eventually reimbursed by the consumers.

It is fairly obvious that it is not possible to make changes of heating value with any facility under either a system of State-wide standards or one of local standards determined by a regulatory body. Only major changes of practice are of enough importance to justify the complications involved in a change of standard. Hence, minor improvements, small economies, and the careful determination of optimum conditions, upon which technical progress is largely dependent, are excluded from the consideration of the industry under either system, if they involve any change of heating value.

Moreover, few regulatory bodies are well equipped to exercise the detailed judgment of technical operations which, in some cases at least, is involved in rendering an intelligent decision regarding the most desirable heating value; and such interference in technical matters is usually contrary to the policy, if not beyond the legal authority, of the official organization. Where a standard has been fixed by regulatory authority, therefore, it has been done, probably in every case, as an essential part of the rate-making function, and has not been a voluntary assumption of the technical responsibilities

of management. These responsibilities have come simply as the undesired result of our traditional custom of determining in two separate steps at what rate its customers shall pay a gas company for service; of deciding in one step how much a customer shall pay for a thousand cubic feet of gas and in another step, usually at a different time, how much of the useful commodity, energy, he will get when he buys that thousand cubic feet.

7. SELECTIVE STANDARDS OF HEATING VALUE

To avoid the assumption of the function of technical management which is involved in setting a standard of heating value, several State commissions have adopted a policy of permitting a gas company to choose its own standard with or without important restrictions. The standards so chosen have come to be known as "selective standards." In each of these States the standard selected is formally recognized as an essential part of the company's rate schedule. In theory, at least, a change of standard is treated in the same way as a change in volumetric rate initiated by the company. However, in only one State, Colorado, has it been formally recognized that a simultaneous change of heating value and volumetric rate such that the cost per heat unit to the customer is not altered leaves the cost of service unaffected and is not, therefore, a cause for interference or concern on the part of the public or its official representatives.

In all other States having selective standards the real situation is always somewhat in doubt. It may be that when a case arises the regulatory body will give the company the same liberty to make changes which do not affect the cost per heat unit that is allowed in deciding other purely technical questions, and that it will take the same action with respect to proposed changes which do affect the cost per heat unit as would be taken in the case of equivalent changes of rate accomplished in another way. If so, the operation of the selective standard rule will be, so far as the commission is concerned, the same as that of Colorado. It may be, on the other hand, that the regulatory body will consider the change of standard to have an indeterminate relationship to volumetric rates and the cost of service, or even that it makes little difference in the latter. In this case all phases of rates and standards are involved in every decision, and the situation does not differ from that which arises in any State in which the two steps in rate making are treated separately, except that a greater liberty for the gas company to make changes has been implied and the case to some extent prejudiced in advance in favor of whatever the company wishes to do. Both attitudes have been taken by regulatory bodies in cases involving "selective standards" in the past.

The attitude of the regulatory body is naturally subject to change with changing personnel. When the application of selective standards is not completely defined in the rules which sanction them, it is therefore not improbable that a policy carefully determined by one group of officials after adequate investigation and hearings may be reversed by less well informed successors without formal consideration. There is relatively little danger that this will happen when correct relationships are recognized in a formal rule, for such

rules are seldom changed without careful investigation and public hearings.

The attitude of the regulatory body is not the only uncertain factor under the usual system of selective standards. The consumers are left to regard the volumetric rate as the principal or only factor in the cost of service because it is nominally the "price of gas." Consumers are therefore likely to overlook proposed changes of standard which affect them adversely and to oppose combined changes of standard and rate which may affect them favorably. This introduces an additional element of confusion and of possible injustice.

The ambiguous character of the usual provisions for a selective standard, therefore, leaves both the gas company and its customers in a position of uncertainty, is likely to involve the commission in complicated and unnecessary cases, and is of benefit to no one. Therefore, it cannot be too strongly urged that wherever a selective standard is permitted the Colorado rule or its equivalent be adopted.

8. SALE OF GAS AT DEFINITE RATES PER HEAT UNIT

The serious difficulties which attend each of the several plans in accordance with which standards of heating value have usually been fixed are the direct result of rate-making in two parts. Apparently the only way in which these difficulties can be avoided is to combine the two parts and to make a rate directly for what the customer buys and uses. If this is done, the very complex problem of standards for heating value and rates is at once resolved into two relatively simple ones. We have the engineering problem of how to deliver energy (Btu) to the customer at minimum total cost to the gas company and the rate-making problem of equitably charging for the energy (Btu) delivered without confusing the public or discarding our volumetric meters.

The sale of gas at definite rates per heat unit instead of at definite rates per unit of volume has been successfully employed, in its simplest form, throughout Great Britain since 1920. The practice applies to all gas sold by public utilities, or "undertakings" as they are called in Great Britain, whether privately or municipally owned. A British undertaking "declares" a heating value which it proposes to maintain. Six months later, or at any time thereafter, it may declare a different value. The customer's bill is computed in therms (100,000 Btu) by multiplying the meter reading in cubic feet by the declared heating value and pointing off five decimal places. If the undertaking maintains a heating value higher than the declared standard it receives nothing for the additional heat. Penalties are provided for falling below the declared standard. Declared changes of heating value do not affect the rate per therm and are considered as a matter which need concern only the management.

Recently, the same method of billing has been adopted by many companies in this country (174 prior to May 1931, according to a report of the American Gas Association) the most important of which is the People Gas Light & Coke Co., which serves Chicago. To what extent this method of billing will be accompanied by freedom for the utilities to select the standard of heating value has not yet been determined in all cases, although the ability to make changes

of standard without confusing the public with respect to the cost of service is usually the object of the innovation.

It is of little importance whether customers are billed in this manner or whether they are billed as formerly in cubic feet, but the utility is allowed freedom in the choice of operating practice, and the "commodity part" of each rate is changed in proportion when heating value is altered. The latter plan, which, as already stated, has been in operation in Colorado for several years, is not as revolutionary as it may seem. While it is now in general effect in only one State, the automatic variation of rates by means of "fuel clauses"[2] or other factors affecting the business is provided for in the rate schedules of companies operating in more than a dozen States. The principal objection that has been urged against either practice is the public misunderstanding that is likely to arise from its application. Actually, little trouble of this kind occurs in connection with fuel clauses, and the reason is not hard to find.

Relatively few of the gas company's customers know what the rate is or pay particular attention to their gas bills unless the amount seems abnormal. A formal action for a change of rate always comes to the attention of newspapers, civic organizations, etc., and serious public opposition to rate changes arises only when such agencies cannot be convinced of the fairness of the change. If changes do not require formal action, and if their fairness can be readily established when questions arise, a little explanation may be called for, but no serious controversy develops. The fairness of changing the volumetric rate in proportion to heating value so that the cost of available heat is not changed is easily understood and even less likely to be questioned than the fairness of application of a fuel clause.

To avoid any possible confusion regarding the application of this method, it may be well to suggest that when the system is put into effect the existing rate schedules should not be changed. Neither the introduction of the system nor future changes of heating value will then require formal hearings as to individual properties. When heating value does change the changes in volumetric-rate schedules necessary to maintain the same cost per heat unit to the various classes of customers will be automatic. The intention to change standards, the reasons therefor, and the changes in equipment which will be involved should, however, be filed with the regulatory body in advance for review and possible adverse action.

Rate schedules should, of course, be subject to nonautomatic changes, as at present, both as to form and amount; but such changes should be based upon the same considerations that would apply with uniform standards and should be entirely independent of variations of standard.

An assumed case may make the system still clearer. Assume that in the case of a water-gas plant both heating-value standard and rate are exactly what they should be, i.e., the heating value is that which will permit the delivery of the most heat to the customer for a dollar of cost and the rate has been adjusted to give the utility what is considered the fairest return. Assume that the cost of oil is then

[2] By a fuel clause is meant a provision in accordance with which the rate at which gas is sold is automatically varied when there is a change in the cost of the fuel used as a raw material by the gas company.

largely increased. This will have two effects: (1) Because enrichment is relatively more expensive than formerly, as compared with the cost of blue gas, the most economical heating value will be changed; (2) because its raw material will cost more, the utility will no longer make a fair return, and will be entitled to an increased rate per Btu.

As soon as the first fact is definitely ascertained, the utility should take steps to adopt a lower standard and set forth the engineering reasons for the change. The corresponding alteration of volumetric rates will be automatic. Entirely independently, and preferably at a different time so that the purposes and results of the two changes may not be confused, the necessary increase in rates per heat unit to once more give the utility a fair return should be made.

Under this system, the standard of heating value and the rate per heat unit are treated as entirely independent problems; under the systems now commonly used, the standard and the volumetric rate are treated as independent. Certain advocates of the prevalent method regard the two as practically equivalent because rates are, theoretically at least, fixed by a fair return to the utility and must eventually be the same under both systems if operating costs are the same. This point of view would be correct only if rates changed automatically to give always the same "fair return" to the utility.

That this kind of change does not actually take place automatically will be recognized by everybody. A change in rate schedule favorable to the utility is obtained only on the utility's initiative and usually with considerable difficulty, expense, and delay. Changes unfavorable to the utility, unless voluntarily accepted by the latter, are accomplished with even greater difficulty, especially when no State commission or other competent regulatory authority has jurisdiction, or when the commission does not itself readily take the initiative in such matters, but acts only in a judicial capacity on formal actions brought by an interested party.

It has usually happened under the prevailing system that the effects of a change of standard, made for any reason, were not anticipated by a readjustment of rates. To change the rate per unit volume so that the rate for the real commodity delivered (heat units) should be even approximately the same has required that formal proceedings be initiated and the burden of proof carried by the party which has suffered from the change. In the case of an increase of heating value, this is the gas company; in the case of a decrease the consumers' protection rests with whatever agency may have undertaken to represent them.

The results have been:

(1) That in some cases of reduction of heating value proposed for engineering reasons the utilities have received, in effect, rate increases which they were not required to justify.

(2) In other cases such reductions have been opposed without much regard to their technical merits because their effects would have been equivalent to increases of rate.

(3) An increase of heating value has involved a decrease in the effective rate received by the utility. Under this condition the utilities, which usually initiate changes of standards and which almost

alone are in position to make a technical study of their effects on economy of manufacture and distribution, have had little incentive to make an impartial engineering study of the facts. They have too often been forced to defend the policy which would maintain or increase the effective rate on the commodity they sell, without much regard to the various technical aspects of the question.

(4) In many cases the relatively simple engineering problem of choosing the economical standards has become inextricably involved with questions of fair return and other rate problems.

(5) The fact that in any question of standards the interests of the utility and the public are identical (they are equally interested in the most economical engineering standard) has been lost sight of, and the two have often been placed in direct opposition to each other.

In view of the fact that opposition to the sale of gas by the heat unit is based mainly upon the danger that it will not be understood by the public, it may not be inappropriate to call attention to the fact that the ill effects of the present system, just enumerated, have been mainly the result of public misunderstanding of facts under that system. Such misunderstanding is fostered, not prevented, by the separate determination of heating value and volumetric rates. It is true that the introduction of "therm" rates or indeed any general discussion of heating values in connection with rates results in the complaint from many customers that the subject is not clearly understood. Such complaints do not arise when heating values are changed without any mention of rates, only because customers are not aware that anything affecting the cost of their heating operations has taken place; but this can hardly be considered an advantage.

The gas industry has nothing to lose and much to gain from the adoption of sale by the heat unit. The trend of sales in the last few years has shown conclusively that the future expansion of the gas industry depends upon the ability to get industrial and space-heating business and that this, unlike the domestic cooking load, can be secured only by a reasonably close cost competition with raw fuels. The freedom and ability to deliver the most Btu to the customer for a dollar of cost is therefore the key to future development.

This freedom the industry will have if it is allowed to base its sales on heat units delivered, and with it will come for the first time a direct incentive to find the most economical methods of supplying available heat energy in every situation.

If the sale of gas by the heat unit is put into effect, every desirable change of plant, source of materials, or operating procedure can be considered and adopted simply on its merits as affecting costs. If it is not put into effect every proposed change in production will drag in the infinitely more complicated question as to whether the company is already earning what it should, and the average company is likely to stand pat on its present operation long after it would normally be looking for improved methods if it were free to take action.

9. CONDITIONS TO BE MET WHEN THE STANDARD OF HEATING VALUE IS CHANGED

(a) SUPERVISION OF CHANGES OF PLANT REQUIRED

If the utility is allowed the privilege of changing the heating value of the gas at will, two cases are to be considered, (1) changes of operation which involve little or no modification of the plant, and (2) changes which require considerable expenditures for reconstruction or permanent additions.

The use of more or less oil in carbureting water-gas is typical of the first class. It may be economical for one utility with ample producing and distributing equipment to save oil by reducing heating value, and for a neighboring utility with inadequate plant to make a gas of increased heating value rather than to finance additional equipment. If the consumers are protected by a fixed rate per heat unit, there is no reason why both utilities should not be allowed entire freedom to make these changes of operating practice. If they result in increased expenditure where a saving was anticipated, a return can be made to the former standard with little harm to anyone.

If, on the other hand, a considerable expenditure is required for the change, and particularly if the existing plant is to be replaced by another, the plans should be carefully considered and approved by the commission before they are put into effect. It is not intended to suggest here that regulatory bodies take a greater responsibility than at present in matters of technical management. The present control of heating-value standards and of new capitalization constitute important limitations of managerial independence which need not be entirely sacrificed by the regulatory bodies if the utilities are given the greater freedom in matters of operating practice here recommended.

Extensive permanent changes, especially those requiring the authorization of new capitalization merit the scrutiny of everyone concerned, including the regulatory body. A mistake may mean that the community will be permanently burdened with excessive fixed charges, and in an extreme case gas service may be interrupted. Such a situation may arise either through lack of competent engineering advice to a small utility or through the use of a small plant for purposes of experimentation or development by a larger and more competent engineering organization. That neither possibility is imaginary has been sufficiently demonstrated by actual cases that have come to the attention of the National Bureau of Standards.

(b) READJUSTMENT OF APPLIANCES

When the option of changing heating value is given to the gas company, it carries with it the obligation to make whatever changes in the customers' appliances may be necessary to insure as satisfactory and efficient utilization of gas after the change as before, or to compensate the customers in some other way, as by a temporary or permanent reduction in the rate per heat unit, for the inconvenience and possible loss to which they are subjected. When the change made is only in the heating value of the gas and not in its general characteristics; that is, when the alterations are only such as accompany

a moderate difference in the extent to which water-gas is enriched or the proportion in which natural gas is drawn from two not widely different fields, no serious difficulty is likely to be encountered in making the readjustments. In this case, there will be very little inconvenience during readjustment, and the appliances after readjustment for the new gas are almost certain to be left in better average condition than prevailed previously. Beyond requiring that readjustments be made, no consideration need be given to this phase of the subject before the regulatory authority grants permission for the change.

However, when the characteristics of the two gases under consideration are as different as those of natural gas and gas manufactured by ordinary methods, it will be found impossible to make satisfactory adjustments of some of the existing appliances. Many burners or whole appliances may have to be replaced to insure the best service with the new gas. Border-line cases always occur in which thoroughly satisfactory adjustments cannot be made but in which it does not seem worth while to make replacements. At the best, there is an interval of time during which adjustments are being made and service is unsatisfactory. Probably in every case in which the supply of gas is radically altered, the gas company expects to profit by the change. It seems only fair that this profit should be shared with the customers to the extent, at least, of compensating them for the period of inconvenience during readjustment, and the small degree of uncertainty as to the permanently satisfactory character of the service which will result. This does not mean that the principle of basing rates on heat units rather than on cubic feet is to be disregarded even in the case of extreme changes in the gas supply. It will be helpful to everybody to keep clearly in mind that it is energy that is being sold and used, and that the average efficiency of application of the energy will be altered but little, if at all, by a change in the character of the gas. A correct view of the situation is probably most easily obtained by considering what should be done if it were proposed to introduce a new gas of the same heating value as the old but of radically different properties in other respects, which would make necessary as extensive alterations of appliances as the changes actually proposed.

The subject of appliance adjustment is more fully discussed in section II (3 and 4); section III, and section VII 3 (b and c).

10. STANDARDS OF HEATING VALUE FOR NATURAL GAS

In most localities, natural gas has always been sold at specified volumetric rates without agreement or requirement as to heating value. In the early days of the industry there was no good reason for any other practice. Then the natural gas available from a given field was piped to a definite market and sold as it came from the wells without consideration being given to modifying it by chemical action, mixing with anything else, or extracting anything except the gasoline that liquefied under the pressure required for transmission. As a natural product, its properties were not regarded as subject to the control of the distributor. Gas drawn from the same wells or from a field of limited extent did not vary greatly in composition; at least the variation was not enough to be a decisive

factor in determining whether gas or a solid or liquid fuel should be used. There was no competition with gas from another source. All users received the same product. The only questions which arose regarding a supply of gas had to do with its adequacy to meet existing and future needs.

Although substantially similar conditions still prevail in many places, recent developments in the industry have so greatly changed the general situation that some method of controlling the heating value of the natural gas sold to consumers has become almost, if not quite, as necessary as the corresponding control of the heating value of manufactured gas. Among the more important of the changes which have taken place or are in immediate prospect are these:

(1) The extension of natural-gas systems to the limit of profitable competition, including in some cases competition with manufactured gas.

(2) The interconnection of supply lines from different gas fields, or even from different wells in what is regarded as a single field, but which produce gases of different composition. This enables the utilities to control, to a considerable extent, the heating value of the gas delivered to a given locality by drawing the desired proportion from each source of supply.

(3) The practice of "reforming" natural gas to a gas of lower heating value.

(4) The mixing of natural and manufactured gases either to make use of an available by product from coke ovens, oil refineries, and the like, or to meet peak loads or supplement a failing suppiy or for any one of several other reasons peculiar to the local situation, including the desire to keep an existing plant in the rate base as "property used and usable."

(5) The production of by products, mainly gasoline, propane, and butane, but in some cases, ethane, carbon black, ammonia, and a considerable group of organic materials from natural gas. The remaining gas of diminished heating value may be, and in the interest of economy usually should be, added to the supply for general distribution.

(6) The contamination of natural gas with air or inerts, sometimes but not always, during operations incidental to the recovery of oil.

The fact has been thoroughly established that natural gas of even the highest heating values, including such constituents as propane (2,575 Btu per cu ft) and butane (3,350 Btu per cu ft), when isolated from the natural mixture, can be used readily in well-designed gas appliances of all types, except the relatively rare "blast burners", with thermal efficiencies equal to those obtained with manufactured gas. Hence, in the case of natural gas as in that of manufactured gas we are dealing simply with a supply of energy which can be delivered through a pipe. If natural gas is regarded thus from the standpoint of the user merely as portable energy, it is much easier to appreciate the need for calorimetric standards than if it is regarded from the producer's standpoint as so many cubic feet of fluid coming naturally from the ground and to be transported, measured, and paid for as such.

A correct view of the subject can, perhaps, be more clearly conveyed by a specific illustration than by any other means. The follow-

ing story is based upon fact, but some of the details which were lacking have been assumed for the purpose of completeness.

A certain brick manufacturer, in planning his plant, had to decide between coal and natural gas as a fuel. He studied the question thoroughly, comparing the relative advantages of the fuels, their relative cost per heat unit, and their relative efficiency. He was given data by the "Industrial salesman" of the gas company who correctly represented the natural gas as having a heating value of 1,250 Btu. The manufacturer decided upon the use of gas and installed the equipment necessary for its utilization, including automatic temperature controls and a calorimeter. The gas supplied for a period of years met expectations. It was paid for by the thousand cubic feet, and its cost, which was approximately half the total cost of the finished product, was regarded as a dependable constant factor. Labor charges and other costs were also well known and permitted very close computation. An economic depression began, and to keep his plant and workmen employed, the manufacturer took a large contract in the face of stiff competition at cost.

The natural gas delivered up to this time had been compressed for transmission and a certain amount of gasoline recovered, but the gas left the compressing station still nearly saturated, at line pressure, with "casinghead gasoline." It also contained a considerable percentage of propane and butane. Then the gas company entered into a contract with a gasoline company by which all the gas was treated in a modern plant for the extraction of propane and butane as well as residual "gasoline." The heating value of the gas declined to 1,080 Btu, but the return paid to the gas company by the gasoline corporation did not justify an immediate revision of rates (still considered on a volumetric basis) by the State commission. The brick manufacturer had to pay 16 percent more for his fuel and faced a loss of 8 percent on his contract. He knew of the change immediately from his calorimeter, and protested to the gas company, but was correctly informed that it was charging only the legally authorized rate of 30 cents per thousand cubic feet for natural gas, and that it would be prevented by law from making any discrimination in his favor. He then appealed to the National Bureau of Standards, which could only refer him to his State commission, which had the authority to settle the case. Nothing further was heard of the case, but in view of the fact that the State had no definition of natural gas and no requirement as to its quality, it is improbable that anything was done about it.

The picture is not complete without mentioning that the brick manufacturer was only one of several thousand customers whose fuel costs had been increased 16 percent. He was probably the only one with a calorimeter and may have been the only one who knew definitely that anything out of the ordinary had happened, since, among domestic customers at least, the effects of weather, of changes in the family routine, etc., almost obscure the effect of a 16-percent change in the rate at which the energy is sold. The effect is real, nevertheless.

Many of these customers before installing natural gas equipment had considered the relative merits and costs of coal, oil, and gas for their uses, and had made or received estimates of their probable

heating bills which were based upon experience with fuel of each type and upon its cost per heat unit. If the customers did not know the meaning of a Btu or how many they would get for a dollar at prevailing rates, the man who made the estimates and sold the equipment did know. These customers who did not have calorimeters were no less entitled than the brick manufacturer to rely upon the constancy of their charges for fuel until a new agreement should be made or until the fairness of any changes should be determined by an impartial authority.

The situation is typical of those which may arise wherever natural gas is sold, and a discussion of the provisions which might have been made to anticipate it will therefore have general application. Suppose a minimum standard of 1,250 Btu had been prescribed for this gas company; that might have made it impossible to market gas of 1,150 Btu from neighboring fields, and would certainly have greatly restricted the company's freedom of action and the resources available to it for future use. A limitation might have been placed on the modification of the gas by specifying that only simple compression and cooling to a definite temperature and pressure should be employed in the recovery of gasoline. But the brick manufacturer was paying about 24 cents and the home owners 45 cents per million Btu, while propane was retailing at $4.25 per million Btu for use in country homes, and was worth the money to many people. Its extraction meant the better utilization of a natural resource as well as a greater return to the gas company. A clear statement of the case is all that is needed to make it apparent that the only reasonable solution of such a problem is to use to the best advantage the energy available and to charge each customer for the energy he receives.

Unfortunately, the unsuitability of fixed minimum standards for the control of natural gas has not been generally recognized, and most of the existing regulations are of this form. Kansas and Pennsylvania have minimum standards of 800 Btu, and numerous municipalities have minimum standards which range from 750 to 1,100 Btu. Other municipalities require that natural gas "shall be furnished at the consumer's meter in its natural state without mixture of air, the abstraction of any natural elements or adulteration; subject, however, to the removal of oil and gasoline vapors", or have provisions of similar meaning. In several places both a minimum standard and a clause prohibiting adulteration are in effect.

The best that can be said for a minimum standard of heating value for natural gas is that it is usually placed so low that it is entirely without effect. At the worst, the effect of such a standard may be the opposite of that intended. As an example, a standard fixed by municipal franchise may be considered. In the case of a franchise granting the right to distribute natural gas without specification, it is probable that a city could make a good case against a utility which resorted to any dilution or to the extraction of the hydrocarbons which are above their boiling point at normal temperatures of distribution and use, even though the heating value of the product as it came from the wells was only slightly affected. If, on the other hand, a definite minimum heating value is set without a provision regarding adulteration, the utility may be considered at liberty to reduce the heating value to the specified minimum

when it chooses. It is rather obvious that the greatest return to the company and the worst that could happen to its customers would result if the company built up its load with a natural gas of high heating value (say 1,200 Btu) until everyone who could be persuaded to do so had replaced their equipment for burning solid and liquid fuels, and then cut the heating value to the prescribed minimum (say 800 Btu), thereby automatically increasing the volume sold and the cost of service (about 50 percent in the assumed case).

If the minimum standard is made high enough to protect the customers from the possibility of unnecessary reductions of heating value, there is danger that it will handicap the gas company in securing an economical and adequate supply of gas, and this danger is likely to be unfavorably reflected in the rate to which the company is willing initially to agree. It may even limit the supply of gas obtainable and correspondingly limit the number of people who can be served with the gas or the duration of such service. For all these reasons a minimum standard of heating value is not likely to be of much benefit and may result in actual disadvantage to the consumers.

A provision against the adulteration or modification of natural gas is much to be preferred to a minimum standard of heating value although it does not apply to cases in which heating value is altered by changes in the natural source of supply. It is also open to the objection that it does not permit the most advantageous use of some of the constituents of natural gas, or the economical development of industries from which a byproduct gas remains. It further prevents the satisfactory utilization of gases available from other than natural sources, particularly coke ovens and oil refineries. This may lead, as it has in the past, to uneconomical duplication of mains or to competing systems in the same territory.

California has applied the system of "selective standards" to natural gas and its mixtures. The gas company specifies the heating value of the gas it will furnish and is obliged to maintain this value, which is considered an essential part of its rate schedule. The plan is much preferable to a State-wide minimum standard, but subject to the objections to a selective standard discussed in the section relating to standards of this type for manufactured gas. In every case of a proposed change of heating value, three involved questions may be brought forward for settlement and perhaps controversy: (1) The engineering and economic desirability of the proposed change, (2) the correct relationship between heating value and rates, and (3) the fairness of the existing rates. The settlement of these questions may involve almost endless argument and confusion and possibly misrepresentation and injustice, which can be completely avoided if the sale of gas is recognized simply as the sale of energy.

The utility then becomes the sole judge of the economic desirability of the practice which results in the change of heating value and has complete freedom to make and profit by changes which result in economy in the conduct of its business or in the better utilization of its resources. It has no opportunity to profit by giving its customers less for their money without taking the steps

necessary for the authorization of a change of rate. Its right and its opportunities to seek an increase of rate which will allow a fair return are not affected in the slightest degree by this arrangement; but in seeking the change the utility must stick to the pertinent questions of cost, investment, and income, and cannot rely upon confusing regulatory body or public with unfamiliar questions of technology.

The sale of natural gas to power plants and other large industrial customers at volumetric rates which vary automatically in proportion to heating value is already very common, at least in the mid-continent region where large differences exist in the heating value of the gas from different interconnected fields and wells. Many of these industries receive their gas directly from "pipe-line companies" which collect and transmit the gas through networks of pipe lines covering large areas. Most of the "distributing companies" which supply given municipalities are organized separately from, though they may be subsidiary to, the pipe-line companies. So far as it may be practicable through interconnecting lines it is obviously profitable for a pipe-line company to deliver the gases from fields or wells of high heating value to those customers or communities which purchase gas by the heat unit, and the gas of lowest heating value to distributing companies which purchase on a strictly volumetric basis. Such a situation might be expected to lead quickly to universal sale on the energy basis were it not that a distributing company has the largest sales and correspondingly makes the largest profit at volumetric rates if the gas it purchases is of low heating value. It can pass any blame for unusually low heating values to the pipe-line company. A situation in which the character of a commodity is determined by agreement between two parties both of whom can profit by making the commodity as poor as possible at the expense of a helpless third party is not a desirable one, and again the remedy is the ultimate sale of the gas at definite rates per heat unit.

The subject of "gas despatching"—that is, drawing gas from various fields or wells in whatever way will best maintain uniformity of both heating value and pressure—has not received the attention it deserves. Without a study of the sources of supply of the gas available to an individual territory it is impossible to say how near to a constant value it is practicable to keep the heating value; but it should be remembered that the amount of variation is by no means always beyond the control of the company, and that uniformity is as important as in the case of manufactured gas. The rule recommended in part X tentatively requires uniformity within the same percentage for gases of both types; but this provision should be considered in the light of special conditions affecting each locality.

11. STANDARD OF HEATING VALUE FOR BUTANE-AIR GAS

Most of the gas companies distributing butane and air are sending out a mixture having a heating value of from 500 to 550 Btu per cubic foot. The practice is so general that the American Gas Association has specified a mixture of 525 Btu per cubic foot for use in testing appliances designed to burn a mixture of butane and air.

Several technical points which merit discussion are involved in the choice of a standard of heating value for a gas of this type. The first has to do with the adjustment of individual appliances.

Any modern gas appliance delivers at the ports of its burners a "primary" mixture of fuel gas and air. Usually it gets the air, without cost, from the immediate surroundings. In the case of butane, air is supplied with the fuel. Some of this air is necessary to prevent condensation of the butane in the coldest weather, and because many of the appliances will not readily entrain from the surroundings enough air to give the best results if pure butane, which requires 31 volumes of air per volume of gas for complete combustion, is distributed. If, however, a mixture of butane and air of 525 Btu per cubic foot, is supplied to an appliance adjusted for a coal gas of the same heating value, at a pressure such as to result in the delivery of the same number of cubic feet (and the same number of heat units) per hour, the total amount of air in the primary mixture will be about twice as much as is desirable. If the 525-Btu mixture is supplied to a burner adjusted for a typical natural gas, the amount of air injected will be about 3.5 times what is wanted. On the other hand, a mixture of butane and air of 1,000 Btu will inject only slightly more air than is needed for best results when supplied to a burner adjusted for 525-Btu coal gas, and 60 percent more than is needed when supplied to a burner adjusted for typical natural gas.

The properties of butane, other than its ability to inject air, are such as to require, for best results, a burner substantially identical with the best burner for natural gas. Most gas appliances are made at the present time to meet the requirements of the American Gas Association when tested with typical natural and typical manufactured gases. Our ordinary appliances will therefore serve excellently for the use of butane-air mixtures of 1,000 to 1,500 Btu, but a 525-Btu mixture is far outside the range of usefulness for which they were designed, and appliances to burn such mixture are built, tested, and sold as a special class under a special set of specifications prepared by the American Gas Association. It has been popularly supposed that the distribution of the 525-Btu mixture paved the way for the subsequent use of manufactured gas of about the same heating value (or made it easier to replace such a manufactured gas with hydrocarbon), but such is not the case. The necessary alteration of appliances is much greater than if a mixture having the heating value of natural gas were delivered.

The large quantity of air delivered with the butane not only results in a troublesome problem in the utilization of the gas with existing appliances, and in the construction and marketing of a special class of new ones, but involves expense for its own transmission. In other words, it is prevailing practice to incur expense to transmit air from the plant to the burner and additional expense to prevent air already surrounding the burner from entering it.

For convenience in discussion, the usual mixture of 525 Btu will be compared with one having twice that heating value, or 1,050 Btu. Of course, an appliance properly adjusted to burn one mixture will have at the burner ports exactly the same quantities of butane and air as when adjusted for the other mixture, and will produce exactly the same results, the only difference being the point at which the air

enters the gas stream. Neglecting the effect of a small difference in specific gravity, it is apparent that, if the same pressures are to be employed in distribution, the distributing system will have to have just twice the capacity in order to transmit the volume of gas needed to supply the same service with a 525- as with a 1,050-Btu mixture. Actually the difference in the necessary capacities of the system may be greater than this, because, in order to permit the use of appliances not specifically designed for a 525-Btu mixture of butane and air, the pressure of distribution may have to be reduced to the level which prevailed in the manufactured-gas industry before the abandonment of open-flame lighting.

The comparison is even more striking if we assume that the piping of a low-pressure system is already laid, and consider the pressures needed to deliver the two mixtures. The drop of pressure through a given system is approximately proportional to the square of the volume of gas transmitted and to the first power of the specific gravity. Hence, in distributing butane in a 525-Btu mixture, about 3.5 times the drop in pressure is encountered that would be necessary for delivering the same amount of butane through the same system in a 1,050-Btu mixture. This means that with the same facilities for distribution, the variations of pressure which trouble the user are multiplied by 3.5 if the lower standard of heating value is employed. If, in addition to this, it is considered necessary to reduce the average pressure to accommodate the appliances not specially designed, the difference in the percentage of variation of pressure is still further multiplied.

These facts are, of course, all well recognized. Considerable inquiry has failed to disclose any technical reason for the low heating values prevalent except the danger that the butane will condense in the distributing system if the heating value is higher. Butane will condense from a 1,050-Btu mixture in a low-pressure distributing system at a temperature of about −24° F. This is a temperature not likely to occur in mains with even the lightest covering of earth necessary for mechanical protection in any part of the United States. It is only when the gas is stored in exposed holders that the probable condensation of butane becomes a determining factor in the selection of a heating value less than 1,050 Btu.

A low-pressure holder obviously has double the storage capacity for fuel if a 1,050-Btu mixture rather than a 525-Btu mixture is employed, and can be used at any temperature above −24° F. The case is somewhat different with a high-pressure holder, which, because of the small amount of storage capacity needed, is commonly used. If capacity is limited by condensation and not by the strength of the holder, as much butane can be stored in the holder, at a given temperature, in one mixture as in the other, but not the same amount is available for use. At −24° F, for example, a 1,050 mixture can be stored at one atmosphere, but none of it will flow through the mains to the appliances whose outlets are also at a pressure of one atmosphere. At the same temperature a 525-Btu mixture can be stored without condensation at a pressure of two atmospheres, and half the butane is available above atmospheric pressure. At 0° F the 1,050-Btu mixture will reach the dew point at about 1.7 atmospheres, hence, 0.7/1.7 of the stored butane is available for distribution. The 525 mixture can be stored at the same temperature at 3.4 atmospheres of

which 2.4 atmospheres can be distributed. However, since the 1,050 mixture is twice as rich in butane, the relative capacity of the holder for delivering stored butane is in the ratio of $2 \times 0.7 : 2.4$, or 59 percent.

At some temperature the pressure at which butane will condense from the 525-Btu mixture exceeds the safe working pressure of the holder, and its relative capacities to deliver butane in the two mixtures are then determined by different and independent factors. At a still higher temperature, the pressure at which butane will condense from the 1,050-Btu mixture becomes equal to the safe working pressure, and at that and all higher temperatures, the holder will have twice the capacity to deliver butane in a 1,050-Btu mixture that it has in a 525-Btu mixture. The relationships are shown in figure 1

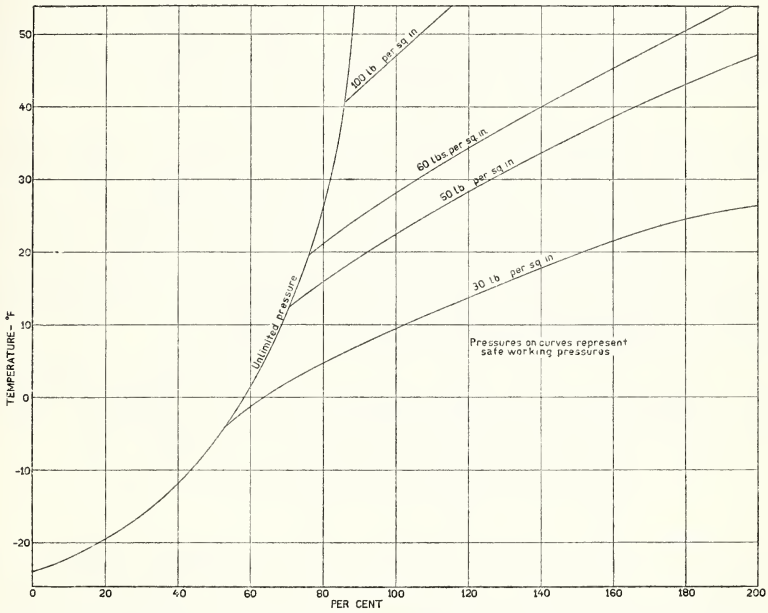

FIGURE 1.—*Capacity of pressure holders to deliver butane in a 1,050-Btu mixture, plotted as percent of capacity to deliver butane in a 525-Btu mixture.*

for holders designed for 30, 50, 60, and 100 lb per sq in., which appear to be the working pressures commonly employed.

In considering the significance of figure 1, the radical difference between the character of a plant for mixing butane and air and one for the manufacture of gas from coal or oil must be recognized. The mixing equipment is inexpensive, practically automatic in its operation, capable of operating to supply gas at a very small fraction of its full capacity, and can be started and stopped without loss of fuel at a moment's notice. The storage of a large fraction of the day's sendout, which is so necessary to permit the economical operation of a manufacturing plant, is not required in the case of a butane plant, which can operate very well without any storage at all. It is desirable, however, to provide some storage to permit minor re-

pairs of the equipment and avoid the need for continuous attendance, which is usually considered desirable even with an automatic system.

However, the butane plant can always be operated in an emergency with very little storage or none at all. During the few days of extremely cold weather it should be practicable to operate the mixer continuously if necessary; but with available storage of even a few percent of the daily demand, operation between 10 p.m. and 6 a.m. would probably be rarely required, since butane is too expensive to be used for house heating in cold climates, and the demand between the heating of evening bath water and the cooking of breakfast is very light. In the coldest climate the greater capacity of the holder to render service with the 1,050-Btu mixture during all but a few days, and the greater capacity of the distributing system at all times, will ordinarily make it more economical to house the holder so that it can be kept at a temperature of 0° F or above, rather than to distribute the 525-Btu mixture. In the greater part of the United States there can be no question as to the relative economy of distributing the two mixtures or their relative desirability for general use.

The determining factor which has led to the present low standard is not a technical one at all, but the traditional belief that the customer will be satisfied only if a large number of cubic feet is registered in supplying his fuel needs so that the "rate" (per thousand cubic feet) will not appear disproportionately high when compared with that paid in another community, or in the same community at a different time, for gas made by another process. The National Bureau of Standards does not share this opinion.

It is therefore recommended that the heating value of butane-air mixtures supplied to the pubilc be made at least 1,000 Btu, and preferably somewhat higher unless definite data are available to show that the practice will be uneconomical in a particular case.

12. METHODS OF MEASURING HEATING VALUE

The instruments most commonly used for the determination of the heating value of gases are of the type generally known as "Junker's" calorimeters from the name of the German inventor of the most successful of the earlier forms. Various makes of instruments of this type, which differ somewhat in appearance, and convenience but not in principle have appeared, and practically all of them will meet the requirements of industrial testing. The different instruments give results in excellent agreement with one another when operated with certain easily taken precautions. There are various sources of error that may affect the result found for the heating value to the extent of several percent, but means have been found to reduce errors by the exercise of suitable precautions. The various forms of apparatus are described, and directions for their operation are given in circular C48 of this Bureau, entitled "Standard Methods of Gas Testing."

Recording calorimeters which give results of satisfactory accuracy when properly operated and cared for are of comparatively recent introduction but have already been widely adopted. Their continuous records have great advantages over intermittent tests both for purposes of operating control and for determining compliance

with standards. Calorimeters of this type will be discussed in a forthcoming edition of the circular on "Standard Methods of Gas Testing."

13. EFFECT OF GAS-METER TEMPERATURE AND PRESSURE ON HEATING VALUE

It is customary to make all regulations as to the heating value of the gas on the basis of the heat which can be obtained from 1 cubic foot of gas when measured under so-called "standard" conditions—namely, 60° F and 30 in. of mercury pressure, the gas being saturated with water vapor. The ordinary gas meter, however, registers the number of cubic feet passing through it under the actual conditions of temperature, pressure, and humidity which then exist in the meter. Gas expands with increased temperature or decreased pressure and contracts when the opposite conditions exist. If, therefore, it is metered at some pressure or temperature other than the standard, the number of heat units available for use by the customer per cubic foot paid for may be different from the rated number.

The effect of the variation of temperature from 60° F may be considerable in individual cases; however, it is utterly impracticable to determine the effect of the temperature of individual meters upon the volume of gas registered. Even the record of a recording thermometer would not suffice, since it would be necessary to know how much of the gas passed through the meter at each temperature. It is impracticable, therefore, to control the effect of temperature on the measurement of gas in the customer's meter otherwise than by locating the meter with care that it will not be exposed to unusual conditions of temperature.

With respect to the influence of pressure [3] a somewhat different condition exists. The barometric pressure is nearly uniform throughout any one city, and the average pressure does not vary enough at any altitude to affect the average readings during a billing period. The day-to-day variations caused by changing atmospheric conditions are of no more significance than the corresponding variations in temperature and may be disregarded in the same way. However, the average pressure will be considerably less than 30 in. of mercury at high altitudes. Thus in a city with an average barometric pressure of 27 in. (10 percent below 30 in.) a cubic foot measured under standard conditions would actually occupy 1.11 cu ft.

However, a given source of supply or a definite combination of process, fuel, and method of operation, will yield a gas of definite percentage composition; and it is desirable for the sake of uniformity of production, for the intercomparison of technical data, for the information of manufacturers of appliances, etc., that gas of the same composition shall be said to have the same heating value wherever it may occur. Hence, the reduction of heating values to a standard condition of measurement of volume is generally practiced and is recommended by the Bureau.

The correction from average conditions to standard conditions is not made on customer's bills because this would require a great deal

[3] The total gas pressure is meant here; i.e., the barometric pressure plus the pressure of the gas above the atmospheric pressure.

of work and would serve no useful purpose. Of course, the people who live where the barometer averages 27 in. receive 10 percent less fuel when they buy a thousand cubic feet of gas than do those who buy the same volume of gas of the same nominal heating value where the barometer averages 30 in. There is no injustice in this if the price of gas is based on the cost of service plus a reasonable profit for the gas company. If, in the assumed comparison, the plants, processes, fuels used, and all other conditions of production and sale were identical except the pressure, the gas company operating under 30 in. pressure would obtain 10 percent less gas (by volume) from the same materials and operating procedure and sell 10 percent less than the company operating at 27 in. The latter company would make the same "fair return" at a rate per thousand cubic feet 10 percent less than that necessary for the company at sea level.

However, in those localities where the average barometric pressure is appreciably less than 30 in. of mercury, it is desirable to include, with any statement published by the regulating authorities, the heating value of the gas, not only under standard conditions but also under the average total pressure of the gas in the consumers' meters, in order that there shall be no misunderstanding concerning the heat per cubic foot of gas as metered to the consumer.

Similar considerations apply to questions involving the saturation of gas with water vapor and the metering of gas under unusually high "gage" pressures (above atmospheric). If these conditions apply alike to all customers and if they are the same as those which existed when the rate was determined, no correction should be made. If such conditions undergo a general change by a significant amount after the rate is agreed upon, a correction is in order; but if the change is permanent it would be better to alter the rate rather than to apply a correction to each customers' bill thereafter.

When gas is metered to certain customers at pressures appreciably above that at which it is metered to other customers it is, of course, necessary to take account of the fact in determining those customers' bills.

14. CHOICE OF A STANDARD OF HEATING VALUE

The Bureau recommends that rate schedules and all other agreements and regulations as to the selling price of gas be based upon definite rates per heat unit, and that the heating value of the gas be left to the engineering judgment of each gas company's management. Although this recommendation, if followed, will relieve regulatory bodies and other public officials of responsibility for the selection of a standard of heating value, it will not be out of place here to discuss briefly the factors which should determine that choice. Many regulatory bodies will without doubt retain their present policy of independently determining heating values and volumetric rates; others will be called upon to give at least the same scrutiny to the decisions of companies under their jurisdiction that is given to other phases of operation and management. To these regulatory bodies, and even to the gas companies which have full liberty and responsibility with respect to the determination of a standard this discussion may be helpful.

The desirability of a particular standard of heating value is determined in all cases mainly, and in most cases entirely, by the total cost to the gas company of supplying energy per heat unit delivered at the consumer's meter. Of course, this principle is to be applied with a reasonable allowance for conditions that are known to be variable, such as the seasonal demand, or the conditions that may be unstable, such as the cost of a particular fuel or the market for a byproduct. An adequate supply must be assured at all times; uniformity of composition, the limitations of existing equipment for producing and distributing the gas and the cost of new construction, and such factors as independence of the byproduct market and the prevention of undesirable competition should be taken into account. These conditions may be expected to change from time to time, and a heating value which is correct at the time of adoption may require change later.

The first step in determining a standard of heating value is necessarily to decide what shall be the sources or methods of manufacture of the gas. Usually, the character of the existing plant will be the principal factor in determining this; but a new process or source of supply may merit consideration either to supplement or replace the existing one. Usually, the tendency will be to attach too much rather than too little importance to the heating value of the gas obtainable from the new source in relation to the existing standard; the first consideration in every case should be the ultimate cost per Btu. If the proposed supply of gas is to come from two or more sources, for example, an existing plant and a purchased byproduct, it must be ascertained that the quantities available from each source are such as to permit the delivery throughout the year of a mixture that is sufficiently constant, not only with respect to heating value but to all characteristics of the gas that affect the operation of appliances, to permit continuous good service without readjustment. What heating value will result when these conditions are fulfilled is immaterial, assuming, of course, that fair rates and correct appliance adjustments will be made in any case.

When the gas to be distributed is secured largely or entirely from an external source, its cost to the company per heat unit will in practically all cases be less than the cost of gas which the company is in position to manufacture for itself, otherwise it would not be used. Therefore, the heating-value standard should usually be that which will permit the use of the purchased gas as received, or with the least possible admixture with gas made in the company's plant. It may be desirable in exceptional cases to "reform" gas from a source which supplies only a fraction of the total used, to permit the making of a mixture of uniform characteristics; but this practice is to be avoided if possible. A considerable fraction of the energy of the gas reformed is necessarily lost in the process (or other fuel is burned), and the process is otherwise expensive. Hence, a given quantity of reformed gas always costs more and is always worth less, except as it is needed to give uniform properties to an otherwise variable supply, than the gas from which it was produced. The reforming or even the diluting of gases merely to avoid exceeding an existing standard of heating value should never be considered for adoption as a permanent practice. When the gas is to be manu-

factured by the gas company, and the general process has been determined, an extremely complicated problem remains to be solved in choosing the best operating practice. Indeed, the problem is so difficult that it appears to have been attacked in a general way only for the manufacture of oil gas by the methods employed on the Pacific coast, which constitute the least complicated of the three major processes used for the manufacture of gas in the United States.[4] The investigation referred to was one conducted by the "Joint Committee on Efficiency and Economy of Gas of the Railroad Commission of California", which included representatives of the commission, the Pacific Coast Gas Association and several of the gas companies of the State. The general conclusion was reached that little difference in uniformity or economy of manufacture per heat unit existed for gases within the range of 530 to 570 Btu, and a minimum standard of 550 Btu was recommended.

An investigation was made of the manufacture of coal gas by the Public Service Commission of Indiana through a committee known as the "Indiana Gas Standards Committee", but the investigation was limited to the review and checking of the results obtained in routine operation of the coal-gas plants of the State and did not include any considerable or systematic variation of operating conditions except the coal used. On the basis of the data assembled a standard 570 Btu was selected for State-wide use. This standard was also applied to water-gas, because a uniform State-wide standard was considered desirable, and it was recognized that any standard set for coal gas could be met very easily with carburetted water-gas.

All or nearly all of the other general investigations of the desirable standard of heating value by regulatory bodies were made when the change from a candlepower to a heating-value standard was under consideration, and the paramount importance of cost per heat unit in determining the desirable standard was not recognized. This does not mean, as is frequently stated, that standards of heating value were established by selecting the heating value of the gas furnished under the existing standard of candlepower. On the contrary, in most cases, less attention seems to have been given to the heating value of the gas distributed under the candlepower standard than was merited.

When a heating-value standard was adopted in Wisconsin, the first State to take such action, a survey was made to determine the heating values of the gases distributed under the existing candlepower standard, and the average found, in round numbers, was taken as the first standard of heating value.

A direct translation of candlepower to a standard of heating value does not appear to have taken place in any other case; usually, the heating value selected was at least 50 Btu per cubic foot lower than the heating value which prevailed when the plants were operated to meet a candlepower standard.

If the lack of adequate investigation by regulatory bodies of the most economical standard for the heating value of water gas and coal gas is surprising, in view of the tendency to set State-wide standards,

[4] A brief description of the principal methods of manufacture of gas is given in part XII, p. 215.

the failure of the industry to provide satisfactorily complete information may appear still more surprising. Certainly there is nowhere in the technical literature any approach to a satisfactory discussion of the subject. This probably results from a realization that each utility is faced by a problem that is essentially local, or by the belief that established standards would prevent the useful application of the information gained from a thorough investigation.

In part XII, following the description of the common methods of gas manufacture, the manner in which various factors affect the economy of the water- and coal-gas processes is considered in a general way.

15. UNIFORMITY OF HEATING VALUE AND OF COMPOSITION

In the preceding discussion it has been mentioned that the effort to find the most economical method of supplying energy must not result in the distribution of a gas mixture of too widely varying properties. The heating value of gas, of course, depends on its composition. Several other properties, including density (which is measured as specific gravity referred to air), the volume of air required for complete combustion, and the somewhat indefinite "ignition velocity", likewise depend on composition and are of importance in connection with the satisfactory adjustment of appliances. It is quite possible to have two gases of the same heating value, or even two which are alike in both density and heating value, but which differ so much in other respects that one will not give satisfactory service if supplied to appliances adjusted for the other, usually because the flames are unstable. (See pt. II, sec. 3, and pt. III.)

When the entire gas supply is the natural product from a field of limited extent, or when it is made with no more than accidental variations by any one of the several common methods of manufacture, heating value alone indicates sufficiently well the uniformity of the product with respect to all properties. This is also true in the case of a mixture of two gases of widely different heating values, provided each of the gases is substantially uniform; it is not true of gases of nearly the same heating value which are as different in other properties as coal gas and water gas.

Carburetted water gas is, of course, essentially a mixture of two gases, "blue" water gas and the gas which results from the decomposition of oil and its reaction with steam at high temperature. As usually manufactured, these two constituents of carburetted water gas differ much more with respect to heating value than any other important property; and therefore, the mixture can be satisfactorily controlled, so far as it affects the operation of appliances, by heating value alone. If a third constituent is introduced, such as coal gas, or "blow-run gas", a uniform heating value is not sufficient and may not even be desirable, considering only the uniformity of operation of appliances. As an example, an average water gas of 600 Btu and an average coal gas of 500 Btu can be interchanged with less difficulty from appliance adjustment than is involved in shifting from a coal gas to a water gas of the same heating value.

In the case of the very complex mixtures distributed in a few communities, it may be necessary to control at least three properties, for

example, heating value, specific gravity, and the percentage of inerts, to insure the satisfactorily uniform operation of appliances.

It would be desirable to make the composition of the gas exactly uniform at all times if this could be accomplished without additional cost. Absolute uniformity is not practicable because of several factors, probably the most important of which are the nonuniformity of the fuels used and the variable schedule of production needed to meet the changing demand for gas. However, there is substantial agreement, among both gas companies and regulatory officials, that it is entirely practicable to limit fluctuations of heating value of manufactured gases to 5 percent above or below the average, and this degree of uniformity should probably be required in all cases. Changes within this range will not ordinarily cause trouble except in industrial processes such as glass-working and metal-tempering, which combine the need for accurate heating with regularly timed mechanical operations. However, greater uniformity than this is desirable when practicable, and will usually be sought by the utility because of the advantage uniformity gives in competition with other fuels in the industrial field. Little attention has been given in the past to maintaining the uniformity of natural gas by controlling the proportion drawn from each source. This deserves careful study.

16. CONDENSATION OF HYDROCARBONS IN THE MAINS

The idea has been prevalent that the difficulty of delivering gas to distant points is an important factor in the selection of a standard of heating value. This idea is mainly an inheritance from the days of high candlepower standards when condensible hydrocarbons, especially "benzol", were purposely added to the gas nearly to the limit of its carrying power, and considerable quantities condensed in holders and mains. Under present conditions there is no reason why this factor need be involved in the selection of a standard, if primary consideration is given to the cost of delivering heat units, and if the process of manufacture is conducted intelligently.

It should be explained that in the manufacture of gas by any of the commercial processes a considerable number of combustible substances are formed which range in volatility from the permanent gases through the decreasingly volatile liquid hydrocarbons called "light oils", "heavy oils", and tar, to lampblack or coke. Every manufactured gas contains, at the end of the high-temperature process involved in its manufacture, an appreciable amount of the condensible combustible materials and a much greater amount of steam. These vapors may be removed to any desired extent by various combinations of the processes of cooling, washing or "scrubbing", and compressing. At each stage during this treatment until the most severe combination of temperature, pressure, and solvent action has been reached, the gas is in approximate equilibrium with a liquid, either a condensate from the gas itself or one introduced for the purpose of washing the gas.

After the most severe combination of conditions has been encountered there is no further condensation although some liquid may be carried along as a fog. If the most severe conditions are produced in the plant, there is no condensation in the distributing system; if they are not encountered until the gas reaches the mains, condensation

occurs there and is accompanied by a loss of heating value whether the heating value of the gases is high or low. In all except new systems of welded piping, some condensation (or some fog which will eventually deposit) is desired to seal minute leaks and to prevent the movement of dust; and a hydrocarbon fog is often introduced deliberately for these purposes, or to dissolve solid deposits of naphthalene and cause them to flow to the receptacles called "drips", placed at low points in the distributing system and provided with easy means for removing a liquid without permitting the escape of gas.

Serious losses through condensation therefore betray faulty equipment or operation in the manufacturing plant or result from an effort to deliver condensable vapors. There is no excuse for the latter under any standard of heating value in existence in the United States at the present time; it has been sufficiently demonstrated that a stable gas of at least 620 Btu per cubic foot can be produced efficiently in the water-gas generator, and at least 600 Btu in an oil-gas generator. While the heating value of coal gas depends on the fuel used and on several other factors which vary to a greater extent than do those affecting the other two major processes, high heating values when obtained are normally the result of a high ratio of methane to hydrogen and nitrogen rather than of the presence of an excessive amount of benzol.

When serious losses through condensation occur at the present time, they usually represent an unjustifiable attempt to deliver a gas containing condensable oil vapors, which should have been converted into permanent gas in the plant. The only cases of the distribution of excessively unstable gases which have come to the attention of the Bureau recently were produced by water-gas plants as the result of the following train of circumstances.

At a time when the cost of oil was very high many utilities supplying water-gas obtained permission to reduce heating values greatly. The change was accomplished by a reduction in the amount of oil used in proportion to the blue gas generated. It happens that the capacity of a water-gas machine to produce blue gas is limited, and that the amount of energy (number Btu) which it is capable of delivering in the gas by means of the gasification of oil is several times as great as its capacity to deliver energy in the form of blue gas. As the demand for gas increases and the capacity of the generating equipment becomes less adequate, the easiest way in which to meet peak loads is to use more oil in proportion to the blue gas made. Since the fraction of the gas mixture made from oil has a very much higher heating value that the blue gas, the utilization of the full capacity of the plant would result in the delivery of a gas of high heating value if only blue gas (free from unnecessary inerts) accompanied the oil gas. Such a high heating value would result in a lower rate per heat unit to the users than that agreed upon. To keep down the heating value and maintain the utility's income, a large quantity of inert is introduced through the "blow-run" or otherwise. The excessive ratio of oil used in such a gas to the amount of inert-free blue gas results in the incomplete gasification of the oil, for the steam and heat used in the latter process are a by-product of the manufacture of the undiluted blue gas.

The rather obvious remedy in a case of this kind is to raise the standard heating value and eliminate the inerts, making such readjustment of volumetric rate schedules as may be called for, of course.

17. LOCATION OF TESTING STATION

It has been customary in the past to specify the location of the testing station at which the heating value of the gas is to be determined. An ambiguity occurs in the recommendations in the earlier editions of this circular. The place at which the testing apparatus was to be set up was specified as "preferably not less than 1 mile from the manufacturing plant"; while the heating value was specified "at any point within 1 mile of the manufacturing plant." It was the purpose of the rules to provide that the heating value of the gas at all points within 1 mile from the manufacturing plant should conform to the standard and, to make sure of this, the testing was to be done at a more distant point. However, one rule could readily be interpreted to mean that the heating values observed at any point within the circle of 1-mile radius, including its center, would be satisfactory for determining compliance with the standard.

In several of the existing State rules, the same ambiguity occurs; in others a slight change of wording has placed the point at which the heating value shall be determined definitely inside or outside the circle of 1-mile radius. In a number of cases, it is specified that the tests shall be made "near the center of distribution of the gas." This phrase has also been variously interpreted as meaning near the center (usually the manufacturing plant) from which the gas is distributed, as referring to the center of the geographical area served, and as referring to a point such that the amount of gas used on the opposite sides of any straight line drawn through it shall be about equal.

The rules relating to the location of the testing station originated during the days of high-candlepower standards and their purpose was to make certain that most, if not all, of the loss of candlepower, which was proportionately much greater than the loss of heating value, caused by condensation during distribution should have taken place before the gas was tested. With the stable gases now usually distributed, the location of the testing station is much less important than it used to be. In the case of a large city, where the cost of providing and operating more than one calorimeteric laboratory is justified, the testing of the gas at a station distant from the manufacturing plant is satisfactory and may be the most desirable practice. In the case of a small system, however, it is an unnecessary burden to require the constant operation of a distant calorimeter in addition to the one needed for the control of the manufacturing or mixing process, and it seems better, therefore, to permit the routine testing of the gas at the plant, with such supplementary tests as may be necessary to insure the distribution of a stable gas (one that does not change composition appreciably in the distributing system). In most cases it will be satisfactory before testing to compress the gas to the highest pressure employed in distribution, and then to pass it through a cooling coil and filter

immersed in a bath at a temperature at least as low as any to be encountered in the distributing system.

18. HEATING VALUE TO BE DETERMINED AFTER COMPRESSION

The prevalent practice of permitting the heating value of the gas to be determined before compression is a relic of the period of rigid State-wide standards and the general use of coal gas, and without doubt resulted from a desire to make the somewhat critical conditions for the economical manufacture of coal gas independent of the subsequent methods of distribution. At the present time unmixed coal gas is little used, and local variations of the heating-value standard are generally permitted. The significance of the heating-value standard has also undergone a change. Formerly regarded merely as a means of compelling the utility to so operate its plant that the product would be of "good quality", the heating-value standard is now recognized as an essential factor in the measurement of the quantity of the commodity sold by the utility, of equal importance with the registration of the meters.

Under present conditions, therefore, there is no justification whatever for permitting the heating value of the gas to be determined before compression. Any heating value lost during compression is the result of the condensation of liquid hydrocarbons, which are recovered by the utility and which can usually be sold readily at a price at least as great as their value as a fuel. In case gas is sent out from the same plant to different communities under radically different pressures, as is likely to be the case, for example, when a large city is served through a system of low-pressure mains and gas is transmitted at high pressure to one of its suburbs, it is fair to determine independently the heating value of the portion of the gas delivered to each community and to make such adjustments in the requirements and rates as may be appropriate.

19. FREQUENCY OF CALORIMETRIC MEASUREMENTS

The regular determination of the heating value of the gas sent out should be required in all cases. The frequency with which such determinations should be made, and the methods employed depend on the magnitude of the business and the process by which the gas is made, or the source from which it is obtained.

Satisfactory recording calorimeters have been developed in recent years and their records are much to be preferred to intermittent tests in all cases in which the volume of business justifies the relatively high cost of the testing equipment. Recording calorimeters must be subjected to frequent checking, either against a gas of known heating value, usually pure hydrogen, or against another calorimeter burning the same gas, or preferably by both means. It is the custom of most of the larger gas companies to check the recording instruments daily, and in some cases hourly, but such frequent testing should not be required. Weekly tests will usually be satisfactory if combined with careful daily observation of the recorder and the records to detect any indicattion of faulty operation. Failure to find agreement between a recording calorimeter and one of the Junker type should not be interpreted without investigation as

indicating error on the part of the recording instrument. The result obtained with either instrument may be in error. An investigation of the cause of the discrepancy will usualy show which instrument is correct.

If a recording calorimeter is not available, the heating value of manufactured gas should be determined at least daily, and enough supplementary tests should be made to assure the plant operator of the quality of the product at all times.

Natural gas which comes from a field that is known to yield a uniform product and which is distributed without modification need be tested only infrequently; but the heating value should be known in every case if only as a guide in the selection and adjustment of appliances. It is probable that no hardship will result in any case by requiring a heating-value determination at least once a month. When gases of decidedly different heating values from different sources are mixed, a continuous recorder or a controller for automatically making a mixture of uniform heating value is almost a necessity. The fact that the gases mixed are all natural gases does not justify any less careful regulation or any less careful compliance with the standard of heating value on which the volumetric rates are based than is customary in the manufactured-gas industry.

In some cases, especially those in which a very simple mixture is employed, such as butane and air, the composition of the mixture can be determined by analysis and the heating value computed with sufficient accuracy to justify the substitution of this procedure for calorimetric tests. The determination of the heating value of complex mixtures by analysis is more difficult, less accurate, and in the long run is sure to be more expensive than direct determination by the use of a calorimeter.

20. DETERMINING AVERAGE HEATING VALUES

The determination of the monthly average of heating value is a matter of considerable importance, for it is principally upon this average that compliance with service standards is judged. In the method most commonly employed, all tests made on a single day are averaged and the arithmetical mean of the daily averages is taken as the monthly average. This method is usually, but not always, satisfactory. It may fail to give a correct average because of either systematic variations during the day or differences in the amount of gas distributed, called the "send-out", on different days. The deviation from a correct average is likely to be of importance only in those cases in which heating value is affected by changes in methods of production or sources of supply made to meet a variable demand. Such cases are quite as likely to occur in connection with the supplying of natural as of manufactured gas and result from the effect of drawing gases from sources of supply ordinarily held in reserve, from the application of vacuum to wells or collecting mains and the dilution of the gas through leakage, or from failure to subject all the gas used during periods of large demand to some process ordinarily employed, such as the extraction of gasoline and other condensible hydrocarbons.

If the daily averages may be regarded as correct, it is an easy matter to compute a correct monthly average by multiplying each daily average by the measured send-out for that day and dividing the sum of the products by the total send-out for the month. Since daily send-outs are practically always measured and recorded, this procedure involves no additional equipment and only a negligible amount of additional work and is to be generally recommended in preference to the use of a simple arithmetical average of the daily averages.

The correct determination of the daily average presents a more difficult problem. The ideal method is, of course, to make a continuous record of heating value or to take tests so frequently that they are nearly equivalent to a continuous record, and to weight each part of the daily as well as of the monthly record in proportion to send-out. With a recording station meter and a recording calorimeter, it is feasible, in this way, to obtain a very accurate daily and monthly average with very little trouble. This method is to be recommended for all large utilities.

Smaller companies which cannot afford the time and equipment necessary for very frequent or continuous calorimetric tests sometimes resort to the continuous collection of an average daily sample of gas, and this procedure is favored by at least two of the State commissions. Such a sample, to be of materially greater value than a momentary one taken during the part of the day when the demand is greatest, must be taken at a rate proportional to send-out. This may be readily accomplished by the use of a meter under nearly balanced pressure, geared to the station meter and discharging at constant pressure into a container such as a small meter prover; but the combination of equipment required for determining average heating values in this way, including the Junker's calorimeter, scarcely possesses enough advantage in cost as compared with a recording calorimeter to offset the other advantages of a recorder, even in a small plant.

Through the operation of the laws of probability, it is possible for a company which cannot afford expensive equipment to get a very nearly correct monthly average with a much smaller number of tests daily than is required to insure correct daily averages and even in spite of systematic daily variations. If the variations in heating value are entirely irregular, that is, without any relation to the time of day, 1 or 2 tests daily made at any convenient time are pretty sure to give a good monthly average; for in as many as 30 tests those which are too high to correctly represent the gas sent out during the day are sure to be compensated for by others which are too low. Significant variations may occur, however, which are not of the accidental or irregular variety, but tend to follow a daily cycle. These may result from the daily cycles of plant operations, and demand, from changes of temperature, particularly of the holder, and from other causes such as the shifting of operating personnel. The tests should therefore be distributed with relation to the time of day in such a way that the number of tests made at each time will be proportional to the average rate of send-out at that time. The system proposed is here illustrated with 2 tests daily; it could readily be adapted for only 1 or for more than 2 daily tests.

A typical or average daily load curve should be assumed in advance. Probably the best method of obtaining this would be to take as typical the last week day of the preceding month and record the send-out from midnight to each hour of the day. Sundays and holidays should not be used because their load curves are abnormal. It is assumed that 60 tests are to be made during the month. One of these should be made some time during the month at a time of day corresponding to that at which about one-sixtieth of the total average day's send-out has left the plant, 10 of them should be completed by the time of day at which one-sixth of the day's supply of gas has been sent out, etc. It requires only a few minutes, with the aid of an adding machine or by plotting the send-out, to determine the distribution of the 60 tests with respect to time of day.

As an example, assume that the typical day's send-out is 270,000 cu ft and that it is distributed in accordance with table 2. One-sixth of the total send-out or 45,000 cu ft has occurred at about 7.30 a.m. Hence, 10 tests or one-sixth of the monthly total should be made before that time in the morning; half the gas, 135,000 cu ft, is sent out before 1 p.m., hence, 30 of the tests should be made before that time, etc. The complete schedule is given in table 2.

TABLE 2.—*Time for making tests to establish monthly average of heating value*

Hour beginning (a.m.)	Send-out M		Number of tests	Hour beginning (p.m.)	Send-out M		Number of tests
	During hour	Total			During hour	Total	
12	5.0	5.0	1	12	19.5	140.5	4
1	2.0	7.0	0	1	13.0	153.5	3
2	4.0	11.0	1	2	15.0	168.5	3
3	3.5	14.5	1	3	17.0	185.5	4
4	3.0	17.5	1	4	19.0	204.5	4
5	9.5	27.0	2	5	20.0	224.5	5
6	15.0	42.0	3	6	16.5	241.0	3
7	18.5	60.5	4	7	6.0	247.0	2
8	14.0	74.5	3	8	7.0	254.0	1
9	14.5	89.0	4	9	6.0	260.0	2
10	14.5	103.5	3	10	7.0	267.0	1
11	17.5	121.0	4	11	3.0	270.0	1

It is next necessary to decide on which day to make the test at a given time. The important thing is to have such a well-distributed record that two tests do not occur very close together and that there is no excessively long period without any test. The most uniform intervals between tests are simply obtained by arranging the 60 tests in the order of time of day and making the first and thirty-first on the first day of the month, the second and thirty-second on the second day, etc. The disadvantage of this arrangement is that no tests would be made in the important afternoon period during the first part of the month and none in the early forenoon during the latter part. This might result in an incorrect average if the daily cycle changed much during the month. Hence it is preferable to "stagger" the tests and to make the first test (with reference to time of day) and the thirty-first on the first day of the month, the sixteenth and forty-sixth on the second day, the second and thirty-second on the third day, the seventeenth and forty-seventh on the fourth day, etc. The complete schedule is given in table 3.

TABLE 3.—*Complete schedule of monthly tests*

Day of month	Hour beginning tests		Day of month	Hour beginning tests	
	a.m.	*p.m.*		*a.m.*	*p.m.*
1	12	12	16	10	6
2	8	5	17	6	3
3	2	1	18	11	7
4	9	5	19	7	3
5	3	1	20	11	7
6	9	5	21	7	3
7	4	1	22	11	8
8	9	5	23	7	4
9	5	2	24	11	9
10	9	5	25	7	4
11	5	2	26	12	9
12	10	6	27	8	4
13	6	2	28	12	10
14	10	6	29	8	4
15	6	3	30	12	11

This schedule should give a correct monthly average in spite of any large but regular daily variations and any probable change during the month in the daily cycle. It will also compensate as well as any other schedule of 60 tests for purely accidental and entirely irregular variations. If such a schedule is employed it should be adhered to rather closely, although, in case there is normally no one capable of making the test on duty during the latter part of the night, it should be satisfactory to make the few tests called for between 10 p.m. and midnight late in the evening and those scheduled between midnight and 6 a.m. at the beginning of the working day. Calorimetric tests should by no means be limited to those scheduled if others are needed to insure uniform operation, but only those scheduled should be used in computing the monthly average even if the tests made on one day do not fairly represent the average for that day. Otherwise the advantage of the system, which is the weighting of the heating value at each part of the daily cycle in proportion to sendout, is lost.

Unless some such definite schedule as this is adopted and adhered to, there is no escape from the necessity of trying to determine with considerable accuracy the actual average heating value of the gas sent out each day. If the latter system is used, the time devoted to testing can probably be more advantageously employed than by making a fixed number of tests at the same hours each day. Preferably, the daily cycle of operations should be studied with some care so that the variations likely to occur are known as definitely as possible; the effect of each change of fuel or variation of operating practice should be ascertained, etc. Probably half of the total number of calorimetric tests should be made in groups devoted to the determination of such facts. The remainder must be distributed among the days on which no special study is made, in such a way as to ascertain as well as possible whether the day's operations as a whole have given the result anticipated. If this system is used all tests must be considered in making each daily average.

21. SUPERVISION OF CALORIMETRIC TESTS BY A REGULATORY BODY

A utility engaged in selling gas must determine heating value with reasonable frequency and regularity for the control of its own operations. It is usually an unnecessary duplication of effort for a public

official to check such determination by a similarly regular series of observations. Hence, it is usually best to make the utility primarily responsible for the determination of the heating value of the gas sent out, with only such supervision as may appear desirable to satisfy the regulatory body that its rules are complied with and the users of gas that they are getting what they pay for.

It is difficult to specify the amount or character of the supervision of the utility's testing that is necessary, because this depends upon the character of the gas supply, the equipment used in testing, and, to a considerable extent, on the personnel involved. In a large city, it is desirable to have a municipal official charged with authority, provided with the equipment necessary and properly trained to check heating values. Generally, such an official should be a regular employee in the office of the city chemist or the city engineer who will devote only as much time to gas testing as seems to be required. Such an official will not only be of value in helping to detect any departure from accuracy of the company's test methods, but will usually acquire a familiarity with the general field of gas service, which should be useful in a routine way in dealing with complaints to the municipal government from users of gas, and should be of considerable value to the municipality in case a major problem, such as the granting of a new franchise, arises. The small amount of municipal supervision here indicated may be desirable even in cities in which gas service is subject to regulation by a State commission. The action of the municipal inspector is not to be regarded as the exercise of police authority, but merely as the performance of the duty of the purchasers' representative in a business transaction, equivalent in character to an inspection by the city engineer of the brick to be used in a municipal building.

The duties of the representative of a State regulatory body are more exacting, for he is charged with the responsibility for determining that the equipment and methods employed by the utility, as well as by himself, are satisfactory for the purpose, a responsibility that a municipal official rarely has. Accuracy is as important as and not much more difficult to obtain in calorimetry than in meter testing. As far as the accuracy of the test itself is concerned, the requirements should be equally severe for both, and are probably best made by requiring the use of certain equipment, methods and records. When comparative tests are made with a calorimeter regarded as standard, agreement within 1 percent should certainly be obtained. If it is not obtained, the cause of the trouble should be ascertained and eliminated. The fault is not always that of the plant calorimeter.

22. COMMENTS ON PROPOSED RULES RELATING TO HEATING VALUE

It is the purpose of a good commercial standard to enable buyer and seller to reach a definite agreement which will apply to all the circumstances of their transaction, which will be clearly understood at all times by everyone concerned, and which will leave the seller free to fulfill his contract by any means not detrimental to the purchaser. The rules relating to heating value (rules 27 to 30, sec. IX), proposed for adoption by State regulatory bodies are believed to

accomplish this purpose and they, together with the following comments on them, will serve as a convenient summary of the discussion of standards of heating value.

The proposed rules were formulated to provide the protection to the users of gas and the freedom of action for the utilities which are inherent in rate schedules based on thermal units, without sacrificing, in individual transactions between the utilities and their customers, the utmost simplicity in computing charges directly from the meter readings.

The desirability of basing charges for gas on the useful commodity (available heat) furnished has been thoroughly discussed in the preceding sections. The manifold advantages of "therm" rates, with the exception of a fraction of their advertising value, depend upon the separation of the problem of how most economically and effectively to render good service to the users of gas from the problem of what constitutes a fair charge for such service. If it is formally recognized in the State rules that these are separate problems and that the standard of heating value with which the utility is required to comply involves only the first of them, while a change in the price of gas per heat unit delivered involves only the second, the advantages of "therm" rates may be secured; but the confusion resulting from the introduction of an unfamiliar unit in the computation of every customer's bill may be avoided.

The provisions which seem necessary to safeguard completely the interests of the user and at the same time permit the utility all possible freedom of management and technical control of its operations are included in rule 29. Requirement 1, under this rule, is necessary to make it certain that the regulatory body will be fully informed as to the operations of the utilities subject to its jurisdiction, and to give it opportunity to investigate in advance the wisdom of a large expenditure for a plant on which the consumers will later be required to pay a return. The last sentence of the paragraph is intended to preclude definitely the reduction of heating value as a disguised method of increasing rates, when the utility itself recognizes that its operating cost is increased by the change. The second requirement provides for the necessary separation of those changes of rate per unit of volume which must be made to maintain a uniform charge for service, from those changes of rate which are made as a matter of policy or are necessary to take account of changes in the costs of the business. Enough latitude in the relative rates to different classes of customers is allowed to permit the utility to round off its charges to a whole number of cents per hundred or per thousand cubic feet without entering a rate hearing. The third requirement gives the commission time to study the utility's proposal; if further time is needed, a suspension of the proposed action may, of course, be ordered; but such a suspension is not likely to be necessary in most cases when the economy of the process only, and not the charges to the consumers, is involved. The fourth requirement is obviously one that should be made in any case of a change of service conditions made at the option of the utility.

Rule 29 differs from the corresponding rules formerly recommended in requiring that satisfactory arrangements be made for determining the heating value of all gas sold including, of course, natural gas, which is now obtained from so many sources and sub-

jected to such diverse treatment that the regular determination and control of its heating value is of as great or greater importance than that of manufactured gas. Unnecessary duplication of tests by utilities receiving gas from the same source is avoided by the last portion of paragraph (a). This clause may also be interpreted to permit the determination of heating value by other means than the use of a standard calorimeter if satisfactory to the commission. For example, analysis might be employed in the case of a simple gas such as a mixture of butane and air.

The location of a testing station is less important than it was when gas was generally manufactured to meet high candlepower standards. When manufacturing operations are conducted in such a way that any appreciable loss of heating value occurs during transmission, the character of the gas delivered at the appliance is subject to undesirable fluctuation, and the various customers served do not receive equal value for the same expenditure. Both these results can be and should be avoided. Instead of offering a gas company a premium for manufacturing an unstable gas, as was formerly done in effect by providing for the measurement of heating value before compression, it is now recommended that the distribution of a seriously unstable gas be forbidden in the rules. Compliance with the requirement can probably be more satisfactorily determined by passing the gas through an appropriate filter under conditions of temperature and pressure as severe as any likely to be encountered in actual distribution, than by testing occasionally at remote testing stations.

The provisions of rule 30, in addition to being simply fair to each customer, should go far toward discouraging the too prevalent practice of allowing heating values to fall during the month and making up the difference in a few days near the end. Under any ordinary conditions of operation there should be no difficulty in avoiding the inconvenience of having to make a deduction from the bills computed from the ordinary rate schedule.

In a few cases, usually where the gas is a purchased byproduct, the heating value of the gas may really be beyond the company's control. Frequent fluctuations may then tend to give an alternation of high and low results with an average that is not far wrong. In such a case the proposed rule may be more stringent than is justified. The general rule should be followed that a cost should not be incurred which is out of proportion to the benefit to the customers affected.

III. COMPOSITION OF THE GAS

1. RELATIONSHIP OF COMPOSITION TO ADJUSTMENT OF APPLIANCES

It has been pointed out in the chapter relating to heating value that if the cost of the gas per heat unit to the customer is the same the composition of the gas distributed is of little importance, provided the appliances are correctly designed and adjusted for the particular mixture supplied to them. This section, therefore, deals only with the adaptation of the appliances in use to the composition of the gas distributed or vice versa. Since there is usually no great difficulty in obtaining appliances that are well designed for almost any mixture it may be proposed to supply, nor in adjusting them

when first installed, the principal problems to be solved relate to the kind and amount of variation of composition that are permissible without making general readjustments or wholesale replacements of appliances already in use.

The inclusion of some discussion of the effects of changes of composition was necessary to clarify parts of the chapter relating to heating value, and those parts (secs. 3 and 15) should be read in this connection if not already familiar to the reader. It was there shown that for each appliance there is a characteristic rate or a limited range of rates of fuel supply, usually expressed in Btu per hour, for which the appliance is adapted. Outside this range the appliance is unsatisfactory, for one reason or another. The manufacturer usually gives the appliance a definite "input rating" showing the number of Btu per hour which should be delivered to its burners, and the most important part of the operation of adjusting the appliance is to provide orifices of such size that the amount of gas delivered to each burner, under prevailing conditions of composition and pressure of the gas, will correspond to the input rating. By the remaining adjustments the supply of air needed to burn the fuel is controlled. Usually, only the primary air which enters the burner with the gas is involved in an adjustment. The flow of secondary air around the burners is the result of convection, and its amount is determined by the amount of heat produced and by permanent features in the design of the appliance which are not usually subject to ready alteration.

The extremely involved relationships between the composition of the gas and the adjustment of appliances can be much more clearly explained by the use of diagrams than otherwise. In figures 2 to 9, the adjustments of appliances are represented by plotting the rate at which heat is produced (i.e., the "adjustment" of the gas supply) against the amount of air injected as primary air, expressed as a percentage of the air required to completely burn the gas. Thus, any point on one of the diagrams represents one definite adjustment, of the appliance being considered, with respect to the amounts of both gas and air which enter its burners.

As an illustration, the point in figure 2 which is marked with a cross and labeled "condition of adjustment of appliance" represents the facts that the appliance in question is supplied with gas at a rate to produce 10,000 Btu per hour and that the primary mixture contains 72.2 percent of the air "required" for the complete combustion of the gas. The figure as a whole represents characteristics of a certain appliance when supplied with water gas of 600 Btu per cu ft which "requires" 5.4 cu ft of air for the combustion of 1 cubic foot of gas. Hence, the point designated represents an adjustment of the burner to take 16.7 cu ft of gas per hour and 3.9 cu ft of primary air per cubic foot of gas. If the diagram represented, without change of coordinates, the operation of an appliance when supplied with propane, the same point would signify an adjustment for 3.87 cu ft of gas per hour and 17.2 cu ft of primary air per cubic foot of gas used, but the various curves would be displaced somewhat from the positions shown in the figure.

The terms employed, and the reasons for the selection of the coordinates used may require some further explanation. A gas appliance is a device to supply heat at a definite place for a certain purpose

and it might be anticipated at the start that to accomplish the same purpose in substantially the same way the same amount of heat will always be required. This, together with the fact that manufacturers of appliances specify the "input ratings" in Btu per hour at which the appliances will give the service for which they are designed, constitute sufficient reasons for considering the adjustment of the gas supply to an appliance in terms of Btu per hour rather than in terms of cubic feet per hour; but additional reasons will appear later. When a given volume of gas mixture of definite composition is completely burned, its constituents react chemically with a definite quantity of oxygen to form water and carbon dioxide. The amount of air which contains this amount of oxygen is called the "air required for complete combustion", and it may be computed readily from the composition of the gas. If all the "air required for complete

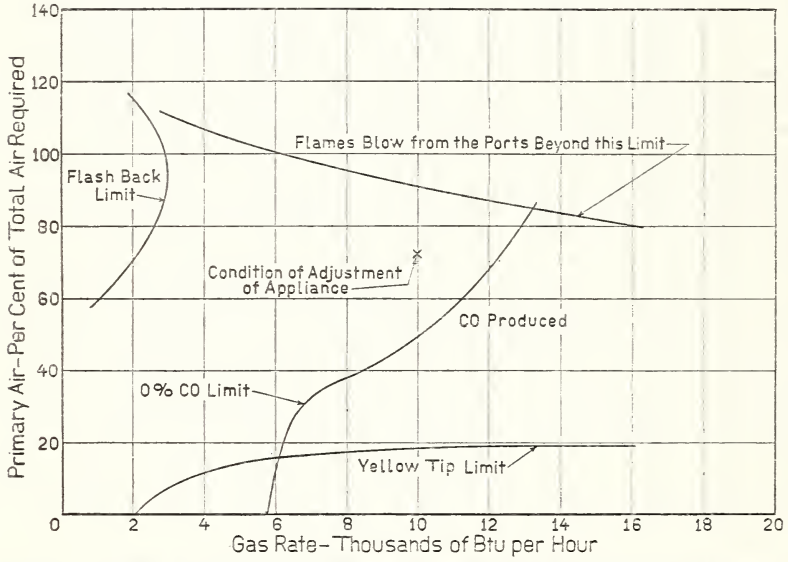

FIGURE 2.—*Typical diagram of operating characteristics and adjustment of an appliance.*

combustion" enters the burner as primary air, it is apparent that no secondary air or at any rate very little,[5] will be needed, whatever the composition of the gas burned may be. If 50 percent of the air required for complete combustion is supplied as primary air, an equal volume of secondary air must enter and react in the flame, etc. It is a frequently used and fairly close approximation that the amount of air required to burn the quantities of commercial fuel gases of different composition which supply equal amounts of heat are the same. Then, for an appliance which is supplied with gas to produce a given number of Btu per hour and which injects as primary air a given percentage of that required for complete combustion, the amount of secondary air required is the same within reasonable lim-

[5] It is a familiar fact that to insure that all of one substance will react chemically at least a small excess of the other reacting substance should be present.

its, whatever the composition of the gas. Moreover, the amount of secondary air which will pass through the appliance is controlled by the heat supplied; and the efficiency of the appliance (so far as it is dependent on adjustment) is determined by the rate at which heat is supplied and the amount of air passing through the appliance. Hence, with the coordinates chosen as they are (Btu per hour, and primary air expressed as a percentage of total air required) the adequacy of ventilation of an appliance and the kind of service it gives, with respect to rate of heating and thermal efficiency, are substantially the same for the adjustments represented by any one point of the diagram, whatever gas is burned.

The curves in figure 2 represent limits of adjustment beyond which dangerous or unsatisfactory conditions in the operation of the appliance develop. A condition represented by a point to the left of the curve marked "flash-back limit" will result in the flashing

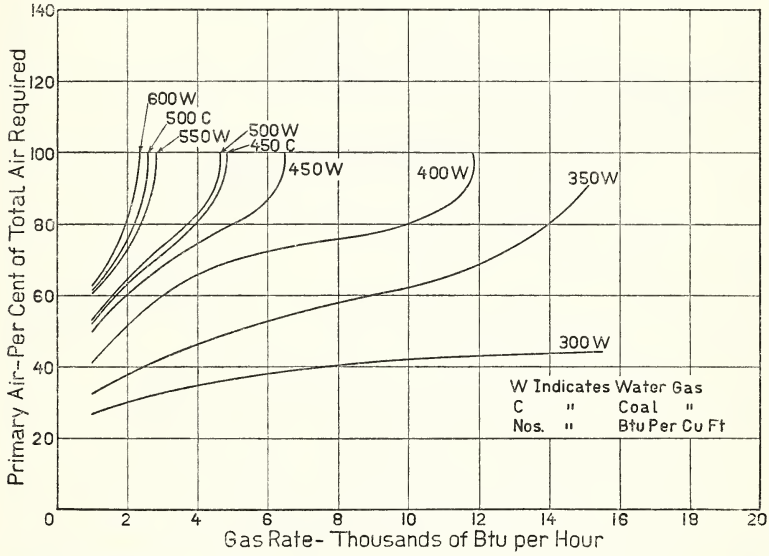

FIGURE 3.—*Effect on flash-back of changing heating value and method of manufacture of gas.*

back (or "back-firing") of the flame to burn within the burner. Any condition represented by a point above the curve labeled "flames blow from ports beyond this limit" will result in the flames "lifting" or blowing from the ports. If an adjustment which would be represented by a point to the right of the curve marked "0 percent CO limit" is made, the gas will not be completely burned, but carbon monoxide will be liberated. If so little primary air is used as to correspond to a point below the curve marked "yellow-tip limit", solid carbon will form in the flame and will be deposited on any object on which the flame impinges. Some of it may also escape into the air and produce a "stuffy" odor or discolor surrounding objects.

The way in which the conditions which limit safe adjustment are affected by certain changes in the composition of the gas is indicated, in at least a qualitative manner, in figures 3 to 5. In figure 3 is

shown the observed limits of flash-back for a single appliance (not the one represented in fig. 2) when burning water gases from 300 Btu to 600 Btu per cu ft and coal gases of 450 and 500 Btu per cu ft. The "blue" water gas in each of the water-gas mixtures is free from excessive inert. Figure 4 similarly shows the positions under which lifting and yellow tips appear with the same appliance and with some omissions the same gases as represented in figure 3. Figure 5 represents the characteristics of another appliance when supplied with 600 Btu water gas, natural gas, and propane. (The appliance represented in fig. 3 would not have burned natural gas at a useful rate without lifting). With this appliance natural gas did not flash back under any conditions, but propane did, though the flames blow from the ports more readily with propane than with natural gas. The effects, on the other limits of safe adjustment, of

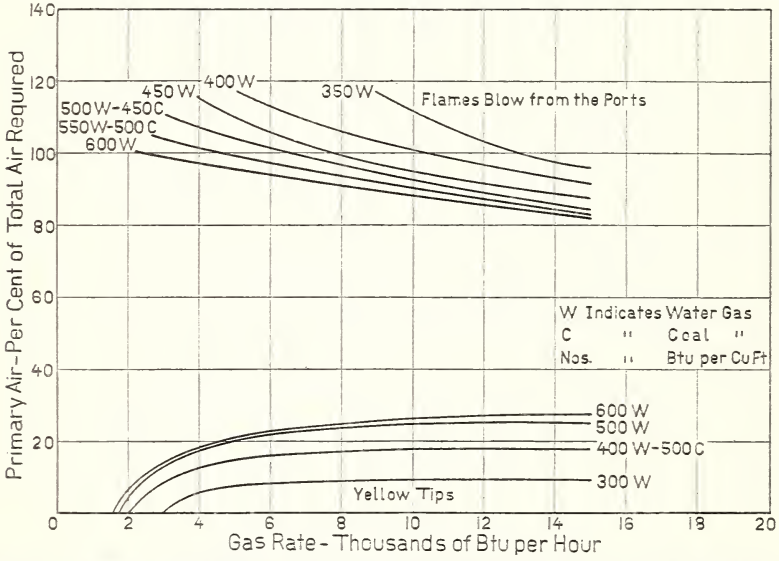

FIGURE 4.—*Effect on lifting of flames of changing heating value and method of manufacture of gas.*

changing from one gas to another are clearly shown and require no explanation.

If an appliance is not readjusted when the composition or pressure of the gas supply is changed, then the rate at which heat is produced or the ratio of primary air to the total required or both are changed, and the position of the point on figure 2 representing the initial conditions of adjustment is shifted. Figure 6 is a reproduction of figure 2 with the addition of a curve showing the changes in the supply of gas and primary air which take place when pressure only is changed. Figure 7 shows the corresponding changes which would take place if only the specific gravity of the gas could be changed without affecting any other property or condition. Figure 8 shows in the same way the changes which would result from a change of heating value assuming that specific gravity, pressure, and the limits of safe operation remain constant. In drawing the

curve it was assumed that the volume of air required for the combustion of unit volume of gas is proportional to the heating value, an approximation which is close enough for use in all except the most precise work. In actual practice, of course, more than one property of the gas supply usually changes at the same time.

The combined effect can be ascertained by a combination of the diagrams representing changes of a single property. In figure 9, for example, is shown the effect of changing the supply of gas to the appliance represented in figure 2 from a 600-Btu water gas of specific gravity 0.67, to a 500-Btu coal gas of specific gravity 0.42, and reducing the pressure from 6.0 to 5.4 in. The changes in the limits of operation are reproduced from figures 3 and 4, and the changes in the amount of heat produced and primary air entrained are represented

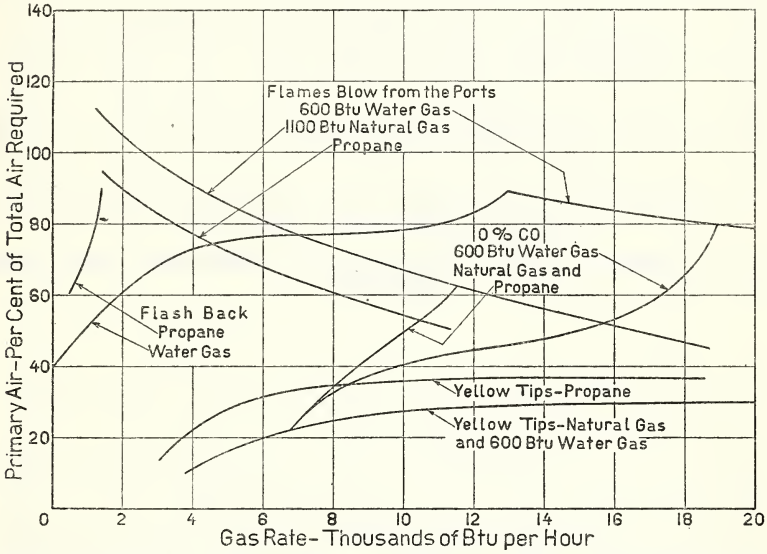

FIGURE 5.—*Comparison between operating characteristics of an appliance with several gases.*

as a resultant of successive changes in specific gravity, pressure, and heating value.

Although it is possible in the case just cited to compensate approximately for the effect of the changes in some of the characteristics of the gas supply by changing other characteristics, this fortunate result is not usually obtainable when a process of manufacture or source of supply is altered for economic reasons. The only general rule for such compensations is that heating value should vary, if at all, in proportion to the square root of the specific gravity. This may also be expressed by stating that the heating value divided by the square root of the specific gravity should be constant. This rule will apply satisfactorily to all cases in which the alteration of the limits of satisfactory operation, as represented on the conventional diagram, is not too great. No quantitative generalization can be made as to the variation of these limits, but a qualitative idea of the effect of most of the

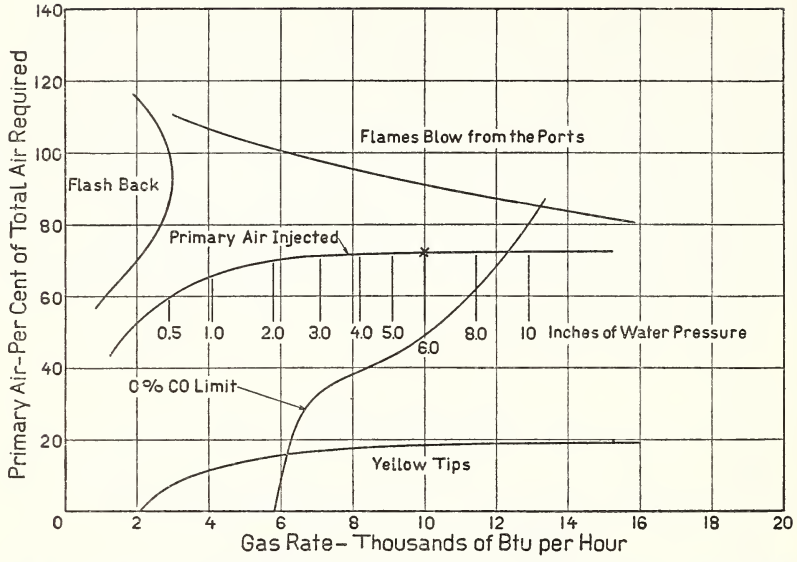

FIGURE 6.—*Effect of a change of pressure on the "adjustment" of a typical appliance.*

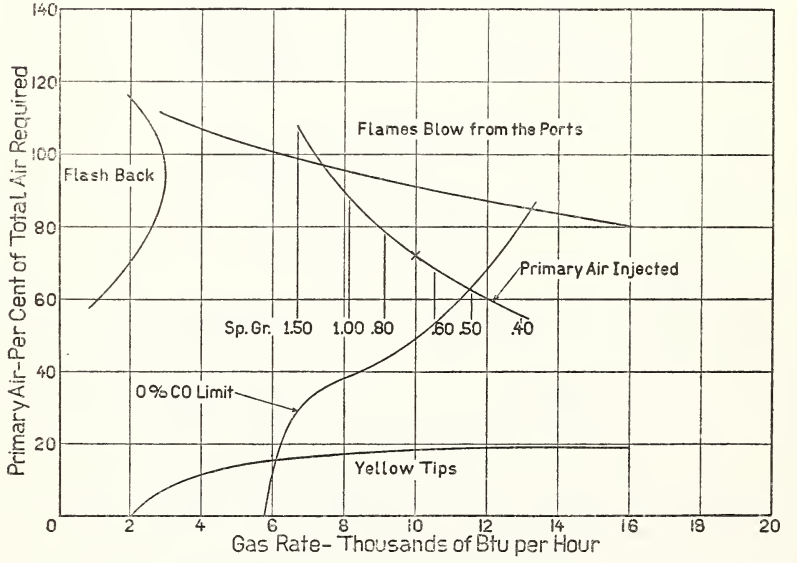

FIGURE 7.—*Effect of a change of specific gravity on the "adjustment" of an appliance.*

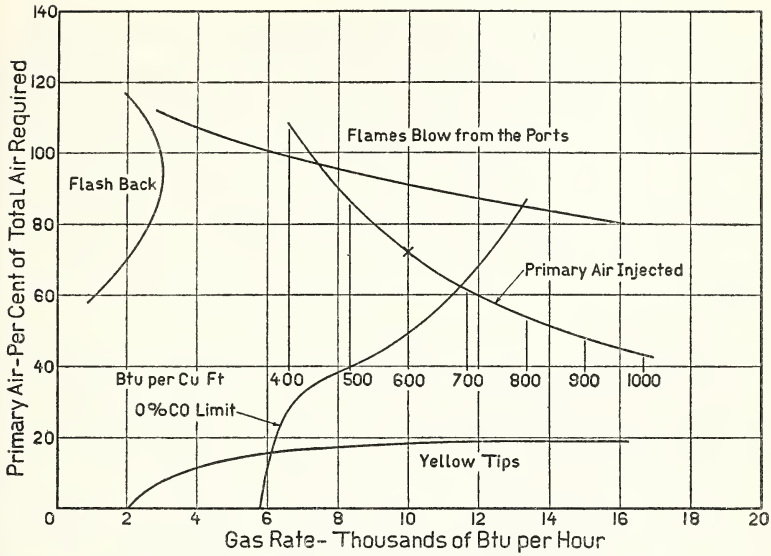

FIGURE 8.—*Effect of a change of heating value on the "adjustment" of an appliance.*

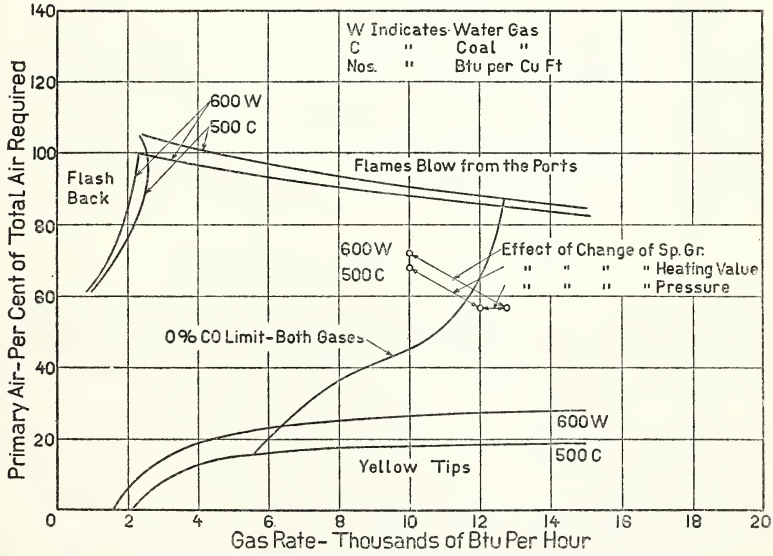

FIGURE 9.—*Combined effects of changing characteristics of gas on the "adjustment" and operation of a typical appliance.*

changes which are likely to be of commercial importance can be obtained from figures 3 to 5.

2. REGULATION OF COMPOSITION AND SPECIFIC GRAVITY

It is impossible to escape the conclusion that, while certain changes of composition of the gas mixture are possible without affecting the operation of appliances, they are changes of a character which do not usually accompany desirable changes in the sources or methods of production of the gas, that changes of composition which do affect the operation of appliances can seldom or never be satisfactorily compensated for by changes of pressure, and that satisfactory service can be maintained only by means of a supply of gas of very nearly the composition for the use of which the appliances in service were adjusted.

It is not usually feasible to specify the composition of a gas supply, and any attempt to do so in terms of the percentage of certain constituents (with the possible exception of inerts) would probably result in seriously hampering the utilities' operations. It is, therefore, preferable to rely for the control of composition, to the extent necessary to insure good service, on the maintenance of constant heating value and constant specific gravity. Care should be exercised, however, to see that in maintaining constant specific gravity more harm is not done by altering the limits of safe operation of appliances than would result from permitting some variation from uniform density. In particular, the use of inerts to control the specific gravity of a mixed gas is likely to do more harm than good. Because of this danger, it is not recommended that the permissable variation of the density be limited without an investigation of the specific case in which it is to be applied.

Where changes in the composition of a mixed gas are a source of trouble with respect to the adjustment of appliances, the same degree of uniformity in the operation of appliances that is provided for in the customary rules, which permit heating value to vary from the average by 5 percent, can be insured by the requirement that the quotient of the heating value divided by the square root of the density of the gas shall not vary from a mean value by more than 10 percent.

3. MIXED GASES AND PEAK LOADS

Although it does not appear desirable to regulate, by means of general rules, the composition of the gas distributed, the problem of maintaining a uniform supply is important enough to merit careful study in all cases, and regulatory action in specific ones. When the most uniform supply is also the most economical, considering the total cost per heat unit delivered to the customer, there is no problem, of course. When it is not, a compromise is always necessary, involving the question as to whether an improvement in uniformity is worth what it will cost under local conditions.

Two situations are of common occurrence. In many cases a by-product, usually that from coke ovens, is available at a cost less than that of independent manufacture but in quantity not always sufficient to meet the demand. The additional gas needed is commonly supplied by the manufacture of water gas. In other commonly occurring

situations, manufactured gas is mixed with natural gas during the winter peaks.

With oil at 1933 prices, the first situation is probably best met by adding to the by-product gas only as much water gas as will be needed to make the percentage of water gas in the total mixture constant and to make up the remainder of the supply by adding oil gas, made by the "Pacific coast process" or its equivalent. "Pacific coast oil gas" has substantially the same properties as coal gas of the same heating value. If the amount of oil gas required is not too great, it may be unnecessary to use separate generators for its manufacture.

By the use of additional oil at high temperature, the operation of the water-gas sets may be modified to make a gas which approximates in composition the mixture of water gas and coal gas regularly distributed. This practice, while uneconomical of fuel, gives the generating equipment a very high capacity and when all things are considered may prove more economical for use during peak loads than a practice that requires less fuel, or less expensive fuel, but more equipment that stands idle during the greater part of the year. The same considerations apply, of course, to the case in which the "base load" is supplied by coal gas, but water gas is used for peak loads because of the lower cost per unit of output of the manufacturing equipment. In this case, however, the utility has additional means of controlling the mixture by modifying the operation of the coal-gas plant to permit the manufacture of some water gas even when the demand is relatively low.

The problem which arises when a supply of natural gas becomes inadequate to meet the demand of the community served is, without doubt, one of the most difficult encountered in supplying or regulating gas service. Natural gas has very different properties from any gas that can be economically manufactured to replace it, hence it is even more important than in the case of mixtures of coal gas and water gas to maintain the proportions of any mixture constant. On the other hand, large differences, not only in the total cost of the two gases but in the character of the items involved, usually make the maintenance of a uniform mixture relatively expensive. This results from the fact that the investment in leases, wells, and pipe lines is so great that the capital charges usually constitute most of the cost of natural gas. To keep the cost of natural gas low per unit of output, in spite of these heavy "fixed charges", requires that the equipment be used as nearly to full capacity at all times as is practicable. On the other hand, the operating cost of a manufacturing plant, including fuels, usually considerably exceeds the fixed charges, and the manufacturing plant may be used intermittently or at a fraction of its capacity with relatively smaller loss than the natural-gas property.

Although these economic factors should be considered in determining to what extent mixing shall be practiced, they should not be allowed to predominate. After all, the cost of all items chargeable to the production of the gas itself is usually a minor item in the total charge to the great majority of those who use gas, even when all the gas is manufactured. It will rarely happen that enough can be saved by the mixing of gases in irregular proportions to compensate for unsatisfactory or hazardous operation of appliances.

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It is true that supplying combustible gas of almost any kind is preferable to permitting an interruption of service, and that manufactured gas, if available, should be used to supplement natural gas whenever the supply of the latter is inadequate to meet the demand of existing customers. However, natural gas is used in such quantity that an idle gas-manufacturing plant capable of supplying any considerable part of the demand is not likely to be available to meet emergencies unless they have been long anticipated.

The two questions to be considered in connection with the mixing of manufactured with natural gas are, therefore, (a) the desirability of extending natural-gas service to so large a market that the supply is not expected to be adequate for peak loads, and (b) the best means of providing for adequate service to territory already supplied with natural gas when it becomes apparent that the failing supply will soon become inadequate. The Bureau's answer to (a) would be that such practice is generally undesirable and that natural gas should be distributed only to such territory as can be supplied with the unmixed natural product for a reasonable number of years or with a uniform mixture including available by-product gases.

Usually a large number of more or less detached communities are supplied from any important gas field. When the full demand of all of them can no longer be met, it is a very serious question whether to replace the natural with manufactured gas entirely in some communities and continue natural gas service in others, or to supply mixed gas to all. In general, the first solution is probably best in the interest of over-all economy and uniformity of service, but the dissatisfaction of the communities cut off from supply of natural gas with what they regard as discrimination may make the policy a hard one to agree upon.

When the failure of a supply of natural gas to meet the demand appears unavoidable, a decision must be made as to the relative desirability of (a) supplying unmixed natural gas to the limit of capacity and using manufactured gas during only a short time, perhaps only a few days of maximum demand, (b) arranging to supply throughout the year a uniform mixture of such composition that it can be made in sufficient quantity for any demand anticipated, and (c) supplying unmixed natural gas during certain months and a uniform mixture during other months. Method (a) probably has the advantage of immediate economy and puts the utility in the best position to compete for the natural gas available from independent producers. Method (b) has the advantage of providing uniform service conditions, of making the frequent adjustment of appliances unnecessary, and of stabilizing the industry over a longer period of years. Method (c) has in part the merits and demerits of both.

If the utility has entire control of the output of the natural-gas field, the choice of the best practice is relatively simple, and policy (b) is probably the desirable one in most cases. Where the production of natural gas is largely a by-product of oil-producing operations and not readily controllable, policy (c) or even (a) may be necessary. Only in extreme cases of inability to control its supply, and as a last resort in providing uniformity of service, should the utility consider the wasteful process of "reforming" the natural gas. Since industrial applications are generally much more affected

by change of composition than domestic uses, and their relatively small number and expert operation make semiannual readjustments relatively easy, it may be advantageous to adopt method (c), but to limit the semiannual changes to a degree that will not seriously affect the operation of domestic appliances, say a change of heating value of not over 10 percent, or possibly 15 percent, accompanied by such a change of specific gravity as will maintain a constant ratio between heating value and the square root of the specific gravity. If this policy is adopted, an oil-gas generator is again the most promising plant for producing the gas for use during peak loads, with the possible addition of some butane to increase the amount of manufactured gas that may be supplied without too greatly changing either heating value or the stability of flames.

4. PURITY OF THE GAS (CHEMICAL REQUIREMENTS)

The preceding discussion has dealt almost entirely with variations in the relative amounts of valuable combustible constituents in the gas mixture. Some attention has been given to inerts; none at all to substances, usually spoken of as "impurities", which have harmful effects even when present in very small amounts.

At the present time it seems impracticable to limit by regulation the percentage of carbon dioxide, oxygen, and nitrogen, which are the principal inert constituents, because of the variety of methods by which gas is produced. The only known State regulation setting such a limit has been abandoned. A general limitation of inerts applying to all utilities regardless of the process of manufacture employed would either be unduly restrictive or so liberal that it would have no effect in the cases in which a limitation might be beneficial. No limitation by rule is, therefore, suggested, but the general undesirability of inerts should be borne in mind, and their amount should not be increased without compelling reasons.

Because of the fact that carbon monoxide is the only constituent which is poisonous in the amounts ordinarily present, some effort has been made at times to limit the amount of it in the gas. However, it is not practicable, and in fact it is generally undesirable, to place limits on the quantity of this constituent; as a result there are now no known regulations in regard to its presence. Coal gas contains from 5 to 10 percent of carbon monoxide, water gas 25 to 30 percent; limiting the amount might, therefore, limit the percentage of water gas which could be made. It is apparent that such regulation as would prevent the operation of water-gas plants, which make by far the major fraction of all gas manufactured, would be very undesirable.

A large proportion of the cases of death or illness caused by gas poisoning are suicidal, or are due to irresponsible conditions, such as drunkenness, or to gross ignorance; and in the majority of these cases the character of the gas would probably have only a small influence upon the seriousness of the result. Of the remaining cases of gas poisoning a considerable number are due, not to the combustible gas itself, but to the carbon monoxide formed by combustion of the gas with an insufficient supply of air, as in a faulty appliance or in an appliance improperly adjusted or connected with insuffi-

cient or improper flues. It is certain that the protection of the public from danger will be found to lie rather along lines of regulating the construction and adjustment of appliances and general education of gas users as to proper precautions than in the limitation of the carbon-monoxide content of the gas itself.

Some of the substances, which are usually regarded as "impurities" by the operating personnel of the utilities, are undesirable because they form deposits or cause corrosion in the mains and service pipes or in the meters, and so interfere with the delivery of the gas to the customer's piping. These materials cause little or no trouble beyond the meters, and because they affect the operations of the company rather than its customers, limiting their amount has been properly regarded as outside the field of service standards.

The most troublesome impurities in both manufactured and natural gases are compounds of sulphur. For several reasons it is desirable to consider one of these, hydrogen sulphide, apart from the other compounds, carbon bisulphide and the more complex organic substances, in which sulphur occurs. Hydrogen sulphide usually occurs in greater quantity both in natural gas and in manufactured gas before purification than does any other compound of sulphur; it can be easily removed at small cost; and the same high chemical reactivity which makes this possible, in turn makes hydrogen sulphide much more troublesome in other respects than the other compounds of sulphur if it is not removed.

(a) TOTAL SULPHUR

All compounds of sulphur when burned produce sulphur dioxide, a compound which slowly oxidizes and combines with water vapor to form sulphuric acid. In the presence of liquid water, sulphur dioxide dissolves, without preliminary oxidation, to form the weak, acid, sulphurous acid. These two acids cause any condensate from the products of combustion of gas containing sulphur to corrode the metal linings and ducts of appliances and to attack the mortar or cement of chimneys in which condensation occurs. A great amount of sulphur in the gas would cause the products of combustion from ranges and other open appliances to irritate the nose, throat, and lungs of the user and might cause damage to books, fabrics, and possibly to hardware in the household.

The total amount of sulphur in a gas is not wholly within the control of the producer, for it depends even more upon the character of the coal and oil which are employed than upon the methods of operating the plant. In fact, limiting the sulphur content of gas really places a limitation upon the kind of fuel which can be used. It is essential, therefore, that the limits of sulphur content be not set so stringently as unnecessarily to preclude the use of coal or oil which otherwise would be very economical for gas-making. However, the users of gas have a right to expect and should be assured of the lowest quantity of sulphur in the gas which it is practicable to maintain with economy; and a restriction on the total sulphur content should always be made even if the quality of gas-making materials is thereby somewhat restricted in order to prevent the distribution of gas containing such quantities of sulphur as might prove disagreeable or injurious to health.

In general, the total quantity of sulphur in commercial gas supplies rarely exceeds 20 grains of sulphur per 100 cu ft, and few plants appear to have much difficulty in keeping within 15 grains. The traditional limit, and that set by most state rules, is 30 grains per 100 cu ft, which permits a rather wide choice in the selection of fuels and is still below, but not much below, the amount which produces a disagreeable odor when the gas is burned.

In view of the results obtained in actual practice at the present time and the authority possessed by most regulatory bodies to set aside their own rules in exceptional cases, it appears desirable to lower the limit in all but unusual circumstances to 20 grains per 100 cu ft, and to require satisfactory evidence that a higher limit is necessary before permission to exceed 20 grains is granted.

Occasionally, if a supply of poor coal is received by a small company, it is impossible for it to furnish gas of a normal purity until this stock is exhausted. To meet such cases, reasonable tolerance in interpretation of the rules is necessary.

In the case of any gas company making as much as 100,000,000 cu ft of gas per year, regular tests of the amount of sulphur in the supply should be made at least twice a month. Smaller companies cannot afford the apparatus and the time of the necessary experienced chemists to make the tests; thus they must depend upon an occasional inspection by the State or municipal authorities, or upon the determinations of the sulphur in the coal and oil which they are using. This determination of the sulphur in the coal and oil is, of course, not an exact measure of the amount of sulphur which will appear in the gas, but it furnishes an indication of the amount to be expected.

(b) HYDROGEN SULPHIDE

Any hydrogen sulphide in the gas will form on burning the same products as the other sulphur compounds which form the "total sulphur" present. However, hydrogen sulphide combines readily with copper and its alloys and with silver at ordinary temperatures, as well as with iron at somewhat elevated temperatures, to form sulphides. A gas containing hydrogen sulphide therefore attacks the copper tubing leading to pilot lights, and the machined parts of brass cocks, automatic controls, etc., and causes the clogging of orifices and sometimes of ports. Usually trouble occurs only where brass or copper is used, but sometimes the ports of radiant heater and oven burners are clogged even when they are drilled in cast iron. The occasional escape of small quantities of gas when appliances are lighted is hard to avoid, and minute leaks in the piping too small to be readily detected sometimes occur. If hydrogen sulphide is present in the gas which escapes in this manner, it will slowly blacken jewely, silverware, and any paint that contains lead compounds, as most paint does. All these effects of hydrogen sulphide are cumulative, and a minute concentration will therefore cause damage if given enough time. For all these reasons hydrogen sulphide must be regarded as much more objectionable than any other compound of sulphur. Fortunately, all of the hydrogen sulphide can be removed at comparatively small expense. Therefore, to leave any appreciable quantity of this impurity in the gas, whether manufactured or natural, is unnecessary as well as very

undesirable. It is because the other sulphur compounds cannot be reduced, except at prohibitive expense, below a certain figure fixed by the quality of coal or oil and the operating methods, that it is undesirable to require their complete elimination also. An additional reason for requiring the practically complete removal of hydrogen sulphide is that this necessitates careful management in the preliminary treatment of the gas—that is, the condensing and scrubbing—and thus the absence of hydrogen sulphide is usually indicative of careful work in the removal of tar and other impurities.

The requirement proposed in this circular, limiting the amount of hydrogen sulphide in a gas to a "trace", is not unduly severe, for it will allow the presence of those amounts which are unavoidable under good commercial plant methods. It is necessary to define what is meant by a trace of hydrogen sulphide; otherwise the rule limiting it has very little significance. However, it is not desirable to set any definite numerical limit (e.g., 0.1 grain of hydrogen sulphide per 100 cu ft of gas, as has sometimes been proposed), because the exact determination by quantitative methods of small amounts of hydrogen sulphide is difficult and requires a lengthy procedure in the hands of a trained chemist. The method proposed for detecting objectionable amounts is in effect quantitative and is ample for all conditions of commercial control.

The limit set by the test proposed conforms closely to good commercial practice in its significance. The influence of various changes in the method of test have been carefully investigated by the Bureau in a research which is described in full in Technologic Paper T41, entitled "Lead Acetate Test for Hydrogen Sulphide in Gas." The test recommended can be carried out with very simple apparatus by anyone without previous experience, and it requires only a few minutes for its completion. It is entirely proper, therefore, to expect that even in the smaller gas plants a daily test will be made for hydrogen sulphide. However, it should be noted that it often requires 1 or 2 days after the detection of hydrogen sulphide in the city supply to insure its removal from all parts of the distributing system; therefore it should not be expected that the company can immediately eliminate all of this impurity if, unfortunately, any appreciable quantity of it has been allowed to remain in the supply sent out from the plant.

(c) AMMONIA

Although the harm which may result from the presence of considerable ammonia in the gas is sometimes disputed, it is generally believed that it has an injurious effect upon the meters and upon gas fixtures, especially brass parts with which the gas comes in contact. It should, therefore, be eliminated from the gas as completely as practicable. Practically no ammonia is produced in the water-gas and oil-gas processes, so that these supplies are free from this impurity. In any large coal-gas works the practically complete removal of the ammonia from the gas is effected because of its commercial value. In smaller coal-gas works a large amount of "scrubbing" water is commonly used, and in these instances the amount of ammonia passing into the gas is correspondingly small. However, some small plants with inadequate capacity for cooling and

scrubbing the gas thoroughly do not remove the ammonia with sufficient care.

Most coal-gas plants need never permit more than 5 grains of ammonia per 100 cu ft of gas. However, in a few plants where the capacity for ammonia removal is limited either through the scarcity of cold water or because of inadequate apparatus, it may be necessary to permit as much as 10 grains of ammonia per 100 cu ft of gas. In a few cases, difficulty may be met in preventing the gas once thoroughly scrubbed from being again contaminated by ammonia taken up from water in the holders or distributing system. This condition would, however, be a very exceptional one and could occur only occasionally in hot weather in a coal-gas works.

Any company making as much as 100,000,000 cu ft of coal gas per year should be expected to provide itself with apparatus and make regular determinations at least twice a month of the quantity of ammonia in the gas supplied by it. Smaller companies must usually depend upon occasional tests by State or municipal officials, but if ammonia recovery is practiced it will often be profitable to the company to have tests made at intervals to insure the maximum recovery of this by-product.

The proposed requirement limiting ammonia is very easy to meet, being much less severe than the ordinary operating practice of well-managed companies. It affords ample protection against any unreasonable amount of this impurity.

5. ODOR OF THE GAS

It is very desirable that a combustible gas possess a strong and distinctive odor to serve as a warning when gas escapes and to assist in the location of small leaks. Fortunately, the manufactured gases which are poisonous usually do possess enough odor not only to be readily detected but to become decidedly disagreeable before a harmful amount has been breathed. Natural gas, propane, and butane, on the other hand, possess very little odor, and a small leak may remain undetected for a long time. Since these gases are not poisonous, their escape is attended by less hazard than the escape of the usual manufactured gases; but it occasionally happens that enough of them escapes to cause disastrous explosions or fire when they eventually become ignited. Explosions of this type are extremely rare in territory supplied with manufactured gas and are relatively much more frequent, though fortunately still rare, where natural gas is distributed. The difference is to be attributed almost entirely to the ease with which the escape of manufactured gas is detected.

For this reason it has frequently been proposed that the distribution by public utilities of gas not possessing a sufficiently strong odor be prohibited. For many years the "regulations" of the National Board of Fire Underwriters as recommended by the National Fire Protection Association contained the following clause:

> No combustible gas should be used unless it has a definite and distinctive odor or is properly odorized.

The clause was not mandatory, however, and does not appear to have been adopted by regulatory authorities where the distribution of natural gas was in question. A recent investigation of practicable

"warning agents", mainly odorous substances, by the United States Bureau of Mines supported by the American Gas Association has shown the practicability and approximate cost of introducing certain materials of this class into the gas, and some commercial development both of odorizing materials and of equipment for introducing them into the gas stream has taken place.

At the present time it appears to be the consensus of engineering opinion that the advantage of introducing an odorant into natural gas is hardly worth the cost, but that it is not far from being so. Accordingly, it is not recommended that the introduction of an odorant be required, but it does appear that the practicability of providing this means of protection should continue to receive the attention of both the regulatory bodies and the utilities. When the cost of an odorizing material rather than the equipment for introducing it is in question, it may be desirable to introduce the odorant periodically for short periods at a time, especially in spring and autumn when a check up of the condition of the distributing system is most desirable.

IV. PRESSURE

The pressure at which gas is supplied to the user is, with the possible exception of heating value, the most important factor determining the quality of the service rendered. Correct and uniform pressure is of even greater importance than is usually recognized; in fact, reports of "poor gas", "low heating value", and "faulty appliances" are very often found upon investigation to be really caused by unsatisfactory conditions of pressure.

Poor pressure is in practice one of the most difficult conditions to guard against, even for a company which makes every effort to give good service; and although correct rules for gas pressure are not particularly difficult to fix, their intelligent enforcement probably presents greater difficulty and requires more experienced judgment than any other phase of regulation of gas standards. For ideal conditions the pressure should be exactly the same at all times; but this is, of course, impracticable, as there are always large variations in the amount of gas used, which give rise to variations in pressure. However, satisfactory service demands sufficient pressure at all times, an excess of pressure at no time, and as uniform a pressure as it is practicable to maintain. As in the case of heating value, it makes little difference within fairly wide limits what pressure is delivered at the appliances, provided it is satisfactorily uniform and the appliances are adjusted to give the best results under the conditions that prevail.

While for satisfactory service proper pressure conditions must be maintained at the burner, yet a departure from these may be caused by conditions on the customer's premises for which the company is not responsible. The pressure at the burner depends not only upon the pressure which the gas company maintains in its mains and service pipes but also upon the size and character of the house piping as related to the maximum demand of the appliances in use. The gas company should be expected to maintain proper pressure conditions at the outlet of its meters, provided the appliances in use do not have an unreasonably high maximum demand as compared with the aver-

age consumption. However, any conditions in the house piping, or that part of the service pipe belonging to the consumer, or any additions to the appliances in use which affect the pressure of the gas, are beyond the control of the company and should be cared for by the customer concerned.

In fixing pressure requirements it is inadvisable to make any specifications as to how the company shall meet the regulations. If reasonable time is allowed, the company should be given entire freedom to choose the best methods of accomplishing the final results. Whether it wishes to use more holders, a high-pressure belt line, a booster system, feeder mains with local or district governors, or larger low-pressure mains is immaterial, if the final requirement is met. It should be recognized also that a gas company cannot always put in force at once such a system of operation as would meet the requirements which can reasonably be expected of it ultimately. If the conditions are such as to make it impossible to distribute the necessary quantity of gas at the pressures desired, the company must be given a reasonable allowance of time in which to make the necessary alterations of its distributing system. However, it is important that the efforts of the company be promptly directed toward meeting proper pressure requirements; and in the interval before they can be fully complied with, temporary regulations, less rigid than those ultimately intended, can be enforced.

After the pressure conditions are once established in a satisfactory way throughout a city, it still means continued vigilance in order to keep them so. The growth of the city, the development of house heating with its great seasonal demand, the shifting of population from one district to another, new industrial business, and many other factors must be expected and anticipated so far as possible in order that the service will not suffer. Not all of these conditions can be anticipated, but regular pressure surveys throughout the entire territory supplied by a company will do much to point out additions or changes required in the distributing system. Continuous records at a few important points on the system should also be maintained and the results from month to month and year to year carefully compared so that gradually changing conditions will be promptly noted.

The minimum pressure and the allowable percentage variation at any outlet during 24 hours have long been subject to regulation wherever the control of gas service is attempted. Maximum limits for pressure, differences of pressure within a given territory, the variations of pressure permissible over long periods of time, the adjustment of appliances to give the best results under local conditions of pressure, and the question as to whether the time of day at which a change of pressure occurs or the suddenness of its occurrence makes a difference in its permissible magnitude are less familiar, but important, subjects.

The following sections covering the important features of good pressure conditions contain recommendations quite generally applicable, but special conditions may occasionally require their modification for a given locality. However, such modifications will generally be with respect to the time which must be allowed before a company can comply with the rules, rather than any change in the rules themselves.

1. MAXIMUM PRESSURE

Since pressure decreases from the point at which gas is delivered into any portion of the piping system (except in a few cases in which great changes of elevation are involved), the maximum pressure is directly controlled by the utility and immediately subject to any alteration that seems desirable.

The reason for employing unusually high pressures or permitting unlimited ones is, in general, to make possible the delivery of increased volumes of gas during peak loads through existing distributing systems without causing too great a percentage variation at the appliances, and without incurring the expense of additional mains or other costly alterations of the system. A change of the maximum pressure on any part of the sytsem should be adopted only after a thorough engineering consideration of what is involved in the change and in its alternatives. The effect of the change on leakage from mains and services, the cost of their repair where necessary, and the cost of making general readjustments of appliances in the district affected involve questions of economy that can be directly compared with the cost of providing for equivalent service by means which do not involve an alteration of the maximum pressures. As economic questions to be decided for each situation individually, these phases do not appear to require regulation by means of general rules, but could be left to the management of the utility were it not for the hazard and the destruction of shade trees and other property which make any leakage of gas a public nuisance. A regulatory body can probably better cover these aspects of the subject by rules regarding the tightness and general condition of the distributing system than by setting a maximum of pressure. The safe-working pressures of the meters in service and the effects of high pressure on the satisfactory operation of appliances are questions of a different character and should be covered by service rules.

The number of meters larger than the "10-light" size (capacity about 300 cubic feet per hour) constitutes a very small fraction of the number in use. If necessary the larger meters can be protected from dangerous pressures by individual governors at very little expense, especially in view of the probability that most of them serve equipment that should have governors to reduce fluctuations of pressure in any case. Therefore, in setting a general maximum for low-pressure distribution the safety of only the "10-light" and smaller meters need be considered.

The ordinary sheet-metal meters of this size are generally regarded as safe at 8 oz (14 in. of water column) and they have been used extensively at pressures as high as this. Some, if not all, of the manufacturers test them at 3 pounds before sending them from the factory.

When maximum pressures (which will be employed at times of peak load) are increased, the pressures at other times must be increased in proportion, or even more than in proportion in order that the greatest benefit may result from the change. This means that the orifice of each burner in the district affected must be changed to permit the delivery of only the normal "rating" of the appliance with the cock wide open. With smaller orifices, more "primary" air is injected into the burner with a given amount of gas, and this

must be given its correct regulation by an adjustment of the air shutter. A considerable number of appliances have no air shutters, and on a great many more the air shutters are not tight enough to permit satisfactory adjustment for very high pressures.

While this difficulty, presented by excessive pressures, may be solved in a particular case by the use of orifices of a special type that dissipate the energy of the gas stream, appliance manufacturers and dealers and the plumbing trade are not at the present time equipped to deal with the selection and supplying of orifices of the special type. The small orifices required at high pressures are also more apt to clog than a larger orifice.

The amount of air injected into a burner is nearly proportional to the velocity with which the gas issues from the orifice over a considerable range of velocities, but falls off much more than in proportion at low velocities. This fact greatly reduces the danger of back-firing which would otherwise accompany the "turning down" of burners. With an appliance correctly adjusted for normal usage at high pressure, the injection of air falls off less rapidly when the gas is turned down than with an appliance adjusted for normal usage at a lower pressure, and the high-pressure appliance will, therefore, give more trouble from back-firing when used at low rates. This consideration is important in connection with the distribution of manufactured gas but not with natural gas, with which back-firing is rarely troublesome.

Another factor which makes excessive pressures undesirable is the difficulty of controlling the flow of gas to the appliance as accurately as desired. When closing the gas cock no great change in the amount of gas flowing takes place until the opening through the cock is reduced to a size comparable with that of the orifice. Therefore, the higher the pressure and the smaller the orifice the greater is the difficulty found in controlling the gas. This is more important in the case of natural than of manufactured gas because the orifices used are smaller.

Still another factor to be considered is the probability that appliances, particularly space heaters of the "portable" variety, will be moved from place to place and installed without adjustment for local conditions. Many of these appliances are dangerous to life when supplied with a greater quantity of gas than they are designed to burn. This consideration makes it of some importance that differences in the conditions of service which exist in different but not distant localities should not be permitted to become too great.

These difficulties of appliance adjustment, rather than the hazard and loss resulting from leakage, are probably the limiting factors in determining a desirable maximum limit for pressure. They affect natural gas service about as much as manufactured gas service; hence, there appears to be no reason for permitting higher pressures in one case than in the other.

Because a lower limit would unfavorably affect economy in distribution, it is not believed desirable to set a general limit for the maximum pressure lower than 12 in. of water column, although it will be best for a utility whose distributing system is of ample size to voluntarily adopt a limit of 10 or, in the case of manufactured gas, even 8 in. In exceptional cases it may be desirable to extend the limit to 15 in., but the utility should be required to show convincing

reasons for such a high pressure, and no higher pressure should be permitted on any low-pressure system.

In the preceding edition of this circular it was indicated that changes in maximum pressure which occur at night when little gas is used were hard to prevent because they might result from slight leakage through governors, and that they were relatively harmless. A different opinion must be expressed at the present time. The use of pilot lights and of appliances such as refrigerators and automatic water heaters is so general that they provide an adequate outlet for any leakage through governors that cannot reasonably be prevented. On the other hand, while fewer appliances are used at night than in the day, the faulty operation of appliances, particularly space heaters, is likely to have more serious consequences at night while people are asleep. Excessive pressure is therefore to be considered as serious a departure from good practice at one time as at another.

2. MINIMUM PRESSURE

Two inches of water column is the traditional minimum limit of pressure for the distribution of manufactured gas in this country. It is the pressure specified in almost all the regulatory ordinances and requirements in effect. No such general agreement appears in relation to natural gas, the pressure of which is usually expressed in ounces per square inch [6] rather than in inches of water column. Two oz is probably the figure most frequently employed.

The recent tendency of the gas industry has been toward higher minimum pressures. A questionnaire, sent to all gas companies serving 1,000 or more customers in 1930, asked for an expression of opinion as to desirable standards with respect to pressure and many other matters. Of 371 utilities which answered the questionnaire, only 15, all distributing manufactured gas, favored a minimum of less than 3 in. Three of these indicated 2.5 in. and the remainder 2 in.

Assuming that appliances will be adjusted as well as is practicable for the prevailing pressure, two factors make excessively low pressures undesirable, however uniform they may be. They are the limitation imposed by the capacity of existing house piping, including the valves, thermostatic controls, etc., of the appliances themselves, and the difficulty of entraining at the burners the amount of primary air needed.

Because of the difficulty of injecting enough primary air when the orifice at the burner is large, it is not possible to obtain satisfactory service in regions of excessively low pressure merely by increasing the sizes of the orifices employed. This consideration will, therefore, serve as a starting point in discussing what the minimum pressure ought to be.

The great majority of present-day appliances are built to meet the approval requirements of the American Gas Association which have also been adopted generally as "American Standards" by the

[6] 1 oz/in.^{2} is equivalent to 1.73 in. of water column. There is a tendency to abandon the expression of gas pressures in ounces, one evidence of which is the fact that the "Approval Requirements" of the American Gas Association express pressures in inches of water, even when referring to natural gas. Since only one system of units is desirable for use in this connection, it is recommended that pressures in low-pressure piping be specified in terms of water column.

American Standards Association. These requirements specify that appliances be adjusted for test to give their normal ratings at a pressure at the appliance of 3.5 in. of water column with manufactured gas and 7 in. with natural gas. The difference results from the fact that much smaller orifices must be used with natural gas to permit the injection of the greater percentage of air needed. Without readjustment, the appliances must burn the gas completely and must not exhibit seriously defective operation in other respects at pressures 50 percent above or below normal (in the case of some appliances only 25 percent above normal is specified). It will probably be generally admitted that the factor of safety provided by this range of pressure is none too large in view of the percentage variations that are permitted to occur and the uncertainty of reproducing a given adjustment in service. If appliances are adjusted to their normal rates for pressures at the orifice lower than those specified, the percentage range of safe operation is reduced. It is not expected, and it is usually not desirable, that appliances shall be adjusted to their normal ratings at pressures as high as the probable maximum. A great many appliances, probably a majority, are given their normal adjustment at pressures not greater than 75 percent of the maximum which may occur. It is customary to permit a total variation of pressure at one point of 50 percent of the maximum. Good practice, therefore, seems to require that the minimum pressure at the appliance shall be not less than $0.50 \times \frac{3.5}{0.75} = 2.3$ in. of water column for manufactured gas or 4.6 in. for natural gas.

The "requirements" of the American Gas Association for house piping and appliance installation recommend the design of house piping for a pressure drop of 0.3 in. This must, of course, be added to the pressure at the orifice, making the minimum pressure 2.6 in. for manufactured and 4.9 in. for natural gas.

The problem of selecting suitable minimum pressures for mixed gases of compositions intermediate between those of the usual manufactured and natural gases is most simply solved by making the minimum pressure at the appliance proportional to the heating value. Of course, the minimum pressure is related to the "air requirement" of the gas and not directly to the heating value, but the substantial proportionality between these two properties permits the one to be substituted for the other, as a matter of convenience, in an approximate computation of this kind.

There is much greater difficulty in designing appliances to pass the test for completeness of combustion with natural gas than with manufactured gas. Hence, the ratio between heating value and pressure should be determined with relation to the test made with natural rather than with manufactured gas. The minimum pressure to be permitted at the appliance, again assuming adjustment at 75 percent of the maximum pressure, is, therefore,

$$0.5 \times \frac{7.0\,H}{0.75 \times 11.35} = 0.41\,H,$$

where H represents the heating value of the gas in hundreds of Btu per cubic foot and 11.35 is the heating value, in the same units, of the gas used for testing. For simplification and as a slight con-

cession to the lower minimum pressures of the past, the second decimal may be dropped.

The minimum pressure at the outlet of the meter, expressed in inches of water, should, therefore, be

$$0.4\ H+0.3.$$

Using this formula, the minimum pressure for the manufactured gas used in the approval test becomes 2.4 instead of the 2.6 in. computed directly, but this difference is not serious. It is interesting that if the formula is applied to pure propane, the minimum pressure indicated is 10.6 in., which is not far below the pressure of 11 in. for which propane regulators are usually set.

In the interpretation of minimum-pressure regulations, it should be understood that a company cannot know what changes in the number or character of appliances will be made by an individual customer unless notified by him. The cooperation of the users with the gas company in this particular is essential if satisfactory service is always to be had.

A sudden drop in pressure with subsequent rise to normal, such as might in rare cases extinguish lights or cause the backfiring of burners, is a most serious condition to be guarded against. However, it is not intended that the minimum-pressure limit shall guard adequately against these dangerously low pressures, for they constitute what are really interruptions of service. This matter is discussed further under this latter heading.

3. RANGE OF PRESSURE WITHIN THE TERRITORY SERVED

With a maximum pressure as high as 12 in., it does not seem desirable to permit a minimum as low as 2.5 in. in the same system, however uniform the pressure may be at any point. At the present time it is common practice for the manufacturers of appliances to determine with some care the size of orifice, and in some cases the details of other parts, such as replaceable burner heads, which should be used in the territory served by each utility to insure the satisfactory performance of appliances; but no option is given to the local dealers and no attempt is made to differentiate between the different parts of the same city. In making the selection of the orifice to be used in the community, the heating value, specific gravity, and the approximate average of pressure (sometimes the maximum) are taken into account. Even if appliances are adjusted at the time of purchase for the conditions of pressure which prevail in the households in which they are used, some of them, particularly the small space heaters, are certain to be moved about as articles of furniture from house to house; and some of them which are satisfactory and safe when used under the conditions to which they are adapted become dangerous under other conditions.

Unless and until the practice of the appliance trade can be essentially changed, public safety requires that the gas company assume the responsibility for the correct adjustment of appliances, new and old, and by whomever installed; or it must maintain reasonably uniform conditions throughout the city. It is believed that a total range of pressure within one city from the minimum at any time and place to three times that minimum need not be exceeded if the dis-

tributing system is at all adequate, and this degree of uniformity may reasonably be required.

4. VARIATIONS OF PRESSURE AT THE SAME OUTLET

The majority of appliances can be adjusted to give good service at any pressure within wide limits, provided that pressure remains constant. The effect of a change of pressure depends upon its relative rather than its absolute magnitude. For example, doubling the pressure by an increase from 2 to 4 in. produces practically the same effect on the operation of an appliance adjusted for 2 in. as does doubling the pressure by an increase from 6 to 12 in. on the operation of an appliance adjusted for 6 in. The undesirable effects of variable pressures result from the fact that the pressure becomes different from that for which an adjustment was made by the orifice, the cock, or otherwise.

These effects may be divided into two groups depending upon whether the adjustment was intended to be temporary or permanent. In the first group, we have to consider such things as the effect of an unexpected change of pressure on an oven set for cake-baking; the extinction, by a decrease of pressure, of a flame set at a minimum to keep food warm; and the boiling over, when pressure increases, of food above a burner adjusted to produce gentle boiling. In the other group we have incomplete combustion at high pressures, particularly in the case of automatically controlled appliances and those customarily used with the burner cocks wide open, inability to heat with satisfactory speed at low pressures, the extinction of pilot lights, etc. Only those changes of pressure which occur within a few hours, at the most, affect the first group; but to prevent trouble of the second class it is as important that variations shall not exceed certain limits over a period of months as it is that they shall not exceed the same limits within 24 hours or even a few minutes.

(a) RAPID, MOMENTARY, AND PULSATING VARIATIONS

It makes little difference whether a change of pressure occurs within a second or occupies 2 or 3 minutes. It makes a great deal of difference whether the change takes place within a few minutes or gradually during several hours, because it then does not greatly affect the majority of manually controlled processes, particularly those of cooking. California and Vermont deal directly with rapid variations of pressure by rules which limit the variation during 15 min to 2 in. of water. In only exceptional situations is a rule of this character needed if the total variation of pressure is kept within reasonable limits. Although the maximum and minimum pressures during the daily cycle usually occur several hours apart, the rate of change during any part of the cycle, as when the evening cooking load is coming on, is usually closely related to the total variation, and the limitation of the latter has the effect of limiting the other also.

Conditions which might be improved by limiting the rate of change of pressure but not by placing a reasonable limit on the total change, may arise from (1) the stepwise opening or closing of manually operated valves or regulators in the distributing system, which should

be manipulated more regularly to anticipate the demand, and (2) the sudden starting or stopping of an industrial furnace or other equipment capable of employing a large fraction of the capacity of the main. Before attempting to limit the rate of change in the latter case, it should be considered whether the variation caused in this manner and which will probably occur not oftener than once or twice a day is or is not more detrimental to other customers than the slower but more numerous and irregular fluctuations which occur as the result of the variable demand of numerous customers. The question tends to become one of the practical desirability of permitting any customer to utilize an important fraction of the capacity of a main not devoted to his exclusive use. Viewed in this way it appears that the rule may have an undesirable result. It is therefore suggested that the limitation of rapid but not excessive changes of pressure be omitted from the general rules and made the subject of special regulation only when unusual conditions appear to require it.

The rule in effect in New York which limits "maximum momentary variations" of pressure that occur on 2 or more consecutive days to ⅛ in. might be interpreted as a more severe limitation of the same character. The rule was probably intended, however, to provide against the operation of defective regulating equipment, either that of the gas company or one of its larger customers. The same purpose may be accomplished, so far as the gas company is concerned, by invoking the usual requirement that all equipment be maintained in good condition. The advisability of attempting through the regulations to control the operations of consumers, to the extent of prohibiting the sudden turning on or shutting off of gas in sufficient quantity to affect the pressure in the mains by ⅛ in. is very doubtful.

Pulsating changes of pressure are also limited in New York to ⅛ in. These pulsations are usually caused by the operation of gas engines or compressors and can be readily eliminated at moderate expense by means of various "antifluctuating" devices, which permit the amount of gas needed to be drawn from the mains regularly with much less adverse effect on the service to other customers. Pulsating pressures are a nuisance to everyone, and because they are so noticeable are likely to cause an amount of dissatisfaction out of proportion to their real importance. A rule requiring the elimination of pulsations which can be invoked as a reason for requiring a customer to put in suitable antifluctuators is of advantage to the gas company and to nearly all of its customers. A regulatory body should not hesitate to order the company to shut off the supply of gas to a customer who will not provide the equipment needed.

(b) TOTAL VARIATIONS OF PRESSURE

We have next to consider variations of pressure in relation to the permanent adjustments of appliances. These adjustments, which limit the rate at which gas can be burned, are essential to the satisfactory or even safe use of gas, even in appliances which are regularly controlled manually by the user. It is, therefore, of the greatest importance that the pressure shall not vary too greatly to permit a single adjustment to provide for satisfactory service, and equally

important that the permanent adjustment of each appliance be correctly made with reference to the range of pressures to which it will be subjected. In order that the workman who adjusts an appliance may do his work properly, it is absolutely necessary that he know whether the pressure at the time of the adjustment is near the maximum, the minimum, or the average of those that will later prevail. If the adjustment is made on a July afternoon, for example, the adjuster should know the limits within which the pressure will be found on a January morning.

It has been customary to base formal requirements on the variations of pressure which occur within 24 hr. This practice has probably resulted from the difficulty of determining percentage variations of pressure over a long period of time rather than from a belief that they are unimportant. In the preceding edition of Standards for Gas Service, the practice was defended on the ground that the maximum variation during a given period was not likely to be much greater than the variation on the worst day. While this is true over a limited period of fairly constant conditions with respect to demand and the capacity of the various parts of the distributing system, it is by no mean always true if seasonal changes and those which result from the gradual obstruction of a main, or the connection of an industrial plant or a new subdivision of real estate to a small main, are taken into account. Such changes may result in shifting the whole range of pressures in a given locality and not merely in altering the pressure at the time of the daily peak. The recommendation that appliances be readjusted to provide for such changes of conditions lacked definiteness, since the amount of change which would make readjustment necessary was in no way indicated.

Under the rules proposed in the present circular, the utility is permitted to outline such pressure districts as it chooses, in each of which it must undertake to maintain pressures between 50 and 100 percent of a maximum specified for the district. In contrast to a rule of the form previously recommended, the proposed rule greatly simplifies the interpretation of pressure data, permits the regulatory body to determine that variations of pressure are not excessive over long as well as short periods of time, and provides the only arrangement that appears to have been suggested to make possible the intelligent control of appliance adjustment. It provides, moreover, a very definite basis for requiring the readjustment of appliances when changes of general pressure conditions make such readjustments necessary.

If the extreme limits of pressure in a district established under the proposed rule differ by only 100 percent of the minimum, the variation at a single outlet must be somewhat less than this. Similarly, the variation during any one day can be no greater and will usually be less than the extreme variation, while the limits of the district remain unchanged. The proposed rule is therefore somewhat more exacting than the familiar rule that the maximum pressure at one outlet during 24 hr shall not exceed twice the minimum at the same outlet. At the relatively high pressures now prevalent, the rule is less restrictive, however, than the rule recommended in the preceding edition of this circular, which included the following schedule

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of permissible variations of pressure corresponding to different minimums.

Minimum pressure (inches)	Greatest variation permissible
	Inches
2 to 3	2
3 to 4	2½
Over 4	3

This schedule has been adopted in several States. Compliance with it limits the extent to which economy in distribution can be effected by increasing pressures.

It was suggested in the preceding edition that the schedule be waived between the hours of 10 p.m. and 5 a.m. to permit the general reduction of pressures and to minimize loss by leakage at a time when little gas was being used. Reasons have already been given in the section on maximum pressure for limiting high pressures as severely at night as in the day. A different and less important reason exists for insisting on as high a minimum at night as would be permissible during the day. Pilot lights and other constantly burning or minimum flames must be set high enough to insure the performance of their functions even at night, and a large variation between day and night therefore results in the use of an unnecessarily large amount of gas throughout the day. It is a fact not generally recognized that in many households pilot flames, including those used in connection with oil-burning house-heating equipment, consume more gas than the kitchen ranges and rival the water heaters. To lower the pressure at night to save loss to the gas company by reducing the leakage from its defective mains, therefore, results in forcing some of the customers to use large pilot flames during the day. These customers have to pay for unneeded gas that may be greater in aggregate quantity than the leakage which would take place at night from the mains. It may pay the gas company, but it certainly does not pay its customers, to increase the total variation of pressure in order to keep the pressure low during the night.

5. ESTABLISHMENT OF PRESSURE DISTRICTS AND THE ADJUSTMENT OF APPLIANCES

Because the recommendation that districts be outlined, each with a fixed maximum of pressure, appears to involve a procedure unfamiliar to a large part of the gas industry, in spite of the fact that substantially the same thing is required by the rules of several States, the procedure will be illustrated by a hypothetical case. Figure 10 represents an area assumed to be served with gas through a network of low-pressure mains, not shown, which are fed from "transmission mains", the locations of which are given. To visualize the situation represented, it may be assumed that the demand for gas per mile of main is greatest near the middle of the bottom of the figure and falls off in general toward the top and the right but with a tendency to increase in a belt extending across the top.

It is assumed that, at the start, governors provide constant pressure at the point of delivery from the transmission mains into the

low-pressure system. Figure 11 represents the pressure conditions in the low-pressure system disclosed by a survey along "section lines" across the territory in question, the location of each of which is shown in figure 10. For each section two curves are given. The curve which shows the greatest variation represents the pressures during maximum demand, while the other curve represents the pressures during minimum demand.

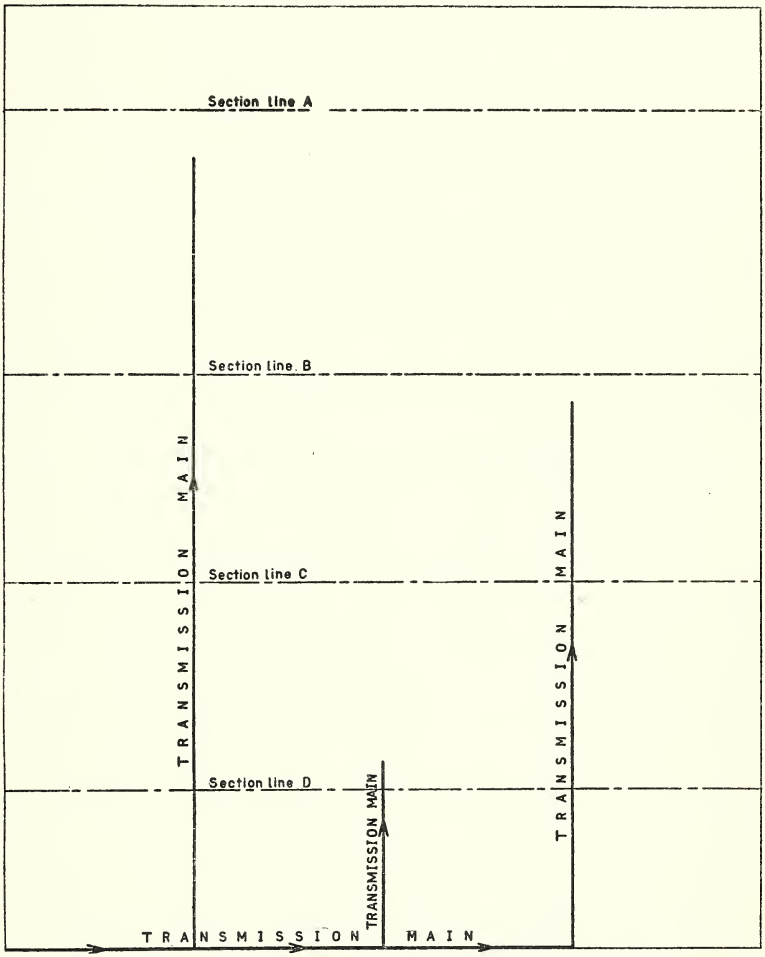

FIGURE 10.—*Diagram of area assumed for discussion of district pressures.*

If the pressure at which gas is delivered to the low-pressure mains is controlled to result in a minimum of variation in any part of the system, the pressure conditions represented by the curves in figure 12 will result. After adjusting the pressures at the inlets to the low-pressure system to give the most favorable conditions practicable, the utility can then decide on pressure zones which will permit compliance with the rules, the lower limit in each zone being 50

percent of the upper limit. The curves representing pressures during both maximum and minimum demand must fall between these limits. The limits selected for the zones along sections A–D are represented by the broken lines in figure 12. The steps in the broken lines, of course, represent the intersections of the "section lines" with the boundaries of the pressure zones.

When these intersections have been transferred to the map, the boundaries of the zones can be filled in by the exercise of judgment

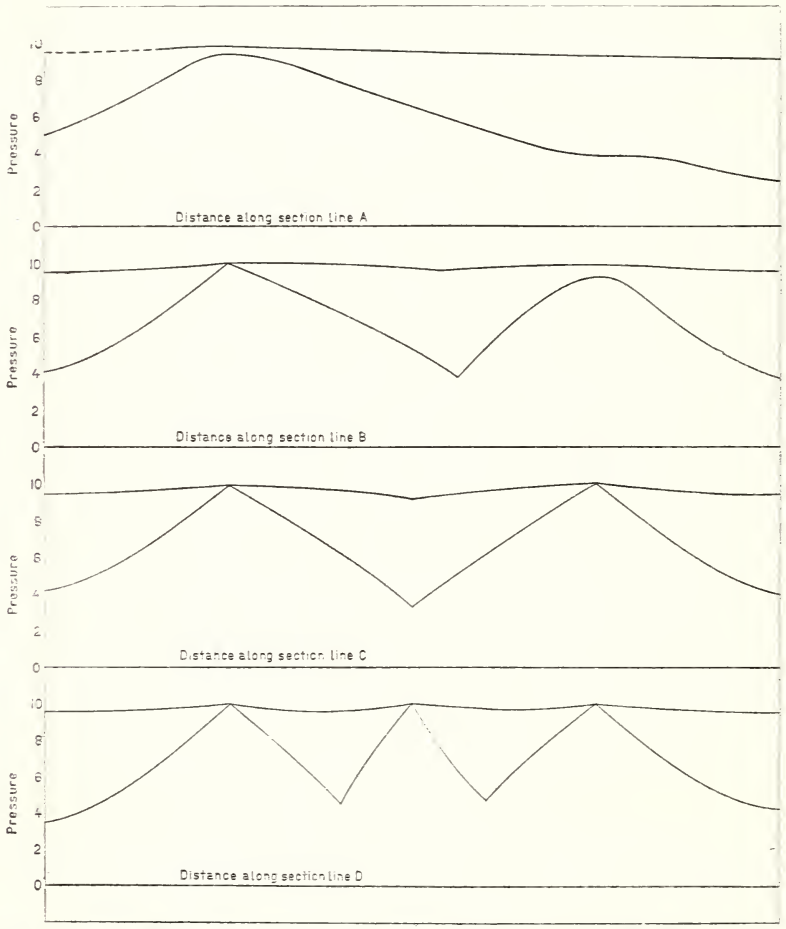

FIGURE 11.—*Original distribution of pressure conditions along the lines of survey.*

and a consideration of the distribution of consumers and the location of points of delivery of gas to the distributing system, as in figure 13. Once the boundaries of the zones are fixed the appliance adjuster has only to look at the map to find in what zone an appliance is located, and he can then proceed with certainty to adjust the appliance for safe and satisfactory operation. Most appliances meeting the "American Standard" are safe at pressures 50 percent greater than those at which they deliver their "normal ratings",

but appliances of certain classes are safe only at pressures not greater than 25 percent in excess of those which result in normal operation. If a general rule is to be followed, appliances to be universally safe must therefore be adjusted to deliver their normal rating at 80 percent or more of the maximum pressure to which they will be subjected. To allow a little margin of safety, it is probably a good rule to make the pressure for normal adjustment about 83 percent of the district maximum. Adjusters of appliances

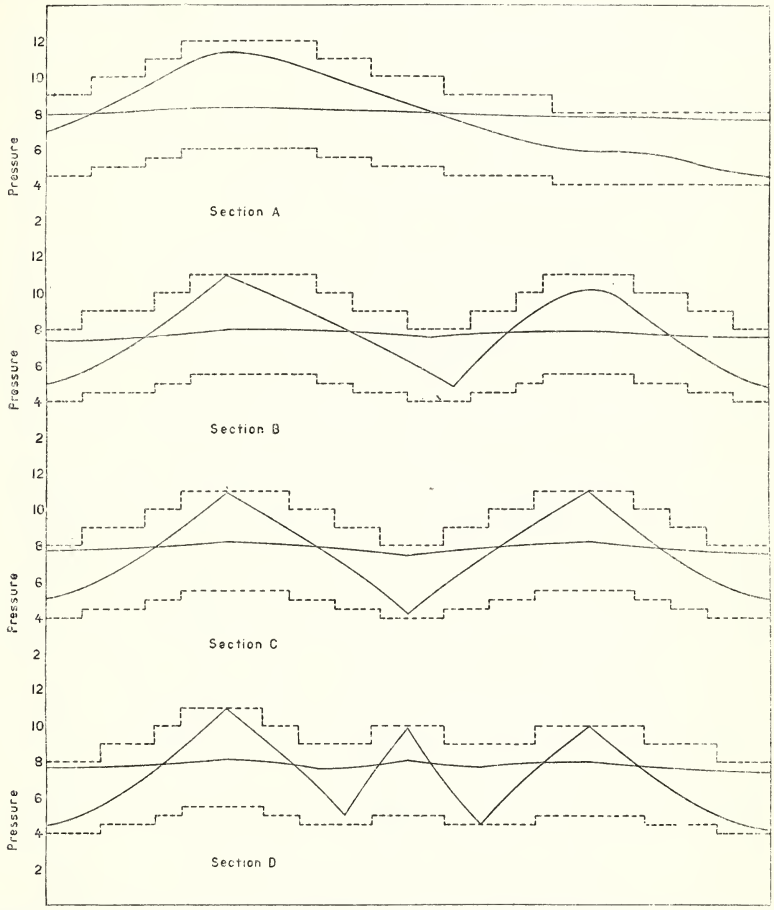

FIGURE 12.—*Maximum and minimum pressures altering pressures at inlets to low-pressure system, and selection of district maxima.*

known to be safe at gas rates greatly in excess of their normal ratings may adjust for a somewhat lower pressure, particularly if the appliance is of a type that does not give satisfactory service at rates much below normal; but in no case should the appliance be adjusted to deliver its normal rating at a pressure less than 70 percent of the district maximum.

If the appliance has a "fixed orifice" (i.e., a simple hole drilled in a metal fitting), an orifice of the correct size can be selected in

the office and sent out for installation. If the orifice is of the adjustable type, the adjuster should be provided with a table showing for any pressure the rate of delivery of gas which will insure safe operation at each district maximum. Whatever the pressure may be at the time of the adjuster's visit, he can then promptly make a safe setting by first connecting a pressure gage to the outlet and

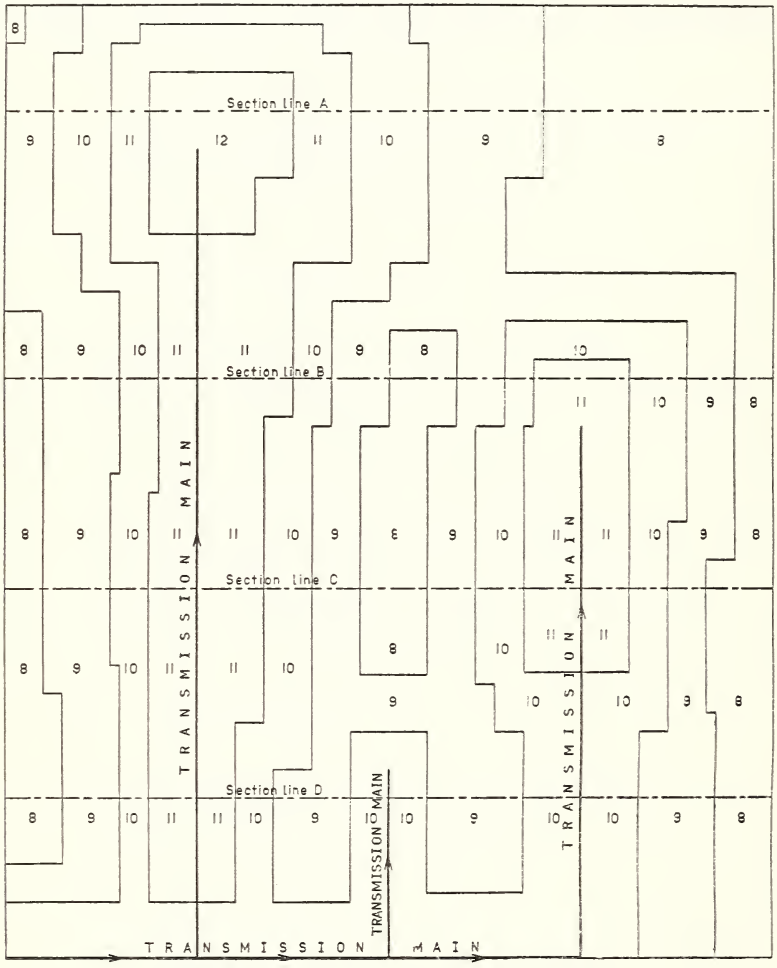

FIGURE 13.—*Outlines of pressure districts.*

Numbers represent pressures in inches.

then adjusting the orifice until the safe rate indicated by his table is obtained.

The result of adjusting appliances with relation to the maximum for each district shown in figure 13 is illustrated in figure 14. The figure shows the maximum and minimum pressures in percentages of the pressures required to effect the delivery of the normal ratings, if each appliance is adjusted to normal rating at 83 percent of the maximum pressure for the district in which it is located. The

solid lines represent pressures at times of maximum demand and the dotted lines the pressures at times of minimum demand.

The freedom given the gas company under the proposed rule to specify and alter pressure districts at will must be accompanied by the obligation to readjust appliances whenever it becomes necessary to change the maximum pressure within a district or to alter the boundaries of the district. Whenever conditions change enough to make it necessary to change the nominal limit, they have changed

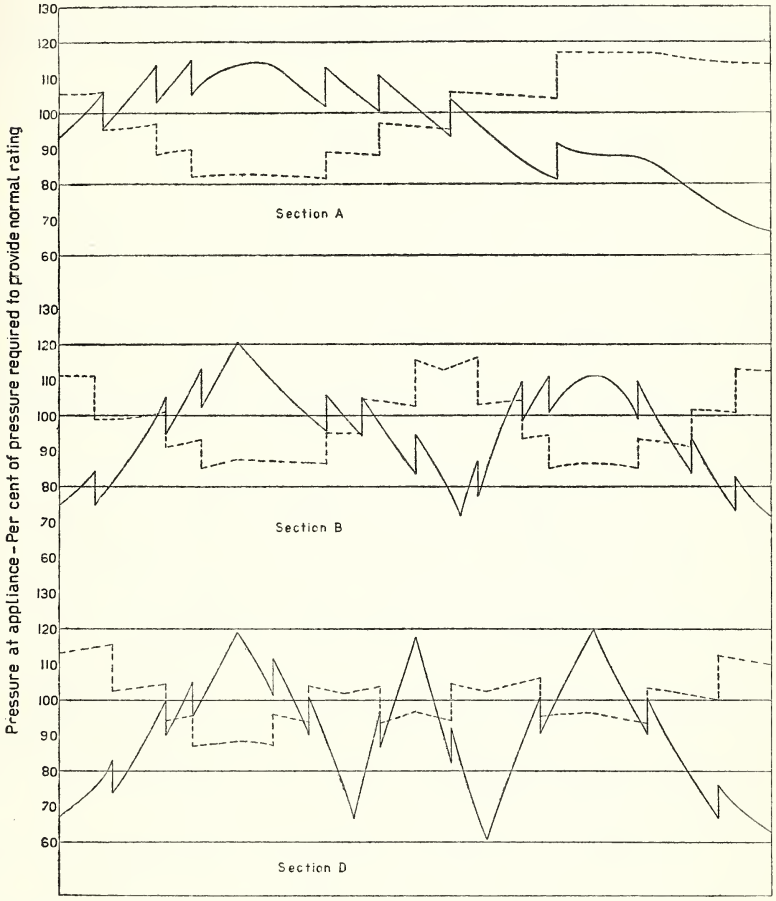

FIGURE 14.—*Pressure conditions at appliances adjusted to normal rating at 83 percent of the maximum district pressure.*

enough to make the readjustment of appliances also desirable. It is to be anticipated that the alteration of pressure districts will be made in small steps; that it will become evident at one time that the rules will be more easily complied with if the boundary of a district is shifted a block or two, and that later it will be seen that the shifting of the boundary of another district is desirable. In each case it will be necessary to adjust the appliances of those customers for whom the nominal pressures have been changed, and only those. It is one of

the principal advantages of the proposed system that it will serve as a definite guide as to when and where appliance adjustments will become necessary as the conditions of demand change.

6. PRESSURE RECORDS AND "SURVEYS"

Whether a system of pressure districts is outlined or not, it is the first essential of good service that the gas company be always well informed regarding the pressure conditions in all parts of the territory served. Without such information it cannot intelligently control distribution or adjust its customers' appliances; and, of all the functions it performs, these are the two of most direct importance to the users of gas.

Records must therefore be taken from which it will be possible to obtain a thorough knowledge of pressure conditions throughout a low-pressure system at any time. If the taking of these records is intelligently planned, they need not be very burdensome, consideration being given (1) to the fact that, if records are taken near the source of supply to any district and near the limit of distribution, intermediate points will have intermediate pressures, which can be judged fairly well from a knowledge of the distribution of customers on the intermediate mains; and (2) to the fact that daily and weekly curves tend to repeat with considerable accuracy so that when a survey has been made of a given district and when no noteworthy changes have taken place in the number or character of the customers served, the conditions in all parts of the district may be judged with considerable accuracy from those in one well-chosen location.

On a large system a pressure "survey" should be continuous, or nearly so, for the sake of economy in equipment and personnel, as well as for the purpose of detecting important changes when they occur. It is not necessary, however, to take uninterrupted records at more than a few "strategic" locations. If a record is made for a week at one point, little is to be learned from taking records at that point during the next month or two, and it is better to move the gage to a new location. Arrangements should be made for returning periodically, preferably at least once in 3 months, to the more important stations, the relations of which to their districts are fairly well known. The relationships of the variations at each of these stations to those of neighboring ones should be known from some overlapping of records.

Recording gages are not very expensive; the greatest bar to their more extensive use is involved in their installation and attendance. In some cities it is the practice to maintain a recording gage in every station of the fire department. It should be easy to arrange through cooperation with the city government to have the records changed and mailed to the company by a fireman at little or no expense. Fire houses are well distributed in every important part of a city and will in most cases serve very well as the permanent stations at which periodic records are taken. They are rarely near the extreme limits of distribution, however, and it is necessary to supplement their records with 24-hour records taken near these limits often enough to indicate the adequacy of the outlying mains. When fire houses are not suitably located or are for any reason unavailable,

gages can be located in school buildings, apartment houses, or private residences, and in most cases arrangements can be made with someone to change the charts when necessary, so that the cost of taking records cannot be given as an excuse for inadequate surveys. As a check upon the constancy of pressure conditions between periodic tests, continuous records should be made at a few suitable locations.

The plans of the distributing systems will differ so much in different communities that it is hardly practicable to provide for suitable pressure control by specifying the number of gages to be used in relation to the length of mains, etc. It seems preferable merely to require adequate records to cover the system at all times and to leave the gas company free to obtain those records in whatever manner it thinks best.

7. POINT OF MEASUREMENT OF PRESSURE TO DETERMINE COMPLIANCE WITH RULES

The point at which the gas passes from the control of the gas company to that of the user is the outlet of the meter. In nearly all localities the maintenance of all the piping and facilities used in bringing the gas to that point is the responsibility of the company. If low pressures or variations of pressure are caused by the sticking of the meter mechanism, as sometimes happens, the customer has as much reason to complain as though the conditions were caused by trouble at the plant. For this reason many regulatory officials have specified pressures and variations of pressure at the outlets of the meters.

There are two reasons, however, why it is more practicable to determine the actual pressure at the outlet of the service pipe (usually the inlet of the meter) than at the outlet of the meter. The first reason is that there is always or nearly always a fitting at the end of the service pipe, one end of which is plugged. The primary purpose of this fitting is to facilitate the removal of foreign material from the service pipe; but it serves conveniently for the attachment of a pressure gage. A more important reason for attaching the gage at the inlet of the meter is that it is impracticable to determine the conditions of pressure in each house individually. The pressure conditions throughout the city must be judged from observations made at relatively few places, and it is not desirable to have the data on which the judgment is based affected by the operation of an abnormal meter. For these reasons many sets of rules, including those recommended in the preceding edition of this circular, specify the outlet of the service pipe as the point at which pressures shall be determined. The rule recommended in this circular is intended to eliminate the disadvantages of both of the earlier forms. By specifying the conditions at the outlet of the meter, the individual customer is fully protected. It becomes obligatory to include the meter in checking up the pressure conditions on the premises of a customer who has complained; but the routine determination of conditions in the system as a whole may be made by attaching the gages to any convenient service outlet. The interpretation of the readings thus obtained with relation to the requirement is stated in the rule.

8. CONTROL OF PRESSURES BY MEANS OF INDIVIDUAL HOUSE REGULATORS

The preceding sections relate primarily to "low-pressure distribution" in which the pressure in the mains in the street is delivered to the customers' house piping without modification by a "governor" or "regulator."

High-pressure or "intermediate-pressure" systems of distribution are commonly employed in which pressures higher than are desirable at the appliance are maintained in the mains and are reduced by means of regulators in each house. By an intermediate-pressure system is usually meant one carrying less than 5 pounds per square inch, but the distinction between intermediate- and high-pressure systems is not fundamental and is not everywhere made. For the purpose of this circular all pressures requiring reduction by regulators may be considered "high" pressures.

If pressure regulators always functioned perfectly, it would assist greatly in maintaining good service to supply each household from a main containing gas at high pressure through a regulator that would insure constant pressure at the inlet of the house piping.

However, the unsatisfactory operation of regulators, especially failure to completely shut off the supply of high-pressure gas because of the presence of foreign material on the valve seat or other mechanical difficulty, is frequent enough to result in service that is generally inferior to that provided by a low-pressure system.

For this reason, the use of a high-pressure system is not to be recommended unless customers are so scattered that a considerable saving results in comparison with the cost of low-pressure distribution. No general restriction of the use of the high-pressure system appears to be desirable, however.

If house governors are employed, the problem of maintaining or enforcing desirable conditions of pressure assumes a totally different character than that involved in low-pressure distribution. A regulator in good condition will deliver any pressure for which it is set with entirely negligible variations; but a regulator that is out of order will usually cause pressures or variations of pressure far beyond any limits that might be considered permissible. All questions as to what constitute permissible variations and limits are therefore eliminated when regulators are used. In their stead appear the problems of providing for safely vented seals or other safeguards against dangerous pressures and of maintaining the regulators to insure that they function properly.

Unless there is special reason for the contrary, regulators should be set to deliver the same pressure to all customers in the same territory. Usually 4 in. will be about the most satisfactory pressure for manufactured and 7 in. for natural gas. Appliances should be adjusted to take their normal ratings at the pressures for which the regulators are set.

No system or schedule for the inspection and maintenance of regulators appears to have been generally accepted. It is suggested that a stopcock and outlet of convenient form for the attachment of a pocket gage be installed near the outlet of every regulator, and that it be made a part of the duty of the meter reader to assure himself monthly that each regulator is functioning at least

reasonably well, and that gas is not blowing continuously from the seal. When any evidence of improper operation is observed, and in any event whenever the meter is changed, the regulator should be returned to the shop for inspection and any repair needed.

The 24-hr records so essential to the control of low-pressure systems appear to be entirely useless as applied at the outlet of a house regulator, since the operation of the regulator depends on its individual mechanical condition, is not much affected by the daily variation of pressure in the mains, and does not represent conditions of service to enough customers to justify a test requiring so much time. Enough records of the pressure in the mains should, of course, be taken to make sure that it is at all times above the pressure for which the regulators are set. Usually this will require very little effort.

At the present time it is difficult to formulate a general rule to be applied to high-pressure distribution, but a regulatory body should require each company to do enough testing of regulators to satisfy the officials of both the company and the regulatory body that the regulators are generally in good condition.

V. METERS AND METER TESTING

Since the record given by a meter of the volume of gas passed is the basis of settlement between the company and the consumer, the importance of correct meter registration is evident. The consumer is justified in expecting that his meter will be correct when installed, and also that it will be retested at sufficiently frequent intervals so that important discrepancies which develop subsequently will probably be detected promptly. In addition, arrangement must be made for special tests when there is any reason to suspect a particular meter of being in error; and a basis for adjustment of such errors when detected should, of course, be provided. The rules proposed to cover meter accuracy and testing provide for all of these contingencies. The fact that some meters may become "fast" and thus result in bills too large, and others "slow" or "D.R." (don't register), making other bills correspondingly too small, does not make frequent meter testing of less consequence to a gas company. For, to neglect meters and permit them to become inaccurate, with the complaints which inevitably result, is a condition not desired by any company. And the gas-using public can well afford a reasonable expenditure for meter testing in order that each user may be protected from possible excessive charge. In some cases the testing work desired is carried out by State or municipal officials, who actually check every meter before it is installed for use on a consumer's premises and check it again when removed. In general, however, this is not necessary, as a gas company can do this work accurately and more economically than is usually possible in municipal and State laboratories. Moreover, even with State or city inspection, practically all of the necessary testing must be duplicated by the gas company as a part of the routine practice of the meter repair shop. In this way State or city inspection of every meter is likely to result merely in duplication that creates an unnecessary expense. The work done by the company can readily be supervised as to apparatus, methods, and records; and in this way at very little

expense the public official having local jurisdiction over matters of gas service can insure accurate and regular work in the company shops, without the necessity of any duplication. The extent to which these details of the company's work need be prescribed in advance is clear from the proposed rules.

In any city where the gas company has as many as 500 meters in service, it should certainly be required to purchase and use a standard meter prover to test its meters regularly, as provided in the rule. Where fewer meters are in use it may often be more economical to arrange with a larger company in a nearby city to do the necessary testing, but under any circumstances regular testing should be maintained and the facilities for this work be readily available.

1. ACCURACY REQUIRED

The custom sometimes followed in the past, of putting a meter back into service without adjusting it, if it is found to be less than 2 percent in error, is not satisfactory. It is recommended that meters be adjusted with the highest accuracy commercially practicable before installation. A tolerance of 1 percent fast or slow is sufficient for any company which carefully supervises its meter shop. With such tolerance meters will start in service as nearly correct as it is practicable to have them. It is possible to set all but a very few old-style meters to be correct within 0.5 percent on every adjustment, and these older styles can be set correct within 1 percent. In all but the smallest companies it is proper, therefore, to require that every meter be set within 1 percent of correct before it is put into use. Of course, it is understood that the allowance of this variation from correctness does not mean that the meters will be set in error by this amount; the tolerance allows only for the unavoidable irregularity of the work on a commercial scale, and the average of the errors will be practically zero, substantially as many being slightly slow as are slightly fast.

For a company which has less than 1,000 customers and which does not have facilities for opening meter cases and adjusting the mechanism, it is probably wise to allow a somewhat greater tolerance than that above mentioned. In such cases, the company should be allowed to put a meter back into service without readjustment, if it is not in error by more than 1½ percent and appears otherwise in good order, rather than to incur the expense of shipping the meter away to a meter shop.

While a meter should be set to be correct within close limits before being installed, it cannot be expected to retain this very high degree of accuracy throughout the period of its use. In fact, it should not be classed as a fast or slow meter unless it is found to be in error by more than 3 percent.

Instead of requiring that meters be adjusted before installation to be between 1 percent fast and 1 percent slow, as here recommended, the New York Commission requires that they be adjusted to be between 0 and 2 percent slow. Some companies in other States have voluntarily adopted the same practice. The reason for this is that meters tend to increase their registration during at least the first 2 or 3 years after they are placed in service, and during this period

they may be expected to give a more nearly correct average registration if they are initially a little slow.

Since a range of adjustment of the same magnitude is permitted by both rules, and the average change from the initial setting which occurs in use may be expected to be independent of that setting, the difference in the two practices must ultimately result in the meters in New York having an average registration, for the same quantity of gas, just 1 percent less than meters adjusted according to the recommendation made here.

If the gas industry were starting anew, it would probably be desirable to make the New York practice general for its psychological effect. To introduce it where the other practice already prevails, however, would amount to making a general reduction of 1 percent in the rate at which gas is sold, the reduction to apply only to those customers who are so fortunate as to have had their meters changed after the initiation of the new policy. Since the existing rate has usually been determined by a consideration of the cost of and the returns from gas as sold in the past, such a reduction of rate made without reconsideration of the costs and returns of individual companies does not appear fair either to them or to those customers whose meters had not been readjusted to the new basis.

Since in most localities the meters in service were adjusted to an average of zero rather than an average of minus 1 percent, it is here recommended that the practice remain unchanged.

2. FREQUENCY OF ROUTINE TESTS

As indicated above, it should be required that all meters be tested before installation for use on the consumer's premises. This would apply not only to old meters which have been repaired or removed from service for any cause, but also to new meters. The testing of a meter which is purchased from a manufacturer may seem unreasonable, for these meters are supposed to be very carefully adjusted. However, the gas company is responsible for the condition of the meters and the manufacturer's adjustment should not be depended upon.

Since a large part of the expense in routine testing of meters is the result of the time required to remove a meter and replace it by a new one, it works no hardship to require that every meter be tested before installation, even though it has been tested only a short time previously. Most companies, because of this fact, never reset a meter without retesting it, even though it may have been in service only a few months.

In the preceding edition of this circular it was recommended that all meters be removed for testing once in 5 years. As a saving to the gas company and indirectly to its customers, a different practice is recommended in the present edition; the frequency of routine testing is made dependent upon the amount of gas metered and the probability that the error in metering it will be great enough to justify the cost of making the test.

The new recommendations are based on the following considerations. A gas company's meters are a part of its system for the maintenance of which it has full responsibility. The condition of

the meters is largely subject to the gas company's control through the frequency and thoroughness with which they are reconditioned and the care exercised to avoid conditions in the distributing system that will result in corrosion, the hardening of the leather diaphragms, or the formation of gritty or gummy deposits. The company is in position to determine for itself to what extent it is profitable to undertake the expenses of removing, testing, and reconditioning meters to protect its own revenues from loss through slow or inoperative meters. Therefore, on the one hand the company should not be allowed to charge a customer for gas which has not been registered by a meter but can only be uncertainly estimated, because of the company's own failure to maintain the meter in good condition; and on the other hand it should not be forced to protect itself from losses of this kind by a greater expenditure for testing and reconditioning than is warranted in the judgment of its management.

These considerations dispose of the question of meter testing so far as it relates to slow meters, and lead to the conclusion that meter testing should be required of the company only to the extent that is justified in order to protect some of the customers from being overcharged through fast meters. Comprehensive data from several sources indicate that, during at least the first 6 or 8 years of the life of meters, the overregistration of fast meters and the underregistration of slow ones are pretty well balanced, so that as far as the total amount of money paid to the company by its customers is concerned, there is no good reason for incurring the expense of routine testing within that time.

In attempting to arrive at the most desirable period for routine testing, let us first assume that no refunds are made for faulty registration and that the customers as a whole pay for the meter testing in the rate, so that the cost of testing is directly balanced against the benefit which the customers derive from it. Since there is no appreciable gain or loss in the aggregate from inaccurate meters, the benefit for which a customer pays, in the general rate, for his share of the cost of testing, is purely that of insurance against the possibility that he will be one of those with a fast meter.

It will be readily agreed that insurance is too expensive if the insured has less than an even chance of saving or recovering without interest in the future only the amount of money he pays at the present. Hence, if the consumers have to pay for meter testing in the rate, they cannot profitably pay more for it than the total amount which they would lose through fast meters if no testing were done. Similar reasoning shows that if the company could refund in each case exactly the amount received through overregistration, but took the loss of underregistration and payed the cost of testing, it would be justified in an expenditure for the latter purpose equal to the underregistration that would be prevented. Since meter errors in the two directions are pretty well balanced, both assumptions lead to the same result; that it is undesirable to incur an expense for meter testing greater than the aggregate errors in one direction which will be prevented thereby.

If this principle is accepted, it is obvious that the probable error of a meter through which but little gas is used (in the extreme case,

less than that corresponding to a minimum bill) will not be sufficient to justify testing at frequent intervals, if at all; but that it may be well worth while to test frequently a meter upon the readings of which large bills are based.

Since the protection of customers against overcharging is the purpose of the required tests, the frequency of such tests should be based on the errors of fast meters, leaving to the utility the responsibility for taking whatever action is necessary to protect itself from loss as the meters approach an inoperative condition.

If we have a table of meter errors corresponding more or less closely with the mortality tables of a life-insurance company, it is possible to compute for any annual demand and any rate schedule the average loss to customers through fast meters and to compare this with the cost of testing the meter at certain intervals. The above statement may be clarified in this way: If customer A pays for having his meter tested every 3 years, it costs him a little more money than if he pays for having it tested only every 4 years. The only justification for paying for the 3-year tests is that he may avoid being overcharged because of error between the time of the two tests. We can compute whether he has or has not an even chance of saving in this way the amount he pays for testing. If he has not an even chance, it is certainly not economically justifiable to make him pay for the more frequent testing. Similarly, we can compute whether he is justified in paying for a test every fourth rather than every fifth year, etc. The same considerations that apply to customer A apply to the community as a whole.

Computations were made using what is probably the most reliable set of available data regarding meter errors, and assuming that the gas is sold at a uniform rate per unit of volume and that there is to be no refunding. The results indicate that if the annual bill is more than 450 times the cost of testing the meter, it pays to have it tested every year; if the annual bill is more than 85 times the cost of a test, it pays to test every second year; and if the annual bill is more than 42 times the cost of a test, it pays to test every third year. It pays to have a meter tested every third year or not at all. The reason that it does not pay to test the meter in later years, considering only protection to the individual customer, is the trend of meter errors toward the slow side with advancing age.

The requirement that refunds be made for fast meters and the inclusion of other data regarding meter errors both tend to increase the computed amount of the bill which justifies a test. Hence, it seems desirable to round off the numbers given to 100 and 50 times the annual bill as the amounts which justify the testing of meters at intervals of 2 and 3 years, respectively. In the proposed rules, wide latitude is given the utility in arranging its work by providing that a meter may be tested at any time within a year after the test is "justified" by the foregoing considerations. The largest meters, under this rule, might be left in service anywhere between 1 and 2 years. Since the computed bill which would justify a test at the end of 1 year is 450 times the cost of testing and that which would justify a test at the end of 2 years is 85 times the cost of testing, it seems that a limit of 200 times the cost of testing is a fair compromise for determining which meters shall be tested between the first and

second years. If the recommendation now made with respect to routine meter testing is generally adopted in the place of existing rules, its net effect will be to relieve most gas companies of the greater part of the testing at present required, since a relatively small fraction of all customers have annual bills as great as 50 times the cost of removing and testing a meter. Most of the meter testing now done is not worth its cost as a protection to the customers.

The above discussion applies only to diaphragm meters of the usual type. Several other types of meters are in use, usually only for the measurement of very large quantities of gas to industrial customers or other gas companies. These meters are so exceptional that it seems best to provide for their testing by means of special rules appropriate to the type of meter employed.

3. TESTING AT REQUEST OF CUSTOMER

The rules formerly recommended by the Bureau have required the utility to test meters on the request of their customers without charge (subject to certain limitations). Such a rule is inconsistent with the requirements for routine testing now proposed. Except for a very rare mistake in the construction of a meter, such as the installation of the wrong set of dials or gears, it is almost impossible for a meter to be more than 10 or 15 percent fast, and the number of meters more than 6 percent fast is so small as to be almost negligible. The error which does occur in this direction develops gradually as a result of decreased friction in the packing and the gradual loss of flexibility of the diaphragms. With possible rare exceptions, the use of gas by an individual customer varies too much from month to month for a gradually developing error of even 15 percent to be detected, hence, complaints of fast meters are substantially never justified by the customers' observations. When a customer requests the testing of a meter for which a routine test would not soon be required by the rules, he is, therefore, asking for an expensive service which, in justice to the other customers, he is not entitled to receive unless he pays for it. Therefore, the utility ought not to be required to make the test without charge unless the result shows that the meter actually needs adjustment. If the meter is either fast or slow beyond the permissible limit, the information is of enough value to the utility, in connection with its responsibility for maintaining its meters in good condition, so that it should bear the cost of the test.

It is realized that requests for meter testing are relatively rare and that the utility may be willing to comply with them without charge for the sake of retaining the customer's good will. The rule recommended leaves the company this option. If the utility thus expends the cost of the test for the sake of promoting satisfactory relations with its customers, it is entitled to credit for the action and should have the opportunity to show that its act is voluntary and not required by the regulatory body. The rule permits the utility to charge only 75 percent of the cost of testing even if the meter is correct, because the information gained is useful to the utility, if only because it postpones the date of the next required routine test.

It is generally better that the gas company should have the opportunity to make tests upon request of the customers and thus adjust

its accounts like any other business organization, rather than that all complaints of suspected meter error should go at once to the city or State inspectors. There is no reason to believe that a gas company will take any advantage of the customer in the sense of improperly testing or incorrectly adjusting meters. When the work of the company is properly supervised by State or city authorities, persistent errors of this sort could not escape detection, and the customer need not anticipate any deliberate overcharges of this sort.

However, a test to determine the accuracy of the meter should be made by the company only if the customer is satisfied in advance to accept the results of such test as the basis for adjustment of the accounts which are suspected of being in error. This is an essential condition on the score of justice to the gas company. Unless the customer is willing to accept the results of the company's work it is better, therefore, that he should secure a test by the city or State officials in the first place.

If a customer desires a test by a city or State representative, he should be expected to pay the cost of the test unless the meter is actually found in error to his disadvantage, in which case the gas company can properly be charged the cost of the test. The basis upon which these tests by city or State authorities can properly be made and the fees adjusted is indicated in the proposed set of rules. The amount of the fee should be made as nearly as practicable equal to the total cost of the test, not only the cost to the city or State but also that cost incurred by the company in removing the meter for test and replacing it with a new one. If the fees are not made adequate to cover the expense, the condition may arise that a company will ask the officials to do the testing work on large meters at nominal fees, and thus the city or State will be incurring some expense that should be borne in the meter-testing department of the company. In one or two instances this has actually been the experience of officials working under a fee system not adequate to provide for the actual expenses incurred in the work.

Whenever a test is made by either company or public official at the request of a consumer, the consumer should be encouraged to be present personally or by representative at the time the test is made so that he may satisfy himself that the work is fairly and carefully done. The actual supervision of the work which the consumer can exercise is of course small, but the psychological advantage of thus handling the case openly and frankly is considerable.

4 ADJUSTMENT OF BILLS FOR METER ERRORS

In case meters are found to be fast by more than 3 percent as a result of any test, the probable excess in charges during the previous period of use of this meter should be refunded to the consumer, and any fee deposited for the test returned.

There is much difference of opinion regarding the manner in which such refunds should be computed, and whether backbilling should be permitted in the case of slow meters. The disagreement involves questions of legal precedent, and policy as well as those of technology. The technical facts will be discussed first.

Two causes for fast meters are recognized. One is the reduction of friction by the loosening of packings and bearings; the other is the stiffening or shrinking of the leather diaphragms. The first change usually takes place in a relatively short time after the meter is placed in service, as is the case with other mechanisms. The hardening of the diaphragms appears gradually, but the rapidity with which it develops depends on several conditions, chief of which is the kind and amount of vapors in the gas stream which are condensed on or absorbed by the leather and the oil with which it is originally impregnated. The available data relating to the rate at which hardening appears are mainly statistical in character and not altogether satisfactory. They indicate, however, that meters placed in service usually tend to become fast at first, but that the change takes place at a diminishing rate either because of the rapid initial decrease of friction, because the diaphragms tend to reach an equilibrium with their environment, or because the effect of the hardening diaphragms is more or less balanced by other conditions that tend to make the meter "slow." While the individual histories of meters are somewhat varied, the general tendency is well enough marked to make it probable that the average registration of a meter during a period of service will be somewhat greater than would be computed on the assumption that it reached its final condition at a uniform rate.

It is therefore only fair to the customer to compute a refund on the assumption that the meter has averaged half as fast during the period of service as it is found to be at the end. It is simpler and, in view of the uncertainties involved, accurate enough to compute the refund for the last half of the period of service, assuming the full error to have existed during that time.

The principal uncertainty regarding the desirability of refunding for so long a period has to do with the effect on the customer's attitude toward the company rather than with the substantial fairness of the adjustment. If a meter remains in service for 8 or 10 years and is then found to be 4 or 5 percent fast, the refund for half the period is large enough to gain a good deal of attention from the customer. In some cases the fact that a refund is made, instead of being taken as evidence of the company's fairness, as it should be, is regarded as indicating that the metering or accounting has not been reliable.

The provision in many rules that past bills shall be examined to determine, if possible, when the meter became fast is worse than useless. Except for the initial relief of friction, overregistration always develops slowly for the reasons already stated, and the percentage of error in that direction is seldom great enough to permit the time of its occurrence to be judged accurately from a change of bills, even if it occurred suddenly. The provision referred to, therefore, merely opens the way for uncertainty and dispute.

If gas is charged for at a uniform rate per thousand cubic feet, the computation of refunds is simple, since only the total amount paid during the period covered by the refund need be considered. With the complicated rate schedules now commonly employed, this method will result in a larger refund than that to which the customer is entitled. To eliminate with accuracy the effect of minimum

bills and service charges or their equivalent, which are not affected by the meter readings, the volume of gas used during each billing period would have to be corrected independently and the corresponding bill determined. Usually, however, this procedure will involve a large amount of bookkeeping and will result in a difference of only a few cents from the result of the simple procedure of basing the refund on the average volume of gas used per billing period, and computing a corrected and an uncorrected average bill from that. The departure from accuracy, if the latter method is employed will always be in the customer's favor. It should, therefore, be optional with the company which of the methods is employed.

A company with small steps in the rate schedule will probably prefer the second method, at least for all but a few of the largest customers. A company with large steps in the rate schedule will certainly use the first method for large customers.

For example, assume that after 2 years in service, a meter is found to be 5-percent fast, and that the schedule of rates is:

cu ft	
First 500 or less	$1.00
Next 1,500	1.50
Next 3,000	1.00
Next 5,000 or less	.75

Meter readings during the second year will be assumed to be:

	cu ft		*cu ft*
Jan. 1	100,000	Aug. 1	128,300
Feb. 1	107,000	Sept. 1	129,000
Mar. 1	113,000	Oct. 1	134,000
Apr. 1	118,000	Nov. 1	138,000
May 1	122,000	Dec. 1	144,000
June 1	126,000	Jan. 1	150,000
July 1	128,000		

The bills rendered would have been:

Jan	$7.75	Aug	$1.30
Feb	7.00	Sept	6.25
Mar	6.25	Oct	5.25
Apr	5.25	Nov	7.00
May	5.25	Dec	7.00
June	3.25		
July	1.00	Total	62.55

Under the method of computing the refund as a percentage of the total bill paid for gas, the refund would be:

$$\$62.55(1-1/1.05)=\$2.98.$$

Under the second alternative in the rule now proposed the refund would be computed as follows:

Average monthly consumption indicated by meter

$$\frac{150{,}000-100{,}000}{12}=4{,}167 \text{ cu ft}$$

Corresponding monthly bill, $5.42.

Average monthly consumption corrected

$$4{,}167\div 1.05=3{,}967 \text{ cu ft}$$

Corresponding monthly bill, $5.22.

Amount of refund

$$12\times(\$5.42-\$5.22)=\$2.40.$$

Under the first alternative now proposed, it would be necessary to compute each month's corrected bill individually by the method just employed for the average bill. The results would be as follows:

Jan	$7.50	Aug	$1.25
Feb	6.78	Sept	6.01
Mar	6.01	Oct	5.06
Apr	5.06	Nov	6.78
May	5.06	Dec	6.78
June	3.11		
July	1.00	Total	60.40

The refund would, therefore, be

$$\$62.55-\$60.40=\$2.15.$$

In many localities the gas companies are permitted to "back-bill" customers for gas used through meters found to be slow. In practically all cases the adjustment permitted is for the same period and the same percentage of the error found by test as in refunding for over-registration.

There are excellent reasons why this practice should not prevail. Whereas meters become fast as the result of two simple causes, the development of which follows a course about which something is known, meters may become slow as the result of internal leakage through valves and through cracked or corroded parts or as the the result of sticking, wear, breakage, displacement, looseness, deformation, or obstruction of moving parts. Several of the conditions that may cause the meter to register less gas than passes through it, or to fail to register at all, can occur suddenly. There is therefore no ground for presumption that a slow meter has been approaching that condition at a uniform or diminishing rate; the probability is rather to the contrary. As already mentioned, the gas company has entire control of the condition of the meters when installed in service and is responsible for the conditions to which they are subjected subsequently. Through its meter testing it has opportunity to know the average condition of the meters which have been in service a definite time and can plan their repair as frequently as is economically justifiable.

Either because they recognize that the responsibility for the meters is theirs or because they find that back bills are difficult to collect and lead to a loss of good will, only a minor fraction even of the gas companies which are authorized to collect for unmetered gas ever avail themselves of the privilege. In a questionnaire previously referred to 340 companies answered the questions relating to their practice with respect to back billing. Of this number 209 indicated that they do not attempt at all to collect for the underregistration of slow meters and only 23 indicated that the collection was placed on the same basis as the refunds for fast meters. An equal number collect only for "D.R." (don't register) meters.

5. PREPAYMENT METERS

"Prepayment meters", which operate to deliver a definite volume of gas after a coin has been inserted, were once popular in this country, but have almost disappeared. They are still extensively used abroad. Meters of this type have always been the source of more than their share of dissatisfaction and disputes which the

regulatory bodies had to settle. Much more important than this consideration is the fact that the automatic turning on and off of gas is hazardous because of the possibility that gas will escape unlighted from forgotten openings. With many types of modern appliances with their pilot lights such a discontinuous supply of gas is prohibitively dangerous.

If there is any place in which the prepayment meter may be safely and conveniently used, it is in tourist camps and summer cottages supplied with one or two simple appliances apiece. Even in such locations, however, it is preferable to install a master meter on the basis of which the gas company will collect from the owner or manager of the camp, and to rent to the management submeters of the ordinary type, leaving the manager or caretaker to collect from guests when they leave, on the basis of the meter readings.

VI. EXTENSION OF MAINS AND INSTALLATION OF SERVICE PIPES

In the introduction to this circular, it was pointed out as one of the essentials of good service that the supply of gas should be made available to all parts of the territory served. The availability of gas is, without question, of great value to the citizens of any community and is usually the principal and frequently the only consideration for which the gas company is granted valuable franchises and privileges, including the right to dig up and permanently occupy the streets, which are public property. Every property owner, even if not already a gas consumer, therefore, has an interest in the system for supplying gas as well as does a regular customer, and his interest should be as fully protected by reasonable and uniform rules as those of existing customers. For that reason, it seems entirely appropriate to include in a discussion of standards for gas service the subject of the conditions under which that service will be made available to those who need it.

1. EXTENSION OF MAINS

Relatively few States have rules which cover completely the initial cost of extensions of the distributing system and the initial cost, ownership, and upkeep of service pipes. These subjects are customarily, though not always, left in part at least to the determination of the utilities themselves; and it is not surprising that we find an extraordinary variety of arrangements.

Some companies make no free extensions of mains to accommodate new customers. Others have no definite rule on the subject. Approximately half the companies make free extensions of standard length to all customers; a majority of the remainder will make an investment equal to the product of a stated factor and the anticipated annual gross revenue to be derived from the extension; and a minority compute the net revenue to be anticipated. The rules reported by several companies are so unusual as to defy classification. A large number of utilities have two or more different bases for determining the free extension. In some cases the choice of the alternatives offered is optional with the customer, in other cases with the company. The standard length of free extension provided

by various companies ranges from 40 to 500 feet; the investments they are willing to make vary from 75 percent to 550 percent of the gross annual revenue; or they require a net return of from 5 to 15 percent of the investment. Practice with respect to customers' deposits and guarantees for extensions is even more varied, and a few of them seem positively unfair.

Although it might be impracticable to state a definite length of extension which all utilities should make in order to serve new customers, there should be no difficulty in stating the principles by which such extensions may fairly be determined, and in formulating general rules which will insure the application of the principles with reasonable uniformity. Theoretically, at least, the utility's rates are based on the cost of its operations plus a fair return on the investment. It is usually assumed for purposes of rough calculation that costs of production are proportional to the amount of gas made, and "customer" costs to the number of customers served. If this is a correct assumption and a rate is exactly fair to everyone before the addition of new customers, it will remain exactly fair if the new customers require an investment to serve them which is proportional to the amount of business they produce.

There is some uncertainty in applying this principle to the determination of a fair basis for extensions, but not much. The recommended rule is intended to make the utility's investment in the distributing system, per unit of output, independent of the addition of new customers. Reasons can be advanced both for a more liberal and a less liberal policy than this. It may be argued that when a small number of customers is added the utility does not, in fact, add new manufacturing equipment, and that in order to keep the investment on a fair basis with respect to the rates the utility should make an investment in the extention proportional to the valuation of its entire plant instead of to the valuation of the distributing system alone. On the other hand, it may be contended that in bringing the gas to the limit of its existing system the utility has already given the same service that is given to other customers, not only with its manufacturing plant but with its distributing system as well, and that the addition of a large number of new customers will require the provision of additional facilities for both manufacture and transmission, so that the new customers are entitled to less in the way of a new investment than is proportional to the cost of the original distributing system.

The divergence between these points of view results, of course, from the fact that the utility's investment increases in a series of steps. If the utility makes an investment in the extension for each customer proportional to the added demand and to the investment in the existing distributing system, as recommended, and if existing facilities for manufacture and transmission are not added to because of the expansion, the rate of return on the general investment is increased. As still more new business is added, it becomes necessary to add facilities for manufacture and transmission. If the last group of customers whose requirements make the new facilities necessary is regarded as "the straw that broke the camel's back", the acceptance of their business decreases the rate of return to the utility. If the ultimate result of a long series of such changes is

considered—that is, if we compare the total investment per unit of output of a company serving a large area with one serving a small area of similar character—it is evident that the investment per unit of output is roughly the same, and the recommendation of the limit of free extension for customers whose estimated demand is used as the basis of computation is justified.

The estimation of the probable individual demand of residential customers presents difficulties, however. A customer may plan to use gas only for cooking and later introduce water heating and house heating, or vice versa. Houses are frequently built for rent or sale and have constantly changing occupants whose wishes cannot be anticipated. To make a long extension for one family and refuse an equal extension to another is likely to cause ill will. For several reasons it is therefore preferable to base the extension to an individual residence on average rather than individual demand. To place the average on exactly the same basis as that applied to industrial customers would require the segregation and averaging of the accounts relating to individual residences. If this were done, the average would not necessarily be fair to newly constructed homes at the edge of the city, which are in the main more fully equipped with modern appliances and larger than the one-family homes in the more congested district. Data from several sources indicate that the average demand of outlying homes is just about equal to the average demand for gas by all customers. It may be more or less than this, depending upon whether the use of gas in industry or by apartment dwellers predominates in the city. It is much the simplest method and probably as accurate as any to regard the owner of a new house, built for the occupancy of a single family, as an average customer and to estimate the demand for gas by dividing the utility's total sales by the number of its customers. This is the basis of estimate recommended for general application. It can, of course, be modified by the regulatory body in the individual case of a utility whose business is distributed among various classes of customers in an unusal way.

The refunding of deposits made by consumers to supplement the utility's investment in a new line is always a somewhat troublesome problem. The proposed plan for refunding, while it appears to be novel, is extremely simple in its operation if not in its exact statement. It is based on the principle of requiring everyone benefited by the extension to contribute in proportion to the service demanded, again assuming average figures for private residences. This principle is qualified by requiring that the deposit made by any customer shall not be greater than would be necessary to provide service for him alone, and that the deposit of a customer already served shall not be increased to provide service to a later customer. The examples in the following section show the working of the rules in every possible case.

The provisions of section (d) and (e) of rule 41 are customary. Charging the average customer for a 4-inch main, which is larger than is required to serve him alone, is justified by the small difference between the cost of installation of a main of this size and a smaller one, and by the greater probability that the customer's deposit will be refunded if the main originally laid is adequate to serve several customers.

Section (f) of rule 41 provides an alternative method of payment of the customer's share of the cost of an extension which has several merits. Chief of these is the fact that in the end the relative ex-

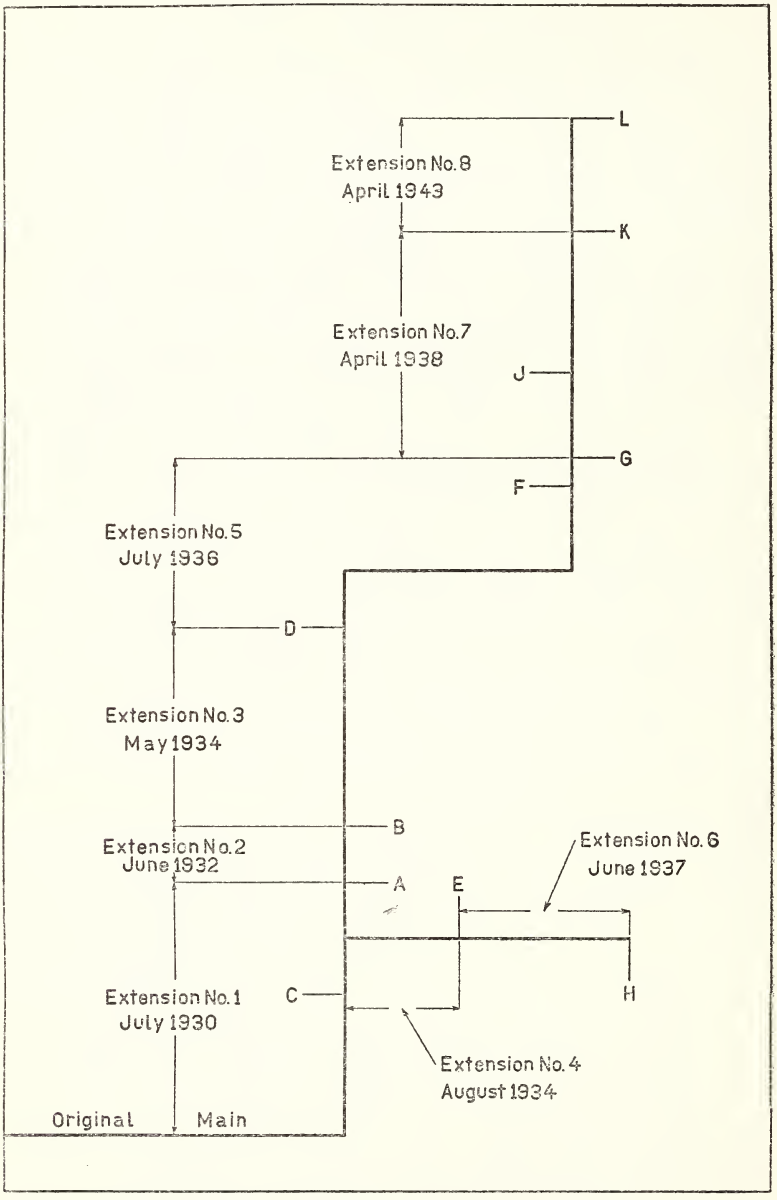

FIGURE 15.—*Diagram of assumed main extensions.*

penditure of customer and company is based on the actual revenue paid by the customer and not on an estimated one. In case the customer actually uses more gas than required by the guarantee, he becomes, in effect, a normal customer; the extension costs him

nothing; and as soon as the utility is satisfied that the demand will remain satisfactory it can close the account. If the customer does not use enough gas to meet the guarantee, the result amounts to the payment of his share of the cost of the extension on the installment plan, but without a carrying charge. The plan thus results to the customer's advantage in any case. Nevertheless, a plan of this type, in some cases even more liberal to the customer, is preferred by many utilities as a promoter of business. It is not only easier to get customers to pay the necessary charge in small amounts over a period of years than to pay a lump sum at the start, but a customer who must meet a guarantee is encouraged to use gas more liberally. The utility is not protected against loss by this plan nearly as effectively as by a deposit at the time the main is laid, hence the plan should be optional with the utility and not obligatory.

2. EXAMPLE OF APPLICATION OF PROPOSED RULE RELATING TO EXTENSION OF MAINS

The following example shows the application of the proposed rule to a number of new customers, whose relative locations are indicated diagrammatically in figure 15. It is believed that every possible case that can arise under the proposed rule is illustrated.

Total value of distributing system exclusive of service piping and meters, $1,200,000. Number of customers, 15,000. Limit of free extension per residential customer:

$$\frac{\$1,200,000}{15,000}=\$80.$$

Total annual revenue from sale of gas, $520,000. Limit of free extension for nonresidential customers per dollar of estimated annual revenue:

$$\frac{1,200,000}{520,000}=\$2.31$$

Extension no. 1, July 1930.

(To serve residential customer A. Illustrates extension from an ordinary main to serve a single customer.)

Cost of extension	$300.00
Investment by utility	80.00
Deposit by customer A, July 1930	220.00

Extension no. 2, June 1932.

(To serve residential customer B. Illustrates cost to new customer and refund to former depositors when cost of extension is less than the "limit of free extension").

Deposits for earlier construction		$220.00
Cost of extension		50.00
		270.00
Investment by utility		80.00
Total deposits required after June 1932		190.00
Deposit from A, July 1930	$220.00	
Refund to A	80.00	
On deposit from A, June 1932		140.00
Deposit by B, June 1932		50.00
Total on deposit after June 1932		190.00

New service connection, November 1932.

(To serve residential customer C. Illustrates refund to depositors for new customer directly connected to existing extension, and priority of refund to customer having largest deposit.)

Deposits for earlier construction		$190.00
Investment by utility		80.00
Deposits required after November 1932		110.00
On deposit from A, June 1932	$140.00	
Refund to A	80.00	
On deposit from A, November 1932		60.00
On deposit from B, June 1932		50.00
Total on deposit after November 1932		110.00

Extension no. 3, May 1934.

(To serve residential customer D. Illustrates the fact that an extension requiring a deposit from the new customer greater than that of existing customers is treated like an extension from an ordinary main.)

Deposits for earlier construction		$110.00
Cost of extension		250.00
		360.00
Investment by utility		80.00
Deposits required after May 1934		280.00
On deposit from A, November 1932		60.00
On deposit from B, June 1932		50.00
Cost of extension	$250.00	
Investment by utility	80.00	
Deposit by D, May 1934		170.00
Total on deposit after May 1934		280.00

Extension no. 4, August 1934.

(A branch main taken from extension no. 1 to serve residential customer E. Since this is a branch, only the main up to and including the extension from which it is taken is considered in determining deposits and refunds.)

Deposits for earlier construction (A's share only)		$60.00
Cost of extension		65.00
		125.00
Investment by utility		80.00
Deposits required after August 1934		45.00
On deposit from A, May 1934	$60.00	
Refund to A, August 1934	37.50	
On deposit from A, August 1934		22.50
On deposit from E, August 1934		22.50
		45.00

Extension no. 5, July 1936.

(To serve nonresidential customer F and residential customer G. Illustrates computation of company's investment to serve nonresidential customers, and adjustment to make deposits from each customer proportional to the "required investment" by the company to serve that customer.)

Deposits for earlier construction, May 1934	$280.00	
Refunded to A, August 1934	37.50	
Deposits unrefunded, August 1934		$242.50
Cost of extension no. 5		1,240.00
		1,482.50
Estimated annual revenue from F	320.00	
Utility's investment to serve F ($320×2.31	808.00	
Utility's investment to serve G	80.00	
Total new investment		888.00
Deposits required after July 1936		594.50
Deposit from A, August 1934		22.50
Sum of deposits required from B, D, F, and G		572.00
Investment by company to serve customers B, D, F, and G	1,048.00	
Deposit by F, July 1936 (572×808/1,048)		441.02
Deposit required from B, D, and G each (572×80/1,048)=$43.66.		
On deposit from B, June 1932	50.00	
Refund to B	6.34	
		43.66
On deposit from D, May 1934	170.00	
Refund to D	126.34	
		43.66
Deposit by G, July 1936		43.66
On deposit from A, August 1934		22.50
Total on deposit, July 1936		594.50

Extension no. 6, June 1937.

(To serve nonresidential customer H, beyond customer E. Illustrates refund in case of branch main, and closing of account when "required investment" exceeds cost of extension as a whole.)

Deposits for earlier construction customer A and E, Aug. 1934	$45.00	
Cost of extension no. 6	150.00	
		195.00
Estimated annual revenue from H	$100.00	
"Limit of free extension" to serve H (2.31×$100)	231.00	

(Since this is in excess of cost of main plus residual deposits, the utility refunds the deposits of A and E and builds the extension. Extensions nos. 1, 4, and 6 become ordinary mains and A, E, and H ordinary customers and their accounts are closed.)

Extension no. 7, April 1938.

(To serve residential customers J and K. Illustrates rule that cost to any customer shall not exceed cost to serve him alone.)

Deposits for earlier construction July 1936	$594.50	
Refunded to A June 1937	22.50	
On deposit after June 1937		$572.00
Cost of extension		345.00
		917.00
Investment by utility (2×$80)		160.00
Deposits required after April 1938		757.00
On deposit from B, D, F, and G		572.00
Cost of extension to serve J alone	150.00	
Investment required to serve J alone	80.00	
Deposit by J (deposit which would have been required from J had extension been made for him alone)		70.00
Deposit by K		115.00
Total deposits after April 1938		757.00
Deposit accrues to company at end of 10 years.		
On deposit June 1942		757.00
June 1942 B's deposit accrues to utility		43.66
On deposit after June 1942		713.34

(B becomes an ordinary customer and extension no. 2 an ordinary main.)

Extension no. 8, April 1943:

(To serve nonresidential customer L. Illustrates the distribution of refunds when possible to make deposit by each customer proportional to the "required investment" by the company to serve him.)

Deposits for earlier construction, June 1942		713.34
Cost of extension		150.00
		863.34
Estimated annual revenue from L $240; investment by utility (240×2.31))		554.00
Deposits required after April 1943		309.34
Total utility's investment to serve D, F, G, J, K, and L	$1,682.00	
Deposit by L ($309.34×554/1682)		101.90
On deposit from F, July 1936	441.02	
On deposit from F, April 1943 (309.34×808/1682)	148.60	148.60
Refund to F	292.42	
Deposit required from each residential customer (309.34×80/1682)	14.71	
On deposit from D, July 1936	43.66	
Refund to D	28.95	
On deposit from D, April 1943		14.71
On deposit from G, July 1936	43.66	
Refund to G	28.95	
On deposit from G, April 1943		14.71

On deposit from J, April 1938	70.00	
Refund to J	55.29	
On deposit from J, April 1943		14.71
On deposit from K, April 1938	115.00	
Refund to K	100.29	
On deposit from K, April 1943		14.71
Total deposits, April 1943		309.34

3. INSTALLATION, MAINTENANCE, AND OWNERSHIP OF SERVICE PIPES

Rules relating to the installation and ownership of service pipes are in as confused a state as those relating to mains. In some cases the customer pays for the entire cost of the service connection, but this is relatively rare. In other cases the utility pays for and owns the entire service connection. Various rules exist as to the length of service pipe installed without charge to the customers; the most common provisions specify 50 or 100 ft. A large number of companies, possibly a majority, install the entire service pipe, but pay for and own only the portion from the main to the curb or to the property line. A few companies will install the service pipe only to the property line and require the remainder of the connection to be made by the customer. There is a similar discrepancy in the rules relating to maintenance. In many cases the utilities specifically provide that they will maintain or repair only the portion of the service pipe which they own; but the majority will maintain the entire service pipe by whomever installed or owned. A policy relating to the extension of mains can be modified without any particular complications; but a policy relating to the ownership of service pipes must be consistent throughout the territory served, otherwise one group of customers is subject to a materially different charge than another. For this reason it is recommended that the utility's practice, submitted to the commission for approval, shall be consistent with the ownership of the existing services. Where not inconsistent with this condition it seems best to provide for the installation and maintenance by the utility of the services to all customers, and for the ownership by the company of all services except those of unusual length, which should be paid for by the customers. As a simple method of providing for the maintenance of the customer's portion of the line, an initial charge above the cost of installation is made at the beginning.

The provisions recommended as to the location of the service pipe are intended to give the owner of the property the right to specify that location, an important consideration when valuable trees or shrubs are to be protected from injury by the trenches. At the same time, the company is protected from unnecessary expenditure by the provision that the customer must pay any cost in excess of the cost of the shortest service line. The rule also protects the customer from being compelled to lay the service pipe from his building to a distant corner of his lot to connect with an existing end of a main which will later be extended past the property. The customer has a right to demand that the usual rules for the extension of the mains shall apply until the main reaches the part of the street opposite his building.

VII. GENERAL SERVICE REQUIREMENTS

1. PLANT AND OPERATION

(a) PLANT INSPECTION AND MAINTENANCE

In the operation of any public utility, it is important that the plant and facilities be maintained in as high a state of efficiency as practicable. This makes it possible to render safe, adequate, and continuous service. In the case of gas utilities, regular inspection of the plant and equipment is essential in order to accomplish this. Public-service commissions have come to recognize this fact and requirements as to inspections are now quite general.

(b) OPERATING RECORDS

All well-managed utilitiy companies keep more or less complete operating records for their own information, even though there are no municipal or State regulations on the subject. It is, however, none the less desirable for a regulatory body to require that certain records be kept, and even in some cases to specify the form in which they shall be kept. Information which it may from time to time require is thus readily available. If such records are kept it is unlikely that inefficient operation or undesirable practice will continue long before it is brought to the attention of the management. For this reason, if for no other, the requirement that certain records be kept is desirable.

(c) INTERRUPTIONS OF SERVICE

One of the first principles of gas-utility operation is that under no circumstances should gas service be interrupted. Cases where the gas supply fails throughout the entire system are not common, and among the larger companies are exceedingly rare. However, even with the most skillful and best-intentioned management interruptions in the service to a part of the system may occur from time to time. Since such interruptions afford a basis for complaint and may give rise to accidents, a record of all such interruptions should be kept.

(d) ACCIDENT RECORDS AND REPORTS

In some States the public-service commission which has charge of standards for service is also responsible for the supervision of safety precautions; the accident records of the utility companies therefore come within its jurisdiction. Even where a State industrial commission is responsible for this work, it is desirable that the public-service commission also receive reports on all accidents that involve the utility and the public, or may directly or indirectly affect either the quality or continuity of service rendered. Where no other agency is charged with the duty of investigating the cause and means of preventing recurrence of accidents, it would be well for the public-service commission to give such attention to this subject as is feasible under the local circumstances, since interest in the subject is thereby increased and exchange of experience between companies is facilitated to the advantage of all concerned.

2. TESTING AND REPORTS

(a) TESTING METHODS AND FACILITIES

The rules recommended for State regulation indicate the extent to which the gas companies or the municipal inspector should make tests. The methods to be used and the equipment or facilities required in this work are described in full in Bureau of Standards Circular 48, "Standard Methods of Gas Testing." In a number of cases, it has proved desirable to indicate that the work done under such regulations must be conducted in accordance with the recommendations of that circular. In any event, it should be prescribed that the apparatus and equipment provided be complete and of a form acceptable to the supervising authorities. It is desirable that the commission be advised regarding the location of testing stations which are being established by companies under their jurisdiction so that the results obtained may be representative of the conditions specified in the rules. Apparatus which requires inspection or calibration before use should, of course, be subject to such examination by the supervising authorities.

(b) RECORDS OF TESTS

The records of tests of gas quality or service should be preserved in a complete form in order that the nature of the test and its significance may be clearly evident upon the test record itself. It is very undesirable to trust to the memory of the inspector or assistant making tests for any important conditions or details pertinent to the inspection. All records of these tests should be preserved for an adequate length of time, usually 2 to 5 years, in order that the service at any particular previous period may be determined. It is desirable that summarized results of all tests be made available to properly authorized local officials, as well as State representatives, so that the actual conditions existing in a locality may be determined by anyone having a reasonable ground for interest in them. Proper publicity will go far toward eliminating a feeling of suspicion regarding the quality of service rendered.

(c) RECORDS OF METERS AND METER TESTS

In the rules suggested by the Bureau there have been indicated the important records as to meters and meter inspections which should be kept. The proposed file arranged by date of installation is more or less novel but will make very simple the determination of the amount of gas used, for deciding when the meter should be tested and computing the amount of refund, if any. Careful attention to these records by the supervising officials of the gas company, as well as by the representatives of the State commission technical staff, will usually reveal promptly any condition which demands special attention. For example, if it were the practice regularly to go over the records of meter tests and note unusual results, an exceptional number of meters found defective or out of adjustment for any particular cause would be quickly revealed. Means for the correction of such faulty conditions could promptly be taken before

serious consequences became general throughout a certain class of meters or even throughout the entire territory served. This point is especially emphasized, as too often these records are assumed to be of interest only as setting down past history, and are seldom given the attention which they merit as an aid in anticipating trouble or correcting faulty conditions.

(d) REPORTS TO COMMISSION

When requested, the companies should transmit to the commission detailed reports of the quality of service rendered, heating value, pressure conditions, etc., but the company should not be put to the expense of compiling such reports unless real use is to be made of them. If such reports are regularly examined by the engineering staff of the commission, helpful suggestions to the companies as to improvement of service and efficiency will often result, and at the same time a more intimate knowledge of conditions throughout the State will be possible by the commission.

Publication by the commission of reports as to service conditions will also often dispel unwarranted suspicion on the part of the public. A frank presentation of facts is frequently a most effective method of encouraging good relations between a company, its customs, and the public officials charged with the supervision of relations between these two interests.

3. RELATION OF COMPANY AND CUSTOMERS

(a) COMPLAINTS

Frequently customers' appliances get out of adjustment, or unforeseen service conditions arise which give the customers real cause for complaint; but also, because of their unfamiliarity with meters and with the difficulties of gas manufacture or distribution, customers sometimes complain without reason. However, the public pays both for the gas which it uses and the cost of inspection and supervision of service; it is therefore entitled to courteous and patient treatment when complaints are made either to the company or to the public officials. There is no question but that most gas managements recognize these principles and do their best to satisfy the public, as well as to serve it fairly.

It is highly desirable that where complaints of service are received by the State commissions or city authorities they cooperate with the company in the investigation of the trouble, rather than merely order the company to remove the cause of the difficulty. On the other hand, these officials should encourage the public to go directly to the gas company with its difficulties and complaints, in the confidence that the company will treat these fairly and thoroughly, so that to the maximum possible extent the relations between company and consumer may be adjusted by the parties themselves. Of course, records of all formal complaints should be made and such records should be examined by company officials from time to time, as the information in them should serve as a guide for improvement both of service and of public relations.

(b) PERIODIC INSPECTION AND ADJUSTMENT OF APPLIANCES

The periodic inspection and adjustment of customers' appliances by the gas company is nowhere mandatory, but a considerable number of gas companies have voluntarily adopted the policy of making such inspections. So far as the National Bureau of Standards has been able to learn, periodic inspections, where they have been tried, have been almost uniformly successful. The satisfactory choice, installation, adjustment, operation, and maintenance of the four or five kinds of appliances in common domestic use require a degree of technical knowledge rarely appreciated by consumers and not always by the gas companies themselves. This knowledge is available in the average community from only one source, which is the gas company. Experience shows that, in general, little can be expected from local plumbers or appliance dealers.

The regular inspection, about every 2 years, of all appliances in use, their correct adjustment for the prevailing service conditions, the proper lubrication of cocks, the replacement of damaged parts, the elimination of undesirable accessories, and of fire and personal hazards caused by faulty installation, and the giving of competent advice to the owner about maintenance and operation, can all be accomplished at very little cost per customer if it is done systematically by a permanent group of well-trained employees. Actually, it has been found by certain companies that the direct profit from the sale of new appliances and repair parts covers the cost of this service. Disregarding this return, however, the general benefit of such service to the customers is worth more than it would cost them if the entire expense involved (probably not more than 0.5 percent of their gas bills) were charged to them in the form of an increased rate. On the other hand, the service is probably worth to the company all it costs as a means of increasing goodwill and promoting the sale of gas.

For the protection of the customer it is necessary that the inspector's advice be entirely disinterested, particularly with respect to the relative desirability of repairing an old appliance or replacing it with a new one. It is therefore recommended that an inspector be compensated only by a fixed salary and that no commission or any other form of reward for selling appliances to customers be given him.

In spite of the fact that periodic inspection has been increasingly practiced, apparently on its merits, it is not recommended that it be formally required. One reason for this is that gas companies as well as gas users are subject to psychological influences; and the forced adoption of the practice would probably result in service of a different character and by a different personnel than would its voluntary adoption as a promotional enterprise.

(c) REPLACEMENT OF APPLIANCES OR PARTS MADE NECESSARY BY CHANGES IN CONDITIONS OF SERVICE

The rules of several States and those recommended by the National Bureau of Standards provide that appliances shall be readjusted by the gas company when changes in the character of the gas

supply make them necessary. In some cases satisfactory readjustment is not possible without the replacement of parts or even of entire appliances. It is by no means simple to provide for the most satisfactory and fair course of action in a case of this kind.

Consider, for example, a change from natural to manufactured gas. Some appliances will require only readjustment. These should, without question, be attended to by the gas company. Other appliances will backfire (flash back) with manufactured gas but can be put in condition for satisfactory service by the replacement of inexpensive burners. Unless the utility takes the responsibility, at least, for such replacement, the owner will usually be in ignorance as to what, if anything, is required and where to obtain it and is likely to get unsatisfactory results at excessive cost or to discard the appliance entirely. It may be possible to adjust other appliances, notably gas ranges with low-set burners, to give the appearance of satisfactory adjustment, but leave them prohibitively inefficient or seriously defective in some other respect. It may or may not be practicable to make the changes necessary to put these appliances into serviceable condition. Appliances will be found in every stage of serviceability and disintegration from new ones with expensive automatic controls, insulation, and ornamentation, to appliances that should have been discarded as junk long before. Some will justify much expense for remodeling for the new gas supply; others none.

Disregarding for the moment the question as to who should bear the expense of adapting the equipment to the new conditions the gas company should take the responsibility for the reason that it alone is sufficiently familiar with the technology involved to decide what should be done and where the needed replacements can be obtained to greatest advantage. This responsibility will be taken more seriously by the company, and its decisions will be more readily accepted by the customer if the company bears a portion, at least, of the expense.

Granting that the cost of the necessary changes must, in the end, be borne by the customers, it makes a great deal of difference in the distribution of cost among them whether it is paid by all in the form of a higher rate than would otherwise be necessary, or individually by each customer taking the burden of the replacements on his own premises. Even for the most difficult change likely to be made, that from natural gas to coke oven gas, the cost of putting all appliances into as good a condition for service after the change as before is not likely to exceed 20 percent of the cost of the distributing system, but the replacements for an individual may cost more than his share of the distributing system, and his loss may be even greater if he is equipped with the best appliances, in good condition. Allowing such an individual to bear the entire burden of a change for which he is not responsible does not seem entirely fair.

A third reason for allowing the utility to bear the burden of appliance changes is that only in this way is the large aggregate expenditure involved likely to receive its proper share of consideration among other economic factors when the change of supply is decided upon. It therefore seems fair and in various ways desirable that the utility should either make such changes in each

customer's equipment as will leave it in as good condition for rendering service with the new supply as it was with the old, or to bear a portion of the expense of replacements equal to the cost of reconditioning the old equipment. It is believed that such a policy would, in most cases, enlist the friendly cooperation of the customer.

(d) INFORMATION FOR CONSUMERS

It is generally required that each utility shall preserve for the information of its customers a record of the rate schedules, the rules or standards in force through the local and State authorities, and similar information. It is also desirable that a company provide means for assisting its customers upon request, to secure more efficient service, to learn how to read the service meters, and in every other way to make clear any matters connected with that part of the business with which the customer comes in contact. A requirement to this effect is therefore recommended in the proposed rules.

(e) METER READINGS AND BILL FORMS

It is highly desirable that a consumer be able to determine from an examination of his monthly statement alone the basis upon which charge is rendered. The requirement that the bill show meter readings and the pertinent portion of the rate schedule is therefore desirable.

If the rates are expressed in therms a bill of the following form is suggested:

SUGGESTED FORM FOR CONSUMER'S BILLS UNTIL CUSTOMER BECOMES ACCUSTOMED TO THERM RATE AND ITS MEANING

For Explanation of Rate Per Therm See Back of Bill

DATE	METER READING		RATE PER THERM		20 CENTS
			multiplied by		
Aug. 26	7,480		HEATING VALUE	570 BTU PER CUBIC FOOT	
Sept. 25	7,521		divided by 1,000 gives		
			RATE PER 100 CUBIC FEET	$0.114	
CUBIC FEET USED	41	00 ×		.114	AMOUNT TO BE PAID $4.67
				10% discount if paid within 10 days	.47
				Net	$4.20

For the explanation the rear of the bill the following two paragraphs are suggested, the first of which should be retained permanently, while the second should be printed for only a few months until the customers become familiar with the system of billing by therm and satisfied as to its purpose.

The rate per therm of 100,000 Btu printed in *boldface* type on the front of this bill is the rate established for the sale of gas. While this rate is unchanged, the cost of service (cooking, water heating, etc.) may be expected to remain the same.

The establishment of the therm rate instead of the equivalent rate per 100 cubic feet (also shown) facilitates the best use of all processes and materials available for rendering good and economical service by making it possible to change the heating value of the gas without establishing new rates or altering the cost of service.

In addition to serving as an explanation as to how the bill is computed, a bill of this form will serve to indicate clearly the essential thing about the therm rate, which is not the form in which the customers receive their bills, but the fact that the established rate is a definite price per unit of available heat and not a definite price per unit of volume.

(f) DEPOSITS FROM CONSUMERS, METER RENTALS, AND SPECIAL CHARGES

Charges such as these are really part of the business arrangement between the utility and its customers, and as such many commissions consider them to be outside the scope of service rules. It is, of course, fair that deposits be required from customers unknown to the utility to guarantee payment of bills, and that it be definitely understood that the utility is justified in charging for certain work. It is important, however, that deposits should not be excessive and that the customer be assured of the return of his deposit when he ceases to use the service; that charges for work done be reasonable; and that there be no unjust discrimination between customers or classes of customers. Therefore, those commissions which do not include in their service rules provisions covering these matters usually require the various utilities themselves to prepare such regulations and file them with the commission for approval as a part of their rate schedules. This general method has the advantage of allowing considerable flexibility to meet local conditions and has been successful in use.

Since matters of deposits and special charges do affect the public relations of utility companies, about one-half of the commissions which have adopted State-wide regulations have considered it proper to cover one or more of these subjects in them. For those who share this view, and also as a guide to utility companies as to the subjects which it may be desirable to cover in preparing such regulations, matters of deposits from customers and other special charges have been included among the "Proposed Forms of Regulations" (sec. IX).

(g) DISCONTINUANCE OF SERVICE

In the same way that certain charges are referred to in these rules, although not strictly matters of service, some commissions have considered it desirable to include a rule as to when service should be cut off from any customer or class of customers. It is, of course, a fundamental principle that service should be cut off

whenever considerations of safety to life or property make it necessary. Reasonable notice of discontinuance of service should be given in all cases where practicable. Where not covered in State-wide regulations, rules regarding discontinuance of service for failure to settle accounts should be adopted by each company, subject to the approval of the commission, and then be made a part of the rate schedule of the company.

(h) ELIMINATION OF NUISANCE TO THE COMMUNITY

A public attitude that is very common is that a gas plant or even a gas holder is a public nuisance that detracts greatly from the value of surrounding property even at a considerable distance. The attitude is a natural one in view of the usual appearance of a gas plant and the carelessness, in the past, of many gas companies in the disposal of purifying materials, "drip liquors", and effluents. In one instance a large and otherwise attractive section of territory on the edge of a city was rendered almost uninhabitable for a period of 15 years by the dumping of spent purifying material.

With proper attention to details, it is possible to operate a gas plant and to dispose of wastes and residuals without the creation of offensive odors or excessive noise, smoke, or dust. The destruction of shade trees by the leakage of gas has already been mentioned. A uniform row of large elms or maples on a residential street is unquestionably worth many times the cost of a gas main in the same street, and their value should be fully protected by whatever means are necessary.

Unless there is direct legal phraseology or a court decision to the contrary, matters of this kind involving the relationship of the technical operations of the gas company to the interest of the community should be assumed to come within the jurisdiction of the regulatory body.

Such jurisdiction may not extend to the appearance of the plant, but it is not out of place to call attention to the fact that in a few cases in which it has been tried the choice of paint and the planting of a few trees and shrubs under the direction of a landscape artist have made an almost incredible difference in the appearance of the plant. Usually, there is some civic organization that will be glad to cooperate with the company in an effort to render its plant and operations less objectionable.

VIII. ENFORCEMENT OF TECHNICAL REGULATIONS

For the full enforcement of the technical regulations discussed in previous chapters of this circular, there are three distinct lines of work necessary, viz: First, regular inspection to determine whether or not there is full compliance on the part of the company with the regulations; second, investigation of each case where noncompliance is found, to determine the cause and, if possible, the remedy for the deficiency; and, third, action to induce compliance or to bring redress for any inexcusable noncompliance which may be found. It is important that careful investigation of each case be made, for any action which may be taken to enforce compliance with a regulation without preliminary consideration of all the facts involved,

frequently results in needless friction, or possibly even in expensive litigation to no useful purpose. Indeed, noncompliance is often the unavoidable result of conditions beyond the control of the gas company, and in such cases cooperation, rather than criticism, should be given.

The service rendered by gas companies in the United States has been supervised and regulated by both State and municipal authorities. The results sought are the same under either jurisdiction, but the methods vary somewhat according to the extent and character of the territory affected.

1. SERVICE INSPECTION UNDER STATE RULES

The systematic testing of gas under State rules may be done by State inspectors or by the companies under the direction and supervision of the State officers. For all except possibly very thickly populated States, where the distance between cities is very small, the plan of requiring that the companies do the routine testing seems to be preferable. This plan is recommended by the Bureau because of the success with which it has been followed first in Wisconsin and more recently also in other States. The performance of all official tests by State inspectors, rather than by the companies under the supervision of the State officials, requires a very fully organized inspection service.

It is well worth while for a State commission to maintain a sufficient staff of inspecting engineers, not only to supervise the testing of meters, the determination of heating value, etc., but to become thoroughly familiar, by the examination of the company's records, by observation, and by independent investigation when necessary, with every phase of the utilities' operations. Such inspectors can be of the utmost value to the utilities, particularly the smaller ones, in connection with their normal operations, and they are almost indispensable when serious controversies between the utilities and the public occur. Their thorough knowledge of conditions and their impartial attitude constitute the best available protection to both parties against unfair claims by the other.

Serious discussion has been given to the practicability of some form of recognition or reward to particularly well managed companies. It has even been proposed that a higher rate of return on the investment be permitted to those companies which maintain the best service. This does not appear practicable; to base a rate of return on quality of service, even if legal, would be to make an impossible requirement of the judgment and impartiality of the rating official. Nevertheless, a rating system, such as that employed in Illinois, is a good thing and probably worth more than it costs, at least in a State with many operating companies. It is likely to lead to a much more intimate knowledge of the affairs of the utilities as they directly affect the public than the commission would otherwise have. An official charged with making a rating under such a system necessarily inquires into many things not covered specifically by rulings of the commission, and the company, recognizing the obligation of the official to attend thoroughly to the duty assigned, will cooperate in activities which it might otherwise resent, for example, such as inquiring among miscellaneous customers regarding their

satisfaction with the service rendered. The rating is, on the one hand, an effective way of indicating the commission's appreciation of good service, and on the other, a tactful way of calling attention to minor deficiencies or even tendencies which could not be handled formally as definite infractions of the rules.

If properly used by the management of the company, the rating may be very useful in checking up on weak departments. It is a stimulus to the men to know that the results of their work, whether favorable or unfavorable, are certain to be brought to the attention of the management through a disinterested observer who has unusual opportunities for comparing them with men in similar positions in other utilities. It should be a stimulus to the management to know that the commission, to which it must frequently appeal for support in its relations with the public, has more than a vague impression or a record of infractions of the rules upon which to base a favorable or an unfavorable attitude.

At the least, a favorable rating is a source of some satisfaction to everyone concerned, while an unfavorable one, even if not entirely deserved, will usually result in an inquiry as to the cause, and improvement should tend to result in either case.

(a) REGULAR TESTING BY COMPANIES

The rules proposed by this circular for State regulation indicate the testing work which it is believed should be done by the companies. Under this scheme each gas company will determine heating value regularly, will take regular pressure records, will daily test the gas for hydrogen sulphide, and will test meters as frequently as conditions or requests justify. The number of records and frequency of tests to be made by the companies can usually be left to the companies themselves. If any company does not make as many or as frequent tests as may seem to the commission to be desirable, an informal request by the latter that the frequency or number be increased will usually be sufficient.

The records of these tests and the complaint files should be open to the State inspectors at all times, and by visits at irregular intervals the tests of the company can be supervised, so that, even were there a desire to make inaccurate or misleading records of this sort, it could not be done without danger of detection by the inspectors calling at unexpected times. This point is emphasized here to meet the possible objection that the companies' tests would not be of real value for inspection work. The Bureau does not believe that this objection is valid, for two reasons: first, the average company desires for its own protection to give satisfactory service, and it has little incentive to make false reports; second, the probability of false reports passing unobserved, even if the company attempted to make them, is small with careful supervision by State officials. Most excellent results can be had by cooperation of the companies and the State inspectors, and the tests will be sufficiently accurate and will be economically made.

(b) SUPERVISION OF COMPANIES' TESTING

When the routine tests are made by the companies, it is desirable that State inspectors make frequent visits to check the work. In the

arrangement of this part of the testing work the first question is as to the frequency of tests required. Although the answer to this question may be largely affected by local conditions, the experience of the Wisconsin Commission has led to a conclusion of perhaps general applicability, expressed by their chief gas inspector as follows:

> In the regulation of gas service throughout an entire State it is believed that the work of the State should be largely supervisory, and that the responsibility in all cases should be left with the company so far as this is possible. Small plants cannot make all of the technical tests required, but the larger plants should be required to make these tests and the State inspectors need only make such visits as will insure compliance with the law. If the companies are required to keep accurate records, it is believed that more visits should be made to small companies than to large ones. Since these smaller plants can do very little themselves in the way of testing, these inspections should be made monthly, at least, to advantage. Plants a little larger, however, which are equipped for testing the quality of the gas, would need to be visited less frequently than monthly. Bimonthly or quarterly inspections should give very good control. The companies should be visited frequently enough to keep track of what they are doing, and occasionally without warning an exhaustive investigation should be made. It is believed that more is accomplished by follow-up inspections where companies have failed to comply with the rules than by very frequent inspections of all plants. Two plants of the same size do not require, of necessity, the same number of inspections.

Testing will generally be done at the office of the gas company, in some cases with the apparatus of the company itself. If the apparatus is set up and tests of heating value made as soon as practicable after the arrival of the inspector, the readings will be uninfluenced by the company's knowledge of his presence. After these readings are taken, the pressure gages can be set and the company's records of gas quality, meter tests, and complaints examined. As all but the smallest companies have testing apparatus for the use of the inspectors, the instruments which need be carried are very few in number.

Another necessary portion of the traveling inspection work is the calibration or standardization of the companies' testing apparatus and instruments which are used for all of the company tests and for many of those by the inspectors. Such calibrations can be made by the regular inspector once or twice a year, as seems necessary. The methods to be employed for routine and for special testing, and the character of stations needed, as well as the methods for adapting the ordinary apparatus to traveling inspection, form a part of Bureau of Standards Circular C48, Standard Methods of Gas Testing.

In the examination and testing of meters, the commission need not undertake the testing and sealing of many meters. The aim should be to supervise the testing performed by the companies themselves in such a manner as to insure the regularity of the periodical testing, the use of suitable equipment and methods, and the keeping of full records of such tests. The inspectors should examine these records whenever a regular inspection is made; and summaries of meter tests may be collected and filed with the commission.

The proposed rules provide that a customer may have his meter tested by the company at any time he may desire, and it is believed that, under the conditions existing, most of the disputes regarding the accuracy of meters can be settled in this way without appeal to

the commission. The rules also provide for the test of service meters by inspectors of the commission on formal complaint of a customer and a few meters will be tested under this provision.

In addition to prescribing methods and checking prover equipment, it is well to send inspectors to the various cities occasionally, and to choose at random and remove from service a number of meters for test. It is believed that, in this manner, the State sufficiently insures the accuracy of service meters at comparatively slight expense.

(c) REGULAR TESTING WORK BY STATE INSPECTORS

In some States it has been thought best to have official tests made regularly in all cities, rather than only to supervise the routine work as done by the companies. It is assumed that under such a system each inspection made by a traveling inspector would include the determination of heating value and impurities and the taking of one or more records of the pressure of the gas. The frequency of visits for such a purpose may be determined by the size of the company concerned, but if the inspector's tests only are to be relied on for the enforcement of so essential a requirement as that for heating value, frequent tests, averaging at least 2 or 3 a month, must be made in the case of even the smallest company.

Having determined the frequency of test necessary in each city, the division of the work into inspection districts is a very simple matter. From the amount of work required in certain of the largest cities, it would probably be necessary to have an inspector permanently located in each of these places. If the inspector also had charge of the meter work of this city, then conditions governing the work would be very similar to those in any municipal inspection office. For the smaller places the visits should be arranged from one week to another.

Meter testing, if done by State officials, would in no case be subject to such definite preliminary arrangement as the traveling gas inspection, since work of this character would be determined by the needs of the various companies for meters which must be tested before installation. The work could, however, be planned by the chief inspector from week to week, according to the requests received from the companies for meter inspection. This plan has met with some success in the State of New York.

If we assume that because of complaints, repairs, purchase of new meters, etc., the equivalent of 30 percent of all the meters in use would require test each year, a basis of calculation is furnished for determining the number of meter testers required in any State. The number of meters which one inspector could test during a year would vary so widely, as the result of difference of distance between meter shops, length of stay at any one place, and the character of the conveniences which could be provided by the various companies, that no exact estimate can be made as to the time required. An allowance of 25 meters per man per working day would be a conservative estimate, and on this basis one inspector would test about 7,000 meters per year. The meter inspectors could readily be aided by the gas inspectors when their time was not wholly occupied with the routine gas tests.

(d) SETTLEMENT OF DISPUTES AND COMPLAINTS

Two classes of disputes will demand consideration by the commission: first, complaints of customers, and, second, differences arising between the companies under supervision and the commission itself.

The complaints of customers as to the service rendered them by the company should, if possible, be first referred to the company itself for consideration, since the commission need take action only in case of a serious difference which cannot be adjusted by this procedure.

Settling the more important disputed cases by public hearing and subsequent ruling of the commission should be an expeditious and satisfactory method, since matters with which the commission should be very familiar are usually in question. The immediate reference of all such disputes to a court of law would make their settlement unnecessarily complex and expensive; resort may be had to legal procedure later if unavoidable.

Whenever it appears that a company cannot, with its current methods of operation, comply with the provisions made by the State, it becomes necessary to investigate the reasons therefor. Such investigations may suggest certain practicable changes in operating methods which will make the gas service conform to the regulations; the commission should have authority to order reasonable changes if the company is unwilling to comply with the suggestions of the commission. If, however, it is not practicable to comply with the general rules, the commission should have authority to amend its rules to provide for each special case.

2. CITY INSPECTION SERVICE

Where a regulatory gas ordinance is adopted by a city, it is customary to provide for municipal gas-inspection service at the same time. However, it is fully as important to make provision, both for the investigation of special cases of noncompliance with the ordinance on the part of the gas company, and for the procedure in case of dispute. The necessity of making full regulations to care for all such situations is the real source of difficulty in the municipal enforcement of gas regulations, which is so well eliminated by the flexibility of the State rules under the administration of a commission with its technical staff.

When granting a franchise, which is in the nature of a formal contract between the company and the city, it will generally be more desirable to make definite provisions as to how rates and the requirements for service may be determined from time to time than to incorporate these matters as provisions of the franchise itself. The reason for this is that new processes, methods of operation, and types of service, or changes in economic conditions may make a revision of the regulations for service desirable before the expiration of the franchise, while changing prices of material and labor may also make necessary a change in the rates for gas. The recommendation as to the form such franchise provisions should take is beyond the scope of this circular.

A very important point that is frequently overlooked is the need for providing for the extension of the franchise, the acquirement of the gas system by the city, or other means for insuring the continuation of service at the expiration of the franchise. Those who represent the public in negotiating a franchise are likely to make the mistake of assuming that when it expires the public will be in a favorable position to obtain concessions from the company. This is based on the legal theory that, on the expiration of the franchise, the company will no longer have the right to use the streets, and must secure that right by a new grant from the public or remove its system for whatever salvage value it can get. As a matter of fact, the advantage is all with the gas company. The investment of the gas company's customers in piping and appliances is nearly or quite as great as the company's investment. If gas service is discontinued, this becomes useless. To replace gas with another fuel will cost more than the value of the displaced equipment, the necessity for chimneys and storage space for the new fuels being considered. Moreover, the gas company can get along very well without the profits of a few days or weeks of operation, while agreement is being reached, but the people who are dependent on gas for cooking their food and keeping their homes warm cannot dispense with the service for even a day. Hence, a company whose franchise has expired finds that it can, and it usually does, continue to operate on whatever basis it chooses.

The regulation of gas service by State officials is now so general and is usually so much preferable to municipal regulation that no form of ordinance for city adoption is recommended in this circular. If such an ordinance is to be enacted, reference may be made to the form recommended in the fourth edition of Circular C32 (1920). For the technical provisions of the ordinance, the discussion and rules recommended for State use in the present circular should be followed, rather than those in the ordinance previously recommended.

It appears to have been the tendency in recent years to abandon municipal inspection even in cities in which the utilities are not under the jurisdiction of State authorities. The purely routine determination of heating values and pressures often appears to be an unnecessary duplication of the tests that the company is compelled to make for its own guidance; the referee testing of meters is called for too infrequently to be of importance; and the authority given to a municipal gas inspector does not usually go much beyond these functions. Often the amount of work called for is not enough to keep an energetic man busy, and the salary and prospect of advancement attached to the office of inspector are not attractive to an ambitious and competent person. For these reasons it appears preferable in most cases to make gas inspection a function of a larger organization, such as the office of the city engineer or a board having general supervision of the city's utilities, and to assure the gas company's compliance with the provisions of the franchise and ordinances relating to it by a method similar to that employed by a State commission. In other words, the responsibility for making the tests necessary to assure compliance with the agreement between the company and the municipality should be placed directly on the

company, with only such supervision as is necessary to determine that the tests made are adequate and accurate and that they indicate compliance with the requirements. Usually, the training of one or more of the engineers already employed by the city to make the needed "check-up" of the company's practice will be less difficult than to secure desirable and well trained candidates for the independent office of gas inspector.

It sometimes happens that serious controversies arise through disagreement between the results of tests made by the inspector and by the company, through differences in the interpretation of the significance of local conditions, or some similar state of affairs. When a difficulty of this kind arises, it may require weeks or perhaps months of hard work and more than one individual to completely unravel it, after which relatively little work will be required for another period of months or possibly years. A gas inspector who is paid for only part-time work may be less thorough than he should be when conditions arise which demand a careful investigation. If he is a full-time employee, he may not always be busy. If gas inspection is under the charge of a relatively large organization, such as that of the city engineer, enough personnel can usually be assigned to meet any need and can be otherwise employed when nothing unusual is required.

What has been said must not be interpreted as deprecating the importance of the gas-inspector's duties. The erection of a building at a cost equal to the annual gas bill of even a small city would not be left to the contractor without inspection by the owner, architect, or building inspector; and so vital a service to the community as the supply of gas is equally deserving of examination by a representative of the purchaser. The question is only as to the best method of providing for such service.

A few large cities retain gas inspectors as independent full-time officials and the following discussion of qualifications and duties will apply to such cases.

(a) APPOINTMENT OF INSPECTORS

The advantage derived from examining the inspector before appointment leaves no doubt as to its advisability.

The following recommendation as to eligibility in the preceding edition has such obvious purposes that comment seems scarcely needed:

> The inspector, his deputies or his assistants, shall not be pecuniarily interested, either directly or indirectly, in the manufacture or sale of gas, gas meters, or any article or commodity used by gas companies or used for any purpose connected with the consumption of gas.

The gas company should welcome all precautions that will protect it from the charge of undue influence over the inspector or the inspection work. However, it should not be supposed that a man formerly in the employ of a gas company is disqualified for the position of inspector, as has been contended in some cases. His experience would be a valuable preparation for this position if the circumstances of his leaving the company's employ were not such as to preclude fair dealing.

The method of appointment of the inspector, his tenure of office, etc., should be consistent with the established municipal system of civil service and designed to make the inspector independent of partisan politics. The examination of the inspector should be made by a board whose members should be selected for their ability and willingness to judge the qualifications of the applicants for the position. They should be fitted to examine the chemical, engineering, and executive business ability of the candidates, and hence the board may well consist of a chemist, an engineer, and a business man. The members of such board should, if possible, be persons not connected either with the political offices of the city or the city council. The choice of men to compose the board who are well known in their professions and whose integrity is above question will be a long step toward securing an inspector who will be fair and satisfactory to all concerned. Where a suitable board of three is not available, a smaller number may be used. Care should be exercised when there is a single examiner that personal interest or prejudice cannot be charged against him. The city chemist or city engineer may at times serve to advantage on the board; but usually the further removed from city officials' influence the examining board is, the better.

The best results will usually be gained not only for the city but also for the gas company, if the latter takes no part in the matter of the appointment of inspectors. It is, however, fair to receive suggestions from the gas company as to the character of the examination. It must not be forgotten that the applicants expect to test the gas, not to make it, and their knowledge of testing methods is more essential than their familiarity with works management, even though the latter be not wholly neglected. The character of the examination will be determined by the duties prescribed by the city for the office in question. The information and directions given in the circular of this bureau on testing methods will offer a basis for the questioning of candidates.

The salary of an inspector is determined by the local conditions and by the number and frequency of tests required of him. In any event, a competent, well-paid inspector is the most economical in the long run. An inefficient inspector may cause trouble between city and company, and will often cause more expense through legal difficulties than is saved by the lower salary.

(b) DUTIES OF THE INSPECTOR

The following quotation from the model ordinance recommended in a former edition of this circular covers fairly completely the duties of a city inspector:

> The inspector in person or by deputy or properly qualified assistant, shall perform the following duties:
>
> (1) He shall test or determine, as hereinafter prescribed, the quality, purity, and pressure of the gas and, upon request by consumers as hereinafter provided, the accuracy of gas meters. He shall have full charge of all testing stations, laboratories, and offices provided for his use for such testing and for the keeping of records.
>
> (2) He shall receive and investigate complaints regarding the quality of the gas or gas service furnished by the company.
>
> (3) He shall keep a record of all regular tests and calibrations made by him or his assistants and of all formal complaints made to him or to other city

officials, all of which records shall be preserved complete and correct. Upon request he shall open said records to the company, and, in his discretion, to any person who wishes to examine them.

(4) He shall make a monthly report containing the results of all tests, made by him or his assistants, of the heating value, impurities, and pressure of the gas, as well as the results of such tests as may have been made on consumers' meters. One copy of said report shall be sent to the company, one to the city council, and one to the city clerk, who shall keep it available for examination by the public.

(5) He shall make a special report to the city clerk whenever the quality or pressure of the gas shall be shown by test not to conform to the requirements of this ordinance. The substance of said special report shall be communicated to the company by telephone or by special messenger from the inspector immediately upon completion of the test which showed such condition to exist. A confirmation of any such telephone message shall be delivered to the company in writing not later than the next working day following that on which the test is completed, and the company shall acknowledge in writing the receipt of the report when so requested.

(6) He shall perform any and all other duties naturally connected with this office as required or implied by any part of this ordinance, or as specially assigned to him at any time by the city council.

(c) REGULAR INSPECTION REQUIRED

In any city large enough to justify the employment of a gas inspector on full time, the heating value of the gas is practically certain to be recorded continuously by the company at one or more stations, and to be checked at frequent intervals by observations with calorimeters of the Junker type. The inspector should determine heating value independently of the company with reasonable frequency, usually at least once a day, but such determinations should not be relied upon as the primary source of information as to the average heating value of the gas distributed. Rather they should be regarded as confirmation of the accuracy of the company's continuous tests. If there is a discrepancy between the results obtained by the inspector and the company, the source of the difficulty must be found and corrected. Until that can be done, neither result should be accepted.

Some of the tests of heating value made by the inspector should be performed near the limit of distribution of gas for the purpose of comparing with the tests made at the works, to determine the stability of the mixture sent out. For routine work, stability can probably be determined satisfactorily in the laboratory by cooling the gas to a temperature equal to that in the mains and filtering out any fog produced, but these results should be occasionally checked by testing in distant parts of the system to make sure that the laboratory data are not misinterpreted.

The inspector should make himself thoroughly familiar with pressure condition in all parts of the city. An occasional check of the company's data or an inspection of the gages should be made to ascertain their accuracy, but most of the inspector's attention should be given to the interpretation of the company's records and to taking records of his own in any territory for which he does not regard the company's as adequate.

Two methods of checking the meters are available—one by which every meter is tested by the inspector, the other by which the company is required to make these tests. The Bureau recommends that the routine testing of meters be done in all cases by the company,

but that authority for inspection of this work be given to the inspector. For State work this plan is unquestionably the better; for cities it seems also preferable. Some city or State official would be expected to make the tests of "complaint" meters, when the company did the routine work. Although some of the most efficient inspection work seems to be done in the shops of the companies themselves, yet, where it is desired, an official inspection of the company's meter testing is reasonable and proper. Indeed, such inspection, even if not strictly necessary, is a valuable protection to the company against unfair public criticism, and the slight inconvenience to the company is more than compensated for. For small cities, where there is neither city nor State gas-inspection service, the complaint tests may be made by the city engineer or some other official.

(d) SPECIAL INSPECTION WORK

The duties of the inspector defined under (b) cover the needs of the largest cities, and may frequently be shortened or modified. However, there are very few subjects that can be entirely omitted even for smaller cities, since the duties defined are, in general, only such as would naturally accompany the office of inspector, whether this officer be specially appointed for this work or one of the other regular city officials to whom the gas testing has been assigned.

The fair and cordial cooperation of the gas company and the inspector in the investigation of complaints and irregularities of service is of utmost importance, although unfortunately such cooperation is not universal. The Bureau believes that, generally speaking, the inspector can best serve the public by the fullest cooperation with the company in the examination of the quality of the gas and the character of the service rendered. The plan of cooperation of public officials with the company in the removal of causes of deficiency in service, which has been applied in some States, should, where possible, be followed in the municipal enforcement of similar regulations.

3. TESTING STATIONS AND METHODS

The location of the testing station is a matter of much less importance than it was during the period of high-candlepower standards. (See section II, 15 to 17, for a more complete discussion of this subject.) If compliance with the standard of heating value is to be judged from the city inspector's tests at a single station, that station should be located at least half-way from the works to the limit of the low-pressure distributing system, distances being measured along the path traveled by the gas. At such a station, most of the condensation in the mains should have taken place. If high-pressure transmission is employed, there is little probability that condensation will occur after cooling to ground temperature in the transmitting main and subsequent expansion into the low-pressure system.

The extremely high velocity through the high-pressure mains may cause a fog to be carried to a great distance, however. To avoid the effect of fog, the testing station should preferably take its supply from a portion of the low-pressure system which is supplied from one of the most distant portions of the high-pressure mains.

The idea formerly prevalent that the loss of heating value was something beyond the company's control and that the station should be located with a view to distributing the loss between the company and its customers is no longer tenable. While it is not always desirable to operate in such a way that no condensation occurs in the mains, principally because the condensate serves to seal minute leaks and prevent dust, the amount of condensation is decidedly in the company's control. Hence, no part of the loss occasioned either by careless operation or with the intention of effecting an economy in manufacture or distribution should be transferred to the customer. A strictly analogous case is that of a grocer weighing out bulk products. It is accepted practice that every customer is given at least as much as he pays for; the loss resulting from inaccuracies in weighing is taken by the grocer in preference to a more important loss of time which would be involved in trying to make every weighing exact.

If the city inspector's tests are not to be the principal or only basis for deciding compliance with the standard, but the company's records are to be used primarily, the discussion of the location of the testing station in section II, 17, which referred primarily to control by a State commission, applies to city inspection also.

In general, only one testing station, other than the company's equipment at the manufacturing plant, need be regularly operated, but in many cases it will be desirable to provide facilities for setting up a calorimeter in at least one additional location for the purpose of assisting in the interpretation of observations as to the stability of the gas. In case gas is supplied from more than one source, it is of course necessary to make observations of gas known to come from each. In a large city employing district holders, at least occasional tests should be made of gas known to have been stored in the holders, since exposure to extreme temperatures and the solvent action of the liquid used to seal the holders occurs in those places.

After a laboratory is properly located the use of an improper service-pipe connection to it may make it difficult to obtain good results. Such trouble is met with when the service pipe is too small or too long, or when it passes through a long air shaft, or through a cold basement or hot furnace room, or has many side connections. The service pipe should be as short as possible, with few or no turns and the least possible change of temperature from the main to the laboratory. No testing station should be chosen where the conditions do not permit approximate compliance with the above requirements of service connections. The inspector, if properly qualified for his position, should be fitted to superintend the purchase and installation of the necessary equipment. Therefore, his recommendations as to the laboratory, the office, and their equipment should be given due weight. The details of station equipment have been investigated by this Bureau and a discussion of certain phases of this question is included in B. S. Circular C48 on Standard Methods of Gas Testing.

One of the most frequent sources of trouble between the gas inspectors and the gas companies has been the selection of testing methods and the interpretation of inspection results. In order to eliminate this difficulty as far as possible, it is desirable for a city to adopt rather detailed provisions in its gas-testing ordinance. However, it is clearly impossible to provide for all details in the

ordinance itself, and some means of settlement of difference is desirable.

In order to furnish to the American gas inspectors a source of information on standard testing methods, the National Bureau of Standards has issued the circular on this subject (Circular C48, Standard Methods of Gas Testing), which represents not only a summary of work done at the Bureau, but also a review of the experience of some of the well-known gas chemists and municipal inspectors. Circular C48 is being revised at the present time in order to have it contain the latest information available. It is believed that the recommendations of this circular can be used as a basis for settlement of differences with fairness to both parties. The effect of any change in the circular upon the methods or apparatus used in testing would be limited by the definite provisions of the ordinance itself, and so could not work serious injury either to the gas company or to the public.

Since cases not covered by any other sections or provisions can readily be imagined, and may occur on rare occasions, they should be provided for. A State commission usually has authority to handle any case that may arise. In a city it is desirable that this be done by an arbitration board rather than by the courts, which in most cases are not familiar with the technical points involved. Resort to this board would be only of rare occurrence.

(a) RESPONSIBILITY FOR ACCURACY OF APPARATUS AND METHODS USED IN TESTING

The regulatory officials should not assume nominal or direct responsibility for the accuracy of equipment and methods employed in testing the gas or determining the character of the service rendered. The utility should be responsible to both the commission and the consumers for the condition of its equipment. The commission owes it to the consumers to assure itself of the substantial accuracy and proper maintenance and use of the company's equipment. It owes it to the utility to advise and cooperate in determining that methods and equipment are reliable, and to be in position to support the utility when its testing work is questioned.

4. PENALTIES

The failure to observe regulations regarding gas quality or service may be due to accident, carelessness, or neglect on the part of the company; but in any case the public by its representative, either city inspector or State official, is entitled to an explanation of the circumstances which caused the deficiency. In the case of accidental and unpreventable violation, the company has nothing to fear from a full understanding of the facts, for no unfavorable criticism or penalty should result. Under other circumstances publicity, or in extreme cases a fine or penalty of some form, is not unjust to the company for violation of a reasonable requirement.

It will be observed that no penalties are proposed in this circular for failure to meet the requirements. Specific penalties have generally been found unnecessary under State commission regulation, and it is believed that in most cases this will also prove true where the

city undertakes the enforcement of an ordinance. The influence of public opinion is powerful, and this, combined with the knowledge that penalties commensurate with the impairment of the service or for violation of the reasonable orders of the proper authorities may be exacted, has in the past always been sufficient to insure good results. It is to the interest of the gas company to furnish good service, and violations of regulations will usually be the result of accident or unforeseen circumstances. Where a definite penalty is specified for a violation, its exaction in compliance with the law may come at a time when the company requires assistance and cooperation in removing the difficulty rather than fine and criticism, and thus is apt to produce ill feeling and aggravate the difficulty. The National Bureau of Standards, therefore, recommends that no definite penalties be fixed for violations of the regulations, but that the power be given the proper authorities, upon intentional noncompliance or inexcusable neglect, to proceed, after notification, to collect from the gas company an amount commensurate with the impairment of the service.

The adjustments recommended for deficient heating value and fast meters are not to be considered as penalties. They are simply business adjustments for measured overcharges. The monthly report of a municipal inspector should be open to the public. This should offer an incentive to the company to furnish gas always within the specified limits. Public advertisement of a slight deficiency in a way to subject the company to unfair criticism is, of course, to be condemned; however, a simple public statement that the quality of the gas was found to be above standard or deficient to a certain degree may sometimes be desirable. This illustrates the need for good judgment on the part of the inspector and shows the importance of careful selection of the man to fill this office.

IX. PROPOSED REGULATIONS

In order to give in convenient form a summary of the recommendations of the National Bureau of Standards, a set of rules suitable for State commissions has been prepared. In some cases it may not be practicable to adopt these proposed forms as a whole, as local conditions may make alterations desirable, but in general they can be closely followed, for it is believed that the requirements will be found to be applicable in the great majority of cases. The importance of the many details in the regulations proposed is greater than may appear at first sight, and it is recommended that any modifications of the general form be made only after careful consideration. Every effort has been made to make the suggested regulations comprehensive; abbreviation may in some cases be possible, but care should be taken that no essential part is omitted. The rules proposed should be considered in the light of the discussion of the preceding sections of this circular; and necessary changes should be made to meet special conditions not covered by the discussion.

Part X, which immediately follows these rules, gives a practically complete review of existing State regulations, and should be consulted for alternative methods of dealing with the various subjects for which regulations are proposed.

The intention of the Bureau in recommending the following rules should be borne in mind both in the consideration of them at the time of adoption and during enforcement of similar requirements. The following principles apply:

1. These rules define good practice which can normally be expected. They should not be rigidly enforced under any conditions that introduce unusual difficulty of compliance, but should be waived temporarily to meet such conditions. Especially should rules be set aside if compliance with them costs more than the results of compliance are worth to the public.

2. The regulatory authorities should make every effort to cooperate with the gas companies in furnishing good service, and in return can expect frank, fair dealing from the companies.

3. Penalties to enforce compliance with rules are not recommended; a penalty may be required as a last resort to insure obedience to formal orders of a commission, but its use should be restricted to this function alone.

4. It is as much the function of the commission and its rules to protect a company from unreasonable demands as it is to prevent inadequate service or unfair charges to the public.

Active control of gas service by a municipal agency has become so rare that it was considered unnecessary to include a model ordinance for municipal enactment, as in previous editions of the circular. The same technical considerations, of course, apply to municipal as to State control, and the rules recommended for State-wide application and the discussion in the preceding sections should be a sufficient guide as to the technical contents of a regulatory ordinance. A form for such an ordinance may be found by consulting the fourth edition of Bureau of Standards Circular C32, pages 77 to 86 (1920), copies of which can be found in Government Depository Libraries if not elsewhere.

Rules and Regulations Recommended for Adoption for Prescribing Standards for Gas Service.

1. GENERAL PROVISIONS

(a) RULE 1. AUTHORIZATION OF RULES[1]

(*a*) The Public Utilities Law of the State of _____ provides that the Public Service Commission shall be empowered to establish rules and fix standards for gas service as follows:

(Extract from law granting this authority)

In accordance with the above provisions the Public Service Commission has adopted the following rules and fixed the following standards for fuel gas service, to become effective the _____ day of _____, 19__. All previous rules or standards conflicting with those contained herein are hereby superseded.

(*b*) The adoption of these rules shall in no way preclude the Public Service Commission from altering or amending them in whole

[1] Rules 1, 2, and 3 would of course be changed to suit the local State laws and regulations. The definitions of rule 3 should correspond with any similar definitions occurring in the public service commission law under which such rules as these may be adopted.

or in part, or from requiring any other or additional service, equipment, facility, or standard, either upon complaint or upon its own motion, or upon the application of any utility. Furthermore, these rules shall not in any way relieve any utility from any of its duties under the laws of this State.

(b) RULE 2. APPLICATION OF RULES[2]

(*a*) These rules shall apply to any person, firm, or corporation which is now or may hereafter become engaged as a public utility in the business of furnishing gas to domestic or commercial customers for use as fuel within the State of _____.

(*b*) The rules are intended to define good practice which can normally be expected. They are intended to insure adequate service and prevent unfair charges to the public, and to protect the utilities from unreasonable demands. The cooperation of the utilities with the commission is presupposed.

(*c*) If hardship results from the application of any rule herein prescribed, or if unusual difficulty is involved in immediately complying with that rule, application may be made to the commission for the modification of the rule or for temporary or permanent exemption from its provisions, provided, that no utility shall submit application for such modification or exemption without submitting therewith a full and complete justification for such action.

(c) RULE 3. DEFINITIONS[3]

In the interpretation of these rules the word "commission" shall be taken to mean the Public Service Commission of the State of _____; the word "utility" shall be taken to mean any person firm, corporation, or municipality engaged in the business of supplying gas for use as fuel to domestic, commercial, or industrial users within this State; and the word "customer" shall be taken to mean any person, firm, corporation, municipality, or other political subdivision of the State supplied with gas by any utility.

2. RECORDS AND REPORTS

(a) RULE 4. RECORDS

(*a*) A complete record shall be kept of all tests and inspections made under these rules as to the quality or condition of service which the utility renders.

(*b*) All records of tests shall contain complete information concerning the test, including the date and place where the test was made, the name of the person making the test, and the result.

(*c*) Each utility shall keep a customers' ledger or other record, which shall contain an accurate account of all revenues derived from each customer. In addition, it shall contain the dates of the period for which the bill is rendered, the readings of the meter on those dates, reference to the rate schedule applicable, and any additional information that may be necessary in computing the bill.

(*d*) All records required by these rules shall be preserved by the utility, for such period as the commission may designate. Such

[2, 3] See footnote to rule 1.

records shall be kept within the State at the office or offices of the utility and shall be open at all reasonable hours for examination by the commission or its representatives, or by others authorized by the commission.

(b) RULE 5. REPORTS TO COMMISSION

Each utility shall, at such times and in such form as the commission may prescribe, report to the commission the results of any test or tests required to be made or the information contained in any records required to be kept by the utility.

3. GENERAL SERVICE PROVISIONS

(a) RULE 6. MAINTENANCE OF PLANT AND EQUIPMENT

(*a*) Each utility shall have and maintain its entire plant and system in such condition that it will furnish safe, adequate, and continuous service. Each utility shall inspect its plant, distributing system, and facilities in such manner and with such frequency as may be necessary to insure a reasonably complete knowledge as to their condition and adequacy at all times. Such record shall be kept of the conditions found as the utility itself shall consider necessary for the proper maintenance of its system, unless in special cases a more complete record be specified by the commission.

(*b*) Each utility shall keep a daily record of the operation of its plant which, so far as practicable, shall show the gas made, gas purchased, gas sent out, fuels and other raw materials used, and length of time each producing unit is in operation. The utility shall also keep a record of such details of plant operation as may be necessary substantially to reproduce its operations.

(*c*) Each utility shall, upon request of the commission, file with the commission a statement regarding the condition and adequacy of its plant, equipment, and facilities, and of its operations and service in such form as the commission may require.

(b) RULE 7. INTERRUPTIONS OF SERVICE

Each utility shall keep a record of any interruption of service affecting its entire system or a major division thereof, including a statement of the time, duration, and cause of the interruption.

Every customer affected shall be notified in advance of contemplated work which will result in an interruption of service. The commission shall be advised in advance of contemplated work which will affect an important portion of the system.

(c) RULE 8. ACCIDENTS

Each utility shall, as soon as possible, report to the commission each accident happening in connection with the operation of its property, facilities, or service, wherein any person shall have been killed or seriously injured or whereby any serious property damage shall have been caused.[4] The first report shall later be supplemented

[4] Where a State industrial commission receives accident reports, it should be unnecessary for the utility to report accidents to the Public Service Commission also. However, in the case of any accident or damage caused by interruptions of service, poor quality of service, or involving in any way the relations of the utility and the public, it is assumed that the industrial commission will transmit a report to the Public Service Commission in order that the latter may also be enabled to make an investigation to determine whether its rules have been violated or are in any way inadequate.

by as full a statement as possible of the cause and details of the accident and the precautions, if any, which have been taken to prevent similar accidents.

(d) RULE 9. COMPLAINTS

Each utility shall make a full and prompt investigation of all complaints made to it by its customers, either directly or through the commission. It shall keep a record of all complaints received, which record shall show the name and address of the complainant, the date and character of the complaint, and the adjustment or disposal made thereof.

Records of complaints shall be kept at least one year and shall not be destroyed until a summary has been prepared for permanent record showing the character of complaints made and the number of each type received in each month.

(e) RULE 10. INFORMATION FOR CUSTOMERS

(*a*) Each utility shall, upon request, give its customers such information and assistance as is reasonable, in order that customers may secure safe and efficient service; and upon request it shall render every reasonable assistance in securing appliances properly adapted and adjusted to the service furnished.

(*b*) Each utility shall adopt some means of informing its customers as to the method of reading meters, either by a printed description, on its bills, of the method of reading meters, or by a notice to the effect that the method will be explained at the office of the utility upon application. It is recommended that an exhibition meter be kept on display in each sales office maintained by a utility.

(*c*) Complete rate schedules, contract forms, rules, and regulations, etc., of the utility, filed with the commission, shall also be on file in the local office of the utility and open to the inspection of the public. A copy of the rules and regulations for gas service as published by the commission shall also be on file and open to the inspection of the public.

(*d*) It shall be the duty of the utility to supply the customer, at the beginning of service and whenever the customer shall request the utility to do so, a copy of the utility's rates applicable to the type or types of service furnished the customer and to assist him in obtaining the rate which is most advantageous for his requirements for service.

(f) RULE 11. METER READINGS AND BILL FORMS

(*a*) Each service meter of the displacement type shall indicate clearly the cubic feet of gas registered. Where gas is metered under high pressure or where the quantity is determined by calculation from recording devices, the utility shall, on request, supply the customer with the information needed to make clear the method by which the quantity is determined.

(*b*) As a matter of general practice, all service meters shall be read at monthly intervals, on the corresponding day of each meter-reading period; but special authority may be granted for the reading

of the meters at other than monthly intervals, if the circumstances warrant.

(*c*) Bills shall be rendered periodically, and they shall show the readings of the meter at the beginning and end of the period for which the bill is rendered, the date of the meter readings, the number of cubic feet of gas supplied, the standard average heating value of the gas, and the unit price, expressed both in terms of price per unit volume and price per therm or other unit of energy. On all bills which include any other items than a definite unit price for gas, the other factors used in computing the bill shall be clearly stated, so that the amount may be readily recomputed from the information appearing upon the bill.

Each bill shall bear upon its face the date when the bill was delivered or the latest date on which it may be paid without penalty.

(*d*) Each utility having prepayment meters in service shall, at the end of each collection period, if requested by the customer, inform him of the readings of the meter at the beginning and end of the period, and the amount of money taken from the meter for the period corresponding to the meter readings.

(g) RULE 12. CHANGE IN CHARACTER OF SERVICE

In case any substantial change is made by the utility in the composition of the gas, the pressure, or other service conditions which would affect efficiency of operation or adjustment of appliances, the appliances of all customers in the district affected shall be inspected and shall be readjusted, if necessary, by the utility for the new conditions without charge.

4. TESTING

(a) RULE 13. DEFINITION OF A CUBIC FOOT OF GAS

For the purpose of testing the gas under these rules, a cubic foot of gas shall be taken to be that amount of gas which occupies the volume of 1 cu ft when saturated with water vapor at 60° F and under a pressure equal to that of 30 in. of mercury at a temperature of 32° F. For the purpose of measurement of gas to a customer, a cubic foot of gas shall be taken to be the amount of gas which occupies a volume of 1 cu ft under the conditions existing in such customer's meter as and where installed, provided, however, that when gas is metered at a pressure more than 12 in. of water column in excess of the prevailing barometric pressure, by agreement with the customer or with the written approval of the commission, the volume of gas metered shall be computed on the basis of the mean pressure in the utility's low-pressure system, or other basis ordered by the commission.

(b) RULE 14. TESTING FACILITIES

(*a*) Each utility shall, unless specifically excused by the commission, provide such laboratory meter-testing equipment and other equipment and facilities as may be necessary to make the tests required of it by these rules or other orders of the commission. The apparatus and equipment so provided shall be subject to the approval

of the commission, and it shall be available at all times for the inspection or use of any member or authorized representative of the commission.

(*b*) Each utility shall make such tests as are prescribed under these rules with such frequency and in such manner and at such places as are herein provided or as may be approved or ordered by the commission. Unless otherwise directed by the commission, the methods and apparatus recommended by the National Bureau of Standards in the latest addition of its Circular C48, "Standard Methods of Gas Testing", may be used.

5. METER ACCURACY AND TESTING

(a) RULE 15. METER PROVER

(*a*) Each utility furnishing metered gas service shall maintain the equipment and facilities necessary for accurately testing all types and sizes of meters employed for the measurement of gas to its customers unless arrangements approved by the commission shall have been made to have such testing done elsewhere. In general, each utility will be required, as a minimum, to provide and maintain a meter prover of approved type and of a capacity of not less than 5 cu ft for the testing of the most numerous class of customers' meters. Each meter prover shall be supplied with all accessories needed for accurate meter testing and shall be located in a room suitable for the work to be done, protected from drafts and excessive changes of temperature. The utility shall maintain this equipment in good condition and correct adjustment so that it shall be capable of determining the accuracy of any service meter to within ½ of 1 percent.

(*b*) The accuracy of all provers and methods of operating them will be established from time to time by a representative of the commission. All alterations, accidents, or repairs which might affect the accuracy of any meter prover or the method of operating it shall be promptly reported in writing to the commission.

(b) RULE 16. USE OF METER REQUIRED

(*a*) All gas sold by a utility shall be charged for by meter measurements, except that which may be otherwise authorized by the commission.

(*b*) Unless otherwise authorized by the commission each utility shall provide and install at its own expense and shall continue to own, maintain, and operate all equipment necessary for the regulation and measurement of gas to its customers. Where additional meters are furnished by the utility to be used as submeters, or for the convenience of the customer, a charge for such meters may be made in accordance with a schedule approved by the commission.

(c) RULE 17. GAS METER ACCURACY

(*a*) *Installation test.*—Every gas-service meter, whether new or repaired, or that has been removed from the service for any cause, shall be in good order and shall be correct to within 1 percent before being installed for the use of any customer; *provided, however*, that

a utility which has less than 1,000 customers and which has no facilities for opening meter cases and adjusting the mechanism, may put a meter back into service, unless it is found to be in error by more than 1½ percent or appears otherwise to be in poor condition.

(*b*) *Method of testing.*—For the purpose of determining compliance with this rule, the registration of a displacement meter shall be determined by one test at a rate of flow of approximately one-fifth of the rated capacity of that meter and one test at a rate of flow of approximately the rated capacity of the meter. The tests at the two rates shall agree within 1 percent. The accuracy of the meter at the lower rate of flow shall be considered as its accuracy in determining compliance with provision (*a*) of this rule and for the purpose of computing refunds.

All tests to determine the accuracy of any gas-service meter shall be made with a meter prover, unless, because of the unusual capacity or construction of the meter, such method of test shall be considered impracticable and another method of test shall have been approved by the commission.

(d) RULE 18. RECORD OF METERS AND METER TESTING

(*a*) Whenever any gas-service meter is tested, the original test record shall be preserved, including the information necessary for identifying the meter, the reason for making the test, the reading of the meter upon removal from service, and the result of the test, together with all data taken at the time of the test in sufficiently complete form to permit the convenient checking of the methods employed and the calculations. The record shall be kept until a subsequent test of the meter has been made, but in no case less than 6 months.

(*b*) A record to be known as the "meter record" shall be kept and shall indicate for each meter owned or used by any utility the date of purchase, its identification, a record of the use, repairs, and tests to which it has been subjected and the general results of such test.[5]

(e) RULE 19. PREPAYMENT METERS

No utility shall use prepayment meters except in special cases or for clearly defined special classes of service authorized by the commission. No utility shall use prepayment meters geared or set so as to cause a rate or amount higher than would be paid if a standard-type meter were used, except under such special rate schedule as may be approved by the commission for this class of service.

(f) RULE 20. LOCATION OF METERS

No meter shall be installed in any location where it may be unnecessarily exposed to heat, cold, dampness, or other cause of damage or in any unduly dirty or inaccessible location. Where these conditions cannot be avoided, a location must be chosen that will least affect the meter's accuracy and condition.

[5] If these records are filed in the chronological order of the first regular periodic meter readings to be made of the meters in their new locations, and corresponding readings are entered on each card annually, the determination as to when, if ever, testing will be required under the provisions of rule 23 can be made with a minor amount of bookkeeping

(g) RULE 21. COST OF TESTING METERS

Each utility shall prepare and submit to the commission for approval a schedule showing the approximate average cost per meter of testing meters of each size and type used by the utility and shall submit at the same time a summary of the data upon which the schedule is based. When approved by the commission, the cost stated in the schedule, which will be referred to as the "scheduled cost", shall include the average cost of replacing a meter in service with another, including the transportation of each meter to or from the laboratory or shop, the actual cost of testing, and the clerical work involved; but it shall not include any part of the cost of making needed adjustments or repairs of the meter.

(h) RULE 22. RECORD OF VOLUME USED THROUGH METER

The reading of each meter at the time of the first periodic meter reading following its installation shall be placed on record, and the corresponding meter reading shall be recorded annually thereafter until the meter is moved to a new location.

(i) RULE 23. REQUIRED PERIODIC TESTING OF METERS

(*a*) No displacement meter of the diaphragm type (the ordinary customer's dry meter) hereafter installed shall be allowed to remain in service longer than the period here indicated from the time when last tested:

Two years if, during the first year in its then existing location, it shall have measured gas of a value as great as 200 times the "scheduled cost" of testing.

Three years if, during the second year in its then existing location, it shall have measured gas of a value as great as 100 times the scheduled cost of testing.

Four years if, during the third year in its then existing location, it shall have measured gas of a value as great as 50 times the scheduled cost of testing.

(The form in which the record is kept is optional with the utility. The entries on the customer's ledgers will suffice, but a saving of clerical labor can probably be made by the systematic practice of transferring one meter reading annually to the meter record.)

(*b*) Service meters other than displacement meters of the diaphragm type or parts of such meters which are subject to change in service shall be tested regularly in accordance with a schedule approved by the commission.

(j) RULE 24. METER TESTING ON REQUEST OF CUSTOMERS

(*a*) If any customer shall request a test of the accuracy of the meter used by him, the utility shall take the action indicated in the appropriate one of the following two paragraphs.

(1) If under the provisions of rule 23 the utility would be required to make a test of the meter in question within a period of 1 year, subsequent to the date of the request, it shall make the test promptly on receipt of the customer's request, and without charge to him.

(2) If under the provisions of rule 23 the utility would not be required to make a test of the meter in question within a period of 1 year, it shall notify the customer of the conditions under which the test will be made both by the utility and by a referee (rule 25). If the customer shall then request the utility to proceed with the test and shall remit with the request an amount equal to 75 percent of the scheduled cost of the test, the utility shall make the test promptly. If when tested the meter is found to be in error by 2 percent or more (fast or slow), no charge shall be made for the test and the amount advanced shall be promptly refunded to the customer. If the meter is not found to be in error, by as much as 2 percent, the utility shall retain the amount advanced by the customer for the test.

(*b*) A customer may be present when the utility conducts the test on his meter or, if he desires, may send an expert or other representative appointed by him.

(*c*) A report giving the name of the customer requesting the test, the date of the request, the location of the premises where the meter has been installed, the type, make, size, and serial number of the meter, the date of removal, the date tested, and the result of the test shall be supplied to such customer within a reasonable time after the completion of the test.

(k) RULE 25. REFEREE METER TESTS BY COMMISSION

(*a*) Upon written application to the commission by a customer a test will be made of the customer's meter as soon as practicable by a representative of the commission. The application for the test shall be accompanied by a remittance of the amount fixed below as the fee for testing. This fee shall be retained by the commission. However, if the meter is found to be more than 2 percent fast, the utility shall repay to the customer the amount of the fee paid by the customer to the commission for the meter test.

(*b*) The amount of the fee to be paid for a meter test made by the commission shall be as follows:[6]

For each gas-service meter—
Not exceeding a rated capacity of 300 ft^3/hr (10 lights)---------- $
Exceeding 300 ft^3/hr, but not exceeding 1,400 cu ft---------- $
Exceeding 1,400 ft^3/hr---------- $

(*c*) This rule shall not interfere with the practice of a utility with reference to its tests of meters, except that in the event of an application by a customer to the commission for a referee test as herein provided, the utility shall not knowingly remove, interfere with, or adjust the meter to be tested without the written consent of the customer, approved by the commission.

(l) RULE 26. ADJUSTMENT OF BILLS FOR METER ERROR

If on any test made by the commission or the utility a gas-service meter be found more than 3 percent fast, the utility shall make a refund to the customer for a volume of gas based on the product of the percentage by which the meter is found to be in error and the volume of gas indicated during the last half of the time the meter

[6] These amounts should be filled in by commissions and should be based on the actual cost of doing the work. They should include compensation to the company for service (if required) in moving the meter to the place of test, which should be done in the presence of the commission's representative.

was used, without test, to measure gas to that customer. At the discretion of the utility, the amount of the refund may be computed either by applying the correction for error to the meter readings for individual billing periods during the interval covered by the refund, or by computing the average consumption per billing period and applying the correction that would be necessary had the average consumption been the actual consumption in each period. No refund is required except to the customer last served by a meter prior to testing.

6. HEATING-VALUE REQUIREMENTS AND TESTS

(a) RULE 27. CALORIMETER EQUIPMENT AND LABORATORY

(*a*) Each utility selling gas shall provide and maintain a calorimeter of a type approved by the commission, and all necessary accessories therefor, unless provision is otherwise made, with the approval of the commission, for the regular determination of the heating value of the gas sold.

(*b*) The calorimetric equipment shall be installed in a suitably located testing station, which station shall preferably be not less than 1 mile from any gas-manufacturing plant, except in the smaller municipalities where a lesser distance may be desirable. The location of such testing station shall be selected by the utility and approved by the commission.[7] Determinations of heating value shall be made of gas drawn from parts of the distributing system remote from the laboratory with such frequency and in such manner as the commission shall consider necessary to establish the stability of the gas distributed, or other tests approved by the commission for the same purpose shall be conducted.

(*c*) The accuracy of all calorimeters, as well as the method of making heating-value tests, shall be subject to the determination and approval of a representative of the commission.

(b) RULE 28. HEATING-VALUE TESTS

(*a*) *Natural gas.*—Every utility selling natural gas shall determine the heating value of the gas at regular intervals of not less than 48 hours unless, because of uniformity of the sources of supply, such frequent testing shall be deemed unnecessary and a longer interval, which in no case shall be more than 1 month, shall be approved by the commission. However, if the heating value of the natural gas purchased by a utility is regularly determined and reported before or at the time of purchase by the utility under conditions satisfactory to the commission, and if the composition of the gas is not subsequently modified (by diluting, mixing, heating, extracting any of the constituents except hydrogen sulphide, or otherwise), the utility shall not be required to redetermine its heating value.

(*b*) *Manufactured and mixed gas.*—Every utility selling manufactured gas, or a mixture of manufactured and natural gas, or a gas obtained by thermal treatment or other process for modifying

[7] Among the smaller utilities it is desirable to use a single calorimeter for the control of the manufacturing operation and to determine compliance with the standard. In such a case the calorimeter should be located at the plant and arrangements made to draw gas for testing from one of the distributing mains. If the stability of the gas is in doubt, it should be checked occasionally by testing at a distant point, or otherwise.

the composition of natural gas, shall determine the heating value of the gas distributed to its customers, daily or as much more frequently as the commission shall require.[8]

(*c*) Each utility shall adopt, subject to the approval of the commission, a standard form for recording the results of heating-value tests. Each determination of heating value shall be recorded originally upon the form adopted for that purpose, and the records shall be retained for a period of not less than 1 year. The average heating value for each day and the monthly average heating value determined by these tests shall be reported to the commission not less than 5 days after the expiration of each calendar month.

(c) RULE 29. HEATING-VALUE REQUIREMENTS

(*a*) *Authorized standard of heating value.*—The monthly average heating value of the gas supplied by each utility in each community or territory served shall be not less than the standard of heating value authorized by the commission for that utility and that community. Unless otherwise ordered by the commission, the authorized standard for each community shall be the standard of heating value in effect when the existing schedule of rates was established for that community; but the authorized standard shall be subject to change at the option of the utility, unless the commission shall order to the contrary, under the following conditions:

1. The commission shall be notified in writing of the intention to change the standard of heating value. The notification shall be accompanied by a complete statement of the reasons for making the change, and by all available data regarding the cost and character of any alterations of plant, process, or materials used which will be involved in the change. The data must show that the change of standard of heating value will not result in an avoidable increase in the cost to the utility of its operations per heat unit delivered to its customers.

2. The utility shall submit a new schedule of rates and charges for its product and service, to accompany the change of standard, of such a character that the cost of service per heat unit delivered shall not be increased to customers of any class, and that the relative cost of service to customers of any two classes shall not be altered by more than 2 percent. The provisions of this rule do not prevent the utility from applying for, or the commission from ordering, changes of rate schedules with respect to either form or amount; but any change of rate schedules, other than provided for in this rule, will be considered entirely apart from any changes of standard of heating value, and as having nothing to do with these service rules.[9]

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[8] In determining the frequency of testing to be required, the commission will consider, first, the magnitude of the utility's business; second, the process by which the gas is produced and the practicability of maintaining a constant heating value without frequent testing and, third, the record of the utility with respect to the maintenance of heating value. Large companies should maintain recording calorimeters and continuous records.

[9] In all but a minor number of uses for gas, the net heating value is a more accurate measure of the energy that can be utilized in practice than the total heating value. The commission will therefore base its decision, as to whether the cost of service per heat unit delivered is in fact increased by the proposed change of heating value and rate schedule, on net heating values. For this purpose the net heating values will be computed from the existing and proposed standards of total heating value by the use of data which have been agreed upon with the utility, or selected after consultation with the utility in case no agreement is reached, and which represent the average composition of each gas.

3. No change of standard shall take effect, and no expenditure shall be incurred for the alteration of plant or equipment for the purpose of supplying gas under the proposed standard until the commission shall have approved the change of standard or until 30 days after the notification, data and schedules required by this rule shall have been transmitted to the commission, but the provisions of this rule shall not be interpreted as forbidding expenditure for engineering services or experimental or development work needed to determine the character and cost of the proposed changes.

4. The utility shall make without charge to its customers such adjustments and replacements of appliances or parts of appliances as may be necessary to insure to all customers as safe, efficient, and satisfactory service after the change of standard as before.

(*b*) To obtain the monthly average total heating value of a gas, the results of all tests of heating value made on any day during the calendar month shall be averaged, and the average of all the daily averages shall be taken as the monthly average: *Provided*, That in cases of unusual difficulty in maintaining uniformity of heating value, the daily and monthly averages shall be determined otherwise as the commission shall direct.

(*c*) *Maximum and minimum limits.*—The heating value of the gas shall be maintained with as little deviation as practicable; and to this end the average total heating value on any one day should not exceed or fall below the monthly authorized standard by more than 5 percent.

(*d*) The heating value of gas which is compressed for transmission shall be determined after compression and cooling to a temperature approximately equal to the temperature of the transmission mains. Where gas is distributed to different territories at different pressures, which result in more than negligible differences in condensation, the territories will be considered to be served with gases of different heating values.

(*e*) *Stability of gas.*—No utility shall distribute gas which contains combustible constituents which will condense under the conditions of distribution, to the extent of more than 3 percent of the total heating value of the gas. Compliance with this requirement shall be determined when the commission deems necessary, in whatever manner it shall direct.

(d) RULE 30. MODIFICATION OF BILLS FOR DEFICIENCY OF HEATING VALUE

On each day on which meters are read, the utility shall calculate the average heating value for the preceding 30 days. If the average is less than the authorized standard by 2 percent or more, the utility shall charge for the gas metered to customers whose meters were read on that day at a rate less than the scheduled rate in the same proportion in which the average heating value for the preceding 30 days is less than the authorized standard.

7. PURITY REQUIREMENTS AND TESTS

(a) RULE 31. PURITY REQUIREMENTS

(*a*) *Hydrogen sulphide.*—All gas distributed in this State shall be free from hydrogen sulphide. It is provided, however, that natural

gas containing hydrogen sulphide may be sold by specific agreement with the purchasers subject to the approval of the commission, and that natural gases containing very small amounts of hydrogen sulphide may be generally distributed without purification when specifically approved by the commission. The gas shall be considered free from hydrogen sulphide if a strip of white filter paper, moistened with a solution containing 5 percent by weight of lead acetate, is not distinctly darker than a second paper freshly moistened with the same solution, after the first paper has been exposed to the gas for 1 minute in an apparatus of approved form, through which the gas is flowing at the rate of approximately 5 cu ft per hour, the gas not impinging directly from a jet upon the test paper.

(*b*) *Total sulphur.*—All manufactured gas or mixtures of natural and manufactured gas distributed in this State shall not contain more than 20 grains of total sulphur in each 100 cu ft. It is provided, however, that not more than 30 grains of sulphur in 100 cu ft may be permitted if the utility shall show cause for such an exception in advance or immediately upon the discovery of exceptional conditions which warrant it.

(*c*) *Ammonia.*—All manufactured gas distributed in this State shall not contain more than 5 grains of ammonia in each 100 cu ft.

(b) RULE 32. TESTS OF PURITY [10]

Each utility supplying manufactured gas shall daily test the gas leaving its holders for the presence of hydrogen sulphide in the manner above specified. Each utility supplying natural gas shall make tests for hydrogen sulphide with such frequency and at such places as the commission shall order.

Each utility selling more than 100,000,000 cu ft of manufactured gas per year shall provide and maintain such apparatus and facilities as are necessary for the determination of total sulphur and ammonia in the gas; and each such utility shall periodically (preferably semimonthly) determine the amount of total sulphur and ammonia in the gas distributed by it, and shall keep a record of the results of all such tests: *Provided*, *however*, That any such utility supplying only water gas or oil gas, or mixtures of these, shall not be required to provide apparatus for or make determinations of the amount of ammonia in the gas.

8. GAS-PRESSURE REQUIREMENTS

(a) RULE 33. PRESSURE DISTRICTS AND ALLOWABLE VARIATIONS OF PRESSURE

(*a*) Each utility may divide the territory served by it into pressure districts and shall specify for each district or for the territory as a whole (which will then be regarded as a single district) the maximum pressure to be maintained within that district.

(*b*) The pressure at the outlet of any customer's service meter shall never be less than one-half of the maximum pressure specified for the district in which the meter is located, nor less than one-third of the maximum pressure specified for any other district of the same

[10] For apparatus required and methods of testing see Bureau of Standards Circular C48, Standard Methods of Gas Testing.

municipality, nor less than the number of inches of water column expressed by the formula, $0.4H+0.3$, in which H is the standard heating value of the gas expressed in hundreds of Btu per cubic foot. (When pressures are measured under such conditions that any drop of pressure between the main and a meter outlet is eliminated from the measurement, it shall be assumed for the purpose of this rule that the pressure so measured is one-half inch of water column in excess of the pressure "at the outlet of any consumer's service meter.")

(*c*) The maximum pressure specified for any district shall not be greater than 12 inches of water column.

(*d*) The utility shall file with the commission, by means of maps or otherwise, an adequate description of the boundaries of each pressure district and the maximum pressure specified for that district.

(*e*) After notifying the commission, the utility shall be at liberty to change the boundaries of districts or the maximum pressure specified for a given district within the limits stated in this rule, subject to the provision that when any such change is made, all customers' appliances located within the territory for which the specified maximum is changed shall be readjusted by the utility for the new pressures which prevail.

(b) RULE 34. PRESSURE-TESTING EQUIPMENT AND RECORDS

Each utility shall make such determinations and keep such records of pressure as will enable it to have at all times a substantially accurate knowledge of the pressure existing in every part of its distributing system. Every utility shall file with the commission a description of the equipment and methods adopted to insure compliance with this rule.

9. PUBLIC RELATIONS

NOTE.—Many commissions make no attempt to regulate the more strictly business arrangements between the utility and its customers, considering such arrangements to be outside the scope of service rules. Nevertheless, the utility is usually required to provide the commission with full information regarding business arrangements, and some provisions, such as are contained in rule 42, should probably be included. Under these circumstances rules 35 to 41, inclusive, may be omitted.

Some of the commissions, however, have considered these business arrangements a proper part of service rules, and in about one-half of the cases where State-wide requirements have been adopted one or more such provisions have been included. For those who share in this view the following forms are given.

(a) RULE 35. DEPOSITS FROM CUSTOMERS TO GUARANTEE PAYMENT OF BILLS

(*a*) Each utility may require from any customer or prospective customer a deposit intended to guarantee payment of current bills. This required deposit shall not exceed the amount of an estimated 90 days' bill of the customer: *Provided, however*, That a minimum deposit of $5 may be required. Interest shall be paid by the utility on the deposits at the rate of _____ percent per annum, payable upon the return of the deposit for the time the deposit was held by the utility and the customer was served by the utility, provided the period was not less than 6 months.

(*b*) Each utility having on hand deposits from customers or hereafter receiving deposits from them, shall keep records to show: (1) The name of each customer making the deposit, (2) the premises occupied by the customer when the deposit was made, (3) the amount and date of making the deposit, and (4) a record of each transaction concerning the deposit, such as payment of interest, interest credited, etc.

(*c*) Each utility shall issue to every customer from whom a deposit is received a nonassignable receipt.

(*d*) Each utility shall provide reasonable ways and means whereby a depositor who makes application for the return of his deposit, or any balance to which he is entitled, but is unable to produce the original certificate of deposit or receipt, may not be deprived of his deposit or balance.

(*e*) In case service is discontinued, the customer shall be notified how the deposit may be reclaimed, after which it shall cease to draw interest.

(b) RULE 36. REFUSAL TO SERVE CUSTOMERS

(*a*) Any utility may decline to serve a customer or prospective customer until he has complied with the State and municipal regulations governing gas service and the reasonable rules and regulations of the utility.

(*b*) Until adequate facilities can be provided, a utility shall decline to serve a prospective customer or to change materially the service to an existing customer, if, in the best judgment of the utility, it does not have adequate facilities to render the service applied for, or if the desired service is of a character that is likely to affect unfavorably service to other customers.

(*c*) The utility may refuse to serve a customer if, in its judgment, the customer's installation of piping or gas-burning equipment is regarded as hazardous or of such character that satisfactory service cannot be given; but in case of refusal the utility shall inform the customer that the question may be appealed to the commission for decision.

(c) RULE 37. DISPUTE AS TO BILLS

In the event of dispute between the customer and the utility respecting any bill, the utility shall forthwith make such investigation as shall be required by the particular case, and report the result thereof to the customer. In the event that the complaint is not adjusted, the utility or the customer may make application to the commission for adjustment of the complaint, and the utility shall notify the customer in writing that he has the privilege of appeal to the commission as indicated in this rule. When the amount to be paid is in question such notification must accompany or precede notice of intention to discontinue service for the nonpayment of bills as provided for in the following rule.

(d) RULE 38. DISCONTINUANCE OF SERVICE FOR VIOLATION OF RULES OR NONPAYMENT OF BILLS

(*a*) No utility shall discontinue the service to any customer for violation of its rules or regulations, or for nonpayment of bills, without first having diligently tried to induce the customer to comply with its rules and regulations or to pay his bills. Service shall

actually be discontinued only after at least 5 days' written notice that bills are delinquent or that the violation of rules must cease shall have been given to the customer by the utility: *Provided, however*, That where fraudulent use of gas is detected, or where a dangerous condition is found to exist on the customer's premises, the gas may be shut off without notice in advance.

(*b*) Whenever the supply of gas is turned off for violation of rules or regulations, nonpayment of bill, or fraudulent use of gas, the utility may make a reasonable charge for the cost to it of turning the gas on again.

(e) RULE 39. NOTICE OF DESIRE TO HAVE SERVICE DISCONTINUED

Every customer who is about to vacate any premises supplied with service by the utility, or who for any reason wishes to have service discontinued, shall give notice thereof to the utility, specifying the date on which it is desired that service be discontinued. Until the utility shall have such notice, the customer shall be held responsible for all service rendered.

(f) RULE 40. EXTENT OF TERRITORY SERVED BY THE UTILITY

Each utility shall file with the commission an adequate description including necessary maps of the territory within which it desires authorization to render service. The commission may alter the boundaries of the territory either by including additional areas or excluding areas not already served by the utility.

(g) RULE 41. INSTALLATION AND EXTENSION OF MAINS AND SERVICE PIPES

(*a*) *Definition of mains and service pipes.*—For the purpose of this rule any pipes laid in public highways, private ways, or on rights-of-way owned or leased by the utility, for the purpose of conveying gas in the direction of such highways or rights-of-way shall be considered as mains. Any pipes used to convey gas from the mains to the premises of or to the piping owned by any customer shall be considered as service pipes.

(*b*) *Free extensions of mains.*—Unless otherwise provided by law or authorized by the commission, extensions shall be made to the mains in accordance with the following provisions: Whenever an extension of a utility's distributing system is necessary in order that an applicant or group of applicants may receive service within the territory within which the utility is authorized to operate, the utility shall extend its mains without cost to the applicants unless the cost of the extension shall exceed an amount to be designated as "the limit of free extension".

Each utility shall submit to the commission for approval statements of the limits of free extension which shall apply to residential customers and those which shall apply to nonresidential customers. The limit of free extension shall be computed originally in the following manner, and shall remain unchanged until a modification is ordered or approved by the commission. For each residential customer occupying an individual dwelling, the limit of free extension shall be computed by dividing the total valuation of the utility's distributing system exclusive of service pipes and meters, recognized

by the commission for rate-making purposes [11] by the total number of customers served by the utility. For customers other than residential customers, the limit of free extension to each customer shall bear the same ratio to the total valuation of the utility's distributing system exclusive of service pipes and meters, that the estimated annual gross revenue from the customer bears to the total annual gross revenue of the utility: *Provided*, That a utility shall have the option of increasing the limit of free extension for either residential or nonresidential customers by not more than 25 percent of the amount computed as stated in this rule. For the purpose of this rule, an apartment house or other building or group of buildings not a private residence served through a single service connection to the main, shall be regarded as a single nonresidential customer.

(*c*) *Extension above free limit.*—If the extension of main required in order to furnish service to any applicant or group of applicants for service is greater than the limit of free extension specified above, such an extension shall be made under the following conditions. The utility may require the applicant or applicants to deposit the excess cost of the extension over the free limit and may retain the amount so deposited without interest unless or until it is refunded in accordance with the following provisions. When any additional customer shall receive gas through a service connection to any main, customers' deposits for the construction of which remain unrefunded, the utility shall refund to the depositors an amount equal to the limit of free extension to serve the new customers as defined in this rule. When an additional extension of main is required which is to be supplied with gas through any portion of main, customers' deposits for the construction of which remain unrefunded, the utility shall invest for the construction of the added extension or the reimbursement of former depositors an amount equal to "the limit of free extension" to which the added customers would be entitled. The money thus provided by the utility shall be so divided that the amount remaining on deposit from each customer, including those served from the new addition, shall be as nearly as possible in proportion to the limit of free extension to which each would be entitled, and the added customers shall be required to deposit the additional amount necessary to complete the added extensions; but no added customer shall be required to deposit more than the actual cost of the addition necessary to serve him, and no depositor shall be required to increase his deposit to provide for construction made necessary to serve added customers.

For the purpose of determining deposits and refunds, the parent stem of a branched system of mains shall be considered a part of each of its branches, but branches shall be considered independent of one another.

(*d*) The deposit required from any customer toward the cost of the main installed to serve him shall not be greater than would be the case if a 4-in. main were installed, unless the customer's demand is such as to require a larger main.

[11] For this purpose only an approximate figure for the valuation is necessary. It can be arrived at with sufficient accuracy from data usually in the possession of the commission with very little difficulty. If satisfactory data are not available, it is suggested that the amount be chosen by informal conference between an engineer of the commission and one representing the company.

(*e*) Ten years after the date of first turning gas into any extension, any deposits made to provide for the construction of the extension and which remain unrefunded shall accrue to the utility, and no further refund shall be made of such deposits.

(*f*) Instead of requiring applicants for service to deposit the cost in excess of the limit of free extension of the main required to serve them, the utility may at its option accept a 10-year guarantee of annual gross income from the applicants. Every utility which elects to use this method of providing for the cost of an extension shall submit to the commission a statement of the numerical formula by which the required guarantee shall be computed. This formula shall be determined originally in the following manner, and shall remain unchanged until a modification is ordered or approved by the commission.

Let A be the cost of an extension in dollars.

Let B be the valuation in dollars of the utility's distributing system, exclusive of service pipes, recognized by the commission for rate-making purposes.

Let C be the current annual gross income in dollars of the utility derived from the sale of gas.

Let G be the guaranteed annual income in dollars required from the applicant.

The annual income to be guaranteed is then represented by the formula

$$G=\frac{AC}{B}.$$

Whenever an additional customer shall receive service from the extension or any addition to it, the factor A, the cost of the extension upon which a return must be guaranteed, shall be reduced by the amount by which a deposit made for the same purpose would be reduced under the provisions of paragraph (*c*) of this rule. If in any year the amount paid for service is in excess of the guarantee, such excess shall be applied, to the extent necessary and possible, to reimburse the customer for any amount previously paid as a guarantee in excess of the amount due for service at normal rates; if the total amount received from the customer is in excess of the total amount guaranteed from the beginning of the contract, the excess shall be applied to reduce the amount of the guarantee for the remainder of the 10-year period. The account shall be closed at the end of 10 years and may be closed at any earlier period, at the option of the utility, provided the customer is first reimbursed for any amount collected in excess of the charge for service at normal rates.

(*g*) In case plans have been officially adopted by the city for regrading the streets traversed by a proposed extension or for other changes which will require the relaying of the main or any considerable portion of it, the utility shall not be required to invest its share of the extension until such changes have been made.

(*h*) Each utility shall file with the commission for approval a complete statement of the utility's practice and requirements relating to the installation and maintenance of service pipes, which shall not be inconsistent with the present ownership of the service pipes

in use. Where not inconsistent with such ownership and where existing conditions otherwise permit, the commission will favor the following practice.

The customer shall be permitted to designate the point of entry of the service pipe into the building in which the gas is to be used, but shall be required to pay for any length in excess of the shortest distance from the main to the building. The service pipe shall be installed by the utility, and no charge shall be made for the portion from the main to and 40 feet beyond the property line bounding the street or right-of-way in which the main is situated, except as provided in the preceding sentence. The cost of the remaining portion of the service pipe, if any, plus an additional charge of 10 percent for future maintenance shall be paid by the customer.

(*i*) Unless agreed to by the customer or authorized by the commission, the cost to the customer of extending the main and installing the service pipe shall not be greater than would be incurred by running the service pipe from the designated point of outlet at a right angle to the street or right-of-way containing the main.

(*j*) The service pipe installed shall be of size adequate for the service required and in no case less than the size of standard 1¼-inch iron pipe.

(h) RULE 42. TEMPORARY SERVICE

In the case of temporary service for short-term use, as distinguished from seasonal use, the utility may require the customer to pay all costs of making the service connection and removing the material after the service has been discontinued, or to pay a fixed amount in advance to cover such expense; provided, however, that if the material is removed the customer shall be credited with the reasonable salvage which the utility shall receive on discontinuance of service.

(i) RULE 43. EXTENT OF SYSTEM IN WHICH UTILITY MUST MAINTAIN SERVICE

Each gas utility, unless specifically relieved in any case by the commission from the obligation, shall operate and maintain in safe, efficient, and proper condition all of the facilities and instrumentalities used in connection with the regulation, measurement, and delivery of gas to any customer up to and including the point of delivery from the meter into the piping owned by the customer.

(j) RULE 44. MAPS

Each utility shall keep on file suitable maps, plans, and records showing the entire layout of every generating or producing plant, and of each compressing or boosting station, with the location, size, and character of each piece of plant equipment, pipe lines, connections, and other facilities used in the production and delivery of gas. Each utility shall keep similarly complete maps, plans, or records of the entire distributing system showing the size, character, and location of each main, district regulator, street valve and drip, and each service connection, together with such other information as may be necessary to enable the utility promptly and accurately to advise prospective customers, and others entitled to inquire,

as to the facilities available for serving any locality. Where there are only inadequate plans of existing facilities, special surveys to locate such facilities will not, in general, be required; but the utility shall endeavor to make its records complete by making entries whenever its operations disclose the location of facilities not already accurately recorded.

(k) RULE 45. RATE SCHEDULES, RULES, AND REGULATIONS

Copies of all schedules of rates for service, forms of contracts, charges for service connections, and extensions of mains, and of all rules and regulations covering the relations of customer and utility shall be filed by each utility in the office of the commission. Complete schedules, contract forms, rules and regulations, etc., as filed with the commission, shall also be on file in the local offices of the utility, and shall be open to the inspection of the public.

This order shall become effective on_____.
(date)

X. SUMMARY OF RULES IN EFFECT IN VARIOUS STATES INCLUDING RULES RECOMMENDED IN PREVIOUS EDITIONS OF THIS CIRCULAR

1. EXPLANATION

In this section an effort has been made to bring together for comparison, and to summarize in as brief a form as is consistent with clearness and completeness, the rules relating to standards for gas service of all the States within which such rules have been adopted by a State regulatory body. Because the rules proposed for the use of State commissions in this circular differ in many respects from those recommended in former editions of C32, and because nearly all of those previously recommended have been adopted by one or more States, it seemed desirable to include in the summary the rules recommended in the fourth edition of this circular.

In the case of nearly every subject considered, at least one rule, either that in effect in one of the States, or that recommended in the last edition of this circular, is directly quoted. In each case the source of the quotation is given, either the name of the State in which the rule is in effect or the symbol "C32", which indicates that the rule is quoted directly from the preceding edition of this circular. In parenthesis following the source of the quotation are given the names of States having substantially the same rule. The wording of the rule in the case of the States in parenthesis may be identical with the quotation or altogether different in form but having the same meaning.

Following the quoted rules, statements are made regarding important additions, exceptions, or variations, and regarding rules on the same subject in States having provisions too dissimilar for inclusion with the quotation.

The compilation is intended to make it possible for the reader to compare without loss of time all existing State rules and the Bureau's former recommendation on any subject. If the published

rules of a given State are unavailable, their substance can be reconstructed practically completely by noting all the quotations and comments in connection with which the name of the State occurs.

2. GENERAL PROVISIONS

(a) AUTHORIZATION OF RULES

C32: "The public utilities law of the State of _____ provides that the public service commission shall be empowered to establish rules and fix standards for gas service as follows:

[Extract from law granting this authority]

In accordance with the above provisions the public service commission has adopted the following rules and fixed the following standards for manufactured-gas service, to become effective the _____ day of _____, 19__. All previous rules or standards conflicting with those contained herein are hereby superseded."

The statement of the authority by which the rules are established is peculiar to each State and no summary is required.

C32 (Alabama, Colorado, California, Illinois, Indiana, Maine, Michigan, Montana, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, Vermont, West Virginia): "The adoption of these rules shall in no way preclude the Public Service Commission from altering or amending them in whole or in part, or from requiring any other or additional service, equipment, facility, or standard, either upon complaint or upon its own motion, or upon the application of any utility. Furthermore, these rules shall not in any way relieve any utility from any of its duties under the laws of this State."

(b) APPLICATION OF RULES

C32: "These rules shall apply to any person, firm, or corporation which is now or may hereafter become engaged as a public utility in the business of furnishing gas to domestic or commercial consumers within the State of _____."

Except as affected by limitations of jurisdiction, the statements of the application of the rules is substantially the same in meaning in all States. In Colorado and Michigan, cities which have "home rule" in utility affairs are not subject to the jurisdiction of the commission, but it is very generally the practice of the utilities in these States to conform to the standards set by the commission unless required by the municipality to do otherwise. In California, Colorado, Kansas, North Carolina, Oklahoma, Pennsylvania, and South Carolina municipally owned plants are outside the jurisdiction of the commission.

Washington: "The abrogation or cancelation of any rule or rules contained herein shall in no way affect the validity of the remaining rules.

"Nothing in these rules shall be construed to supersede or abrogate, in any manner whatsoever, any general or specific order of the Department now in effect, or which may hereafter be made, which may be inconsistent with such rules, except as specified below."

In all other States in which the subject is mentioned, a set of rules, where adopted, superseded all earlier rules or orders in conflict therewith.

(c) PURPOSE OF RULES

C32 (Montana, North Carolina, Oklahoma, South Carolina): "The rules are intended to define good practice which can normally be expected. They are in-

tended to insure adequate service and prevent unfair charges to the public, and to protect the utilities from unreasonable demands. The cooperation of the utilities with the Commission is presupposed."

(d) MODIFICATION OF RULES

C32 (Montana, North Carolina, Oklahoma, South Carolina): "In any case where compliance with any of these rules introduces unusual difficulty, such rule may be temporarily waived by the Commission upon application of the utility. If in such case compliance with the rule would cost more than the results of such compliance are worth to the public and gas consumers, it may be permanently set aside by the Commission."

Washington: "Upon acceptable showing by any utility the Department may waive or modify, as to such utility, the provisions of any rule herein contained, except when such provisions are fixed by statute."

Illinois: "Where compliance with any rule or rules cannot be effected the utility shall notify the Commission in writing within 30 days after the circumstances arise which make it impossible to comply, and shall make a satisfactory showing why it is unable to comply with said rule or rules. Failure on the part of a utility to make application for such exemption where compliance cannot be effected shall receive serious consideration by the Commission in any subsequent issue involving rates or service in the territory affected.

California: "If hardship results from the application of any rule herein prescribed because of special facts, application may be made to the Commission for a modification of such rule provided that no utility shall submit any rule or regulation for the approval of the Commission which is contrary to any section of this order without submitting therewith a full and complete justification for such rule."

The Missouri rules gave every utility and municipality 30 days in which to file a motion for a rehearing on the rules; and ordered that within 30 days each utility and municipality should "notify the Commission whether the terms of this order are accepted and will be obeyed."

The New York rules provided that the commission be notified by each utility affected within 10 days whether the rules would be accepted and obeyed.

(e) RECONSTRUCTION NOT REQUIRED

Connecticut: "This order shall not be construed to require general reconstruction or reequipping to conform with rules for equipment or construction contained herein, not in force when such equipment was installed or construction made. The Commission reserves the right to deal with specific cases as the particular conditions require.

(f) DEFINITIONS

C32: "In the interpretation of these rules the word 'commission' shall be taken to mean the Public Service Commission of the State of _____; the word 'utility' shall be taken to mean any person, firm, corporation, or municipality engaged in the business of supplying manufactured gas to domestic, commercial, or industrial users within this State; and the word 'consumer' shall be taken to mean any person, firm, corporation, municipality, or other political subdivision of the State supplied by any such utility."

Substantially all sets of State rules define the important terms used, which need not be reviewed.

3. RECORDS AND REPORTS

(a) RECORDS

C32: "(*a*) A complete record shall be kept of all tests and inspections made under these rules as to the quality or condition of service which it renders.

"(*b*) All records of tests shall contain complete information concerning

the test, including the date, hour, and place where the test was made, the name of the person making the test, and the result.

"All records required by these rules shall be preserved by the utility for at least 2 years after they are made. Such records shall be kept within the State at the office or offices of the utility and shall be open for examination by the commission or its representatives at all reasonable hours."

Alabama, Arizona, California, District of Columbia, Missouri, Nevada, New Hampshire, New Jersey, West Virginia, and Wisconsin have no general rules relating to the keeping of records; but whatever requirements are made are stated in the rule relating to the subject of the record.

Colorado, Connecticut, Illinois, Indiana, Kansas, Maine, Massachusetts, Michigan, Montana, North Carolina, North Dakota, Oklahoma, Pennsylvania, and South Carolina specify that the records required by the rules shall be kept within the State.

The length of time during which records of tests and service conditions must be retained follow:

Alabama, Colorado, Missouri, Montana, New York, North Carolina, Oklahoma, and South Carolina: 2 years.

Illinois, Kansas, Maine, Michigan, and Vermont: 3 years.

Connecticut: 2 years for all records except those of meter tests which must be kept during the life of the meter.

Indiana: 5 years.

Washington: Until permission is given for their destruction by the department of public works.

It is stated in many cases and is probably understood in all others that all records shall be open to the inspection of authorized representatives of the commission. Indiana and Kansas require further that the records be open to the inspection of municipal officials, and Nevada and Oregon that they be open to the inspection of the public. Some other States require that records relating to particular subjects, especially complaints and pressure conditions, be open to the inspection of the public. These will be listed under the subject of the record.

(b) RECORD OF BILLINGS

Washington: "Each utility shall keep a customers' ledger or other record, which shall contain an accurate record of all revenues derived from each customer. In addition it shall contain for all meter customers the dates of the period for which the bill is rendered, the readings of the meter on those dates, the number and kinds of units supplied, and reference to tariff schedule applicable. . . . There shall be shown such additional factors as may be necessary in computing the bill."

(c) REPORTS TO COMMISSION

C32: "Each utility shall, at such times and in such form as the commission may prescribe, report to the commission the results of any test or tests required to be made or the information contained in any records required to be kept by the utility."

It may safely be assumed that all State regulatory bodies make requirements of the utilities under their supervision equivalent to this rule. Only about half of them state the requirement in their general rules; the others presumably make each class of reports the subject of an independent order. In two or three States the reports regularly required are listed in the service rules, but this is exceptional.

4. GENERAL SERVICE PROVISIONS

(a) INSPECTION OF PLANT AND EQUIPMENT

C32: "(*a*) Each utility shall inspect its plant, distribution system, and facilities in such manner and with such frequency as may be necessary to maintain them in proper condition for use in rendering safe, adequate, and continuous service. Such record shall be kept of the conditions found as the utility itself shall consider necessary for the proper maintenance of its system, unless in special cases a more complete record be specified by the commission.

"(*b*) Each utility shall, upon request of the commission, file with the commission a statement regarding the condition and adequacy of its plant, equipment, facilities, and service in such form as the commission may require."

A requirement similar to the rule quoted is stated in the rules (in the State law in Massachusetts) in Alabama, California, Colorado, Maine, Maryland, Montana, Massachusetts, North Carolina, Oklahoma, Pennsylvania, South Carolina, and Washington.

Important additions or variations follow:

Oklahoma, Alabama, and Connecticut: "Each utility shall have and maintain its entire plant and system in such condition that it will furnish safe, adequate, and continuous service."

California: "Whenever any equipment or facilities, the failure of which would involve life or property hazard, are removed from service for any reason, they must be thoroughly inspected and tested before being again placed in service. No equipment or facilities shall be placed in service or continued in service which have for any reason become detrimental to service, dangerous, or liable to cause injury to persons or damage to property."

California further requires the capping "at or outside the property line" of service pipes to dismantled buildings.

(b) PLANT METERS AND RECORDS

Alabama: "Each gas utility shall install such station meters and instruments as may be necessary to obtain a daily and monthly record of the amounts of gas made or purchased and gas sent out, readings being taken at sufficiently frequent intervals to show the characteristics of the load. Records shall be kept, insofar as practicable, of the pressure supplied to low-pressure distributing systems from plants or district regulators, and may be in the form of pressure-gage charts. These records shall be available for inspection by the commission for a period of at least two years."

California has a detailed statement, too long for inclusion here, of the very complete records which are required of items relating to the operation of manufacturing and distributing equipment and to the materials employed in and the products of such operations. The requirements are separately listed for companies distributing manufactured and mixed gas, hydrocarbon gases, and natural gas.

Illinois: "Each utility shall keep a daily record of the plant operation which so far as practicable, shall show the gas made, gas sent out, coal carbonized, oil and fuel used, time each machine is in operation, length of blows and runs, length of charges, weight per charge, and the details of any changes in the use of equipment which may affect the operation."

Maryland: "The utility shall also keep a record of the installation and period of use of all district regulators and the daily use of manually operated regulators used for the maintenance of uniform gas pressure."

(c) INSPECTION OF EQUIPMENT

Pennsylvania: "Each utility shall inspect its equipment and facilities, including the necessary tests for water and leaks in its lines, in accordance with good practice, and in a manner satisfactory to the Commission, and shall

maintain as specified in rule IX, a complete record of all such inspections and tests, and shall file with the Commission a statement of the condition of its equipment and facilities, and such copies of its reports of inspections when and in such form as the Commission may require."

Washington: "Each utility shall install such approved graphic recording pressure gages and such other devices as may be necessary to obtain an accurate daily and monthly record of the amount of gas supplied to its distribution system.

"Each utility may be required to install and maintain metering or recording devices at such points on its system as are necessary to show the character of service being rendered therefrom, unless the expense of installing and maintaining such meters is out of proportion to the benefit that may be derived. Each utility may also be required to install such metering and recording devices as may be required by the Department in connection with making special investigations.

"Each utility may be required to maintain a written record of its daily output of service from such points on its system as may be designated by the Department. Such records must be kept available for the inspection of representatives of the Department.

"A record shall be kept by each utility which will clearly show the amount of gas supplied daily to its distribution system. Each utility shall for 1 day between the hours of 5 a.m. and 9 p.m. on any of the first 5 days of each month, except Sunday, record such readings of its meters as will show the hourly demand on its system."

(d) COMMISSION INSPECTION

New Hampshire: "The Commission will, from time to time, inspect the methods of manufacture and test the quality of gas supplied by each utility. Under the provisions " (of law) "a fee of $15 will be collected from the utility for each such inspection."

(e) PROPERTY IDENTIFICATION

Connecticut: "Each group of buildings or structures used in the production, refining, or distribution of gas shall be provided with such signs as will definitely designate the name of the gas company owning or having the custody or maintenance of the same."

(f) JOINT OPERATION

Alabama: "Where a utility is jointly operated with any other enterprise, suitable instruments shall be installed and records kept so that the cost of the utility operation may be accurately determined at any time."

(g) ACCEPTED GOOD PRACTICES

Oklahoma: "The transmission and distribution systems including transmission lines, distribution mains, compressing equipment, regulators, meters, services, etc., shall be constructed, installed and maintained in accordance with accepted good practice."

(h) WASTE

West Virginia: "All practices in the production, distribution, consumption, or use of natural gas which are wasteful, such as flambeau lights and the like, are hereby expressly prohibited."

(i) OPERATING SCHEDULE

Colorado: "Where gas service is not rendered continuously or is subject to discontinuance during certain periods in favor of preferred classes of customers, the utility shall provide specific rules and regulations subject to the approval of the Commission covering such service and file with the commission copies of all contracts deviating from any rule thus established."

(j) INTERRUPTIONS OF SERVICE

C32 (California, Colorado, Connecticut, Illinois, Kansas, Maryland, Maine, Missouri, Montana, New York, Oklahoma, Oregon, Pennsylvania, South Caro-

lina, Vermont, Washington, West Virginia): "Each utility shall keep a record of any condition resulting in an interruption of service affecting its entire system or major division thereof, including a statement of the time, duration, and cause of any such interruption."

Additional requirements follow.

California: Contemplated work which will result in an interruption must be submitted to the commission for approval in advance.

Illinois (Indiana, Michigan, Missouri, North Dakota, and Washington): "Each utility shall make all reasonable effort to prevent interruption of service. When interruptions occur the utility shall reestablish service with the least possible delay."

Illinois (Michigan, Missouri, Washington): "Whenever the service is interrupted for the purpose of working on the distribution system or station equipment this work shall be done at a time which will cause the least inconvenience to consumers, and those who will be most seriously affected by such interruption shall so far as possible be notified in advance."

Washington: "Whenever practicable, all customers, the police department and the fire department affected by such interruptions shall be notified at least 6 hours in advance."

West Virginia defines an interruption as a period of time during which the pressure is less than half the normal pressure for the district. In Illinois a pressure of less than 1½ in. of water at the inlet to the distribution system is defined as an interruption.

Reports to the commissions are required in various States if interruptions of the durations listed below occur.

California, 2 hr; Indiana, 12 hr; Montana, 24 hr (by telegraph); New York, 5 min (written), 15 min (by telegraph); North Dakota, 12 hr.

(k) ACCIDENTS

C32 (Colorado, Maryland, Maine, Massachusetts, North Carolina, Oklahoma, South Carolina): "Each utility shall, as soon as possible, report to the commission each accident happening in connection with the operation of its property, facilities, or service, wherein any person shall have been killed or seriously injured or whereby any serious property damage shall have been caused. Such first report shall later be supplemented by as full a statement as is possible of the cause and details of the accident and the precautions, if any, which have been taken to prevent similar accidents."

Alabama, Kansas, Pennsylvania, and West Virginia require a complete record of accidents and of means taken to prevent their recurrence.

In California, the industrial accident commission has direct authority in the matter of accidents and the means taken for their prevention, but the inspectors for the railroad commission, which has jurisdiction over all utilities, undertakes to report unsafe conditions to the accident commission. A summary of the rules of the accident commission is given in the "Gas Service Bulletin", which contains the detailed directions of the Railroad Commission with respect to service matters.

(l) SAFETY

Connecticut: "Every gas company shall at all times use every effort to properly warn and protect the public from danger and shall exercise all possible care to reduce the hazard to which employees, customers, and others may be subjected by reason of its equipment and facilities."

Additional provisions of various States follow:

Alabama (Oklahoma): "It is required that all reasonable care shall be exercised by each utility to reduce the life hazard (1) to which employees are subjected in and about its plants, and on its distribution system; (2) to

which the utility's customers may be subjected by the introduction of its facilities into the premises of the customers; (3) to which the general public may be subjected by the presence of its facilities in the public streets and ways."

Colorado (Maryland): "Each utility shall further give all reasonable assistance to the Commission in the investigation of the cause and suitable means for the prevention of any such accidents in the future."

Connecticut: "Every gas company shall . . . report all accidents in which any of its facilities are involved.

"In order to assist the Commission in promptly examining into the causes of, and the circumstances connected with, all fatal accidents and the other accidents of a serious nature . . . the gas company involved shall notify by telephone or telegraph the office of the Commission or one of the engineering staff of the nature and location of such accidents. Such gas company shall also give all reasonable assistance to the Commission in the investigation of the cause and determination of suitable means for prevention of such accidents."

North Carolina: "Such reports or statements" made to the Commission "shall be kept confidential by the Commission and shall not be accessible for public inspection."

Maryland defines the seriousness of the accidents which must be reported as those which cause 3 or more days' disability or any property damage in excess of $150.

Massachusetts requires a rather elaborate investigation by the Board and by local authorities.

(m) COMPLAINTS

C32 (Alabama, California, Colorado, Connecticut, Illinois, Indiana, Kansas, Maine, Maryland, Michigan, Montana, Nevada, New Hampshire, New Jersey, North Dakota, Oklahoma, Oregon, South Carolina, Washington, and Wisconsin): "Each utility shall make a full and prompt investigation of all service complaints made to it by its consumers, either directly or through the Commission. It shall keep a record of all such complaints received, which record shall show the name and address of the complainant, the date and character of the complaint, and the adjustment or disposal made thereof."

Vermont: "Each utility shall keep a record of all complaints as to heat content or purity of gas, pressure conditions, meter accuracy, and general character of service supply, including the name and address of the complainant, date and nature of complaint, and the remedy for or disposal of the complaint."

Pennsylvania requires that a record be made of written complaints only.

Illinois, Kansas, and Washington require that written complaints be acknowledged in writing.

Alabama and California require that the complaint record be kept 2 years.

Several States specifically require that the record of complaints be open to the commission, others that complaints be reported to the commission when requested; compliance with these requirements is to be taken for granted in all cases, whether stated in the rules or not.

Indiana requires that the complaint record be open to municipal officials.

Wisconsin requires that the complaint record be open to public inspection.

Nevada requires that a summary of complaints be sent to the commission monthly.

(n) INFORMATION FOR CONSUMERS

C32 (Alabama, California, Colorado, Connecticut, Illinois, Maryland, Missouri, Montana, North Carolina, Oklahoma, Oregon, South Carolina, West Virginia): "Each utility shall, upon request, give its consumers such information and assistance as is reasonable, in order that consumers may secure safe and efficient service; and upon request it shall render every reasonable assistance in securing appliances properly adapted and adjusted to the service furnished."

New Jersey: "Each company supplying gas shall inform each of its customers, where peculiar or unusual conditions prevail, as to the conditions under which efficient and satisfactory service may be secured from its system."

Oklahoma (Alabama, California, Colorado, Maryland, Washington, West Virginia): "Each utility shall inform the consumers of any change made, or proposed to be made, in the character of the service supplied which would affect the efficiency or safety of operation of the appliances or equipment which may be in use by said consumers."

Kansas: "In order that its patrons may be taught economy in the use of gas, each distributing company and each pipe line or producing company shall prepare and mail to its patrons at the time of mailing the October bills of each year a printed pamphlet containing full information regarding the economical adjustment and use of gas-burning equipment."

C32 (Alabama, California, Colorado, Maryland, Montana, New Jersey, North Carolina, Oklahoma, South Carolina, West Virginia): "Each utility shall adopt some means of informing its consumers as to the method of reading meters, either by printing on its bills a description of the method of reading meters, or by a notice to the effect that the method will be explained at the office of the utility upon application."

C32 (Alabama, Colorado, Maryland, Montana, New Jersey, North Carolina, Oklahoma, South Carolina): "It is recommended that an exhibition meter be kept on display in each office maintained by a utility."

C32 (Alabama, Colorado, Connecticut, Maine, Michigan, North Carolina, North Dakota, Oklahoma, South Carolina): "Complete schedules, contract forms, rules and regulations, etc. [of the utility] as filed with the Commission shall also be on file in the local office of the utility and open to the inspection of the public."

Alabama (California, Colorado, Michigan, Oklahoma, West Virginia): "It is required that a copy of the rules and regulations for gas service as published by the commission be on file and open to the inspection of the public."

Colorado (Alabama, Michigan, North Dakota): "The attention of the public shall be called to these files of schedules, rules and regulations, and orders, by placing a suitable placard in the office of the utility."

Alabama: "It shall be the duty of the utility to advise the customer at the beginning of service . . . and whenever the customer shall request the utility in writing to do so . . . the rate which is most advantageous to the customer for his requirements of service."

Connecticut: "Every gas company shall, upon request, furnish a customer with the schedule of rates applicable for such customer."

West Virginia: "Where a special class of service is available to only a part of the district served, this should be stated to each applicant for gas."

(o) METER READINGS

Michigan: "All service meters shall be read not less frequently than once a month on the corresponding day of each meter reading period, provided, that special authority may be granted by the commission for the reading of the meters less frequently than once a month if the circumstances warrant."

(p) METER READINGS AND BILL FORMS

C32 (Alabama, California, Colorado, Connecticut, District of Columbia, Indiana, Maine, Maryland, Massachusetts, Montana, Nevada, New Jersey, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, Washington): "Each service meter shall indicate clearly the cubic feet of gas registered by such meter."

C32 (California, Maine, Montana, North Carolina, Oklahoma, South Carolina): "Where gas is metered under high pressure or where the quantity is determined by calculation from recording devices, the utility shall supply the

consumer with such information as will make clear the method by which the quantity is determined."

Alabama (Colorado, Connecticut, Illinois, Indiana, North Dakota, Oregon): "In cases where the dial readings of a meter must be multiplied by a constant to obtain the cubic feet consumed, the proper constant to be applied shall be clearly marked on the face or dial of the meter" (or on the meter case).

Washington: "Where the commodity is metered under such conditions as require the application of a constant or where the quantity is obtained by calculation from recording devices, the utility, upon request, shall supply the customer with complete information to enable the customer to compute readily the quantity consumed."

Nevada: "Gas and electric companies shall furnish printed instructions as to the method of reading meters and post copies of the same in a conspicuous place near the meter. They shall also have their meter readers instruct all customers in the correct method of reading their meters, and shall have their meter readers present to customers at the time meter is read a duplicate record of his reading, which shall give the present reading, the previous reading, the consumption for the month just passed, the consumption for the previous month and the dates of readings."

Oregon (Alabama, Colorado, Missouri): "On written request by a customer the utility shall cause the meter reader, at the time the customer's meter is read, to leave on such meter, or with the customer, a statement showing the date and time such reading was made and the reading of the meter. . . ."

Indiana (North Dakota): "Upon request of any consumer a meter tag shall be securely attached to the meter and the meter reader shall place on the tag at each reading of the meter his identification number, the date and the meter reading."

C32 (Alabama, Arizona, California, Connecticut, Illinois, Indiana, Kansas, Maine, Maryland, Michigan, Missouri Montana, Nevada, New Hampshire, New Jersey, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, Washington, West Virginia, Wisconsin): "Bills shall be rendered periodically, and they shall show the readings of the meter at the beginning and end of the period for which the bill is rendered, the date of the meter readings, the number of cubic feet of gas supplied, and the unit price."

C32 (Alabama, California, Colorado, Connecticut, District of Columbia, Illinois, Indiana, Kansas, Maine, Michigan, Missouri, Montana, North Carolina, North Dakota, Oregon, South Carolina, Washington): "On all bills which include any other items than a definite unit price for gas, the other factors used in computing the bill shall be clearly stated, so that the amount may be readily recomputed from the information appearing upon the bill."

C32 (Arizona, Maine, Montana, North Carolina, South Carolina, Washington): "Each bill shall bear upon its face the date when the bill was mailed or left at the premises of the consumer or the latest date on which it may be paid without loss of discount or incurring of penalty."

Oklahoma: "Each bill shall bear upon its face the date when due; the latest date upon which it may be paid without loss of discount or incurring of penalty; the date when service will be discontinued for nonpayment and the charge made for restoring service."

Michigan: "The complete rate schedule for the class of service used shall also appear upon the bill."

Connecticut: "Any utility shall upon request supply to a customer a statement of the past readings of such customer's meter for any period not necessarily in excess of 15 months."

West Virginia: "Utilities desiring to adopt mechanical billing of such nature as to render compliance with all the terms of" (the paragraph stating the information which must be printed on the bills) "impracticable, may make application to the commission for relief from part of these terms. After consideration of the reasons given when asking for relief, the commission may allow the omission of part of these requirements."

Alabama (Maryland, New Jersey): "Each utility having prepayment meters in service shall, at the end of each collection period, inform the customer of the readings of the meter at the beginning and end of the period, and amount of money taken from the meter for the period corresponding to the meter readings."

Connecticut: "Every gas company shall, upon written request of a customer served through a prepayment meter, cause the meter reader to leave with such customer at the time of the reading of the meter, a memorandum of its reading and the amount of money collected from it."

(q) APPLICATION OF DISCOUNT

Michigan: "Gas rates made effective or approved by the Commission will provide for the allowance of discounts for prompt payment of bills for gas service, and such bills should show both gross and net charges. Discounts allowed for prompt payment of bills shall be forfeited by consumers if the bill is not paid on or before the discount date. Failure to receive a bill rendered by a utility will not extend the discount period. Consumers mailing remittances before midnight of the last day of the discount period shall receive the benefit of the discount, the time of mailing being taken as the time shown by the postmark on the envelope."

(r) IDENTIFICATION OF EMPLOYEES

Washington: "Employees of the utility who must have access to the customers' premises shall be properly identified by uniform clothing or badge, or shall carry with them proper identification cards, all of which may be subject to the approval of the Department."

(s) CHANGE IN CHARACTER OF SERVICE

C32 (Alabama, Colorado, Maine, Montana, North Carolina, South Carolina): "In case any substantial change is made by the utility in the gas pressure or other service conditions which would affect efficiency of operation or adjustment of appliances, the appliances of all consumers in the district affected shall be readjusted by the utility for the new conditions without charge."

Washington: "In case any substantial change is made by the utility in the character of service rendered, which change would affect the efficiency of operation or the adjustment of equipment of customers, all customers liable to be affected shall be promptly notified by the utility and, where adjustments of such equipment need to be made to permit use under such changed conditions, such adjustments shall be made and the cost thereof shall be equitably adjusted between the utility and the customer; except, that when the customer has been advised of such contemplated change prior to his taking the service, or when such change shall be required by law, the customer shall bear all cost in connection with making changes in his own equipment."

The requirement made in Alabama, California, Colorado, Maryland, Oklahoma, and West Virginia that customers must be notified of changes was covered under "Information for Consumers".

(t) DEFINITION OF A CUBIC FOOT OF GAS

C32 (Alabama, California, Colorado, Connecticut, Illinois, Indiana, Kansas, Maine, Maryland, Michigan, Missouri, Montana, New Hampshire, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, Vermont, Washington, Wisconsin): "When the gas itself is to be tested under these rules, a cubic foot of gas shall be taken to be that amount of gas which occupies the volume of 1 cubic foot when saturated with water vapor and at 60°F. and under a pressure of 30 inches of mercury."

C32 (Alabama, California, Colorado, Connecticut, Indiana, Maine, Maryland, Michigan, Montana, North Carolina, North Dakota, Oregon, South Carolina, Washington): "For purpose of measurement of gas to a consumer a cubic foot of gas shall be taken to be the amount of gas which occupies a volume of 1 cubic foot under the conditions existing in such consumer's meter as and where installed."

The rule is modified by the following additions in various States:

Illinois: . . . "provided consumer's meter shall not be set so close to any source of artificial heat as to subject it to a temperature exceeding 75°F."

Missouri: . . . "provided such meter is not subject to abnormal temperature conditions."

Oklahoma: . . . "provided, however, where the gas delivered to the consumers is measured at a pressure greater than the pressure base upon which it is computed, the volume registered by the meter shall be corrected by a multiplier determined as specified in rule 27 a."

In California it is specified that gas metered at "other than normal delivery pressure" shall be reduced to 14.73 pounds per square inch.

(u) TESTING FACILITIES

C32 (Alabama, California, Colorado, Illinois, Maine, Montana, North Carolina, Oklahoma, South Carolina): "Each utility shall, unless specifically excused by the Commission, provide such laboratory meter-testing equipment and other equipment and facilities as may be necessary to make the tests required of it by these rules or other orders of the Commission. The apparatus and equipment so provided shall be subject to the approval of the Commission, and it shall be available at all times for the inspection or use of any member or authorized representative of the Commission."

C32 (Alabama, Maine, Montana, North Carolina, South Carolina): "Each utility shall make such tests as are prescribed under these rules with such frequency and in such manner and at such places as is herein provided or as may be approved or ordered by the Commission. Unless otherwise directed by the Commission, the methods and apparatus recommended by the National Bureau of Standards in the latest edition of its Circular No. 48 'Standard Methods of Gas Testing' may be used."

California (Colorado): "Each gas utility shall make such tests as are prescribed under these rules with such frequency and in such manner, and at such places as herein provided, or as may be approved or ordered by the Commission."

California: "Each gas utility shall file with the Commission a detailed statement showing the location of each laboratory, meter-testing shop, and service inspection station owned, controlled, or operated by the utility, together with a full and complete description of each major testing or standardizing instrument or apparatus maintained therein. Any major change or addition to testing instruments and apparatus or abandonment of testing instruments or apparatus shall be reported to the Commission within 10 days after the change has become effective."

Connecticut: "All tests made by any gas company under these rules shall be performed according to such methods and at such places as may be in accordance with accepted practice and the apparatus, equipment, and rooms used for such tests shall be at all reasonable times available for inspection by or the use of any member of, or authorized representative of, the Commission."

District of Columbia: "The testing done under these regulations shall be by the methods prescribed by the National Bureau of Standards except as otherwise prescribed by law or by direction of the Commission."

Missouri: "It is suggested that those utilities not required to maintain certain testing equipment as hereinafter specified arrange to perform the tests set forth by making use of the testing equipment of some nearby utility required to maintain same."

"Complete equipment for all tests specified will be maintained at the Laboratories of the State University at Columbia, Mo. The Engineering Laboratories of the State University will be prepared to standardize all testing equipment submitted for a nominal fee."

Nevada: "Each company is required to have an equipment of measuring and testing devices approved by the Public Service Commission, and the Commission's engineer will assist the companies in maintaining this equipment in a suitable condition by comparison with standards under the direct control of the Commission." (Testing equipment required is then specified.)

New Hampshire: "Each utility shall provide, equip, and maintain a station for the testing of gas and gas meters, and such equipment therefor as may be necessary for the testing required by any rules of this Commission, and shall provide such facilities for the use of the Commission's inspector as the Commission may prescribe, to be arranged in a location and according to plans approved by the Commission."

Oregon: "Each utility shall provide such laboratory meter-testing shop, and other facilities as may be necessary to make the tests required by these rules. All tests made by any utility under these rules shall be carried out in a manner and at such places as may be approved by the Commission, and the apparatus and equipment used for these tests shall be at all times available for the inspection or use of any member or authorized representative of the Commission."

5. METERS

(a) USE OF METERS REQUIRED

Kansas: "All gas service shall be metered."

(b) USE OF METERS

Michigan: "Service meters owned by the utility shall be placed in service for measuring all gas consumed by every consumer (including the utility itself). The utility shall at all times have access to meters, service connections and other property owned by it on consumer's premises for purposes of maintenance and operation. Neglect or refusal on the part of consumers to provide reasonable access to their premises for the above purposes shall be deemed to be sufficient cause for discontinuance of the service on the part of the utility. The use or establishment of flat rates for unmeasured gas, except for street lighting, will not be approved by the Commission."

Oklahoma: "All gas transmitted by any utility shall be measured accurately by proper apparatus prior to entering the pipe line and upon its exit from the pipe line, and all gas consumed for light, heat, or power in connection with its transmission, shall be measured accurately in order that the 'lost and unaccounted for' in transmission may be determined."

The same requirement is made with respect to all gas distributed.

Oklahoma: "All the measurements required by this rule shall be recorded and the totals reported to the Commission each month. . . . The measurements shall be reported on an 8-ounce pressure base regardless of the pressure base upon which the gas is purchased or sold; provided, however, that sales to consumers shall be reported as billed when the pressure at which the gas is measured is not greater than 8 ounces."

West Virginia: "All gas sold within the State shall be charged for by meter measurements, except such as is used in street lights of the mantle type and for the drilling and repairing of isolated wells.

"All gas delivered as compensation for leases, rights-of-way, or, for other reasons, not charged for at the utility's regular schedule of charges shall be metered and a record kept thereof."

(c) MEASURING PRODUCTION INTO AND OUT OF THE STATE

West Virginia: "Every utility shall measure by meter or meters, and record the quantity of, all gas produced and purchased by it.

"Every utility shall likewise measure and record the quantity of gas piped out of the State and the amount brought into the State."

(d) SELECTION OF METERS

Missouri: "Each service meter shall be suited to the particular installation to which it is assigned and chosen with a view of obtaining the best adaptation to local conditions and to the load.

California: "Each utility shall install service lines and meters of adequate capacity to provide satisfactory service and to assure accurate meter registration under the load conditions imposed."

(e) MEASUREMENT OF GAS UNDER HIGH PRESSURE

Oklahoma: "When gas is measured through positive or proportional meters at a pressure greater than the pressure base upon which the measurement is computed, such meters shall be equipped with reliable pressure-volume recording gages."

(f) COMPUTING VOLUME OF GAS MEASURED AT HIGH PRESSURE

Oklahoma: "In computing the volume of gas on a given pressure base from a pressure-volume chart, the multiplier shall be obtained by the weighted average method, which method consists in determining the average pressure of each unit volume indicated on the chart.

"In computing the volume of gas at a given pressure base from an orifice meter chart, the average static pressure and the average differential pressure shall be determined for periods not exceeding 1 hour."

(g) METER RENTALS AND MAINTENANCE

Arizona: "No meter rental shall be charged by a utility supplying gas for any meter installed by it."

West Virginia: "No utility shall make any charge for furnishing and installing any meter or other appliance necessary to measure the gas furnished, except by mutual agreement in special cases."

Alabama (Colorado): "No meter rental as distinguished from a minimum charge for service shall be charged by any utility for any meter installed by it which is used by the utility as a basis for rendering its bills. Where additional meters furnished by the utility are to be used as submeters, or for the convenience of the customer, a charge for such meters may be made in accordance with a schedule approved by the Commission."

Colorado: "The utility shall keep such submeters in good operating condition, but will not be required to keep a record of the monthly readings of these meters.

"All meters used in connection with metered service shall be furnished, installed, and maintained at the expense of the utility. Any appliance furnished at the expense of the utility shall remain its property and may be removed at any time after the discontinuance of service."

Oklahoma: "Each utility shall provide and install at its own expense and shall continue to own, maintain, and operate all equipment for the regulation and measurement of gas to its customers.

"Where additional meters are furnished by the utility to be used as submeters, or for the convenience of the consumer, a charge for such meters may be made in accordance with a schedule approved by the Commission."

Washington: "No rental shall be charged by any utility for the use of a meter installed by it, excepting that if a customer desires for his convenience the installation of more than one meter at one premises for one class of service, then the utility may install such meters upon the payment, by the customer, of a reasonable rental therefor. The utility shall install a master meter ahead of such group of rental meters, the reading of which shall be used in computing the bills to be rendered. No rental shall be charged for the master meter."

(h) TAMPERING WITH MEASURING AND REGULATING EQUIPMENT

Washington: "No regulator, regulator station, meter, meter house, or other property or equipment owned by a utility, wherever situated, whether upon consumer's premises or elsewhere, shall be tampered with or interfered with either for the purpose of adjustment or otherwise, except by authorized and accredited representatives of the utility owning the same; and official responsibility under a municipal government shall not constitute an exemption from this rule."

(i) LOCATION OF METERS

C32 (Alabama, Indiana, Maine, Montana, North Carolina, North Dakota, South Carolina, Washington): "No consumer's meter shall be installed in any location where it may be unreasonably exposed to heat, cold, dampness, or other cause of damage or in any unduly dirty or inaccessible location."

California: "All service meters hereafter installed on consumers' premises shall normally be located at a point near where the service pipe enters the building, or at a point adjacent to the front or rear property line and so placed as to be at all times accessible for inspecting, reading, and testing."

California (Washington): "Prepayment meters shall be so located as to be easily accessible to the consumer."

Connecticut: "All meters must be accessible for reading. They shall be installed as near as practicable to the point of entrance of the service and be in a clean, dry, safe place where the temperature is reasonably uniform and on a support as free as possible from vibration."

California: "If the customer's building or consuming equipment is located at a considerable distance from the street or road, or if the service traverses cultivated land and is hence subject to injurious action by the soil, or if the

customer is supplied with gas from a high pressure transmission line, the meter may be located at or near the property line, as close as possible to the main and in line with the point of service as closely as good construction will permit."

Maine: "Meters shall not be installed within 3 feet of an electric meter unless a suitable barrier is provided between the meters.

"Meters should not be placed in coal or wood bins or on the partitions forming such bins, nor on any unstable partitions or supports. Meters should not be installed in attics, sitting rooms, bedrooms, bathrooms, show windows, or restaurant kitchens, over doors, over windows, or in any other location where the visits of the meter reader will cause annoyance to the customer."

Illinois: "Meters shall not be so close to any source of artificial heat as to subject them to a temperature exceeding 75° F. On all new installations of meters the utility may require that the meter be installed, if possible, in a location where a temperature not lower than 40° F is maintained. Where existing meters are so located as to permit an interference with service on account of freezing it is recommended that the meter location be changed to meet the above maximum and minimum temperature requirements, such work to be done at the utility's expense."

Michigan: "After the taking effect of these rules, no meter shall be installed unless the meter connections consist of steel pipe and screwed fittings or a standard type of meter bar. The meter shall be located in a clean, dry place secure from injury and from great variation in temperature and convenient of access."

Oklahoma (Illinois, Washington, West Virginia): "It is recommended that all meters hereafter installed on consumer's premises be located inside the building and as near as possible to the point where the service pipe enters, in a clean, dry, safe place, not subject to wide temperature variations and so placed as to be at all times accessible for reading, inspecting, and testing."

Oklahoma (Illinois): "Meters shall not be placed in coal or wood bins, or in close proximity to stoves or furnaces. Unless unavoidable, meters shall not be installed in sitting rooms, bedrooms, bathrooms, or in any location where the visits of the meter reader or inspector will cause annoyance to the consumer."

Oklahoma: "When it is necessary to install meters out of doors, they shall be protected from the weather by inclosing them in houses specially built for them, and it shall be the duty of the consumer to provide such shelter. There will be no objection to the installation of meters at the property line on the alley if necessary means are employed to properly protect such meters."

Washington: "The customer shall furnish a reasonable convenient and accessible place in which to install the metering devices which may be required for the proper rendition of service, such place to be in all respects properly adapted to the preservation of the integrity of the metering device, and to be free from any conditions which would adversely affect such device."

West Virginia: "When a number of meters are placed in the same location, each house line should be tagged close to the meter so as to indicate the particular part of a building or premises served by such meter."

West Virginia: "When the distance between the utility's main and the nearest point of consumption is more than 150 feet, the meter shall be located as near to the utility's main as may be practicable. This shall apply whether or not all or part of the service line shall have been constructed by either the consumer or the utility.

"When consumers are served from high-pressure lines, the meter, regulator or regulators and safety devices shall be located as near to the utility's main as is practicable. When under the terms of any contract the consumer agrees and undertakes to bear part, or all, of the cost of maintenance of the pipe between the utility's main and the meter, regulator, or regulators, the utility shall make from time to time such tests as are necessary to determine the condition of the pipe. If such test discloses leaks from the pipe, the utility shall give the consumer written notice of such leaks. If the consumer does not within 3 days make satisfactory arrangement to bear his proper part of the cost of such repairs as are necessary the utility may, at its discretion, either move the meter and regulators to a point near its main line, or repair the leaks and bill the consumer for his proper part or notify both the consumer and the commission and after receipt of permission from the commission discontinue service."

(j) INSPECTION OF METER INSTALLATION

Illinois: "At the time of installation, each meter shall be checked for proper mechanical condition and suitability of location. Service pipes, meter connections, and house piping should be inspected for leaks, adequacy, and general fitness with a view of insuring the furnishing of a satisfactory grade of service."

Michigan: "No utility shall establish gas service to any applicant until such utility has made a test of all supply piping and gas appliances by observing the meter when all appliances are shut off and gas pressure is on such piping and appliances, and finds that no gas passes the meter under such conditions. In case of refusal to establish service, the utility shall notify the applicant in writing of the defects, and shall also keep a record of all cases where refusal to establish service is made. . . . Such record shall be preserved permanently. Nothing in this rule shall be construed to make the utility liable for the installation, maintenance, or use of piping or appliances owned by the consumer beyond the making of the test above required; nor shall the utility be held liable for any continuing duty of inspection of piping or appliances."

(k) INSTALLATION OF METERS

Pennsylvania: "Each gas service meter installed . . . shall have been tested for accuracy by the utility within 1 year previous to its installation. It shall also be inspected by the utility for proper connections, mechanical conditions, and suitability of location within 60 days after installation."

West Virginia: "All gas utilities shall adopt a standard method of meter installation. Such methods shall be set out with a written description and with drawings to that extent necessary to a clear understanding of the requirement; all of which shall be submitted to the Commission for its approval. Copies of approved standard methods shall be made available to prospective consumers and contractors or others engaged in the business of placing pipe for gas utilization."

6. ACCURACY AND TESTING OF METERS

(a) EQUIPMENT FOR TESTING METERS

California: "Each gas utility shall adopt and maintain standard methods of testing gas-service meters, which methods and the facilities used in connection therewith shall be reported to the Commission for approval."

C32 (Alabama, Arizona, California, Connecticut, District of Columbia, Illinois, Indiana, Maine, Maryland, Nevada, New Hampshire, New Jersey, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, Wisconsin): "Each utility furnishing metered gas service shall own an approved type of meter prover, preferably of not less than 5 cubic feet capacity, equipped with suitable thermometers and other necessary accessories."

California: "Additional district meter proving stations shall be installed when and where found necessary by the Commission."

Colorado requires only utilities having 200 or more meters to maintain a prover.

Kansas requires meter provers "except where in the opinion of the Commission such requirement would be unreasonable on account of the small number of consumers."

Massachusetts requires that a prover be maintained by a utility if it has a paid-in capital of $100,000 or more.

Michigan: "Each utility selling more than 10 million cubic feet of gas annually shall provide and maintain at least one standard meter prover and necessary appurtenances of a form approved by the Commission. Such prover or provers shall be subject to test for accuracy by the Commission. Each utility selling 10 million cubic feet of gas or less annually shall make some arrangement whereby it shall have available equipment for testing its meters by some other utility or some meter manufacturer, and shall make arrangements whereby the test records of meters tested by outside parties shall be furnished to it."

Missouri requires that a utility maintain a prover only if it has 100 or more meters in service.

New York: "Unless otherwise provided by the Commission each gas company subject to the jurisdiction of the New York Commission must provide facilities for meter testing for the use of the Commission's inspectors." The equipment required is fully specified in the rules. The equipment used is tested and certified by the Commission every 2 years.

Washington: All except class D utilities (which have "a gross annual operating revenue" of less than $10,000) are required to maintain provers. "Class D utilities may have meters tested at a testing laboratory approved by the Department."

West Virginia: All utilities must maintain provers "unless specifically excused by the Commission."

C32 (Alabama, California, Colorado, Connecticut, District of Columbia, Illinois, Indiana, Kansas, Maine, Maryland, Missouri, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, West Virginia, Wisconsin): "The utility shall maintain such meter-testing equipment in proper adjustment so that it shall be capable of determining the accuracy of any service meter to within one-half of 1 percent."

C32 (Alabama, California, Connecticut, Illinois, Indiana, Maine, Maryland, New Hampshire, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, Wisconsin): "Each such meter prover shall be so placed that it will not be subjected to drafts or excessive temperature variations."

Colorado (Missouri): "Such meter provers must be located in a large comfortable working space free from excessive temperature variations, equipped with all necessary facilities and accessories, and at all reasonable hours accessible for inspection and use by the duly authorized representatives of this Commission."

C32 (Alabama, California, Illinois, Indiana, Kansas, Maine, North Carolina, North Dakota, Oklahoma, South Carolina, Washington, West Virginia): "The accuracy of all provers and methods of operating them will be established from time to time by a representative of the Commission."

Colorado (Michigan, Missouri): "Each meter prover must be accompanied by a certificate of calibration indicating that it has been tested with a standard which has been certified by the National Bureau of Standards or some testing laboratory of recognized standing."

Maryland (New Jersey): "The meter prover will be bottled by the Commission with its standard cubic foot bottle which has previously been calibrated and certified by the Bureau of Standards, Washington, D.C. The accuracy of the prover having been established to within one-half of 1 percent, the prover will be sealed and certified for use in testing the service meters; and no prover shall be used which has not been so sealed and certified."

Massachusetts (District of Columbia): Meters are tested and sealed under supervision of the Commission which takes the responsibility for their accuracy.

Oklahoma: "Whenever any utility is maintaining or shall hereafter establish and maintain a standardizing laboratory, periodic inspection by the Commission will be made of the equipment and methods in use, and if equipment and methods are acceptable to the Commission after such inspection, certification of meters and equipment for its own use and for other utilities may be made by such laboratory."

Washington (Connecticut and West Virginia): "All testing instruments and other equipment shall at all times be accompanied by a certificate signed by a proper authority giving the date when it was last calibrated and adjusted."

Illinois: "The companies owning more than one meter prover shall check them against each other from time to time for accuracy.

C32 (Alabama, California, Connecticut, Illinois, Maine, North Carolina, North Dakota, Oklahoma, South Carolina, West Virginia): "All alterations, accidents, or repairs which might affect the accuracy of any meter prover or the method of operating it shall be promptly reported in writing to the Commission."

(b) FACILITIES FOR TESTING METERS OF UNUSUAL SIZE OR TYPE

California: "Each utility using orifice meters, high-pressure meters, proportional meters or other large capacity meters shall own and maintain testing apparatus of a type approved by the Commission."

Oklahoma: "(1) Each utility furnishing metered gas service through proportional and large positive meters, shall provide for and have available a portable flow meter of suitable capacity, together with the necessary accessories, and it shall maintain such equipment in proper adjustment so that it will be capable of determining the accuracy of any proportional or large positive meter to within one-half of 1 percent.

"(2) Each utility furnishing metered gas service through orifice meters shall provide for and have available a portable water column and test gages of suitable range, and it shall maintain such equipment in proper adjustment so that it will be capable of determining the accuracy of any orifice meter to within one-half of 1 percent.

"(3) The accuracy of all flow meters shall be established at least once a year by a laboratory of recognized standing, such as provided for in (a) of this rule." (See above). "All pressure gages shall be checked with a dead-weight tester at least once a month and all aneroid barometers shall be checked against a mercurial barometer at least once a week when continually in use.

(c) INSTALLATION TEST

C32 (Alabama, Montana, North Carolina, South Carolina): "Every gas-service meter, whether new, repaired, or removed from the service for any cause, shall be in good order and shall be adjusted to be correct to within 1 percent when passing gas at 6 cubic feet per hour per rated light capacity before being installed for the use of any consumer: Provided, however, that a utility which has less than 1,000 consumers, and which has no facilities for opening meter cases and adjusting the mechanism, may put a meter back into service if it is not found to be in error by more than 1½ percent and appears otherwise to be in good order."

Illinois and Missouri require that meters when opened for repair or adjustment shall be adjusted to have an error within 1 percent, but do not require that meters be opened if in error by not more than 2 percent.

North Dakota makes a similar distinction, but the limits of accuracy required are 1½ and 2 percent, respectively.

California requires adjustment to within 1 percent fast or 2 percent slow before installation.

Colorado, Connecticut, Kansas, Oregon, and West Virginia require adjustment to within 1 percent of the correct value; Indiana, 1½ percent; District of Columbia, Maine, Massachusetts, Michigan, Missouri, Nevada, New Hampshire, New Jersey, Oklahoma, Pennsylvania, Texas (by law), Washington, and Wisconsin, 2 percent. Arizona, 3 percent; Vermont (by law), 4 percent. New York requires the meter to be correct, or slow by not more than 2 percent.

Maryland: "No gas service meter . . . shall be used on any consumer's premises . . . unless it has been previously tested and found to be accurate within 1 percent, provided that in testing a number of new, repaired, or removed meters not more than 15 percent of the total number shall exceed an error of 1 percent and no meter to exceed an error of 2 percent."

Illinois: "No meter which is mechanically defective shall be placed in service or allowed to remain in service after such defect has been discovered. When any gas meter is not connected in service the inlet and outlet shall be corked or capped to prevent the drying out of the diaphragms."

Washington: "Meters must not leak and must deliver gas without any noticeable fluctuation due to the mechanical operation of the meter."

(d) METHOD OF TESTING

C32 (Alabama, Indiana, Maine, Michigan, Missouri, Montana, New Jersey, North Carolina, North Dakota, South Carolina, West Virginia): "All tests to determine the accuracy of registration of any gas-service meter shall be made with a suitable meter prover."

Connecticut: "All tests in determining accuracy of any gas-service meter shall be made with a meter prover unless, because of the unusual capacity or construction of the meter, such method of test shall be considered impracticable, and another method of test shall have received the approval of the Commission."

Illinois, Indiana, Kansas, Maryland, Missouri, and North Dakota require that two checked tests be made which shall agree within 0.5 percent.

California requires an "open" and a "checked" test which must agree within 2 percent; and no test shall show the meter more than 1 percent fast.

Connecticut and Oklahoma require agreement within 1 percent between an "open" and a "checked" test. The checked test (at one-fifth of the rated capacity of the meter) determines whether the meter comes within the tolerance.

Washington requires that the test be repeated if the first test shows error between 1½ and 2 percent. Three tests, to be averaged, are required for all complaint meters. The New York rule is similar except that the first test is repeated unless the registration is accurate or not more than 1 percent slow. Meters more than 0.5 percent fast or 2 percent slow are readjusted without further test.

West Virginia: "If after running not less than two check tests, a meter is found to be in error by an amount less than that commercially practicable of correction it may be passed. If the error is practicable of correction, additional tests must be made the average of which shall determine the percentage of error of the meter 'as found.'"

"It is possible to set all but a very few old style meters within one-half percent of 100 percent accuracy on every adjustment, and these older styles can be set within one percent of 100 percent accuracy. It shall be understood that the allowance of this variation from 100 percent accuracy does not mean that the meter be set in error by this amount; the tolerance allows for unavoidable irregularity of the work on a commercial scale, and the average of the errors should be practically zero, substantially as many being slightly slow as are slightly fast."

California, Maryland, Michigan, New York, Oklahoma, Washington, and West Virginia give more or less detailed directions for making meter tests, which are too varied to be easily summarized and too long to quote. The directions given by California (in the Gas Service Bulletin) and by West Virginia are particularly full.

(e) MARKING METERS

C32 (Kansas, Montana, New Hampshire, North Carolina, Oregon, Washington): "Each meter shall be marked with the date of the last test made on that meter."

District of Columbia, Maryland, Massachusetts, and West Virginia require the official seal of approval of the Commission on correct meters.

Washington: . . . "All meters in service shall be sealed with a seal and by a sealing device acceptable to the Department."

(f) SPECIAL METERS

C32 (Alabama, California, Maine, Montana, North Carolina, South Carolina): "Any meter, the readings or record of which is based on the differential pressure in such meter or upon the measurement of any portion of the total gas delivered to a consumer, shall be tested for accuracy before installation in a manner satisfactory to the Commission."

California gives full instructions for testing special meters in the Gas Service Bulletin.

Oklahoma: "All tests on proportional and large positive meters in service provided for in these rules, shall be made with approved testing apparatus as specified in Rule 11 (*d*). It is recommended that such meters be tested in the place of permanent location on the consumer's premises whenever practicable. The accuracy shall be determined at various rates of flow ranging from approximately 10 percent of rated capacity to full rated capacity, and at a pressure not to exceed the pressure carried on the testing apparatus.

"All tests on orifice meters in service provided for in these rules, shall be made in the place of permanent location on the consumer's premises, with approved testing apparatus as specified in Rule 11 (*d*). The accuracy of the differential pressure registration and the static pressure registration shall be determined on a rising and falling pressure throughout the entire range of the gage."

West Virginia: "Every proportional meter shall be tested by the meterman of the utility using the orifice or the flow meter test. Proportional meters may be tested at the meter-testing shop of the utility or after installation at the option of the utility.

"Every orifice meter and orifice plate for use therewith shall be tested before installation by a meterman employed by the utility or by the manufacturer of the meter.

"Subsequent direct tests in the field shall be made of differential and direct pressure gages of orifice meters and recorded in the manner specified in Rule 25. The record shall give the original test data of the meter as found and as adjusted and left. In addition to this information, the record must show the manufacturer's number of the original plate or plates, with date of their testing, together with record of date of installation and date of removal of each particular plate used in said meter since previous test.

"Differential and direct pressure gages on all orifice meters or other type of meter so equipped shall be tested after installation and before meter becomes operative.

"Meter attendants are required, when changing recording pressure gage charts on all types of meters requiring charts, to check recording pen for zero reading, when recording instrument is relieved of pressure."

(g) APPOINTMENT OF METERMEN

West Virginia: "Every utility shall have in its employ a competent meterman whose duty it shall be to perform such tests as may be necessary to determine the accuracy of the utility's meters. The name of such employee shall be submitted to the Commission and thereupon the Commission will furnish to the utility its form entitled, "application for appointment of meterman", and after compliance with the requirements as noted in this form and its return to the Commission, the applicant may be certified as meterman and furnished with a card authorizing him to perform tests of gas meters.

"The utility shall notify the Commission when a certified meterman ceases to be in its employ and shall return to the Commission the meterman's card."

The Oklahoma Commission directs a course of instruction annually in which the metermen of the utilities may be trained for their duties.

(h) TOLERANCE FOR METERS

Missouri: "The allowance of certain variations from correctness on meters as hereinafter specified does not mean that meters may deliberately be set in error by the amount of the tolerance. This tolerance is specified to allow for the necessary irregularities in meter tests and maintenance conducted on a commercial scale."

(i) RECORD OF METERS AND METER TESTS

C32 (Alabama, California, Colorado, Illinois, Indiana, Kansas, Maine, Maryland, Michigan, Missouri, Montana, Nevada, New Hampshire, North Carolina, North Dakota, Oregon, Pennsyvania, South Carolina, Washington, Wisconsin): "Whenever any gas service meter is tested, the original test record shall be preserved, including the information necessary for identifying the meter, the reason for making the test, the reading of the meter upon removal from service, and the result of the test, together with all data taken at the time of the test in sufficiently complete form to permit the convenient checking of the methods employed and the calculations.

"A record shall also be kept, numerically arranged, indicating for each meter owned or used by any utility the date of purchase, its identification, a record of the use, repairs, and tests to which it has been subjected, and its present location."

Arizona, District of Columbia, Massachusetts, and Nevada require that records be kept of the results of meter tests, but do not prescribe details.

Vermont: "Each utility shall keep a classified record, showing for each gas meter owned, or used, the identification number, date of purchase, name of manufacturer, type, rating, serial number, the name and address of each consumer on whose premises the meter has been in service, the dates of setting and removal, the result of all tests and adjustments."

West Virginia: "A complete record of all tests and adjustments and data sufficient to allow checking of test calculations shall be recorded by the meterman and shall be reported to the Commission either monthly or quarterly as required on . . . such forms as may be prescribed by the Commission.

"The test records shall be so kept that they may be readily inspected and checked by the Commission's representative.

"All meters shall be given a company number plainly stenciled on the meter case or stamped upon a metal strip, suitably attached to the meter case.

"It is recommended that a separate card be prepared for each meter, that this card be so arranged that the date and data of each test may be entered thereon, that the card be of such character that a marker system can be used that will record the date of the last test and indicate the proper date for the next periodic test required by these rules. (Such a system has been developed and complete information will be furnished by the Commission upon application.)"

(j) PERIODICAL SUMMARY OF TESTS

Michigan: "There shall be also made and preserved a summary of all meter tests for each calendar year, showing the number of meters within certain limits of accuracy, intervals between tests and any other desirable information."

Connecticut: "Every gas company shall report annually, or oftener if requested by the Commission, a summary of the 'as found' tests in such form as may be designated by the Commission."

Washington requires that the past record of a meter be supplied to a consumer when requested.

Illinois: "Each utility shall make a monthly and annual tabulation of the results of all tests."

Indiana (North Dakota): "Annual tabulation of all meter tests above mentioned should be made and arranged according to type of meters and intervals of test."

New York: "A record clerk shall file and have charge of the daily reports made by the meter inspectors. From these reports he shall make up, not later than the 15th of the month, summaries of all meters tested during the preceding month. From such monthly summaries he shall prepare an annual statistical analysis showing:

"(*a*) Numbers of meters by size tested each month, subdivided to show complaint meters, new meters, and repaired and removed meters.

"(*b*) Meters tested on complaint—arranged by months and by companies.

"(*c*) Complaint meters tested, arranged as to years in service, showing for each service period the number of correct, fast, and slow meters and the

average percentages fast and slow, and the weighted average percentage fast or slow of all complaint meters tested.

"(*d*) New meters tested each month, subdivided as to correct and rejected meters, and percentage relation to total meters tested.

"(*e*) Repaired and removed meters tested each month subdivided as to correct and rejected meters, and percentage relation to total meters tested.

"These summaries shall be retained as permanent records of the Commission."

(k) PREPAYMENT METERS

C32 (Alabama, Illinois, Kansas, Montana, North Carolina, South Carolina): "No utility shall use prepayment meters geared or set so as to cause a rate or amount higher than would be paid if a standard-type meter were used, except under such special rate schedule as may be approved by the Commission for this class of service."

Connecticut prohibits a higher rate than standard for prepayment meters "without the consent of the customer."

North Dakota entirely prohibits a special rate for prepayment meters.

Washington: "When a utility uses prepayment meters geared or set so as to cause the registration of a greater amount or so as to result in a greater charge than would result if a standard-type meter were used, it shall specify in its tariff the manner in which the prepayment meters shall be set."

Indiana prohibits the use of prepayment meters entirely.

North Dakota (Alabama): "In case of discrepancy between dial reading and the prepayment mechanism, the dial readings shall be taken."

Alabama: "Adjustment shall be made annually or at the end of the service period, if less than one year, for the difference, if any, between the charges for the service received by the customer, as indicated by the meter readings, and the money which was collected from the meter."

(l) PERIODIC TESTING OF METERS

C32 (Alabama, Colorado, Connecticut, District of Columbia, Indiana, Kansas, Maine, Missouri, Montana, New Hampshire, North Carolina, North Dakota, Oklahoma, Oregon, Pennsylvania, Washington, West Virginia, and the cities of North Platte, Nebr., and Portsmouth, Ohio): "(*a*) No gas-service meter hereafter installed shall be allowed to remain in service more than 5 years from the time when last tested.

"(b) During each period of 12 months after these rules take effect, until all meters now in service shall have been tested, each utility shall remove approximately 20 percent of all meters now in service, those longest in service being removed first. Such meters shall not be replaced in service until tested and made to comply with the other provisions of these rules."

Arizona and Nevada and Minneapolis, Minn., require that meters be tested every 3 years.

Wisconsin requires that meters be tested and "overhauled" every 4 years.

New Jersey requires testing every 6 years; California, Illinois, Michigan, New York, Vermont, and Iowa City, Iowa, and Philadelphia, Pa., every 7 years. In several States the routine tests listed above apply only to "domestic" meters or to meters of the usual type with leather diaphragms. The rules given below apply to flow meters and other special types.

Oklahoma: "Large positive meters shall be tested at least once every year. Proportional meters shall be tested at least every 6 months. Orifice meters shall have their recording gages tested at least every 2 months, and the diameter of the orifice meter plate or plates shall be determined at least once in every 6 months."

Pennsylvania: "Proportional meters shall be tested once every 5 years and readjusted if necessary, and cleaned by a competent man at least once every 3 months."

West Virginia: "(*a*) Periodic tests shall be made of all meters according to the following schedule:

"(1) All domestic gas meters shall be tested at least once every 5 years.

"(2) All proportional meters, at least once every year.

"(3) All orifice meters shall have their recording gages tested at least once every 2 months and the constant of the orifice plate retested every 5 years.

"(*b*) Other gas meters not included in the above classification shall be tested at intervals to be determined by the Commission.

"(*c*) In making such tests, the meters longest in service without a test shall be tested first."

(m) METER TESTING ON REQUEST OF CONSUMERS

Colorado (Alabama, Arizona, Connecticut, District of Columbia, Kansas, Maine, Maryland, Michigan, Missouri, New Hampshire, North Dakota, Oregon, Washington): "Each utility furnishing metered gas service shall at any time when requested by a consumer make a test of the accuracy of any gas-service meter free of charge; provided; first that such meter has not been tested within a period of 12 months prior to such request . . ."

C32, Illinois, Indiana, Nevada, and New Jersey have the same rule except that the period, from one meter test until another must be made without charge, is only 6 months. In Vermont this period is 3 years.

Connecticut (C32, Colorado, Kansas, Maine, Maryland, Michigan, Montana, North Carolina, North Dakota, Oklahoma): A meter shall be tested without charge (other conditions being met) provided "that the customer will agree to abide by the results of such tests as the basis for the adjustment of disputed charges."

C32 (Montana, North Carolina, Oklahoma): "No deposit or payment shall be required from the consumer for such meter test except when a consumer, whose average monthly bill for gas service is less than $25, requests a meter test within 6 months after date of the installation or of the last previous test of his meter, in which case he shall be required by the utility to deposit with it, to cover the reasonable cost of such test, an amount not to exceed the following:

For each standard type gas service meter—
Not exceeding 10 lights capacity---------- $
Exceeding 10 lights, but not exceeding 45 lights capacity--------
Exceeding 45 lights capacity----------
For any meter rated other than by lights capacity—
Including increased capacity meters commonly called A and B meters, the deposit shall be the same amount as is required for a meter of corresponding size rated by its lights capacity."

California has the same rule except that an average monthly bill of $50 (instead of $25) is necessary to make the customer exempt from the payment of a fee for retesting within 6 months.

Maine and South Carolina vary from the rule in C32 by making no provision for exempting customers from the test fee because of the quantity of gas used.

Pennsylvania and West Virginia make no distinction in favor of meters that have been in service a long time without testing, but require the customer to deposit a test fee in every case.

The amount of the deposit required from the customer in each State follows:

	Rating of meter capacity (in lights)			
	10 or less		10 to 45	45 or more
Maine	$2.00		$4.00	$6.00
Montana	2.00		3.00	4.00
North Carolina	1.00		2.00	4.00
South Carolina	1.00		2.00	4.00
	10 or less	10 to 30	30 to 80	80 or more
Pennsylvania	$2.00	$4.00	$6.00	$10.00
	Rating of meter capacity (in cu ft per hr)			
	250 or less		250 to 400	400 to 4,000
California	$1.00		$2.00	$4.00
Oklahoma	½ the fee for referee tests.			
West Virginia	$0.50 for meters not exceeding a capacity of 1,000 cu ft per hr. Others ⅓ the fee for referee tests.			

C32 (Maine, North Carolina, Oklahoma, South Carolina): "The amount so deposited with the utility shall be refunded or credited to the consumer, as a part of the settlement of the disputed account, if the meter is found when tested to register more than 3 percent fast; otherwise the deposit shall be retained by the utility."

New York requires the company to give each complainant a specified form on which to make application for a test. The form fully explains the conditions under which tests will be made by the commission, but does not state any conditions regarding a test by the company, which appears (by implication) to be free. No other requirement as to testing by the company appears in the rules.

Montana and West Virginia require the return of the deposit if the meter is more than 2 percent fast; California and Pennsylvania if it is either fast or slow by more than 2 percent.

Colorado: "No charge shall be made to the consumer for any such test except as may be allowed by the Commission in special cases."

California requires tests to be made within 5 days after the request. Washington allows 10 days.

Arizona: "When an application is made by a consumer for a meter test within a period of less than 12 months, the utility shall refer the consumer to the State or City Sealer of Weights and Measures, to whom application can be made by the consumer for a meter test."

C32 (California, Connecticut, Illinois, Maine, Montana, North Carolina, Oklahoma, South Carolina): "A consumer may be present when the utility conducts the test on his meter, or, if he desires, may send an expert or other representative appointed by him."

Michigan: "The consumer shall be entitled to be present at such test if he makes a request to this effect at the time of filing request for testing of the meter."

Missouri: "The consumer shall be notified of the time and place of such test so that he may be present to witness same should he so desire."

Washington (Pennsylvania): "When a customer desires, either personally or through a representative, to witness the testing of a meter, he may require the meter to be sealed in his presence before removal, which seal shall not be broken until the test is made in his presence, or until permission to break the seal has been granted by the Department."

Colorado (Connecticut, District of Columbia, Illinois, Indiana, Kansas, Maryland, Michigan, Missouri, Nevada, New Hampshire, New Jersey, North Dakota, Pennsylvania, West Virginia). A written report giving the results of the tests shall be made to the consumer who requested it.

C32 (California, Maine, Montana, North Carolina, Oklahoma, South Carolina): "A report giving the name of the consumer requesting the test, the date of the request, the location of the premises where the meter has been installed, the type, make, size, and serial number of the meter, the date of removal, the date tested, and the result of the test shall be supplied to such consumer within a reasonable time after the completion of the test."

California and Nevada require that duplicate reports be filed with the Commission.

Washington: "The utility may be required to submit to the Department at such time as the Department may designate, reports of meter tests made in response to customers' complaints. These reports are to contain the name and address of the customer, the manufacturer's and utility's meter number, complete information as to the size or capacity of the meter, the date tested, the reading of the meter when tested, the name of the meter tester, the accuracy of the meter as found and the accuracy of the meter as left."

Alabama and Colorado require that a complete record of such test shall be kept on file at the office of the utility for at least 2 years.

West Virginia requires that the records be kept 3 years.

Indiana, Michigan, Missouri, New Jersey, North Dakota, and Pennsylvania have the same requirement, except that the length of time the meter record must be kept is not specified.

Connecticut requires all records of meter tests to be kept during the life of the meter.

In the following cities the testing of meters is done by the city: Little Rock, Ark.; Cedar Rapids, Iowa; Fort Dodge, Iowa; Pontiac, Mich.; Minneapolis and St. Paul, Minn.; Greenville, Miss.; Cleveland, Ohio; Charleston, S.C.; Fort Worth, Tex. In general, if not in every case, tests made on complaint are paid for by the complainant unless the meter is found to be in error to his disadvantage.

(n) DISPUTE AS TO ACCURACY OF METERS

Washington: "In the event of a dispute between the customer and the utility respecting the accuracy of a metering device, the utility shall forthwith make such investigation as shall be required by the particular case, and report the result thereof to the customer. In the event that the complaint is not adjusted, the utility or the customer may make application to the Department for adjustment of the complaint.

"If any complaint involves the accuracy of a metering device, and the utility has been notified in writing that such complaint has been lodged with the Department, such device must not in any event be changed unless a representative of the Department is present, or unless the Department authorizes the utility to remove the device or to make such changes as the Department may direct. Violation of this rule may be considered as a substantiation of the complainant's contentions, insofar as such change in the device might affect the proof of such contentions."

(o) DESIGNATION OF TESTING LABORATORIES FOR REFEREE TESTS OF METERS

Washington: "The Department shall designate two or more laboratories where the tests required by these rules other than those tests to be made by the companies shall be made, and will appoint inspectors under whose direction the tests shall be made at the several laboratories so designated or elsewhere as near as practicable to the locality where the test is desired."

Missouri specifies that all referee tests shall be made at the University of Missouri.

(p) REFEREE TESTS OF METERS

C32: "Upon written application to the Commission by a consumer a test will be made of the consumer's meter as soon as practicable by a representative of the Commission. The application for such test shall be accompanied by a remittance of the amount fixed below as the fee for such test. This fee shall be retained by the Commission. However, if the meter is found to be more than 3 percent fast the utility shall repay to the consumer the amount of the fee paid by the consumer to the Commission for such meter test."

Alabama, Arizona, California, Colorado, Connecticut, District of Columbia, Illinois, Indiana, Kansas, Maryland, Michigan, Missouri, Montana, Nevada, New Hampshire, New Jersey, New York, North Dakota, Oklahoma, Oregon, Washington, West Virginia, and Wisconsin have identical or similar provisions. The important differences follow.

In Arizona the testing is done by municipal or State "sealers of weights and measures" to whom the utility refers customers who are not satisfied with the free tests provided for by the utility. In Michigan, referee tests are made by municipal gas inspectors where such officials exist. Where there are no gas inspectors, the work is done by the commission. In Missouri, the engineering department of the State University is the referee.

In Alabama, Arizona, Michigan, Oklahoma, and Oregon the fee is paid by the customer if the meter is correct, slow, or less than 3 percent fast. In Colorado, Connecticut, District of Columbia, Illinois, Indiana, Kansas, Maryland, Missouri, Montana, Nevada, New Hampshire, New Jersey, New York, North Dakota, West Virginia and Wisconsin the utility pays for the test if the meter is 2 percent or more fast. In California the utility pays for the test if the meter is either fast or slow by as much as 2 percent.

Washington: "If any customer of a gas, electric, or water utility desires a meter test other than that provided for in the preceding rule" (the free test by the utility not more frequently than once a year) "said customer shall first make application to the utility, which shall have 10 days within which to make said test and report the result thereof to the customer, or to refuse altogether to make said test.

"Should the utility refuse to make said test or should the customer not be satisfied with the accuracy of any test made by the utility, the customer may then make formal application to the Department, which shall cause such test to be made by an inspector appointed by the Department as soon as practicable after the receipt of the application.

"If the meter is found to be slow or correct within the allowable limits or if the results of the Department's tests are substantially the same as those reported by the utility, or show that the meter is substantially slower than reported by the utility, then the customer shall be required to pay a fee of $3, but if the meter is found to be fast, beyond the allowable limit or substantially beyond the amount found by the utility, the utility shall pay the $3 fee."

North Dakota also requires that a test be requested from the utility before a customer may ask for a referee's test.

C32: "The amount of the fee to be paid for a meter test made by the commission shall be as follows:

For each gas-service meter—

Not exceeding 10 lights capacity---------- $

Exceeding 10 lights, but not exceeding 45 lights capacity-------

Exceeding 45 lights capacity----------

For any meter rated other than by lights capacity—

(Including increased capacity meters commonly called A and B meters), the fee shall be the same amount as is required for a meter of corresponding size rated by its lights capacity."

TABLE 4.—*Fees charged for referee tests*

State	Size of meter and amount of fee				State	Size of meter and amount of fee			
	Not more than 10 lights	10 to 45 lights	45 to 100 lights	Larger meters		Not more than 10 lights	10 to 45 lights	45 to 100 lights	Larger meters
Alabama	$1.50	$2.50	(1)	(1)	Montana	$4.00	$5.00	$10.00	$10.00
Arizona	1.00	1.00	$1.00	$1.00	Nevada	1.50	1.50	1.50	1.50
Colorado	2.00	4.00	8.00	8.00	New Hampshire	1.00	(1)	(1)	(1)
Connecticut	1.00	1.00	1.00	1.00	New Jersey	1.00	1.00	1.00	1.00
Dist. of Columbia	.50	.50	(2)	1.00	North Dakota	2.00	4.00	8.00	8.00
Illinois	2.00	4.00	8.00	8.00	Oklahoma [4]	2.00	4.00	10.00	10.00
Indiana	2.00	4.00	8.00	8.00	Oregon	2.00	4.00	8.00	8.00
Kansas	2.00	4.00	8.00	(1)	Washington	3.00	3.00	3.00	3.00
Maryland	1.00	2.00	(1)	(1)	West Virginia	(3)	(3)	(3)	(1)
Michigan	2.00	4.00	8.00	8.00	Wisconsin	2.00	4.00	8.00	8.00
Missouri	[3] 2.00	(1)	(1)	(1)					

	Capacity of meter in cubic feet per hour, and amount of fee			
California	0 to 250	250 to 400	400 to 4,000	+4,000
	$2.00	$4.00	$8.00	(1)
New York	0 to 150	200 to 425	500 to 800	900 to 1,200
	$0.75	$1.00	$1.50	$2.00
	1,500 to 2,500	3,000 to 16,000	40,000	+40,000
	$3.50	$5.00	$10.00	(1)

[1] Fee is determined or stated by commission at time of application.
[2] Meters not larger than 60 lights, 50 cents; greater than 60 lights, $1.
[3] The fee stated is additional to transportation charges.
[4] Oklahoma has a complete schedule for other types of meters also.
[5] Capacities not greater than 1,000 cu ft per hour, $1; 1,000 to 10,000 cu ft per hour, $2; 10,000 to 100,000 cu ft per hour, $5; more than 100,000 cu ft per hour, and proportional meters, flow meters and other special types on application.

C32 (Alabama, California, Connecticut, Indiana, Montana, North Dakota, Oklahoma): "This rule shall not interfere with the practice of a utility with reference to its tests of gas-service meters, except that in the event of an application by a consumer to the Commission for a referee test as herein provided, the utility shall not knowingly remove, interfere with, or adjust the meter to be tested without the written consent of the consumer, approved by the Commission."

Illinois: "The meters shall in no way be disturbed after the utility or its representative has received notice that application has been made for a referee test, unless authority to do so is first given in writing by the Commission or by the consumer."

Kansas: "Such tests shall be made by a representative of the Commission as soon as practicable after the receipt of the application, and the meter in question shall not be removed or tampered with in any way by either party before said test is made."

Missouri: "Meter to be tested must be removed and packed by or with the consent of the utility furnishing gas service, but the consumer shall be given an opportunity to witness the disconnecting, packing, and shipment of the same should he so desire."

New Jersey: "Each meter to be so tested is to be removed and will be tested by an inspector of the Board using the nearest certified prover. In certain cases, tests will be made with a portable test meter. In cases of dispute, however, as to the accuracy of such meter, the test made with the prover shall be considered the correct one."

District of Columbia: "Each gas-light company shall transport to the [Gas Inspection] Bureau all its meters to be tested by the Bureau."

Connecticut: "For the purposes of Rule 5–b (a referee test) the Commission will be inclined to determine the average error of a meter by taking one-fifth of the sum of—

"(1) The error at approximately full rated or maximum capacity.

"(2) The error at light load or rate.

"(3) Three times the error at normal or nominal rated capacity."

(q) METER TESTS BY COMMISSION OTHER THAN ON REQUEST OF CONSUMERS

Colorado (District of Columbia, Oklahoma): "Upon written application to the Commission by any gas utility, the Commission will make a test on any of the utility's service meters upon payment of the scheduled fee."

New Hampshire: "The Commission will, from time to time, test such meters of each utility as it shall judge expedient." A fee is charged the utility for these tests.

(r) ADJUSTMENT OF BILLS FOR METER ERROR

(1) Fast Meters

C32: "If on test of any gas-service meter made by the Commission or the utility at the request of a consumer it be found more than 3 percent fast, the utility shall refund to the consumer such percentage of the amount of his bills for the period of 6 months just previous to the removal of such meter from service—or for the time the meter was in service, not exceeding 6 months—as the meter shall have been shown to be in error by such test: Provided, however, that if the error was due to some cause, the date of which can be fixed, the overcharge shall be computed back to, but not beyond, such time. No part of any minimum-service charge shall be refunded."

Connecticut requires a refund if the meter is more than 4 percent fast.

Alabama, Maine, Michigan, New Hampshire, North Carolina, Oklahoma, Oregon, and South Carolina require refunds when meters are found to be more than 3 percent fast.

Colorado, Illinois, Indiana, Kansas, Maine, Montana, North Dakota, Pennsylvania, Washington, and West Virginia require refunds when meters are found to be more than 2 percent fast.

The following cities also require refunds for meters more than 2 percent fast: Cedar Rapids and Iowa City, Iowa; Louisville, Ky.; Pontiac, Mich.; Minneapolis, Minn.; Grand Island, Nebr.; North Platte, Nebr.; Portsmouth, Ohio; Philadelphia, Pa.; Charleston, S.C.; and Fort Worth, Tex.

Colorado, Connecticut, Indiana, Maine, Montana, New Hampshire, North Dakota, Oklahoma, and Washington require refunds only when the meter has been shown to be fast by tests made at the request of a customer.

Alabama, California, Illinois, Kansas, North Carolina, Oregon, Pennsylvania, South Carolina, and West Virginia require refunds when the meter is shown to be fast beyond the prescribed limit by any test.

Vermont requires a refund if the meter is found to be 2 percent or more fast by a test made at the consumer's request or 5 percent or more fast by any test.

Michigan requires a refund to be made if the meter is shown to be more than 3 percent fast by a test made at the request of a customer or more than 5 percent fast by any test.

Colorado, Connecticut, Illinois, Kansas, Maine, Michigan, Montana, New Hampshire, and Vermont require the refund for the period the meter has been in service since the previous test, not exceeding 6 months. Oregon requires the refund to cover the period the meter was in service, not exceeding 3 months.

North Carolina and South Carolina require the refund to be made for the period the meter has been in service, not exceeding 60 days.

Alabama and Indiana require refunds for not more than 6 months nor more than half of the period the meter was in service after the previous test.

North Dakota, Oklahoma, Washington, and West Virginia require refunds for not more than 3 months nor more than half the period in service.

West Virginia provides that in case the periodic test of the meter was not made within the 5 years required, the refund must cover the time between tests minus 5 years, in addition to the 3 months normally required.

Pennsylvania requires that the refund shall cover "the entire period of the current bill."

Connecticut, Illinois, Kansas, Maine, Montana, North Carolina, Oklahoma, Pennsylvania, South Carolina, and Washington have the provision that the correction shall be computed from the time the meter became in error, if it can be ascertained.

North Carolina and South Carolina require that refunds shall be for the amount by which the meter was in error in excess of 3 percent. In all other States which have rules on the subject, the refund, if made at all, is based upon the total error.

Illinois: "Whenever a utility or the Commission shall find a gas meter in its place of service to be registering gas on account of a leak in the meter or in the connection between the meter and the house piping, an estimate based upon a period of inaccuracy as defined in 17 (a) shall be made of the registration which has been produced by the leakage, and a corresponding refund shall be made to the consumer."

(2) Slow Meters

C32: "If on test of any gas-service meter made by the Commission or the utility at the request of a consumer it be found more than 3 percent slow, the utility may collect from the consumer the amount estimated to be due from the consumer for gas used but not charged for in bills rendered for not to exceed the 6 months previous to removal of the meter."

Alabama, Maine, Michigan, and Oklahoma permit the utility to collect for gas not paid for because of the error of meters more than 3 percent slow, under the same conditions and for the same periods that apply to refunds for fast meters. Colorado, Indiana, Montana, and North Dakota similarly permit the utility to collect when the meter is more than 2 percent slow. Vermont permits backbilling after a meter is tested at the request of the customer if found more than 2 percent slow and after any test if more than 5 percent slow. In the remainder of the States, backbilling is either not provided for,

or the conditions which apply to it differ essentially from those applying to refunds for fast meters.

Illinois: "If the meter be found to under-register, the utility may render a bill to the consumer concerned for the estimated consumption not covered by bills previously rendered during the period of inaccuracy as defined in paragraph 17 (a). Such action shall be taken, however, only in cases where the bills for estimated inaccurancy amount to 50 cents or more, and all such bills shall be conditional upon the utility not being at fault for allowing the incorrect meter to remain in service. In the case of a nonregistering meter which has been read during the period of nonregistration, the utility shall not render a bill for an estimated consumption extending over more than twice the regular interval between readings."

North Carolina and South Carolina permit the collection, in the case of meters more than 3 percent slow, of "the amount estimated to be due from the consumer for gas used, but not charged for in bills rendered not to exceed the 60 days previous to removal of the meter."

New Hampshire: "Whenever a meter so tested is found to be more than 3 percent slow, the utility may make application to the Commission for authority to render a bill to the consumer for gas supplied during the preceding 6 months, not covered by bills previously rendered; but such application should be made only in cases of substantial importance, and should be accompanied by a statement showing the utility not to be in fault for allowing the incorrect meter to be in service."

Colorado (Alabama, Indiana, North Dakota, Oklahoma): "If a meter is found not to register for any period the utility shall estimate a charge for the gas used but not metered by averaging the amounts used over similar periods preceding or subsequent thereto or over corresponding periods of previous years."

Oregon: "If the meter is found not to register, or to register less than 50 percent of the actual consumption, an average bill may be rendered to the customer by the utility subject to the approval of the Commission."

Indiana (North Dakota): "Such action (blackbilling) shall be taken only in cases of substantial importance where the utility is not at fault for allowing the incorrect meter to be in service."

California: "The nonpayment of any average bill rendered in accordance with this section shall not be held sufficient cause for permitting discontinuance of gas service except under written authority from the Railroad Commission."

Michigan: "No part of minimum or service charges shall be subject to refund or additional charges in case of meter error."

C32: "Each utility shall file with the Commission a statement setting forth its practice with respect to refunds and collections from consumers when upon test other than at the request of the consumer the meter is found to be fast or slow in excess of 3 percent."

Except as it may be included in the general requirements as to rules, schedules, etc., to be filed by the utilities, the equivalent of this provision has not been adopted in any State.

7. HEATING-VALUE TESTS

(a) CALORIMETRIC EQUIPMENT AND LABORATORY

C32 (Maine, Michigan, Montana, North Carolina, Oregon, South Carolina, Washington): "Each utility selling more than 10 million cubic feet of manufactured gas per year shall provide and maintain a calorimeter of a type approved by the Commission and all necessary accessories therefor."

Connecticut, Indiana, New York, North Dakota, and Vermont require all companies to have calorimeters.

Nevada requires a calorimeter if the utility sells 5 million cubic feet annually; California, Illinois, Maryland, and Massachusetts, if the sales exceed 15 million; and Alabama, Colorado, Missouri, New Jersey, and Pennsylvania, if the sales reach 20 million.

C32 (Maine, North Carolina, New York, metropolitan area): "The calorimeter equipment shall be installed in a suitably located testing station, which station shall preferably be not less than 1 mile from any gas manufacturing plant, except in the smaller municipalities where a lesser distance may be desirable."

In other States the location of the testing station is specified as follows: Massachusetts, not less than one-quarter mile from the plant; Montana, in or adjoining the company's main office.

California: "Each gas utility supplying manufactured or mixed gas shall provide and maintain testing stations . . . as follows:

"(1) One testing station at each gas manufacturing or mixing plant supplying each district, division, or community where the annual domestic and commercial sales exceed 15 million cubic feet; provided that such testing station may be installed at a point near the center of distribution, subject to the approval of the Commission.

"(2) An additional testing station at a point near the center of distribution approved by the Commission in each district, division, or community where the annual sales exceed 100 million cubic feet.

"(3) One testing station, or take samples, at a point near the center of distribution in each district, division, or community served through a transmission line where the annual sales exceed 100 million cubic feet."

"(4) A gas utility distributing in any district or community artificial or mixed gas purchased from a second utility shall be considered an artificial or mixed gas utility and shall install testing stations in accordance with these rules."

Connecticut: "When two or more communities are served entirely from a common gas supply the Commission may permit the heating value to be determined at a single suitable location."

C32 (California, Maine, Montana, New York, South Carolina, Washington): "The location of such testing station shall be selected by the utility and approved by the Commission."

C32. (Alabama, California, Colorado, Illinois, Indiana, Maine, Michigan, Montana, North Carolina, South Carolina, Washington): "The accuracy of all calorimeters, as well as the method of making heating-value tests, shall be subject to the determination and approval of a representative of the Commission."

Pennsylvania: "The accuracy of all calorimeters will be established from time to time by a representative of the Commission at a place to be designated by it. Tests made with an uncertified calorimeter will not be deemed authoritative."

Indiana: "In the municipalities where gas service is being supplied, it is recommended by the Commission that the municipality either own, maintain, and operate its own calorimeter outfit and pressure gages, or designate a representative to inspect the tests and record the results obtained by the utility's testing outfit." Qualifications of the municipal representative are then given in considerable detail.

(b) FREQUENCY OF TESTS

(1) Manufactured Gas

C32 (Maine, North Carolina, South Carolina): "Each utility maintaining a calorimeter testing station shall there determine the heating value of the gas supplied to its consumers at least once each day (Sundays and holidays excepted), unless the sales of that utility in the community or communities for which this station is to serve are less than 50 million cubic feet of gas per year, in which case the heating value of the gas shall be determined on not less than 3 days each week."

Alabama and Maryland similarly require tests on every working day by large companies and on 3 days per week by small companies, but the dividing line is placed at sales of 100 million cubic feet in Alabama and 30 million cubic feet in Maryland.

Massachusetts relies upon official inspections to determine compliance with heating value standards. These must be made at least twice a year.

Missouri, Montana, Oregon, and Pennsylvania require tests by all companies on at least 3 days per week.

Colorado requires tests on at least 4 days per week and Illinois on at least 5 days per week by all companies.

Connecticut, Indiana, and North Dakota require tests daily except Sundays and holidays by all companies.

Vermont: "Where such calorimeter is not of an automatic recording type, the utility shall make two tests of heat content per day: One between 8 and 11 a.m. and one between 2 and 5 p.m., Sundays and holidays excepted."

New York requires tests daily by companies in the metropolitan area, and at least 3 times per day at intervals of not less than 3 hours of companies in the remainder of the State.

Washington requires tests at least 3 times daily.

Nevada merely requires that tests be made "periodically."

Michigan: "Each utility selling more than 10 million cubic feet of gas annually shall make tests of heating value to conform at least to the minimum requirements of the following schedule.

Annual sales of gas (M cu ft)	Minimum number of tests per week day	Minimum interval between consecutive tests in hours
10,000 to 75,000	2	4
75,000 to 250,000	4	2
250,000 upward	6	2

"In cases where city gas inspectors make tests of heating value to conform to the above schedule, compliance on the part of utilities will be optional."

California: "Each utility supplying manufactured or mixed gas and maintaining a testing station at the generating or producing plant shall determine daily the heating value of the gas leaving the plant. This determination shall be as near a weighted average of the quality of gas sent out each day as practical limitations will permit, obtained either by averaging a series of tests taken at intervals determined by the rate of send-out in a manner approved by the Commission or by a test made upon an average proportional and continuous sample taken and held by a device approved by the Commission.

"Each utility supplying manufactured or mixed gas and maintaining a testing station at or near the center of distribution shall determine the heating value of the gas being delivered, on at least 6 days per week in the manner prescribed above.

"Each gas utility supplying manufactured or mixed gas and maintaining a testing station shall determine the heating value of the gas in its mains at least three times each day at intervals of not less than 3½ hours unless in the opinion of the Commission more frequent determinations should be made, in which event determinations shall be made in the manner and at such times as may be approved by the Commission."

Washington (Indiana, North Dakota): "This requirement (as to frequency of test) may be modified with respect to any utility by special permission from the Department."

C32 (Maine, Montana, North Carolina, South Carolina): "Each utility making heating-value determinations shall adopt, subject to the approval of the Commission, a standard form for recording the results of each such test. Each determination of heating value shall be recorded originally upon the form adopted for that purpose and such forms shall be retained as a permanent record."

Alabama, Colorado, New York, and Washington have practically the same rule except that records are to be kept 2 years only.

Illinois: "The results of every heating value test made by the utility shall be kept on file together with all data taken at the time of the test in sufficiently complete form to permit the convenient checking of the methods employed and the calculations."

New Jersey: "A record of these tests shall be made and kept on file in the office of the Company, and a summary of the results sent to the Board's office monthly."

Nevada: "A record of these tests shall be open to the public."

Pennsylvania: "A complete record shall be kept as specified (in the general rules relating to records)."

Connecticut: "Each such company shall report to the Commission not later than the 10th day of each month the monthly average, together with the number of tests included in the average, and the maximum and minimum day averages of the heating value of the gas supplied during the calendar month preceding."

(2) Natural Gas

California: "Each gas utility supplying natural gas or hydrocarbon gas for domestic, commercial, or industrial purposes shall make tests of the gas delivered to its customers at such places and with such frequency as may be prescribed by the Commission and shall keep a permanent chronological record of these tests of total heating value of the natural gas received or delivered to it; provided, that if heating value determinations of the same gas are satisfactorily made by another utility these determinations may be used for the purpose of the above record upon written approval of the Commission. In cases where unmixed hydrocarbon gas is served, the heating value may be calculated upon the basis of analysis of the shipment as received by the utility from the producer or manufacturer."

Kansas: "The heating value of natural gas shall be determined at least semiweekly, except when, in the opinion of the Commission, conditions warrant a different period of time.

"When a distributing utility obtains its supply from a pipeline or producing utility it shall be deemed sufficient for the pipeline or producing utility to make one determination and report covering the heating value of gas furnished any group of cities, provided such determination is made at a point on a line beyond which no additional gas enters, and that conditions are such that the samples tested may be accepted as fair averages of the gas furnished the cities in question.

"When such determinations are made by a pipe line or producing utility, a certificate shall be furnished the Commission, naming the cities, and a copy of the certificate shall also be furnished the distributing utility in each city so supplied. When considered necessary, the Commission will require separate determinations to be made in each of the cities so supplied.

"Each pipe line or producing utility, whether engaged in distributing its own output or not, whose total gas output exceeds 20 million cubic feet per year, shall equip itself with a complete standard calorimeter outfit approved by the Commission. Utilities doing a smaller volume of business may have their testing done by any other utility having an approved calorimeter.

"All operating pipe line and producing utilities shall furnish chemical analyses of the gas from any and all wells from which their supply is obtained, at such times as the Commission may require."

Illinois, Missouri, and Pennsylvania require every natural-gas utility to determine the heating value three times per year.

8. HEATING VALUE REQUIREMENTS

(a) MANUFACTURED AND MIXED GAS

The varied forms of the rules for heating value are classified below on the basis of the freedom given to the utility to determine its plant operation:

1. In Indiana, Michigan, and North Dakota a minimum is stated for the average heating value, and limits of variation from this

minimum are given which practically preclude the maintenance of either a higher or a lower average within the State.

2. In Illinois and Missouri a minimum standard is set for the average heating value, but utilities having a higher average standard are required to maintain the high standard unless given specific authority to reduce it.

3. In Arizona, District of Columbia, Nevada, New York, Oregon, and Pennsylvania a minimum is set for the average heating value, and another minimum for the heating value at any time; but no upper limit is stated for either and no provision made for exceptional cases.

4. In Connecticut and Massachusetts no provision is made for controlling the average heating value, but the minimum at any time is specified. In Massachusetts the State-wide minimum is subject to modification in exceptional circumstances.

5. In Maine, Maryland, Montana, North Carolina, and South Carolina, State-wide standards are specified for average heating value, but provision is made in the rule for allowing different standards in exceptional circumstances.

6. California, New Hampshire, New Jersey, Vermont, and Wisconsin provide that each utility shall select its own standard for average heating value, but provide a limit below which this option is not permitted. The standard selected is treated as a part of the utility's rate schedule.

7. In Alabama and Washington the standard is likewise treated as a part of the rate schedule and the same liberty to select its own average heating value is given to the utility, but without limiting the selection by prescribing a minimum.

8. Colorado gives entire freedom to the utility in the selection of a standard. A change in standard automatically involves a proportional change in the rates.

The quotations which follow will sufficiently illustrate the essential features of the different classes of rules.

Indiana: "Each utility supplying manufactured gas shall supply gas having a monthly average total heating value of not less than 570 Btu per cubic foot, and at no time shall the heating value of the gas be less than 540 nor more than 600 Btu per cubic foot."

To a rule similar to the above North Dakota adds: "Provided, that before the gas utility may lower its present standard the Commission may make an investigation of the operating conditions of the plant to determine whether the rates may not be reduced at the same time. The present standards of the gas utility shall not be changed until specifically relieved by the Commission."

Connecticut: "The heating value of all manufactured gas sold by each gas company shall not be less than 528 Btu per cubic foot. The heating value of the gas shall be maintained with as little deviation as practicable; and to this end the average total heating value on any one day should not vary from the monthly average by more than 5 percent."

Arizona: "The utility furnishing gas which within a 1-mile radius of the distributing center, gives a monthly average heating value of not less than 600 Btu with a minimum heating value which shall never fall below 550 Btu may be considered as giving adequate service insofar as the heating value of the gas is concerned."

New York: "Under conditions of complete combustion, corrected to a temperature of 60° F. and atmospheric pressure corresponding to a 30-inch column of mercury the monthly average heating value of the gas furnished as determined by at least 3 tests per day at intervals of not less than 3 hours shall be not less than 537 Btu per cubic foot and the average of said 3 daily tests per day for any 3 consecutive days shall be not less than 525 Btu per cubic foot.

The heating value as determined by said tests shall not on any 3 consecutive days in any calendar month exceed the aforesaid average by 5 per centum."

Massachusetts (from State law): "For the purpose of establishing a calorific standard for gas, the board of gas and electric light commissioners may . . . determine how many British thermal units shall hereafter be required of gas supplied to their consumers by gas companies or municipal lighting plants. If, after the establishment of a standard as aforesaid the gas of any gas company or of any city or town supplying gas is found on 3 consecutive inspections or on 3 inspections made within a period of 30 consecutive days, to be below the calorific standard so established . . . such company, city, or town shall be liable to a forfeiture of $100 . . . ."

(From order of the Board of Gas and Electric Light Commissioners): "The Board of Gas and Electric Light Commissioners, after notice and a public hearing, hereby determines that, until otherwise ordered, 528 total Btu a cubic foot shall on and after January 1, 1918, be required of gas supplied to their consumers by gas companies or municipal lighting plants."

C32 (Maine, Montana, North Carolina, South Carolina): "*Average requirement.*—Each utility supplying manufactured gas shall maintain the monthly average total heating value of such gas at any point within 1 mile of the manufacturing plant at not less than _____ Btu per cubic foot: *Provided, however,* That in the case of gas produced by the byproduct coke-oven process, or in case of other good and sufficient reason any utility finds it impracticable or uneconomical to manufacture gas of the heating value aforesaid, it shall file a statement with the Commission clearly setting forth all pertinent facts, and the Commission, after investigation, may by special order fix such lower average heating-value standard as may by them be deemed proper for said utility.

"*Maximum and minimum limits.*—The heating value of the gas shall be maintained with as little deviation as practicable; and to this end the average total heating value on any one day should not exceed or fall below by more than 30 Btu, the monthly average standard herein fixed, or otherwise fixed by special order of the Commission for a particular utility."

Vermont: "In case any utility finds it impractical or uneconomical to manufacture gas with the required heat content, it may file with the Commission an application to change its selected standard, setting forth all pertinent facts, and thereafter the Commission may revise the heat-content requirements for such utility."

California: "*Heating value standard for manufactured and mixed gas.*—Each gas utility supplying manufactured or mixed gas for domestic, commercial, or industrial purposes, either directly or through a second utility, shall establish and maintain, with the approval of the Commission, a standard heating value for its product. The monthly average heating value of the gas measured in the manner and place as hereinafter provided shall meet the requirements of the standard established.

"Each gas utility supplying manufactured or mixed gas shall file with the Commission as a part of its schedule of rates, rules and regulations, a statement of the standard heating value of the gas supplied by it—

"(a) At the outlet of its plant at low-pressure delivery.

"(b) To its consumers in each district as may be ruled a separate distribution system by the Commission.

"A similar statement shall be inserted in its schedule of rates, rules, and regulations kept open to public inspection at each office or location where applications for service are received.

"No standard of heating value established by any gas utility as herein provided shall be changed in any way by such utility except with specific written authority from the Commission.

"*Minimum monthly average heating value of manufactured and mixed gas.*—Unless specifically permitted in writing by the Commission no gas utility supplying manufactured gas for domestic, commercial, or industrial purposes shall deliver from its manufacturing or mixing plant to its distribution or transmission system a gas which shall have a monthly average total heating value of less than 550 Btu per cubic foot.

"The minimum monthly average total heating value of manufactured or mixed gas delivered by any gas utility to its customers in any district as may be ruled a separate distribution system by the Commission shall be such as to meet the approval of the Commission; provided that in the case of low pressure and intermediate high pressure distribution systems, supplied directly from a manufacturing or mixing plant, the minimum monthly average total heating

value, as measured at or near the center of distribution, shall not be less than 540 Btu per standard cubic foot unless specifically permitted in writing by the Commission.

"*Daily variations in heating value.*—The maximum variation from the standard of total average heating value of manufactured gas established as herein provided, shall at no time exceed 25 Btu per cubic foot above or below the standard."

New Hampshire (New Jersey): "Every gas utility shall establish its own standard of heating value for the gas it furnishes the public, provided the standard it establishes shall be a monthly average total heating value of not less than 525 Btu per cubic foot, tested anywhere within a 1-mile radius of the manufacturing plant; that the variation shall not exceed 15 Btu per cubic foot at said point, above or below the standard established, and that each utility shall file with this Commission the standard it chooses to adopt before it is put into effect."

Wisconsin: "Each utility furnishing gas service must supply gas of such standard of heating value as will enable it to obtain the greatest practicable efficiency with its equipment and the raw materials available, giving due consideration to the uniformity of the quality of the service rendered. A minimum monthly average shall be maintained of not less than 520 Btu total heating value per cubic foot, as referred to standard conditions of temperature and pressure. No fluctuations from the standard selected by the individual companies shall exceed 4 percent below or 5 percent above, that standard."

Alabama: "Each gas utility shall establish and maintain a standard heating value for its gas. The heating value standard adopted shall comply with the following conditions: (1) It shall be consistent with good service; (2) it shall be that value which the utility, from its experience determines is the most practical and economical to manufacture and supply to its customers.

"The gas utility shall be prepared to justify the standards adopted before the Commission, by such facts as may be required. The Btu standard adopted shall be expressed as part of schedule of rates on file with the Commission, and shall not be changed without approval of the Commission.

"The gas utility shall maintain the heating value of the gas with as little variation as is practicable, but such variation shall not be more than 5 percent above, or 5 percent below the standard adopted."

Washington: "All gas furnished to customers for lighting or heating purposes shall be as follows:

"In Seattle the gas furnished to customers for lighting and heating purposes shall contain a total heating value of not less than 500 nor more than 530 Btu per cubic foot.

"In Spokane, gas furnished to customers for lighting and heating purposes shall contain a total heating value of 450 Btu per cubic foot with a maximum allowable variation of 5 percent above and 5 percent below this value.

"In Tacoma, the gas furnished to customers for lighting and heating purposes shall contain a total heating value of not less than 450 nor more than 475 Btu per cubic foot.

"In all other cities in the State of Washington the British Thermal Unit standard of each gas company shall be that now on file with the Department of Public Works as a part of its present tariff.

"Any new gas company shall state in its tariff the standard heating value of the gas which it proposes to furnish. Any change in the calorific standard shall be considered to be a change in the tariff. Provided, however, that no change in standard heating value shall become effective except by express permission of the Department.

"Each utility supplying gas for domestic or commercial purposes shall adopt the standard prescribed above, which standard shall be the monthly total average heating value of the gas as delivered to customers at any point within 2 miles of the manufacturing plant."

Colorado: "Each utility supplying gas for domestic or commercial purposes shall establish and maintain a standard heating value for its product which standard shall be the monthly average total heating value of the gas as delivered to consumers at any point within 1 mile of the manufacturing plant or center of distribution. The utility shall declare this standard expressed in Btu per cubic foot as a part of its schedule of rates on file with the Commission.

"This standard heating value shall be that value which is on file with the Commission as a part of the utility's schedule of rates on the effective date of this Revised Rule No. 18, or that value which shall be declared by the utility, provided, however, that any change in value shall be made in accordance with the conditions hereinafter stated.

"If the utility finds it more practical, economical, and efficient to render service with gas of another heating value than the standard heating value on file with the Commission, the utility may file a new heating value standard and a new rate schedule; and if the conditions hereinafter stated shall have been complied with and the Commission shall not have suspended the new rate schedule as provided in section 48 of the Public Utilities Act or ruled against the change, such new heating value standard and rate schedule shall become effective 30 days from the date on which they are filed with the Commission. The conditions which must be met by a utility thus voluntarily changing its heating value standard are as follows:

"(1) The rate schedule for gas shall be so changed that every part or kind of charge in the rate shall be reduced and may be increased in direct proportion to the reduction or increase in the Btu content, except that the minimum charge, service charge, or customer charge shall remain unchanged.

"(2) Readjustment of customers' appliances and devices to render unimpaired service under the new standard shall be promptly made by the utility without charge to the customers.

"(3) The utility shall be prepared to justify the standard it adopts before the Commission by such pertinent facts as may be required.

"The utility shall maintain the heating value of the gas with as little deviation as is practicable and such deviation is limited to the range of 5 percent above to 5 percent below the standard adopted."

Table 5 summarizes the standards set in the various States.

(b) REGION WITHIN WHICH STANDARD APPLIES

The portion of the distributing system within which the "standard" is to apply is variously defined.

Maine, Maryland, Missouri, Montana, New Hampshire, North Carolina, North Dakota, Pennsylvania, and South Carolina specify heating values "within 1 mile of the manufacturing plant" or the equivalent.

Oregon: ". . . when tested at any point within a radius of 1 mile of the manufacturing works, and also in case the gas is manufactured outside the city, when tested at any point within the city near the center of consumption.

Connecticut: ". . . at points not more than 1½ miles from the manufacturing works.

Washington: ". . . at any point within 2 miles of the manufacturing plant.

Illinois: ". . . at any point at least 1 mile from the plant."

Massachusetts: ". . . not less than one-fourth mile from the gas works."

Wisconsin (Arizona, Michigan, Nevada, New Jersey): ". . . Anywhere within a 1-mile radius of the center of distribution."

California: ". . . At or near the center of distribution."

Indiana: "At a point near the center of consumption in the city where the gas is made or in the city nearest where the gas is made and at a point or points approved by the Commission."

Alabama (Colorado): ". . . At any point within 1 mile of the plant or center of distribution."

District of Columbia: ". . . At any of the Commission's testing stations."

TABLE 5.—*Heating value of manufactured gas required in various States*

[All values in Btu. per cubic foot. "Optional" indicates that the standard is selected by the utility. A number followed by "with exceptions" indicates that the rule in effect provides for the authorization of a different standard in exceptional cases]

State	Minimum monthly average	Heating value at any time	
		Maximum	Minimum
	*Btu/ft*³	*Btu/ft*³	*Btu/ft*³
Alabama	Optional	5 percent above standard	5 percent below standard.
Arizona	600		550.
California	Optional above 550	25 Btu above standard	25 Btu below standard.
Colorado	Optional	5 percent above standard	5 percent below standard
Connecticut		5 percent above average	528 and 5 percent below average.
District of Columbia	600		550.
Georgia (individual companies).	575		
Illinois:[1]			
Low pressure	565		530.
High pressure	530		520.
Indiana [1]	570	600	540.
Maine	525 with exceptions		
Maryland:			
State at large	600 with exceptions		550.
Baltimore	500		490.
Massachusetts			528.
Michigan	530	5 percent above standard	5 percent below standard.
Missouri	570		520.
Montana	475 with exceptions	30 Btu above standard	30 Btu below standard.
Nevada	550		500.
New Hampshire	Optional above 525	15 Btu above standard	15 Btu below standard.
New Jersey	525		515.
New York	537	5 percent above standard	525.
North Carolina	540 with exceptions	30 Btu above standard	30 Btu below standard.
North Dakota	525	550	500.
Oregon:			
Oil gas	575		550.
Petroleum-air	550		25 Btu below standard.
Other gas	600		550.
Pennsylvania	520		500.
Rhode Island: Providence.			510.
South Carolina	540 with exceptions	30 Btu above standard	30 Btu below standard.
Vermont	Optional above 515		5 percent below standard
Washington	Optional		
Wisconsin	Optional above 520	5 percent above standard	4 percent below standard

[1] Both Illinois and Indiana have authorized the distribution of gases much above the prevailing standard in certain places and have revised the rates per cubic foot substantially in proportion or have authorized rates per therm.

The following cities require the average heating values stated:

Minimum average heating value (Btu)	Cities
450	Grand Island, Nebr.
500	Virginia, Minn.
530	Tampa, Fla.; Iowa City, Iowa; Philadelphia, Pa.
540	Keokuk, Iowa; North Platte, Nebr.
550	Fort Dodge, Iowa; Pontiac, Mich.; Minneapolis, Minn.; St. Paul, Minn.
600	Cedar Rapids, Iowa; Charleston, S.C.

(c) METHODS OF DETERMINING AVERAGES

Connecticut: "The average for any day shall be determined from the record of a recording calorimeter where such record is available, or it shall be taken as the average of the results of all tests of heating value made on that day. The average of all such day averages shall be taken as the monthly average."

C32 (Alabama, Colorado, District of Columbia, Illinois, Indiana, Maine, Maryland, Michigan, Missouri, Montana, New York, North Carolina, North Dakota, Oregon, South Carolina, Washington): "To obtain the monthly average total heating value of a gas, the results of all tests of heating value made on any day during the calendar month shall be averaged, and the average of all such daily averages shall be taken as the monthly average."

In California, only the results of determinations made upon the average samples of gas are used in computing the monthly average. Tests made to determine uniformity during the day or for other purposes are not included.

Vermont: "To obtain the monthly average heat content, the average daily value from a continuous recording calorimeter may be employed, otherwise it shall be the average of the daily determinations."

(d) ALLOWANCE FOR COMPRESSION

C32 (Maine, Michigan, Montana, North Carolina, South Carolina, Vermont): "Where manufactured gas is delivered to the mains under a pressure in excess of 5 pounds per square inch, the heating value may be determined before compression."

Connecticut similarly permits testing before compression to 2 pounds.

Illinois: "In case gas is carried by mains at 5 pounds pressure or over per square inch, there shall be an allowance in the service of such high pressure district of 35 Btu per cubic foot in the monthly average and the minimum heating value shall not fall below 520 Btu per cubic foot."

California: "Each gas utility supplying manufactured or mixed gas whose operations involve compression or other processes tending to affect the heat content of all or any portion of its gas after the gas has been delivered from the generating plant shall maintain such equipment and make such tests as may be prescribed by the Commission, to determine the heating value of such gas as delivered to consumers in each district as may be ruled a separate distributing system by the Commission."

Indiana: "When gas is compressed and transmitted to other municipalities or communities, for purposes of information, heating-value tests shall be made before and after compression."

(e) NATURAL GAS

California: "Each gas utility supplying natural gas or hydrocarbon gas for domestic, commercial or industrial purposes shall file with the Commission as a part of its schedule of rates, rules and regulations, the average total heating value of the natural gas or hydrocarbon gas together with the maximum fluctuation above and below the average total heating value which may be expected of the gas supplied by it in each district, division, or community served."

Kansas (Pennsylvania): "No utility shall offer for sale to the consumers in Kansas, natural gas having a heating value lower than 800 Btu per cubic foot except by permission of the Commission."

The following cities have the requirements stated for the minimum heating value of natural or mixed gas:

Minimum heating value	Cities
Btu	
1,100---	Los Angeles, Calif.
1,000---	Fort Worth, Tex.
980-----	Henderson, Ky.
950-----	Lexington, Ky.; Greenville, Miss.; Memphis, Tenn.
900-----	Columbus, Ohio.
850-----	Louisville, Ky.; Niles, Ohio.
800-----	Denver, Colo.; Cincinnati, Ohio; Cleveland, Ohio.
740-----	Dallas, Tex.

(f) REPORT OF HEATING VALUES

New York: "Said corporation shall file with this Commission . . . not less than 5 days after the expiration of each calendar month a report showing the daily average for each day and the monthly average."

Indiana (North Dakota): "On or before the 10th day of each month the above daily and monthly heating value averages for the preceding calendar month shall be reported to the commission."

(g) PENALTIES FOR DEFICIENCY OF HEATING VALUE

Indiana has a schedule of penalties to be applied to deficiencies in the heating value of the gas in the form of a reduction in the rate to be paid by the user. The rate that can be charged falls slightly more than in proportion to heating value from the established standard of 560 to 500 Btu and thereafter falls rapidly to zero at 400 Btu.

(h) APPLIANCE ADJUSTMENT FOLLOWING A CHANGE OF HEATING VALUE

Alabama (Colorado, Washington): "It shall be incumbent upon the utility to properly adjust the customer's appliances to the heating value as adopted under this rule."

9. COMPOSITION OF GAS

(a) GAS ANALYSES

New York (Metropolitan District): "Each such corporation at its approved testing station or stations shall make analyses of its gas and determinations of the total sulphur and ammonia content at least once each month and when otherwise required by this Commission."

"Standard forms approved by this Commission shall be used for recording all tests, and analyses made by such coroprations and shall be retained as permanent chronological records in the stations where made for a period of 2 years from the recording date."

Kansas: "All operating pipe line and producing utilities shall furnish chemical analyses of the gas from any or all wells from which their supply is obtained, at such times as the Commission may require."

(b) ODORIZATION

Oregon: "Any gas not having a natural odor to serve as a warning agent in the event of the escape of such unburned gas must be artificially odorized in a manner satisfactory to this commission before its introduction into any local distribution system."

(c) PURITY REQUIREMENTS

C32 (Alabama, Arizona, California, Colorado, Connecticut, District of Columbia, Illinois, Indiana, Maine, Maryland, Massachusetts, Missouri, Montana, Nevada, New Hampshire, New Jersey, New York, North Carolina, North Dakota, South Carolina, Vermont, Washington, Wisconsin): (*a*) "*Hydrogen sulphide.*—All manufactured gas distributed in this State shall not contain more than a trace of hydrogen sulphide. The gas shall be considered to contain not more than a trace of hydrogen sulphide if a strip of white filter paper, moistened with a solution containing 5 percent by weight of lead acetate, is not distinctly darker than a second paper freshly moistened with the same solution after the first paper has been exposed to the gas for 1 minute in an apparatus of approved form, through which the gas is flowing at the rate of approximately 5 cubic feet per hour, the gas not impinging directly from a jet upon the test paper. "(*b*) *Total sulphur.*—All manufactured gas distributed in this State shall contain in each 100 cubic feet not more than 30 grains of total sulphur.

Michigan has substantially the same rule with respect to hydrogen sulphide, but does not limit total sulphur.

Oregon has substantially the same rule with respect to hydrogen sulphide, but limits total sulphur to 25 instead of 30 grains per 100 cu. ft. Pennsylvania limits total sulphur to 30 grains per 100 cu ft but has no requirement relating to hydrogen sulphide.

C32 (Alabama, California, Colorado, Connecticut, District of Columbia, Indiana, Maine, Missouri, Montana, New York, North Carolina, Oregon, South Carolina, Washington): "*Ammonia.*—All manufactured gas distributed in this State shall contain in each 100 cubic feet not more than 5 grains of ammonia."

Maryland, Massachusetts, and New Hampshire limit ammonia to 10 grains per 100 cu ft.

(d) TESTS OF PURITY

C32: "Each utility supplying manufactured gas shall daily test the gas leaving its holders for the presence of hydrogen sulphide in the manner above specified."

All States which limit the hydrogen sulphide require daily tests except New York, which requires 3 tests daily at intervals of at least 3 hours, and Arizona, District of Columbia, Massachusetts, and New Jersey, which do not specify the frequency of test.

C32 (Alabama, Montana, North Carolina, South Carolina): "Each utility selling more than 100 million cubic feet of manufactured gas per year shall provide and maintain such apparatus and facilities as are necessary for the determination of total sulphur and ammonia in the gas; and each such utility shall periodically (preferably semimonthly) determine the amount of total sulphur and ammonia in the gas distributed by it, and shall keep a record of the results of all such tests, as provided for in rule 4: Provided, however, that any such utility supplying only water gas or oil gas, or mixtures of these, shall not be required to provide apparatus for or make determinations of the amount of ammonia in the gas.

California, Connecticut, Indiana, and Maryland also require tests for total sulphur or both total sulphur and ammonia by utilities selling more than 100 million cubic feet annually; Colorado and Washington require tests by utilities selling 75 million or more; Maine, 70 million; and Illinois and Missouri, 50 million.

In addition to the States mentioned before the quotation of the rule, Maine and Washington have the same provision with respect to the frequency of testing. California, Illinois, Indiana, and Nevada require that these tests be made weekly; Connecticut requires them monthly; Colorado and Maryland require that they be made

"regularly", and Missouri that they be made "at sufficiently frequent intervals to insure compliance with the foregoing requirement." In the District of Columbia and Massachusetts the utilities are not required to make tests, but the responsibility for determining compliance with the rule is placed upon the Commissions' inspectors.

Alabama, California, Colorado, Connecticut, Illinois, Indiana, Maine, Maryland, Missouri, North Carolina, South Carolina and Washington have the provision exempting companies making only oil gas or water gas from the ammonia requirement.

California: "In the case of those utilities supplying a mixed gas these standards of gas purity shall apply to the manufactured gas prior to the mixture."

10. PRESSURE REQUIREMENTS

(a) MAXIMUM AND MINIMUM LIMITS FOR GAS PRESSURE

C32: "The pressure of manufactured gas supplied by any utility, as measured at the outlet of the utilities service pipe to any consumer, or in the case of high-pressure systems at the outlet of the house governor, should be maintained as uniform as practicable, and it should never be less than 2 inches nor more than 8 inches of water pressure, except as the consumer may request in writing the maintenance of some higher pressure."

The following maximum and minimum limits are set in various States:

Limit	States
Maximum	
6 in. of water	Maryland, Nevada, New Jersey, New York (Metropolitan District), Oregon, Wisconsin.
8 in. of water	Alabama, Colorado, District of Columbia, Maine, Missouri, Montana, New Hampshire, North Carolina, Pennsylvania (manufactured gas), South Carolina, Washington.
8 oz/sq in	Kansas, Oklahoma.
10 in. of water	Illinois.
12 in. of water	California, Connecticut, Michigan.
14 in. of water	Pennsylvania (natural gas).
Minimum	
1.5 in. of water	Arizona, Nevada, New Jersey, North Carolina, Pennsylvania, South Carolina.
2 in. of water	Alabama, California, Colorado, Connecticut, Illinois, Indiana, Maine, Maryland, Michigan, Missouri, Montana, New Hampshire, New York, North Dakota, Oregon, Washington, Wisconsin.
2 oz/sq in	Kansas, Oklahoma.
3 in. of water	District of Columbia.

Exceptions to these limits are provided for in the following ways: Alabama, Maine, Montana, New York, North Carolina, South Carolina, and Washington, substantially as in C32 quoted above.

Colorado (California, Maryland, Michigan, Missouri): ". . . except by special permission from this Commission for the maintenance of higher service pressure . . ."

Illinois (Kansas, Pennsylvania): ". . . except where greater pressure is specified and provided for in the contract between the utility and the consumer, and provided there be no unfair or unreasonable discrimination or preferences."

Oklahoma: ". . . except as may be required for commercial or industrial purposes."

(b) PLACE AND CONDITIONS OF MEASUREMENT OF PRESSURE

To determine compliance with the rules, pressures are measured at the outlet of the service pipe in Alabama, Colorado, District of Columbia, Indiana, Maine, Maryland, Missouri, Montana, New Hampshire, New York, North Carolina North Dakota, Oklahoma, Oregon, South Carolina, Washington, and Wisconsin. The practically equivalent meter inlet is specified as the point of measurement in Arizona, Connecticut, Nevada, and New Jersey.

Pressures must be measured at the outlet of the meter in California, Illinois, Kansas, Michigan, Pennsylvania, and West Virgina.

(c) ESTABLISHMENT OF DISTRICT PRESSURES

The second edition of Circular C32 (1913) recommended the following rule: "Subject to the approval of the commission each company may divide its distributing system into as many districts as it shall consider desirable, and it shall fix for each such district or for its distributing system as a whole a normal pressure which it purposes to maintain. Gas shall be supplied at a pressure never varying by an amount more than 2 inches of water pressure above or below the normal pressure thus fixed as measured at the outlet of the company's service pipe to any customer: Provided, however, that the maximum pressure on any day at any such outlet shall never exceed twice the minimum pressure on that day at that outlet; and the pressure shall never be less than 2 inches of water pressure at any such outlet.

"The normal pressures thus fixed by each company and any proposed changes in these normal pressures shall be reported to the Commission and shall be approved by the Commission before going into effect."

Rules of this form more or less modified have been adopted by California, Colorado, Indiana, North Dakota, Oregon, Vermont, and West Virginia.

Vermont: "Each utility supplying manufactured gas shall select a maximum pressure which it shall maintain as nearly as possible at all customer service outlets in a given distribution area. The minimum pressure shall never be less than one-third of the maximum selected, except during service interruptions, unforeseen demand, or temporary conditions beyond control of the utility; except under such abnormal conditions, a consumer's pressure shall not vary between 5 a.m. and 10 p.m., more than 100 percent of the minimum as above determined and also shall not vary more than 2 inches water column during any 15 minutes of this period."

(d) ALLOWABLE VARIATION OF PRESSURE

Of the States which require the establishment of pressure districts, Colorado alone does not specify the permissible variation of pressure with relation to the normal or standard pressure in the district. California requires that the pressure shall not vary from the district standard by more than 50 percent above or below normal nor from the standard by more than 4 inches of water column. West Virginia requires pressures to be maintained within 25 percent below and 50 percent above the normal for the district. Indiana, North Dakota, and Oregon require that pressures be maintained within 2 inches above or below the district normal.

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Connecticut: "The pressure of the gas measured at the outlet of the service meter of any customer shall never be less than one-half of the maximum pressure nor less than 2 inches of water column."

Colorado (District of Columbia, Illinois, Indiana, Kansas, Maryland, Missouri, Nevada, New Jersey, North Dakota, Oklahoma): "The maximum pressure on any day at any consumer's service shall never exceed twice the minimum pressure at that outlet on that day."

Wisconsin (Washington): " . . . the maximum pressure at any such outlet" (of the company's service pipe to any consumer) "shall never be greater than double the minimum pressure at that outlet."

Michigan specifies that the variation of pressure between 5 a.m. and 6 p.m. shall not be greater than 6 inches; New Hampshire, that the daily variation shall not be greater than 3 inches; New York (Metropolitan District), that it shall not be greater than 2 inches; Pennsylvania, that it shall not be more than 4 inches above or below "the normal pressure maintained at such point of delivery."

C32 (Alabama, Maine): "*Allowable variation.*—Between the hours of 5 a.m. and 10 p.m. the pressure of the gas at the outlet of the utility's service pipe, or house governor, to any consumer shall never vary by more than the following amounts:

Minimum pressure maintained	Maximum pressure variation permissible
Inches	*Inches*
2 to 3	2
3 to 4	2½
Over 4	3

Montana has an identical rule with the exception that the period within which the limitations of pressure apply is 6 a.m. to 10 p.m.

North Carolina and South Carolina have a rule of the same form; but the following table of pressure limits applies between 5 a.m. and 10 p.m.

Minimum pressure	Variation permitted
Inches	*Inches*
1½ to 3	3
3 to 4	3½
Over 4	4

The District of Columbia limits the variation in one day at any gage station to 2½ inches.

(e) RAPID, MOMENTARY, AND PULSATING VARIATIONS

California and Vermont provide that the pressure at the outlet of any consumer's meter shall not vary by more than 2 inches of water column within a period of 15 minutes.

New York: "The maximum momentary pressure variation (defined as a constant increase or decrease of pressure, practically instantaneous and not recurring with regular periodicity or frequency, nor necessarily with the same amplitude at the consumer's end of the company's service pipe to any consumer) shall not exceed a total range of 0.8-inch water column on two consecutive days."

"The maximum pulsating pressure variation (defined as a constant increase or decrease of pressure of short duration, practically instantaneous and recurring with regular periodicity or frequency and usually with approximately the same amplitude) at the consumer's end of the company's service pipe shall not exceed a total range of 0.5-inch water column on two consecutive days."

(f) CONDITIONS UNDER WHICH FAILURE TO COMPLY WITH RULES IS NOT CONSIDERED A VIOLATION

C32 (Alabama, Indiana, Maine, Montana, North Carolina, North Dakota, Oklahoma, South Carolina): "No utility shall be deemed to have violated the preceding paragraph of this rule if it can be shown to the satisfaction of the Commission that the variations occurring in gas pressure were due to unforeseen demand or to temporary conditions beyond the control of the utility."

Alabama (North Carolina, South Carolina): "No utility shall be deemed to have violated any stipulation of this rule with respect to individual cases, if it can be shown to the satisfaction of the Commission that in any such individual case the service lines or any pipe lines on consumer's property are of such size or condition as to render the maintenance of the pressure and pressure variations impracticable."

Illinois: ". . . provided that variations in pressure entirely beyond the control of the utility shall not be considered as a violation of this rule.

"Variations of pressure in excess of those specified above caused (1) by operations of the consumer in violation of his contract or the rules of the utility, (2) by infrequent and unavoidable fluctuations of short duration due to conditions of operation, or (3) by the action of the elements, shall not be considered an infraction of this rule."

Kansas: "It shall not be considered a violation of rule 3 should compliance therewith be rendered impossible by unusual operating conditions."

Maryland: "Any utility supplying natural gas shall not be deemed to have violated the preceding paragraph of this rule if it can be shown to the satisfaction of the Commission that variations in gas pressure occurring are due to extraordinary demand in extreme weather or to inadequacy of supply, which is clearly beyond the control of the utility."

Pennsylvania: "Provided that variations in pressure caused by operation of consumer's apparatus in violation of contract or the rules of the utility or by causes entirely beyond the control of the utility shall not be considered a violation of this rule."

West Virginia: "A utility supplying natural gas shall not be deemed to have violated the preceding paragraph of this rule if it can be shown that variations from said pressures were due to (1) use of gas by the consumer in violation of contract or the rules of the utility, (2) infrequent fluctuations of short duration due to unavoidable conditions of operation.

"Allowable variations in standard pressure other than those covered by paragraph (*a*) of this rule will be established by the Commission when application is made and good cause shown therefor."

New York does not consider a deviation from the prescribed limits as a violation of the rule unless it occurs on 2 consecutive days.

(g) PRESSURE-TESTING EQUIPMENT AND PRESSURE SURVEYS

C32 (Alabama, Maine, Montana, North Carolina, South Carolina, Vermont): "(*a*) Each utility shall maintain on its distribution system in each city in which it supplies gas at least one recording gas-pressure gage for each 50 miles of mains, or fraction thereof, and no utility shall maintain less than 2 such recording-pressure gages, of which 1 should be portable.

"(*b*) Each utility shall regularly make records with such recording gages of the pressures in various parts of its distribution system. The charts or records thus obtained shall bear the date and place where the pressure was taken and shall be filed as a permanent record."

Montana omits from the above rule the requirement that one recording gage be provided per 50 miles of mains.

Connecticut: "Every gas company shall make such determinations and keep such records of pressure as will enable it to have at all times a substan-

tially accurate knowledge of the pressure existing in every part of its distributing system."

District of Columbia: "On or before the 1st of December 1931 there shall be supplied, installed, and maintained by the company pressure gages, the type, the number, and the locations thereof to be approved by the Commission, which will furnish an accurate record of the pressures maintained throughout the District of Columbia. These gages shall be subject to inspection and test by the Commission at any time. The original record of each and every gage shall be available for inspection by the Commission and shall be preserved for not less than 1 year, and the maximum and minimum pressures measured at each gage during all gage periods shall be regularly reported to the Commission monthly . . . ."

Arizona (Nevada, New Jersey): "Each gas utility shall, at frequent and regular periods, make measurements of the pressure and pressure variations, and these shall be kept on record and open for public inspection."

Wisconsin (Illinois, New Hampshire, North Dakota, Pennsylvania): "Each gas utility shall provide itself with one or more portable graphic recording pressure gages, and shall make frequent measurements of the gas pressure and pressure variations throughout the system, and these shall be kept on record and open for public inspection."

New Hampshire adds that such records shall be made "not less frequently than the Commission may direct." North Dakota adds: "The Commission may require the utility to make such survey at any time and submit all information to the Commission." Pennsylvania adds that the records shall be kept 2 years and shall be made only with recording gages which have been certified by the Commission.

Illinois: "Each utility shall make pressure surveys at such intervals and of such comprehensiveness as may be necessary to keep itself fully informed regarding the character of the service being furnished from its system.

"All charts and readings taken in pressure surveys shall be preserved and filed in a systematic manner, accompanied by such information as may be required to show the date, hour, and place of the test, the instrument used, and the name of the person making the test.

"In each city where the utility has more than 500 gas consumers a pressure gage shall be kept in continuous use at some fixed point suitably located to reflect changes in pressure arising through changes in plant operation. This instrument shall not be used as a portable gage in making pressure surveys. In other cities or villages portable recording pressure gages used in making surveys shall so far as practicable be kept in continuous use."

Colorado (Missouri): "Each utility serving gas in cities of 2,500 inhabitants or over shall furnish a graphic recording pressure gage at its plant, down-town office, or some central point in the distributing system or each subdivision thereof, where continuous records shall be made of the service pressure at that point.

"Utilities operating in cities of 5,000 or more inhabitants shall equip themselves with one or more graphic recording pressure gages in addition to the foregoing, and shall make frequent records, each covering intervals of at least 24 hours duration, of the gas service pressure at various points on the system. All records or charts made by these meters shall be identified, dated, and kept on file available for inspection for a period of at least 2 years."

Connecticut (Oregon): "Every gas company shall maintain on its distributing system at least one curve-drawing pressure gage for each district fixed under the provisions of paragraph *b*, and no gas company shall maintain less than two such gages by which a continuous record of gas pressure shall be made."

Indiana: "Each gas utility shall maintain on its distributing system at least two recording pressure gages. Periodic tests should be made of pressure maintained in various districts, using portable recording pressure gages, and the charts shall be filed where they may be conveniently examined by properly accredited inspectors."

Washington: "Each gas company whose output exceeds 10 million cubic feet per year shall maintain, at different points on its mains, 1 mile or more from any distribution station, two or more recording pressure gages, by which means

a record of pressure at all times shall be made, and these records shall be kept on file and open for public inspection at the principal offices of the company in the city where the service is rendered."

Michigan: "Each utility selling more than 10 million cubic feet of gas annually shall keep continually in use at some location in its distribution system an approved form of recording pressure gage and shall keep on file the charts from said gages showing the pressures at such location."

West Virginia: "Every utility shall maintain on its distribution system or on each subdivision thereof serving 50 or more consumers, at least one graphic recording gas pressure gage. Every utility shall make a sufficient number of pressure surveys to indicate the service furnished and to satisfy the Commission of its compliance with pressure requirements.

"Every utility shall keep at least one recording gage in continuous service at the plant, office, or some consumer's premises. All pressure records shall be kept open for public inspection."

California: "Each gas utility shall own and maintain at least one recording pressure gage on each principal distribution main leaving each gas manufacturing plant, compressor, or holder station, and no utility shall maintain less than two such gages unless specifically relieved in writing by the Commission.

"Each gas utility shall own and maintain at least one low-pressure, portable recording pressure gage for each 100 miles or fraction thereof of low-pressure main in any district as may be ruled a separate distributing system by the Commission.

"On low-pressure distribution systems each gas utility shall during the 6 months of the peak season of the year make at least one 24-hour record of pressure each week at the outlet of customers' meters for each 100 miles of main or less in each district or separate distributing system. Such record shall bear the address of the customer where the pressure is taken and the dates, together with such other information as the Commission may from time to time direct, and shall be filed and retained as a continuous record in the principal office of each district or division. In lieu of 50 percent of the above required number of records from portable pressure gages at customers' premises, there may be substituted an equal number of 24-hour records from recording pressure gages permanently located at critical points on the distribution system.

"On high-pressure distribution systems gas utilities shall maintain permanently located pressure gages at critical points and shall preserve in the district or division offices the charts from these gages as a continuous record for a period of at least 2 years.

"Pressure conditions on the customers' pemises on high-pressure distribution systems shall be determined by water column tests made during service calls in answer to complaints. A report on such tests shall be made on the complaint order, which report shall state the pressure observed when appliances were on and when all appliances, excepting pilot lights, were off . . . ."

Kansas: "All gas-distributing companies shall keep and maintain recording pressure gages, at the point or points where gas is received from pipe lines or supplying companies, showing pressure of gas received at the point of its entrance into the distributing system.

"All gas-distributing companies shall keep recording pressure gages at each and every regulator station, on the low-pressure side thereof, and at such other points as may be necessary to record the pressure of gas furnished to consumers in any section not reflected with reasonable accuracy by pressure gages at regulator stations.

"A map showing all gas mains, gas regulators, and districts covered by each regulator shall be filed with the city clerk of each municipality, and a copy sent to the Public Utilities Commission.

"Recording pressure gages shall be of standard and satisfactory make and shall be kept in good repair and properly adjusted.

"All recording gages shall be open to inspection by duly accredited officials of the city in which they are located and the Public Utilities Commission. Daily record of these gages shall be kept on file in the office of the gas company, and subject to inspection by officials named above at any time within 3 years from date record is made.

"A reasonable and efficient pressure for domestic use is hereby defined to be not less than 4 nor more than 8 ounces. A pressure less than 4 ounces is declared to be generally insufficient and unsatisfactory. Upon proper showing

by the distributing company that a different pressure will render an efficient and sufficient service to the consumer in any section whose pressure is indicated by any particular gage, the same may be established as a normal operating pressure, upon application and approval by the Public Utilities Commission.

"The approved operating pressure shall be recorded in the office of the gas company, and a copy of the record of the same, showing the location of the gage to which it applies, shall be filed with the city clerk and the Public Utilities Commission.

"It is further ordered, That when the gas pressure shall register less than 75 percent of the approved operating pressure at any pressure-recording gage, the company in charge thereof shall take the same into consideration in making its charges for gas service to its customers included in the district the pressure of which is indicated by such recording gage, in accordance with the following:

"For each hour or fraction thereof during which the pressure is less than 75 percent of the normal operating pressure and above 25 percent of said pressure, there shall be made a reduction of 0.003 of the total amount of the bill for the month during which such shortage occurs.

"For each hour during which the pressure is 25 percent or less of the normal operating pressure, there shall be made a reduction of 0.006 of the total amount of the bill for the month during which such shortage occurs.

"Distributing companies shall, at the time of making up their monthly accounts, file with the city clerk a copy to be forwarded to the secretary of the Public Utilities Commission a statement showing the number of hours, during the period covered by the statement to be made, that the pressure was below that established by this or subsequent orders, and the total deduction due to be made on that account for each district. Each customer's bill shall show on its face the deduction to be made, expressed both in percentage of the total bill and the actual amount to be deducted."

Oklahoma: "(*a*) Definitions. For the purpose of this rule, a low-pressure distribution system shall be taken to mean one from which the gas is introduced from the mains directly into the consumer's house-piping without passing through a regulating device. A high-pressure system shall be taken to means one in which the gas in the mains is maintained at a higher pressure than that at which it is used, and the pressure reduced by a house-governor before passing through the meter.

"(*b*) Each utility shall maintain on its distribution system in each city or town in which it supplies gas, a recording pressure gage of suitable range at each point where the gas enters the system, indicating the pressure at which the gas is received from the furnishing company. Gas-pressure records necessitated in the measurement of gas at the receiving points will answer the requirements of this rule, provided such records are available by the utility, in case the Commission requests such information.

"(*c*) Each utility operating a low-pressure distribution system shall maintain in addition to the requirements in (*b*) above, a recording pressure gage of suitable range at each district regulator station on the low-pressure side thereof.

"(*d*) Each utility operating a medium-pressure distribution system shall maintain in addition to the requirements in (*b*) above, a recording pressure gage of suitable range at one or more low-pressure points on the system.

"(*e*) Each utility shall regularly make records with such recording gages of the pressures at these points in its distribution system. The charts or records thus obtained shall bear the date and place where the pressure was taken, and shall be filed as a permanent record.

"*Pressure surveys.*—(*a*) Each utility shall provide itself with one or more indicating pressure gages or water gages, of suitable range and each utility serving more than 200 consumers shall have one or more portable recording pressure gages of suitable range. Each utility shall make a sufficient number of pressure surveys to indicate the character of the service furnished from each center of distribution and to satisfy the Commission upon request, of its compliance with the pressure requirements. Each utility having portable recording pressure gages shall keep at least one of these instruments in continuous service at a low-pressure point on the system.

"(*b*) Each utility shall regularly make records with such gages of the pressures in various parts of its distribution system. The charts or records thus obtained shall bear the date and place where the pressure was taken, and shall be filed as a permanent record."

(h) READJUSTMENT OF APPLIANCES AFTER A CHANGE OF STANDARD PRESSURE

District of Columbia: "Whenever consumers' appliances have not been adjusted for proper and economical operation with the maximum pressure of 8 inches of water . . . such adjustment shall be made by the gas company immediately, except within areas, if any, as determined by the Commission, where the pressure limits fixed by this order will not cause any variation from the pressure limits under which consumers' appliances were used prior to January 1, 1929."

11. PUBLIC RELATIONS

NOTES.—California does not give details of requirements with respect to public relations in the mandatory rules, but requires that the company issue its own rules for approval. However, a very complete set of model rules is given in the Gas Service Bulletin and since these models are generally followed, many of them have been included in the following. Provisions attributed to California in this section are, therefore, to be regarded as accepted rather than mandatory practice.

(a) ADJUSTMENT OF APPLIANCES

California: "Each gas utility, unless specifically relieved in any case by the Commission from such obligation, should upon request of any consumer and without extra charge, make an inspection and adjustment of appliances in use by that consumer."

(b) ACCESS TO PREMISES

Washington: "The utility may reserve the right of ingress to or egress from the premises of the customer at all reasonable hours for the purposes of inspection and testing, or for the removal of its property."

(c) CONTRACT FOR SERVICE

Washington: "Whenever the classification of service under which the applicant is to be served requires that such service be taken by the applicant for 1 year or more, a contract may be executed between the utility and the applicant. A blank copy of each typical contract form used by the utility shall be filed with the Department, and the Department shall be notified when any change other than a minor deviation is made in these forms."

"Whenever an applicant desires service of a character for which there is no tariff provision, a contract shall be executed between the utility and the applicant, a copy of which shall be filed with the Department."

(d) APPLICATION FOR SERVICE

Washington: "An applicant desiring service may be required to make application for it in writing, in accordance with the forms prescribed by the utility and filed with the Department. Such application shall be deemed to be a notice to the utility that the applicant desires service and an expression of his willingness to conform to such reasonable rules and regulations regarding service as are in effect and on file with the Department."

(e) DEPOSITS FROM CONSUMERS TO GUARANTEE PAYMENT OF BILLS

C32: "Each utility may require from any consumer or prospective consumer a deposit intended to guarantee payment of current bills. Such required deposit shall not exceed the amount of an estimated 90 days' bill of such consumer: *Provided, however,* That a minimum deposit of $5 may be required. Interest shall be paid by the utility upon such deposits at the rate of —— percent per annum, payable upon the return of the deposit for the time such deposit was held by the utility and the consumer was served by the utility, provided such period was not less than 6 months."

The deposit is based upon an estimated bill for the following periods in the several States: Maine, Massachusetts, North Carolina, 90 days; Colorado, 90 days, if bills are payable in advance, 60 days; Connecticut, South Carolina, 60 days; Maryland, Oregon, 60 days, if bills are payable in advance, 30 days; Montana, 45 days; Washington, two times the average billing period; Connecticut, Missouri, 30 days in excess of the billing period; Alabama, two times the average billing period; if bills are paid in advance, one billing period. In Oklahoma the deposit is one-sixth of the estimated annual bill. In West Virginia it is 1½ times the estimated average monthly bill if bills are rendered monthly, and three times the monthly bill if bills are rendered quarterly. In Indiana and North Dakota the deposit is not specified, but it must be selected "with the consent of the Commission". In Michigan "a reasonable deposit" may be required.

In Maine and Oklahoma a deposit of at least $5 may be required in every case; in West Virginia, $2.50; in Maryland, $2. In California the deposit for residential service is uniformly $2.50.

South Carolina: "If security other than cash is tendered by consumer, and such security is not acceptable to the utility, then the consumer may submit to the Commission security offered and the action of the Commission may be binding on both parties."

West Virginia: "No deposit shall be required of any receiver or trustee operating a business requiring utility service under an order of court."

Alabama, California, Colorado, Indiana, Maine, Maryland, Missouri, Montana, North Carolina, North Dakota, Oregon, South Carolina, Washington, and West Virginia require the payment of 6 percent interest on deposits; but Colorado requires only 4 percent interest and Missouri 3 percent if the utility keeps the deposits "in a separate and distinct trust fund and deposited as such in some bank or trust company and not used by the utility in the conduct of its business." Oklahoma requires 5 percent interest on deposits; Connecticut and Massachusetts, 4 percent.

California requires interest to be paid only on deposits retained as long as 12 months. Alabama, Colorado, Indiana, Maine, Maryland, Massachusetts, Michigan, Missouri, Montana, North Carolina, North Dakota, Oklahoma, South Carolina, and Washington require interest on deposits retained 6 months; Connecticut and Oregon on deposits retained 3 months.

Colorado specifies that "in computing interest no consideration need be given to fractional parts of months or dollars". Washington requires interest to be computed to the nearest month.

California, Maine, North Carolina, and South Carolina provide for the payment of interest only when the deposit is returned; Connecticut, Missouri, and Montana provide for the payment of interest when the deposit is returned or annually. Massachusetts and Oklahoma make obligatory the payment of the interest annually. Alabama, Colorado, Indiana, Maryland, Michigan, North Dakota, Washington, and West Virginia require the payment of interest annually if requested by the customer. Michigan requires that interest on deposits greater than $50 be paid semiannually.

C32 (Alabama, Colorado, Indiana, Maine, Michigan, Montana, North Carolina, North Dakota, South Carolina): "Each utility having on hand deposits from consumers or hereafter receiving deposits from them, shall keep records

to show: (1) The name of each consumer making such deposit, (2) the premises occupied by the consumer when the deposit was made, (3) the amount and date of making the deposit, and (4) a record of each transaction concerning such deposit, such as payment of interest, interest credited, etc.

"Each utility shall issue to every consumer from whom a deposit is received a nonassignable receipt.

"Each utility shall provide reasonable ways and means whereby a depositor who makes application for the return of his deposit, or any balance to which he is entitled, but is unable to produce the orignial certificate of deposit or receipt, may not be deprived of his deposit or balance."

Alabama: "Upon final discontinuance of service the utility shall apply such deposit with accrued interest thereon to any account due by customers. If any balance is due customer, same shall be refunded to customer by utility." The equivalent of this rule, though not specifically stated in the majority of States, is to be taken for granted in all cases.

West Virginia requires the utility to advertise annually any deposits not returned to the customers after the discontinuance of service.

California recommends in its "Standard Rules for Adoption by the Utilities" a more elaborate and very different set of rules regarding customer's credit than is in effect in any other State. The California rules are therefore quoted in full.

California: "No. 6. Establishment and reestablishment of credit. Each applicant for service will be required to establish his credit to the satisfaction of the company before service will be rendered.

"(*a*) *Establishment of credit.*—The applicant's credit will be deemed established: (1) If applicant is the owner of the premises upon which the company is requested to furnish service, or is the owner of other real estate within the district of the company in which service is requested.

"(2) If the applicant makes a cash deposit with the company to secure the payment of any bills for service to be furnished by the company under the application as provided in Rule and Regulation 7 herein contained.

"(3) If the applicant furnishes a guarantor or bond satisfactory to the company for the payment to the company of bills of applicant for the service to be furnished by the company under the application.

"(4) If the applicant has previously been a consumer of the company, and has paid all bills for gas service on the average within the period as set forth in Rule and Regulation 9–a for a period of 12 consecutive months immediately prior to the date when the applicant for service previously ceased to take service from the company, provided such service occurred within 2 years from date of the new application for service.

"(*b*) *Reestablishment of credit.*—(1) An applicant who has been a gas consumer of the company, and whose service has been discontinued for failure to pay his gas bills within the period as set forth in Rule and Regulation 9–a, within the last 12 months of service may be required to reestablish his credit by making the regular cash deposit.

"(2) A consumer who fails to pay bills as provided in Rule and Regulation 9–a, and who further fails upon second notice of not less than 5 days to pay said bills in time required by the second notice may be required to pay said bills and to reestablish his credit by making a cash deposit with the company of an amount not to exceed a sum equal to twice the estimated average periodic bill for that service.

"A consumer whose service has been discontinued for failure to pay bills as provided in Rule and Regulation 9–a may be required, before service is resumed, to restablish his credit as provided in the last preceding paragraph.

"*No. 7. Deposits*—(*a*) *Residence or domestic service.*—The amount of the deposit to establish credit required of applicants to obtain gas service for residence or domestic purposes shall be $2.50.

"(*b*) *Other classes of service.*—The amount of the deposit to establish credit required of applicants to obtain gas service for all classes of service, other than residence or domestic service, shall not exceed a sum equal to twice the estimated average periodic bill for that service.

"(*c*) *Reestablishment of credit.*—The amount of the deposit to reestablish credit for any class of gas service from an applicant for service as set forth

in Rule and Regulation 6–b or from any consumer whose service has been discontinued for nonpayment of bills, or who has failed to pay bills upon second notice in time required by second notice which will not be less than 5 days, shall not exceed a sum equal to twice the estimated average periodic bill for that service.

"*No. 8. Return of deposit—Interest on deposit.* (*a*) *Return of deposit.*—The company will notify the consumer that his deposit is subject to return, and will refund the deposit (with interest as set forth under b), upon surrender to the company of the deposit receipt properly endorsed, or upon signing a cancellation receipt for same.

"(1) When the service is ordered discontinued by the consumer, except when there are charges due the company for gas service to the consumer, in which case the deposit will be applied to the charges and the excess portion of the deposit will be returned.

"(2) When the consumer has received continuous service and has paid his gas bills on the average within the period as set forth in Rule and Regulation 9–a for a period of 12 consecutive months.

"(*b*) *Interest on deposit.*—Interest at the rate of 6 percent per annum will be paid on deposit held by the company for the first 12 consecutive months during which time the consumer has received continuous gas service, and has paid all bills for such gas service on the average within the period as set forth in Rule and Regulation 9–a, and for such additional time thereafter as the company may hold the deposit, up to the date on which the consumer is notified that the deposit is subject to return.

"No interest will be paid if service is discontinued for any cause within less than 12 months from date of making deposit."

(f) SERVICE TO DIFFERENT PREMISES

Connecticut: "For residential service every gas company shall establish each point of delivery as an independent customer and shall calculate the amount of the bill accordingly."

(g) DISPUTE AS TO BILLS

Washington: "In the event of dispute between the customer and the utility respecting any bill, the utility shall forthwith make such investigation as shall be required by the particular case, and report the result thereof to the customer. In the event that the complaint is not adjusted, the utility or the customer may make application to the Department for adjustment of the complaint."

Oklahoma (Alabama, California): "Any utility may decline to serve a consumer or prospective consumer until he has complied with the State and municipal regulations governing gas service and the reasonable rules and regulations of such utility."

(h) DISCONTINUANCE OF SERVICE FOR VIOLATION OF RULES OR NONPAYMENT OF BILLS

C32 (Maine, Montana, North Carolina, South Carolina, West Virginia): "No utility shall discontinue the service to any consumer for violation of its rules or regulations, or for nonpayment of bills, without first having diligently tried to induce the consumer to comply with its rules and regulations or to pay his bills. Service shall actually be discontinued only after at least 24 hours' written notice of such intention shall have been given to the consumer by the utility. Provided, however, that where fraudulent use of gas is detected, or where a dangerous condition is found to exist on the consumer's premises, the gas may be shut off without notice in advance."

States which specify the period of delinquency after which service may be discontinued for the nonpayment of bills follow: Arizona, 20 days. California, 15 days, if bill is rendered monthly, 7 days if rendered fortnightly, 4 days if rendered weekly; but in no case until the deposit made to secure payment of bills is exhausted. Michigan, 10 days after the end of the discount period. Washington, 10 days.

West Virginia, after the deposit made to secure payment of bills is exhausted.

Oklahoma requires that every gas bill rendered shall bear a statement as to when gas will be shut off for nonpayment.

Notice must be given in advance of the shutting off of gas as stated below. In California and Oklahoma this notice applies only to discontinuance of service for violation of rules; in other States it apparently applies to discontinuance for nonpayment of bills as well. Alabama, California, Michigan, 5 days. Oklahoma, 3 days. Colorado, Kansas, Missouri, 48 hours. Maine, Montana, North Carolina, South Carolina, Washington, West Virginia, 24 hours. Indiana, North Dakota, the gas shall not be turned off "until after reasonable notice is given and then the utility must exercise reasonable diligence to see that provision is permitted to be made for children or sickness in the home before the gas is turned off".

Alabama, California, Colorado, Maine, Missouri, Montana, North Carolina, Oklahoma, South Carolina, and West Virginia specifically provide that gas may be turned off without notice in advance in case of fraud or danger.

California (Missouri): "In the event of discontinuance of service for any of the reasons herein set forth, the consumer shall be notified of such discontinuance immediately with a statement of the rule violated and the nature of the violation."

Alabama and Missouri carefully define what shall constitute a notice that service will be discontinued. In Alabama a notice given to the customer in person, left on the premises on which the gas is used, or sent by mail to the last known address of the customer, is recognized. In Missouri, notices must be given to the customer in person or left with a member of his family who is more than 15 years old or sent by registered mail for which a return receipt is required.

Arizona: "Any utility supplying gas, who detects the fraudulent use of gas by a consumer, may discontinue the service, and need not reinstate same until an amount shall be paid to the utility covering the estimated amount of such commodity fraudulently used, and a charge of $2 to cover extraordinary expenses incident thereto. In such case the utility shall estimate the amount of gas or electricity fraudulently used, from previous or subsequent meter readings or other proper data."

Washington: "Whenever a fraudulent use of the service is detected the utility may discontinue service without notice: Provided, however, that if the customer shall make immediate payment for such estimated amount of service as has been fraudulently taken and all costs resulting from such fraudulent use, the utility shall continue such service. If a second offense as to fraudulent use is detected, the utility may permanently discontinue service, subject to the appeal to the Department. The burden of proof will be upon the utility in case of such an appeal. This rule shall not be interpreted as relieving the customer or any other person of civil or criminal responsibility."

California: "The company shall have the right of refusing to or of ceasing to deliver gas to a consumer if any part of the consumer's services, appliances, or apparatus shall at any time be unsafe, or if the utilization of gas by means thereof shall be prohibited or forbidden under the authority of any law or municipal ordinance or regulation, and may refuse to serve until the consumer shall put such part in good and safe condition and comply with all the laws, ordinances, and regulations applicable thereto.

"The company does not assume the duty of inspecting the consumer's services, appliances, or apparatus or any part thereof, and assumes no liability therefore. In the event that the consumer finds the gas service to be defective the consumer is requested to immediately notify the company to this effect."

Oklahoma: See rule on "Extent of System in which Utility Must Maintain Service", page 196.

California: "If the consumer should fail to comply with any of the company's rules and regulations from time to time in force, the company will advise the consumer of such failure. If the consumer does not remedy same within a reasonable time, the company shall have the right, after giving due notice, to discontinue service to the consumer."

"The company will not furnish service to gas apparatus or appliances, the operation of which will be detrimental to the gas being furnished by the company to its other consumers in the immediate vicinity or supplied from the same distribution system, and the company will refuse to continue furnishing gas to any consumer who shall, after being notified by the company to discontinue the use of gas for such gas apparatus or appliances, continue to so use the same."

Washington: "Service may be discontinued for any of the following reasons, provided the utility so specifies in its tariff:

"(*a*) For the use of gas for any other property or purpose than that described in the application.

"(*b*) Under the flat rate service, for addition to such property or fixtures, or increase in the use to be made of gas supply without notice to the utility.

"(*c*) For willful waste of gas through improper or imperfect pipes, fixtures, or otherwise.

"(*d*) For failure to maintain in good order connections, service pipes, or fixtures owned by the applicant.

"(*e*) For molesting any service pipe, meter, stopcock, or seal or any other appliance of the utility.

"(*f*) In case of vacation of the premises.

"(*g*) For neglecting to make or renew advance payments or for nonpayment for gas service, or any other charges accruing under the application when such payments are required.

"(*h*) For refusal of reasonable access to property for the purpose of inspecting the facilities or for reading, maintaining, or removing meters.

"Service must be restored when the causes of such discontinuance have been removed and there has been received payment of all proper charges due from the customer or applicant, as provided for in the tariff of the utility."

Alabama: "A utility shall not be required to furnish service at any premises to any applicant for such service where such applicant at the time of his application is indebted to the utility for similar service furnished either at the same or at other premises within 60 days previous to such application, until such applicant shall have paid such indebtedness to utility."

California: "A consumer's gas service may be discontinued for nonpayment of a bill for gas service of the same class rendered him at a previous location served by the company, provided said bill is not paid within 30 days after presentation at the new location.

"No gas utility shall discontinue the service of any consumer for any infraction or violation of any rule of the utility, after the violation has been discontinued by the consumer."

(i) RESPONSIBILITY FOR DELINQUENT ACCOUNTS

Washington: "A utility shall not refuse or discontinue service to an applicant, or customer, who is not in arrears to the utility, even though there are unpaid charges due from the premises occupied by applicant or customer on account of the unpaid bill of a prior tenant or unless there is evidence of conspiracy."

C32 (North Carolina, South Carolina): "Whenever the supply of gas is turned off for violation of rules or regulations, nonpayment of bill, or fraudulent use of gas, the utility may make a reasonable charge for the cost to it of turning the gas on again."

The maximum charge that may be made for turning on gas after discontinuing service follows: Arizona, $2; Alabama, $1.50; California, Indiana, North Dakota, Oklahoma, West Virginia, $1; Maine, "such reasonable charge as is contained in its schedules";

Montana, "actual cost"; Washington, "reasonable charge, the amount of such charge to be specified in its tariff."

Alabama also permits a charge of 75 cents to cover the cost of sending a man to shut off the gas even though the bill is paid and the shut-off is made unnecessary.

Alabama: "The utility shall not be required to restore service after suspension in accordance with this rule until the customer has complied with all reasonable rules of the utility designed to prevent a recurrence and the utility has been reimbursed for full amount of service rendered."

Oklahoma: "After the condition has been remedied for which the customer's service was discontinued, the utility shall restore service as soon as possible: Provided, however, where service has been discontinued for fraudulent use of gas or for tampering with the utility's regulating and measuring equipment, the utility may refuse to restore service until ordered to do so by the Commission pending or after a hearing by said Commission."

Kansas: "A complete record of all transactions under this rule shall be maintained by the utility."

(j) REPLACEMENT OF METERS AND CHANGES IN LOCATION OF SERVICE

C32 (Alabama, Maine, Montana, North Carolina, Oklahoma, South Carolina): "Whenever a consumer requests the replacement of the service meter on his premises, such request shall be treated as a request for the test of such meter, and as such shall fall under the provisions of rule 20."

C32 (Alabama, Indiana, Maine, Montana, North Carolina, North Dakota, Oklahoma, South Carolina): "Whenever a consumer moves from the location where gas is used by him and thereby requires the disconnecting and connecting at a new location of the gas supply, and the same work has been done for him within 1 year preceding, the utility may make a reasonable charge for the work."

Indiana, North Dakota, and Oklahoma specify that the charge for changing the location of services not exceed $1. Montana specifies that the charge for the work shall be "based on actual cost".

(k) CHANGING METER

New Jersey: "No company shall make any charge for changing a meter found defective or where test is to be made; and no charge shall be made for changing a meter of one type for a meter of another type unless the first meter referred to has been in use less than 1 year, in which case a charge, which in no case shall exceed $1, may be made to cover the actual expense of making the change."

(l) CHANGES IN USE

Washington: "The customer shall notify the utility, in writing, of all changes in his equipment or usage, which will materially affect the service to be rendered. Such notice shall be given within a reasonable time to permit the utility to provide the necessary facilities, and the cost thereof shall be equitably adjusted between the utility and the customer."

(m) DISCONTINUANCE OF SERVICE BY CUSTOMER

California: "Each consumer about to vacate any premises supplied with service by the company shall give written notice of his intended removal at least 2 days prior thereto, specifying the date service is desired to be discontinued; otherwise he will be held responsible for all gas furnished to such premises until the company shall have notice of such removal."

Washington: "A customer may be required to give a reasonable notice of his intention to discontinue service."

West Virginia: "Any consumer desiring service discontinued shall give 5 days written notice thereof to the utility."

12. MAINS AND SERVICES

(a) EXTENT OF SYSTEM IN WHICH UTILITY MUST MAINTAIN SERVICE

C32 (Alabama, California, Maine, Montana, North Carolina, Oklahoma, South Carolina): "Each gas utility, unless specifically relieved in any case by the commission from such obligation, shall operate and maintain in safe, efficient, and proper condition all of the facilities and instrumentalities used in connection with the regulation, measurement, and delivery of gas to any consumer up to and including the point of delivery into the piping owned by the consumer."

Oklahoma: "The consumer's service pipe shall be of sufficient size to afford adequate service, and the piping owned by the consumer shall be maintained in safe, efficient, and proper condition by and at the expense of the consumer. In the interest of the public the utility shall have the right of inspection of new service and may refuse service until the foregoing provision has been complied with, or where test reveals excessive loss of gas through leakage on consumer's premises."

(b) MAPS

C32 (Alabama, Maine, Montana, North Carolina, Oklahoma, South Carolina): "Suitable maps or records shall be kept on file showing the size, character, and location of each street main, district regulator, street valve, and drip."

Alabama requires that consumers' services be shown and that the maps be kept current within 90 days.

Oklahoma: "An up-to-date map shall be filed with the Commission on or before January 1, 1923, and such map shall be brought up-to-date annually, either by revising the map on file or filing a new one."

California: "(*a*) Each gas utility shall keep on file with the Commission up-to-date maps of the territory which it holds itself in readiness to serve, outlining rate or operating districts and showing major transmission lines.

(*b*) A suitable map or maps shall be kept on file in the principal office of each division or district, which maps shall at all times show the size, character, and location of each street main, district regulator, street valve, and drip, and when practicable each service in the corresponding territory served. In lieu of showing service locations on maps, a card record or other suitable means may be used."

"(*c*) In each division or district office there shall be available such information relative to the distribution system as will enable the local representatives at all times to furnish necessary information regarding the rendering of service to existing and prospective customers.

"(*d*) Each gas manufacturing or mixing plant and each compressor or holder station shall be provided with an accurate ground plan drawn to a suitable scale, showing the entire layout of the plant or station, the location, size, and character of each piece of plant equipment, major pipe lines, connections, valves, and other facilities used for the production and delivery of gas, all properly identified."

Kansas: "A map showing all gas mains, gas regulators, and districts covered by each regulator shall be filed with the city clerk of each muncipality and a copy sent to the Public Utilities Commission."

(c) REPORTS ON CERTIFICATES OF CONVENIENCE AND NECESSITY

Alabama: "The utility must file within 10 days, notice of the beginning and of the completion of any construction authorized by any certificate of convenience and necessity, and within 4 months, a detailed report including a record map and detailed statement of the cost of such construction."

(d) STREET MAIN EXTENSIONS

C32 (California, North Carolina, South Carolina, Washington): "Each utility shall adopt rules, subject to the approval of the Commission, under which it will, upon written request for service by a prospective consumer or a group

of prospective consumers located in the same neighborhood, make the street main extension necessary to give service and furnish service-pipe connection or connections."

California has a "standard rule" and Washington a recommended form for the utility to adopt. In Michigan and Indiana primary jurisdiction rests with the muncipalities, subject to appeal to the commission by either party. In both States forms are given to indicate the considerations upon which the appeal will be decided by the commission. In Arizona a form, which is usually adhered to in referee cases, has been determined but not made the subject of a definite order. In all these cases the forms used or recommended have nearly the effect of State-wide rules and their provisions will be included, without further explanation, in the discussion of existing State rules.

Missouri (Colorado, Maine): "The practice governing service main extensions by any utility must likewise be filed with the Commission as a portion of the schedule of rates on file."

The following provision in Oregon's rules should probably be interpreted to include the extensions of mains: "No utility may require from any customer or prospective customer a deposit to pay any part of the cost of installation, except under the rules and regulations approved by the commission and set out in the published schedules of the utility."

California requires a free extension of 150 feet per customer; District of Columbia, 125 feet; Illinois, 100 feet of low-pressure main or 200 feet of high-pressure main; New York (by law), 100 feet; Oklahoma, 75 feet; and West Virginia, 50 feet. For the purpose of this rule in Illinois a main carrying gas at a pressure of 2 pounds per square inch or more is considered a high-pressure main. Indiana requires the utility to make a free extension, costing not more than 4 times the estimated annual gross revenue from the customers served through the extension; Montana, 3 times; Arizona, Michigan, New Jersey, and North Dakota, 2 times; and Washington 1½ times the annual revenue.

The following cities require free main extensions of the lengths stated:

Free extension	City
Feet	
100	Iowa City, Iowa, Warren, Ohio, Dallas, Tex.
110	Cedar Rapids, Iowa.
133	Minneapolis, Minn.

California, District of Columbia, Illinois, Indiana, Michigan, Montana, New Jersey, North Dakota, Oklahoma, and Washington have rules which govern the depositing by prospective customers of the cost of extensions above the free limit and the refunding of such deposits when additional customers are served from the extension. Illinois makes it optional with the customer, and New Jersey makes it optional with the utility in agreement with the customer to provide for

the cost of an extension by a guarantee of revenue instead of by an initial deposit to cover the cost of the extension above the free limit.

New Jersey (optional): "The applicant for the extension shall guarantee the utility a monthly revenue equivalent to one twenty-fourth of the total cost of the extension; provided, however, that the utility shall not be required to accept a guarantee of more than 50 percent above the normal charge for service to the particular applicant."

The optional Illinois rule will be quoted later in connection with refunds to customers.

California: "The cost of the excess portion of the main advanced by the applicant shall be based upon a 3-inch main or upon the main as installed if it be less than a 3-inch main."

Indiana (Montana, North Dakota, Oklahoma): "In estimating the cost of an extension the estimate shall be based on the diameter of the pipe to be used, provided, however, the estimated cost to the consumer or consumers shall not be based on a pipe diameter in excess of 4 inches, unless actual consumption estimated for the proposed consumer or consumers requires a larger pipe."

The District of Columbia bases the deposit upon a uniform charge of $1.75 per foot of extension.

Illinois: "The distance of the applicant from the nearest existing main shall be used in determining whether the applicant is entitled to a free extension and the cost of extending the nearest street main shall be used as a basis in determining the amount of deposit necessary in case the extension is above the free limit."

Oklahoma: "In arriving at the length of main extension necessary to render service at any point, the distance from such point to the nearest distribution main shall be considered along lines of proper construction, due consideration being given to the general layout of the system; provided, however, that extensions across streets, highways, alleys, lanes, roads, or railroads, extensions caused by irregularities in city platting, and extensions past property already being served by the utility, provided such property frontage does not exceed 50 feet, shall be made at the expense of the utility and shall not be considered in arriving at the length or cost of the extension to the consumer. This rule shall apply to the extension of distribution mains only and shall not be applicable to reinforcing lines or belt lines. The length of the extension shall be measured along lines of proper construction from the center of the property last served or from the nearest distribution main to the center of the property to be served, and from this measurement the above-mentioned free allowances shall be made."

The following rule (Oklahoma) is typical of the more common provisions for deposits and refunds.

"If the main extension required . . . is greater than the free extension specified above, such an extension shall be made under the following conditions: The utility may require a deposit of the excess cost of the extension over the free limit, and shall, in such a case, refund an amount equal to the cost of the free main extension, per consumer, for each additional consumer whose service shall be connected therewith within a period of 5 years from the making of such extension, but at no time shall the rebate made exceed the original deposit."

The clause "for each additional consumer whose service shall be connected therewith" may be interpreted to include only new customers who receive service directly from the original extension, or it may be interpreted to include customers who receive service from mains subsequently connected to the original extension. The rules of Indiana, Michigan, Montana, New Jersey, North Dakota, and Oklahoma share this ambiguity. California definitely limits refunds to the cases of new customers served directly from the original extension; further extension and use of the main do not lead to the

reimbursement of customers who paid for the connecting link. The District of Columbia and Illinois, on the other hand, definitely provide for the reimbursement of the customers who made a deposit for an extension, by an amount equal to the cost of a free extension, whenever an additional customer is connected to the main originally installed or to any extension of it.

The length of time after which refunds cease and the remaining deposits accrue to the utility is 10 years in California, Illinois, Montana, and New Jersey; 8 years in Indiana and North Dakota; 5 years in Michigan and Oklahoma; and 3 years in Washington. In the District of Columbia the period is not limited.

District of Columbia (Illinois): "In the case of serving additional consumers from mains on which there are two or more deposits as herein provided, refunds shall be made to the several depositors in chronological order, i.e., the deposit first made in point of time shall be totally refunded before any refund is made on a later deposit."

Washington: "Subsequent applicants requesting service on such an extension within 3 years after the establishment thereof shall obtain in writing from each and all of the original applicants, their successors or assigns, who make deficit payments on the extension under these rules, either (*a*) a receipt acknowledging a pro rata share of the amount paid on the extension by the original applicants, or (*b*) a waiver of payment in lieu of receipt under (*a*), provided, however, that when the cost of furnishing such service exceeds the investment required of the utility, then the connection will be treated as a new extension."

In Arizona, Michigan, and under the optional rule in Illinois, refunds are based upon the revenue from the extension rather than upon the number of customers connected; the principal provisions follow:

Michigan: ". . . such subsidy to be refunded to the original prospective consumer or consumers in annual installments equal to 20 percent of the excess of the actual annual gross revenue after the first 2 years above 1½ times the average estimated annual gross revenue for the first 2 years. Such actual annual gross revenue shall include not only the revenue received from the original prospective consumer or consumers, but also that received from all other consumers served from the same extension."

Illinois (optional): "The consumer shall guarantee to the utility a definite revenue for the first year during which the service is to be furnished. The utility shall then install at its own expense an amount of constrution the cost of which, including items of material and labor only, is equal to three times this annual guarantee and may require a deposit to cover the excess of this cost over three times the guaranteed annual revenue.

"At the end of the first year the utility shall refund to this consumer three times the excess of the actual revenue from this consumer over the guaranteed revenue. The utility shall refund also to this consumer an amount equal to three times the first annual revenue from each additional consumer who is furnished service from this extension or from any extension thereto within 10 years after its construction."

Illinois (Indiana, Michigan, Montana, North Dakota, Oklahoma): "If the extension is of such length and the prospective business which may be developed by it is so meager as to make it doubtful whether the business from the extension would ever pay a fair return on the investment the fact shall be reported to the Commission for investigation and determination as to the reasonableness of such extension." In Indiana, North Dakota, and Oklahoma, new real-estate developments are specifically included under the provisions of this rule.

California: "Extensions to real-estate subdivisions will, in general, be made only on special contracts."

New Jersey: "Where applications for extensions into newly developed tracts of land are made by individuals, partnerships, or corporations interested in the

development and sale of land, but not as ultimate residents, the utility may require a deposit from the applicant covering the entire cost of installing the necessary main lines to serve the tract.

"Such deposits are not to carry interest.

"Such deposits are to be returned to the depositor when and as new houses abutting on such main lines are completed, the prospective consumer's equipment installed, the house occupied by a bona fide owner or responsible tenant who has entered into a contract for use of the utility's service.

"Upon such completion and occupation there shall be returned to the depositor an amount equal to the estimated charge for 2 years' service; provided, however, that no part of the deposit remaining over 10 years is to be returned."

Indiana (Montana, North Dakota, Oklahoma): "This rule shall not be construed as prohibiting any utility from making free extensions of lengths greater than above specified, or from providing a method of return of deposits for extensions more favorable to consumers, so long as no discrimination is practiced between consumers whose service requirements are similar."

North Dakota (Michigan, Oklahoma): "The extension shall at all times be the property of the utility and at the end of the —— year period any unrebated portion of such advancement or deposit shall accrue to the utility as partial compensation for the maintenance and operation of such extension for said period."

Other States do not specify the ownership of the main; but Montana has the following provision which indicates that the customer has title to an extension for which he has provided all or a part of the cost. "If at any time the utility desires to purchase an extension to its distributing system which was built in whole or in part by the consumer or consumers, it may do so subject to the approval of the Commission, after making payment of a fair and reasonable price fixed by the Commission, due allowance being made for depreciation and previous payments made thereon."

Illinois (Oklahoma): "A utility shall not be obliged to make the extension as required by this rule unless the applicant shall furnish a suitable guarantee that he will use the service for at least 1 year, or unless the owner of the property served by such extension or some other responsible party shall guarantee that the service will be used for that length of time."

Indiana, Montana, and North Dakota require a 2-year guarantee by a similar rule.

Washington: "No extension will be considered as coming under this rule where the ratio of the total cost of the extension to the estimated yearly revenue is greater than 6 to 1."

Arizona: "This rule applies to extensions costing less than $300. Other extensions by mutual agreement or special contract.

"When the estimated cost is more than twice the estimated annual revenue, extension will be built if consumer deposits with the company the cost of the construction. Company will refund immediately upon execution of agreement $200 for each $100 of estimated normal annual revenue and in January of each year $200 for each $100 of estimated normal annual revenue received from the extension during the previous 12 months, less the amount of money refunds theretofore made to the consumer, and less 5 percent depreciation per year from the date of installation."

(e) TEMPORARY SERVICE

California: "Temporary service, as herein considered, refers to service to circuses, bazars, fairs, temporary restaurants, construction work, etc., of a temporary nature.

"The company will, if in its opinion the furnishing of such service will not work an undue hardship upon it or its then existing consumers, furnish temporary service under the following conditions:

"(*a*) The applicant for such temporary service shall be required to pay to the company in advance, or otherwise, as the company may elect, the net cost

of installing and removing any facilities necessary in connection with furnishing of such service by the company.

"(*b*) Each applicant for temporary service may be required to deposit with the company a sum of money equal to the estimated amount of the company's bill for such service, or to otherwise secure, in a manner satisfactory to the company, the payment of any bills which may accrue."

Washington: "In the case of temporary service for short-term use, as distinguished from seasonal use, the utility may require the customer to pay all costs of making the service connection and removing the material after the service has been discontinued, or to pay a fixed amount to cover such expense; provided, however, that if the material is removed the customer shall be credited with the reasonable salvage which the utility shall receive on discontinuance of service."

Oklahoma: "If any utility is making main extensions of greater length than required by these rules, or is installing services of greater length than required by these rules, no change in such practice shall be made before determination by the Commission of the proper rate to be charged the consumer for the lower grade of service."

(f) SERVICE CONNECTIONS

Colorado (California, Illinois, Michigan, North Dakota, Oklahoma, Washington, West Virginia): "Service connections to the consumer's property line shall be installed and maintained at the expense of the utility.

"This rule shall not apply when unusual conditions are encountered, or to very long service connections. When such special cases arise, the Commission will, if necessary, prescribe the proper charge."

California: "In connection with service, extensions to the property line or curb line, railroad and street railway rights-of-way or other similar continuous rights-of-way immediately adjacent to any public street, highway, alley, lane, or road will, for the purpose of these rules, be deemed to be a portion of the public highway beyond which each gas utility must extend its service pipes at its own expense."

Oklahoma (California, Colorado, Michigan, Washington): "Service pipes may be installed by a utility from the main to the meter and the consumer charged for his portion of the service pipe from the curb or property line to the meter under uniform rules to be adopted by the utility and set forth in its schedule of rates, rules, and regulations on file with the Commission."

North Dakota: "Where the utility so elects, however, it may, by standardizing its practice as to a particular city or town, install and own as much more of the service (beyond the property line) as it may elect."

California: "No gas utility which has established the practice of extending service pipes at its own expense beyond the property line or curb line shall abandon or alter such practice in any respect, except upon a showing before the Commission that a change in such practice is justified."

Michigan: "In order to secure payment of such charges by consumers, the utility may require an advance deposit to cover the estimated expense when application is made for the service extension."

Colorado: "Any utility may require through its rules and regulations that prospective consumers advance the full cost of service connections, the amount so advanced to bear no interest, and to be applied to the consumer's bills until such time as the amount of service furnished under the prescribed schedule of rates shall equal the amount so deposited. Such deposits shall not cover the cost of meters, since these may be recovered by the utility upon the discontinuance of service by the consumer. Any utility may likewise require such deposits from consumers whose service connections are replaced for any cause. It is further provided that no consumer's deposit or advance payment for service shall be required from consumers making deposits for service connections until such time as the amount so deposited for service connections shall have been exhausted."

West Virginia: "The consumer shall furnish and lay the necessary pipe to make the connection from his property line to the place of consumption. . . .

"In the installation of a service line, the consumer must not install any tees or branch connection and must leave the trench open and pipe uncovered until it is examined by an inspector of the utility and shown to be free from any irregularity or defect."

(g) SERVICE COCKS OR CURB SHUT-OFFS

California (Michigan, West Virginia): "On and after the effective date of this order each and every gas-service line installed or reconstructed shall include a suitable shut-off valve or cock, properly housed or encased so as to be accessible at all times, located outside of the structure served and between said structure and the gas main from which said service is supplied."

(h) SIZE OF SERVICE CONNECTION

Michigan: "After the taking effect of these rules no gas-service pipe shall be installed for the use of any consumer, which is smaller than standard 1¼-inch steel pipe, in case the gas pressure does not exceed 12 inches water column or which is smaller than standard ¾-inch steel pipe in case the gas pressure exceeds 12 inches water column. In case the pressure in said service pipe exceeds 12 inches water column, the utility shall install and maintain in good operating condition a standard type of house governor or regulator between the service outlet and the consumer's meter. . . ."

Illinois likewise requires 1¼-inch service pipes in low pressure systems, while North Dakota requires pipe of the same size in all cases.

Oklahoma requires that "the consumer's service line shall be of sufficient size to afford adequate service".

(i) LOCATION OF SERVICE CONNECTION

West Virginia (Washington): "A consumer's service line shall extend to his property line and to that point thereon easiest of access to the utility from its existing distribution system or requiring the least extension of the existing distribution line.

"In any case where a reasonable doubt exists as to the proper location for consumer's service line, the utility shall be consulted and its approval of the location secured in writing."

(j) MAINTENANCE AND REPLACEMENT OF SERVICE PIPES

Illinois: "The utility shall at its own expense maintain service pipes so as to furnish the best possible service. All condensate, water, or other matter accumulating in such manner as to interfere with the uniform flow of gas at any point between the consumer's meter and the utility plant, shall be removed by, and at the expense of the utility. Existing services so laid as to cause an interference with service on account of freezing shall be changed at the utility's expense to eliminate trouble from this source, and traps in service which repeatedly cause pressure trouble shall be permanently removed at the utility's expense. It is recommended that services hereafter installed or replaced in low pressure systems be not smaller than 1¼ inches in diameter and that existing construction be made to conform with this requirement when pressure conditions become unsatisfactory or when other conditions make replacement advisable.

"If it becomes necessary to replace a service pipe to furnish satisfactory pressure at the outlet of the consumer's meter, the utility shall at its own expense make such changes unless it can show to the satisfaction to the Commission that the particular pipe was not installed at its direction or under its supervision and further that the original installation was not made in accordance with specifications effective at the time the pipe was laid. When a service pipe has to be materially enlarged for any purpose such as providing for a heavy industrial load, the matter may be brought to the attention of the Commission for a determination as to the reasonableness of requiring the utility to bear the expense."

Indiana requires the removal of obstructions from the service pipe at the expense of the utility.

Oklahoma, Washington, and West Virginia require the customer to maintain or pay for the maintenance of the portion of the service line on his own property.

North Dakota: "The service shall be so graded to drain toward the gas main as to preclude the possibility of water and oil condensing in the service and stopping the flow of gas. In case of inability to secure drainage toward the main a suitable drip shall be located near the meter and the service graded toward this drip. Periodic inspection of these drips shall be made to determine the satisfactory operation of same."

Washington: "The utility may reserve the right to refuse to connect with or render service to any applicant, or any customer, where such connection and rendition will adversely affect the service to other customers, or where the applicant or customer has not complied with State or municipal regulations concerning the rendition of such service.

"The installation of proper protective devices on a customer's premises may be required whenever the utility deems such installation necessary to protect its property or that of its customers."

Oklahoma: "In the interest of the public the utility shall have the right of inspection of new service and may refuse service until the foregoing provision has been complied with, or where test reveals excessive loss of gas through leakage on consumer's premises."

13. MISCELLANEOUS

(a) RATE SCHEDULES, RULES, AND REGULATIONS

[See also rule relating to "Information for Customers"]

C32 (Alabama, California, Colorado, Indiana, Maine, Missouri, Montana, North Carolina, North Dakota, Oklahoma, South Carolina, West Virginia): "Copies of all schedules of rates for service, forms of contracts, charges for service connections and extensions of mains, and of all rules and regulations covering the relations of consumer and utility shall be filed by each utility in the office of the Commission. Complete schedules, contract forms, rules, and regulations, etc., as filed with the Commission, shall also be on file in the local offices of the utility, and shall be open to the inspection of the public.

Michigan: "Each utility may adopt such reasonable rules and regulations governing its relations with consumers as it finds necessary and which are not inconsistent with these rules. Such rules and regulations shall constitute an integral part of the utility's rate schedule and be filed with the rate schedule as directed in Order No. 1529 . . . or in pertinent superseding or modifying orders."

Oklahoma: "To be authentic, at least one copy of the utility's rate schedules and rules and regulations must bear the Commission's official stamp of approval."

South Carolina: "No schedule of rates, contract forms, nor rules and regulations shall be changed until after proposed change has been approved by the Commission."

West Virginia: "No rules and regulations or schedules of rates or charges shall be effective until filed with the Commission as provided by law."

Washington: "Rate schedules and rules and regulations governing service shall be published on prescribed standard forms and in accordance with the rules and regulations governing the filing of tariffs as prescribed by the Department."

It is probable that all commissions exercising jurisdiction over gas companies require the filing of the utilities' rules and schedules; but only in the States mentioned is this requirement embodied in the service rules.

Colorado (Connecticut, Oklahoma): "If the reasonableness of any charge, rule, regulation, or practice of any utility with reference to service connections, or extension, or any rule covering the relations between consumer and utility is challenged, the Commission will, upon complaint and investigation, prescribe the proper charge, rule, regulation, or practice which shall thereafter be followed."

(b) PRACTICE UNDER THESE RULES TO BE FILED

Colorado (Missouri): "Each utility shall file with the Commission . . . (*a*) Description of test methods employed and frequency of tests or observations for determining quality, voltage, and pressure of gas, electric, and water

service furnished. (*b*) Description of meter testing equipment including methods employed to ascertain and maintain accurancy of all testing equipment. (*c*) Rules covering testing and adjustment of service meters when installed and periodic tests after installation.

"Revisions in any portion of this statement after filing will necessitate the filing of an entire new statement, properly identified and dated, canceling the one on file."

(c) SPECIAL RULES OR REQUIREMENTS

West Virginia: "A utility desiring to establish any rule or requirement supplementing the rules of the Commission shall first make application to the Commission for authority for such rule or rules clearly stating in its application the reason for such establishment.

"A consumer who has complied with the rules of the Commission shall not be denied service for failure to comply with rules of the utility that have not been approved by the Commission."

(d) MODIFICATION OF RULES

California: "Any gas utility may of its own accord establish uniform nondiscriminatory rules more favorable to its consumers than the rules herein established. The rules herein established shall take precedence over all orders, general or special, heretofore made by the Commission insofar as said orders may be inconsistent with these rules.

"The rules herein established shall take precedence over all rules filed or to be filed by gas utilities insofar as inconsistent therewith. Rules now on file and inconsistent with the rules herein established shall be properly revised and refiled within 30 days from the effective date of this order."

(Illinois): "In any case where any gas utility is supplying or is under contract to supply gas to consumers under conditions more favorable or advantageous to such consumers than are provided in these rules, either as to quality or character of service, no change shall be made in such service conditions without the further approval of the Commission."

(e) REFERENCE TO COMMISSION

Michigan: "In any case where the parties concerned shall fail to agree upon the application or interpretation of any of these rules, or in case of disagreement regarding regulations promulgated by any utility concerning service, the matter may be referred by either party to the Commission for settlement."

XI. SUMMARY OF DATA REGARDING GAS-COMPANY SERVICE STANDARDS FOR 1930

The data summarized in Tables 6 to 24 represent the substance of replies received in the summer and autumn of 1930 to a questionnaire regarding the operating practice of gas companies in the United States. It was the intent of the questionnaire that each company report the practice which it regarded as both desirable and practicable, and which it attempted to maintain. Without doubt, however, some of the replies represented existing unsatisfactory conditions even though the utility might be endeavoring to improve them; and others, e.g., those which indicated zero variation of pressure in a low-pressure distributing system, indicated the ideal without much regard to the practicability of attaining it. To give a better indication of the extent of each practice tabulated, both the number of companies reporting it and the approximate number of customers served by these companies are reported in most of the tables. The companies are also classified, for the purpose of several tabulations, into those distributing natural and those distributing manufactured gas. Companies supplying mixed gas are classified according to the predominant constituent of the mixture.

1. CLASSIFICATIONS OF REPORTING COMPANIES

TABLE 6.—*Size of reporting companies*

Approximate number of customers (thousands)	Number of companies	
	Natural gas	Manufactured gas
1 to 2	36	139
5 to 19	24	88
20 to 49	6	33
50 to 99	6	13
100 or more	7	14
Unknown		2
Total	79	287

TABLE 7.—*Distribution of reporting companies by States*

State	Number of companies	Approximate number of customers (thousands)	State	Number of companies	Approximate number of customers (thousands)
Arizona	4	21	New Jersey	7	927
Arkansas	1	5	New Mexico	2	4
California	17	953	New York	26	2,345
Colorado	4	93	North Carolina	6	20
Connecticut	6	145	North Dakota	1	3
District of Columbia	1	123	Ohio	11	701
Florida	7	75	Oklahoma	9	173
Georgia	6	70	Oregon	1	88
Hawaii	1	14	Pennsylvania	20	935
Illinois	16	1,231	Philippine Islands	1	17
Indiana	30	179	Puerto Rico	1	3
Iowa	10	83	Rhode Island	2	33
Kansas	10	82	South Carolina	3	7
Kentucky	6	88	South Dakota	3	14
Louisiana	4	36	Tennessee	3	41
Maine	3	15	Texas	10	205
Maryland	4	217	Utah	1	19
Massachusetts	27	681	Vermont	4	10
Michigan	31	663	Virginia	8	58
Minnesota	6	33	Washington	4	68
Mississippi	1	2	West Virginia	4	20
Missouri	11	352	Wisconsin	18	270
Montana	4	8	Wyoming	4	6
Nebraska	6	80	Anonymous	2	
Nevada	1	3			
New Hampshire	4	20	Total	371	11,239

TABLE 8.—*Kind of gas supplied by reporting companies*

Kind of gas supplied	Number of reports	Approximate number of customers (thousands)
Coal gas	42	112
Coke-oven gas	15	298
Carburetted-water gas	110	1,329
Oil gas	22	176
Mixture of carburetted-water gas with coal or coke-oven gas:		
Water gas used only for peak loads or emergencies	15	182
No seasonal variations permitted	20	183
Mixture permitted to vary only within fairly definite limits	15	1,225
Reported that no limit to variation of the mixture is set	8	834
No report concerning permitted variation	28	3,428

TABLE 8.—*Kind of gas supplied by reporting companies*—Continued

Kind of gas supplied	Number of reports	Approximate number of customers (thousands)
Constant mixture of coal gas and blue-water gas: Carburetted-water gas used in emergency	1	6
Constant mixture of coke-oven gas and producer gas: Carburetted-water gas used for peak loads	1	39
Mixture of coke-oven gas and oil-refinery gas	1	31
Mixture of water gas and oil gas	1	4
Water gas, coke-oven gas, and oil-refinery gas	2	602
Mixture of producer gas and oil-refinery gas	1	1
Mixture of coal gas, coke-oven gas, carburetted-water gas, producer gas and oil-refinery gas	1	201
Natural gas	78	2,387
Constant mixture of natural gas with blue-water gas	7	68
Natural gas supplemented by carburetted-water gas in winter only	1	78
Mixture of natural gas and coke-oven gas	1	55

TABLE 9.—*Method of distribution of reporting companies*

[Any system requiring individual house governors is classified as a high-pressure system]

Pressure	Natural gas		Manufactured gas	
	Number of companies	Number of customers (thousands)	Number of companies	Number of customers (thousands)
Low only	44	1,069	142	1,892
Partly high	30	1,229	121	6,843
High only	2	116	19	91

2. PRESSURES

TABLE 10.—*Pressures in low-pressure mains*

[Inches of water column]

Maximum	Minimum	Natural gas		Manufactured gas		Maximum	Minimum	Natural gas		Manufactured gas	
		Companies	Customers (thousands)	Companies	Customers (thousands)			Companies	Customers (thousands)	Companies	Customers (thousands)
30	18			1	13	15	7			1	2
30	4			1	3	15	5	1	113		
22	10.5			1	5	14	14	1	6		
22	10	1	5			14	10.5	1	1		
21	14	1	1								
						14	7	8	52		
20	10	1	4			14	6	1	4	1	15
20	6			1	1	14	5			1	2
18	10			1	5	14	4			1	1
18	6			1	2	14	3.5	1	4		
17	10.5	1	1								
						14	(1)	3	331		
17	8.5	1	1			13.5	8	1	81		
17	7	1	8			13	5.5			1	10
16	3.5			1	2	12	10.5	1	12		
15.5	12	1	1			12	9	1	7		
15.5	10.5	1	5								
						12	8.5			1	15
15.5	5	1	16			12	8	1	7		

[1] None stated.

TABLE 10.—*Pressures in low-pressure mains*—Continued

[Inches of water column]

Maximum	Minimum	Natural gas		Manufactured gas		Maximum	Minimum	Natural gas		Manufactured gas	
		Companies	Customers (thousands)	Companies	Customers (thousands)			Companies	Customers (thousands)	Companies	Customers (thousands)
12	7.5			1	2	7	7	1	3		
12	7	2	117			7	6			3	14
12	6	1	222	6	67	7	5.5	1	4	4	33
						7	5	2	79	3	5
12	5	1	320	3	7						
12	4.5			1	3	7	4.5			1	2
12	4	2	152	3	30	7	4	2	19	12	190
12	3			1	15	7	3.5			5	49
12	2			1	26	7	3			7	441
						7	2.5			1	32
11	4			1	10						
10.5	10.5	1	10			7	2			1	4
10.5	7	4	93			7	(1)	1	2		
10.5	5	1	1			6.5	5.5			1	4
10.5	3.5			1	55	6.5	5	1	3		
						6.5	4			2	8
10	8			3	29						
10	7			1	2	6.5	3.5			6	88
10	6			3	11	6	5			3	7
10	5.5			1	2	6	4.5			1	13
10	5			2	6	6	4	3	118	18	396
						6	3.5			11	243
10	4			1	1						
10	3	1	2	3	42	6	3	1	5	33	1,518
10	2			1	39	6	2			10	302
9.5	6.5			1	17	6	0.5			1	3
9	6	3	105	2	14	6	(1)			1	3
						5.5	5			1	718
9	5			2	4						
9	4.5			2	920	5.5	4			3	211
9	4			1	3	5.5	3.5			2	11
9	3.5			2	34	5	4			3	18
9	3			1	20	5	3.5			1	60
						5	3			5	107
8.5	7	3	10								
8.5	5	1	36			4.5	4			1	2
8.5	(1)	1	2			4.5	3.5			1	3
8	7			1	13	4.5	2.5			1	1
8	6			7	57	4	4			1	1
						4	3.5			2	3
8	5	2	48	11	220						
8	4	2	17	15	187	4	3			1	6
8	3			6	576	4	2			2	777
8	2	1	3	1	4	None	3			2	27
8	(1)			2	61						
						Average					
7.5	6			1	32	pressure					
7.5	5.5			1	306						
7.5	5	1	20	1	5						
7.5	4			1	19						
7.5	3.5			1	23	5				1	2
						3	3	1	475		
7.5	3			3	84						

[1] None stated.

TABLE 11.—*Ratio of maximum pressure to minimum pressure in low-pressure mains*

[Percent, computed from stated maximum and minimum]

Maximum pressure (percent of minimum)	Natural gas		Manufactured gas	
	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)
1,200			1	3
600 to 650			2	29
500 to 599			1	39
400 to 499	2	7	3	21
301 to 399	1	2	6	48
300	4	281	16	409
250 to 299	1	8	17	769
201 to 249	3	329	13	87
200	15	302	66	3,899
180 to 199			13	121
170 to 179	4	136	23	433
160 to 169	7	175	22	382
150 to 159	14	349	24	434
140 to 149	1	2	7	106
130 to 139	6	91	12	582
120 to 129	5	34	14	100
110 to 119	1	12	8	753
100	3	19	1	1
Total	67	1,747	249	8,216

3. METERS

TABLE 12.—*Percentage of meters tested annually*

Tested annually (percent)	Companies with prescribed routine test periods		Companies without prescribed routine test periods		Natural-gas companies		Manufactured-gas companies	
	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)
50 to 100	10	61	7	23	4	19	13	65
40 to 49	12	162	4	30	2	4	14	188
30 to 39	15	311	8	47	6	163	17	195
25 to 29	36	1,000	24	267	16	637	44	630
20 to 24	94	2,329	43	782	37	1,112	100	1,999
16 to 19	6	979	16	1,289	3	44	19	2,224
14 to 15	16	291	27	2,411	5	133	37	2,560
10 to 13	9	89	25	515	5	7	29	597
Less than 10	3	5	3	9	2	3	4	11

TABLE 13.—*Average frequency of meter tests*

Approximate average period within which meter is tested (years)	Percentage of meters in service in each group of companies which is tested within a given average period of years			
	Companies with prescribed routine test periods		Companies without prescribed routine test periods	
	Natural gas	Manufactured gas	Natural gas	Manufactured gas
2.5	1.2	5.3	0.9	1.0
3.3	12.9	9.3	1.3	2.0
4	53.4	21.0	13.0	5.8
5	95.9	66.1	82.6	11.3
6	97.8	90.8	84.9	38.9
7	99.6	97.6	99.3	88.8

TABLE 14.—*Error permitted without resetting or repairing meters after testing*

Error permitted		Number of companies	Customers (thousands)	Error permitted		Number of companies	Customers (thousands)
Fast (percent)	Slow			Fast (percent)	Slow		
	Percent				*Percent*		
None	None	8	177	1.5	2.0	2	42
0.3	0.3	1	2	2.0	2.0	235	5,868
0.5	.5	5	519	3.0	3.0	12	179
1.0	1.0	33	2,402	4.0	2.0	1	10
1.0	1.5	1	7	5.0	5.0	3	9
1.5	1.0	1	14	All meters repaired and adjusted to read 1 percent slow		1	222
1.0	2.0	13	581				
1.5	1.5	7	36				

TABLE 15.—*Payment for meter testing*

Payment for test	Complaint tests		Referee tests	
	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)
Cost of test borne by company	309	9,663	86	2,007
Customer charged for test (charge usually refunded if meter is fast)	48	916	139	7,882
Tests paid for by city	1	1	3	19
No referee tests made			67	891

TABLE 16.—*Refund for fast meters*

Period for which refunds are made for fast meters	Number of companies	Customers (thousands)
Entire period in service since last test	7	163
Full error for 1 year plus half the period in service above 1 year	1	718
½ period in service since last test	16	399
Period in service not exceeding—		
2 years	1	3
1 year	27	569
6 months	123	4,300
4 months	4	313
3 months	54	1,141
2 months	8	43
½ the error for 3 months	1	15
1 month	7	56
Current bill	3	135
"From time meter is assumed correct" (or equivalent)	5	18
"To the satisfaction of the customer"	3	24
"By agreement"	5	24
Cases settled individually	4	1,136
"Only in special cases"	1	185
"On complaint only"	1	481
Refunds made but basis not stated	61	785
No refund made	15	68
Policy relating to refund not stated	24	663
Refund if meter is fast by more than—		
1 percent	2	67
2 percent	86	2,973
3 percent	20	274
4 percent	3	93

TABLE 17.—*Backbilling for slow meters*

Backbilling	Number of companies	Customers (thousands)	Backbilling	Number of companies	Customers (thousands)
No backbilling employed	209	4,830	Backbilling employed—Continued		
Backbilling employed rarely or for nonregistering meters only:			No general rule. Cases settled individually or "by agreement"	6	1,209
Settlement for not more than—			No statement made regarding backbilling	12	542
3 months	1	3	Backbilling employed only if meter is in error by as much as (percent)—		
2 months	2	920	2	15	659
1 month	1	3	3	8	18
Settlement by agreement	8	305	10	1	23
Basis of settlement not stated	38	566	20	1	1
Backbilling employed:			25	3	82
Settlement for ½ period since last test	3	36	50	1	16
Settlement for not more than—			75	2	115
1 year	1	1	100 (nonregistering)	21	1,354
6 months	30	1,182	"Very slow"	1	36
3 months	19	227			
2 months	4	29			
Settlement for 1 month on "current bill"	4	163			

4. CALORIMETRY

TABLE 18.—*Frequency of calorimetric tests*

Frequency of test	Number of companies reporting a given frequency									
	Natural gas					Manufactured gas				
	Thousands of customers per company					Thousands of customers per company				
	1 to 2	2 to 5	6 to 19	20 to 99	+100	1 to 2	2 to 5	6 to 19	20 to 99	+100
Continuous			3	9	2	3	10	31	34	9
Twice per hour							1			
30 times per day									1	
Hourly							2			1
2 hours								1		1
3 hours							2			
4 hours							1	1	1	
5 times per day						1	1	2		
6 hours						3	4	3	1	
3 times per day						5	13	12	4	
2 times per day		1				16	29	3	1	
Daily	1		1	1	1	7	35	15	4	1
6 times per week							1			
5 times per week								1	1	1
2 days		1								
3 times per week							1	1		
2 times per week				1			1			
Weekly		2	4		1	1	1			
10 days		1								
2 weeks		1								
Monthly	2	2	2		1	1				
8 times per year								1		
3 months					1					
6 months			1			1	1			
Yearly			1							
Irregular	1	1	1				1			
Made by supplying company [1]		2					1			
None made		3								
Not reporting	6	13	4	2	2	3	7	3	1	

[1] 8 of the 27 natural-gas companies which did not report are required by State rules to determine heating value unless it is determined by the company from which the gas is purchased.

5. ADJUSTMENT AND MAINTENANCE OF APPLIANCES

TABLE 19.—*Routine inspection of customers' appliances*

Frequency of inspection	Type of appliance																							
	Not specified		"Commercial"		"Industrial"		Hotels, restaurants, and "institutions"		House heating		Water heaters		Refrigerators		Boilers		Domestic		Ranges		Except ranges	
	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)	Number of companies	Customers (thousands)
7 years	3	77																				
6 years	1	59																				
5 years	15	407																				
4 or 5 years																	1	3				
4 years	5	10																				
3 years	8	51																				
2 years	9	524																				
1 year	35	1,063			1	8			4	179	7	237			1	29						
Twice a year	5	24			1	87			2	96	4	78	2	44							1	1
3 times a year									1	8												
4 times a year	1	2									2	15	1	88					1	5		
2 months	1	2							2	47												
1 month	6	42	3	172	5	271	5	196	3	163					1	43						
1 week to 1 month			1	64	1	64																
1 week			1	222	1	30	2	108	2	15												
"Irregular"	3	200																				
"Continuous"	10	794																				
"Depends on type"	4	1,157																				
"Inspected with meters"	1	3																				

TABLE 20.—*Charges for appliance adjustments made on request*

Charges made	Number of companies	Customers (thousands)
A charge is made but no details given	9	101
In special cases	2	23
For work requiring more than—		
1 hr	1	22
15 min	1	10
Regular maintenance service to which a regular schedule of fees applies	1	88

6. PURITY OF GAS

TABLE 21.—*Total sulphur allowed in gas*

Kind of gas	Number of companies					
	Coal gas	Coke-oven gas	Water gas	Mixed coal or coke-oven and water gas	Oil gas	Oil-gas mixtures
Sulphur allowed (grains per 100 cu ft):						
Less than 5			1	3		
5.0 to 9.9			8	13	2	1
10.0 to 14.9	2	1	7	10	6	
15	1	2	2	1	1	1
15 to 20					1	
18	1	1				
20			4	1	5	
25	1		1			
30	6	4	6	8	1	

NOTE.—All companies reporting 30 grains simply indicated the existing requirement under State regulation.

7. EXTENSION OF MAINS

TABLE 22.—*Free main extensions*

Basis of extension	Number of companies	Customers (thousands)
No free extensions made	8	275
Free extension of standard length	121	4,417
Extension based on anticipated revenue	40	1,129
Extension based on either standard length or anticipated revenue	86	2,715
Unclassified	4	96

TABLE 23.—*Free main extensions of standard length*

Length of free extensions per customer (feet)	Number of companies	Customers (thousands)	Length of free extensions per customer (feet)	Number of companies	Customers (thousands)
40	3	217	200	14	536
60	6	62	300	1	6
66	1	6	500	1	1
70	1	1	50 to 100	1	36
75	7	128	75 to 100	1	12
80	1	20	75 to 150	1	28
85	1	4	100 to 150	1	115
90	1	33	Low pressure, 100	1	26
100	122	3,599	High pressure, 150		
120	1	2	Low pressure, 100	9	1,202
125	1	3	High pressure, 200		
130	1	2	Low pressure, 100	1	306
150	16	566	High pressure, 300		

TABLE 24.—*Free main extensions based on anticipated revenue*

Basis of extension	Number of companies	Customers (thousands)	Basis of extension	Number of companies	Customers (thousands)
Extension to cost (times annual revenue):			Extension to yield a net return of percent:		
0.75	1	7	5	2	6
0.80	1	13	6	2	50
1.0	4	31	7	1	13
1.5	3	174	8	2	81
2.0	9	810	9	2	5
2.4	1	33	10	8	102
2.5	11	67	15	1	3
2.7	1	4			
3.0	43	2,083			
3.5	1	33			
4.0	28	236			
5.0	1	16			
5.5	2	43			

8. STATISTICS RELATING TO THE TOTAL MAGNITUDE OF THE GAS INDUSTRY

Tables 25–28 which show the magnitude of the gas industry are included here as a matter of general interest, although they do not belong to the group of tables reporting " company standards ". Those relating to manufactured gas are taken (with permission) from the Annual Statistics of the Manufactured Gas Industry in the United States, by Paul Ryan, published by the American Gas Association, October 1932. The following quotation from the foreword of the publication is needed in explanation of the tables.

It should be noted that the data in all tables included in this bulletin present revised figures on the manufactured-gas industry for the years 1929 and 1930, since companies formerly distributing manufactured gas, but which were distributing natural gas at the beginning of 1931 have been excluded from the tabulations for all 3 years. The tables therefore present a comparable and consistent picture of the operations of an identical group of companies over the 3-year interval, ...

The statistics relating to natural gas are taken from Natural Gas in 1931, by G. R. Hopkins and H. Backus, a separate reprint from the Mineral Resources of the United States issued by the United States Bureau of Mines. Both publications from which these data are taken contain much more information of value and should be consulted for details.

The extent to which the mixing of manufactured and natural gas is practiced is indicated by table 28, data for which were taken from Natural Gas in 1931. The classification employed by the American Gas Association evidently does not include all the mixed manufactured and natural gas in the manufactured-gas industry.

TABLE 25.—*Manufactured-gas industry in the United States*

[Comparative data on customers, sales, and revenue—1929, 1930, and 1931]

NUMBER OF GAS CUSTOMERS AT END OF YEAR

Type of service	Year		
	1929	1930	1931
Domestic	9,942,810	9,951,250	9,848,810
House heating	43,890	53,440	58,670
Industrial and commercial	456,700	467,370	487,880
Miscellaneous	7,310	7,130	7,180
Total	10,450,710	10,479,190	10,402,540

GAS SALES TO CONSUMERS

[Thousands of cubic feet]

Domestic	281,201,200	282,767,700	276,975,600
House heating	14,261,000	18,383,800	19,908,100
Industrial and commercial	103,489,800	99,667,600	92,248,300
Miscellaneous	2,202,400	2,334,200	2,065,300
Total	401,154,400	403,153,300	391,197,300

REVENUE FROM SALES TO CONSUMERS

Domestic	$340,449,500	$341,741,200	$335,428,900
House heating	12,075,500	15,234,400	16,061,500
Industrial and commercial	89,684,500	87,876,800	82,297,500
Miscellaneous	1,905,300	1,903,200	1,602,200
Total	444,114,800	446,755,600	435,390,100

TABLE 26.—*Manufactured-gas industry in the United States; gas produced and purchased by the industry for distribution to consumers*

[Thousands of cubic feet]

	1929	1930	1931
Gas produced:			
Water gas	216,566,300	208,502,200	193,402,700
Coke-oven gas	48,814,000	50,839,300	56,265,500
Retort-coal gas	41,886,400	40,870,000	38,686,200
Oil gas	8,485,500	8,485,500	7,918,700
Reformed oil-refinery gas	646,000	2,204,800	4,478,500
Butane-air gas	9,800	88,600	517,200
Total gas produced	316,408,000	310,990,400	301,268,800
Gas purchased:			
Coke-oven gas	114,944,100	118,463,500	109,455,900
Oil-refinery gas [1]	2,175,800	2,008,600	1,472,600
Natural gas	1,578,100	2,299,600	6,931,400
Total gas purchased	118,698,000	122,771,700	117,859,900
Total gas produced and purchased	435,106,000	433,762,100	419,128,700

[1] Not including quantity used in production of reformed oil-refinery gas.

TABLE 27.—*Summary of statistics for natural gas in the United States, 1929, 1930, and 1931*

	1929	1930	1931
Production—millions of cu. ft.	1, 917, 693	1, 943, 421	1, 686, 436
Consumption:			
Domestic—do.	359, 853	295, 700	294, 406
Commercial—do.		80, 707	86, 491
Industrial:			
Field—do.	705, 083	723, 165	571, 365
Carbon-black plants—do.	261, 197	266, 625	195, 396
Petroleum refineries—do.	103, 729	98, 842	75, 548
Electric public-utility power plants—do.	112, 707	120, 290	138, 343
Portland cement plants—do.	41, 643	41, 256	31, 381
Other industrial—do.	333, 329	315, 059	291, 319
Total	1, 917, 451	1, 941, 644	1, 684, 249
Number of consumers:			
Domestic—thousands	5, 098	5, 035	6, 456
Commercial—do.		413	520
Industrial—do.		21	28
Value (at wells) of gas produced:			
Total—thousands of dollars	157, 596	147, 048	117, 505
Average per M cubic feet—cents	8. 2	7. 6	7. 0
Value (at points of consumption) of gas consumed:			
Total—thousands of dollars	413, 153	415, 519	392, 156
Domestic—do.	223, 172	200, 615	208, 262
Commercial—do.		38, 558	41, 347
Industrial—do.	189, 981	176, 346	142, 547
Average per M cubic feet:			
Domestic—cents		67. 8	70. 7
Commercial—do.		47. 8	47. 8
Industrial—do.	12. 2	11. 3	10. 9
Domestic and commercial—do.	62. 0	63. 5	65. 5
Domestic, commercial, and industrial—do.	21. 5	21. 4	23. 3

TABLE 28.—*Consumption of natural gas mixed with manufactured gas in 1931*

Use	Number of consumers	Cubic feet (thousands)	Value at points of consumption
Domestic	1, 604, 530	16, 409, 400	
Commercial	106, 750	4, 449, 000	
Industrial		3, 286, 600	
Total		24, 151, 000	$17, 591, 000

Figure 16 represents graphically the number of customers served with gas of different types or different heating values in the United States and Canada, as compiled by the American Gas Association. Practically all the gas of less than 500 Btu is used in Canada.

XII. THE COMPOSITION OF GASES OF VARIOUS TYPES AND THEIR SOURCES OR METHODS OF MANUFACTURE

1. CHEMICAL CONSTITUENTS OF COMMERCIAL GAS MIXTURES

Although a very large number of substances can and do exist in commercial gas mixtures, only a few of them are ever present in sufficient quantities to be of much importance as fuels. The important ones are included in table 29, which lists the specific gravities and heating values (both total and net), the volume of air required to burn each of the gases, and the volumes of their "products of combustion." The term "illuminants" covers a group of unsaturated

hydrocarbons which are not usually determined separately in a gas analysis. Ethylene is the principal constituent of the illuminants made by ordinary methods of manufacture, and propylene and ben-

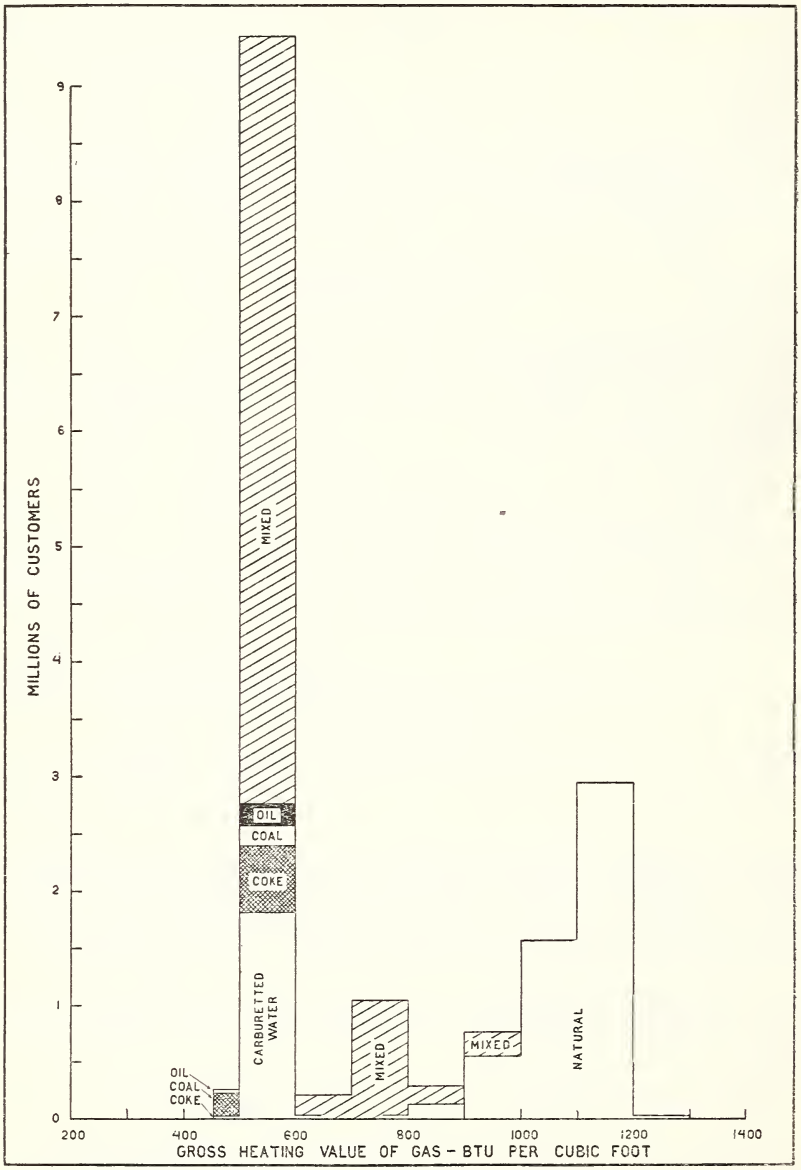

FIGURE 16.—*Types of gas delivered to customers in the United States and Canada during 1933.*

[Courtesy of the American Gas Association]

zene are important ones. The illuminants vary with the method of manufacture and the fuel used, but do not change much unless one or both of these conditions is materially altered. Hence the

properties of the illuminants, once determined for one method of operation of the plant, can be used with satisfactory accuracy in ascertaining from analysis the properties of the gas made by the same method at another time. Illuminants will usually, though not always, be found to have properties within the range given in the table.

TABLE 29.—*Specific gravity (air=1), heating value, "air requirement" and products of combustion of important constituents of fuel gases*

Gas	Chemical formula	Specific gravity	Heating value (Gas sat. at 60° F, 30 in Hg)		Volume of air required to burn 1 cu ft	Volume of products of combustion		
			Total	Net		H_2O	CO_2	N_2
Hydrogen	H_2	0.07	318.5	269.2	2.39	1	0	1.89
Carbon monoxide	CO	.97	315.3	315.3	2.39	0	1	1.89
Methane	CH_4	.55	994.1	895.2	9.55	2	1	7.55
Ethane	C_2H_6	1.04	1,757	1,607	16.71	3	2	13.21
Propane	C_3H_8	1.56	2,535	2,333	23.87	4	3	18.87
Butane, normal	C_4H_{10}	2.09	3,330	3,080	31.03	5	4	24.53
Butane, iso	C_4H_{10}	2.09	3,300	3,050	31.03	5	4	24.53
Ethylene	C_2H_4	.97	1,572	1,473	14.32	2	2	11.32
Propylene	C_3H_6	1.45	2,337	2,186	21.48	3	3	16.98
Acetylene	C_2H_2	.91	1,464	1,414	11.93	1	2	9.43
Benzene	C_6H_6	2.70	3,700	3,550	35.79	3	6	28.29
"Illuminants"		1.25 to 1.60	2,000 to 2,400	1,875 to 2,275	18.5 to 22.5	2.2 to 2.4	2.8 to 3.5	14.6 to 17.8
Atmos. nitrogen	N_2	.97						
Carbon dioxide	CO_2	1.53						
Air		1.00						
Oxygen	O_2	1.11						

Any of the properties listed in table 29 may be computed for a mixture from the properties of the single constituents by the application of the simple "rule of mixtures." Thus, if a, b, c, ------ are the percentages of several constituents and P_a, P_b, P_c, ------ the properties (e.g. the heating values) of the corresponding constituents in the pure state, the property P of the mixture will be given by the formula

$$P = \frac{aP_a + bP_b + cP_c \text{ ------}}{a + b + c \text{ ------}}.$$

To determine the properties other than those given in table 29, upon which the "stability" of the flames depend, is not so simple a matter. Chief of these is the property which determines the rate at which flame will travel through a mixture of the gas with air. To permit the reader to form an approximate estimate of this property, two factors, F and f, are listed in table 30. If the factor F for one gas is divided by the factor f for the same gas, the result will be approximately the maximum speed of ignition in mixtures of the gas with air, expressed as a percentage of the maximum speed of ignition of hydrogen. If F_a, F_b, F_c, ---- represent the values of the factor F for each of several constituents, f_a, f_b, f_c,---- represent values of the factor f for the corresponding constituents, and a, b, c, ---- represent the percentages of each constituent in the mixture, the maximum speed of ignition, S, for the mixture will be given in terms

of percentage of the maximum speed of ignition of hydrogen by the equation

$$S = \frac{aF_a + bF_b + cF_c \text{ ----}}{af_a + bf_b + cf_c \text{ ----}}.$$

Several approximations are involved in the computation and use of this formula and the results, therefore, are not highly accurate. They will serve, however, to give a fairly good idea of the relative stabilities of flames of various gas mixtures. With gases having a value of 40 percent or more for S, considerable trouble with backfiring and little or none with the lifting of flames may be anticipated with average appliances. A mixture having a value of S less than 20 percent may be expected to give no trouble from backfiring but much trouble from the lifting of the flames, particularly if the ratio of water to carbon dioxide formed during combustion is also low. This results from the fact that lifting is determined largely by the rate of reaction in the "outer cone" of the flame in which only hydrogen and carbon monoxide are being burned, all hydrocarbons having been decomposed at an earlier stage of combustion. The high rate of reaction of hydrogen serves to stabilize any flame in which much water is formed even though the rate of reaction of the gas with primary air is slow.

TABLE 30.—*Factors for computing the relative "speed of ignition" of mixtures*

Gas	F	f	S	Gas	F	f	S
H_2	700	7	100	C_2H_4	960	32	30
CO	126	7	18	C_3H_6	1,480	49	30
CH_4	300	22	14	C_2H_2	1,620	27	60
C_2H_6	630	37	17	Inerts	0	2	0
C_3H_8	840	52	16	Illuminants	1,250	50	25
C_4H_{10}	1,070	67	16				

The hydrocarbons in natural gases and the hydrogen and saturated hydrocarbons in manufactured gases are usually determined by combustion, and the actual compounds present are not determined. Most of the properties which affect the use of the gas as a fuel (heating value, specific gravity, air required for combustion and products formed by combustion) would be the same for a mixture of the composition stated as the analysis as they would for the mixture analyzed; but the flame velocity in a mixture with air would not. For example, a mixture of 1 volume of hydrogen and 1 of ethane has almost the same heating value, specific gravity, air requirement, and products of combustion as 2 volumes of methane, but will burn with a much shorter flame. However, the amount of ethane in a manufactured gas is usually too small to be of much importance in this connection; hydrogen is absent from natural gas, and the hydrocarbons of one series are so much alike in their properties that it is usually unnecessary to distinguish between them more definitely than is done in the usual report of an analysis.

In the following sections, typical analyses will be given of natural gas and of gases made by each of the important general methods of manufacture. By using the tables of properties given in this section with the typical analyses stated, the reader may make a good pre-

liminary estimate of the probable properties of almost any mixture of gases in which he may be interested.

2. CHEMICAL PROCESSES EMPLOYED IN THE MANUFACTURE OF GAS

(a) GASES MADE FROM SOLID FUEL

The method by which "illuminating gas" was first manufactured consists in heating externally a retort containing bituminous coal. At the start, the coal is a complex mixture of chemical substances the elementary constituents of which are mainly carbon and hydrogen. The original coal substance is decomposed by the heat into other substances, of which some are permanently gaseous, some are driven from the retort as vapors but condense to liquid "tar" on cooling, and some remain behind as a solid called "coke". The decomposition of the coal is gradual, and the heating may be discontinued while the coke still retains a considerable amount of material that would decompose and form additional gas if heated further. If the heating is sufficiently intense and long continued, the coke will be practically free from any substance except carbon and the ash-forming minerals. The gas produced by this process is commonly called *coal gas* or *coke oven gas* depending upon the type of apparatus in which it is produced, but will usually be referred to in this discussion indiscriminately as coal gas. The manufacture and composition of coal gas will be described in more detail in the next section.

When coal or coke is burned with air, the hydrogen of the fuel is burned to water vapor and the carbon to carbon dioxide. There is evidence that the first chemical reaction of the carbon with oxygen results in the formation of carbon monoxide according to the chemical equation

$$2C+O_2=2CO.$$

However, carbon monoxide reacts with oxygen much more readily than carbon does, according to the equation

$$2CO+O_2=2CO_2.$$

Until all the oxygen is used up, carbon monoxide burns as fast as it is formed, and the net result is the same as though the carbon had burned directly to carbon dioxide according to the equation

$$C+O_2=CO_2.$$

Carbon dioxide will react with hot carbon to form carbon monoxide according to the equation

$$CO_2+C=2CO.$$

If the production of heat at the time of burning the solid fuel is the only object, as in the usual stove or boiler, the fireman tries to adjust the depth and temperature of the fuel bed and the rates at which air is supplied above and below it so that no oxygen and no carbon monoxide (or other combustible gas) will remain in the products of combustion. If the fireman is successful in this, the flue

gases, after the condensation of water, consist almost entirely of nitrogen and carbon dioxide in proportions which depend to some extent on the composition of the solid fuel, but usually approximate 15 to 18 percent of carbon dioxide and 82 to 85 percent of nitrogen. For convenience, such a mixture will be referred to in what follows as "flue gas" because it is discharged in great quantities from the flues or chimneys of furnaces and boiler plants.

If the bed of solid fuel is sufficiently deep and hot the reaction between carbon dioxide and carbon takes place to an important extent. If the reaction were carried to completion with a nearly pure carbon, the gaseous products would contain approximately 34 percent of carbon monoxide to 66 percent of nitrogen; but in practice the hydrogen in the fuel usually results in a reduction of several percent in the carbon monoxide; and the elimination of carbon dioxide is never complete. Probably the nearest approach in a major industry to the complete conversion of the carbon dioxide formed during combustion to carbon monoxide occurs in blast furnaces, the gas from which is used as a fuel in the steel plants, but seldom or never enters a public supply. A typical "blast-furnace gas" has a heating value of about 100 Btu per cu ft and approximately the following composition:

	Percent
Hydrogen	1
Carbon monoxide	27
Carbon dioxide	8
Nitrogen	64

The principal source of a gas of this type in the gas industry is the "blast" of a water-gas generator, and such gas will therefore be referred to as "blast gas". The blast gas from the water-gas generator is intermediate in composition between a typical flue gas and a blast-furnace gas and may approach either in composition.

True "water gas" or "blue gas" is the product of the reaction between steam and hot coke or coal represented by the equation

$$C+H_2O=CO+H_2.$$

This reaction takes place rapidly enough to be useful only at temperatures near to or above the melting point of iron. It is a reaction that absorbs heat and so reduces the temperature of its surroundings, much as the melting of ice and salt chills an ice-cream freezer. When steam is introduced into a bed of hot coke, the temperature of the coke, therefore, quickly falls, and only a small amount of gas can be produced at a time. In practice a bed of coke in the "generator" is alternately heated by combustion with a strong current of air (the "blast" or "blow") and cooled by a current of steam (the "run") with which it reacts to give the useful product. The combination of the water-gas process with the production of the gas from oil to give "carburetted water gas" is the gas-making process principally employed in the United States, and will be discussed later. When used without qualification by those engaged in the industry the term water-gas usually refers to carburetted water gas. The product of the reaction of steam with coke, because it burns with a blue flame even when unmixed with primary air, is almost always referred to as "blue gas." In certain

types of coal-gas plants, especially in those with continuous vertical retorts, steam is used to cool the hot coke just before or after discharging from the retort, and the water-gas produced in the process is added to the coal gas.

As already mentioned, the combustion of coal in boilers and ordinary furnaces is usually controlled to produce carbon dioxide and not carbon monoxide, principally by passing the air at relatively high velocity through a shallow bed of fuel. In the "gas producer" the fuel bed is much deeper, and the carbon dioxide first formed reacts to produce carbon monoxide. The amount of heat produced in burning the carbon to carbon monoxide is somewhat in excess of that necessary to maintain a satisfactory temperature for the reaction, and the loss of sensible heat can be minimized, and a higher ratio of combustible gas to inert produced in the product, by introducing some steam with the air. The steam reacts exactly as in the water-gas process. Thus the processes for making "blue" water-gas and producer gas are chemically identical; the essential difference between them is that in the water-gas process the reaction of solid fuel with air and the reaction with steam take place in successive steps, and the gaseous products of the reactions are kept separate, but in the gas producer the two reactions occur simultaneously, and the mixture of gases formed constitutes a single product. Bituminous coal is ordinarily used as the fuel in a gas producer, and the fresh coal at the top of the producer is subjected to heating in the stream of hot producer gas, and consequently decomposes as in a coke-making plant, adding coal gas to the mixture. Thus producer gas may be regarded as a mixture of coal gas, "blue" water gas, and blast gas.

A mixture of the following composition is fairly typical of producer gas:

	Percent
Hydrogen	15
Carbon monoxide	23
Methane	3
Carbon dioxide	6
Nitrogen	53
	Btu/cu ft
Heating value	150

A water-gas generator is sometimes operated during a portion of the time as a producer, i.e., steam and air are admitted to the solid fuel simultaneously and the producer gas formed is added to the water gas. This operation is called the "blow run."

By "complete gasification" is meant any process or combination of processes by which coal is used to produce gas without leaving coke as a byproduct. Strictly speaking, the manufacture of producer gas is one method of complete gasification but is seldom spoken of as such. The term is sometimes applied to the manufacture of coal gas and the subsequent use of the coke in the manufacture of water gas, but is more frequently used in the still more limited sense of a combination of the coal-carbonizing and water-gas processes in a single unit.

(b) GASES MADE FROM OIL

The definition of coal as "a complex mixture of chemical substances the elementary constituents of which are mainly carbon and hydrogen" will serve equally well for crude petroleum and for most of the partially refined oils used in gas-making processes. They differ from coal in having a higher ratio of hydrogen to carbon, in the percentage that is volatile at a definite temperature, and in their physical state; but the chemical behavior which is of interest to the gas-maker is almost identical with that of coal. When the oils are strongly heated, they decompose into a portion that is more volatile and a portion that is less volatile than the original substance. If either portion is further heated, it decomposes in the same way into portions more volatile and less volatile than itself. The process may be continued, if desired, either in one operation or in several, until hydrogen and carbon are the only products. Usually intermediate products are desired, and only partial decomposition is employed. This process of thermal decomposition is strictly analogous to the "carbonization" of coal, but in the case of oil it is referred to as "cracking."

Gases made by cracking alone, in plants built for the purpose, once had a considerable commercial importance and were sold under several trade names, of which the most familiar are Pintsch gas and Blaugas (both named for the inventors; the latter is not to be confused with blue gas). Gases made in this way have been replaced almost completely by other products, but great quantities of gas made by the cracking of oil are available from oil refineries, and constitute an increasingly important source of supply for public utilities as well as for "bottled" gases to be distributed in rural districts. The analyses of several gases made by "cracking" oil are given in table 31. Of the refinery byproducts, those from the "cross still" are made by heating liquid oil under high pressure, while those from the "gyro still" are made by heating oil vapors at comparatively low pressures.

TABLE 31.—*Compositions of gases made by "cracking oil." Representative analyses from various sources*

Component	Formula	Blaugas [1]	Pintsch gas [1]	Oil-refinery byproducts [2]	
				Cross still	Gyro still
		Percent	*Percent*	*Percent*	*Percent*
Hydrogen	H_2	11.0	10	6.1	13.1
Carbon monoxide	CO			1.2	1.2
Methane	CH_4	4.2	54	4.4	23.3
Ethane	C_2H_6	30.6		72.5	21.7
Ethylene	C_2H_4	16.2	17	7.8	19.4
Propylene	C_3H_6	38.0	12	4.9	15.7
Butylene	C_4H_8		2	2.3	4.5
Benzene	C_6H_6		2		
Toluene	C_7H_8		2		
Carbon dioxide	CO_2				.1
Oxygen	O_2			.2	1.0
Nitrogen	N_2		1	.6	.0
Heating value [3] (Btu/cu ft)		1,755	1,225	1,628	1,455

[1] Communication from manufacturer.
[2] R. G. Rincliffe, Am. Gas. Assn. Proc. 1930, p. 1473.
[3] Computed from analyses.

Oil reacts with steam just as coke does in the manufacture of water gas. Most oil contains approximately twice as many hydrogen as carbon atoms. The simplest reaction with steam may be represented by the equation

$$C_nH_{2n}+nH_2O=nCO+2nH_2$$

This product might well be called oil-water-gas, as it is in Germany. A combination of this reaction and cracking takes place in the carbureter and superheater during the manufacture of carburetted water-gas. Carburetted water-gas may, therefore, be regarded as a mixture of blue gas from coke, oil gas from cracking, and oil-water-gas.

In the "Pacific-coast process", of which there are several modifications, a mass of refractory brick, laid in open "checker-work", is heated to a high temperature by a flame, usually of oil supplied with enough air for complete combustion, after which oil and steam are introduced together. Cracking and the formation of oil-water-gas take place as in the carbureter and superheater of a water-gas generator. The process differs from the carburetted water-gas process in the following respects: (*a*) during the period of heating or "blasting", the fuel used is introduced mainly from the outside. (A portion of it is residual carbon from the preceding "run"); (*b*) The heat absorbed by the reaction with steam is obtained from heat stored entirely in refractories instead of partly in refractories and partly in solid fuel; (*c*) The reaction of steam is entirely with oil instead of being in part with oil and in part with solid fuel; (*d*) A higher temperature and longer contact are maintained in the Pacific-coast process, which results in more complete decomposition of the oil; and (*e*) The compositions of the finished gases differ mainly because of this difference in temperature and because of the fact that the portion derived from the reaction with steam consists of approximately 2 volumes of hydrogen to 1 of carbon monoxide in the case of oil gas, and of nearly equal volumes of hydrogen and carbon monoxide in the case of water gas.

It is obvious that an "oil producer gas" can be made by a method bearing the same relationship to the Pacific-coast process that the manufacture of producer gas does to that of blue gas. That is, the combustion of oil for producing the heat needed in the process is conducted simultaneously with the decomposition of more oil, and no attempt is made to separate the products. The primary reaction may be represented by the equation

$$2C_nH_{2n}+O_2=2nCO+2nH_2$$

If this reaction were conducted with oxygen instead of air, to eliminate nitrogen, the product would be practically identical with ordinary blue gas. Oxygen is not used in practice, and nitrogen is a major constituent of the mixture formed. To be wholly analogous to commercial producer gas practice, some steam and some oil should be introduced so that the reactions of cracking and of producing oil-water-gas might take place. Usually, however, the steam is omitted in order that as much heat as possible may be available for oil-cracking. Probably the most familiar process of this type is known as the "Dayton process."

(c) GASES MADE FROM OTHER GASES

The manufacture, by chemical means, of gas of one composition from gas of another composition is commonly called "reforming." Although "reforming" is to be avoided when possible as uneconomical, the processes employed are here included for the sake of completeness. "Reforming" is practiced in most cases to permit the delivery of gas of uniform properties while using variable proportions of gases of widely different properties from two or more sources of supply.

The gases which are "reformed" are always hydrocarbons or mixtures of hydrocarbons and are subject to reactions of the same type as coal and oil. Chief of these are thermal decomposition, called cracking as in the case of oil, reaction with steam to form hydrogen and carbon monoxide, and reaction with oxygen to form the same products. Hence, as in the manufacture of gas from oil, the method employed for reforming may be analogous to the manufacture of coal gas, water gas, or producer gas.

Thermal decomposition, the analog of coal-gas manufacture, is usually accomplished by passing the gas to be reformed through a bed of incandescent coal or coke, just as steam is decomposed in the manufacture of water-gas. This process of reforming is most frequently employed in the case of natural gas which is mixed with or used interchangeably with a manufactured gas, and has for its principal object the addition of hydrogen to increase the rate of propagation of flame in the slow-burning natural gas. The reforming of natural gas by a method exactly analogous to the Pacific-coast process for the manufacture of oil gas was at one time extensively employed in California, but has been generally abandoned since the supply of natural gas has become adequate to meet the demand at all seasons of the year. Byproduct oil gas from refineries is reformed by substantially the same method, or by introducing it with steam into the generator of a water-gas "set", or by substituting it for oil in the carbureter of the water-gas set. In all these cases the reactions are the same in general character, differing only in the degree of cracking and in the amount of steam which reacts. Both natural gas and oil gas have been reformed to some extent by partial combustion with air and the inclusion of inerts in the product. This may be regarded as the manufacture of producer gas using gas as the raw fuel.

Table 32 gives analyses, from several sources, of samples of reformed gases made by various methods.

TABLE 32.—*Analyses reported for "reformed" gases*

[Gases A and B are natural gases reformed by reaction with steam on hot refractories. Gases C and D are oil-refinery byproducts reformed by passing through moderately heated coke beds with different proportions of air and steam. Gases E and F are natural gases reformed by partial combustion with air]

Component	Formula	Gas A	Gas B	Gas C	Gas D	Gas E	Gas F
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Hydrogen	H_2	48.6	36.7	52.1	34.5	16.1	5.7
Carbon monoxide	CO	13.2	4.4	18.2	16.4	12.6	7.6
Methane	CH_4	33.2	50.3	16.7	20.4	17.1	30.9
Illuminants		1.6	5.1	3.6	2.9	2.2	9.1
Carbon dioxide	CO_2	2.4	1.1	4.0	4.0	1.7	.9
Oxygen	O_2	.2	.1	.6	.9	.2	.2
Nitrogen	N_2	.8	2.3	4.8	20.9	50.1	45.6
Btu/cu ft		548	759	479	426	300	500

3. MANUFACTURE OF COAL GAS

Coal is carbonized in plants of the most varied construction. At one extreme are simple "horizontal" fire-clay retorts of D-shaped cross section, arranged in groups of from 3 to 9 in coal or coke-fired furnaces called settings or benches. Three hundred to five hundred pounds of coal is shoveled into each of these retorts by hand, to form a layer from 8 to 12 inches deep, and the fire-clay blocks which form the doors are replaced and sealed with clay. After carbonization is complete, the coke is removed with a rake. At the other extreme are rectangular coke ovens as much as 40 feet long, 14 feet high and 20 inches across and holding 15 or more tons of coal each. They are built of silica refractories, charged and discharged entirely by machinery, and possess elaborate arrangements for heating as economically as possible, for permitting thermal expansion without loss of tightness, and for recovering the several products. Large numbers of these ovens, often 60 or more, are built into a single complicated structure. Between these extremes is every imaginable variation of size and mechanical arrangement. In all types of plants, however, the process of carbonization is essentially the same.

The yields and quantity of the products, gas, tar, and coke, depend on the character of the coal used, the intensity and duration of heating, the thickness of the layer of coal, and in the case of gas and tar, their exposure to contact with hot walls after expulsion from the coal. Only such coals as contain a high percentage of volatile matter, are reasonably free from sulphur, and will sinter during decomposition to form the "coke" structure are suitable for the production of coal gas, while a low ash content is very desirable because the coke recovered has a correspondingly higher value.

A rather sharp distinction is drawn in the gas industry between coal-gas plants and coke-ovens, depending upon whether the plant is operated primarily to produce gas and the coke is regarded as a byproduct, or the plant is operated to produce coke and the gas is considered the byproduct. The distinction is more important than it may at first seem to be. A gas plant must produce from day to day just the amount of gas demanded by its customers without regard to the amount of coke that can be sold; but if the process is not to be prohibitively expensive the coke, which has a value comparable to that of the gas, must somehow be disposed of to advantage. The operator of a plant making coal gas only is therefore necessarily engaged in 2 lines of business, 1 of which, the supplying and sale of gas, is usually regarded and regulated as a public utility; and 1 of which, the sale of coke, is essential to the success of the first and of nearly the same magnitude, but is usually regarded as a private business. Much of the coke sold is used as a crude fuel for generating steam or similar purposes, and its properties, density, resistance to breakage, and content of volatile matter and ash, are of only moderate importance. It is therefore possible for the manager of a coal-gas plant to vary the character of the fuel used and the duration and intensity of heating to effect economy or make production balance demand, without undue regard to the quality of the coke produced.

On the other hand, a coke-oven plant is operated to supply a given market or industry with coke, usually for metallurgical purposes, and the quality of coke is of first importance. In order to keep its quality uniform, a definite operating schedule is usually adhered to, which precludes any considerable variation in the production of gas except by varying the number of ovens in use. The great heat capacity of the ovens and the damage that can be done to them by too rapid changes of temperature make it impracticable to vary the number of ovens in use from day to day to meet the fluctuating demand for gas. As a consequence, the operation of coke ovens is usually conducted without regard to either the daily or seasonal demand for gas. A gas company using only a small fraction of the output of a coke-oven plant may sometimes rely upon it as the only source of supply, but a company normally taking the major part of the gas produced by a coke plant must provide other means for meeting at least a large fraction of its peak load, which may occur when the production of coke-oven gas is at a minimum.

Coal gas, when first liberated from the coal, contains large quantities of tar and ammonia in the form of vapor, while part of the sulphur in the coal accompanies the gas in the form of either hydrogen sulphide or organic compounds of sulphur. Tar and ammonia are removed by a combination of cooling, called " condensing ", mechanical impingement to remove fog, called " tar extraction ", and solution in water or other liquids called " scrubbing." In some cases dilute sulphuric acid is used at one stage as a scrubbing liquid for the purpose of recovering ammonia, in others only water is employed for this purpose. In coke-oven plants " light oils ", mainly benzene and its closely related compounds, are usually removed by scrubbing with a nonvolatile oil from which the light oils can subsequently be distilled. This is not usually done in small coal-gas plants because the product recovered is worth so little more than its value as a constituent of the gas that the additional process is not justified. If scrubbing with oil is not employed, condensation and scrubbing with water must be thorough to prevent undesirable condensation in the distributing system, particularly in cold weather. On the other hand, the condensing process must be conducted carefully with suitable apparatus to prevent the inclusion of an undesirable amount of the valuable light oil with the tar.

The tar, ammonia, and light oils removed in these processes are usually sold with a minimum of purification at the gas or coke plant, to be refined or used as fuels by the purchasers.

The hydrogen sulphide is removed in most cases by passing the gas through a solid purifying material, but sometimes by scrubbing with an alkaline liquid. The active ingredient of the purifying material is usually a specially prepared iron oxide, which is mixed with shavings or other material to make the mass sufficiently porous to permit the gas to flow readily through it. The organic sulphur compounds are usually not removed, because no economical method for their recovery has been discovered. The control of sulphur in coal gas therefore depends mainly on the selection of coals in which this element is not too abundant.

In practice, each pound of coal carbonized may be expected to produce from 4.5 to 5.5 cu ft of gas, but this varies with the quality of the coal and with several of the details of the carbonizing process.

Bituminous coals from Pennsylvania, West Virginia, and eastern Kentucky generally give greater yields of gas of higher heating value than do coals of the type found in Indiana and Illinois. Vertical retorts and coke ovens usually give greater yields of gas per pound of coal than do horizontal retorts.

In general, the factors which influence the yield also affect the heating value of the gas. For example, long exposure to the hot surface of the retort or oven after the gas is formed tends to break down the hydrocarbons, particularly the illuminants, into hydrogen

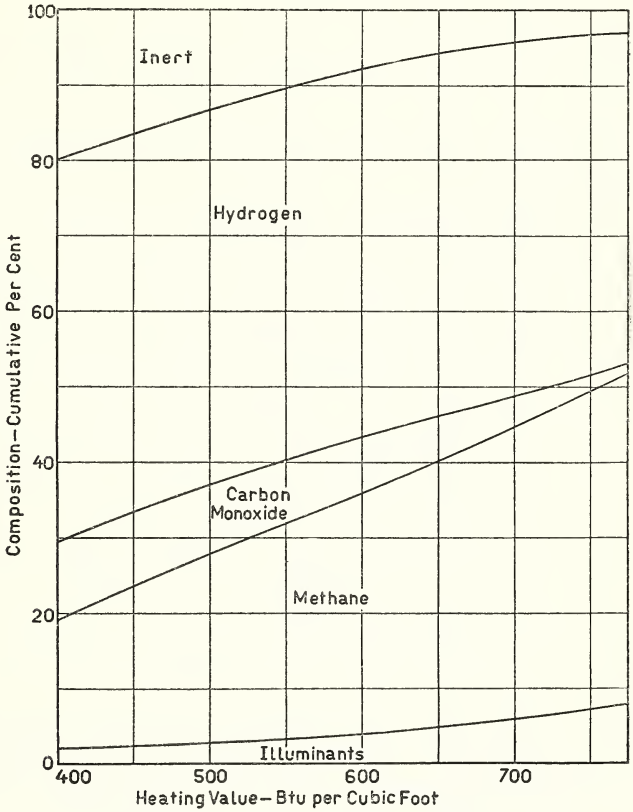

FIGURE 17.—*Compositions of typical coal gases.*

and carbon, or hydrogen, carbon, and methane. The gas produced during the early part of the carbonizing period—that is, the gas first driven off from the coal—contains high percentages of illuminants and methane, and is thus of high-heating value. As carbonization progresses, the illuminants almost entirely disappear, the percentage of methane decreases and that of nitrogen increases, but hydrogen becomes the principal constituent of the gas. The heating value of the gas thus decreases rapidly during carbonization.

Figure 17 shows the composition of typical coal gases of various heating values. The figure was drawn after an intercomparison of

data from numerous sources. Figure 18 represents the progress of production of gas during the period of heating. Such production curves vary with the type of plant, the character of the coal used, and the temperature, but show a general similarity. Figure 18 is drawn, like figure 17, to represent the approximate average of data from several sources rather than the results from a single plant.[7] The data correspond approximately to the results obtainable from gas coal of excellent quality carbonized in vertical retorts. The duration of the carbonizing period in horizontal retorts is shorter, and in coke ovens longer, than that shown.

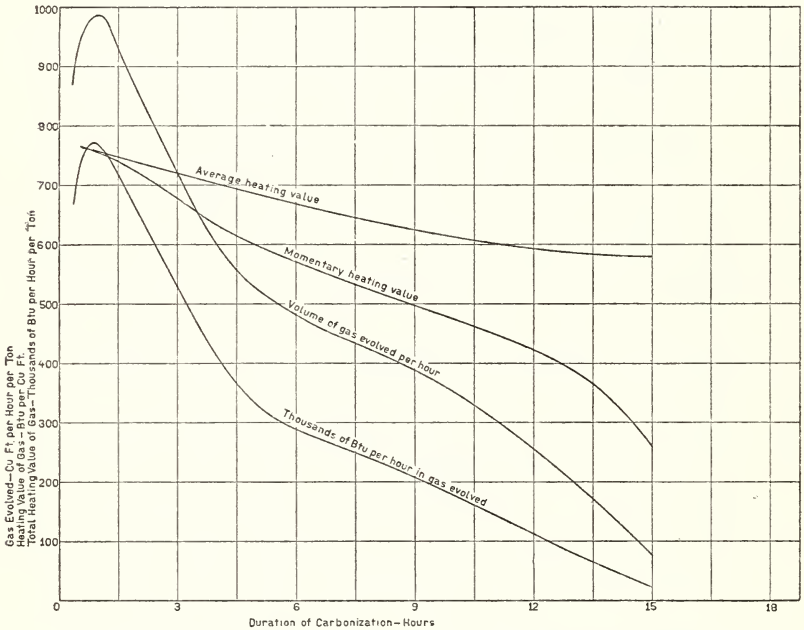

FIGURE 18.—*Progress of a typical coal-carbonizing operation.*

The effect of the temperature of the retorts on the production of gas is shown in figure 19. The curves represent the average of tests with 11 different coals made in a metal retort by Fieldner and Davis. The temperatures are lower than the temperatures that must be maintained in the heating flues of a carbonizing plant to obtain comparable results, because of the insulating effect of the thick refractory walls. The curve representing the rate at which gas is produced from a ton of coal shows clearly why "low-temperature carbonization" has not displaced the high-temperature process, in spite of a greater yield of valuable byproducts other than gas.

[7] The most helpful source of data for the figures relating to the production of coal gas was the series of papers by A. C. Fieldner and J. D. Davis of the U.S. Bureau of Mines on Gas, Coke, and Byproduct-Making Properties of American Coals, Am. Gas Assn. Proc. 1929–32. The carefully controlled laboratory tests reported in these papers served to supply the necessary detail in the general data relating to the operating results of typical plants.

4. MANUFACTURE OF CARBURETED WATER-GAS

The apparatus employed for making carbureted water-gas usually consists of three cylindrical steel shells lined with insulating and refractory material and provided with doors, piping, and valves for in-

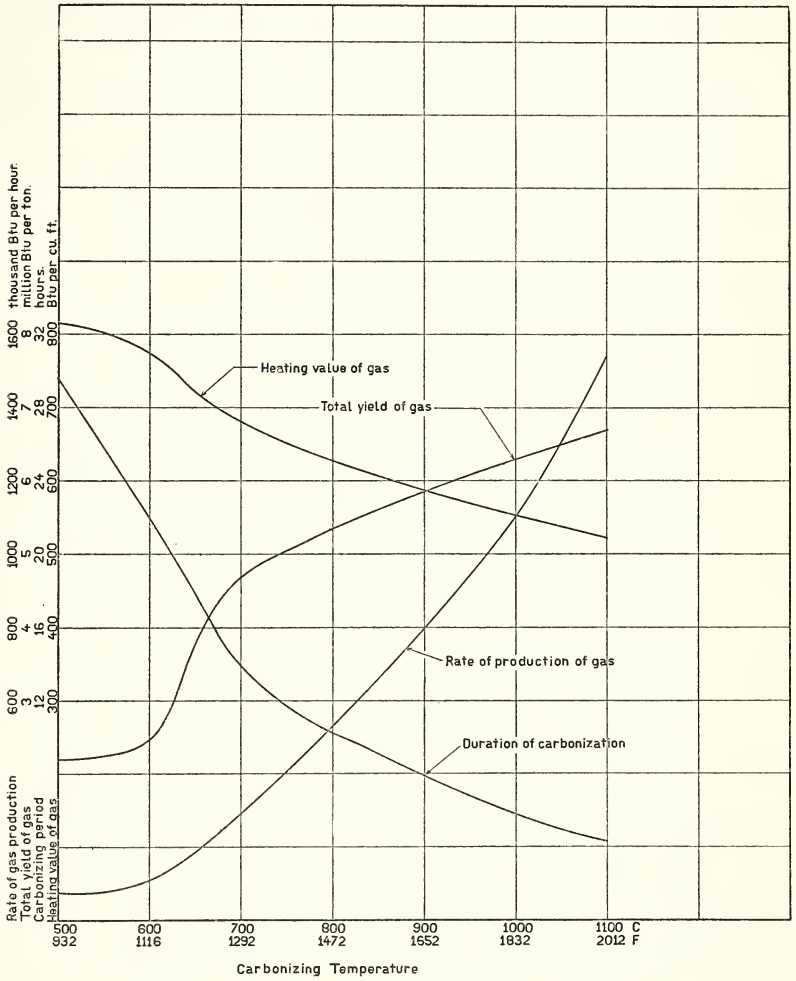

FIGURE 19.—*Effect of temperature on the progress of carbonization.*

troducing solid fuel, air, steam, and oil, and for removing gas and products of combustion. The shells are usually insulated with blocks of infusorial earth, within which is a lining of fire brick or, in the hottest part only, of silicon carbide (carborundum).

The first of the three chambers, the generator, contains a coke or coal fire, usually from 4 to 9 ft deep, laid on a grate which, in

the more modern machines, includes a mechanism for breaking up the clinker and improving the packing of the fuel bed. A door or more complicated feeding device at the top of the generator provides for replenishing the fuel, while doors near the bottom allow the removal of clinker and ash. The second chamber, the carburetor, is the space into which the oil is usually introduced for vaporization. In former years the carburetor was filled with an open checker work of fire brick but is now frequently left without solid heat-retaining material, the heat in the water-gas as it leaves the generator and that transferred from the lining being depended on for the vaporization and initial decomposition of the oil. Most of the deposition of solid carbon from the oil takes place in the carburetor, and it is largely because of the difficulty of removing this from the checker bricks that the latter are often left out.

The third chamber, called the superheater, is filled with a checker work of fire brick and maintained at a temperature usually somewhat higher than that of the carburetor.

The process of manufacture consists of an alternate series of "blows", during which the equipment is heated to the desired gas-making temperatures, and "runs", during which the gas is actually made. During the blow, air is forced through the solid fuel in the generator, burning some of it, and thus raising the temperature of that which remains. The products of combustion, themselves at high temperature, pass to the carburetor and superheater where they give up part of their heat to the checker-brick and linings. Usually they pass from the superheater to a "waste-heat boiler", where they serve to produce a large part or all of the steam required in the process. Some carbon monoxide is formed in the generator during the blow and is burned in the superheater by the admission of air, adding to the supply of heat in that portion of the equipment. When favorable temperatures have been reached in all parts of the "set", the air is shut off; steam and oil are turned on; and the outlet of the superheater is changed to direct the gas through its train of condensing, scrubbing and purifying equipment. The steam, acting on the highly heated coke or coal, as described in section 2, produces "blue" water-gas. As the blue gas enters the carburetor, the oil is sprayed into it. The oil quickly vaporizes, and thermal decomposition or cracking and reaction with steam begin. These chemical processes continue as the gases pass through the superheater, and the product is the crude carbureted water-gas. The formation of blue water-gas and the gasification of oil both absorb heat, so that the run can continue for only a short time before the temperatures become too low for the efficient production of gas. Then the oil and steam are shut off and the cycle is repeated.

The control of temperatures in different parts of the plant to give stable gas of the desired heating value with the least consumption of solid fuel and oil is the principal problem of the operator of a water-gas plant.

To maintain a favorable distribution of temperatures in the generator, the steam, and sometimes a little of the air, are run downward through the fuel bed during a portion of the time.

The relative amounts of heat produced in generator and superheater are subject to control, within a limited range, by several

methods. A deep fuel bed, low blast pressure through the generator, and a long period of blasting favor relatively high temperatures in the superheater. The reverse of these conditions, of course, favor relatively high temperatures in the generator, which can be further increased by preheating a portion of the steam used to produce blue gas by reversing the usual direction of flow and passing the steam first through the superheater (the "back-run process").

The operation of the generator as a gas "producer" during a fraction of the time, either by directing the products of combustion of the last portion of the blow into the product to be sold, or by mixing air with the steam during a portion of the run, has already been referred to in several places under the name of "blow-run", by which it is generally known. The blow-run is so closely involved in the consideration of standards for water-gas that a thorough discussion of its effects is merited.

The blow-run is usually employed for the purpose of increasing the gas-making capacity of the plant rather than for the sake of saving the small amount of carbon monoxide which would otherwise go to the superheater during the blast, and any study of the results obtained reveals that the increase in capacity is simply the result of using more oil. A water-gas set has several times the capacity for making the oil-gas fraction of its product that it has for making the blue-gas fraction. Unless the standard of heating value is high, approximately 620 Btu per cu ft or more, the capacity to make oil-gas is not fully employed if the portion being enriched with oil already has a heating value near 300 Btu. But if a considerable fraction of the gas from the generator is inert, a great deal more oil gas is required to bring it up to standard heating value. Since almost the same quantity of the combustible constituents of blue gas and a larger quantity of oil gas can be made with a set without employing the blow-run, the capacity of the set to supply service is not actually increased, but rather diminished by its use. The apparent advantage in capacity results from the fact that inerts are distributed with the useful gas, making the total volume greater.

Although it can hardly be considered an advantage to pump useless inerts through an expensive and frequently overloaded distributing system, the greatest disadvantage of the blow-run, in the extreme to which it is sometimes carried, is the production of an unstable gas. Several decades of oil-gas manufacture on the Pacific Coast have shown that it is not difficult to make stable gas of heating values even much above those commonly employed, and to make it entirely from oil that would be considered of very low grade for water-gas carburetion. To make a stable gas with a high "oil efficiency" (that is, without producing an excessive amount of tar) requires that enough heat be supplied to the checker-work to produce the necessary reactions during the short time the oil vapors are in the carburetor and superheater; the more heat there is, the more complete is the reaction.

Since the heat for the manufacture of the oil-gas fraction of carbureted water-gas is stritcly a byproduct of blue-gas production, it follows that the more blue gas (exclusive of inerts) is made per gallon of oil the more complete will be the reaction by which the oil is

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converted to gas. (This is true only within limits. It is possible to have the checker-brick so hot that the yield of gas from the oil, measured in heat units, is reduced, but the conditions under which this would occur are outside the range of operations under present discussion.) Figure 20 shows the number of cubic feet of blue gas per gallon of oil required to give gases of various heating values and percentages of inerts. The assumption made in computing the curves is that the oil-gas fraction will have a heating value of 1,600

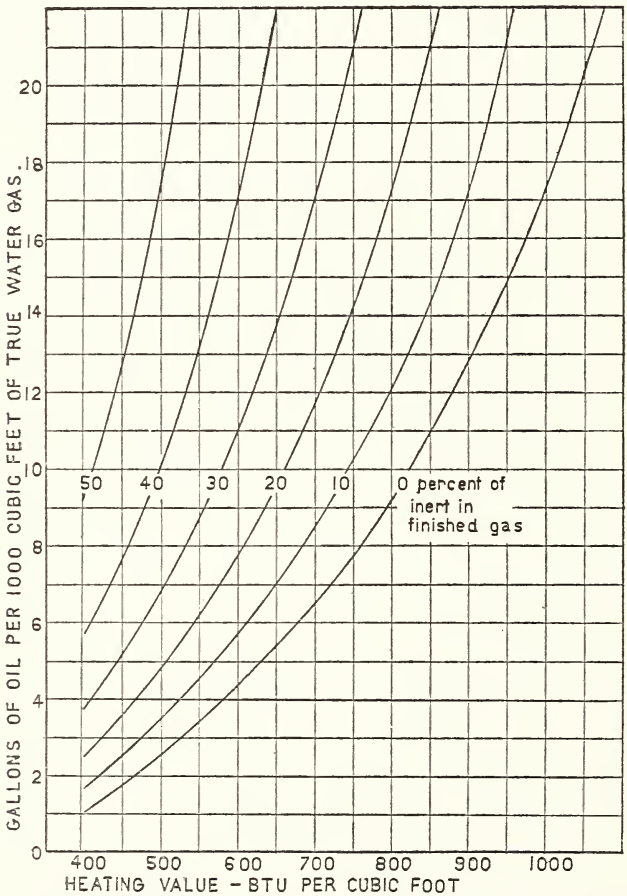

FIGURE 20.—*Relationship of inert and heating value to stability of water gas.*

Btu per cu ft and that 105,000 Btu will be obtained in the oil gas per gallon of oil used. These are probably fairly near to average figures. Different yields and heating values are possible, of course, depending on the oil used and other factors. The yields and heating values would also tend to change with the amount of oil per thousand cubic feet of true water-gas, but changes of both types would affect the several curves similarly and leave their relative positions approximately unaltered. From these curves it appears that a water-gas of 550 Btu made with enough blow-run to give the

finished gas an inert content of 40 percent would probably be about as unstable as a gas of 875 Btu made without blow-run, but with only the amount of inert not readily avoidable, if the same condensing and scrubbing treatment is employed in both cases. A 550-Btu gas with 30 percent of inert (not an uncommon figure where the blow-run is employed at all) may be expected to have about the same stability (freedom from condensation of combustible constituents) as a gas of 735 Btu made without blow-run. The gases of extremely high candlepower distributed in earlier days approached this heating value, but for their manufacture the amount of air passed through the fire was determined by the requirements of the superheater, not those of the generator. In other words, producer gas was made in the generator and burned in the superheater deliberately for the purpose of avoiding an unstable gas. The old gases made to a high-candlepower standard might, therefore, have been expected to be more stable than some of the gases made recently to a low standard of heating value, a conclusion that is verified by some recent experience.

As in the case of coal gas, the crude water-gas contains tar, hydrogen sulphide, and organic sulphur compounds, but there is no ammonia. The tar, which is produced from the oil and to a certain extent from bituminous coal when it is used in the generator, is quite different in composition from coal tar and of less value. It is removed from the gas in the same general manner as coal tar, and at present is principally used as fuel, sometimes in the water-gas machine itself. The sulphur comes from both the generator fuel and the oil, but the quantities of both hydrogen sulphide and organic sulphur are usually less than in coal gas. The hydrogen sulphide is removed by the methods employed for coal gas; the reduction of organic sulphur again depends mainly on the selection of the raw materials, but to some extent on the control of the process.

The compositions of typical water-gases of various heating values are shown in figure 21. The breaks in the curves above 300 Btu represent the fact that 300 Btu is about the highest heating value it is practicable to obtain without carbureting, and that it requires care to exclude inerts. On the other hand, carbureting is not likely to be employed to the very slight extent necessary to raise a blue gas of high quality from 350 to 400 Btu, and carbureted gases of such heating values are almost sure to contain high percentages of inerts.

The change of slope of the curves at about 625 Btu represents the fact that above this heating value all the waste heat from normally conducted blue-gas manufacture is needed to gasify the oil used. Since no excess heat is available for carbureting inerts, unless the plant is deliberately operated to make producer gas to be burned in the superheater, inerts are likely to be as carefully excluded as when manufacturing 300 Btu blue gas. Below 600 Btu, less attention is likely to be paid to inerts, or they may be deliberately included.

It must not be supposed that the methods of conducting the manufacture of carbureted water-gas which have been discussed cover the entire range of possibilities. It is feasible, with a water-gas set, to make gases of widely varied compositions from a great variety of materials, and to do so with reasonable efficiencies. In particular the introduction of the carbureting material into the generator makes it possible to use tars and oils not formerly considered suit-

able for gas making, and to materially change the hydrogen content of the gas at will.

5. MANUFACTURE OF OIL GAS

The manufacture of gas from oil has been accomplished by the use of a large variety of methods and apparatus, but by far the most successful of these is the use of hot checker-brick to produce the reaction of steam and oil just as in the carburetion of water-gas. The process, which is conducted with apparatus of several somewhat

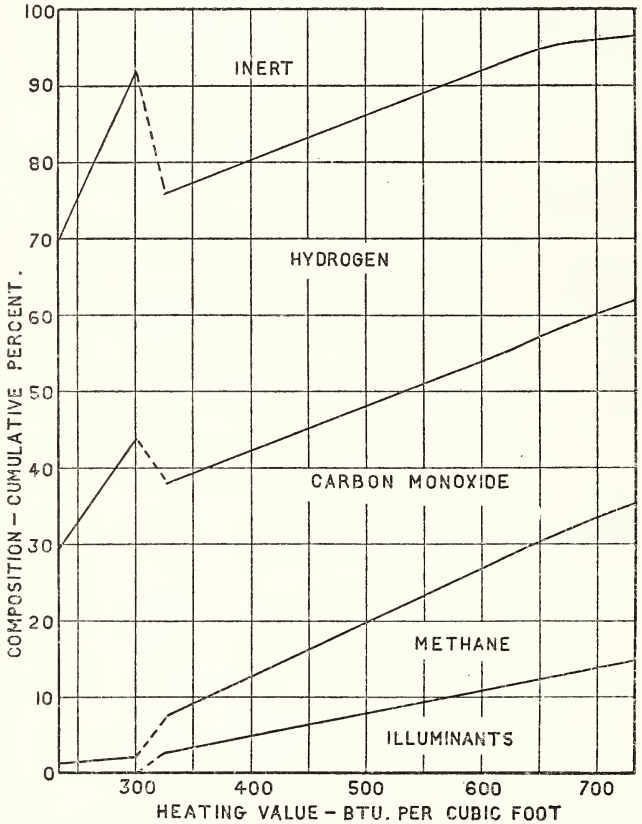

FIGURE 21.—*Compositions of typical water gases.*

different forms, differs from the production of the oil-gas fraction of carbureted water-gas principally in the fact that the heat for the process is supplied by burning oil instead of coal or coke, and in the use of a relatively high temperature which results in more nearly complete reaction of the steam and the more complete decomposition of the oil, to form lampblack as a by-product rather than tar.

Many of the plants consist of single cylindrical shells lined and checkered with refractory brick, and equipped with the accessory apparatus needed for supplying steam and air, condensing and scrubbing the gas, and so forth. In other plants, two shells are

used. The total length of the checker-brick columns is in some cases nearly 80 feet. The oil used for heating is introduced in a fine spray with air at the top of the checkerwork. The heated blast is forced downward to prevent convection currents from interfering with uniform heating. When the desired temperature is reached, the blast is discontinued and a spray of oil and steam is introduced, also at the top. The oil reacts in part with steam to produce hydrogen and carbon monoxide and is in part cracked into carbon, hydrogen, and methane. Part of the carbon is carried along as finely powdered lampblack and is recovered, briquetted, and sold as an ashless solid fuel of superior quality. The remainder of the carbon is deposited on the checker brick, from which it is incompletely burned during the next blast, forming a portion of the fuel for heating the generator. It is customary to convert a part of the deposited carbon into water-gas by introducing steam before introducing oil in the next run. During the average cycle as much carbon must be removed from the refractories by burning or by reaction with steam as is deposited.

This process of making oil gas is generally known as the "Pacific Coast process" because it was developed in that region as a result of the cost of transporting coal from distant coal fields. At one time the quantity and value of the gas made by the process were much greater than those of the coal gas manufactured in this country, but natural gas has now displaced oil gas in most of the territory in which it was previously used.

In a recently developed modification, called the "refractory-screen process", an ordinary water-gas set is modified by appropriate changes of connections and by replacing the grate and solid fuel in the generator with a heap of small blocks of very refractory material. This pile of blocks, the "refractory screen", is heated by an oil flame, after which an oil spray is passed through the screen. The thermal decomposition of the oil deposits carbon on every exposed surface of refractory. Thereafter the carbon on the refractory screen is used just as the coke is used in ordinary water-gas making. It is burned to supply the heat needed, and is allowed to react with steam to supply some of the "blue gas" which goes to make up the finished gas. The carbon on the refractory screen is renewed during each cycle by cracking a portion of the oil used in the generator, additional oil being added in carbureter and superheater if desired, just as in the ordinary water-gas process. After first heating up the plant it is unnecessary to employ an oil flame, enough fuel being available from carbon deposited during gas making.

It is obvious that the process is the same as the modification of the water-gas process in which part of the oil is introduced into the generator, except that each piece of solid fuel is of uniform size, has a core of incombustible refractory, and cannot be burned to ash and clinker. It differs essentially from the Pacific coast process only in the two following respects: (1) Very different temperatures are maintained in different parts of the refractory filling and these permit different portions of oil to be treated at different temperatures at the will of the operator; (2) most of the carbon which would be discharged from the Pacific Coast machines as lampblack is retained in the generator for use as fuel in the process.

The compositions of typical oil gases of various heating values are shown in figure 22. These compositions are, of course, subject to considerable variations depending on the oil used, the extent to which thermal decomposition is carried, and the relative proportions of the product obtained from cracking and from reaction with steam.

In general, the oil gases approximate the characteristics of coal gas of the same heating value, rather than those of water-gas, particularly with respect to the percentage of hydrogen, which so largely determines specific gravity and speed of ignition.

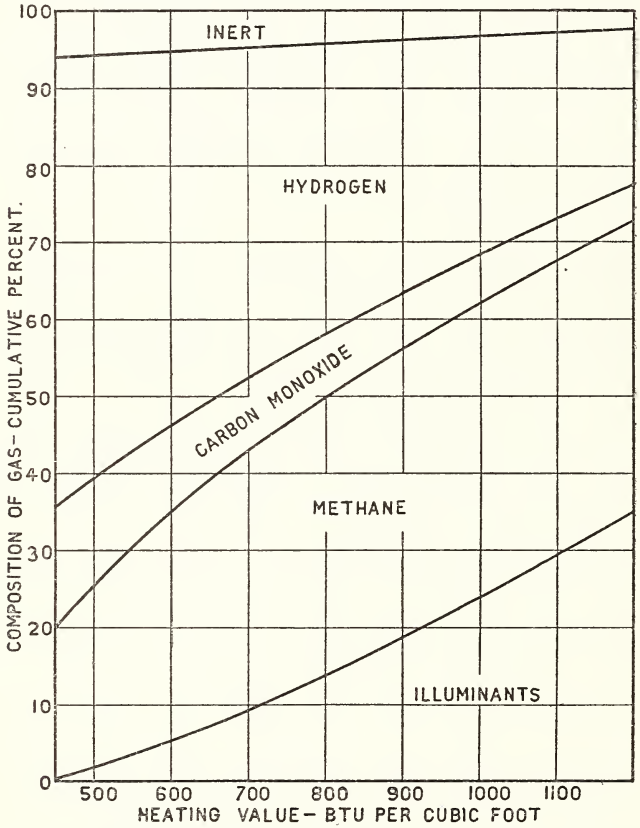

FIGURE 22.—*Heating value of typical oil gas made by the Pacific Coast or related method.*

Of the various methods proposed for making an "oil producer gas", the one called the "Dayton process" is the best known in this country. A refractory-lined shell without checker brick is heated internally to a high temperature by means of an oil flame burning with sufficient air. After a suitable temperature is reached, the relative amount of oil, with respect to air, is greatly increased and a continuous production of gas results, the temperature being maintained by the partial combustion of the oil. The air used is preheated to some extent by interchange with the hot products. Tar is formed as a byproduct; the amount reported is considerably less than that

formed from the same quantity of oil in the average carburetion of water-gas. Table 33 shows the compositions of gases of several heating values made by this process.

TABLE 33.—*Composition of oil-producer gas*

[Data from H. E. Ferguson, American Gas Assn. Proc. p. 1362, 1930]

Heating value (Btu per cu ft)	300	400	500
Composition (percent):			
Hydrogen	12.0	3.9	1.5
Carbon monoxide	11.4	8.7	5.5
Methane	10.8	7.6	8.7
Illuminants	6.6	12.0	15.9
Carbon dioxide	3.6	5.4	6.1
Nitrogen	55.1	61.9	61.8
Oxygen	.5	.5	.5
Specific gravity	.85	1	1.03

6. FACTORS GOVERNING THE CHOICE OF THE PRINCIPAL MANUFACTURING PROCESSES

The coal-gas process has the advantage, over other methods of making gas, of using as a raw material only bituminous coal, which is the most abundant and cheapest fuel available in most parts of the country. It has the further merit that its byproducts are usually worth more than the raw materials employed, sometimes enough more to pay the costs of operation and leave only the "capital charges" and other items which do not depend directly on production to constitute the "cost" of the gas.

The investment in a coal-gas plant is very much higher than that in a water-gas or oil-gas plant of the same capacity. If capital charges are not to be excessive, a coal-gas plant must, therefore, be used nearly to its full capacity. For this reason and others already stated, the coal-gas process is inherently unsuitable for supplying a highly variable demand for gas. The necessity of profitably disposing of the byproducts adds to the other disadvantages of the process for use as a source of public supply. Together, these disadvantages have usually outweighed the merits of the coal-gas process, with the result that it has been generally displaced as an exclusive method of production. It is widely used in combination with other processes, however.

In addition to its lower cost per unit of capacity, the water-gas process excels that for making coal gas with respect to its easy adaptability to fluctuating demands and the need for less labor. In all three respects, however, the manufacture of oil gas is considerably superior even to the water-gas process. Water gas possesses the advantage over oil gas of being made from fuel of greater variety and lower average cost; but in localities in which the difference in the cost of fuel is not too much in favor of water gas the manufacture of oil gas is preferable.

The use of coal gas to supply the principal part of the "base load" (that is, the approximate minimum daily demand that can be relied on throughout the year), and of water gas or oil gas to meet peak demands, is often expedient and is common practice. For this purpose, the fact that surplus coke can be used in the manufacture of water gas favors this product in comparison with oil gas.

The possibility of varying the quantity of water gas produced makes it possible for the gas company to partially control the amount of coke offered for sale to correspond to market conditions. The gas producers used for heating the retorts, in which either coal or coke may be used, serve the same purpose to only a limited extent, because there is usually enough unsalable coke for the producers, even when the market is favorable. Oil gas is superior to water gas in the important respect of having so nearly the same composition as coal gas of the same heating value that it can be mixed with the latter in almost any proportions without seriously affecting the operation of appliances; water gas cannot. For this reason, the manufacture of oil gas to carry the peak loads of coal-gas plants deserves more consideration than it appears to have received.

7. NATURAL GAS

Incredibly great quantities of natural gas occur in sand or porous rock strata in many parts of the United States, often, but not always, associated with petroleum. It is estimated by Hopkins and Backus [8] that 60 percent of the natural gas produced comes from the approximately 300,000 oil wells in the United States, and 40 percent from about 56,000 wells which produce gas only. This would indicate an average production, from the gas wells alone, of about 12 million cu ft annually per well. There are very great differences between the amounts of gas produced by different wells. For example, the first seven wells drilled in the Kettleman Hills District of California are said to produce an average of 10 million cu ft per day per well; but if the total volume of natural gas produced in Indiana is attributed to its 1,100 operating gas wells (allowing nothing for production from oil wells), the average per well is only 1.2 million cu ft per year.

The major constituent of natural gas is usually methane. Ethane and other saturated hydrocarbons, and nitrogen are nearly always present. Hydrogen, oxygen, carbon, monoxide, and unsaturated hydrocarbons are seldom found, although small amounts of each have been reported in certain gases, perhaps erroneously in some cases or as a result of accidental contamination. There is one apparently well authenticated report of a well which produces a gas that is principally ethylene, supposed to have been formed by the "cracking" of a body of petroleum which has been heated by some recent geologic change. Carbon dioxide occurs to an important extent in some gases, especially in California, but it is only a negligible constituent of most of the natural gas available. It is interesting that the otherwise very rare element, helium, occurs to the extent of about 1 percent in much of the gas of Kansas, Oklahoma, and Texas. The limited extent to which other substances occur leaves nitrogen and the saturated hydrocarbons (methane, ethane, propane, butane, etc.), as the only important constituents of most of the gas produced. The Appalachian region, including Eastern Kentucky, West Virginia, Pennsylvania, and Western New York, produces gas in which there

[8] U.S. Bureau of Mines, Mineral Resources of the United States in 1931, pt. 2, p. 349–71. This report is the source of substantially all the information given regarding the production and value of natural gas and should be consulted for further detail.

is rarely more than 2 percent of nitrogen and often less than 1 percent. These gases are, therefore, almost entirely composed of saturated hydrocarbons, in which the amount of the heavier constituents may be estimated from the heating value. Specific gravity, air required for combustion, and all other properties which affect combustion may be assumed, in the absence of more exact information, to be the same as those of a mixture of methane and ethane or methane and propane, of the same heating value.

The nitrogen content of the natural gases tends to become more variable and in general to increase toward the west. It is generally greater in Ohio and Indiana than in the Appalachian region, and very much greater in parts of the large mid-continent region (Kansas, Oklahoma, and Texas). Analyses of the gas supplied to Dallas and Fort Worth, Tex., in 1914 showed more than 38 percent of nitrogen.[9] The nitrogen contents of the natural gases of California and of Louisiana are usually only a few percent, as in Ohio and Indiana. The differences in the composition of the gases from nearby fields, or even from different wells in what is commonly regarded as a single field, are unfortunately sometimes too great to permit gas to be drawn indiscriminately from one source or another; gases that are almost pure hydrocarbons and gases that contain so much nitrogen that they will not support a flame sometimes come from wells near enough together to be readily delivered to the same market through a common pipe line. If all the available natural gas is to be utilized under conditions uniform enough to permit the satisfactory operation of appliances, it is necessary that attention be given to what may be regarded as the "dispatching" of the gas, that is, the selection of the wells from which gas is to be drawn under any condition of demand, so that the supply is at all times both adequate and uniform.

In all regions, with the possible exception of a part of the mid-continent field, the variation in the relative amounts of the different saturated hydrocarbons is the principal factor which determines the heating value and other important properties of the gas. Natural gas, particularly that which comes from oil wells, usually contains all members of a long series of hydrocarbons in percentages which diminish with increasing molecular weight. The amounts of the hydrocarbons above propane and probably those above methane usually represent saturation with the vapor of a liquid petroleum at the pressure at which gas and liquid were last in contact. Just as in the case of manufactured gas (see p. 226) liquid hydrocarbons can, therefore, be condensed from the gas by cooling, compressing, scrubbing with oil, or adsorption in charcoal, or by a combination of these processes. The liquid thus obtained is called natural gasoline as distinguished from the gasoline made in oil refineries. The extent of the natural gasoline industry is indicated by the fact that in 1931 about 98 percent of all natural gas produced was treated for its extraction, while only about 92 percent of the gas was subsequently used; the remainder was blown into the atmosphere after the recovery of the gasoline. The money value of the gasoline thus extracted was about one-third of the total value (in the field) of the

[9] Bureau of Mines Tech. Paper 109. Composition of the Natural Gas Used in 25 Cities.

natural gas; its heating value was probably about 10 percent of that of the gas before extraction. The value of the extracted portion of the gas was, therefore, approximately trebled by making it more readily portable. In many places, not only are the hydrocarbons which can be sold as the unconfined liquid gasoline removed from the gas, but the propane and butane are removed as well. These are marketed as liquids under pressure in strong steel cylinders or "bottles", and are widely used as a source of gas supply in rural communities, in industrial plants, and by gas companies. The use of these bottled gases by public utilities will be further discussed in the next section.

The compositions of some typical natural gases are given in table 34.

TABLE 34.—*Composition of some typical natural gases*

[Quoted from International Critical Tables, vol. 2, p. 166, 1926. The last column of each series of hydrocarbons in which a number is entered includes higher homologs]

Source of gas	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	N_2	Heating value
Appalachian field:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Btu/cu. ft.*
A	90.7	3.8	3.3	0.8	0.4	1.0	1,094
B	84.7	9.4	3.0	1.3	-------	1.6	1,128
C	80.4	8.7	4.1	4.0	1.3	1.5	1,250
D	44.7	7.9	21.3	9.9	16.2	1.0	2,213
Oklahoma	74.7	13.0	6.0	1.5	.8	4.0	1,216
Texas "wet gas"	50.6	3.1	2.4	8.4	-------	35.5	962
Same after removal of gasoline	54.8	3.3	2.6	.8	-------	38.5	700

Certain phases of the economics of supplying natural gas as a public utility deserve discussion. There seems to exist a popular disregard of the fact that average natural gas is intrinsically worth about twice as much as average manufactured gas (per thousand cubic feet) and a tendency to insist that natural gas is and must be cheap. This tendency frequently complicates the "public relations" of gas companies and affects the policies of regulatory commissions. Communities frequently resist the introduction of natural gas at rates which are considerably lower per heat unit than that of an existing supply of manufactured gas and, therefore, decidedly advantageous to the users. On the other hand, they will sometimes acquiesce in the mixing of the supposedly more valuable manufactured gas with natural gas, when it is to their interest to stoutly resist such an innovation except as a last resort in maintaining an adequate supply of fuel.

Actually, natural gas in the field is, on the average, very cheap. Its average "value" at the wells in 1931 was 7 cents per thousand cubic feet, which is not much more per heat unit than the average for bituminous coal at the mouth of the mine. The average by no means adequately represents the true situation, however. A great quantity of the gas is produced strictly as a byproduct of the oil industry in regions remote from large centers of population or established industries and, because there is no other market for it, it is sold at a very low price for conducting drilling operations, or used for making carbon black. About 4 cents worth of carbon black is recovered, on the average, per thousand cubic feet of gas burned, and the normal value of the gas used for drilling is probably even less. Nearly half of the gas produced is used for these two purposes.

The " cost " of natural gas at the well may thus be almost nothing; but under different conditions it may be anything up to a prohibitive figure. Many wells are drilled which produce no oil and only a small quantity of gas. Others produce nothing. The cost of drilling the " dry holes " must be included with that of the successful wells if the capital needed to continue development in a given region is to be attracted, and the price obtained for the gas must return the entire investment during the sometimes brief period within which the wells will produce.[10]

Even if the cost of the gas at its source was the only cost involved, it would be evident that no conclusions of value could be drawn regarding the fair cost of gas in a given locality from the low average cost of natural gas at the wells; each situation would have to be studied individually. In many cases, probably in most of them, it will be found that much the greater part of the cost of gas at the point of consumption is represented by the cost of the pipe lines required to collect and transmit it from the wells. The average value of the natural gas at points of consumption reported for 1931 was 23.3 cents as compared with the value at the wells of 7 cents. Considering the fact that about half the gas was used at points very near to the wells, it may be computed that the remainder must have had a " value " where sold to the ultimate consumer between 3 and 5 times as great as its value at the wells.

After the wells are drilled and the pipe lines laid, the cost of the operations connected with delivering natural gas to the point of entry into the local distributing system is almost negligible. The difference between the cost of the gas at the " city gate " and its cost in the field, therefore, consists almost entirely of items that are determined by the investment, including amortization (which will here be considered as the eventual recovery by the investor of the original cost of the property before it becomes useless, rather than in the more technical sense of a sinking fund set aside for the purpose), interest on the unamortized portion of the investment, and taxes. Interest and taxes are the same regardless of the amount of gas delivered; therefore, the cost of a unit quantity of gas attributable to these items decreases in inverse proportion as the amount delivered is increased. These items tend to make it important that the system be used at all times to as nearly as possible its full capacity. The portion of the total cost attributable to amortization, in the sense defined, does not follow a similar rule, however; still less does it correspond to the rapid initial depreciation of equipment in which obsolescence is a factor. The reason for this is that the useful life of the main transmitting pipe line is likely to depend, and the life of the wells and the collecting lines is almost certain to depend, on the exhaustion of the supply of gas rather than on physical depreciation. It does not depend at all on obsolescence, so important in other industries. The subject is, of course, complicated by the fact that much of the gas is a by-product and must be used when produced, or not at all. At least a partial solution of

[10] A comprehensive discussion of the cost of production of natural gas in a region in which conditions are none too favorable is given in Investigation re Natural Gas Rates, Regulations, Etc., of the Public Service Commission of New York, case 7091, Jan. 12, 1932.

the problem of advantageously disposing of gas produced from oil wells, for which there is no immediate demand, appears in the growing practice of pumping gas back into the ground through an exhausted well and thus accomplishing the double purpose of forcing the petroleum toward the producing wells drilled in the same formation and storing the gas for future use in a reservoir which has remained tight through geologic ages. It is noteworthy that some success has attended the practice of pumping coal gas or water gas made during off-peak seasons into exhausted oil or gas fields. In certain cases, at least, the manufactured gas has been enriched enough to more than pay for the cost of the operation and the losses in transmission. By a similar use of natural gas which has been freed from condensible hydrocarbons it may be possible not only to save the gas itself for peak loads, but to recover a considerable quantity of natural gasoline which would otherwise be left in the earth.

8. USE OF VOLATILE LIQUID HYDROCARBONS IN GAS MAKING

The isolation of propane and butane from natural gas and their transportation as liquids under pressure in steel cylinders was mentioned in the preceding section. Propane boils at −48° F and is, therefore, a gas at atmospheric pressure at all temperatures likely to be encountered in practice. Butane boils at 33° F, and cannot be distributed undiluted without danger of condensation, except in the warmer parts of the country. Both hydrocarbons are used to some extent for supplying small towns. Propane is always, or nearly always, distributed without dilution. Butane is nearly always mixed with air. A discussion of the standards of heating value for such mixtures is given in part II, section 11, which includes some technical information that might otherwise be appropriately given here.

If the appliances in use are properly designed for burning propane, and if the cost of the raw material is disregarded, it is the ideal gas for a public supply, particularly in a small town. The equipment required at the distributing station is extremely simple and, with the exception of the tank in which the liquid propane is stored, very inexpensive. Practically no labor or attendance is required in connection with production, since the vaporization of the liquid takes place automatically to meet any demand. Distribution is also exceedingly simple and economical. No holder is needed, there is no condensation and no corrosion in the mains, and the high heating value permits the distribution of the same amount of fuel through the same system with only about 11 percent of the variation of pressure that would be involved in the distribution of average manufactured gas. The product is always of uniform composition and for the reason just given can be maintained at nearly uniform pressure, which eliminates much of the trouble from the adjustment of appliances.

A plant for sending out a mixture of butane and air is also nearly automatic but requires some power-driven machinery, demands more attention, and possesses more possibilities for trouble than a propane system.

If we consider systems of increasing size, from the domestic unit to that which supplies a large town, it is evident that the advantages

of propane are of decreasing importance and the high initial cost of propane is of increasing importance. Small systems can, therefore, use propane the more advantageously; for large systems the cost of the liquid hydrocarbon overbalances the superiority of propane in other respects and makes preferable the supplying of butane. For still larger systems the cost of butane becomes prohibitive in comparison with the cost of a manufacturing plant for the use of ordinary fuels, and one of the older manufacturing processes becomes the most practicable.

The use of these hydrocarbons to supplement manufactured or natural gas during peak demands is of much interest. If either propane or butane is in storage, it can be introduced into the supply of other gas without delay, at a rate equal to the capacity of an enormous plant for manufacturing the usual gases, and with only a negligible amount of additional labor. The potential supply of propane and butane from natural gas and from petroleum refineries, together with unsaturated hydrocarbons of the same range of volatility from the latter source, is said to be adequate to replace all the gas manufactured in the United States. There is, therefore, no dearth of these materials. There is only the economic problem of comparing their recovery, transportation, and storage with the manufacture of gas by other methods to meet the same conditions of demand, and the technical problem of so modifying the mixture distributed that the operation of appliances will not be interfered with if these gases are used.

In the case of manufactured gas, the key to the solution of the latter problem, if there is a practicable solution, appears to be in the fact that a mixture of hydrogen with either propane or butane will have a higher speed of ignition and a somewhat lower specific gravity, but otherwise nearly the same properties as coal gas of the same heating value. A mixture of the hydrocarbon with blue gas will have a lower speed of ignition and a higher specific gravity than the usual carburetted water gas of the same heating value, a difference which may be increased by including in the mixture some products of incomplete combustion (producer gas) which are always available. The operation of the manufacturing equipment to produce gas with a greater content of hydrogen than normal, as by cracking oil in the fire of a water gas generator or maintaining unusually high temperatures in the coal-gas plant, will therefore permit a portion of the demand for fuel to be met by "cold carburetion" with the volatile hydrocarbons. To be advantageous, the changes must be made in a way to give greater capacity than would result from normal carburetion with oil, otherwise the use of a more expensive hydrocarbon would not be justified.

For the replacement of natural gas, propane and butane have the merit of possessing about the same speed of ignition as the natural gas, but they are much heavier. They should, therefore, be diluted, if practicable, with another gas having much the same speed of ignition as natural gas but a considerably lower specific gravity. Actually, this is not practicable, and it is necessary to compromise.

Specific gravity cannot usually be considered more important than speed of ignition, but the fact that most natural gas burners are much nearer to instability from the lifting of the flames than from back-

firing permits a rather large increase in the speed of ignition without introducing much hazard. An equal change in the opposite direction will not be permissible. Carburetted water gas enriched with butane to the heating value of natural gas should, therefore, have properties as close to those of natural gas as are attainable and should be at the time as economical to manufacture as any gas that can be made during peak loads only.

It is not recommended that natural gas be replaced by another mixture in this way, if it can well be avoided. A company distributing natural gas should make every reasonable effort to provide adequate facilities for supplying its customers with natural gas alone, or with a mixture than can be kept uniform throughout the year if such a mixture can be produced more economically. But under some conditions the cost of providing facilities for meeting the extreme peak of demand without changing the mixture is greater than is justified by the advantage gained, and in such cases it is much better, so far as uniformity of service is concerned, to supplement natural gas with producer gas or water gas enriched with butane to the heating value of the natural gas than to use for the purpose the producer gas alone, as has sometimes been done.

The economy of using butane for peak loads depends largely on the frequency, duration, and magnitudes of the excessive demands. If it could be known that a peak load would occur on a single day during the season, or on a small number of individual days sufficiently scattered to permit the replenishment of the butane supply in the intervals, it would unquestionably be cheaper to provide for the storage of enough butane to meet the demand than to build enough producers or water-gas sets, and have them stand idle almost all the year. If, however, a fairly uniform excessive demand occurs on several consecutive days, the advantage of storing butane is rapidly lost.

In the cost of supplying very large demands during brief periods the capital charges are preponderant. If the cost of equipment for storing butane and the cost of additional manufacturing units are both known, it is easy to compute the extent to which the introduction of butane would be an economy for any quantity of gas that may be assumed to be needed on consecutive days. The large factor of uncertainty is involved in the estimation of the magnitude and distribution of the demand. It is probable that in most cases in which existing facilities are becoming inadequate a saving can be made by planning to meet the extreme peaks by the use of some butane rather than by adding as much manufacturing equipment as would otherwise be needed. If the practice of using the liquefied hydrocarbons in this way became general, the problem of peak loads would be in large part transferred to the producers of the liquefied gases, who would then experience a seasonal demand that might be hard to meet without maintaining much idle equipment through the summer.

The use of ordinary gasoline for the enrichment of gases of low heating value has been practiced to some extent. Its effect on specific gravity is worse than that of butane, and condensation will take place in the mains if it is used to excess. Otherwise it has much to recommend it. It will affect the properties of the mixture in substantially the same way as will butane, and in many cases it can

be used to supply 5 percent or more of the heat units needed without serious condensation. It can usually be obtained locally as needed without placing a burden on the company supplying it, since the demand for gasoline for the enrichment of gas is most likely to occur when the amount used for other purposes is a minimum.

9. SELECTION OF THE MOST ECONOMICAL HEATING VALUE FOR MANUFACTURED GAS

It has been pointed out in part II, that the most favorable standard of heating value will be, in general, that which permits the delivery to the customer of the most heat units per dollar of cost to the gas company. The problem of ascertaining the relationship of heating

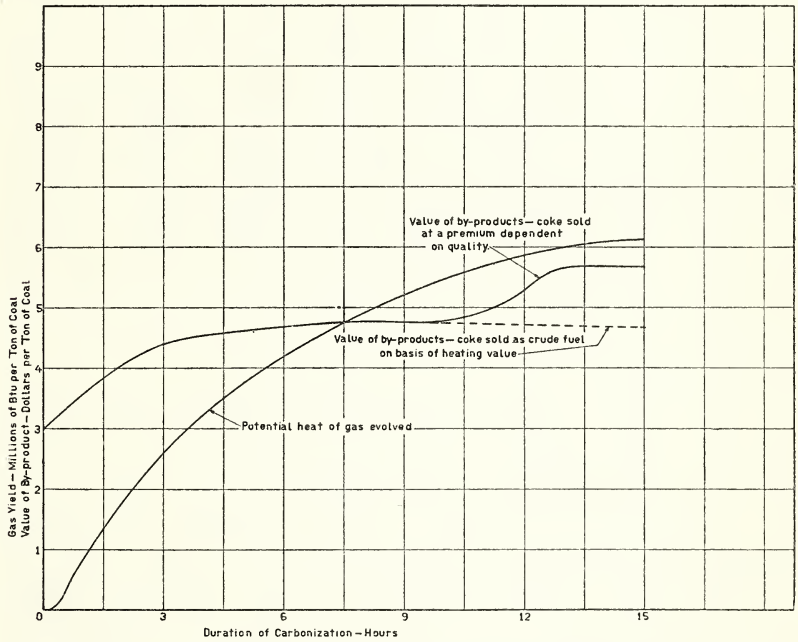

FIGURE 23.—*Assumed relationship between duration of carbonization, potential heat of gas, and value of by-products.*

value to cost seems to have been attacked in a general way only in the case of the simplest of the three major gas-making processes, which is the manufacture of oil gas.[11] It is the purpose of the present section to discuss briefly the factors which must be considered in determining the most economical standard of heating value for coal gas and water gas.

In the case of coal gas, the discussion will be introduced by reference to figure 18, which will be assumed to represent the effect on the yield of products, the heating value of the gas, etc., of the duration of carbonization in a particular plant heated to a "car-

[11] See the several reports of the Joint Committee on Efficiency and Economy of Gas published by the Railroad Commission of California.

bonizing temperature", measured at some point in the flues, of 2,150° F. The total potential heat of the gas evolved from a ton of coal is represented by one of the curves of figure 23. It will be assumed that the bituminous coal used costs the gas company $4 per ton at the plant. It is next necessary to assume some relationship between the duration of carbonization and the value of the byproducts. The value with which we are concerned is not, of course, the selling price of the byproducts, but their value to the gas company as a dealer in fuels, which is equal to the selling price minus the cost of selling and handling. Obviously a very short period of carbonization would result in the gas company's having to dispose of a great quantity of crushed and only partially carbonized coal which could probably be used only in industrial plants or boiler rooms as powdered fuel. The solid would therefore be worth considerably less than the original bituminous coal. However, the byproducts other than coke are produced mainly in an early stage of carbonization, and these usually command a market price considerably in excess of coal of the same fuel value, hence the curve rapidly rises. Two assumptions regarding the further change of value of byproducts are made. One is that the coke will find no outlet except on a calorific basis in competition with bituminous coal. The result of this assumption is represented by the broken line. The other assumption is that much of the coke can be disposed of at a premium as a smokeless fuel, as will usually be the case, and is represented by the solid curve. Because coke which will command a premium over raw coal will be obtained only when carbonization has been fairly well completed, the two curves do not separate until near the end of the process. From the curves of figure 23 it is easy to plot, in cents per million Btu, that portion of the cost of the gas which represents the difference between the cost of the fuel and the value of the byproducts. The result is the lower curve of figure 24. Above this curve is a series of other curves representing the successive additions of other items of cost. The quantity of fuel assumed necessary for heating the retorts is intermediate between the amounts reported for some of the older plants and the best modern practice; and the further assumption is made that the quantity of fuel used will be equal to the sensible heat in the discharged coke plus an amount that is proportional to the duration of carbonization. The two factors tend to compensate each other, and there is no great difference in the amount of fuel used per million Btu for moderate differences in the duration of carbonization. The operating labor was likewise assumed to be intermediate between that required in old-fashioned coal-gas plants and the fully mechanized modern ones. On trying to estimate the effect of changes of operation on the cost of labor, an arbitrary division was made into labor that would be constantly employed without regard to the operation of the plant, labor that would be proportional to the number of hours of operation, and labor that would be proportional to the quantity of coal and coke handled. The miscellaneous items include purification, power, etc., and that portion of the maintenance of the plant which is necessary because of wear and destruction by use. Another portion of maintenance, which is proportional to time and would be needed

if the plant were not used at all, belongs in the next class called "manufacturing demand costs".

The costs attributed to "manufacturing demand" require more extensive discussion. In determining rate schedules it is customary to classify the items which affect the cost of gas under four headings,[12] called "Customer costs", "manufacturing demand costs",

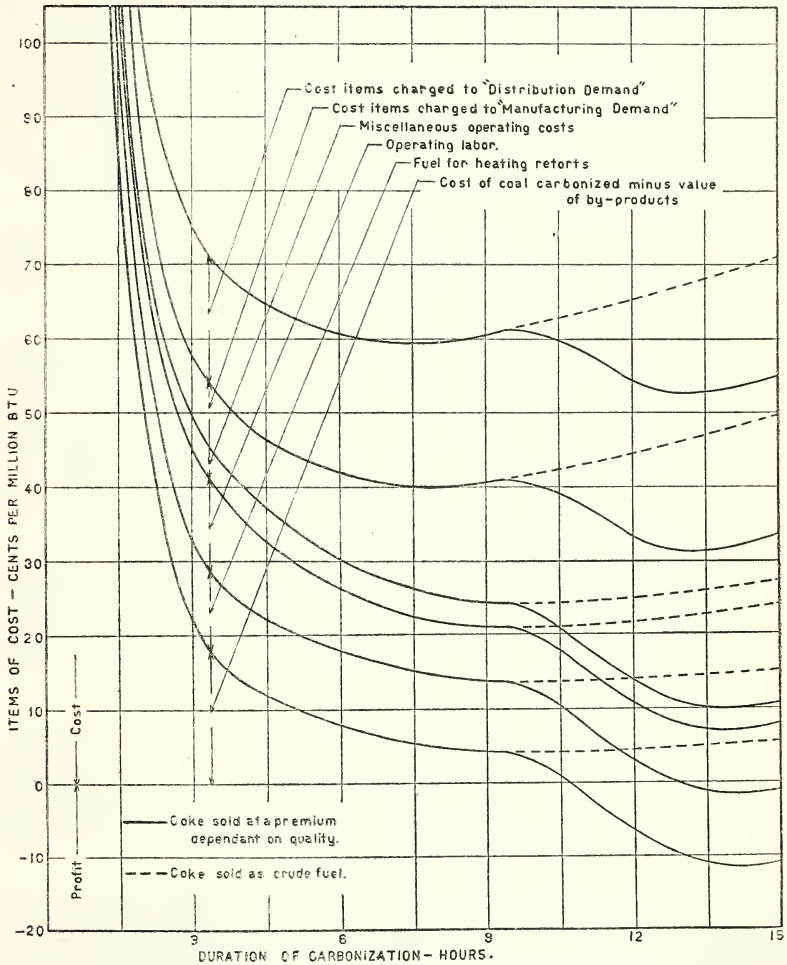

FIGURE 24.—*Items of cost of producing coal gas under conditions assumed.*

"distribution demand costs", and "commodity costs." Customer costs consist of items assumed to be the same for every customer, such as reading the meter; commodity costs consist of items assumed to be the same for every unit quantity of gas sold, such as the fuel used in manufacture. Manufacturing demand costs include those items which are assumed to increase in proportion as the capacity

[12] See report of Committee on Rate Structure, Proc. Am. Gas. Assn., p. 123–230 (1923).

of the plant to produce gas is increased by the addition of new equipment, etc. The principal items are capital charges, taxes, etc., which are proportional to investment. Distribution demand costs include those items which are assumed proportional to the maximum instantaneous demand in cubic feet, which determines the necessary capacity of the distributing system. It is readily apparent that a change in operating practice which will double the output per retort will have the same effect on the capacity of the plant to produce gas as will doubling the number of the retorts, but without increasing investment, etc. A little study of the problem shows that all items properly included under manufacturing demand are of the nature of annual costs, which are large or small depending on the amount of equipment that must be provided to meet the peak of demand. It is readily apparent that a change in operating practice which will double the output per retort will reduce by one-half the number of retorts needed to meet a given demand. A similar relationship holds with respect to other items of the "manufacturing demand costs." All costs properly allocated under this heading are therefore inversely proportional to the capacity of the same equipment under different methods of operation. The item of figure 24 labeled "cost items charged to manufacturing demands" was therefore computed by assuming that the manufacturing demand cost given as an example in the 1923 report of the rate structure committee of the American Gas Association, would apply in this case for the manufacture of coal gas of 580 Btu, which was about the average heating value in 1923. The changes in the costs corresponding to changes in plant capacity for gases of other heating values were then computed.

The "distribution demand costs" are those assumed in allocation to be proportional to the number of cubic feet of gas distributed, and the cost per million Btu is therefore clearly in inverse proportion to the heating value. The computation of the costs shown in figure 24 was again made from the example given by the rate structure committee.

By noting the time at which the final curve of figure 24 shows a minimum and the corresponding time in figure 18, it is found that, for the case assumed, the most economical heating value is about 585 Btu per cubic foot if the quality of the coke is involved in its sale, and 645 Btu per cubic foot if the coke is to be sold as a raw fuel only.

The temperature to which the retorts are heated has not been considered as a variable in the construction of figure 24. To make a complete survey of the possibilities, it would be necessary to construct similar curves to represent operation at other temperatures. As an illustration, the final curve of figure 24 is replotted in figure 25, together with curves computed from similar assumptions and representing probable results of operating at higher and at lower temperatures. Even as complete a set of data as here represented would apply to only one grade of coal and would have to be appropriately modified if other coals were under consideration.

It must be emphasized that the curves constructed as an illustration are wholly hypothetical, since they are based on an assumed combination of conditions which might exist in an actual plant, but probably do not. They therefore have no quantitative signifi-

cance with respect to the operation of any existing plant. On the other hand, the known general effects of various changes have been taken into account with some care, and the general characteristics of the curves are probably about what would result from the complete study of any actual case. They indicate correctly the predominant importance of making salable by-products and the effect of heating value on the capacity of the manufacturing and distributing equipment, factors which have been frequently ignored in the discussion of standards of heating value.

All of these predominant factors are controlled by local conditions which are no more common to all the companies of a state than are the considerations on which rates are based. This again

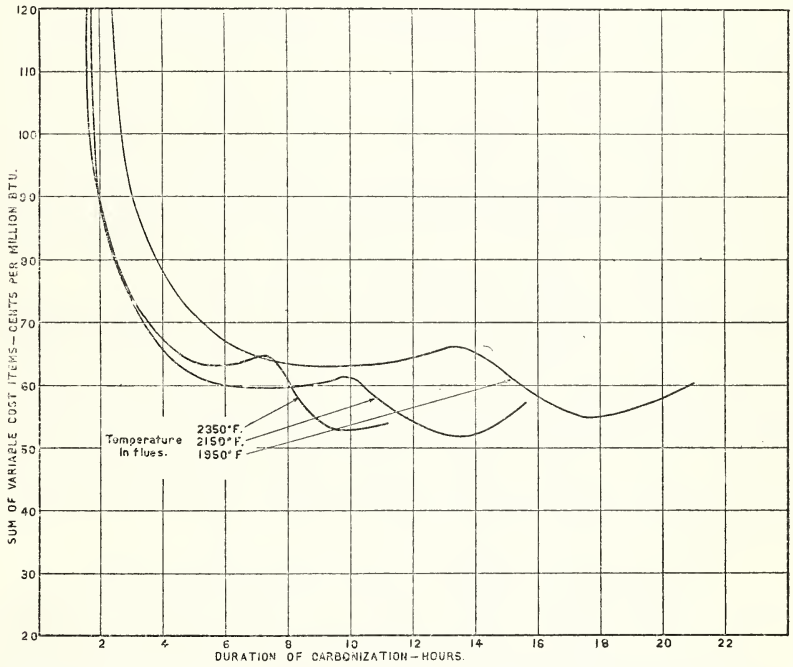

FIGURE 25.—*Approximate effect of temperature on cost of producing coal gas under conditions assumed.*

indicates that a State-wide standard of heating value is hardly more logical than a State-wide rate. The objection may be made that it is not possible to know the effect of such a variable as the duration of carbonization on the marketability of coke with enough accuracy to permit the construction of a definite curve. The answer is, of course, that the selection of the best standard of heating value can be no more definite or intelligent than the judgment of the factors which determine its desirability, of which this is one of the most important.

The discussion of the selection of the most economical heating value for water gas is much simplified by the fact that the by-products are of all but negligible importance, and the fact that both the heating value and the several items of operating expense are di-

rectly dependent on the relative costs and amounts of the two classes of fuel used, oil and generator fuel (coal or coke). However, when we come to select the "most economical" heating value for water gas we encounter a rather surprising difficulty. Within the range of usual operating practice, both the amounts of oil and solid fuel used appear to be linear functions of the heating value of the gas produced, within the limit of accuracy of the available data. Furthermore, the other items which directly affect operating cost, such as labor and residuals, are very nearly linear functions of the amount of either solid fuel or oil used, and hence also linear functions of heating value. It follows that operating costs computed from ordinary data do not pass through either a maximum or a minimum, but appear to be a linear function of heating value which will be either increasing or decreasing, depending mainly upon the costs of the fuels used. In other words, it appears that the economical heating value for water gas is either much higher or much lower than the usual range of operating practice. The alternative conclusion is that the economical heating value is determined mainly by considerations not usually discussed in this connection—cost of distribution, the capacity of the plant to meet peak loads, and the difficulty of adjusting appliances to use water gas of extremely high or extremely low heating values. Bringing in the capacity of the plant and distributing system does not help much, for these also are approximately linear functions of heating value.

The most satisfactory means of dealing with the problem therefore appears to be to determine whether the economical heating value is at the top or bottom of the range within which linear relationships are believed to exist, and to compare heating values within that range with still more extreme values whenever suitable data are obtainable. To do either involves the comparison of relative costs of gases of two heating values, and the remainder of the discussion will be given to the general method of making such a comparison. The following symbols will be used:

A = number of gallons of oil used per million Btu.

B = number of pounds of coke used per million Btu.

C_o = capacity of a given plant in million Btu per unit time when making gas of some specified heating value, H_o.

C = capacity of the same plant in the same units when making gas of heating value H.

L = cost of labor and miscellaneous operating expenses in cents per million Btu.

R = value of residuals in cents per million Btu.

M_o = "manufacturing demand costs" in cents per million Btu when making gas of specified heating value H_o, exclusive of any items which may have been included in L.

M = "manufacturing demand costs" in the same units when making gas of heating value H. It is apparent that

$$M = M_o \frac{C_o}{C}.$$

$K + DV$ = total cost of distribution of the gas supplied where K and D are constants. (This is in agreement with the usual practice of assuming that the cost of dis-

tribution may be divided into a part proportional to the volume distributed and another part independent of volume. DV is, of course, the total "distribution demand cost", D is the "distribution demand cost" per unit volume and may be expressed in cents per 1,000 cu ft. Then $1{,}000\,\frac{D}{H}$ is the "distribution demand cost" in cents per million Btu.)

X = cost of oil in cents per gallon.

Y = cost of solid fuel in dollars per ton.

$0.05Y$ = cost of solid fuel in cents per pound.

The total cost of the manufacture and distribution of gas, in cents per million Btu, is expressed in these symbols by

$$AX+0.05BY+L-R+M_o\frac{C_o}{C}+\frac{1{,}000K}{HV}+\frac{1{,}000D}{H}.$$

Two gases of different heating values, H_1 and H_2, are equally expensive per million Btu if the following equation is true, the same subscript referring to the same gases throughout.

$$A_1X+0.05B_1Y+L_1-R_1+\frac{M_oC_o}{C_1}+\frac{1{,}000K}{H_1V_1}+\frac{1{,}000D}{H_1}=$$
$$A_2X+0.05B_2Y+L_2-R_2+\frac{M_oC_o}{C_2}+\frac{1{,}000K}{H_2V_2}+\frac{1{,}000D}{H_2}$$

However, since the demand for heat is in practice independent of heating value, $H_1V_1=H_2V_2$, and the sixth terms on the two sides of the equation cancel. Combining terms

$$X(A_1-A_2)+0.05Y(B_1-B_2)+L_1-L_2+R_2-R_1+$$
$$M_o\left(\frac{C_o}{C_1}-\frac{C_o}{C_2}\right)+1{,}000D\left(\frac{1}{H_1}-\frac{1}{H_2}\right)=0.$$

It is very convenient to put this equation into a graphical form, which will permit the rapid solution of the problem of finding under what conditions the costs, per million Btu, of gases of the two heating values will be equal.

Solving for X and rearranging in the order in which the terms will be used in plotting,

$$X=\frac{L_2-L_1+R_1-R_2}{A_1-A_2}+\frac{0.05Y(B_2-B_1)}{A_1-A_2}+$$
$$\left(\frac{M_o}{A_1-A_2}\right)\left(\frac{C_o}{C_2}-\frac{C_o}{C_1}\right)+1{,}000D\left(\frac{1}{H_2}-\frac{1}{H_1}\right)$$

The construction of the diagram is illustrated by figure 26. The cost of solid fuel is marked on an appropriate scale on the left-hand margin of the sheet, that of oil on the right. From the left-hand margin at the point representing a cost of zero for the solid fuel, a diagonal line is drawn at a convenient angle upward and to the right.

This line is labeled $M_o=0$ in figure 26. From a point on the left-hand margin opposite a point representing the numerical value of

$$\frac{L_2-L_1+R_1-R_2}{A_1-A_2}$$

on the right-hand scale, another diagonal line, labeled $D=0$, is drawn downward to the right to a point P, which is located by dropping a vertical line from the point of intersection of line $M_o=0$ with the horizontal line representing a cost of $20 per ton or 1 cent per

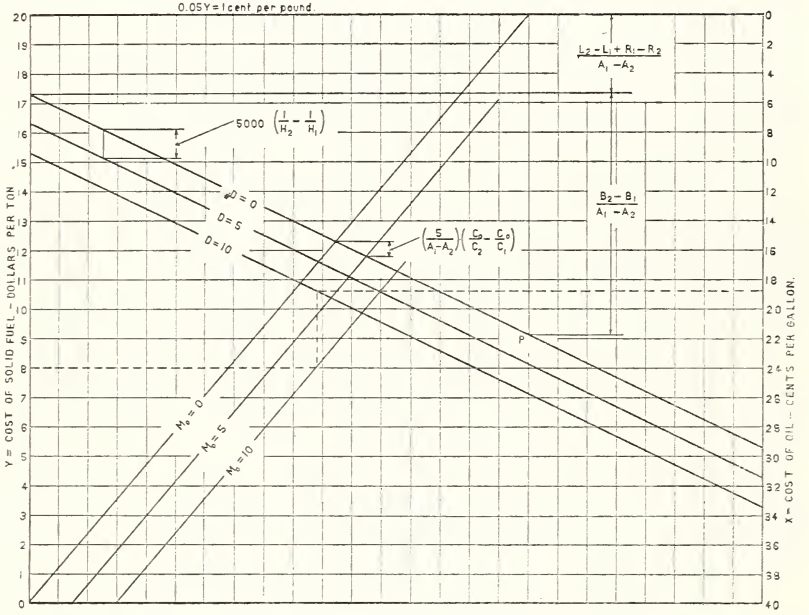

FIGURE 26.—*Method of constructing a diagram to show conditions under which water gases of two heating values are equally expensive.*

pound ($0.05Y=1$) for the solid fuel, and laying off a vertical distance equal to

$$\frac{B_2-B_1}{A_1-A_2}$$

below the point of origin of the line $D=0$. For the solution of the equation, a line parallel to $M_o=0$ may be drawn to intersect the line D=0 at a point which is below the intersection of lines $M_o=0$ and $D=0$ by an amount equal to the numerical value of

$$\left(\frac{M_o}{A_1-A_2}\right)\left(\frac{C_o}{C_2}-\frac{C_o}{C_1}\right).$$

It is convenient to lay off a series of lines for different values of this expression corresponding to different values of M_o. Similarly for the solution of the problem, a line parallel to $D=0$ and vertically below it by the distance

$$1{,}000D\left(\frac{1}{H_2}-\frac{1}{H_1}\right)$$

is needed. Again it is convenient to lay off a series of lines corresponding to different values of D. The figure is now ready for the solution of equations. A solution for one case is represented by the dotted line which is drawn horizontally from the point representing the price of solid fuel (assumed \$8 per ton) to the diagonal line representing the value of M_o (assumed 10 cents per million Btu) thence vertically upward to the line representing the value of D (assumed 10 cents per thousand cubic feet), then horizontally to the scale representing the price of oil.

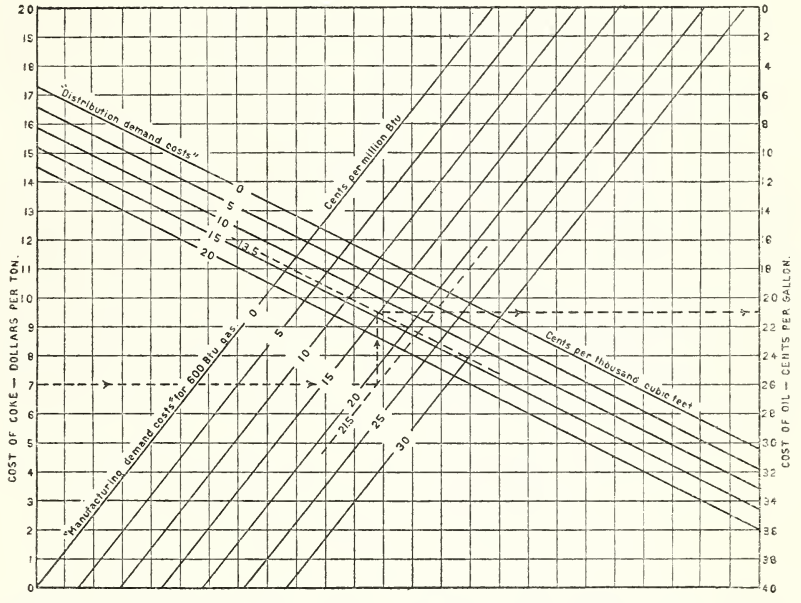

FIGURE 27.—*Conditions under which 600 and 500 Btu water gases would be equally expensive.*

(For source of data assumed for illustration, see text.)

A numerical illustration will perhaps make the method clearer. Almost the only published table of data in which the costs of manufacturing water gases of various heating values are analyzed with any degree of completeness, is that prepared by the Public Service Co. of New Jersey in Gas Age, volume 46, page 87, 1920. Although this table no longer represents the best current practice, it probably does represent fairly well the costs of operating old-style plants in which clinkering is done by hand, etc. At any rate it will be used for illustration because of its completeness. The following values can be readily computed from the table.

Quantity	Heating value (Btu)			Quantity	Heating value (Btu)		
	600	500	400		600	500	400
A	6. 13	4. 92	3. 07	L	28. 03	34. 17	43. 60
B	55. 9	74. 9	103. 4	R	2. 97	2. 38	1. 50
$\frac{1}{C}$	1. 00	1. 338	1. 847				

The comparison will be made between 500 and 600 Btu gases. Using the data given above, figure 27 is obtained by the method of construction described, H_0 being assumed, 600 Btu per cu ft. For illustrating the use of the figure, it is assumed that, in a particular case coke costs $7 per ton, and the "manufacturing demand costs" and "distribution demand costs" are taken from the illustration in the report of the 1923 rate structure committee, as in the case of coal gas. (The manufacturing demand costs were reduced by the entire amount charged to "production", assumed to apply to a 550 Btu gas, and corrected to the basis of 600 Btu for entry in the figure.) These costs were 21.5 cents per million Btu for "manufacturing demand" when making 600 Btu gas, and 13.4 cents per thousand cubic feet for "distribution demand." The solution of the problem is again shown by the dotted line. It is found that at any price for oil less than 20 cents per gallon the 600 Btu gas should be the more economical.

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