THE AMERICAN PRACTICE

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BY

WM. PAUL GERHARD, C.E.

CONSULTING ENGINEER FOR HYDRAULIC AND SANITARY WORKS,
MEMBER AMERICAN SOCIETY MECHANICAL ENGINEERS,
AMERICAN PUBLIC HEALTH ASSOCIATION, ETC.,
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PREFACE

In preparing this book my object was not to treat of the various processes of manufacture and distribution of illuminating gas, nor to discuss the lighting of public streets, alleys, parks and squares.

It should be distinctly understood by the reader that I take up the subject of gas installation and gas utilization practically at the point where it reaches the consumers' premises. I endeavor to explain how gas-fitting should be done so that gas may be advantageously employed in the illumination of the interior of buildings. Incidentally, other uses of gas are mentioned and their advantages pointed out.

To give a detailed technical instruction regarding the practical work and the mechanical details of the gas-fitter's work in the piping of buildings was beyond the scope of the book. Several smaller handbooks, mentioned in the bibliography, are available, which cover the ground fairly. In compiling the bibliography (Chap. XXVII) the author arranged the literature, as far as dates were available, by the year of publication.

The book is intended chiefly for the use and enlightenment of the gas consumer and the householder. However, it will also be found useful by architects, engineers, builders, and building superintendents to enable them to acquire a better knowledge as to how to introduce, distribute, and utilize gas in buildings. It should also be of value and interest to gas companies and superintendents of gas distribution service.

The author is under many obligations to Mr. Otis Allen Kenyon, M.E., for valuable suggestions, as well as for his critical revision of the manuscript. He also desires to acknowledge assistance received from Norman P. Gerhard in preparing the bibliography, from Hans W. Gerhard in making the alphabetical index, and from Mr. R. N. Hart in careful proofreading.

THE AUTHOR.

NEW YORK CITY, *January*, 1908.

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THE AMERICAN PRACTICE OF GAS PIPING AND GAS LIGHTING IN BUILDINGS

CHAPTER I.

PREJUDICES AGAINST THE USE OF GAS.

In the following pages the term "gas" is used to designate an aeriform mixture, used either as an illuminant or as a fuel. When used for lighting, gas is called *illuminating* or *lighting gas*, and when used for heating, cooking, or power purposes it is called *fuel gas*. Gas used for illumination is largely hydrogen enriched by carbon.

We also distinguish between *natural* or *rock gas* and *artificial* or *manufactured gas*, the former being found in nature beneath the earth's surface and brought up by means of bored wells, the latter being gas manufactured in industrial establishments or gas works, or in special private gas plants or apparatus. The bulk of manufactured illuminating gas is either *coal gas*, the product of the distillation of bituminous coal in closed retorts, to which a high degree of heat is applied, or else it is *water gas*, made more cheaply than coal gas by passing steam over glowing coals, and afterwards enriching it with vapors of oil or naphtha to make it luminous. Very little *oil gas* is made from hydrocarbon oils. Water gas has considerably less heating power than coal gas, but in all other respects both kinds of gas, supplied from a central station through a system of distributing pipes, and brought by service pipes into the houses of the consumers, are well adapted for light, heat and power.

Air gas is a special gas, used to a limited extent in the lighting of country houses, and made by forcing common air to pass over gasoline or other fluid hydrocarbons, the air becoming saturated with the vapors of the fluid. *Acetylene gas* is another special gas discovered more recently, and obtained by the contact of calcium carbide with water.

Sometimes the term "gas" is used to designate a gas lamp, a gas jet or a gas burner, or the light produced by burning gas.

A rather unusual, but witty, definition of "gas" is the following, which I quote from the "*Silly Cyclopædia*": "gas — a substance we make light of until the bill comes in."

. . . . .

The industry of manufacturing illuminating and fuel gas celebrated the anniversary of its first century in 1892, for it was in 1792 that Thomas Murdock, in England, first illuminated his house with gas.

Although the advent of the electric incandescent lamp, in 1880, threatened at first to revolutionize completely the methods of both interior and street illumination, the gas-lighting industry has continued to flourish and to show during the past 25 years an ever-increasing consumption of gas for lighting, heating and power purposes. The growth has been particularly noticeable in the so-called "day consumption" of gas, it being at present used to a large extent in gas heating and gas cooking appliances, and also for power purposes, in gas motors and engines.

Notwithstanding the numerous improvements, introduced in gas appliances and in gas illuminants, there are still found, in certain quarters, ill-conceived and old-fashioned prejudices in opposition to the use of gas, and it is with a view of doing away with these, and of clearing up misconceptions and exaggerated or erroneous statements that this brief chapter is introduced. The many popular fallacies regarding gas and its uses will be taken up and discussed in Chapter II.

We have become so accustomed to the benefits derived from the introduction and use of gas in our dwellings, and from the not less important advantages due to the lighting of our streets, squares, and parks with gas or electricity, that we can scarcely believe it possible that a newspaper should have appeared in Germany in the year 1819, in which the following, to say the least, ludicrous, objections against street lighting were brought forth.

The writer of the article denounced the artificial illumination of streets after sunset because "God had decreed that darkness should follow light, and mortals had no right to turn night into day." He declared that people did not require any light at night outside of their houses, and argued that the lighting of street lamps imposed an unnecessary tax upon the people. He also claimed that the fumes of oil lamps or of gas poison the air (!)

and affect the health of delicate persons, while public lighting encourages healthy persons to stay out of doors after dark and thereby to catch cold. Street lighting, in his judgment, would lower the standard of morality and remove the fear of darkness which alone prevents weak-minded individuals from committing crimes. The lighting of streets would make robbers bold and cause horses to shy (!). It would also reduce patriotism as evinced in special night illumination during public festivals, because if streets were lighted every night, these special functions would lose their effect.

We can, possibly, pardon a man for foolishly decrying in the above words a new industry, at a time when it was first being introduced. But what shall we say of people who, at the beginning of the twentieth century, still adhere to notions like the following:

"Illuminating gas is poisonous, and hence dangerous to use; it is explosive and thereby becomes the cause of fires; the combustion of gas produces irritating and unhealthy vapors;" or of those who cry out that "gas is too expensive to use," or those who do not care to introduce gas "because it will soon be superseded, anyhow, by electricity?"

It may not be amiss to take up briefly some of the prejudices mentioned, in order to analyse them and to point out why the statements made are erroneous and misleading.

There are some persons who claim that very soon electric lighting will supersede gas entirely, and who, for this reason, are opposed to the introduction of gas into buildings, at least for illuminating purposes. Persons who argue in this way are entirely unfamiliar with the true facts, which they could easily establish by a diligent research, namely, that since the introduction of electric lighting the use of gas has made rapid strides forward. Nearly all gas works show a large increase in gas consumption, and many instances are named where electric incandescent lamps have been replaced by the improved forms of incandescent gas lamps. Even in the lighting of railroad cars, no progress has been made in recent years in the use of electric lamps, whereas, only recently, successful experiments were made in lighting passenger cars with the Pintsch gas, burned in neat-looking, inverted, incandescent mantle burners.

Many other facts could be cited to show that there are no indications whatever that electricity will replace gas entirely.

A number of important inventions in the gas industry are recorded each year, and the old question: electricity or gas? is no longer of importance, for *both* forms of lighting have their merits, advantages and uses in special cases, and there is certainly room for further improvements in both fields of illumination.

Contrary to recent opinions held by some architects, the author can give no better advice to those who are building residences, than to have their houses both piped for gas and wired for electricity. Many instances are on record where the electric lighting has failed temporarily, for local reasons, or because the electric lighting plant or works were, for a time, put out of commission. It is at such times that the fact that gas is available will be most appreciated.

There are a number of other persons who have no real objection to the use of gas, but who fondly maintain the notion that "gas is an expensive luxury."

There was a time when gas did cost more than other materials for illumination, such as oil or kerosene, but that time has long gone by, and the price of gas has gradually come down, so much so that at the present time residents in many cities are charged less than one dollar per thousand cubic feet of gas consumed.

It is true that gas is a luxury, if burned in wasteful burner tips; and it is also a fact that many persons using gas in their cooking ranges have large gas bills, because the cook is indifferent as regards turning off the gas the moment it is no longer wanted. But such objections cannot be considered valid, because they can be overcome by the use of a little care or judgment and by proper instruction. On the other hand, it is a well-known fact that consumers can obtain for less money than formerly a very much higher degree of illumination, as, for instance, by using the modern forms of incandescent gas burners, all of which are much more economical in gas consumption than the flat-flame burners.

Others again are afraid to use gas for illumination or other purposes because "the products of combustion of gas are unhealthy." The chief products of combustion of illuminating gas, whether coal or water gas, are carbonic acid and water vapor. If gas is properly purified at the works and burned in the houses under proper conditions, only a trifling amount of deleterious compounds escapes into the air of the rooms.

The objection raised can certainly not be restricted to gas illumination, for it is well known that other forms of illuminants, such as kerosene or oil lamps and candles, contaminate the air to an even greater extent. Where many people congregate together, as in theaters or other halls of assembly, the air is polluted much more by the products of respiration and by exudations from the skin than by the lighting flames. Proper and sufficient ventilation should, of course, be provided in all cases, and it may be said that while the electric light doubtless exercises a less deteriorating influence on the air of closed rooms, the gas flames, on the other hand, assist in their natural ventilation.

Scientific authorities and noted hygienists seem to agree that one has little to fear from the use of gas for illumination, and the fact is worth pointing out that the improved burners, like the Welsbach incandescent and others, create a very much smaller amount of pollution, by reason of the fact that they burn less gas for a same amount of illumination than the large flat-flame burners.

Still other people, who do not deny that gas offers many advantages, entertain and cling to the prejudice that "illuminating gas is dangerous to life because it is poisonous." But when gas is introduced into dwellings it is conveyed in *tightly jointed* pipes and fixtures. Both piping and fixtures can and should be made perfectly gas-tight. No doubt this is not always the case, and leaks frequently exist, due to carelessness and indifference. But granting that escapes and leakage of gas are possible, the remedy is a simple one and easily applied.

Gas only becomes dangerous to life when it escapes unburned, and in most cases gas leaks are readily noticeable, owing to the odor of the gas. There is somewhat more danger where water gas is distributed to the consumer, owing to its much higher percentage of carbon monoxide, yet statistics in countries where coal stoves are much used show that more deaths by asphyxiation occur through defective stoves, or by the wrong use of the damper in the stove flue, than from gas leaks. A German writer points out that many poisons are used without hesitation in workshops or industrial establishments, and even in the household, also that many of our articles of daily food contain poison, also that carbonic oxide is generated in considerable quantity in tobacco smoking, yet nobody would think of giving up on that account the things which contribute to our comfort. Many deaths from electricity occur, owing to accidental contact with apparatus or wiring carrying a high voltage, yet this fact is never cited as a valid objection against the use of electricity.

The danger from gas leakage and the proper precautions and remedies to be applied will be discussed in later chapters, and it may suffice here to reiterate the statement that the objection quoted is not an important one, and certainly should not deter people from using gas in the household.

The last objection to gas to be mentioned comes from persons who claim that it is "explosive," and frequently causes fires. As a matter of fact, coal gas only becomes explosive when mixed with air in a proportion of not less than 4, nor more than 13, parts of air to one of gas. As a rule, accidental escapes of gas are noticed long before the mixture of air and gas become explosive. Then, again, gas requires air in order to burn, and when a gas jet is lit the gas burns only at the point where it issues and not in the pipes. A large gasometer, filled with gas, might be struck by lightning, yet, unless it be rent open to permit the gas to escape and then to become lighted, nothing serious would happen.

The danger from fire, incident to the use of gas, is no greater than that attaching to the use of other illuminants with open flames. In fact, reliable fire statistics confirm the view that more fires or explosions are due to the use of petroleum or alcohol lamps than to gas.

In a recent number of *Cassier's Magazine*, Mr. Washington Devereux, inspector for the Philadelphia Fire Underwriters' Association, writing on "Fire Hazards and how to Avoid Them," relates that the Grocers' Exchange of London, England, "has offered a prize of £120 sterling, which for the last three years has gone begging. It is to go to the inventor of the best-constructed safety lamp in which mineral oil can be burned, the chief merit of which must be absolute safety. The reason for this prize offer is the fact that the number of accidents resulting from the upsetting of mineral oil lamps in the United Kingdom has been enormous, and thousands of deaths have been caused by such accidents. In London alone, there were, in 1901, three thousand accidents, more or less serious, due to defective mineral-oil-burning lamps, stoves and lanterns."

The use of gas is not in any way extra hazardous, and the notion that electric lighting is very much safer in this respect is erroneous. Many fire insurance companies, on the contrary, regard the use of gas as safer than that of electricity. Some underwriters hold the view that no rebates or reductions should be given on policies for buildings illuminated by electricity, and that the relative danger to property and life is not less with electricity than with gas.

As an example, I quote the following enumeration of fatal accidents which took place in Germany in 1905: gas explosions killed 9 persons; electricity killed 15 persons; explosions of kerosene lamps, 250 persons.

In this connection it might be mentioned that in five years (from 1900 to 1905) not less than 21 fires occurred in Berlin theaters, out of a total of 66 fires, which were caused by short-circuits in the electric wiring installation; hence there seems to be some reason for doubting the greater safety of theaters, in which gas lighting is excluded by building department regulations.

While these remarks are not intended to undervalue the dangers incidental to the use of gas as an illuminant, they are given to point out the fact, that illuminating gas is not extra hazardous, if proper care and judgment are used in its management.

CHAPTER II.

POPULAR FALLACIES ABOUT GAS.

Having in the preceding chapter referred to some of the common prejudices against gas lighting and the use of gas in buildings, I will now mention a few of the popular misconceptions, which seem to arise largely from ignorance or want of knowledge.

Among the more common fallacies are the following:

a. That gas companies mix air with the gas to increase its volume. This admixture of air is never attempted, because it would obviously result in a serious deterioration of the illuminating power of gas, for even a 1 per cent admixture of air reduces the candle-power of gas by 6 per cent, and a 10 per cent admixture reduces the same by 67 per cent. Gas companies are required by law to make and furnish illuminating gas of a specific candle-power, and the weekly tests of the gas examiners show that the quality of the gas rarely falls below this standard, as it certainly would if air were mixed with the gas. It is a fact, however, not so well known, that the quality of gas is variable with atmospheric changes. For instance, a fall in the barometer reduces the brilliancy of lighting by 5 per cent for every inch of fall. According to Dr. Letheby, "in London the difference in the value of the light when the barometer is 31 inches as compared with what it is at 28 inches is fully 25 per cent, and this, no doubt, accounts for many of the complaints of 'bad light' in November, when the barometer is usually very low." The quality of the light is likewise said to be variable with the amount of moisture in the air.

b. That gas companies blow or pump air from the works into the gas mains during the day, to make the meter go around and to make the index register. This is sheer nonsense, for not only can the consumer at any time by lighting a burner convince himself that the pipes contain illuminating gas and not air, but where no gas is burnt and the house pipes are tight, the consumer, by watching the small hand of the meter during the day, will find that it remains stationary.

c. That large gas meters lead to an increase in the gas bills, and that large gas pipes in houses, as advocated by gas engineers, increase the consumption, and therefore the monthly gas bills, both of which beliefs, of course, are erroneous, as the gas consumption depends only upon the number and size of burners in use, and upon the gas pressure, but not upon the size of the conduit or pipe conveying the gas to the burner, and not upon the capacity of the instrument measuring the gas. No one having large pipes and a large gas meter in his house need burn more gas than he wishes to, and he can control this gas consumption perfectly.

d. That the gas company willfully puts on more pressure at the works at night in order to make the gas meters in the consumers' dwellings go around faster. While the fact is true that the pressure is increased in the early part of the evening, when a general lighting up begins, the gas company is obliged to do this to supply the distant consumers and those located in low-level districts. The increased pressure causes increased leakage of gas at the joints of the street mains, and also leads to increased consumption at the street lamps with ungoverned burners, for which the companies, as a rule, receive a fixed annual sum by the municipality, hence it may be accepted without question that the gas companies would not increase the pressure if it were not quite necessary to do so.

e. That large burners lead to a waste of gas, and that where gas companies offer to put better, or larger burners on the fixtures of the consumer they do this, not for the sake of giving a better light, but in order to increase the gas consumption. Careful observation shows that one large burner gives, with less consumption of gas, a better light than two small ones, which demonstrates the fallacy of the above misconception.

f. That gas vitiates the atmosphere more and creates more heat than either candles or oil lamps, whereas for the same amount of illumination the opposite is true.

g. That gas is more dangerous as regards accidents, such as fire, explosions, escape or leaks of gas causing asphyxia, than other illuminants, whereas the statistics of fire underwriters and the records of hospitals show more fires and accidents caused by lamp explosions than by gas.

h. That if in one house, owing, perhaps, to insufficient size of the gas service or of the house pipes, the pressure is low and the light accordingly poor, the gas company should be able to remedy this by giving to this consumer more pressure, if he desires it, than to the neighboring houses, which is obviously impossible.

i. That gas pipes may burst from the inside gas pressure, which mistaken idea possibly arose at the time when natural gas was first supplied to towns under sometimes very heavy pressure. With gas as supplied and distributed from gas works, the pressure is, comparatively speaking, very low, fluctuating from 10/10 to 40/10 inch of water pressure,* and there is not the slightest reason for fearing that the gas pipes may burst.

k. That inasmuch as the manufactured gas emits a strong and unpleasant odor, the same odor must exist and become disseminated in the rooms, when gas is burning. It is a fact, however, sufficiently well established by experience, that properly purified gas, if properly burnt, gives off no obnoxious odors.

l. That gas may, and sometimes does, burn inside of the gas pipes. I have met well educated and otherwise intelligent people, who displayed their utter ignorance on the subject by making such statements, thus reminding me of the people, in the early days of gas lighting, of whom we are told that they put on gloves before touching the gas pipes, and of architects who required in their specifications "gas pipes, to be carried at a safe distance from all woodwork." The fact is, of course, that illuminating gas does not burn while confined in a vessel or in pipes and fittings conveying the same, because air is necessary in all cases for combustion to take place.

m. That manufacturers of gas meters and gas companies work hand in hand to defraud the consumer, whereas the fact is that gas meters are measuring machines constructed with accuracy and on scientific principles, by responsible manufacturers, and that before use all meters are tested as to their accuracy by special State meter inspectors. Therefore, whenever a consumer believes his meter to be wrong, he may have it tested, exchanged, or repaired by notifying the gas company.

n. That gas bills are made out regardless of the amount of gas

* Gas pressure is always expressed in tenths of inches of water pressure.
W. P. G.

consumed, which popular error has been already alluded to in speaking of the prejudices of consumers.

o. A popular fallacy, which is met with occasionally, is that the gas, after once having flowed through, and been registered on the index of the consumers' meter, may pass back into the street supply pipes, so that gas companies will benefit by a second registration of the same volume of gas. A slight study of the construction of the gas meter (see Chapter XVII) will show the impossibility of this happening.

p. Another erroneous impression, which quite frequently prevails among gas consumers, is that if the size of the gas pipes is made larger than is common in most houses, there will necessarily be an excessive pressure and a correspondingly increased gas consumption. Practically, however, the reverse is the case, for a higher pressure is required to supply the gas burners or the gas cooking ranges with sufficient gas where the pipes are made very small; and, on the other hand, the pressure can be more readily regulated by the consumer, where the gas pipes are of a good size.

Much can, doubtless, be done to remove these and similar popular fallacies by giving to gas consumers proper explanations. The gas companies have constant opportunities to give to their customers information and advice upon many of the matters touched upon in this chapter, and it is to their interest to avail themselves of them.

CHAPTER III.

ADVANTAGES OF GAS AS AN ILLUMINANT.

In this chapter, I shall consider only the many advantages of gas as a source of light, leaving the consideration of the use of gaseous fuel, as compared with liquid and solid fuel materials, for heat and power, for the next chapter.

To some it may seem superfluous, at this day, to dwell upon the advantages of gas lighting as compared with other illuminants, and particularly so when it must be admitted that electric lighting is, in some important respects, superior. Electric energy, however, is as yet far from being a cheap source of illumination; it certainly cannot be looked upon as a source of light adapted to the means of the bulk of the general public, and it must be said that, notwithstanding many recent improvements, electric lighting is still far from perfection. In the regulation of the intensity of the flame, for instance, the gas has the advantage over the electricity in that it can be readily adjusted, regulated, increased or diminished at the will of the consumer. If we except one special form of electric incandescent lamp (the "Hylo" lamp), not universally used, this regulation cannot be accomplished in electric lighting.*

But, leaving out of consideration the electric lamp, let us see what chief advantages gas lighting offers.

The gaseous form of the illuminant involves some important advantages not possessed by liquid or solid illuminants. Thus, gas is readily conducted in pipes to any place where it is to be used as a source of light. It becomes available in an almost unlimited quantity, this being restricted merely by the size of the service pipe. From the service it is easily distributed to as many different places or outlets as wanted, and its flow is conveniently regulated.

There are other important considerations of convenience where gas is used, such as the avoidance of loss of time, the

* Since writing the above, another device has been introduced, the object of which is the regulation of the light intensity of incandescent lamps. W. P. G.

labor or annoyance of purchasing and getting the materials required for illumination, the candles or the kerosene oil and the lamp wicks; nor is any trimming and cleaning of wicks of the lamps and of lamp chimneys required.

Regarding the purchase of gas for lighting, it should be mentioned that gas is charged for at a unit price, which, in recent years, has been steadily *decreasing*, so that at the present time, for instance, consumers in New York obtain one thousand cubic feet of gas at eighty cents, whereas the market price of good lighting oils fluctuates more or less. When buying oil or candles, consumers pay in advance, as it were, whereas payment for gas is made after it has been used.* The bills for gas are made out from the records of the gas meters, which are officially tested measuring apparatus, and even the quality of gas is controlled at municipal testing stations, at least so far as the candlepower of the gas furnished to consumers is concerned.

Kerosene oil may, *in itself*, be cheaper than gas but if we add to its cost the breakage of lamp chimneys and the cost of trimming the lamp wicks, and for cleaning and filling the lamps, gas becomes the cheaper illuminant of the two.

One great advantage lies in the convenience of gas lighting. The gas flame is instantly lighted, available at all points where gas outlets are placed, and quickly put out.

Gas burners are also cleaner than oil lamps, there is no objectionable smell, and less heat is created and the air is polluted by products of combustion to a lesser degree than where candles or lamps are used.

Finally, gas lighting involves less danger from fire than illumination by oil lamps, and while the portability of lamps is claimed by some to be one of their advantages, it also renders them dangerous in use, as many lamp explosions prove.

What interests the consumer more than other things is the cost of an illuminant, and, as regards economy, gas lighting, in particular when the modern incandescent gas lamp is used, is ahead of all other modes of lighting, as the following comparison shows, in which the *electric-arc* lamp is not included, as it is not well adapted for dwelling-house illumination.

The electric energy, if taken from a central station, costs in New York at present 10 cents per kilowatt-hour. Hence the

* This statement does not apply to gas burned in the more recent prepayment gas meters. W. P. G.

consumer obtains, for one dollar, ten kilowatt-hours, and as the incandescent electric lamp of 16 candlepower uses on an average 55 watts, he can, for the expenditure of one dollar, burn the lamp

$$\frac{10,000}{55} = 182 \text{ hours.}$$

Illuminating gas costs at present in New York 80 cents per 1000 cubic feet, and as a good incandescent gas lamp, of 60 candlepower, burns about 3.5 cubic feet of gas per hour, the consumer obtains, for the expenditure of one dollar,

$$\frac{1250}{3.5} = 357 \text{ hours.}$$

Kerosene oil costs at present in New York about 14 cents per gallon; hence, for one dollar the consumer buys a little over 7 gallons. A good kerosene lamp giving 16 candlepower uses per hour 0.025 gallons, hence the consumer can burn it for one dollar

$$\frac{7}{0.025} = 280 \text{ hours.}$$

Summarizing the above, a consumer obtains for one dollar, with the incandescent lamp,

$$182 \times 16 = 2912 \text{ candlepower-hours;}$$

with the kerosene lamp

$$280 \times 16 = 4480 \text{ candlepower-hours;}$$

with the incandescent gas lamp

$$357 \times 60 = 21,420 \text{ candlepower-hours.}$$

Hence, he obtains the greatest amount of illumination by using the incandescent gas lamp, and the least by using the incandescent electric lamp.

To put the above in another form: One electric incandescent lamp costs per hour

$$\frac{55 \times 10}{1000} = 0.55 \text{ cents;}$$

one incandescent gas lamp

$$\frac{3.5 \times 80}{1000} = 0.28 \text{ cents.}$$

one kerosene lamp

$$0.025 \times 14 = 0.35 \text{ cents;}$$

hence, the incandescent gas lamp furnishes the highest illumination for the least expenditure of money. In this calculation it has been assumed that the life of the mantle, of the carbon filament in the electric lamp, and of the wick in the oil lamp are about the same.

In making the above computations, I have followed closely the statements made in an excellent little German pamphlet, entitled "No house without gas," published and widely distributed by the German Association of Gas Engineers, but the figures and prices have been adapted to current American conditions.

Another statement, somewhat similar in results, is taken from O'Connor's Gas Engineer's Pocketbook, and is as follows:

The relative costs of lighting with gas flames, oil lamps, and electric lamps are as 305 for Welsbach burners, 449–589 for petroleum lamps, and 1954 for electric incandescent lamps, and according to Prof. D. E. Jones, the number of candlepower-hours which can be provided at the same cost for different illuminants are:

- for wax candles 33 hours;
- for stearine candles 77 hours;
- for electric incandescent lamp 440 hours;
- for coal gas burnt in flat-flame burner 625 hours;
- for large petroleum lamp 2250 hours;
- for a Welsbach incandescent burner 2300 hours;
- for a Welsbach incandescent burner with water gas 4350 hours.

It should be mentioned that in the above comparisons no consideration was given to the latest development of electric lamps, like the Nernst, Osmium, Tantalum and Tungsten lamps, which, although from 8 to 10 times more expensive in first cost than ordinary carbon filament lamps, are much more economical in the use of electric power (requiring about 1.5 as against 3.5 watts per candlepower), and which also prove to be more durable and lasting, some of these lamps having a life of 1000 hours and more.

CHAPTER IV.

ADVANTAGES OF GAS AS A SOURCE OF HEAT AND POWER.

While gas was at first manufactured and used for illuminating purposes only, other uses suggested themselves, as soon as the price of gas was reduced. The greatest stimulus to the use of gaseous fuel for domestic, industrial and commercial purposes was, perhaps, given by the development of the abundant, and therefore cheap, natural-gas supply. But the use of manufactured gas for cooking, heating, and for running engines became likewise quite popular, largely because of its superior convenience. The advantages which gas offers for lighting purposes are even to a higher degree true of the use of gaseous, as compared with solid or liquid fuel.

One of the greatest advantages of gaseous fuel over coal or wood lies in the fact that a fire may be started instantly without previous preparation, and that the fire almost immediately gives off a high degree of heat, while its intensity may be regulated at will and stopped entirely in a moment by the mere turning off of the stop-cock or gas valve. It is for this reason, chiefly, that we find an ever-increasing use of gas fuel in our homes, in small workshops, and in large industrial establishments.

It is sometimes asserted that the advantages of gas for cooking become specially manifest where cooking is done on a large scale. This may be true; but, on the other hand, it is a fact that gas as fuel is becoming of the greatest importance in the dwellings of people of small means.

A gas cooking stove or range is convenient, time- and labor-saving; it does away with the various manipulations necessary where coal, wood or peat are used as fuel; there is no periodical stirring and shaking of the grate, and no refilling of the fire pot, while less attention is required by the fire. The use of gaseous fuel means a much greater cleanliness in the kitchen, as there is no residue from the fire, no ashes, no soot, smoke or dirt, nor does the chimney flue require cleaning. Very little heat escapes into the chimney, whereas in a coal range there is not only much heat lost which passes up the chimney, but the top plate also radiates a good deal of objectionable heat, and in this respect the use of gas cooking ranges is much appreciated in summer time, for the kitchen is thereby kept cooler. There is also no trouble such as is caused where chimneys smoke or do not draw well.

Add to this the numerous other advantages, for instance, the well-observed fact that viands cooked by gas are more palatable and lose less in weight, that roasted meats retain more of the juice; also the fact that no space is required in the kitchen for the coal scuttle and the kindling wood, that coal bins are not wanted in the cellar, that there is no purchase, transportation and storage of kitchen fuel, and finally that a gas range is *ready at all times*, day and night, and requires only the application of a lighted match to be put at once in full operation. In short, the use of gas for cooking purposes is becoming more popular from year to year, and rightfully so.

In view of all that has been said above, it seems quite proper to ask the question: What are the disadvantages of cooking by gas? And the only possible reply which can be made is, that it must be more costly than other methods, because considering the heat units obtained from coal as compared with those from gas, gaseous fuel appears to be at a disadvantage.

A ton of coal of average quality and costing $6.25 contains about

$$2000 \times 12{,}000 = 24{,}000{,}000 \text{ heat units,}$$

whereas 7,800 cubic feet of gas, the equivalent in price (gas at 80 cts. per 1,000 cubic feet), yield only

$$7{,}800 \times 710 = 5{,}538{,}000 \text{ heat units.}$$

Hence, heat derived from burning gaseous fuel costs at least five times as much as heat derived from burning a medium quality of coal.

Nevertheless, cooking by gas is *actually* cheaper than with coal, always supposing there is no wasteful burning of gas, because a gas fire is extinguished quickly, giving off no further heat, whereas a coal fire must be kept burning until it goes out, even when no longer required. Much saving can also be effected by a nice regulation of the cooking burners. In general, it may be stated, that while in coal ranges only about 10 per cent of the heat generated is utilized, the rest passing up the chimney or heating the kitchen, in gas ranges this percentage is usually 50 per cent or even more. Many experiments, conducted by gas authorities to ascertain the actual facts, show that with proper management cooking by gas *is* really cheaper than by coal.

Statistics seem to confirm the growing popularity of gas as a kitchen fuel, for some gas works report an even larger day than night consumption, which fact cannot be explained in any other way than by the increased use of gas in cooking. It is also pleasant to record the fact that people of small means have, in the last ten years, become more and more aware of the advantages of gas, have relinquished their former prejudices that gas for cooking is an expensive method, and are now full of praise for the economy effected by using gas. Nothing could be more erroneous than to suppose that cooking by gas is a luxury to be indulged in only by well-to-do people. There are a number of households, in which gas is used and properly managed in the kitchen twice a day, not only for cooking, but also for boiling clothes to be washed, heating the laundry irons, and making hot water for dish washing in gas water heaters, and where the average monthly gas bill does not exceed $3.00 in the summer months and $5.00 in the winter months, including the gas for lighting. Many improvements in the construction of gas cookers and gas ranges have been made in recent years; the ovens are better ventilated, and are heated more uniformly, and better non-luminous burners are used in the top plate, which can be easily cleaned, and have an adjustable air supply, thus doing away with the former tendency of burners to light back.

During the summer months, gaseous fuel may be advantageously used for heating the water required for bathing, ablutions, and for shaving. Not more than one cent per day is required to heat enough hot water for dish-washing purposes, by a gas water-heater supplying a kitchen faucet directly, and enough hot water can be heated for a bath in about 30 minutes with a gas consumption of about 7.5 cubic feet, costing only 0.75 cent. The use of such gas water-heaters is growing in popularity every year.

In order to arrive at the cost of heating water by city gas, the Ruud Manufacturing Company, of Pittsburgh, who are makers of several types of gas water-heaters, had a special installation made in a house. The heater used supplied three bathtubs, three laundry tubs, a kitchen sink and three lavatories. A separate gas meter was installed on the gas service supplying the gas water-heater. The gas supplied averaged about 650 B.t.u. per cubic foot, and cost $1.00 per 1000 cubic feet. The result of the reading of the meter for a period covering one and one-half years showed that the average monthly cost of gas to operate the gas water-heater including the pilot light amounted to $2.73. This sum appears to be very moderate indeed, and is explained by the fact that the kitchen boiler was, during the winter months, heated by the coal range, the gas water-heater being fitted up so as to act as "supplementary" or "re-heating" system. It should be mentioned that the pilot light used in the gas water-heater, used on the average 32 cents worth of gas per month. There are, on the other hand, some so-called automatic gas water-heaters, which require the constant burning of a pilot light, which are not quite so economical, but the smaller sizes of instantaneous heaters, in which the gas flame is controlled by a thermostat and cut down automatically to the smallest possible size, as soon as the water has attained the maximum required temperature, may be safely recommended for use.

In the laundries of many public institutions the heating of irons is economically effected by means of gas; the use of gas is likewise popular in tailoring and other industrial establishments. Gas is also used in households, for warming dishes in plate warmers, for the running of domestic pumping engines, and for purposes of ventilation to create a positive upward draught in exhaust flues.

The majority of advantages enumerated for gas used as fuel in cooking are equally true of the heating of rooms by means of gas stoves. But in one important respect there *is* a difference, because heating by gas, at present rates charged for manufactured gas, is somewhat expensive if applied to rooms or apartments which are constantly occupied, and which, therefore, require gas heating stoves or gas logs to be kept burning for many hours; in such cases the use of gaseous fuel costs more than warming by the use of coal or other fuel.

Nevertheless, there are numerous instances where the use of gas heating stoves is both convenient and comparatively economical, for instance in the heating of bathrooms, or of rooms not constantly occupied, as in hotels, where heat is only occasionally wanted. Here again, the same as in the case of cooking by gas, the chief superiority lies in the fact that no preparations for heating are required, that no fuel has to be carried in or ashes taken out and removed, that the apartments can be quickly heated, because the heat from the fully turned on burners becomes at once available, and that the heat can easily be regulated and quickly turned off, when not wanted any longer.

As an auxiliary heating method, heating by gas is advantageous, for there are days in the fall or spring of the year when one does not need to put the regular heating apparatus in operation; gas stoves and gas fireplace heaters are also useful in supplementing the regular steam, hot-water or furnace heat on extremely cold days, or for very exposed rooms; and, finally, heating by gas may be of much service in an emergency, for instance, if the coal supply has become exhausted at the time of a coal miners' strike, when coal cannot possibly be obtained at any price.

There are, finally, numerous uses of gaseous fuel in manufacturing industries, to which I can refer but very briefly.

Gas is utilized extensively as a source of power in the modern gas engine, and in many smaller industries and workshops this form of prime motor competes very successfully with the steam engine, principally on account of the low operating expenses and the small amount of attendance required. The smaller machines do not require the constant employment of a skilled and licensed engineer, hence are preferred for many purposes, except where the buildings must be heated by exhaust steam from steam engines. Gas engines are now made in many sizes, ranging from 0.5 horsepower to many hundred horsepower. In the last ten years great improvements have been made in the design and constructive details of gas engines, and in the simplification and increased strength of important working parts.

A gas engine consumes, according to size, on an average from 20 to 30 cubic feet of gas per horsepower-hour, at an expenditure of from 1.6 to 2.5 cents, whereas steam engines require from 5 to 10 pounds of coal per horsepower-hour, costing, with coal at $4 per ton, from 1 to 2 cents per hour, so that the cost of fuel, *per se*, is nearly the same. It is stated on good authority that more than one-tenth of the entire output of gas from gas works in Germany is used at present for the production of power.

It may be possible that in the future a still larger utilization of gaseous fuel may be brought about, if arrangements can be economically perfected for conducting cheap fuel gas from the large coal fields to the principal cities instead of adhering to the present practice of shipping the coal at expensive freight rates.

CHAPTER V.

THE ARRANGEMENT OF GAS PIPES IN BUILDINGS.

Gas piping may be defined as the art, or process, of fitting a building with pipes intended for gas supply. It designates the trade, or mechanical labor of cutting, fitting and putting together the pipes used for the conveyance of gas for lighting, for heating and cooking, or for power purposes. Gas fitters are skilled workmen who cut, fit and put up pipes, fittings and fixtures intended for gas lighting, or for the use of gaseous fuel for heat or power.

In former times, the gas piping of buildings in the United States was done by a special class of craftsmen or mechanics, and the gas fitters formed a trade entirely distinct from the plumbers. Nowadays, however, nearly all the gas piping done in buildings is carried out by plumbing contractors, though the journeymen, who do the work, are generally special gas-fitters. In exceptional instances, parts of the gas piping in houses are done by mechanics employed by the gas companies. Although this is a common practice in England and in some parts of the continent of Europe, it is not usual in the United States, except possibly in cases where gas companies do odd pieces of piping, such as may be required for a gas cooking or gas heating stove, furnished and installed by them.

When a building is to be piped for gas, the first thing to do is to make a correct layout of the piping on the several floors. This layout should be based upon the general plans of the architects, which should show the location of all the outlets required for gas, whether for light, heat or power. In order to determine the sizes of the gas service, of the risers, of the distributing lines, and of the branches to these outlets, it is necessary to ascertain at the beginning the number of gas flames required for light, and, where gas is used for fuel, to ascertain separately the number of gas stoves, gas ranges, gas logs and gas water-heaters, and to figure up their total maximum hourly gas consumption. In counting the number of gas outlets, it is necessary to take into account the number of burners, which will be required at each outlet.

The term "service pipe" is usually applied to that portion of the gas-pipe system of a building, which begins at the street gas-main and ends at the consumer's gas meter.

The gas service from the street main to the inside of the cellar is always put in by the gas company, and the custom of gas companies in American cities is not to charge the owner for the furnishing and laying of the service pipe.

Both the gas service-pipe and the gas meter remain the property of the gas company, and the latter's responsibility does not extend beyond them; in other words, in case of any trouble or defect in the gas supply of a house, the company looks only after the gas meter and the service pipe, and keeps both in repair or attends to the cleaning out of the same in case of stoppages, while it devolves upon the house owner to have the house pipes for the distribution of gas examined and kept in proper condition. Many gas companies, however, exercise a control over the gas pipes while they are being put into a building, and in one exceptional case, mentioned in Chapter XVI, the gas company issues and enforces rules regarding the proper manufacture of the gas fixtures.

The material for the main service-pipes from the street into the house is either cast- or wrought-iron pipe. Lead pipe is scarcely ever used for this purpose in the United States.

Cast-iron service pipes, with lead-caulked joints, are used only in the case of a very large building or a group of buildings, such as public institutions, which require gas pipes four inches in diameter and upward.

Large service pipes, up to and including three inches in diameter, are as a rule put in with wrought-iron, screw-jointed pipes, while for smaller services both lead and wrought iron are employed. Usually, wrought-iron, screw-jointed service pipe is preferred to lead, at least in the United States, probably because the lead pipe is liable to sag in the trench, unless well supported, and thus dips or traps are caused in the pipe, which may accumulate water of condensation, and thereby cause the flickering of the light, or may even cause the gas to cease flowing.

In the use of wrought-iron pipes, however, certain precautions should be observed for the protection of the pipe against corrosion. The pipes should be laid in trenches with a firm bottom, and their outside should be coated with asphalt or coal-tar pitch, particularly where they are laid in soils containing acid or alkaline residues, or in soils mixed with ashes, cinders, furnace slag or chemical refuse, all of which have a tendency to cause a quick destruction of the pipe by corrosion.

Gas service-pipes should always be laid with a good pitch, either toward the street main or toward the house, and depressions or low places in the pipe should be avoided, so that no condensed tarry vapor will remain in this portion of the pipe. It is equally necessary that such pipes be protected against frost, by laying them at a proper depth in the ground. Where gas service-pipes are necessarily exposed to the outer air, as sometimes does happen in crossing basement areas, they should be thoroughly wrapped with some non-conducting material such as is applied to steam pipes to prevent loss of heat. In addition to this, it is advisable to fasten over the pipe a slanting board, to prevent snow and ice from lodging on the pipe.

In laying gas service-pipes it is always advisable to place on the line a shut-off, operated by a long key from a box in the sidewalk near the curb, to control the gas supply to each house from the outside. While the shut-off is not a necessity in the case of private dwelling houses, it is required by all good building laws in the case of theaters, churches and all public buildings, and to this should be added schoolhouses, colleges, hospitals and asylums of all kinds, and workshops, factories, warehouses and large manufacturing establishments, all of which require large gas service-pipes. In case of a fire in any of these buildings it is important to have means to cut off the supply of gas from the outside. It is preferable to place this valve on the sidewalk near the curb, where it remains more accessible than when located in the pavement of the roadway.

All gas shut-offs on service pipes should be of the full diameter of the pipe, and of such construction that when full open they will not reduce the available inside diameter of the gas pipe; in other words, either gate valves or round-way stopcocks of steam metal should be used in preference to globe valves or to ordinary stopcocks.

The size of the service pipe is governed by the number of gas outlets to be supplied, or, what is the same thing, by the estimated total maximum hourly consumption of gas. In ascertaining this, the mistake should not be made of counting the number of gas *outlets* in the rooms, halls and staircases, but the exact number of burners to each outlet should be designated on the plans, and the size of pipe should be in proportion to the number of gas burners, a suitable allowance being made in addition for fireplace gas logs, cooking gas stoves, ventilating gas jets, supply to domestic gas motors, etc.

The rule should be laid down that no service pipe, even for the smallest house, should be less than one inch inside diameter, and it is, at this day, the practice of most gas companies to run nothing less than 1-inch gas services, and $1\frac{1}{4}$ inches would be even better. While these sizes are slightly larger than called for by the requirements of small dwellings, they will prove more satisfactory in the end, as larger services are not so liable to stoppages by naphthaline, while their cost is only a trifle more. It should also be borne in mind that large supply or service pipes act, to some extent, as governors in reducing the influence of a sudden closing of a number of burners. Besides, it often happens that additions are subsequently built to a house, or to a factory, and the gas service-pipes in such buildings often become insufficient and inadequate for the service which they have to perform, unless allowance has been made in the beginning for a possible increase in the number of burners. Larger buildings require service pipes from 2 to 4 inches in diameter.

The sizes of gas service-pipes may be computed from formulas for the flow of gas, which will be referred to later on, or they may be readily found in the elaborate and complete tables calculated from such formulas, a number of which are given hereafter. It is well to remember that where water gas or naphtha gas is used (the latter in gasoline gas or air machines for country houses) the sizes of pipes should be increased 15 to 20 per cent over those required for coal gas.

The following condensed table of sizes of service pipes answers for all practical purposes:

Burners.	Size of Service Pipe.
	Inches.
For 1 to 15	1
16 to 25	1.25
26 to 60	1.50
60 to 100	2
101 to 170	2.50
171 to 250	3

The material used almost universally for gas pipes within the building is standard welded wrought-iron gas pipe. A great deal of steel pipe is nowadays sold in the market, but this is much more brittle, and the threads do not cut so readily or so evenly on this kind of pipe. It is, therefore, always preferable to specify or to order "genuine" wrought-iron pipe. In some of the better class of work galvanized-iron pipe is used to prevent rust accumulations on the inside of the pipe.

Lead, tin and composition pipes are used to some extent in European cities, and chiefly in England, at least for the smaller sizes. The advantages of such pipes are, that owing to their greater interior smoothness they offer less resistance to the flow of gas, and that they do not corrode, but it is dangerous to run them in concealed places, for nails may accidentally be driven into them causing leaks. Bends in such pipes must be made with great care, otherwise the area of the pipe may be contracted.

Copper pipes are not recommended for gas piping, for it is said that a chemical compound of copper and acetylene may form as an incrustation in the pipes, where the gas supplied is insufficiently purified, and this compound may give rise to explosions.

Iron gas pipes are first cut to measure from the layout made by the gas-fitter; the ends are then threaded by means of sharp dies with standard threads. The burr due to the cutting must be carefully removed, and the pipe ends reamed out, since it tends to reduce the area of the pipe. The precaution is particularly important for smaller sizes of pipes.

The pipes are put together with screw joints and red lead. Fittings, such as sockets, elbows, bends, tees, crosses and reducers, are used for the running of branches, for making changes in direction, for providing the outlets for the fixtures, etc. The better and stronger fittings are malleable-iron fittings with beads or shoulders, but for sizes above two inches in diameter cast-iron fittings are used. Black fittings often have sandholes, and for this reason it is advisable to use nothing but galvanized fittings. In screwing up the pipe and the fittings, the joints should be made entirely gas-tight without using any lubricant other than oil, or possibly some red lead. Threads which permit the pipe to screw up to the shoulder of the fitting, while the joint is still loose, should be avoided. Red lead should be used sparingly so that it may not become squeezed into the inside of the pipe where it would cause an obstruction to the flow of gas, and a reduction in the clear bore of the pipe. Where it is used at all, it should be put on the pipe threads and not into the fittings. Before putting pipes together, they should be blown into and examined for obstructions, and it is a good practice to tap the pipe with a hammer to cause any rust flakes to fall off.

The practice, which was formerly quite a common one amongst gas-fitters, of making the joints tight by using gas-fitters' cement cannot be approved, for such cement is liable to crack and break off when cold; it may also become softened by the action of the gas, and if in the vicinity of steam or hot-air pipes, it is liable to melt. It is a good practice to prohibit entirely the use of gas-fitters' cement. Careless or unscrupulous mechanics often apply such cement, not only to leaky joints, but also to fittings having small sandholes. Where defective fittings are encountered, the only right thing to do is to reject the imperfect fittings and to use only those which are perfect.

Equally bad is the practice of filling up the gas pipes with water, or other liquid, or with diluted muriatic acid, to induce rusting up of the joints to make the piping tight. This practice, which generally leads to subsequent troubles, owing to the stopping up of the pipes with rust, should be forbidden, in view of the fact that there is always in old houses considerable accumulation of rust in pipe systems, even where the pipes have not been so treated.

Where iron gas pipes are bedded in cinder floor-fillings they should be painted on the outside with some protective coating to prevent corrosion from the outside.

Risers should be controlled by round-way stopcocks or soft-seat globe-valves, placed at the foot of the line, generally at the cellar ceiling.

When a gas-piping system is completed, its tightness should be tested by means of a force pump and a mercury gauge. The use of pressure or spring gauges is to be deprecated as they are hardly reliable for such low pressures as are applied in the testing of gas-piping systems.

Where good materials are used and put together by competent workmen, there is no difficulty whatever in getting the pipe system sufficiently tight to withstand a test equal to a pressure of 18 inches of mercury in the glass tube, equivalent to approximately 9 pounds pressure to the square inch. Should the mercury in the gauge drop, it is a sure indication that there are leaks somewhere. Such leaks are generally found by introducing some sulphuric ether into the pipes, or else by applying soapsuds with a brush to the outside of the joints and fittings, and waiting for the appearance of soap bubbles. Split pipes or defective fittings should be at once removed when discovered by the test. (See the Chapter on the Testing of Gas Pipes.)

Branches to side-wall burners are generally made 0.375 inch in diameter, and branches for chandeliers 0.5 inch. In the best practice no gas pipes smaller than 0.5 inch are used, and these are reduced at the outlet for the side-wall burners to 0.375 inch; in the same way the pipes for center lamps or chandeliers with more than four burners are made 0.75 inch in diameter. In Dresden, a municipal rule prescribes that all gas pipes which are not carried exposed should be not less than 0.75 inch. The rule is a good one, and might, with advantage, be adopted in the American gas-piping practices.

In laying out the system of main distributing pipes and branches to outlets, the endeavor should be to get an equal supply of gas, to arrange the distribution in a systematic manner and, wherever practical, to provide a circulation system, the advantages of which are particularly noticeable in larger buildings.

The greater the specific gravity of the gas, and the rougher the inside of pipes, the larger should they be. Gas-fitters are generally governed by some kind of table of pipe sizes, and in using these, it is well to bear in mind a possible future increase in the number of outlets. It is always advisable to be on the safe side, as a larger caliber of pipe is never an objection, but may be, at a future time, a decided benefit. In former years the gas companies used to give much more attention to this matter than at present, and each company had its own rules and regulations and tables of sizes, but only a few companies publish such tables at the present time. Some of these will be given in full further on. (See Chapter VII.)

Table I, on page 29, is a useful one for correctly proportioning the sizes of risers, distributing lines, and branches.

TABLE I.

Diameter of Pipe in Inches.	Length of Pipe in Yards.								
	20	30	40	50	60	70	80	90	100
0.50	7	6	5	4	4	4	3	3	3
0.75	17	14	12	10	10	9	8	8	7
1.00	32	26	22	20	18	17	16	15	14
1.25	52	43	37	33	30	28	26	25	23
1.50	79	64	56	50	45	42	39	37	35
2.00	150	123	106	95	87	80	75	71	67
	Number of Burners								

It is advisable to run several vertical gas-risers, in order to shorten the horizontal gas distribution. The main gas-risers should, if practicable, be kept accessible, or even exposed, in minor closets.

All gas pipes should be run with a continuous fall of at least 1 inch in 100 feet toward the gas meter, and the greatest care is necessary to insure that the entire gas-piping system is free from any low places or sags, where water or vapor of condensation may accumulate, for this interferes with the free flow of gas and causes the annoying "jumping" of the light.

Branches from running lines to ceiling outlets should not be taken directly from the bottom of a running line, because any water of condensation will run into the fixture and give trouble; it is much better practice to start these branches from the side or top of the running lines. In the same way, it is better to run bracket outlets up from below, which can be done on all floors, except the lowest floor of the building.

No gas pipes should be run through flues, nor should they be placed under hearthstones.

Where right-angled turns in horizontal piping are made, it is advisable to use plugged tees instead of elbows, as these fittings can be utilized in making changes or additions. The floor boards over such places should be fastened down with brass screws.

All outlets should be well strapped and fastened; all drop fixtures as well as the nipples for side-wall fixtures should be perfectly plumb or at right angles to the surface, from which they project. The nipples should be cut off the exact length for putting on the gas fixtures.

In order to measure the amount of gas consumed in buildings, gas companies furnish to their customers, and set, generally free of charge, a gas meter or instrument measuring the consumption of gas. The general construction and accuracy of these will be referred to in a later chapter. (See Chapter XVII.) It is usual to fit up the gas meter in a cool place in the cellar. The location of the meter should be such that the index of the same can be readily read by the gas companies' inspector. Where much gas is used for fuel purposes, in cooking or heating, and also where gaseous fuel is sold at a lesser price than gas for lighting purposes, many gas companies furnish and set a second meter, which registers the consumption for cooking, etc., separately from that for lighting a building.

In the best practice separate gas-service lines are run to all places where gas is to be consumed for either heating or cooking, and such branches are never taken from the nearest line which supplies gas for lighting.

A badly executed gas-lighting system is often one of the greatest troubles a house owner has to contend with; it leads to constant annoyances, and may cause injurious leaks and sometimes dangerous gas explosions. Gas piping costs but a very small fraction of the total cost of a building, hence it is advisable to have it done only by thoroughly competent and honest contractors.

In dwelling houses erected by speculative builders this work is usually done very badly. The lowest-priced gas-fitter is chosen; no specification is given for the work, and the fitter seldom takes the interest in his work which the importance of the subject requires. Being chiefly concerned with completing his contract as cheaply as possible, without regard to safety and efficiency, he buys pipes and fittings of inferior quality, and of insufficient size, employs mechanics without intelligence, experience or integrity, and compels them to do their work in a hurry, to use as little material as possible, while they in turn pay no attention to the proper laying, supporting and jointing of the pipes.

When the piping is completed the enterprising builder goes to the cheapest gas-fixture store, buys ill-constructed fixtures with inadequate tubing and inferior burners, and has these put up in a hurry. The buyer or occupant of the house soon encounters endless annoyances, resulting from the insufficient size of the gas pipes, from insufficient or careless support of pipes, from leaky joints, split pipes or fittings with sandholes. The gas will burn badly, the flames will jump, and there will be numerous leaks of gas. It is a matter of common occurrence that in such houses the piping has to be entirely reconstructed to get proper illumination, and to get rid of the gas leaks which endanger the health of the occupants and threaten gas explosions.

The following editorial is taken from *Building*:

"*Installation of Gas Pipes.*"

"If there is any one appliance more than another that is left to the discretion of the mechanic, it is the gas-fitting. Much time and care may be taken in selecting the fittings and choosing artistic brackets or chandeliers, but little thought is apt to be given to the general system of the mains, or the layout of the pipes. We have learned to study our plumbing and drainage carefully, but further than seeing that the pipes do not leak, there is little attention paid to the gas piping.

"In a lengthy letter to the *Boston Transcript*, Mr. J. Lyman Faxon, a well-known Boston architect, calls special attention to the danger from gas fixtures. Among all the appliances that enter into the complex make-up of the modern house, there is nothing, perhaps, that invites more danger and is attended with so many fatal accidents as gas. Every paper we pick up notes some case of asphyxiation from gas, involving the lives often of several individuals in a single casualty. These fatalities, due to asphyxiation, says Mr. Faxon,

'are directly attributable to two causes: (1) improper and unscientific installation of gas-pipe systems, resulting in inequality of pressure and distribution, and (2) to the carelessness of people in turning down the gas. In my judgment, he says, comparatively few cases of fatality are due to ignorant people blowing out the gas flame.'

"After explaining the nature of gas, its volatile character, he states that,

'the natural flow or direction of gas in pipes, when under pressure or free from obstructions, is upward and toward the freest combustion; it can be forced, by pressure, through down pipes, but if the pressure is unequal by reason of imperfectly disposed piping or by larger consumption at other points, its flow will be towards those parts of the system which are under greatest pressure or freest consumption. It is, therefore, of greatest consequence that the pressure in any system of pipes shall be equal and constant at all points. The pressure in vertical pipes increases about ten per cent for every thirty feet of rise, and a relaxation of pressure of about five per cent for every thirty feet down, so that the difference in pressure between two burners sixty feet apart, vertically, will be about fifteen per cent of the initial or normal pressure, which accounts for the extinguishing of the gas flame when turned down low; indeed, I have observed flames at full cock which could hardly hold their own against the air for lack of pressure in the system.'

"He condemns the present system of gas piping as being radically wrong, entirely inadequate, and dangerous. As may be inferred from the above, the pressure in the upper rooms of a building is much greater than in the lower, and a burner turned down in a lower room would easily blow out, where, under the pressure of gas in the upper rooms, it would hold its light. The present system is to take the main from the meter for the whole house to some central point in the basement, thence running a central riser to the top of building and then tapping this at each floor for its supply, carrying a branch pipe

'with tap circuits or feeders to the ceiling and wall fixtures to the story below, all ending in dead ends and rarely any subdivision of the system into individual circuits, and generally the outlet taps are taken off the bottom of all horizontal lines of piping, instead of off the side or top of the pipe, thus causing all such taps and the appended fixtures to constitute receptacles for impure condensation instead of providing for the return of condensation to the base, and further, with no provision whatever for equality of pressure throughout the entire system.'

"In illustrating the effect of this system, Mr. Faxon states the following hypothetical case, and one which is likely to occur in any building of three or more stories:

'For instance, time ten o'clock P.M., room on a lower floor. Occupant goes to bed, or ill and sleeping. Gas flame turned down to one quarter candlepower, windows and door closed, no ventilation. Twelve o'clock or later, party returns from theater with friends to room in top story, turns on all burners to full cock — Presto! Flame in lower room extinguished by indrawing of the flame into the pipe, caused by the excessive use of gas in upper rooms. In a few moments the draught is relieved and gas is ejected into the lower room through the open burner, and the occupant is asphyxiated in three or four hours, if the accident is not discovered.'

"This illustration explains many fatalities that have occurred from escaping gas, and shows the need of remodeling our present methods of gas piping. The following is Mr. Faxon's suggestion for piping a building:

'The proper system for installing gas pipes is as follows: (1) Each and every separate story or apartment in a house, hotel, office building or other, liable at any time to contain a sleeping occupant, should have its individual circuit from the base or initial circuit. (2) All gas heaters and gas stoves should have separate circuits from the initial source. (3) All corridor, hall, and vestibule outlets should have equalizing pressure pipes, making complete circuits throughout individual systems from individual sources, up, around and back to initial source. I have found in practice that the sizes of such equalizing pressure pipes need to be about five-eighths the size of the main supply circuits, and that proper installation costs 20 to 25 per cent more than under the old system. (5) The individual main circuit supply pipes should be taken off a properly calculated header or drum, and each circuit cut off by a suitable valve at the header. Thence the individual circuit should be run to a center of distribution of branch and tap circuits. All vertical pipes should be run up and not down, and all off-takes should be at the top or side of pipes, and in no case off the bottom. All piping should pitch toward the initial source for drip of condensation. The main circuit or supply pipe should be continued throughout and around the entire individual system, and returned from the farthest point to and connect with the base or initial circuit pipe. This is of the utmost importance.'

"The frequent accidents from asphyxiation from gas emphasize the necessity for special attention to this matter, and for the remodeling of our laws in this respect. The necessity for equalization of pressure in upper and lower stories is apparent, and this could, without doubt, be secured by such measures as suggested. With this provision no such accident as the case instanced by Mr. Faxon could occur. A remodeling of the laws for gas installation is evidently as much needed as are plumbing regulations."

. . . . .

In the *Engineering Record*, of September 22, 1894, appeared a lengthy editorial on this subject, and its importance must be my excuse for reprinting it here in full:

"*Gas Piping for Buildings.*"

"There are few features of modern building construction which do not receive thorough treatment when the design is fortunate enough to fall into the hands of competent engineers and architects, and yet there is one very important portion of the structural outfit, so to speak, of a building, which up to the present time receives no intelligent consideration whatever, except in very rare cases. We refer to the gas piping of buildings of all classes. The gas companies have made practically all possible advances in processes of manufacture and distribution, and while there may be unfairness in some exceptional instances, in the main the gas consumers have largely reaped the benefit of the resulting economies.

"Municipal building regulations have generally prescribed fairly wise and reasonable general rules under which buildings and their various structural appointments are to be constructed, but on the question of running gas lines for proper distribution within the buildings they have been essentially silent. Architects also virtually have turned over to gas-fitters, as a general statement, the whole question of fitting the buildings which come under their design and supervision. What ought to be everybody's business seems to have been nobody's business, and consequently there probably has never been any portion of the construction and fitting of a building which has exhibited more ignorance and gross blundering than the general run of the gas-pipe plans of many structures now standing, and that is saying a great deal. As is almost or quite the invariable result in such matters the purchaser and the consumer are the principal sufferers. It certainly is not creditable to the architect or engineer thus to fail to properly specify, or generally to specify at all, for so important a part of his work, and no municipal regulation can be considered as complete, either in its form or operation, unless it suitably covers a class of work which so immediately affects the comfort and health of almost every human being and the welfare of every business within its corporate limits. It is the legitimate desire, of course, of the gas-fitter to reduce the total cost of his work to a minimum for his client and he gets his work as the lowest bidder; hence the result is all but a universal decrease of size of pipes in a building far below those which ought to exist for a proper supply at the points of actual consumption. Besides, a lack of proper knowledge of design causes a very general and sometimes an utterly absurd disproportion between the main and running lines and branches, which results, in connection with the fundamental difficulties of small pipes, in excessive complaints from users in many instances, and in costly and inefficient, if usually unnoticed, illumination or heating, and very costly alterations and additions to the piping in the modern fireproof building.

"Indeed it cannot be expected that gas-fitting will be done carefully and efficiently or with materials and workmanship of excellent quality unless, like other branches of mechanical work, it is done under intelligent specifications, faithfully executed.

"It is true that there have been a few very creditable efforts to remedy this state of things, but they may be said almost to be included in the excellent little work by William Paul Gerhard,[1] and perhaps the unduly short printed regulations of one or two gas companies in the country, and they have not produced any apparent improvement in the general situation.

"Since the advent of high buildings with fireproof floors, and the demand for gas for cooking and heating has arisen, the embarrassment due to the causes cited has been more pronounced. In view, therefore, of the interests involved, the *Engineering Record*, in pursuance of its policy to elevate and advance all branches of building construction, submits to architects and engineers, as well as municipal authorities, a general system of specifications and rules under which buildings may be fitted with gas pipes so as to produce the greatest excellence in design and the most efficient and economical use of gas. After a very thorough examination of the whole question, and after many conferences with large firms of gas-fitters, engineers of gas works, and others directly interested in the attainment of the desired end, the specifications, tables, and rules, which we print in another column, have been prepared. These regulations have been made essentially to agree with the few best efforts which have already been made for the same purpose; they involve no conditions inconsistent with the best interests of gas consumers, gas producers, or gas-fitters, but they have been based upon such reasonable conditions as will secure in all respects the best practice to all those departments of gas interests. The tables showing the sizes required for the prescribed number of burners, logs, heaters, and ranges are based upon a very careful and thorough investigation, both analytical and experimental, in regard to the flow of gas through the pipes of the maximum lengths indicated. The resulting sizes are in some cases a little larger than hitherto prescribed, while in other cases they are not; but in all cases they will insure the free flow of the necessary volume of gas, and thus

[1] "Gas Lighting and Gas Fitting." Third edition.

entirely avoid the annoyances and loss due to too small pipes. The slight increase of cost of piping from this source is too small to be appreciable in the total cost of any building whatever.

"Should it be desired by architects or engineers, these general regulations can be easily supplemented by other clauses or paragraphs designed to cover special cases or details which it would not be proper or suitable to recognize in the concise regulations designed to meet the purposes of those which we print. We commend these specifications to the most careful and favorable consideration of architects, gas companies, and the building departments of cities. They have been carefully and rationally designed to fill a gap in building specifications and general regulations which has been the cause of most serious and widespread annoyance and loss."

"*Essential Requirements for the Gas Piping of Buildings.*"

(From the Engineering Record).

"As the result of a special investigation the following tables and recommendations are submitted as the basis for proper specifications for the gas piping of buildings to meet the demands of modern requirements for lighting, heating, cooking, and manufacturing:

TABLE II.

SIZES OF GAS PIPES, MAXIMUM LENGTHS AND MAXIMUM NUMBER OF BURNERS (AT 6 CUBIC FEET EACH).

Diameter of Pipe.	Maximum Length.	Maximum Number of Lights.
Inches.	Feet.	
$\frac{3}{8}$	20	2
$\frac{1}{2}$	30	3
$\frac{3}{4}$	40	6
1	60	10
$1\frac{1}{4}$	70	15
$1\frac{1}{2}$	100	30
2	150	60

TABLE III.

SIZES OF GAS PIPES FOR GAS LOGS AND COOKING RANGES.

Diameter of Pipe.	Maximum Length.	Gas Required for —
Inches.	Feet.	
½	100	1 cooking burner or 1 gas log.
¾	100	2 cooking burners or 2 gas logs.
1	100	Gas cooking stove with 4 burners or 4 gas logs.
1¼	100	Larger gas ranges or 7 gas logs.

Gas logs and burners of cooking ranges are assumed to have a consumption not exceeding 35 cubic feet per hour. For a larger consumption increase the size of pipe supplying log or range.

General Requirements.

1. All lines of piping throughout the building, except drops, must be laid with grade so as to drip or drain back into the risers, with no depressions to hold condensation. Drips with drip pipes where needed must be provided at meters and at such other points as the plan of piping may render necessary.

2. No riser must be less than three-fourths inch in diameter in any case, and all risers must be covered up on inside partitions so as to be thoroughly protected from freezing. Wherever risers or other pipes cannot be guarded in this manner, they shall be protected from frost by special and effective coverings.

3. Wherever practicable all piping shall be exposed, but piping that must be concealed shall first be thoroughly inspected by the gas company, and the gas-fitter shall give due notice when the piping is ready for inspection. Unexposed piping must be so concealed as to be readily accessible in case of examination or repairs. Wherever practicable, as in floors, the concealment shall be made by boards over the pipes, secured by brass or other non-corrosive screws.

4. In cases where extensions are made, care must be taken to extend with such sizes that the rules already prescribed shall be maintained.

5. All drop pipes must be left perfectly plumb and well secured in that position.

6. Long runs of piping must be firmly supported at frequent intervals so that no sagging nor depressions can occur in which condensation can collect.

7. If pipes run across wooden beams or joists the requisite cutting, notching, or boring shall never be more than 2 inches in depth nor more than 3 feet from bearings, and as near the latter as possible.

8. Lines of piping shall not be placed under tiled or parquet floors, marble or other stone or metal platforms, or under hearth stones, unless the local conditions render such procedures imperatively necessary.

9. All pipes shall be of the best quality of wrought-iron welded gas pipe, and all fittings, including couplings, elbows, bends, tees, crosses, reducers, etc., under 2 inches diameter, shall be extra heavy malleable fittings; those of larger diameter may be of cast iron. These pipes and fittings may be plain, galvanized, or made non-corrosive by any effective method.

10. Pipes and fittings are to be put together with screw joints and red lead, or red and white lead mixed, with joints made perfectly gas-tight.

11. All pipes shall be firmly and safely secured in position with hooks, wrought-iron straps, or hold-fasts, secured with screws at close intervals, so that continued use in proper line and grade may be effectively secured.

12. Meters shall be placed where they will be most conveniently accessible for reading the index and for examination and repairs, and when placed on the walls the minimum height above floors shall be 2 feet for the bottom of the smallest meters, and the maximum height shall be 8 feet for the top of the largest meters. The sizes of connections shall be as follows:

TABLE IV.

3-light	$\frac{3}{4}$ inch diameter	60-light	2 inch diameter
5-light	$\frac{3}{4}$ inch diameter	100-light	2 inch diameter.
10-light	$1\frac{1}{4}$ inch diameter	150-light	$2\frac{1}{2}$ inch diameter
20-light	$1\frac{1}{4}$ inch diameter	200-light	$2\frac{1}{2}$ inch diameter
30-light	$1\frac{1}{4}$ inch diameter	250-light	3 inch diameter
45-light	$1\frac{1}{2}$ inch diameter	300-light	4 inch diameter

13. The completed piping shall be tested by some competent authority, who shall give a written certificate of the results before any of it is covered at any point. All outlets shall be tightly capped and the whole system shall be tested preferably with a mercury gauge, or by a low-pressure spring gauge which

has been recently and authoritatively tested by a mercury column. When air is pumped into a completed system of pipes until the pressure reaches 12 inches of mercury and stands or remains stationary for five minutes, or if the column of mercury does not fall more than 1 inch per hour, the system may be considered satisfactorily tight. Otherwise leaks must be sought and stopped and the testing repeated until the preceding requirements are satisfied. While extensions to completed systems are made the same tests shall be applied to the extensions before they are put in use. In the case of large buildings the entire system may be tested in suitable sections."

. . . . .

I will close this chapter by giving a brief summary of points which building superintendents should bear in mind when the building is being piped for gas:

Summary of Chief Points to be Observed in Piping Buildings for Gas.

1. The layout of the pipe system to be arranged in ample and proportionate sizes according to the table of sizes of gas pipes for lamps, gas logs, gas cooking ranges, and for gas engines.

2. All gas pipes to run to fixture outlets as directly as possible. All pipes to be graded to get proper drainage back to the rising lines. No depression to exist in the running lines. All accumulation of condensation to be avoided. Drip pipes or emptying siphons to be put in wherever needed.

3. No gas riser to be less than 0.75 inch. All risers to be protected against cold and preferably to be placed on inside partitions. The use of several risers, and the shortening of horizontal distribution lines is recommended to avoid excessive cutting of timbers.

4. All large gas risers and distributing lines to be kept exposed wherever possible, or to be arranged so that they can be reached when future repairs or additions become necessary, without entailing damage to walls or floors. Smaller gas pipes, when to be concealed, to be first inspected and tested. All concealed pipes in floors to be rendered accessible by boards secured by brass screws.

5. All side outlets to be fed by risers rather than drop pipes where it is possible to do so.

6. Additions and extensions to the gas piping of a building to be governed as regards sizes and number of burners by the table.

7. All long horizontal runs of piping to be firmly supported.

8. Joists to be cut or notched not more than two inches in depth, nor more than two feet from bearing walls.

9. No gas piping to be placed under tile or parquet floors, marble, stone or metal platforms, or hearth stones.

10. The gas pipes to be of welded wrought-iron. The fittings under two inches to be extra-heavy beaded malleable-iron fittings, to be plain, galvanized, or otherwise made non-corrosive. Fittings larger than two inches to be of cast iron.

11. The joints in the piping to be screwjoints, to be made perfectly gas-tight. Red and white lead mixed to be used as a lubricant for the threads.

12. All gas pipes to be held securely in position by wrought-iron straps, hooks, hold-fasts, and screws.

13. Gas meters to be placed in accessible positions for the sake of the reading of the meter, but so as to be protected from injury. Gas meter connections to be of iron pipe; no lead connections to be used.

14. The gas-piping system, when completed, to be tested. All outlets to be tightly capped, and the whole piping to be tested by mercury gauge and air pump, the testing pressure to be from 12 to 18 inches of mercury (6 to 9 pounds per square inch); the gauge not to fall more than 0.25 inch per hour. All leaks to be sought and to be repaired and the test to be repeated. All extensions to be tested in the same way. All larger buildings to be tested in sections.

CHAPTER VI.

SPECIFICATION FOR GAS PIPING FOR COAL OR WATER GAS.

In piping a building for gas, it makes some difference whether the gas supplied is manufactured water or coal gas, or whether it is natural gas, machine-made air gas, or finally acetylene gas. In this chapter I give a specification prepared by me and suitable for manufactured city gas. In later chapters special specifications and rules are given governing the piping where other kinds of gas are intended to be used.

GAS–PIPING SPECIFICATION.

Gas Service. — To be of wrought-iron pipe, of ample size; to be run into the building with pitch back to street main, where possible; or else to be provided with siphon, or drip pipe and emptying plug, where service must necessarily be graded toward the house.

Gas service to be protected from frost wherever necessarily exposed.

Gas Meter. — To be preferably a dry gas meter; to be of ample size; all connections to be preferably of wrought-iron pipe and tube of full bore.

Fittings to be beaded malleable-iron fittings. No lead meter connections to be used.

Meter to be set in a cool, ventilated, well-lighted place, easy of access, but protected from accidental injury.

House Gas Pipes. — To be of a good quality of welded wrought-iron pipe, preferably galvanized.

Steel pipe, being somewhat brittle, is not so good; lead gas pipes should not be permitted.

Cast-iron pipe is sometimes used for services larger than 2.5 or 3 inches in diameter.

All pipe to be examined and blown into, before being used, to guard against obstructions.

Pipe Fittings. — To be of malleable iron, preferably beaded fittings; fittings to be selected and examined for sandholes; galvanized fittings to be preferred.

In making turns or bends, use fittings in preference to bending the pipe.

Joints. — To be screw joints. Use red and white lead mixed, or boiled linseed oil in joints.

Use precaution not to get any lead on the inside of joints.

No gas-fitters' cement to be used on joints under any circumstances.

The practice of rusting up the pipes by filling the gas pipes with water is bad, and should be prohibited.

Unions should be avoided, particularly in concealed gas piping; if required, use ground-joint union fittings.

No washer joints should be permitted.

All joints must be made absolutely tight.

Shut-Offs. — Use the best quality heavy brass work; round-way ground-key lever cocks are preferable to valves, as they indicate at once by position of lever, whether the pipe line is open or shut.

Valves, if used, should be soft-seat brass valves.

Iron valves are not to be permitted, as they quickly corrode from the action of the gas.

Hooks, Straps, and Clips. — All pipes to be well fastened by hooks, straps, or clips of wrought iron — not of cast iron.

Use screws for fastening pipe hold-fasts.

No bent nails or common hooks should be used to hold gas pipes in position.

Cutting of Floor Joists. — This should never be done by the gas-fitter.

The carpenter to do all the cutting, and beams should not be notched, bored, or cut more than two inches in depth, and never farther away from wall or bearing, supporting the beams, than two feet.

Sizes of House Pipes. — No pipe to be less than three-eighths inch; it is better to make 0.5 inch the minimum size.

In determining sizes of pipes, follow Table II for sizes of house pipes for gas lighting (see page 36), and Table III (see page 37) for sizes of gas pipes for gas ranges and gas logs.

Make all piping ample in size.

Arrangement of Gas Piping. — No risers to be placed in outside walls.

No riser to be less than 0.75 inch.

A number of separate risers is desirable; these should be connected at the top, for a better circulation of the gas, and also to avoid undue variation in the gas pressure.

Another method of accomplishing this is to have separate risers for each floor.

For gas logs in fireplaces, run entirely separate risers, one for each group of vertical fireplaces.

Provide a separate riser for the gas cooking range in the kitchen.

Provide a separate riser for the gas water-heater, also for the gas laundry-irons.

A separate meter for gas, used in cooking or heating is desirable.

Larger risers to be kept exposed in closets; smaller pipes to be tested before being covered up or plastered over.

Running lines in floors to be kept accessible by floor boards, secured with brass screws instead of nails.

Run all branches for side or wall fixtures up from below, and do not drop them from above (except in the cellar).

Place no running gas lines under tiled floors or hearths.

Run no gas pipes through flues.

Supply drop fixtures from branches, taken off from side or top of running lines; never drop the branch from the bottom of a line.

All horizontal gas pipes to be run with sufficient fall back to the riser; the horizontal run at cellar ceilings to have a fall toward the gas meter.

All long horizontal runs between floor beams to be well supported to avoid sagging and traps.

Avoid all condensation of gas in pockets or depressions.

Keep gas pipes and risers away from pipes or flues of the heating apparatus.

Gas Outlets. — Place no gas outlets behind doors or too near window trims or curtains.

Place outlets for side-wall fixtures at proper height, and center fixtures in the exact center of the room.

At completion of gas piping, check off all outlets from plans.

Make all nipples and drops plumb, and of proper length for the fixtures.

Test of Gas-Pipe System. — The entire gas piping, when completed, and before plastering is begun, to be tested by a gas-fitter with an air pump and a mercury gauge (22 inches long); spring gauges are not reliable.

Test the pipe system under a pressure equivalent to a column of mercury in gauge, 18 inches high (9 pounds pressure).

The mercury in the gauge must stand one hour without indicating a greater fall than 0.25 inch per hour.

All leaks and defects, which the test reveals, to be searched for with ether or by the application of soapsuds; the same to be made good by gas-fitter.

No split pipe or broken fitting, or fitting having sandholes, to be repaired with cement or solder.

In large buildings, test gas piping in sections.

After the test, have a number of capped outlets opened slowly, on each of the floors, to make sure by the falling of the mercury in the gauge that the entire piping has been under the test, and that no parts are accidentally or intentionally disconnected.

After test, leave all outlets capped tightly.

When alterations in the gas are made, or additional burners are put in, test the altered work in same manner as in the first test.

Before the gas fixtures are hung or put up, the gas-fitter is to repeat the test in the presence of the contractor for the gas fixtures, so as to demonstrate to him the tightness of the entire piping.

This leaves the fixture man responsible for any leaks discovered when the gas is first turned on at fixtures.

After fixtures are hung, the contractor for the fixtures to apply another pressure test, with three inches of mercury in the gauge.

CHAPTER VII.

RULES, TABLES AND REGULATIONS OF GAS COMPANIES AND OF BUILDING DEPARTMENTS.

ONE of the chief faults of gas piping, as commonly done by gas-fitters, is that *too much small pipe* is put into the work. To determine by calculation the sizes of pipe required, at least for the main risers and distributing lines, appears to the ordinary gas-fitter to be an ultra-refinement not worthy of a serious thought; but, worse than that, even the handy tables, gotten up for the purpose of rendering tedious calculations unnecessary, are neither consulted nor followed by him.

Before giving a number of rules and regulations of gas companies, I should, perhaps, discuss briefly the flow of gas through pipes, and the formula used to determine the theoretical discharge. Many of the tables, embodied in some of the rules given later on, should be used cautiously, because the sizes and gas discharges therein given apply to large and *smooth* pipes. For this reason the advice will be found in some of the tables to increase the sizes, in case rough or old iron pipes are used. The English tables generally are based upon the assumption that the gas pipes are of smooth lead, a material which is not used in the American practice of gas-fitting.

But even some of the American tables recently published (for instance those of the United Gas Improvement Co., of Philadelphia) have increased the required pipe sizes materially to make proper allowance for partial stoppages, due to gradual accumulations of rust and condensed naphthaline in the pipes.

The formula almost universally used for the flow of gas through pipes is that by Dr. William Pole, and reads as follows:

$$Q = 1350\, d^2 \sqrt{\frac{h \times d}{s \times l}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1).$$

in which formula

s = specific gravity of gas, air being taken as 1.00,
l = length of pipe in *yards*,
d = diameter of pipe in *inches*,
h = pressure of gas in inches of water,
Q = quantity of gas delivered in *cubic feet* per hour.

The specific gravity is often taken as equal to 0.40. For any other specific gravity the value of Q should be multiplied by 0.635 or $\sqrt{0.40}$, and divided by the square root of the specific gravity.

To find the theoretical diameter required for a given discharge, we derive from the above formula the following:

$$d = \sqrt[5]{\frac{Q^2 \times s \times l}{(1350)^2 \times h}} \quad \ldots\ldots\ldots\ldots \quad (2).$$

In making calculations of this kind it will be found convenient to make use of logarithmic tables, and in that case the above formula may be expressed:

$$\log d = 0.2\,[2 \log Q + \log s + \log l - 2 \log 1350 - \log h]. \ . \ (3).$$

The value of (d) so obtained applies only to large, new and smooth pipes. The discharge for small pipes is less than the calculated quantity, hence the value of (d) should be increased one-third for lead pipes, and at least one-half for iron pipes.

The following table, originally published by Clegg, and republished in Newbigging's Handbook, gives the diameter of pipes, in decimals of an inch, for the supply of a certain number of burners, each of 5 cubic feet per hour, under one inch pressure, at various distances from the main pipe:

The following example illustrates the manner in which the table is used. Suppose there are 50 burners to be supplied in a building at a distance of 150 feet from the main, then the tabular number opposite 150 and under 50 is 0.93688. Add to this 50 per cent for an iron pipe and we find 1.405, or a one and one-half-inch pipe, as the size required.

Experiments on the discharge of gas pipes tend to confirm the statement that the *actual discharge* is considerably *less* than the theoretical quantity deduced from the Pole formula (1). A

TABLE SHOWING THE DIAMETER OF PIPES, IN DECIMALS OF AN INCH, TO SUPPLY OUTLETS AT CERTAIN DISTANCES FROM THE MAIN.

Distances of Outlets from Main in Feet.	Number of Burners each consuming 5 cubic feet per hour, under a pressure of 1 inch (water).												
	3	5	10	15	20	25	30	40	50	100	150	200	300
	Diameter of pipes, in decimals of an inch.												
5	.15457	.18882	.24912	.29424	.32876	.35946	.38824	.43381	.47430	.62577	.73911	.82581	.97525
10	.17682	.21691	.28617	.33660	.37765	.41291	.44415	.49832	.54484	.71881	.83775	.94862	1.1157
15	.19176	.23524	.31034	.36504	.40956	.44779	.48167	.54041	.59086	.77954	.91693	1.0288	1.2099
20	.20311	.24916	.32872	.38666	.43381	.47429	.51019	.57241	.62585	.82571	.97123	1.0897	1.2815
30	.22027	.27020	.35649	.41932	.47045	.51438	.55329	.62076	.67872	.89546	1.0533	1.1817	1.3898
40	.23331	.28620	.37760	.44415	.49830	.54483	.58605	.65753	.71891	.94848	1.1156	1.2517	1.4721
50	.24396	.29927	.39483	.46441	.52105	.56970	.61280	.68753	.75172	.99177	1.1665	1.3089	1.5393
60	.25302	.31024	.40950	.48167	.54041	.59086	.63556	.71307	.77928	1.0286	1.2099	1.3574	1.5965
70	.26094	.32010	.42231	.49675	.55733	.60936	.65546	.73540	.80405	1.0608	1.2478	1.3999	1.6464
80	.26802	.32876	.43375	.51255	.57241	.62585	.67011	.75530	.82582	1.0895	1.2874	1.4378	1.6910
90	.27439	.33660	.44408	.52235	.58606	.64077	.68925	.77331	.84550	1.1155	1.3121	1.4721	1.7313
100	.28023	.34377	.45354	.53348	.59854	.65442	.70393	.78978	.86351	1.1394	1.3400	1.5035	1.7681
150	.30391	.37281	.49185	.57054	.64909	.70970	.76339	.85649	.93688	1.2356	1.4532	1.6305	1.9175
200	.32191	.39489	.52098	.61281	.68753	.75173	.80860	.90720	.99191	1.3088	1.5393	1.7270	2.0311
250	.33660	.41291	.54476	.64077	.71891	.78604	.84550	.94862	1.0371	1.3685	1.6095	1.8058	2.1238
300	.34901	.42825	.56507	.66457	.74561	.81523	.87691	.98389	1.0757	1.4197	1.6693	1.8729	2.2540

table, based on such experiments, is given by Hurst, which illustrates this:

DIAMETER OF PIPE 1 INCH.

(Discharge by Experiment.)

Length of Pipe in Yards.	10	20	30	50
Cubic feet per hour under 1 inch pressure	337	233	190	148
Cubic feet per hour under 1.25 inch pressure	368	260	212	164

DIAMETER OF PIPE 1 INCH

(Discharge by Pole Formula.)

Length of Pipe in Yards.	10	20	30	50
Cubic feet per hour, 1 inch pressure	675	476	389	301
Cubic feet per hour, 1.25 inch pressure . . .	738	522	427	329

in other words, the actual discharge was only *one-half* that given by the formula.

The smaller the gas pipes are, the greater is their liability to become obstructed with tarry matter, naphthalene, rust or water.

The following table was prepared by Dr. Schilling, the well-known gas expert of Munich, from actual experiments. It makes provision for the rusting of pipes, for friction in small pipes, and for a general surplus capacity of 25 per cent.

LENGTH OF PIPE IN FEET.

Inside Dia.	10	20	30	40	50	60	70	80	90	100
Inch.										
¼	1	...	...	...	...	...	...	...	...	...
⅜	4	3	2	1	...	...	...	...	...	...
½	10	7	5	4	3	2	1	...	...	...
¾	25	14	10	8	6	5	4	3	3	2
1	60	38	26	19	15	12	10	8	7	6
1¼	100	64	42	32	25	20	16	13	10	8
1½	150	95	65	48	37	30	25	20	16	13
2	350	228	156	114	90	70	60	50	40	25

Number of Burners at 5 cubic feet per hour each.

In making computations of discharges of gas pipes it will be found useful to bear the following *axioms* in mind:

1. The discharge of gas is doubled if the length of pipe is divided by four.

2. The discharge of gas is reduced to one-half if the length is increased four times.

3. The discharge of gas is doubled if the pressure of gas is increased four times.

4. The delivering capacity of a pipe of given diameter varies directly as the square root of the pressure and inversely as the square root of the length.

The specific gravity of the gas also has some effect on the volume delivered, for the formula shows that the smaller the specific gravity of the gas, the larger will be the discharge.

This is illustrated in the following table, which I take from the "Handbook of American Gas Engineering Practice," by M. Nisbet-Latta (1907). In this table the loss of head or pressure is in each case taken at 0.1 inch in 30 feet length.

TABLE OF CAPACITY OF GAS PIPES OF THE LENGTH AND DIAMETER GIVEN, IN CUBIC FEET PER HOUR FOR VARIOUS SPECIFIC GRAVITIES.

Diameter of Pipe in Inches.	Length of Pipe in Feet.	Specific Gravity: 0.42.	0.55.	0.68.
		Cubic Feet per Hour.	Cubic Feet per Hour.	Cubic Feet per Hour.
$\frac{3}{8}$	20	18	16	14
$\frac{1}{2}$	30	37	32	29
$\frac{3}{4}$	50	101	88	80
1.0	70	210	180	162
$1\frac{1}{4}$	100	360	310	280
$1\frac{1}{2}$	150	577	500	450
2.0	200	1200	1030	930
$2\frac{1}{2}$	300	2050	1800	1610
3.0	450	3300	2850	2560

As a rule, tables of gas pipes give the number of burners which can be supplied from a pipe of given size and length, under a certain pressure of gas. In many respects, it is much more convenient to have the tables express the number of cubic feet of gas which pipes are capable of discharging per unit time. This is so, for instance, in the table below, quoted from an English book by Grafton.

TABLE SHOWING THE NUMBER OF CUBIC FEET OF GAS PER HOUR SUPPLIED FROM PIPES OF DIFFERENT DIAMETERS AND LENGTHS UNDER 10/10 INCHES PRESSURE.

(W. GRAFTON.)

Diameter of Pipe.	Length of Pipe in Feet.				
	45	75	150	225	300
Inch.					
½	44	40	37	32	27
¾	114	108	95	78	67
1	223	212	187	152	128
1¼	388	368	323	263	222
1½	613	590	507	413	345
2	1280	1225	1070	880	750
2½	2220	2115	1820	1520	1270
3	3497	3330	2880	2370	1975
4	7170	6800	5875	4820	4025

If it is proposed to use a burner of a certain size, consuming a certain number of cubic feet per hour, divide the cubic feet in the table by the capacity of the burner per hour; the result is the number of burners, which can be supplied by a pipe of certain size and length.

Should the gas pressure exceed 10/10 inches of water, apply the rule that the carrying capacities of pipes are increased directly as the square root of the pressure, and inversely as the square root of the length.

See also Table on page 77.

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GAS-PIPING RULES OF THE OLD MANHATTAN GAS COMPANY OF NEW YORK.

Size of Tubing.	Greatest Length Allowed.	Greatest No. of Burners.	Size of Meters.	Greatest No. of Burners.
¼ inch	6 feet	1 burner	3-light	6 burners
⅜ inch	20 feet	3 burners	5-light	10 burners
½ inch	30 feet	6 burners	10-light	20 burners
¾ inch	50 feet	20 burners	10-light	40 burners
1 inch	70 feet	35 burners	30-light	60 burners
1¼ inch	100 feet	60 burners	45-light	90 burners
1½ inch	150 feet	100 burners	60-light	120 burners
2 inch	200 feet	200 burners	100-light	200 burners

In the following pages, I give a compilation of a number of rules and regulations of different American cities, my purpose in doing so being to give a true picture of the present American practice of piping buildings for gas. A few rules and tables from English, French and German gas-engineering practice are added for the sake of comparison.

SPECIFICATIONS OF THE CONSOLIDATED GAS COMPANY OF NEW YORK FOR HOUSE PIPING.

The following specifications for gas piping should be observed, in order to secure the company's acceptance and certificate:

1. The piping must be tight under a pressure of 10 inches of a mercury column. This test will be made before the fixtures are hung, and after the piping is closed in.

The use of cement for repairs to leaks is to be avoided.

2. The sizes of pipe shall not be less than those called for in the following table:

Size of Pipe.	Greatest Length Allowed.	Greatest Number of Burners.
3/8 inch	20 feet	3 burners
1/2 inch	25 feet	6 burners
3/4 inch	40 feet	20 burners
1 inch	60 feet	30 burners
1 1/4 inch	100 feet	60 burners
1 1/2 inch	150 feet	100 burners
2 inch	200 feet	200 burners
2 1/2 inch	300 feet	300 burners
3 inch	450 feet	400 burners
4 inch	600 feet	700 burners

The foregoing table shows, for any given number of outlets, the greatest length allowed for each size of pipe.

The following rules should also be observed:

3. No house riser shall be less than 0.75 inch.
4. No house pipe shall be less than 0.375 inch.
5. No branching for a range shall be smaller than 0.5 inch.
6. Gas is never to be supplied from a smaller pipe to a larger one.
7. No pipe smaller than 0.5 inch shall be used between outlet of meter and outlet of range pipe.
8. Piping must be free from obstructions.
9. Of any given size pipe, do not run a longer length than the longest length given in the table for that size.

10. In figuring out the size of pipe, always start at the outlets, or extremities of the system, and work toward the meter.

11. White lead or other joining material should be used sparingly so as not to clog the pipe.

12. All pipe should be blown through after being connected, to make sure it is clear.

13. The piping must be free from traps.

14. All pipe should grade back toward the riser, and thence to the meter.

15. Pipe laid in a cold, damp place should be properly dripped and protected.

16. The riser must be extended to a point within 24 inches of the proposed location of the meter.

17. In piping new houses the gas company is to decide where the gas meter should be located, and the fitter shall extend the riser to terminate within 2 feet of this point.

18. The location of meters shall not be under stoops or sidewalks, near furnaces or ovens, or such as to render the meter inaccessible or liable to injury.

19. When, to accommodate different tenants, one or more meters are desired in a given building, the company will set as many meters as there are separate consumers, connecting the meters to one service pipe, provided that the risers or pipes leading to these different tenants are extended to within 2 feet of the location of the meters.

20. As far as possible, meters should stand side by side in the cellar or basement, and fitters should obtain from the gas company the proper size of the meter to set, and also the spacing for outlets in header.

21. Risers should not be scattered, but should drop together in alignment to the cellar or basement. They should not extend more than 3 inches below the ceiling, and they should be kept at least 3 inches apart.

22. No elbow should be put on the bottom of any riser or rising service, but the bottom of all risers should have a " T."

23. In making outlets, always use fittings; do not bend the pipe.

24. Unions should not be used in concealed work.

25. Long runs of horizontal pipe should be firmly supported at short intervals to prevent sagging.

26. All branch outlet pipes should be taken from the sides or tops of running lines, never from below.

27. Bracket lines should be run up from below when practicable.

Rules 28, 29 and 30 are omitted, being the same as those on page 57 of the Philadelphia Rules.

31. The use of galvanized pipe for gas is to be avoided on account of the chemical action between the condensation in the gas and the covering on the pipe, which has a tendency eventually to result in the obstruction of the pipe.

32. Galvanized iron fittings are not so objectionable, as the galvanizing tends to close the pores, which are frequent in malleable or cast-iron fittings.

33. In piping residences a 0.5-inch line, or preferably a 0.75-inch line should be run from a point near the meter to the kitchen, to provide for a gas range. This line should terminate about 15 inches from the floor, when protruding from a wall.

34. In piping for prepayment meters in buildings which have on a floor four families, the following plans should be carried out: The pipe from the service to the bottom of the front riser should be 1.25 inches; from the bottom of the front riser to the bottom of the rising services it should be 1 inch, to within two floors of roof, where 0.75 inch may be substituted. All openings to be left shall be at least 0.5 inch.

35. Prepayment meters will not be set in bedrooms; and all prepayment meters must be set within the apartment.

36. Before piping a building for prepayment meters, fitters should consult the gas company to avoid mistakes.

37. The running of gas pipes on the inside of outside walls is to be avoided as much as possible; owing to the exposed location, they are easily stopped by frost, and are often a source of annoyance during the cold weather.

38. When the fitter has completed the system of piping, made the test, and found the pipes tight, he should promptly notify the company. An appointment will be made, and the company's inspector will call and witness the test. If the pipes are found tight, the following certificate will be issued:

39. This is to certify that the Consolidated Gas Company of New York, has inspected the piping at No. —— ———— Street, and has found it to be gas-tight.

As any injury may occur to the piping subsequent to this inspection, its future soundness is not guaranteed.

CONSOLIDATED GAS COMPANY OF NEW YORK.

Date———— By————————*Inspector.*

40. During the inspection, the fitter or his representative must be present.

FROM SUPPLEMENT TO RULES FOR PLUMBING AND DRAINAGE ADOPTED BY THE BUREAU OF BUILDINGS FOR THE BOROUGH OF MANHATTAN, CITY OF NEW YORK.

Gas Piping and Fixtures.

1. Hereafter the gas piping and fixtures in all new buildings, and all alterations and extensions made to the gas piping or fixtures in old buildings, must be done in accordance with the following rules, which are made in accordance with the provisions of Section 89 of the Building Code.

For additional requirements of public buildings, theaters, and places of assemblage, see Part XXI, of the Building Code.

2. Before the construction or alteration of any gas piping in any building or part of any building, a permit must be obtained from the Superintendent of Buildings. This permit will be issued only to a registered plumber. Application must be made and complete floor plans filed, showing each and every outlet, and the number of burners to go on each outlet before beginning work. Small alterations may be made by notifying the Bureau of Buildings, using the same blank forms provided for alterations and repairs to plumbing.

3. All gas pipe shall be of the best quality wrought iron, and of the kind and weight classed as standard pipe.

No pipe allowed of less than 0.375 inch in diameter.

4. All fittings (excepting stopcocks or valves) shall be of malleable iron. All bends or angles in the piping system must be made by means of fittings. The bending of pipes will not be permitted.

5. There shall be a heavy brass straightway cock or valve on the service pipe immediately inside the front foundation wall. Iron cocks or valves are not permitted.

6. Where it is not impracticable so to do, all risers shall be left not more than five feet from front wall.

7. No pipe shall be laid so as to support any weight (except fixtures) or be subjected to any strain whatsoever. All pipe shall be properly laid and fastened to prevent becoming trapped, and shall be laid, when practicable, above timbers or beams instead of beneath them.

Where running lines or branches cross beams, they must do so within thirty-six inches of the end of the beams, and in no case shall the said pipes be let into the beams more than two inches in depth.

Any pipe laid in a cold or damp place shall be properly dripped, protected, and painted with two coats of red lead and boiled oil, or tarred.

8. No gas pipe shall be laid in cement or concrete unless the pipe or channel in which it is placed is well covered with tar.

9. All drops must be set plumb and securely fastened, each one

having at least one solid strap. Drops and outlets less than 0.75 of an inch in diameter shall not be left more than one inch below plastering, centerpieces, or woodwork.

10. All outlets and risers shall be left capped until covered by fixtures.

11. No unions or running threads shall be permitted. Where necessary to cut out to repair leaks or make extensions, pipe shall be again put together with right and left couplings.

12. No gas-fitters' cement shall be used, except in putting fixtures together.

13. All gas brackets and fixtures shall be placed so that the burners of the same are not less than three feet below any ceiling or woodwork, unless the same is properly protected by a shield, in which case the distance shall not be less than eighteen inches.

14. No swinging or folding gas brackets shall be placed against any stud, partition or woodwork.

15. No gas bracket on any lath and plaster partition or woodwork shall be less than five inches in length, measured from the burner to the plaster surface or woodwork.

Gas lights placed near window curtains or any other combustible material shall be protected by a proper shield.

14. Gas outlets for burners shall not be placed under tanks, back of doors, or within four feet of any meter.

15. All buildings shall be piped according to the following scale:

Diameter.	Length.	Burners.	Diameter.	Length.	Burners.
⅜ inch . . .	26 feet	3	1½ inch . . .	150 feet	100
½ inch . . .	36 feet	6	2 inch . . .	200 feet	200
¾ inch . . .	60 feet	20	2½ inch . . .	300 feet	300
1 inch . . .	80 feet	35	3 inch . . .	450 feet	450
1¼ inch . . .	110 feet	60	4 inch . . .	600 feet	750

16. Outlets for gas ranges shall have a diameter not less than required for six burners, and all gas ranges and heaters shall have a straightway cock on service pipe.

17. When brass piping is used on the outside of plastering or woodwork it shall be classed as fixtures.

18. All brass tubing used for arms and stems of fixtures shall be at least No. 18 standard gauge and full size outside, so as to cut a full thread. All threads on brass pipe shall screw in at least five-sixteenths of an inch. All rope or square tubing shall be brazed or soldered into fittings and distributors, or have a nipple brazed into the tubing.

19. All cast fittings, such as cocks, swing joints, double centers, nozzles, etc., shall be extra heavy brass. The plugs of all cocks must be ground to a smooth and true surface for their entire length, be free from sand-

holes, have not less than 0.75 of an inch bearing (except in cases of special design), have two flat sides on the end for the washer, and have two nuts instead of a tail screw. All stop-pins to keys or cocks shall be screwed into place.

20. After all piping is fitted and fastened, and all outlets capped up, there must be applied by the plumber, in the presence of an Inspector of the Bureau of Buildings, a test with air to a pressure equal to a column of mercury six inches in height, and the same shall stand for five minutes; only mercury testing gauges shall be used. No pipes shall be covered up, nor shall any fixture, gas-heater or range be connected thereto until a card showing the approval of this test has been issued by the Superintendent of Buildings.

21. No meter will be set by any gas company until a certificate is filed with them from the Bureau of Buildings certifying that the gas pipes and fixtures comply with the foregoing rules.

22. When for any reason it may be impracticable to comply strictly with the foregoing rules, the Superintendent of Buildings shall have power to modify their provisions so that the spirit and substance thereof shall be complied with. Such modification shall be indorsed upon the permit over the signature of the Superintendent of Buildings.

. . . . .

OTHER SECTIONS OF THE BUILDING CODE APPLICABLE TO GAS PIPING.

Gas and Water Pipes.

Every building other than a dwelling house, hereafter erected, and all factories, hotels, churches, theaters, schoolhouses, and other buildings of a public character now erected, in which gas or steam is used for lighting or heating, shall have the supply pipes leading from the street mains provided each with a stopcock placed in the sidewalk at or near the curb, and so arranged as to allow of shutting off at that point.

No gas, water, or other pipes which may be introduced into any building shall be let into the beams unless the same be placed within thirty-six inches of the end of the beams; and in no building shall the said pipes be let into the beams more than two inches in depth.

All said pipes shall be installed in accordance with the rules and regulations prescribed by the Board of Buildings.

All gas brackets shall be placed at least three feet below any ceiling or woodwork, unless the same is properly protected by a shield; in which case the distance shall not be less than eighteen inches.

No swinging or folding gas bracket shall be placed against any stud, partition or woodwork.

No gas bracket on any lath-and-plaster partition or woodwork shall be less than five inches in length, measured from the burner to the plaster surface or woodwork.

Gas lights placed near window curtains or any other combustible material shall be protected by a proper shield.

. . . . .

Gas-Piping Regulations for Theaters and Places of Assembly.

Every portion of the building devoted to the uses or accommodation of the public, also all outlets leading to the streets, and including the open courts and corridors, shall be well and properly lighted during every performance, and the same shall remain lighted until the entire audience has left the premises. All gas or electric lamps in the halls, corridors, lobbies, or any other part of said buildings used by the audience, except the auditorium, must be controlled by a separate shut-off, located in the lobby and controlled only in that particular place.

Gas mains supplying the building shall have independent connections for the auditorium and the stage, and provisions shall be made for the shutting off of the gas from the outside of the building.

When interior gas lamps are not ignited by electricity, other suitable appliances, to be approved by the Bureau of Buildings, shall be provided.

All suspended or bracket burners surrounded by glass, in the auditorium, or in any part of the building devoted to the public, shall be provided with proper wire netting underneath woodwork, ceiling, or in any part of the building, unless protected by fireproof materials.

All burners in passages and corridors in said buildings, and wherever deemed necessary by the Bureau of Buildings, shall be protected with proper wire network.

The footlight burners, in addition to the wire network, shall be protected with a strong wire guard and chain, placed not less than two feet distance from said footlight burner, and the trough containing said footlight burners shall be formed of and surrounded by fireproof materials.

All border light burners shall be constructed according to the best-known methods, and subject to the approval of the Bureau of Buildings, and shall be suspended for ten feet by wire rope.

All ducts or shafts used for conducting heated air from the main chandelier, or from any other burner or burners, shall be constructed of metal and made double, with an air space between.

All stage burners shall have strong metal wire guards or screens not less than ten inches in diameter, so constructed that any material in contact therewith shall be out of reach of the flames of said burners, and must be soldered to the fixture in all cases.

The stand pipes, gas pipes, electric wires, hose, footlight burners, and all apparatus for the extinguishing of fire or guarding against the same, as in this section specified, shall be in charge and under control of the Fire Department; and the Commissioner of the said department is hereby directed to see that the arrangements in respect thereto are carried out and enforced.

SPECIFICATIONS OF THE UNITED GAS IMPROVEMENT COMPANY, PHILADELPHIA, FOR HOUSE PIPING FOR GAS.

The gas-pipe system must stand a pressure of 3 pounds per square inch, or 6 inches of a mercury column, without showing any drop in the mercury column of the gauge, for a period of 10 minutes. After the fixtures are in place, the piping and fixtures must stand the same test. Leaky fittings or pipes must be removed; cement-patched material will be rejected.

The sizes of pipe shall not be less than those called for in the table. This table shows for any given number of outlets the greatest length allowed for each size of pipe.

The piping must be free from obstructions. Every piece of pipe should be stood on end and thoroughly hammered and blown through before being connected. Use white lead, or other jointing material sparingly, to avoid clogging the pipe. Always put jointing material on the male thread on end of pipe, and *not in the fitting.* The use of gas-fitters' cement is prohibited. All piping should be blown through after being connected, to make sure it is clear.

The piping must be free from traps. All pipes shall grade back toward the riser, and thence to the meter; use a spirit level in grading. Any pipe laid in a cold or damp place should be properly dripped and protected.

The pipes must be rigidly supported by hooks and straps. Outlets for brackets or drops must be secured by straps or flanges, which are nailed or screwed to the woodwork. Where the walls are of masonry they should be plugged and the straps fastened to the plugs.

The riser must extend to a point within 24 inches of the proposed location of the meter, and if a horizontal line is needed, a tee, with a plug looking down, must be put on the bottom of the vertical pipe. In piping new houses, the gas-fitter should decide where the gas meter ought to be located, and extend the riser to terminate within 24 inches of this point. In determining the proper location of the meter, he should be guided by the following:

Meters will not be located under stoops, sidewalks, or shop windows; near furnaces or ovens; locked in compartments, nor placed in any other situation where they will be inaccessible, or liable to injury.

If the building is on a street corner, the company should be asked from which street the service will be run, and where the meter should be located. If at any time the fitter is in doubt as to the future location of a meter, on application to the proper office, some one will be sent to instruct him.

Where more than one meter is desired in a given building, to accomodate different tenants, the company will set as many meters as there are separate consumers, connecting them to the one service pipe, provided that the risers, or pipes leading to the different tenants, are extended to within a reasonable distance (say 6 feet) of the actual or proposed location of service. All the meters must stand side by side in the cellar or basement, within view of the end of the service. The company will not set meters on the different floors of a building. Risers must not be scattered, but must drop together to the cellar or basement, preferably in the front part of the building. They should not extend more than 3 inches apart. They must never end in such a place that beams, girders, heater pipes, etc., to be put up subsequently, would prevent making connections to the meter.

Always use fittings in making turns; do not bend the pipe. Do not use unions in concealed work; use long screws, or right-and-left couplings. Long runs of approximately horizontal pipe must be firmly supported at short intervals, to prevent sagging. All branch outlet pipes must be taken from the sides or tops of running lines, never from below. Bracket lines must be run up from below; never drop them from overhead, except in lowest floor or cellar of buildings.

Where pipes pass through masonry walls they must be encased, the gas pipe resting on the bottom of the casing pipe, with a clearance of half an inch at the top.

Pipes must be run and covered so as to be readily accessible. Do not run them at the bottom of floor beams, which are to be lathed and plastered. They must be securely attached to the top of the beams, which should be cut out as little as possible. Where pipes are parallel to beams, they must be supported by strips nailed between two beams. These strips must not be over 4 feet apart. All cutting of beams should be done as near as possible to the ends, or supports, of the beams. Pipes must not be laid beneath tiled or parquet floors, under marble platforms, or under hearth stones, where it can be avoided. Floor boards or pipes should be fastened down by screws, so that they can readily be removed.

TABLE SHOWING THE CORRECT SIZES OF HOUSE PIPES FOR DIFFERENT LENGTHS OF PIPES, AND NUMBERS OF OUTLETS.

No. of Outlets.	Length of Pipes in Feet.								
	$\frac{3}{8}$-In. Pipe.	$\frac{1}{2}$-In. Pipe.	$\frac{3}{4}$-In. Pipe.	1-In. Pipe.	$1\frac{1}{4}$-In. Pipe.	$1\frac{1}{2}$-In. Pipe.	2-In. Pipe.	$2\frac{1}{2}$-In. Pipe.	3 In. Pipe.
1	20	30	50	70	100	150	200	300	400
2	...	27	50	70	100	150	200	300	400
3	...	12	50	70	100	150	200	300	400
4	...	...	50	70	100	150	200	300	400
5	...	...	33	70	100	150	200	300	400
6	...	...	24	70	100	150	200	300	400
8	...	...	13	50	100	150	200	300	400
10	...	...	...	35	100	150	200	300	400
13	...	...	...	21	60	150	200	300	400
15	...	...	...	16	45	120	200	300	400
20	...	...	...	...	27	65	200	300	400
25	...	...	...	...	17	42	175	300	400
30	...	...	...	...	12	30	120	300	400
35	...	...	...	...	...	22	90	270	400
40	...	...	...	...	...	17	70	210	400
45	...	...	...	...	...	13	55	165	400
50	...	...	...	...	...	...	45	135	330
65	...	...	...	...	...	...	27	80	200
75	...	...	...	...	...	...	20	60	150
100	...	...	...	...	...	...	...	33	80
125	...	...	...	...	...	...	...	22	50
150	...	...	...	...	...	...	...	15	35
175	...	...	...	...	...	...	...	...	28
200	...	...	...	...	...	...	...	...	21
225	...	...	...	...	...	...	...	...	17
250	...	...	...	...	...	...	...	...	14

This table is based on the well-known formula for the flow of gas through pipes. The friction, and therefore the pressure necessary to overcome the friction, increases with the quantity of gas that goes through per unit time, and as the aim of the table is to have the loss in pressure not exceed one-tenth of an inch water-pressure in thirty feet, the size of the pipe increases in going from an extremity toward the meter, as each section has an increasing number of outlets to supply. The quantity of gas the piping may be called on to pass through is stated in terms of 0.375-inch outlets, instead of cubic feet, outlets being used as a unit instead of burners, because at the time of first inspection the number of burners may not be definitely determined. In designing the table, each 0.375-inch outlet was assumed as requiring a supply of ten cubic feet per hour.

How to Use the Table.

In using the table observe the following rules:

1. No house riser shall be less than 0.75 inch. The house riser is considered to extend from the cellar to the ceiling of the first floor. Above the ceiling the pipe must be extended of the same size as the riser, until the first branch line is taken off.

2. No house pipe shall be less than 0.375 inch. An extension to existing piping may be made of 0.25-inch pipe to supply not more than one outlet, provided said pipe is not over six feet long.

3. No gas range shall be connected with a smaller pipe than 1 inch.

4. In figuring out the size of pipe, always start at the extremities of the system and work toward the meter.

5. In using the table, the lengths of pipe to be used in each case are the lengths measured from one branch or point of juncture to another, disregarding elbows or turns. Such lengths will be hereafter spoken of as "sections." No change in size of pipe may be made except at branches or outlets, each "section," therefore, being made of but one size of pipe.

6. If any outlet is larger than 0.375 inch, it must be counted as more than one, in accordance with the schedule below:

	In.	In.	In.	In.	In.	In.	In.	In.
Size of outlet . .	0.5	0.75	1.0	1.25	1.5	2.0	2½	3
Value in table . .	2	4	7	11	16	28	44	64

7. If the exact number of outlets given cannot be found in the table, take the next larger number. For example, if 17 outlets are required, work with the next larger number in the table, which is 20.

8. If, for the number of outlets given, the exact length of the "section" which feeds these outlets, cannot be found in the table, the next larger length corresponding to the outlets given must be taken to determine the size of the pipe required. Thus, if there are 8 outlets to be fed through 55 feet of pipe, the length next larger than 55 in the 8-outlet line in the table is 100, and as this is in the 1.25-inch column, that size pipe would be required for 7 outlets.

9. For any given number of outlets, do not use a smaller size pipe than the smallest size that contains a figure in the table for that number of outlets. Thus, to feed 15 outlets, no smaller size pipe than 1-inch may be used, no matter how short the "section" may be.

10. In any piping plan, in any continuous run from an extremity to the meter, there may not be used a longer length of any size pipe than found in the table for that size, as 50 feet for 0.75-inch, 70 feet for 1-inch, etc. If any one "section" would exceed the limit length, it must be made of larger pipe. Thus 6 outlets could not be fed through 75 feet of 1-inch pipe, but 1.25-inch would have to be used.

When two or more successive "sections" work out to the same size of pipe, and their total length or sum exceeds the longest length in the table for that size of pipe, make the "section" nearest the meter of the next larger size. For example, if we have 5 outlets to be supplied through 45 feet of pipe, we should find by the table that 10 outlets through 30 feet would require 1-inch pipe, and that 5 outlets through 45 feet would also require 1-inch pipe, but as the sum of the two "sections," 30 plus 45 equals 75 feet, is longer than the amount of 1 inch, that may be used in any continuous run, the 30-foot section, being the one nearer the meter, must be made of 1.25-inch pipe.

The application of the limit in length of any one size in a continuous run may also be shown as follows: Eight outlets will allow of 13 feet of 0.75-inch pipe in the section between the eighth and ninth outlet (counting from the extremity of the system toward the meter), provided that this 13 feet added to the total length of $\frac{3}{4}$-inch pipe, that may have been used between the extremity of the run, and the eighth outlet, does not exceed 50 feet, which, according to the table, is the greatest length of 0.75-inch allowable in any one branch of the system. Therefore, up to the eighth outlet, 37 feet of 0.75-inch pipe could have been used, and yet allow 13 feet of 0.75-inch to be used in the section between the eighth and ninth outlet. If more than 37 feet had been used, then the entire 13 feet between the eighth and ninth outlets would have to be of 1-inch pipe.

11. Never supply gas from a smaller size pipe to a larger one. If we have 25 outlets to be supplied through 200 feet of pipe, and these 25 and 5 more, making 30 in all, through 100 feet of pipe, we should find by the table that 25 outlets through 200 feet would require $2\frac{1}{2}$-inch pipe, and 30 outlets through 100 feet would require 2-inch pipe, but as under this condition a 2-inch pipe would be supplying a 2.5-inch, the 100-foot section must be made 2.5-inch.

CIRCULAR OF THE BOSTON GAS LIGHT COMPANY TO GAS-FITTERS ON RULES FOR GAS PIPING (SEPTEMBER, 1890).

In order to secure an uninterrupted flow of gas, it is deemed proper to require adherence to a Table and Regulations. This table is identical with the one formulated by the New York City Building Department.

Note. It will be noticed that no greater length of pipe of each size is allowed than that specified in the list; and that no more burners can be taken from any size than the number stated, even if the length of pipe is diminished.

No job will be approved in which copper pipe is used.

In all cases the position of the meter shall be determined by the gas company's inspector of fittings.

The connection with the meter must never be less in size than the largest pipe used in the house distribution.

Every service pipe must have a T placed so as to be easily opened, in order that the service pipe may be cleared when any stoppage occurs, and a brass cock must be furnished and placed near the wall where the service enters.

All service pipes, and other connections between street mains and meters, passing through arches under sidewalks, coal-holes, or areas, and all other pipes in exposed places, must be protected from accident and the weather, at the expense of the party for whose benefit the gas is supplied.

Care must be taken to avoid crossing the gas pipes with electric wires, as buildings so piped will not be passed by inspector.

Brass cocks with a gas-way not less than the capacity of the riser, must be placed on all risers of 2 inches and above.

No job will be approved where "gas-fitters' cement" has been used as a material to stop sandholes or other leaks, or for any other purpose.

REVISED REGULATIONS PERTAINING TO GAS-FITTING AND GAS-FITTING MATERIALS, ADOPTED JULY 29, 1898, BY THE BOARD OF HEALTH AND THE BUILDING COMMISSIONER OF BOSTON, TO TAKE EFFECT OCTOBER 1, 1898.

1. In all cases of repair of leaks, a notice giving the location and extent of all work performed shall be filed with the building commissioner immediately upon completion of the same.

2. No pipe or fitting shall be covered or concealed from view until approved by one of the gas inspectors of the building department, or for twenty-four hours after notice has been given to the building commissioner.

3. No pipe shall be so laid as to support any weight (except fixtures), or to be subjected to any strain.

4. All outlets for fixtures shall be securely fastened to the satisfaction of the building commissioner; all outlets not covered by fixtures shall be left capped, and the number of burners for each outlet shall be marked on the builders' plans.

5. Any pipe laid in a cold or damp place shall be properly dripped and protected.

6. All swing brackets shall have a globe or guard to prevent the burner from coming in contact with the wall. All bracket outlets shall be at least 2 inches away from window or door casings.

7. Gas or combination fixtures in all public buildings, theaters, and public halls shall be made safe to the satisfaction of the building commissioner.

8. All stop-pins to keys or cocks or fixtures shall be screwed into place.

9. The use of gas-fitters' cement is prohibited, except in putting fixtures together.

10. Gas shall not be let on in any building until the work performed has been approved by the building commissioner. Inside services shall be tested by the fitter who receives the permit to connect the service or meter.

11. There shall be a brass straightway valve on the service pipe close to the foundation wall, one at the inlet and one at the outlet side of each meter. Iron valves shall not be used.

12. There shall be a final test, by a gas-fitter, of fixtures and pipes, by two inches of mercury, which must stand five minutes; this test to be made in the presence of one of the gas inspectors of the building department; the gauge to be made of glass tubing of uniform interior diameter, and so constructed that both surfaces of the mercury will be exposed.

13. All gas pipe shall be of wrought iron, all fittings of malleable iron, and all meter connections of lead pipe of the same size as the fit or riser. Galvanized fittings are prohibited.

14. Brass solder nipples shall be used on all meter connections.

15. No riser shall be left more than five feet away from the front foundation wall.

16. All buildings shall be piped according to a *scale* [which is omitted here, because it is practically the same as the one of the N. Y. City Building Department].

17. All outlets and risers shall be left capped or covered with fixtures.

18. All service pipes in cold or damp places shall be painted with two coats of red lead and boiled oil.

19. Gas outlets for burners shall not be placed under tanks, back of doors, or within four feet of any meter.

20. All gas burners less than three feet from ceiling or woodwork shall be protected by a shield.

21. All brass tubing used for arms or stems of fixtures shall be at least No. 18 standard gauge and full size outside so as to cut a full thread. All threads on brass pipe shall screw in at least five-sixteenths of an inch. All rope or square tubing shall be brazed or soldered into fittings and distributers, or have a nipple brazed into the tubing.

22. All cast fittings, such as cocks, swing joints, double centers and nozzles shall be *extra heavy*. The plugs of all cocks must be ground to a smooth and true surface for their entire length, be free from sandholes, have not less than 0.75-inch bearing (except in cases of special design), have two flat sides on the end for a washer and have two nuts instead of a tail-screw.

23. Outlets for gas ranges shall have a diameter not less than that required for six burners, and all gas ranges and heaters shall have a straightway valve on the service pipe.

24. Pipes in buildings shall be laid above timbers instead of beneath them, where it is possible to do so.

25. No secondhand gas pipe shall be put into use in any building without the written permit of the building commissioner.

26. Drops or outlets less than 0.75 of an inch in diameter shall not be left more than 0.75 of an inch below plastering, centerpiece or woodwork, and other outlets shall not project more than 0.75 of an inch beyond plastering or woodwork.

27. Fastening boards shall not be cut away to accommodate electric wires. All outlets shall be fastened according to methods illustrated.

28. All iron pipes used for piping buildings, all arms, and all items of fixtures, shall be of the kind classed as standard pipe.

29. No gas pipe shall be laid in cement, unless the pipe and channel, in which it is placed, are covered with tar, nor within 6 inches of an electric wire.

EXTRACTS FROM THE REGULATIONS GOVERNING THE PRACTICE OF GAS-FITTING IN THE DISTRICT OF COLUMBIA.

Sec. 9. Upon the completion of any system of gas piping in a building, and before the floors are laid or the pipes and fittings concealed, there shall be filed in the office of the inspector of plumbing, by the plumber doing the work, a detailed plan of the same, showing the location and size of each pipe, with a statement that the system is ready for inspection.

Sec. 10. Upon the filing of the plan described in section 9, the inspector of plumbing shall promptly cause the system to be inspected, and tested with a pressure of not less than six inches upon a mercury gauge.

If the test and inspection be satisfactory a certificate of approval shall be issued by the inspector of plumbing.

No meter shall be attached to any pipe, or system of pipes, previous to the issuance of such certificate.

Sec. 11. The sizes of the pipes used shall not be less, nor the length greater, to the number of burners stated, than those specified in the table (the table is omitted because it is, for sizes above 1¼ inches, identical with the one of the N. Y. Consolidated Co.).

Smaller pipe than 0.5-inch shall not be used for ceiling outlets, except for lighting halls, pantries, washrooms, bathrooms and kitchens.

Sec. 12. The pipe used shall be the best quality of wrought-iron pipe, with galvanized-iron fittings, and joints shall be made with white lead.

All pipes shall be suitably supported and stayed with pipe hooks, straps and screws.

All pipes shall be properly graded.

All split pipes must be removed.

Sec. 13. All main risers shall be run in an inside partition.

Sec. 14. Each gas meter shall be located in accordance with directions given by the inspector of plumbing.

All meters located in cellars must be set at least four feet above the cellar floor.

Sec. 15. The service pipe shall be run, and both connections with the meter shall be made, by the gas company.

Sec. 16. No extension or alteration of any existing system of gas piping in a building shall be made without the inspection and approval of the inspector of plumbing.

Sec. 17. Upon the completion of the building in which a system of gas piping is run, and before the hanging of the gas fixtures, an application for a final test and approval of the entire system shall be made, to be followed by the final inspection and approval.

EXTRACT FROM RULES AND REGULATIONS OF THE HUDSON COUNTY GAS LIGHT COMPANY, OF HOBOKEN, N. J.

Sec. 1. On the application of the owners of property, situated on the avenues and streets, through which the Hudson County Gas Light Company have their gas mains, a service pipe of sufficient size to furnish all the gas that may be required will be placed, free of cost, from the said gas main in the avenue or street, to a distance not exceeding 25 feet from the curb line thereof; should more than the said 25 feet from the curb line be necessary, then the owner will be charged, for each additional foot, the actual cost of pipe and labor.

. . .

Sec. 9. Consumers are requested to give notice at the office of the gas company of any escape of gas in the service pipe, or of any insufficient supply of gas, or of any jumping of the light, or any defect in the service as soon as possible, in order that it may be remedied at once.

. . . . .

Sec. 11. The inspector of the gas company shall at all times be in readiness to examine the pipes in the building of all applicants for gas free of charge, on receiving one day's notice, and no gas meter will be placed in any building, that is not found to be perfectly gas-tight; also no rising pipe from the gas meter to the running line of the building will be accepted of a less size than 0.75-inch diameter.

Sec. 12. The tubing and fitting for the conveyance of gas within the walls, after it has passed the meter, may be put up by any competent mechanic employed by the proprietor of the premises, subject however to the approval of the gas company's inspector. The proportionate size of the tubing must conform to the *Table,* and no service will be laid from the main to the meter of less diameter than one inch.

Note. The Table referred to is omitted, being identical with the one of the old Manhattan Gas Company of N. Y. (see page 49).

EXTRACT FROM MILWAUKEE BUILDING DEPARTMENT RULES.

Gas Piping.

1. The tubing and fitting for the conveyance of gas within the walls of a building after it has passed the meter may be put in by any competent gas-fitter, but consumers and property owners should require for their own protection that such work be done under these rules, and that the work is only to be paid for after the gas company has passed upon it and given its certificate.

2. In alterations in the piping of buildings, consumers or property owners should use the same care as when piping new buildings.

3. The certificate to be given by the gas company, as per form provided, will only be given after the property owner has made application on the form provided.

4. All piping should be inspected on completion and before lathing the building. It should be again inspected after completion of the building, and before the fixtures are hung. The two inspections when passed upon are sufficient to warrant the gas company in issuing a certificate.

(*A*.) Illuminating System.

5. The following table shows the proportionate size and longest length of tubing to be used, with the greatest number of burners allowed: 0.375-inch pipe, 15 feet, 3 burners; 0.5-inch pipe, 25 feet, 6 burners; 0.75-inch pipe, 40 feet, 20 burners; 1-inch pipe, 60 feet, 25 burners; 1.25-inch pipe, 100 feet, 50 burners; 1.5-inch pipe, 150 feet, 75 burners; 2-inch pipe, 200 feet, 150 burners.

When one-fourth the length of pipe is used, the number of burners may be doubled; 0.25-inch pipe not to be concealed and not more than 6 feet in length, nor more than one burner to be allowed in any case.

6. The risers in any building must in no case be of less than 0.75-inch pipe, and must in all cases be run on inside walls, and in no case should they be within three feet of an outside wall. Extensions from the risers to the meters must be so run that the meters shall be conveniently located for reading the index, and such extensions and places for meters so located as to insure protection from frost or excessive heat.

All openings from the riser must be securely capped when the work is finished and tested.

7. All drops and openings for wall brackets must be made with a bend, the concealed end of which should be at least 6 inches long, and be well fastened with gas hooks or straps. Ells and nipples or fastenings with nails will in no case be allowed.

When outlets are not in close proximity to studding or joists, a notched wooden cross-piece must be securely fastened to secure the same. Drops in large rooms must never be less than 0.5 inch.

8a. All pipe and fittings must be put together with litharge cement.

8. Split pipes or fittings will not be accepted, even though skillfully cemented.

9. All pipes must be well fastened and entirely free from traps.

10. In no case will drips be allowed, except where absolutely necessary.

11. The company reserves the right to determine the location of the meter.

12. All tests will be made under a pressure of air, ten pounds to the square inch or twenty inches of mercury.

13. Risers for bracket lights should never be put in place until after the studding for partition is firmly fastened.

(*B.*) **Fuel System.**

14. All piping for a separate fuel system must be taken from a branch from the service pipe, a separate meter provided, and must be run and used for supplying gas for fuel only.

15. No illuminating flames will be allowed, and no branches or outlets provided for other openings than those connected with fuel appliances.

16. Illuminating burners will positively not be allowed on the fuel systems under any circumstances.

17. A fuel meter will not be furnished under any circumstances, until the gas appliance is in place and connected.

18. Fuel meters will not be connected to a pipe leading from the outlet to another meter.

19. Fuel rate will not be allowed for any appliance attached to pipes supplying gas for illuminating purposes.

20. Lighting burners will not be allowed on any pipe connected with fuel meter.

21. Should illuminating burners be found on any pipe supplying gas at the fuel rate, the gas light company reserves the right to remove the fuel meter upon forty-eight (48) hours notice, and to charge the full illuminating rate for all gas furnished such consumer from such time as such fuel meter was set.

22. To govern the size of tubing to be used in piping for fuel systems, the following rules should be followed:

(*a*) Consider that each piece of apparatus will be used to its maximum, and all pieces at one and the same time.

(*b*) Use as a basis for figuring pipe, that a four-hole range uses 50 feet per hour, six-hole range uses 80 feet per hour. Each gas fire or log uses 50 feet per hour, each water heater uses 25 cubic feet per hour. (If in connection with range, add 25 feet to consumption of range.) Smaller appliances, 25 feet per hour.

(*c*) Figure each length of pipe between openings separately, commencing at the meter.

(*d*) Do not run over 20 feet of 0.5 inch; 50 feet of 0.75 inch; 80 feet of 1 inch; 100 feet of 1.25 inch; 150 feet of 1.5 inch: 200 feet of 2 inch.

23. Openings for fuel appliances should as a rule be 12 inches from the floor and project 1.5 inches clear from the finished wall.

24. All other rules for piping and inspecting not inconsistent with these will be the same as for the illuminating system.

RULES AND REGULATIONS OF THE DENVER CONSOLIDATED GAS COMPANY.

Illuminating Pipes.

Section 1. Pipes are to be run in the building to supply burners where indicated by red checks or stars on the plans; should there be an omission of a red check in any room, it must be supplied, notwithstanding such omission.

The following table of runs, sizes, and openings will govern the running of pipes:

Size of Pipe.	Length of Run Allowed.	Total Openings Allowed.	Remarks.
$\frac{3}{8}$ inch	20 feet	1	This table permits a much smaller number of outlets for each size pipe than all other tables given. — W. P. G.
$\frac{1}{2}$ inch	25 feet	1	
$\frac{3}{4}$ inch	50 feet	4	
1 inch	70 feet	7	
$1\frac{1}{4}$ inch	125 feet	11	
$1\frac{1}{2}$ inch	200 feet	16	
2 inch	300 feet	30	

Sec. 2. Risers to be placed as near the center of the building as possible, and at least four feet from the heating apparatus. Where floors vary in height, there will be a separate riser for each height. Large buildings will have one or more risers as designated by plans and hereinafter specified.

Sec. 3. All pipes for bracket lights must run up from below and the outlets securely fastened; the nipples must be level and project one and one-half inches beyond plastering and no more, and at right angles to same.

Sec. 4. Drops must be plumb and securely fastened above and below, to extend one and one-half inches below the ceiling and no more. Where plaster centerpieces are used, drops to extend the same distance below centers and always at right angles with plastering.

All drops and brackets to be made by means of elbows and tees and not by the use of bent pipe.

Fuel-Gas Pipes.

Sec. 5. A separate line of pipe to be run for fuel gas as indicated by yellow lines on plans; the openings for gas grates or gas stoves to be not less than three-fourths of an inch, and where indicated by yellow checks or stars on plans.

The following table of sizes, runs, and openings will govern the running of pipes for fuel gas:

Size of Pipe.	Length of Run Allowed.	Total Openings Allowed.	Remarks.
1 inch	40 feet	1	See note in the preceding table. — W. P. G.
1¼ inch	60 feet	2	
1½ inch	100 feet	4	
2 inch	150 feet	6	

Risers for fuel-gas pipes to be placed two feet from the riser for illuminating gas, so that the two meters can be set side by side.

Sec. 6. All pipes to be of the best wrought iron, and the same are to be tested before use by blowing through them to see that there is no obstruction. All split or defective pipe to be replaced with new pipe.

Sec. 7. All pipes to be secured in position by means of galvanized-iron straps — No. 20 or heavier, as occasion requires — and wrought-iron hold-fasts. No nails are to be used in place of the above-mentioned straps and hold-fasts.

Sec. 8. All cementing to be done with the best quality of "gas-fitters' cement" and applied with an alcohol lamp.

All pipes must be free from sags and decline toward main rising pipes.

All outlets to be capped.

All joints or connections are to be made with red lead.

Sec. 9. No studding, joist, or other timber about the building to be cut for the letting in of gas pipe without first obtaining the consent of the architect, or his representative in charge of the work, and in case of no architect, then whoever may be in charge of the work. All horizontal pipes are to be run as near the bearing of the joists as possible and not through the center of the span.

All pipes are to be let in at the top of the joists and not hung from the bottom.

RULES OF THE CINCINNATI GAS LIGHT AND COKE COMPANY FOR GAS-FITTERS, ARCHITECTS, CONTRACTORS, OWNERS, OR AGENTS OF BUILDINGS.

The tubing and fittings for the conveyance of gas within any building, after it has passed the meter, may be put up by any competent gas-fitter employed by the consumer or proprietor of the premises, subject, however, to the inspection and approval of the company, which requires an inspection of all pipe before it is covered over by plastering or flooring.

The notice for inspection must be accompanied by a plan of the fittings, drawn to a scale of one inch to eight feet, on which must be marked the size and length of tubing, from joint to joint, and the position of the burners — said plans to be numbered, by the inspector, to correspond with the register of application, and filed in the office for future inspection.

All tubing and screws must be of wrought iron, brass, or copper, but no more of the latter than may be required to run from the ceiling or wall to a gas burner. All Ts, Ls, Xs, springs, bends, etc., must be of hard brass (gun metal) or iron. All stopcocks must be plugged and bushed with brass, and the ways equal to the bore of the tubing, and all fittings must be put together with gas-fitters' cement, when the inspector shall require it.

After all the fittings are completed, written notice must be given at the office of the company, whose inspector will examine the work, in whose presence air shall be forced into the whole of the system of pipe and fittings, until the pressure is equal to thirty inches of mercury; and unless the fittings shall be perfectly tight, under such pressure, and otherwise satisfactory to the company, the gas will in no case be supplied.

Drops and bracket outlets must be well fastened with gas hooks. Nails will not be allowed. Split pipes or fittings will not be accepted even though skillfully cemented. All risers must start from the cellar, and so run that required extensions to meters may avoid cellar openings. All pipes must be well fastened and entirely free from "traps." Under no circumstances will "drips" be allowed except where absolutely unavoidable.

No riser in any building must be of less than 0.75-inch pipe, except where there are but three outlets, when 0.5-inch will be allowed. In buildings with large rooms the drops must be 0.5 inch, with a set from the main line of pipe of not less than 4 inches, dropped square and well secured by gas hooks to the joists. The same rule to be observed on all cross lines of pipe. No outlets intended for gas stoves must be of less than 0.5-inch.

In all cases where alterations are required to be made, notice must be given at the office of the company on the day previous, to enable the company to turn off the gas. As soon as the work is completed, the same rules must be observed as in rule relating to testing.

The table given in the rules, but omitted here — exhibits the proportionate length and size of tubing permitted by the company to be used.

All outlets intended for gas stoves must not be of less size than 0.5 inch, the same to be so located as not to exceed 24 inches above the floor.

All outlets for gas logs must not be of less size than 0.5-inch, and only one log allowed on 0.5-inch pipe, two on 0.75-inch, and three on 1-inch pipe, location of same to be in center of fireplace, 4 inches from back and 1 inch above level of floor in room.

No outlets for drop fixtures or side-wall fixtures will be allowed on branches intended for gas stoves or gas logs after leaving main line of pipe.

All center drops in churches or public halls must not be of less size than 0.75-inch, and only one drop allowed on 0.75-inch pipe, two on 1-inch, and four on 1.25-inch pipe.

Theaters and lodge-rooms which may have several lines of pipe, same to be controlled by stage-cocks, must have extra large size of pipe run from meter to stage, so as to give ample supply of gas for distribution to all lines of pipe running from that point.

All side fixtures in bedrooms, unless otherwise ordered by owner of building, to be not over five feet from floor. Side fixtures for hallways, bathrooms, and water-closets must not be less than 6.5 feet from the floor.

Gas-fitters and plumbers are positively prohibited from using water for the purpose of testing or finding leaks in pipes.

In making connections to meters, in no case will the size of uprights in house be allowed to be reduced. Lead pipe of same size as house pipe must be used. Gas will not be turned on to any premises where this rule is violated until the proper change is made.

GAS-FITTER'S RULES AND TABLES OF THE PEOPLE'S GAS LIGHT AND COKE COMPANY, CHICAGO.

The following tables show the proportionate size and length of tubing allowed:

(A) OFFICE BUILDINGS, DWELLING HOUSES AND FLATS. MANUFACTURED GAS FOR LIGHT.

Size of Tubing.	Greatest Length Allowed.	Greatest Number of 0.375-in. Openings Allowed.
⅜ inch	20 feet	2 openings
½ inch	30 feet	3 openings
¾ inch	60 feet	10 openings
1 inch	70 feet	15 openings
1¼ inch	100 feet	30 openings
1½ inch	150 feet	60 openings
2 inch	200 feet	100 openings
2½ inch	200 feet	200 openings
3 inch	300 feet	300 openings

Drops in double parlors, large rooms, and halls of office buildings must not be less than 0.5 inch.

(B) STORES, HOSPITALS, SCHOOLS, FACTORIES, ETC. MANUFACTURED GAS FOR LIGHT.

Size of Tubing.	Greatest Length Allowed.	Greatest Number of 0.5-in. Openings Allowed.
½ inch	20 feet	1 opening
¾ inch	60 feet	8 openings
1 inch	70 feet	12 openings
1¼ inch	100 feet	20 openings
1½ inch	150 feet	35 openings
2 inch	200 feet	50 openings

For stores the running line to be full size to end of last opening.

All drops to be 0.5 inch with set not less than 4 inches. Twenty feet of 0.375-inch pipe allowed only for bracket fixtures.

MANUFACTURED GAS FOR FUEL.

Size of Tubing.	Greatest Length Allowed.	Greatest Number of 0.75-in. Openings Allowed.
¾ inch	50 feet	One ¾ inch or two ½ inch
1 inch	70 feet	Two or one ¾ inch and two ½ inch
1¼ inch	100 feet	Four or two ¾ inch and four ½ inch
1½ inch	150 feet	Seven or four ¾ inch and six ½ inch
2 inch	200 feet	Fifteen or eight ¾ inch and fourteen ½ inch

For mantles, grates, and small heating appliances, for heating space not to exceed 1728 cubic feet, 30 feet of 0.5-inch pipe is allowed for one opening only, and two such openings are considered as one 0.75-inch opening.

FOR GAS ENGINES.

Size of Engine.	Size of Opening.	Greatest Length Allowed.
1 H.P.	1 inch	60 feet
2 H.P.	1¼ inch	70 feet
5 H.P.	1½ inch	100 feet
7 H.P.	1½ inch	100 feet
12 H.P.	2 inch	140 feet

Supply for gas engine must be separate, and an independent service will be required.

Building Services.

In running service pipe from front wall to meters, the following rules will apply.

Size of Opening.	Greatest Length Allowed.	Greatest Number of 0.75-in. Openings Allowed.
1 inch	70 feet	1 opening
1¼ inch	100 feet	3 openings
1½ inch	150 feet	5 openings
2 inch	200 feet	8 openings

All openings in service must be equal to the size of riser, which in no case must be less than 0.75 inch.

Rules.

1. All branches or cross lines of pipe from the main line must have a set not less than 4 inches dropped square, and must be well secured to joists by gas hooks or straps.

2. All openings must be closed with iron caps, no split pipe or broken fittings repaired with cement or lead will be allowed.

3. All drops on branch lines and openings for side brackets must be square bends; no nipples allowed.

4. The risers in all buildings must be carried up in an inside partition out of reach of frost, and must be placed where the meter and stopcock can be readily gotten at. Vestibules not to be considered as inside partitions.

5. To avoid trapping, gas-fitters must grade all pipes to riser or drops.

6. In no case will a meter be set where it is not easily accessible, or where it is exposed to frost and dampness, or liable to injury from any cause.

7. All pipes for fuel must be run independently, and connected to lighting risers at the meter end, with right and left unions, or running threads.

8. Supply for gas engines must be separate, and an independent service will be required.

9. Drops in churches, schools, public halls, stores, double parlors, large rooms, etc., must not be less than 0.5 inch.

10. No riser in any building must be less than 0.75 inch and in stores must not be under deck of show windows, as meter will not be set there.

11. The riser in any building must not be less than 20 inches from the floor for two to ten openings; 2 feet 6 inches for ten to thirty openings;

4 feet for thirty to sixty openings; 5 feet for sixty to one hundred openings; 6 feet for over one hundred openings.

Where meters are to be set on wall, no riser must be higher than 9 feet from floor.

12. In all cases where extensions are made, care must be taken to break pipe where the rule for size can be maintained, and in no case shall extension be made from small pipes.

13. In flat buildings meters should be set in basement or in room provided for meters; otherwise in premises where gas is consumed.

14. All risers and building services must be brought to front of building and within 18 inches of wall or partition, and must not be less than 15 inches apart where risers are grouped.

15. In all cases where building service is used, provide header with an opening for each riser; where risers are in groups, openings must not be less than 15 inches apart.

16. Underground work by gas-fitters between main and meter will not be allowed or accepted.

17. To avoid complications, gas-fitters should consult this company before locating risers in corner buildings.

18. In flat buildings where appliances are installed for the joint use of tenants, such as laundry stoves, driers, etc., run pipe from each meter to laundry and provide a header with a lock cock for each tenant. Fasten securely to each cock a metal tag with the flat number plainly marked thereon.

19. All work must be proved with mercury gauge, not less than a six-inch column of mercury being allowed.

20. All pipe must be examined by the inspector of this company before being concealed, and twenty-four hours' notice must be given by gas-fitters when any pipe is ready for inspection.

21. If the rules concerning the size of pipes are not clearly understood in each case, or if unusual conditions are met with, which the rules do not cover, communicate with the company's inspector.

22. It is the purpose of the company to strictly enforce the above rules, and no certificate of inspection will be given when they are not complied with.

23. Architects, builders, and owners of buildings are requested not to allow a bill for gas-fitting unless accompanied by a certificate of inspection.

HINTS AND INSTRUCTIONS TO GAS FITTERS.*

1. Gas-fitters, when beginning the work of fitting up a building, should read the rules of the gas company and see how many outlets are allowed on each size of pipe.

2. When running extra pipe or making alterations in new buildings, after the original work is completed, the fitter should put on the gauge and test before and also after the alterations are made.

3. Fitters must put in drops with bends instead of elbows, according to the gas company's rules.

4. Be careful in locating the meter. Risers should not be run on the outside wall, for if they are the gas will condense in winter and cause the light to flicker.

5. When running service pipe, be sure not to trap the pipe. Always put alcohol cock where it can be got at conveniently in case of freezing in winter. When the service is completed, test it by blowing into the alcohol cock; then close it and allow the pressure to stand five or ten minutes; then open the key and if there is sufficient back pressure the piping is tight; if not it leaks and must be remedied.

6. In making alterations in old buildings, before making any extensions the fitter should disconnect the meter and cap the riser, put on his gauge and see whether the work is tight; also prove it when the work is completed.

7. Drops should be fastened properly by putting in cleats between joists.

8. In parlors one-half-inch drops should be put in. When running pipe for bracket fixtures, fitters should be careful when there are two or three in one room to put them the same height from the floor and see that they extend just the same length through the plaster so as to make an even finish for back plates.

9. In leaving openings for fireplace logs, they should be one-half inch in fireplaces, and for gas stoves they should not be less than one-half inch and, for large ones, three-quarters of an inch.

10. Fitters should not run risers across the floor under the tile of the vestibule in the main hall.

11. In placing one or more fixtures in a house, the fitter should always smell of the joints and see if there is a leak; after turning on the gas he should watch the meter and see whether the hands on the dial move, if so there is a leak. These are matters which are ignored by fitters altogether and cause a great loss of time.

12. Fitters should examine the brackets of fixtures after the gas is burning, for very often the nozzles have sandholes in them and the fitter

* Issued by a prominent gas-piping firm in Chicago.

does not screw his burners up tight and does not put them on properly. He thinks that because it is tight to the key that is sufficient.

13. In all new work in houses, offices or stores, the fitter should put on his pump before he puts the fixtures on and if there is a leak and he cannot find it in the caps, he should report it to the foreman and the parties who first put in the work will be notified and they will have to find it, but should the fitter put on the fixtures without testing and if there should be a leak afterward he would be held responsible for it and would have to make it tight. After the fixtures are all up and tested he should report to the gas office in the district where the work is completed.

FROM "INSTRUCTIONS FOR GAS DISTRIBUTION EMPLOYES." J. M. ROBB.

(Paper read before the Ohio Gas Light Association, in March, 1906.)

To determine the size of a gas meter is largely a matter of judgment as no hard and fast rules can be laid down to govern all cases. Sometimes, on a large job, only one or two gas burners will ever be used at the same time, and in such cases a meter large enough to supply sufficient gas to all of the burners connected, should they all be used at the same time, would be a waste of money.

Generally, the following *Table* will apply:

MAXIMUM WORKING CAPACITIES OF GAS METERS.

	Cu. Ft. per Hour.
3-light	60
5-light	90
10-light	120
20-light	180
30-light	270
45-light	360
60-light	420
80-light	510
100-light	600
150-light	900

The above capacities are for a drop of 5 tenth inches of pressure between the inlet and outlet of the meter, for the average capacities of a number of meters of different makes.

If conditions are such that this drop in pressure cannot be permitted, use a meter of next larger capacity than the rating required by the apparatus to be supplied. In case of doubt, report the matter to the superintendent for special instructions.

When determining the required size of a meter, rate the apparatus to be supplied as follows:

	Cu. Ft. per Hour.
Open flame burner, each	6
Mantle burner, each	5
Arc lamp, per mantle each	5
Top stove burner, each	15
Oven burner, each	15
Circulating water heater, depending on size, each	30–60
Instantaneous water heater, each	100
Gas grate, each	35
Gas heater, each	25–50
Gas engine, per horsepower per hour, each	30

Never set less than a 5-light meter for a gas stove.

Never set less than a 10-light meter for an instantaneous water heater.

With a little attention given to the study of the greatest amount of gas that the meter will be called upon to pass at any one time, you will have no difficulty in selecting the size meter required. In cases of doubt be on the safe side. It is better to set too large a meter than to risk a complaint from a consumer.

Always, when setting a meter, teach the consumer to read it, if you can persuade him to take the time, and tell him the statement of the meter you are setting for him.

Plan your pipe system in accordance with the following table:

CAPACITIES OF GAS PIPE AND GREATEST LENGTH PERMITTED.

Diameter, Inches.	Length, Feet.	Capacity, Cubic Feet per Hour.
3/8	20	11
1/2	30	22
3/4	50	60
1	70	127
1 1/4	100	222
1 1/2	150	349
2	200	718
2 1/2	300	1253
3	450	1977
4	600	4059

Use the next size larger when the length in the table for a given capacity must be exceeded.

Never run a fuel line smaller than 0.75 inch.

Never run a supply pipe to a gas engine less than 1 inch.

Always make a run of pipe for a hot plate of 0.75-inch pipe, unless you are sure the hot plate will never be replaced by a gas stove.

Always, in determining the size of pipe to be run, follow the table for gas consumption of various apparatus, given under "Instructions for setting meters."

Ask for special instructions when you are running piping for special fuel apparatus.

BRITISH REGULATIONS AS TO INTERNAL GAS FITTINGS.*

1. The company will in all cases lay on the service pipe, conveying the same through the outer wall of the premises to be supplied with gas.

2. The main cock must be attached to the end of the service pipe within the building, and close to the outer wall.

3. The gas meter must be placed perfectly level, either on the floor, or on a substantial support, and within 2 feet 6 inches of the main cock.

4. The piping attached to the meter, whether inlet or outlet, must not be smaller in internal diameter than that of the meter unions.

5. The following are the sizes of the meters, and their measuring capacity, from which the number of lights which they supply can be readily calculated:

Size of Meters.	Size of Inlet and Outlets in Inches.	Measuring Capacity per Revolution in Cubic Feet.	Measuring Capacity per Hour in Cubic Feet.
2-light . . .	½	$\frac{1}{12}$	12
3-light . . .	⅝	⅛	18
5-light . . .	¾	¼	30
10-light . . .	1	½	60
15-light . . .	1	¾	90
20-light . . .	1¼	1	120
30-light . . .	1⅜	1½	180
50-light . . .	1½	2½	300
60-light . . .	1½	3	360
80-light . . .	1¾	4	480
100-light . . .	2	5	600
150-light . . .	3	7½	900
200-light . . .	3	10	1200
250-light . . .	4	12½	1500
300-light . . .	4	15	1800
400-light . . .	4	20	2400
500-light . . .	5	25	3000
600-light . . .	5	30	3600

To ascertain the number of burners which any size of meter will supply, divide the measuring capacity per hour by the quantity of gas per hour which each jet is estimated to consume. Example: What number of burners consuming 4 cubic feet of gas per hour will a 20-light meter supply? Then 120/4 — 30 burners.

* From Thomas Newbigging's "Handbook for Gas Engineers."

6. The following are the sizes and lengths of iron, lead, or composition tubes to be used according to the number of ordinary burners.

(The table is omitted as it is substantially the same as the one adopted by the Consolidated Gas Co. of N.Y.)

7. The tubes or pipes must be laid with proper fall, and in such a manner that they are easily accessible, and protected from liability to damage. Attention is to be given to leaving a space round them at such places as wall crossings, etc., where fracture or crushing of the pipes might be caused by the subsidence of the building. The joinings of the tubes and pipes are to be made in the most solid and substantial manner; and carefully rounded bends (not elbows) are to be used wherever the direction of the pipe is changed.

8. Floor boards covering pipes must be secured with screws, so that they may be easily removed to afford access to the pipes, especially at the points of connection.

9. On the completion of the work of fitting, and before the piping is covered up, notice thereof must be given in writing to the gas manager, who will cause an inspection to be made of the work, and if found in accordance with the regulations herein contained, it will be passed by the company, and the gas turned on.

10. If the regulations are not conformed to in every respect, the company reserve the right to refuse a supply of gas until the necessary alterations are made.

11. Gas-fitters complying with these regulations have their names registered on the company's list of approved gas-fitters, and they are at liberty to designate themselves "authorized gas-fitters." Repeated negligence will cause the license to be withdrawn.

The Table of Pipe Sizes of the Committee of North British Gas Association is substantially the same as the one adopted by the N. Y. Consolidated Gas Co.

This table is the standard of the principal English gas works. Services should never be undersize, as the difference in cost is not proportionate to the advantage.

For gas stoves the following provisions must be complied with:

Average Inside Size of Oven.	Distance of Stove from the Meter.
11 in. × 11 × 14 in.	If under 30 ft., ½-in. pipe required If under 60 ft., ⅝-in. pipe required
14 in. × 14 × 24 in.	If under 30 ft., ⅝-in. pipe required If under 60 ft., ¾-in. pipe required
15½ in. × 15½ × 24 in. . . .	If under 30 ft., ¾-in. pipe required If under 60 ft., 1-in. pipe required
19 in. × 18 × 24 in.	If under 30 ft., 1-in. pipe required If under 60 ft., 1¼-in. pipe required

TABLE TAKEN FROM THE MUNICH GAS REGULATIONS OF 1890.

Length of Pipe in Meters.	Size of Pipes.							
	⅜ In.	½ In.	⅝ In.	¾ In.	1 In.	1¼ In.	1½ In.	2 In.
2	3	10	18	30	60	120	180	400
4	3	8	16	25	50	100	150	320
6	2	6	13	20	40	80	120	260
8	2	5	10	15	32	64	100	220
10	1	4	8	13	25	50	80	180
15	1	3	5	9	20	40	60	155
20	...	2	5	8	17	35	55	132
25	...	1	4	7	15	30	50	120
30	...	1	4	6	12	25	45	112
35	...	...	3	5	11	22	40	103
40	...	...	2	4	10	20	35	96
45	...	...	2	4	9	19	30	88
50	...	...	1	3	8	17	28	80
60	...	...	1	3	7	16	26	70
70	...	...	...	2	6	15	24	65
80	...	...	...	2	5	14	22	60
90	...	...	...	1	4	13	20	55
100	...	...	...	1	3	12	18	50
150	...	...	...	...	2	9	15	43
200	...	...	...	...	1	8	13	36
250	...	...	...	...	...	7	12	30
300	...	...	...	...		6	11	25

No pipe to be less than ⅜ inch.

The table gives the number of burners, each at 5 cubic feet (142 liters).

TABLE OF SIZES OF SERVICE PIPES, BY D. MONNIER, FORMERLY ENGINEER-IN-CHIEF OF THE MARSEILLES (FRANCE) GAS WORKS.

Number of Burners.	Size of Service	Size of Service in Millimeters.
1 to 5	¾ inch	20 mm.
6 to 10	1 inch	25 mm.
11 to 20	1¼ inch	30 mm.
21 to 30	1½ inch	35 mm.
31 to 40	1⅝ inch	40 mm.
41 to 60	1¾ inch	45 mm.
61 to 80	2 inch	50 mm.
81 to 100	2¼ inch	55 mm.
101 to 150	2½ inch	60 mm.
151 to 200	3 inch	70 mm.

CHAPTER VIII.

PIPING FOR NATURAL GAS.

In certain districts of the United States, extensive use has been, and is still being, made of natural gas, and as it is in many respects different from manufactured or city gas, it seems desirable to devote a short chapter to it, and to refer to some special rules and regulations necessary for its proper and safe use.

Before giving these rules, it may be of interest to give a brief review regarding the history, production, composition, transmission and utilization of natural gas.

Natural gas is an inflammable gas, generated in large quantities by the decomposition of vegetable matter in the deeper strata of the earth; the gas is found in porous rock, chiefly in the vicinity of the coal fields and in the oil regions. Many of the rocky strata, which carry oil in their deeper parts, yield gas in their higher layers.

Natural gas has been known since ancient times of history. It occurs in the petroleum oil regions of the Caucasus, in Italy, in Alsace, Persia, China, Northern India, and in many localities of the United States. Near the oil wells at Baku, on the western shore of the Caspian Sea, on the southern coast of the peninsula Apsheron, numerous gas wells exist, chiefly at a place called Surachanah, and these gas springs are known as the "eternal burning fires."

Probably the largest supply of natural gas occurs in the United States, where it was first discovered about the year 1821 at Fredonia, N. Y., Many gas wells have been bored in the oil regions of Western Pennsylvania, also in West Virginia, in Ohio, Indiana, Illinois, and in smaller quantities in some other states. Since about 1840, natural gas has been used quite extensively as fuel. It has been transmitted in pipe lines for very long distances to the great cities, like Buffalo, Pittsburg, Detroit and Chicago, and many villages and towns in the gas-well regions are lighted at night with the gas.

According to chemical analysis, natural gas is a mixture of marsh gas with other hydrocarbons, and with some hydrogen, carbonic acid, and nitrogen. Marsh gas is its principal constituent, the amount being in some cases as high as 75 per cent.

The illuminating power of natural gas is far below that of coal gas, but it can be improved by carburetting, or else by burning it in Welsbach incandescent mantle burners; on the other hand, it has one-third more heating value than coal gas, hence it is largely used as fuel, not only in industrial establishments, but also in dwelling houses in cities supplied with natural gas.

This gas is obtained from the earth by drilling or boring wells, much in the same manner as is done for oil or water. Iron-pipe casings, from 8 to 12 inches in diameter are used, with a steel shoe at the bottom of the pipe. A gas well is any well from which natural gas issues in more or less large volume. Some gas wells are driven or bored to very great depths. The locating of a gas well is about as uncertain as the locating of a well for water, except in those districts where gas has been found before. When gas is struck in such a well, the gas sometimes rushes to the surface under a very heavy pressure. In some cases, water is yielded with the gas and should be intercepted to prevent its getting into the distributing conduits. The gas pressure generally becomes less after a number of gas wells, located not far apart, have been drilled.

Owing to this high pressure of natural gas, the danger from leaky pipes, in buildings where natural gas is used, is much greater than with ordinary gas, and likewise the risk of explosions. Natural gas explodes violently when mixed with ten times its volume of air and then lit, hence the greatest care is required from the gas-fitters, and pressure-reducing valves are always inserted on the gas services.

Much use has been made of this kind of gas for heating purposes, not only in open grates, but also in steam boilers, hot-air furnaces and other heaters, and for many manufacturing industries, such as puddling furnaces, foundries, enameling works, potteries, etc., it has been of inestimable value.

For many years its use reduced the smoke nuisance in Pittsburg and other cities, which formerly used bituminous or soft coal, for natural gas became the general domestic fuel for cooking ranges, for baking, etc. It is a clean and easily handled fuel, which when properly burned creates no smoke. Like all gaseous fuel, it offers the advantage of leaving no ashes, cinders, or clinkers like coal.

For illuminating purposes, the natural gas is not so well adapted, as the flame is neither bright nor steady.

Unfortunately, the supply has in some regions of Ohio and Pennsylvania become greatly reduced, the annual output of gas is growing less every year, and some wells have ceased to flow gas altogether, particularly in the gas-bearing lime-stone regions. In Indiana, too, the natural gas supply is becoming exhausted and many wells have given out.

The following statistics of the natural gas production in the United States in the year 1906, prepared by B. Hill, of the United States Geological Survey, and taken from "Mineral Resources of the United States, 1906," are of interest.

In 1906 the production of natural gas amounted to 388,-842,562,000 cubic feet, and the value of the gas product was $46,873,932. The average price of natural gas was $5.00 per short ton, whereas the corresponding price for bituminous coal in 1906 was only $1.11.

"The difference in price," says the report, "is fully made up by the superior fuel efficiency of natural gas, and by the great economy of labor in its use, and the saving of cost in the removal of ashes."

In 1906 there were 1871 natural gas companies in the United States. For years Pennsylvania, West Virginia, Ohio, and more recently Kansas, Oklahoma, and Indian Territory produced more gas than they consumed. In 1906 Pennsylvania reversed the conditions and borrowed from West Virginia to make up the deficiency. The transportation of the gas, in pipe lines and by pumping, is so much cheaper than that of coal that natural gas competes with coal at comparatively great distances.

In the following I give the rules which the fire marshal of Pittsburg, at the instance of the Board of Fire Underwriters, issued regarding piping for natural gas.

All pipes must be tested by the company's inspectors with mercury column to ten pounds pressure, from end of line, where connection is made, to end of pipes under grates, stoves, etc.

The fitter should have his pump on and see that the pipes are perfectly tight before sending for the inspector.

The ends of pipes under grates, stoves, etc., should first be capped, so as to allow the stopcocks to be tested; then remove the caps and see if the cocks allow the gas to escape.

In case the mercury drops, a test for leak, by putting ether in the pump, or with soap water, will be made.

In no case shall a fire test be used in dwellings, offices, stores, etc. No cement of any kind shall be used for repairing faulty fittings or work; nor is the use of blind gaskets permissible.

When an attempt to hide leaks is made, the name of the fitter will be kept on record in this office, and future work done by him will not be approved without a rigid examination.

In running pipes in buildings no set rules can be given, except that pipes must, in all cases, when possible, be so placed that they can be easily inspected, and that in case of accident any leaking gas may escape easily.

Cement wall carefully where the service pipe enters the building, and use a large pipe for the main that runs through the cellar. Provide valves to shut off gas from all risers. In running pipes through flues great care is necessary, and lead pipe for the bends should not be used.

Do not run between floors or walls when any other method can be employed. Do not place cocks between floors or ceilings. Do not use any valves which require packing at the stem in places where leaking gas may be dangerous. If pipes run outside of walls, provide a drip.

Allow plenty of air under the grates, so that the hearthstone may not get too hot. Set the back tile in the grate so that the unburned gas may be directed up the chimney, and not allowed to enter the room.

Admitting more air under the grate, so that it will percolate through or between the hot bars in grate, results in a cheerful bright fire from bottom of grate to the top of the fittings, and also in front.

In fitting up a building all gas-fitters will be required to furnish the gas company, which is to supply the fuel, with a statement giving the number of fireplaces fitted up, and also any additional fireplaces that may be connected afterwards in the same building, so that a complete record may be had at this office. Blank forms for this purpose will be furnished by the different companies supplying the natural gas.

It should be borne in mind that a leak of natural gas is not so perceptible as that of artificial gas, on account of the very slight odor arising from it; and consequently more care should be taken in piping a building for its use.

Fitters should also remember that accidents and explosions are likely to occur through defects in fittings and pipes; and as the introduction of natural gas is a benefit to the fitters, to the community at large, and to the insurance companies, the fitters should do all in their power to make the use of natural gas as safe as possible; and they can materially aid in this by endeavoring to put in pipes and fittings in a perfect manner.

The underwriters have issued the following rules regarding piping for natural gas.

MEMORANDUM OF CONDITIONS FOR THE INTRODUCTION AND USE OF NATURAL GAS AT PITTSBURG, BY THE PITTSBURG BOARD OF UNDERWRITERS.

(a) *In Manufacturing Establishments.*

1. When gas is to be introduced into any premises, a regulator shall be placed as remote as possible from building, by which the pressure shall be reduced to not exceeding two pounds.

2. A safety valve shall be placed between the governor or regulator and buildings, which will blow off when the pressure exceeds two pounds.

3. A mercury gauge must be placed inside of buildings which will indicate the exact pressure in the pipes.

4. All pipes leading from the regulator, and into the mills, shall be of as large diameter as possible; on entering building it shall be elevated and carried overhead, and above all furnaces and boilers.

5. Pipes, valves, and fittings shall be carefully inspected, when the work is completed, by the Secretary of this Board, before the privilege is given to use natural gas.

(b) *In Dwellings.*

Natural gas for fuel may be used under the following conditions:

All pipes and fittings must be tested to a pressure of 10 pounds to the square inch, and a certificate of such test furnished to the customer. A pressure regulator must be placed on service pipe, and so set that the pressure at which the gas is used shall not exceed four ounces to the square inch.

Gas should not be burned at night, unless the fires are all turned down low.

(c) *In Mercantile Buildings.*

Pipes and fittings to be tested same as in dwellings, and provided with regulator, pressure not to exceed four ounces.

All fires must be turned off at night, unless a competent man is left in charge.

Note. As nearly as can be ascertained the danger of natural gas is caused by a lack of proper control of the pressure, and it is very dangerous when the pipes are connected directly with the wells.

Underwriters have concluded that a 10-ounce pressure may be considered safe, but they prefer a lower pressure. Experts on natural gas claim that the best results, as to combustion and safety, are obtained with 4 ounces of pressure.

RULES OF PEOPLE'S GAS-LIGHT AND COKE COMPANY, OF CHICAGO, FOR SIZE OF PIPE FOR NATURAL GAS FOR FUEL.

Classification of Appliances.	Size of Openings in Inches.	Greatest Length Allowed in Feet.
Small, portable, gas cooking stove	½	20
Small, portable, gas heating stove	½	20
Kitchen boiler heater, when separated from range	½	20
Miscellaneous appliances consuming less than 15 cubic feet per hour each	½	20
Gas cooking ranges	¾	30
Ordinary coal ranges, equipped for the use of gas	¾	30
Large heating stoves	¾	30
Gas logs or other grate fires	¾	30
Miscellaneous appliances consuming 40 to 75 cubic feet of gas per hour	1	60
Hot-air furnaces for heating 10-room buildings or less	1¼	70
Hot-air furnaces for heating 10 to 15-room buildings	1½	100
Low-pressure steam or circulating water boiler for heating 10 rooms or less	1½	100
Low-pressure steam or circulating water boiler for heating 10 to 15-room house	2	140
Low-pressure steam or circulating water boiler for heating 16 to 26-room houses	2½	200
Low-pressure steam or circulating water boiler for heating 27 to 50 rooms	3	300
Low-pressure steam or circulating water boiler for heating 50 to 80 rooms	4	400

CHAPTER IX.

PIPING FOR AIR GAS OR GASOLINE MACHINE GAS.

AIR GAS, as was stated in Chapter I, is a gas obtained by saturating common atmospheric air with the vapors from liquid hydrocarbons, like benzine or gasoline. It is, therefore, a mechanical mixture, and the gas obtained is used in special burners for lighting, cooking, heating, and for power purposes.

The apparatus used for the purpose will be described in the chapter on "The Lighting of Country Houses." It should, as far as possible, be automatic, require simple manipulations, but no tedious hand-regulation.

If the gas obtained is too rich, it is apt to smoke, and special air mixers are used with the best apparatus to avoid this fault. For lighting, it is found best to burn the gas in incandescent mantle burners.

The precautions to be taken where gasoline gas machines are installed are discussed in Chapter XIX, and it will suffice to point out that owing to the dangerous character of gasoline and its vapors, it is necessary to have all pipes absolutely tight. Hence the specifications for piping should be very strict. In the following I give a complete specification for gasoline gas lighting, which was published by the *Progressive Age* and copied by them from *Domestic Engineering:*

SPECIFICATIONS FOR GASOLINE GAS LIGHTING.

General Conditions.

The owner and the architect wish the contractor to bear these points in mind throughout the installation of this work, viz:

First. — That although many other ways are "just as good" as the specific directions here given, it is what is called for here that the contractor agreed to do, and which it is intended he shall have furnished before the work is completed, unless privilege is given to deviate from that for which contract was made.

Second. — That not only the letter, but also the spirit, of these specifications are to be lived up to; that is, in all cases wherein the good judgment and honesty of the contractor is relied upon he shall endeavor to embody the true intentions of the designer in his work.

To aid the contractor in doing this, the details of certain connections, usually left entirely to the will of the workman, are given, and which the contractor will make the disposition and the workmanship of other parts in keeping with.

Third. — Award of the contract is made with the understanding that the contractor will not scrimp or slight the work in any sense at any point, even though there is opportunity to do so, and take refuge behind some technicality in the wording of the specifications. In short, anything that is obviously needed or necessary to make a complete, durable, and satisfactory job for this particular house, with the fixtures specified, is be to furnished and put in place as a part of the work in this contract.

The contractor will furnish, transport at his own cost, and put under such cover as the premises afford, at his own cost, all the material to be used on the work. He will also pay all railroad fare to and from the premises, occasioned by himself and workmen, and pay living expenses of workmen for whatever time they board in the vicinity, while the work is being put in.

The contractor shall progress with this work so as not to cause unnecessary expense or delay to other contractors. Their contracts bind them to reciprocal treatment.

Setting the Apparatus.

Furnish, transport to premises, and set one carburettor and air pump complete and ready for good service, of sufficient size to supply fifty (50) 5-cubic-feet-per-hour burners at the same time and capable of utilizing 86-degree gasoline with the least heavy residual product.

The manufacturer's instructions for setting the carburettor and pump will be carried out to the letter, and if the maker of the machine does not so specify, the following, in addition to the maker's requirements, will be embodied in the work of setting the machine without extra cost to the owner.

A union will be placed in each line connecting to the carburettor, near the carburettor.

Both the air supply and the carburetted-air pipe will incline down to the carburettor from the pump and house riser, respectively.

A union will be placed in the air pipe, and one in the run to the riser, within the cellar.

The "runs" to the carburettor shall be below frost line of zero weather, at all points, and firmly supported by the trench bottom, direct or otherwise, in such a manner as to insure no traps resulting from settling of the dirt over the pipes.

The carburettor will be set at the rear of the house not less than thirty (30), nor more than fifty (50) feet from center of rear line of house. It may be assumed that the carburettor will be placed just outside of a line drawn thirty feet from and parallel to the rear line of the house. If more than fifty feet of pipe are required for the air-pipe "run" from foundation wall to carburettor, the owner will pay extra for it.

The pump will be placed in the cellar near a wall, at a point requiring the shortest "run" to the carburettor.

Where air and gas pipes pass through the wall to the carburettor, tees will be placed with opening full size of the line, in line with the runs and openings plugged.

An opening for three-eighth-inch pipe will be placed in gas pipe near pump and plugged.

The gas pipe will be required to connect with house main at point marked (X) on plans which may be inferred near enough for estimating purposes by referring to specifications governing distributing pipes.

The pump and carburettor pipes and connections shall be the full size of openings in pump and carburettor.

Both the air and the carburetted-air pipe will have a stopcock in cellar near exit points.

In this job the owner will excavate pit and trench for carburettor and pipes and fill same when the contractor is ready. If the machine used requires a vault walled up with manhole cover and ring, the owner will provide same at his own cost. The owner will also furnish and deliver on premises, at his own cost, the gasoline with which to give the machine an actual test. The first gasoline will be put in and machine started by contractor as part of his contract.

The contractor will make his bid in a way to show how much he will allow or deduct in case the owner decides to omit the carburettor and pump and their connections as hereinbefore described.

House Piping.

The house-service main will begin at a point convenient to reach the cellar light nearest to the rear wall, and will be one and one-half (1.5) inches in diameter to within three feet of the rising mains, which will be three in number and 1.25 inches in diameter each.

Previous to dividing the main for the three risers, a tee with a one-inch opening, plugged and turned to the side, will be put in the line.

The branches for the rising mains will be provided with stopcocks, properly labeled, placed near the division of the main.

The distributing pipes will be so disposed that one of the rising mains will supply all the center fixtures on the first floor, and all the bracket fixtures for the second floor. If the owner wishes two veranda fixtures, their supplies will be run from a first-floor center or a second-floor bracket fixture supply.

The second rising main will supply all second-floor center fixtures, and third or attic-floor bracket fixtures.

The third riser will supply third-story center fixtures and lanterns on deck of roof, and also fixtures in pipe-way passage to storage tank.

The rising mains will be full size to first, second, and third-floor ceiling joists, respectively.

All other branch pipes and mains will be made one size larger than is required for same number of burners and distance on coal-gas work.

Main risers will be of galvanized pipe.

No pipe used for gas in this work will be less than 0.375-inch inside diameter.

All first-floor bracket fixtures will be supplied from the branch which supplies the cellar fixtures.

The branch for the first-floor and cellar bracket fixtures will be 0.75-inch and will be furnished with a stopcock and label in keeping with the cocks on rising mains.

This arrangement of the distributing pipes provides for supplying all first-floor and cellar bracket fixtures by a branch from house main, controlled by a stopcock; all first-floor center fixtures, veranda fixtures, and second-floor bracket fixtures from a separate riser controlled by a stopcock; all fixtures above level of second-floor bracket fixtures, except third-story center, deck lanterns, from a separate main also controlled by a stopcock.

The pipe used inside of the house on this gas work, except rising mains, will be plain wrought iron, all new and perfect, and of the same quality as would be used for water work.

The fittings will be malleable iron, galvanized throughout.

The cocks will be heavy lever-handle, round-way, of brass, with hexagon ends.

The thread joints will be made with asphalt varnish, except where ceiling drops screw in and where nipples are used to extend through plaster for bracket lights; these will be screwed up hot in gas-fitters' cement.*

Ceiling drops will extend four inches below plaster, and must be securely fastened so they cannot be pushed in any direction at the upper end nor at a point just above the laths.

Bracket openings will be set so as to protrude uniformly about one inch through the plaster.

Caps on bracket outlets and drops will be screwed up only moderately tight, in gas-fitters' cement.*

The fittings into which drops and bracket nipples are fitted must be fastened in place so securely that any drop or nipple for bracket may be removed and put in place again easily without cutting floor or wall.

Bracket toilet light openings will be 4 feet 10 inches from top of floor;

* The author does not approve of the use of gas-fitters' cement as specified. —W. P. G.

hall, kitchen, pantry, and bathroom bracket lights will be 6 feet from top of floor boards.

Every inch of gas pipe supplying burners must have a distinct "fall," so that it will drain, either toward the carburettor or toward a fixture or bracket, preferably to the carburettor.

Previous to putting in place, every fitting and pipe will be tested by exhausting the air with the lungs, and the pipe will be blown through to insure it being clear.

All pipe will be well fastened in place, and so "routed" as to run between joists, if possible; if pipe crosses joists, it must be near supports.

A 0.75-inch plugged branch will be placed in main in cellar for supply to gas range, and a 0.5-inch capped opening will be placed in bathroom for heating purposes; location of opening optional with owner.

If owner desires, 0.5-inch drops will be placed in parlor and library and extend 1 foot through plastering; otherwise all drops will be 0.375-inch pipe.

For estimating purposes, bidders will assume that the number of openings for brackets and gasoliers, all told, will not exceed forty. If more are wanted, the owner will pay extra.

The owner, or his wife, or both, will go over the plans or visit the building, in company with the contractor or his workmen, for the purpose of locating the openings for fixtures, etc., before the work is commenced.

In locating fixtures, due attention will be paid to probable drafts, height of ceilings, width of dressing cases to be used, and common centers of spaces to be lighted, etc.

Test of Piping.

When the gas pipe in the house is installed, the contractor will, at his own expense, test the entire system under air pressure sufficient to support a column of mercury 10 inches high, using a mercury gauge for the purpose. If the pipe is not tight, he will stop the leaks in a permanent manner.

I also quote in full a very compact and practical specification issued some years ago by the Springfield Gas Machine Co.:

SPECIFICATIONS OF THE SPRINGFIELD GAS MACHINE CO., FOR PLACING GAS PIPES IN POSITION.

Kind of Pipe.

1. Ordinary wrought-iron pipe, such as is used for steam or water, is suitable and proper for all kinds of gas.

Kind of Fittings.

2. *Galvanized* malleable-iron fittings, in distinction from plain iron are very superior. The coating of zinc inside and out effectually and

permanently covers all blow-holes, makes the work solid and durable, and avoids the use of perishable cement.

Precautions about Obstructions.

3. Before the pipe is placed in position it should be looked and blown through. It is not infrequent that it is obstructed, and this precaution will save much damage and annoyance.

Avoid the Use of Cement.

4. What is known as gas-fitters' cement should never be used. It cracks off easily; in warm places it will melt, and it can be dissolved by several different kinds of gas. Nothing but solid metals are admissible for confining gas of any kind.

Cutting Floor Timbers.

5. When pipes under floors run across floor timbers, the latter should be cut into near their ends, or where supported on partitions, in distinction from being cut in or near the centers of rooms. It is evident that a ten-inch timber, notched two inches in its middle is no stronger than an eight-inch.

Side Outlets.

6. All branch outlet pipes should be taken from the sides or tops of running lines.

Taking Drops from Running Lines.

7. Never drop a center pipe from the bottom of a running line. Always take such outlet from the side of the pipe.

Bracket Pipes.

8. Bracket pipes should be run up from below, in distinction from dropping from overhead.

The Drip of Pipes.

9. The whole system of piping must be free from low places or traps, and decline toward the main rising pipe, which should run up in a partition *as near the center of the building* as is practical. It is obvious that where gas is distributed from the center of a building, smaller running lines of pipe will be needed than when the main pipe runs up on one end. Hence, timbers will not require as deep cutting, and the flow of gas will be more regular and even. For the same reason, in large buildings, more than one riser may be advisable.

Drip Pipes.

10. When a building has different heights of post, it is always better to have an independent rising pipe for each height of post, in distinction from dropping a system of piping from a higher to a lower post, and grad-

ing to a low point and establishing drip pipes. Drip pipes in a building should always be avoided. The whole system of piping should be so arranged that any condensed gas will flow back through the system, and into the service pipe in the ground.

Fastening Outlet Pipes.

11. All outlet pipes should be so securely and rigidly fastened in position that there will be no possibility of their moving when the gas fixtures are attached. Center pipes should rest on a solid support, fastened to the floor timbers near their tops. The pipe should be securely fastened to the support to prevent lateral movement. The drop pipes must be perfectly plumb, and pass through a guide fastened near the bottom of the timbers, which will keep them in position despite the assaults of lathers, masons, and others.

Height of Bracket Pipes and Length of Nipples.

12. In the absence of express directions to the contrary, outlets for brackets should generally be four feet and six inches high from the floor, except that it is usual to put them six feet in halls, and five feet in bathrooms. The upright pipes should be plumb, so that the nipples, that project through the walls, will be level. The nipples should project not more than three-quarters of an inch from the face of the plastering. Laths and plaster together are usually three-quarters of an inch thick; hence, the nipples should project one and one-half inches from the face of the studding.

Length of Drop Pipes.

13. Drop center pipes should project one and one-half inches below the furring, or timbers if there be no furring, where it is known that there will be no stucco or centerpieces used. Where centerpieces are to be used, or where there is a doubt whether there will be some or not, then the drop pipes should be left about a foot below the furring. All pipes being properly fastened, the drop pipe can be safely taken out and cut to the right length, when gas fixtures are put on.

Location of Pipes.

14. Gas pipes should never be placed on the bottoms of floor timbers that are to be lathed and plastered, because they are inaccessible in the contingency of leakage, or when alterations are desired, and gas fixtures are insecure.

Proving Pipes.

15. The whole system of piping should be proven to be air- and gas-tight under a pressure of air that will raise a column of mercury six inches high in a glass tube. The pipes are either tight or they leak. There is no middle ground. If they are tight, *the mercury will not fall a particle.*

A piece of paper should be pasted on the glass tube, even with the mercury, to mark its height while the pressure is on. The system of piping should remain under test for at least a half-hour.

Inspection.

16. It should be the duty of the person in charge of the construction of the building to thoroughly inspect the system of gas-fitting, surely as much so as to inspect any other part of the building.

He should know from personal observation that these specifications are complied with. After being satisfied that the mercury does not fall, he should cause caps on the outlets to be loosened in different parts of the building, first loosening one to let some air escape, at the same time observing if the mercury falls, then tighten it, and repeat the operation at other points. This plan will prove whether the pipes are free from obstruction or not.

When he is satisfied that the whole work is properly and perfectly executed, he should give the workmen a certificate to that effect, and no job of gas-fitting should be considered complete until such certificate is issued.

Sizes of Pipes.

17. The following scale of sizes of pipes and number of burners to be supplied therefrom is found by experience to be best adapted for securing a good flow of common city gas, and it is very important that it be rigidly observed, when machine or air gas is to be used. Do not confound fixture *outlets* with *burners*. In establishing the sizes of pipe in a building, count the number of *burners* that there will be on each *outlet*, and have the pipes of a size to correspond therewith.

Greatest Number of Feet to be Run.	Size of Pipe.	Greatest Number of Burners to be Supplied.
20 feet	$\frac{3}{8}$ inch	2
30 feet	$\frac{1}{2}$ inch	4
50 feet	$\frac{3}{4}$ inch	15
70 feet	1 inch	25
100 feet	$1\frac{1}{4}$ inch	40
150 feet	$1\frac{1}{2}$ inch	70
200 feet	2 inch	140
300 feet	$2\frac{1}{2}$ inch	225
400 feet	3 inch	300
500 feet	4 inch	500

Finally, I reprint in full the rules for the guidance of gas-fitters, issued by the Detroit Heating and Lighting Company. These, as well as the other rules quoted, are fully applicable to modern gas piping.

RULES OF THE DETROIT HEATING AND LIGHTING COMPANY

To be observed by gas-fitters for properly laying gas pipe, for either gasoline or coal gas.

1. As a rule, the carburettor is located at the rear or side of the building to be lighted, and at a point somewhat lower than where the building stands. The location of the riser should be as near that of the carburettor as practicable, on an inside wall, and in that portion of the building that will allow the pipes to have a fall towards it with the least possible cutting of joists.

2. In large buildings it is sometimes difficult to get a fall to the pipes without considerable cutting of joists; in such cases we recommend having two or more risers at different locations.

3. Keep the upper end of the riser, or tee, where you take off the connection for horizontal pipe, low enough to enable you to get the desired fall to all the pipe connecting into riser at that point.

4. All pipe in a building that is warm, and where joists have to be cut, should have a fall of at least $\frac{1}{16}$ inch to the foot; in buildings or parts of buildings where the pipe is exposed and where it is not necessary to cut joists, the fall should be at least $\frac{1}{8}$ inch to the foot, but if it is convenient to get more, it is all the better to have it, as you cannot get too much, especially in cold places.

5. If the building is so constructed as to make it impossible to have all the pipes laid with a fall toward the riser, the pipes may be laid with a fall toward some convenient point and connected into a drip can, so the condensation will run into the can instead of into the riser. This can should, where possible, be placed outside of the building or in the cellar, and never in a place where it can be gotten at conveniently, excepting when necessary.

6. A stopcock must be put on the pipe before it is connected, so that the gas can be shut off from the can while it is being emptied.

7. Under no circumstances must there be any sags or traps in the pipe. Every inch of pipe must have a fall towards the main riser, and this must be determined by the use of a spirit level. Never depend on the joists or floors, as they are seldom level. A very good way to do is to put a piece of wood, the thickness of the fall the pipe is supposed to have in two feet, on the bottom of the level, two feet from one end, then you can run the level along the pipe and see that it is proper with but little trouble.

8. All pipe should be secured with gas-fitters' hooks in such a manner as to make it impossible for any portion of it to settle and form traps.

9. All drops must be taken from the side or top of main line of pipe, and run horizontally to location of drops. The drop must be securely screwed up, well stayed both at top and bottom of joists, hung plumb, and brought about three inches below bottom of joists; if centerpieces

are used, the drops will have to be longer, according to thickness of centerpiece.

10. All brackets must be supplied from the pipe in the floor below. Drop elbows should be securely fastened to wall to prevent turning when brackets are being put on. Where pipe is run on a brick wall, the brick should be chipped out to allow the pipe to be sunk in so the plaster will fully cover it.

11. Use white lead mixed with boiled oil for making joints, being very careful not to get so much of it in the fitting or on the pipe that when screwed together the lead will close up the opening.

12. Each piece of pipe should be looked into or blown through to see that the bore is clear.

13. No pipe should be laid on an outside wall or in exposed places. If impossible to avoid doing so, they should be well protected by boxing or wrapping.

14. No riser in any building should be less than one inch (inside) in diameter, and no pipe used in any portion of the building, even to supply one light, should be less than 0.375 inch.

15. The following table gives the proportionate sizes and lengths of pipe allowed by us to be run:

Size of Pipe.	Greatest Length Allowed.	Greatest Number of Lights.
3/8 inch	15 feet	3
1/2 inch	20 feet	6
3/4 inch	50 feet	12
1 inch	75 feet	25
1 1/4 inch	90 feet	75
1 1/2 inch	125 feet	100
2 inch	150 feet	200

16. Where additions are made to piping, the connections for additional outlets should in all cases be taken from pipe where the rule for sizes can be followed.

17. In buildings where there are prospects of adding burners to present number, the pipes put in should be of sufficient size to allow for all possible additions.

18. After all the pipe is in, it must be tested with at least five pounds air pressure. If there are any large leaks, either sandholes or splits, the defective piece must be taken out and replaced by a perfect one.

If the leaks are very small, they may be repaired by caulking them, with the pressure on, using soapsuds to tell when leak is stopped, and then cement them.

Cementing them without first caulking is useless and must not be done.

CHAPTER X.

PIPING FOR ACETYLENE GAS.

SPEAKING generally, the piping of buildings for acetylene gas does not differ materially from the piping as done for coal or illuminating gas, except in one respect, namely in the sizes required for the pipes.

As is well known, the burners used in acetylene gas-lighting are of much smaller capacity than ordinary gas burners; it is usual to use burners using from 0.5 to 0.7 cubic feet of gas per hour. It would, therefore, seem as if much smaller pipes were required for acetylene gas. On the other hand, the specific gravity of acetylene gas is much higher than that of coal gas, and this naturally should be taken into consideration in fixing upon the pipe sizes.

The diameters of the gas mains and services for acetylene must be of such size that they will supply the maximum required volumes of gas to the burners without the necessity of carrying an excessive pressure in the pipes.

The flow of all gases through pipes is expressed by the well-known formula of Dr. W. Pole, established by him in 1852, in a paper on "The Motion of Fluids in Pipes," namely:

$$Q = 780 \sqrt{\frac{h \times d^5}{s \times l}} \quad . \ . \ . \ . \ . \ . \ . \ . \quad (1)$$

in which

l = length of pipe in feet,
d = internal diameter of pipe in inches,
h = actuating pressure in inches of head of water,
s = specific gravity of gas, air being = 1.
Q = volume of gas delivered by pipe in cubic feet per hour.

Or, if we express l in *yards* instead of feet,

$$Q = 1350\, d^2 \sqrt{\frac{h \times d}{s \times l}} \quad . \ . \ . \ . \ . \ . \ . \quad (2)$$

and $$d = \sqrt[5]{\frac{Q^2 \times s \times l}{(1350)^2 \times h}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Because of the increased friction in the smaller pipes, the formula was modified by Bernat so as to read

$$Q = 1313.4 \sqrt{\frac{h \times d^5}{s \times l}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and if we take $s = .91$ for acetylene

we have $$Q = 1376.9 \sqrt{\frac{h \times d^5}{l}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and $$d = 0.05552 \sqrt[5]{\frac{Q^2 \times l}{h}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

A still later formula for acetylene gas-piping is that of Morel, which gives

$$d = 0.045122 \sqrt[5]{\frac{Q^2 \times l}{h}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and $$Q = 2312.2 \sqrt{\frac{h \times d^5}{l}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

For convenient tables worked out from this formula see Leeds and Butterfield, "Acetylene," London, 1903.

The piping for acetylene gas must be perfectly sound, and the joints must be perfectly tight. It is advisable to use only the very best class of gas-fittings, which should be either beaded fittings or the heavier steam-fittings. The gas-fitter's work should be done with the utmost care, the fittings must be well-threaded and the threads on the ends of pipes cut sharp and clear, so as to secure tightness by metallic contact between pipe and fittings. No lead or composition pipe should be used for acetylene gas, as it is too liable to be damaged where exposed, and to be pierced by nails where concealed.

All piping should be rigorously tested, and any leaks found repaired. The test should be, if anything, more severe than that for pipes carrying coal or water gas. Regarding fixtures, jointed brackets and sliding chandeliers should be avoided on account of the greater risk of leakage. Ordinary rubber hose for portable lamps should be avoided, and only metallic flexible hose connections used.

In a paper on acetylene generator installations, by Mr. Meissner, published in 1906, he advises that the piping should not be too small. "No mistake is made," he says, "by using too large pipe, while a serious mistake can be made by using too small pipe."

I give below a few tables of piping for acetylene gas, which show a great diversity in the requirements. Note, for instance, that the sizes called for by the rules of the National Board of Fire Underwriters are the same, substantially, as those called for for ordinary gas.

The following table shows the size of pipe to use to carry the amount of gas at the left column, to the distance at the top column, allowing a pressure loss of 0.04 inch of water in the length of pipes.

TABLE FOR ACETYLENE GAS PIPING.

(From the *Acetylene Journal.*)

Cubic Feet.	Distance in Feet.													
	10	15	20	25	30	35	40	45	50	60	70	80	90	100
2	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
4	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
6	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
8	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
10	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
15	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
20	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
25	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1
30	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1
35	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1	1	1	1
40	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1	1	1	1	1	1
45	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1	1	1	1	1	1	1
50	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1	1	1	1	1	1	1	1
55	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1	1	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$
60	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
65	$\frac{3}{4}$	1	1	1	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
70	$\frac{3}{4}$	1	1	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
75	$\frac{3}{4}$	1	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
80	1	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
85	1	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
90	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$
100	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$
110	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$
120	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$
130	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$
140	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2
150	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	2

SIZES OF PIPING FOR ACETYLENE LIGHTING.

(Russell C. Miller, Supt., Lakeville Conn. Gas Company.)

For House Piping.

⅜ inch pipe for up to 45 lights (1-foot burners).
½ inch pipe for up to 77 lights.
¾ inch pipe for up to 130 lights.
1 inch pipe for up to 208 lights.

For Street Mains, for village lighting.

1 inch pipe up to 175 lights.
1¼ inch pipe up to 377 lights.
1½ inch pipe up to 490 lights.
2 inch pipe up to 784 lights.
2½ inch pipe up to 1097 lights.
3 inch pipe up to 1645 lights.
4 inch pipe up to 2565 lights.

A prominent acetylene apparatus manufacturer published a few years ago the following pipe table:

TABLE.

Showing average length of pipe in feet used for a given number of 0.5-cubic-foot-per-hour burners and size of pipe. Based upon an even distribution of outlets.

0.5 Cu. Ft. per Hour Burners.	Size of Pipe.								
	⅛	¼	⅜	½	¾	1	1¼	1½	2
1	20	50	100	200	...	...	...	...	...
5	15	40	75	175	...	...	...	...	...
10	10	20	50	150	...	...	...	...	...
20	...	15	40	100	250	...	...	...	...
30	...	10	30	75	225	...	...	...	...
40	...	...	20	50	200	500	...	...	...
60	...	...	10	40	175	450	750	...	...
90	...	...	...	30	125	400	600	1000	...
120	...	...	...	...	100	300	500	900	1000
150	...	...	...	...	75	200	400	750	900
200	...	...	...	...	50	150	300	600	750
240	...	...	...	...	...	125	250	500	600
300	...	...	...	...	...	100	200	400	500
400	...	...	...	...	...	...	150	350	475
500	...	...	...	...	...	...	...	300	450
600	...	...	...	...	...	...	...	200	400
800	...	...	...	...	...	...	...	...	350
1000	...	...	...	...	...	...	...	...	300

Rules: Do not use pipe of a greater length than given in the table, even for a smaller number of burners.

Do not use a greater number of burners than given in the table, even for a shorter length of pipe.

The number of angles in any system of piping must be considered. If there are many, the pipe must be larger.

The arrangement of outlets must also be taken into account. If unevenly distributed the pipe must be larger.

RULES AND REQUIREMENTS FOR PIPING FOR ACETYLENE GAS.

(By the National Board of Fire Underwriters, 1903.)

Piping.

a. Connections from generators to service pipes must be made with right-and-left-thread nipples, or long-thread nipples with locknuts. All forms of unions are prohibited.

b. Piping must, as far as possible, be arranged so that any moisture will drain back to the generator. If low points occur of necessity in any piping, they must be drained through tees into drip cups permanently closed with screw caps or plugs. No pet-cocks shall be used.

c. A valve and by-pass connection must be provided from the service pipe to the blow-off for removing the gas from the holder in case it should be necessary to do so.

d. The schedule of pipe sizes for piping from generators to burners should conform to that commonly used for ordinary gas, but in no case must the feeders be smaller than three-eighths inch.

The following schedule is advocated:

$\frac{3}{8}$ inch pipe, 26 feet, three burners.
$\frac{1}{2}$ inch pipe, 30 feet, six burners.
$\frac{3}{4}$ inch pipe, 50 feet, twenty burners.
1 inch pipe, 70 feet, thirty-five burners.
$1\frac{1}{4}$ inch pipe, 100 feet, sixty burners.
$1\frac{1}{2}$ inch pipe, 150 feet, one hundred burners.
2 inch pipe, 200 feet, two hundred burners.
$2\frac{1}{2}$ inch pipe, 300 feet, three hundred burners.
3 inch pipe, 450 feet, four hundred and fifty burners.
$3\frac{1}{2}$ inch pipe, 500 feet, six hundred burners.
4 inch pipe, 600 feet, seven hundred and fifty burners.

e. (omitted) . . .

f. Piping must be thoroughly tested both before and after the burners have been installed. It must not show loss in excess of two inches, within twelve hours, when subjected to a pressure equal to that of fifteen inches of mercury.

g. Piping and connections must be installed by persons experienced in the installation of acetylene apparatus.

CHAPTER XI.

THE TESTING OF GAS PIPES.

In the foregoing chapters, I have laid much stress upon the necessity of making the gas piping perfectly gas-tight. It is, however, desirable to have some positive knowledge that the piping is absolutely free from any leaks, and such certainty can be gained only by submitting the pipe system to a pressure test.

In all new buildings the test is applied as soon as the gas piping is completed, before any plastering is begun, and also before any gas fixtures are connected, *i.e.*, while all gas outlets are still tightly capped.

After the fixtures are hung or connected, it is no longer possible to apply the same test which is used for the piping only, because the fixtures and the gas keys are rarely constructed so tight as to stand the heavy air pressure which is applied to the piping. It is feasible, however, to repeat the test with a much lighter pressure, or else to rely upon an odor test, by turning on the gas at the meter.

There is really but one good method of testing new gas pipes in buildings: it consists of a test with air pressure. The apparatus required for such a test comprises an air pump, a pressure gauge, preferably a mercury glass gauge, some ether, and a brush and soapy water. The mercury gauge is preferred, because it is much more sensitive than a spring gauge, To know the pressure with which one deals, it is but necessary to remember that a column of mercury one inch high in the gauge tube is equivalent to 0.5 pounds pressure per square inch. Thus, a pressure which raises the mercury twenty inches in the glass gauge amounts to 10 pounds.

In all work under my charge or done under my specifications, I require a test with a pressure equivalent to 18 or 20 inches of mercury. Some argue that such a heavy pressure is uncalled for, as the gas piping when in use will never carry anything like such pressure (the usual pressure of gas in buildings being only from 20 to 40 tenths inches of water). I maintain that it is feasible so to put the gas pipes together that they will, for all practical purposes, be absolutely gas-tight, and I use the heavy pressure merely to have it demonstrated to me that the pipes are tight. From practical experience I find that there is no difficulty whatever about making a gas-piping system stand this heavy pressure, if proper care is exercised in using good material, in cutting the threads, and in screwing the pipes and fittings together. "Leaks rarely occur in gas piping after it is put in properly, *i.e.*, without the cementing up of sandholes in fittings or the cementing of leaky joints" (Galloway). In all cases, however, where the gas-fitter has used red or white lead in his joints it is well not to apply the test until the lead has thoroughly set or become hard.

A few words about the way in which the test is carried out. The testing apparatus is connected to any convenient gas outlet, preferably to a side outlet, so placed that the mercury gauge will stand at a convenient height for observing the same. Before applying the test, the gas-fitter should make sure that all outlets are quite tightly capped, so that there may not be any escape of air at the outlets.

After forcing air into the pipes and pumping up the pressure so that the gauge will indicate from 18 to 20 inches of mercury, the pumping is stopped, and the valve on the testing apparatus is tightly closed.

The time is noted when the watching of the gauge begins. A few minutes' observation of the gauge will quickly tell whether there are leaks. It would be a mistake to require the mercury in the gauge to stand for *one* or *more hours* without changing its position, for changes both in temperature and in barometric pressure might occur during that time, which would affect the indications of the gauge.

If the mercury stands firm and rigid at the same height (which can be conveniently marked by a strip of paper or by a ring on the gauge glass), and if the top of the mercury, which shows slightly rounded, does not flatten out, the piping is tight. If the mercury drops, there must be some leaks. Should it drop very rapidly, the leak is large, and is usually more easily found. If it drops slowly, the leak is small and not so easy to find, though the rate of fall will necessarily depend somewhat upon the extent of the piping under test. The watching of the gauge should be continued for about 15 minutes. If at the end of this period of time the gauge still indicates at the same height, the system may be passed as tight.

If the mercury drops, one should note the rate of fall during the period mentioned before, for the rate of fall, taken in connection with the cubic contents of the piping under test, indicates the extent of the leak. If the fall is very rapid, it is possible that the gas-fitter forgot to close some gas outlet, or there may be a split pipe, or a nipple may have been omitted.

There are several ways in which leaks are found. One is to put ether into the testing apparatus, to force it into the pipes, and to trace the leak by the odor of escaping ether. This, in a new unenclosed building, is sometimes a difficult matter. It is much better to apply soapsuds by means of a brush to the fittings and joints suspected of being leaky; wherever there is a leak, the escaping air will cause soap bubbles to form, and will in this way show its location.

When the cause of the leak is determined, the remedy should be applied; fittings with sandholes, and split pipes or pipes with defective seams should be removed and replaced by perfect work. Leaky screw joints should be tightened up where it is possible to do so. After this is done, the test should be again applied and the watching of the gauge should be continued.

Sometimes one finds the advice given to test a gas-pipe system by filling the pipes with water under pressure, much in the manner of the plumbing test for the rough work. I do not recommend the practice, for it leads to annoying rusting up of the gas pipes; the water is also difficult to remove from the drop pipes after a test.

Some writers wrongly advise the search for leaks with a match, a candle, or an open flame of any kind. This is dangerous when ether has been applied to the pipes; it is folly in cases when escapes of gas are noticed in a pipe system after the meter has been connected and the gas turned on. Other writers on the subject qualify their advice by stating that "judgment should be used when hunting for a leak with a lighted candle." My advice is to let well enough alone, and *never to use a lighted candle* for finding gas leaks.

Where the pressure of air used in testing is heavy, the hissing sound of the escaping air frequently indicates the place where the leak is.

If it is at a joint, or if a fitting is found to have a sandhole, a common practice is to use gas-fitters' cement to close up the leak, but this cannot meet approval. It is, in fact, bad advice, for cement should not be used at all in a gas-pipe system, for reasons given elsewhere in this book.

Where the building is large, or has a great many stories, it is safer and easier to test the gas piping in sections, or by floors, and to repeat the test for the entire building only after having made sure that the sections are tight.

In testing old work, it is much more difficult to find leaks, because a good part of the piping is hidden or covered up. In such a case it is best to test first the exposed piping wherever practicable, and after making sure that it is tight, to test the portions which are permanently out of sight.

The Joslin indicator, manufactured in England, by William Sugg & Co., if fixed on the house side of the gas meter, on a by-pass, is a good telltale for indicating small leaks. A similar appliance is made by Muchall in Germany.

In occupied houses the fact that there are gas leaks may sometimes be discovered by putting the ear to the gas meters, all burners being of course turned off. A noise in the gas meter indicates a movement of the recording works inside of the meter, and consequently a passage of gas — in other words, leaks either in pipes, fittings or fixtures.

When the gas is turned on at the meter, it is best to use the nose in hunting for leaks. Some books on gas-fitting state that leaks may be found by "using a lighted taper in the search," but although they add that "great care must be exercised to guard against setting the building on fire," I am strongly opposed to such practice. At the point where the gas leaks, the open flame may ignite the gas, and cause it to burn, perhaps, with a very small bluish flame, which is either scarcely perceptible or which may be out of sight. The flame may finally set some woodwork on fire, particularly if the leak is in a closely confined place, in partitions or between floors. In other cases the mixture of gas and air may be such as to become explosive, and gas explosions may result. (See "Hints to Gas Consumers," Chapter XXI.)

When one is satisfied that the gas-pipe system is tight, it is a good practice to have some of the caps on the outlets loosened on each of the floors, while the pressure is still kept on the pipes. Care should be taken to have the cap loosened only sufficiently to indicate by the falling of the mercury in the gauge that the particular section of piping, which feeds the gas outlet selected, has been under test. The experiment also gives useful indications that the piping is not clogged up.

Where the gas fixtures are hung by parties other than the man who did the piping, it is a good plan for the gas-fitter to retest the pipes just before the fixtures are connected. If they are shown by the test to be tight, it necessarily follows that any subsequent gas leaks must be at or in the gas fixtures, and they will be found either at the gas keys, or the swing joints of folding brackets, or at the joint where the fixture is hung.

In some cities in Europe, the tightness of a gas-pipe system is tested with the aid of a small gas-holder of 1 to 2 cubic feet contents, which can be loaded with weights up to a pressure of 3 pounds or 6 inches mercury. The gas-holder has a scale divided to one three-hundredths of a cubic foot, and an escape of one six-hundredth to one nine-hundredth cubic foot can be readily measured. In applying the test, the gas-holder is connected with the pipes to be tested, and filled with either air or illuminating gas. The sinking of the gas-holder, when the apparatus is connected with the gas pipes, indicates leaks, which are searched for as described above. In England, use is often made of "tell-tale meters," with which the smallest leak can be detected at the instrument. It is usual in this case to divide the piping in smaller sections. This test may be more accurate and scientific, but it is neither as simple nor as rapid as the test usually applied by American gas-fitters.

It is difficult to fix upon a limit for allowable small leaks (no system of gas pipes being really absolutely gas-tight). When the gas-holder test is used, it is sometimes ruled that the hourly loss by leakage should not exceed one-thirtieth to one-fifteenth cubic foot per three hundred lineal feet of pipe.

The following remarks, contributed by a practical gas-fitter to the columns of *The Metal Worker* are to the point:

"If the mercury stands at a given height for from fifteen to twenty minutes with a round bead on top, and does this repeatedly, there is no leak that any man can find or detect with any appliance that I have knowledge of. I often have had my men report to me that the mercury, after standing some time, will rise if the atmosphere became warmer while they were testing. Just so will it fall toward evening if it is pumped up during the afternoon or while the atmosphere is warm, which goes to show that the expansion or contraction of air in the pipe affects the mercury.

"I once had a leak in a small gas job that two men worked faithfully for ten hours to find. The mercury would fall about $\frac{1}{32}$ inch in fifteen minutes, showing that there was a very small leak. We could detect a slight smell of ether on a piece of $\frac{3}{8}$-inch pipe, 18 inches long. We lathered it, but could get no bubble. I turned the gas on it, but found that it would not burn through the hole. I had the pipe removed and a sound one put in. This did the work effectually, curing the leak and proving that a very slight leak will show on a mercury column in a short time. I afterward tested the defective piece of pipe, and under forty pounds water pressure it would sweat a drop about once a minute through a hole that you could not see."

It is a good plan, in all large buildings, particularly in factories, mercantile buildings, churches, theaters, and hospitals to have the gas pipes tested periodically, and at least once a year. To do this thoroughly, it is advisable to take off all the gas fixtures and to cap the outlets. Where one does not care to go to this trouble, it is possible to find out if there are leaks by watching closely the small index of the gas meter. (See Chapter XVII.) A great many small leaks usually exist at the fixture joints, at the gas keys, at the stuffing-box joints of chandeliers, and at the points where the lava tips are inserted in the burners. Leaky gas keys should be carefully reground, but, for the time being, a leak at a gas key may be stopped by applying a mixture of grease and beeswax.

CHAPTER XII.

GAS-LIGHT ILLUMINATION.

THE chief means for obtaining a good and satisfactory illumination by gas-light should be briefly mentioned.

The term "gas lighting," or gas-light illumination, signifies the artificial illumination of interiors, and of streets, parks, and public squares, by means of gas flames or gas jets. In the houses, gas lighting is accomplished by means of more or less ornamental wall brackets and chandeliers, adapted for burning illuminating gas in burners or tips, arranged singly or in clusters. It is not intended to discuss in this book the illumination of streets and squares.

It will be assumed: (*a*) That the gas supplied to the consumer is properly purified at the gas works, and that in quality it is of the requisite and sufficient candlepower.

(*b*) That the gas piping in the building has been done in a first-class manner, and in accordance with the rules given in the preceding chapters; that pipes and fittings of proper materials and of ample size have been used; that these pipes and fittings have been put together in a workmanlike manner and are tightly jointed; that the distributing pipes have been properly run, with sufficient grade and with good fastenings and supports; that all gas outlets have been securely strapped; and that the piping has stood a severe pressure test and has no leaks or imperfections.

(*c*) That the gas company has run a service of ample size into the premises, and has set a gas meter of sufficient capacity to supply all burners likely to be in use at one time.

Under such conditions, the factors upon which the illumination depends are the gas burners, the pressure regulators, the globes and globe holders, and the gas fixtures.

The essential preliminary steps which gas consumers who desire a good illumination should take, are:

(1) To select and use the best quality of gas burners, for these will not only give a better light, but they will burn less

gas in proportion to the candlepower developed than poor burners, or, to put it in other words, they will produce a higher candlepower per unit of gas consumed.

(2) To regulate the pressure with which the gas issues at the burner, which may be accomplished either by the use of gas-pressure regulators on the main house pipes for gas, or by using volumetric or governor burners at the gas fixtures.

(3) To regulate the air supply to the flame, which is accomplished by the use of suitably shaped and suitably placed gas globes, and in the case of Argand burners, by the use of well-proportioned glass chimneys.

(4) By selecting well-designed and well-constructed gas fixtures and judiciously placing the same in the apartments to be lighted.

According to an elaborate report, made by the London Gas Referees, in 1870, a serious waste of gas occurs, owing to the great number of bad burners in general use. Consumers may, by using good instead of poor burners, obtain from thirty to fifty per cent more light without any increase in the gas bills. From this it is evident that gas may be used wastefully or economically, this depending largely on the selection of the burners. Burners suitable for ordinary coal gas are not adapted for gas of high candlepower, and vice versa. Unfortunately, the proper methods of burning gas are little understood, not so much owing to want of popular information on the subject as on account of the general indifference of the gas-consuming public as well as of the gas companies.

Gas consumers are, as a rule, very slow in the adoption of progressive methods or appliances in domestic gas lighting, and the gas companies, with a few commendable exceptions, have not in the past made the slightest efforts in the interest of the consumers, by explaining in a lucid manner the problem of how to burn gas economically, and how a maximum efficiency of light, combined with perfect and complete combustion, may be obtained from the burning of a cubic foot of gas.

Much remains to be accomplished in this direction; many widely existing fallacies regarding gas lighting have to be fought and removed, and in their place a correct knowledge of the principles of gas illumination should be disseminated. In by far too many cases, the existing conditions, such as too small pipes, meters of insufficient capacity, excess of pressure, bad burners, ill-shaped globes, cumbersome globe holders, and defective gas fixtures preclude any chances of obtaining a successful illumination.

I cannot here go into a consideration of the nature of the gas flame or into the theory of combustion, and will simply state as a general axiom that gas should be burnt at a low pressure. The most favorable pressure varies slightly with the quality, candlepower and specific gravity of the manufactured gas, but may be taken on an average as five-tenths of an inch of water pressure at the burner. An excessive high pressure of gas has a tendency to reduce the illuminating power of the gas flame, and it also causes the roaring or singing of flames, the flickering of the lights, the cracking of glass globes and a waste of gas. On the other hand, if the pressure is too low, the flame is apt to smoke, becomes dull and reddish in appearance, and vitiates the air.

The art of illumination is practically a new science, and it is only recently that professional men have taken up the subject from a scientific as well as practical point of view. A large yet untrodden field is open to the new profession of the "illuminating engineer." Those in search of sound information on the subject would do well to obtain a copy of an excellent treatise, recently published, entitled "Practical Illumination,"* by Cravath and Lansingh, both authors being men who have devoted years of study and investigation to the subject. The monthly issues of a new magazine, called *Illuminating Engineer*, also contain important information.

* Practical Illumination, by Cravath and Lansingh. McGraw Publishing Company, 1907. Price $3.00.

See also the following six instructive pamphlets, issued by the Holophane Glass Company of New York City:

Light *vs*. Illumination.

The Lighting of the House.

The Lighting of Large Buildings, Offices and Stores.

The Lighting of Theaters and Public Halls.

The Lighting of Churches, Schools, Libraries, and Hospitals.

The Lighting of Hotels and Clubhouses.

See also a pamphlet, issued by the Nernst Lamp Company, of Pittsburg, in 1907, entitled The Art of Lighting, by Lux

CHAPTER XIII.

GAS BURNERS.

A GAS BURNER may be defined as the point at which illuminating gas issues from the service pipe to be ignited for the purpose of giving light (or in some cases heat). A gas burner generally consists of a metal, lava, or steatite tip attached to the gas fixture, which by its size or opening regulates to some extent the size of the flame and the amount of the gas consumed. The common gas burners for lighting are generally composed of two parts, the body and the tip of the burner.

Before mentioning in detail the different kinds of gas burners in common use, a few words should be said about the nature and the chemical process involved in what is known as the "luminous flame."

The process does not vary in principle whether the illuminant burned be *solid* (like the tallow, wax, paraffine, or other candles), or *liquid* (such as colza oil and kerosene burnt in lamps), or *gaseous* (coal or water gas). All gas contains hydrogen and carbon. In all illuminants the heat of the flame eliminates carbon; the hydrogen combines with the oxygen of the air, creating a very high temperature, which causes the carbon particles to become incandescent. The carbon is finally consumed in the flame, and carbon dioxide, some carbon monoxide, and watery vapor are formed.

While in candle and oil-lamp illumination the gas is only generated during combustion, it is in the case of gas illumination already prepared at the gas works and therefore issues at the burner ready to be lit.

Every luminous flame has three distinct parts or zones, namely: an inner zone, where there is no combustion; a middle or intermediate zone, in which partial combustion takes place, and which is the luminous or light-giving zone, as it contains the carbon particles raised to incandescence; and finally an outer zone where complete combustion takes place, and which is non-luminous.

The luminosity of a flame, of whatever nature, depends, therefore, first, upon the amount of carbon or light-giving substance contained in the flame, and, second, upon the proper, sufficient, but not excessive air supply to the flame.

Should there be too much air supply, the intensity of the flame will be reduced. The bluish or non-luminous flame of the Bunsen burner is due to the excess of air furnished to the flame. For this reason, gas should not issue at a burner under too high a pressure, for this causes too much air to come in contact with the flame. It is an axiom, which should be borne in mind, that in the flat-flame and Argand burners gas should be burned under a low pressure.

In determining upon the kind and size of burners to use, one should take into consideration not only the amount of light, *i.e.*, the candlepower desired, but also the gas pressure at the burner orifice and the specific gravity of the gas, or its proportion of hydrocarbons.

The lighter the gas is, the more volume will flow out at a burner. Those gases which are rich in hydrocarbons have the smallest specific gravity but the highest illuminating power, hence require small burner openings; heavy gas, on the other hand, or gas which contains a lesser amount of hydrocarbons, requires to be burned in larger burners.

Early in the history of gas lighting we find the energies of able inventors devoted to the improvement of the original and crude devices which had served as gas burners, but the correct principles, according to which a perfect gas flame was to be produced, were not then known. It is both interesting and instructive to follow the gradual developments of the better class of burners. Nearly a century after the invention of gas lighting a fresh impetus was given to the gas-burner industry by the introduction of the electric lamp. This compelled gas companies to devote attention to the available better gas appliances for street illumination, and also caused consumers to make inquiries about the details of properly constructed gas burners for interior lighting. The London Gas Referees called attention to the fact that by the use of good burners 50 per cent more light without increased gas bills could be obtained. At the present day, the simplest as well as the most scientifically and accurately constructed gas burners are available, and new improvements are constantly being made.

Broadly speaking, we may distinguish between the following types of gas burners, viz.:

(*a*) Single-jet burners.
(*b*) Flat-flame burners: (1) Bat's wing. (2) Fish-tail.
(c) Round-flame or Argand burners.
(*d*) Multiple flat-flame burners.
(*e*) Regenerative burners.
(*f*) Incandescent burners: (1) Upright. (2) Inverted.

Of all gas burners, the single-jet burner is the simplest, oldest, and crudest device, consisting of a plain body and tip, generally combined, having only one small, round aperture for gas. These burners were used only to a limited extent, where a very small flame was required, and hence they may be dismissed with these few words.

The second and third types of burners, viz.: the flat-flame and the round-flame burners, are those with which we were chiefly concerned in dwelling-house illumination until the invention of the incandescent gas-burners brought about great and far-reaching changes. Of the two types named, the bulk of burners used belong to the flat-flame type.

All flat-flame burners, as the name implies, spread their flame in a thin, broad sheet. It is usual to distinguish two kinds of flat-flame burners, viz.: the bat's-wing or slit-union burner, and the union-jet or fish-tail burner.

The bat's-wing burner has a hemispherical tip, with a narrow vertical slit, from which the gas issues in a thin and broad sheet, whereas the union-jet, originally invented by James Milne, of Edinburgh, consists of a flat and sometimes of a slightly depressed or concave tip, with two small holes drilled under a certain angle to each other, from which two jets of equal size issue, and by impinging upon one another produce a flat flame.

Flat-flame burners do not require the use of a chimney to prevent the smoking of the flame, but the gas flame is usually sheltered against draft by surrounding it with a glass globe, except in the case of the imitation candle burners which, however well they may look on gas chandeliers do not give a good illumination as they usually have very small tips, and also because they are apt to flicker.

As originally constructed, the two burners produced flames widely differing in character, the bat's-wing burner giving a flame of great width and little height, while the fish-tail burner produced a flame considerably narrower and longer. While the bat's-wing burner is better adapted for burning heavy gas, the fish-tail burner should be selected for gases rich in hydrocarbons.

On account of its great width, the flame of an ordinary bat's-wing burner is easily affected by even slight currents of air, which cause the flame to smoke, and the protection which a glass globe affords to the flame cannot be so readily applied to the common bat's-wing burner, because the slightest lateral deviation of the broad flame often causes the cracking of a glass globe. This is one reason why ordinary union-jet burners are so commonly used on gas fixtures with glass globes, although the bat's-wing burner is slightly preferable, as regards the development of light.

An early step in the improvement of flat-flame burners consisted in simple devices, intended to reduce the velocity with which gas issues at the burner orifice owing to the gas pressure, experiments having established the fact that a greater degree of illumination could be obtained by burning gas at a low pressure. These devices consisted in introducing some mechanical obstruction, such as wire gauze, cotton, wool, or a mica disk, or a regulating screw, into the body of the burner. Owing to the fact that coal gas is not always well purified, all devices which serve to constrict the lower part of the burner are very liable to stop up with tarry matters carried in suspension in the gas, which become condensed and are deposited in the wire gauze or in the wool. After some time, such "check burners," as they are sometimes called, generally become unfit for use, or at least produce a very ragged and uneven flame, owing to the material in the body of the burner becoming more obstructed in some parts than in others.

The first valuable improvement in gas burners consisted in the selection of a more suitable material for the tip or head of the burner. The old burners were usually made entirely in one piece, either of iron or of brass. Movable tips were introduced later on, and were inserted in the metal body of the burner, but at first these tips were still made of iron. This material is objectionable for two reasons, viz.: first, the burner orifices in union-jet and in bat's-wing burners become rapidly choked by the corrosion of the metal. Such obstructions by rust may, it is true, be removed from time to time with burner cleaners, sold in hardware stores or obtainable from the gas companies, those for union-jet burners being in shape of a small awl, while those for slit burners consist of thin strips of sheet brass or steel, fastened to a suitable handle. The average householder rarely bothers himself with such matters; but even where these burner cleaners are used, the inevitable result of their too frequent or careless use will be that the burners quickly become injured or destroyed. The nickel plating of the iron burner tips obviates to some extent the corrosion of the burner orifice, and quite recently a non-corrosive aluminum gas tip has been put on the market, for which the advantage is claimed that it does not chip or crack, as lava tips sometimes do.

A second and more important objection against brass or iron burner tips is that metal, being a good conductor, abstracts much heat from the burner tip, and thereby reduces the temperature of the flame, causing some loss in the degree of illumination.

Therefore, a great step forward was made by the introduction of non-metallic, non-corrosive, and non-conducting substances for burner tips. The material most commonly used is lava, but this is brittle and cracks easily, and various gas-burner manufacturers employ other materials, such as porcelain, or steatite (a sort of soapstone of very fine grain, which burned in a kiln becomes hard and incorrosive, and is easily polished) or "adamas," a compound artificial material of a mixture of various earths or minerals, or some sort of "enamel." Sugg's and Brönner's burners have steatite, Bray's burners enamel, and Leoni's burners adamas tips; and all modern improved flat-flame and round-flame burners have tips made of one or the other of these materials, which are practically everlasting and not susceptible of oxidation.

Further improvements made relate to the shape of the tip and of the body of the burner. In some gas burners, for instance, the body is suitably enlarged to form a sort of expansion chamber wherein the velocity of the gas, as it issues from the pipe, is, to some extent, checked.

The bat's-wing burner was improved by making the interior of the top of the burner hollow. The slit thereby becomes of equal depth throughout. Sugg also improved the bat's-wing burner by cutting the slit with a circular saw, which has a favorable effect upon the shape of the flame. The advantage is thereby gained that gas issues more uniformly at all points of the tip, and the shape of the flame thus becomes improved, *i.e.*, it is less broad and somewhat taller.

A further improvement of the bat's-wing burner was made by William Sugg, who applied a rim-like projection to the outside of the burner below the slit, a so-called "table-top," the object of which was to check the rush of the outer air in the immediate vicinity of the flame. Thus the flame is better protected from drafts, the shape of the flame is more evenly preserved, and all smoking is prevented.

Manufacturers of union-jet burners, in turn, were not slow in applying improvements to their type of burner. Some introduced into the body of the burner layers of muslin to check the flow of gas, others inserted plugs or washers of enamel, perforated with small apertures for the passage of gas. These apertures can be adjusted to various pressures, and the ultimate object in view is to cause the gas to issue at the burner tip at the lowest pressure consistent with proper illumination. The result is that the height of the gas flame, which in the common fish-tail or union-jet burner is excessive, becomes considerably reduced and the roaring and flickering of the light is prevented. A similar result was obtained by making the burner top slightly hollow, and the angle at which the two streams of gas meet more obtuse.

By all these improvements, the two at first quite different flames of the bat's-wing or slit burner, and of the union-jet or fish-tail burner, have been modified and gradually altered so much that in their modern and most improved form the shapes of the flames of the two types are practically identical.

Among the best improved flat-flame burners are those of Broenner, Leoni, Sugg, Bray and Silber. The Sugg improved hollow-top steatite slit burner, the Sugg circular-slit table-top steatite burner, the Bray enamel non-corrosive "regulator" fish-tail and slit burners, and the Silber "Concordia" flat-flame burner, which has two small burner orifices separated by an intervening wedge-shaped piece of brass, are among the best ordinary flat-flame burners obtainable in the market. These burners are all of English make, except the Broenner burners, made in Frankfort-on-the-Main, Germany. Of the latter burner eleven numbers are made, consuming from one to eight cubic feet of gas per hour. They give a uniform light with varying gas pressures, and if judiciously selected and fitted with the "Cornelian" globes with large bottom and top opening and a shadowless glass holder, as recommended by the manufacturers, they give a good and satisfactory illumination.

I have not learned of any efforts on the part of American gas-fitting manufacturers to bring out improved flat-flame burners, comparable at all in efficiency with those above mentioned.

The mill burner with screw check, the "Empire" check burner with inside adjustable screw cylinder with slot, the "Imperial" burner with wire gauze to check the flow of gas, the Gregory mica-flap burners, and the "Young America" burner with small brass diaphragm pierced by minute holes, are gas burners of American make, and being in the nature of check burners are somewhat better than the ordinary kind. I shall, however, have occasion in another chapter, on governor burners, to mention some very excellent American flat-flame burners.

In a dwelling house of average size a comparatively small number of burners are required, hence it will pay gas consumers to put on their fixtures only the best burners, whatever their price may be. Improved gas burners are also much preferable from a sanitary point of view, because there is less contamination of the atmosphere in a house.

Regarding the size of the burners, I would say, wherever a dim light only is required, as in halls, passageways, and bathrooms, two- or three-foot burners, and for bedrooms three- or four-foot burners, may be used; but for the gas fixtures in the principal rooms large burners, consuming from five to six cubic feet of gas per hour are much to be preferred, and it should be borne in mind that for bright illumination a few large burners — under low pressure — are preferable to a large number of small burners. Under all circumstances consumers should avoid making the mistake of procuring gas burners promiscuously from irresponsible agents, or from peddlers, and afterwards blaming the gas company for "poor light," or for exorbitant gas bills.

Before leaving the flat-flame burners, I ought to mention some automatic safety gas burners recently devised, the object of which is to automatically shut off the gas supply, in case a gas light is accidentally extinguished, or "blown out," or in case the gas key is inadvertently turned on. An American patented device of this kind has a wire protruding from the burner tip, and extending down to the bottom of the burner, where it comes in contact with a small valve. While the burner is cold the valve is closed, cutting off the gas supply. When a light is applied to the burner the wire becomes heated, expands, lengthens, and pushes the valve away from its seat, thereby admitting the gas to the burner tip. As soon as the flame is extinguished, the wire, by cooling, contracts and again cuts off the gas. A simple safety regulator burner is patented by Jahn, and manufactured by Frederick Lux, of Mannheim, Germany.

These burners would seem to be specially adapted for hotels and lodging houses, where gas is often "blown out" by ignorant people, and they may prove successful in preventing suffocation, suicides, explosions, and other accidents due to escaping gas.

I have devoted considerable space to the discussion of the ordinary flat-flame burners because, notwithstanding the Argand, regenerative, and incandescent burners, the flat-flame are usually the consumer's favorite burners, and because the bulk of illuminating gas used for lighting purposes is still burnt in bat's-wing and fish-tail burners. Further mention of flat-flame burners will be made in the discussion of governor burners. (See Chapter XIV.) I will now pass on to consider the round-flame or the so-called Argand burners.

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Argand or round-flame burners consist essentially of a hollow ring, connected with the gas tube and perforated on its upper surface with a series of fine holes, from which the gas issues, forming an annular, hollow, round flame. The Argand burner derives its name from its similarity with the Argand oil lamp, and like the latter always requires a glass chimney, properly proportioned in diameter and height, to induce a perfect combustion by increasing the air supply to the flame, and also to lessen its susceptibility to side drafts. The Argand burner gives a higher candlepower per unit of gas consumed than flat-flame burners, but it also develops a greater amount of objectionable heat. The original burners of this type were not constructed on scientific principles, no provision having been made in them for regulating the air supply to the flame and — what is equally important — the pressure of gas, and hence these burners were liable to smoke.

We are indebted for important improvements in this direction to Mr. William Sugg, the well-known English manufacturer of improved gas-lighting appliances. In his improved Argand burner, gas is delivered at a very low pressure; the supply is distributed evenly throughout the entire ring of holes; the flame generated is of even and regular shape; the chimney, which is so essential to the round-flame burner, is properly proportioned in diameter and height, and the burner is made of "steatite" instead, as formerly, of metal, which abstracts too much heat from the flame. The Sugg "London" Argand burner, with twenty-four holes, has so many good qualities that it was selected by the London Gas Referees, in 1869, as the standard test burner for sixteen-candle gas.

Further improvements were embodied in Sugg's "London" improved Argand governor burner, which developed a still better light from the gas consumed, and in which a regular and uniform supply of gas to the burner was insured by the use of either a steatite float or a leather diaphragm governor.

An equally excellent Argand burner, with automatic governor, is made by the Silber Light Company, of London, while of American round-flame burners I mention the "noiseless" Argand burner, made by the Gleason Manufacturing Company. All these burners are much improved by the addition of the volumetric gas governor, which maintains a steady flow of gas and regulates the pressure. Of this apparatus I have occasion to speak in the next chapter.

The Siemens precision burner is an improved Argand burner, having a flat disk in the center of the flame, which causes the same to bulge out and tends to a more perfect combustion with increased luminosity of the round flame. This is similar in principle and construction to the metal button deflector placed over the air tube, as adopted in many of the modern improved central draft oil lamps. Similar modifications of the Argand burner are the Grand gas lamp, the Niagara Argand burner, the Royal Argand, the Gordon-Mitchell high-power gas lamp, with inverted annular burner, forming a small regenerative Argand burner, and the Morey incandescent gas burner.

In order to obtain increased illumination, duplex and multiple gas burners were invented. In the double, duplex, or "twin" flat-flame burner, two bat's-wing or sometimes two union-jet burners are placed together on the same body and set at a certain angle to each other, so that the two flames are made to combine. A somewhat greater amount of light is developed thereby than by using the two flames separately, but the light is no better than that obtained through a large single burner. Such burners are used very rarely, but recently they have been revived for acetylene gas lighting.

Multiple burners consist of several concentric rings of round burners, or else of a series of three, five, or more, flat-flame burners arranged in such a manner that from whatever point they are looked at, a flat side of the flame is exposed. Bray's high-power street-lamp burners belong to this class, as well as Sugg's "Walthamston" and "Taj" high-power lamps. They have been gotten up and used to some extent to obtain a brighter street illumination, but also for the lighting of stores and large halls. The street lanterns of this type are made stormproof, so that the flame is not affected by the wind, and are provided with milk-white glass at the top of the lantern for the purpose of reflecting the light downward. Multiple round-flame burners have been adopted to a limited extent in lighthouse and street illumination, such as the Wigham multiple burner and the Germania double and triple concentric Argand burners.

The "Shaw" reflector lamp is a regenerative multiple flat-flame burner, in which an attempt is made to superheat the gas before ignition. Halliday's "Clapton" lamps are similar in principle, and in the United States similar lamps largely used are the Gregory incandescent and the Gleason "Beacon" lamps.

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I will next consider the high-power or regenerative gas burners. In all burners of this type the high temperature due to the combustion in the gas flame is directly utilized to raise the temperature of the gas before ignition, or of the air supply before combustion, or of both, the result being an intensified and more perfect combustion, and a vastly increased illuminating power. All regenerative lamps produce a higher efficiency of candlepower per cubic foot of gas consumed than is secured by ordinary burners, the burners are economical in gas consumption, and the light produced is intense and steady.

One of the first regenerative burners was the Siemens burner, invented by Friedr. Siemens in 1879. In its original form this burner is a round-flame burner, in which the flame burns around a central porcelain cylinder, over the top edge of which it turns. From this point the products of combustion pass downward through a central flue, and in their passage they heat a chamber through which the air passes upward, becoming highly heated by contact with the burning body. The products of combustion are then carried to the escape pipe by means of one or two side tubes.

The first regenerative burner gave a very powerful light, but it was clumsy and inelegant in form and appearance; the shadow cast by the large body of the burner was objectionable, and hence it did not find much favor for interior lighting, although it was extensively applied for the lighting of streets, squares and parks, and large halls. Regenerative gas lamps have since then been modified and constantly improved, and the Siemens inverted regenerative lamp is now manufactured in several different forms.

The Lungren regenerative lamp, which resembles the Siemens, is practically an inverted Siemens lamp, in which the flame burns outward and upward around a central shell which it heats to a high temperature. The air supply enters above the flame by means of tubes extending across the escape flue, and passes down on both sides of the flame. The flame is enclosed in a clear glass bell, semi-globular in shape, which is supported by a hinged ring.

Other regenerative lamps, some having the flame burning from the inside out and others from the outside towards the inside, and all similar in principle, but different in details of design and construction, are the improved Siemens, the Wenham, Bower, Clark, Grimston, Thorp, Gordon, Sugg, Bray, Brown's "Brilliant," Fullford, "Meteor," Butzke, Schülke, Westphahl and Muchall lamps.

For dwelling-house illumination regenerative lamps have, up to the present time, been used to a very limited extent only, although the fact that nearly all of these lamps are powerful ventilating agents and may be made to assist materially in the removal of the vitiated air of apartments, would seem to recommend them particularly from a sanitary point of view. Their application has been largely confined to special cases, such as the lighting of large assembly halls, stores, and for lighting streets and squares, and wherever used they have proven to be very economical in gas consumption. The burners of regenerative lamps are somewhat complicated, require a nice adjustment, and are liable to clog up with deposits of carbon, and need, together with the enclosing glass globe, frequent cleaning and attention. This, together with the high price of the lamps, has also acted as a drawback against their general introduction.

Among the latest regenerative gas lamps, especially adapted for interior lighting, I mention Sugg's patent "Cromartie" gas lamp. In these lamps "a special form of steatite burner is used inverted, with the object of retarding the motion of the carbon particles through the length of the flame, thus allowing sufficient time for the oxygen of the atmosphere to combine with the carbon of the gas in combustion. This arrangement produces an intensely white flame in the form of a camelia, diffusing a perfectly steady, white, shadowless light of great illuminating power." Each lamp is provided with a Sugg automatic leather diaphragm governor. These Cromartie lamps are made in two forms, either as ventilating or as non-ventilating lamps. In the ventilating lamps the heat developed by the combustion of gas is not only carried away without entering the room, but it is utilized to assist in educing heat or vitiated air from the apartments. In the case of smoking rooms this arrangement is particularly effective, all smoke being rapidly conducted to the exterior. The air at the ceiling level is kept cool and pure, and furniture, pictures, and gilt frames are not subjected to damage. The Cromartie lamps are said by experts to produce very high results in candlepower, the quality of the light is said to be excellent, and as these lamps are gotten up in a variety of pleasing and artistic designs, shapes, and colors, they lend themselves admirably to decorative lighting.

Mr. MacFie, gas engineer of the firm of Milne, Sons & MacFie, in a paper read at the annual meeting of the North British Association of Gas Manufacturers in Edinburgh, in 1891, has pointed out one notable feature of all regenerative lamps, namely, that they throw the light downwards where wanted, whereas all flat-flame burners tend to light up the ceilings and upper parts of the walls.

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A further advance in the perfection of gas lighting was made by the invention of the incandescent gas burners. In these burners the flame is not luminous in itself, but its heat is utilized in raising to incandescence some refractory substance introduced into the burner. The latter is usually an atmospheric or Bunsen burner with bluish flame. The light-giving substance may be a basket of platinum, as in the Lewis burner; or a conical-shaped basket or network of magnesia, as in the Clamond lamp; or a row of finely-shaped, parallel, suspended rods of magnesia, such as is used in the Fahnejelm lamp; or finally a funnel-shaped wick or mantle of cotton treated chemically with sulphate of zirconium, and other rare elements, such as yttrium, thorium, didymium, and lanthanium, as seen in the original Welsbach incandescent burner.

The Clamond was, and the Welsbach incandescent gas lamp is, used to a very great extent in Europe, while the use of Welsbach mantle lamps has also become very general in this country. The former is the invention of a Paris chemist, the latter of a Vienna chemist, Dr. Auer von Welsbach.

After being first put on the market the Welsbach burner disappeared again, owing to various imperfections. But it afterwards reappeared, in much improved form, and since a few years there are numberless similar incandescent burners, like the Kern burner, the Yotto burner, the Lindsay lamp, and others. The Welsbach and other incandescent lamps are very excellent while the mantle is new, but the light deteriorates after some use and loses some of its intensity, and this is particularly the case where the atmosphere carries much dust, which settles on the mantle, forming a sort of incrustation, which renders the light less incandescent and changes it from white to red. One objection to the Welsbach style of incandescent lamp is that the cotton mantle is extremely delicate and readily breaks, also that the glass cylinders surrounding the filament crack at times, and in doing so break the mantle. As good mantles are expensive, the Welsbach lamp, although undoubtedly very economical in the use of gas, in the end sometimes proves to be quite costly. Among its advantages are the steadiness of its light, particularly when used with a volumetric governor, and the decreased radiation of heat as compared with other high-power gas lamps.

The Welsbach incandescent lamps have for many years been adopted in European cities for street illumination, and quite recently street lamps in the United States were fitted with incandescent mantles, and very favorable results have been obtained as regards lighting power. In New York and Brooklyn all flat-flame street gas-lamps are now replaced by Welsbach burners.

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The latest modification of incandescent gas lighting, introduced in 1905, consists in the use of *inverted* burners. The inverted gas burners throw the light downward and hence do not cast shadows; the mantles are shorter and hence do not break quite so easily; the light given off is better and stronger, and the gas consumption is less. For these reasons the inverted incandescent gas lamp has quickly proven successful, and its popularity is bound to increase. Quite recently, such lamps have been used in connection with the compressed-gas system for the illumination of railroad cars, both here and abroad, and the mantles seem to be but little affected by the vibration and jarring of the cars.

Another modification of the incandescent-mantle burner is what is usually called an "air-hole burner," the chimneys having a number of holes to furnish air to the burner. The device seems to increase the luminosity of the mantle, and accordingly air-hole incandescent burners have become quite popular, and a number of such burners have been put on the market.

In Europe self-lighting devices, and even self-lighting mantles are used to a large extent. A number of these have been introduced and repeatedly tried here, but failure resulted in most cases. The composition of the water gas, so much used in American cities, has undoubtedly been one cause of the commercial failure of these devices. It is claimed that the gas used here does not contain sufficient hydrogen to make the device operate successfully.

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The foregoing description of gas burners would be incomplete without a brief mention of the albo-carbon light, which gives a much increased illumination and a very white, soft, and steady light, by the carburetting of the ordinary gas. This process consists in supplying to the ordinary gas, at the gas burner, a further amount of carbon illuminants. The enriching solid carbon material is kept in a vessel combined with the gas fixture, and the heat of combustion of the gas flame is used to preheat the gas supply and to vaporize the carbon, which thus enriches the gas, and effects a saving in the gas consumption.

The discomfort and feeling of oppression existing in rooms lighted with gas burners, and which is due to the heat created by the flames, to the products of incomplete combustion escaping into the air, and to the amount of watery vapor given off, has led to the invention of so-called "ventilating" gas burners.

Among such burners may be mentioned the sunlight burner, a fixture with one or more concentric clusters of burners, placed near the ceiling. The clusters are placed under a ventilator, which is connected at its upper end with a ventilating duct leading either to the outer air or to some larger vertical vent duct or shaft. Some of the regenerative gas lamps already spoken of have such a vent duct, and cause an efficient ventilation of the room. It is stated that a ventilating regenerative gas burner, using about 20 cubic feet of gas per hour, will remove not only its own products of combustion, but in addition about 5000 cubic feet per hour of vitiated air of a room.

In large rooms of assembly, lighted by gas, it is imperative that either ventilating gas lamps be used, or that special ventilating arrangements be provided at the ceiling to remove all injurious products of combustion.

In the same way, it is true that no large gas heating or cooking stove, or gas water-heater should be used without thorough and sufficient means of ventilation.

CHAPTER XIV.

GAS-PRESSURE REGULATION.

GAS governors may be defined as devices for regulating the flow of gas in a gas main, in a gas fixture, or in a gas burner.

As we shall see in this chapter, such devices are beneficial in preventing wasteful gas consumption and in preventing the roaring of gas flames; we shall also learn that they are more useful and serviceable than the method of regulating the pressure at the meter stopcock or at the fixture gas key.

It is a well-known fact that the gas pressure in the supply mains is constantly fluctuating, and that, at times and in certain districts, it is greatly in excess of what is required for proper combustion at the burners. The burning of gas under too high pressure means a large waste of gas and a loss in illumination, amounting sometimes to from 33–50 per cent. Consumers are made aware of an excessive gas pressure by the roaring, hissing, or singing gas flames, by the jumping up of the flames and by other irregularities.

The pressure of gas is measured by siphon or U-shaped glass gauges, filled with water, and provided with a scale of inches and tenths of inches. The pressure is always given in tenths of inches of a column of water.

The gas pressure should be about $\frac{8}{10}$ inch at the gas meter, and since the friction in the pipes would cause a loss of from $\frac{2}{10}$ to $\frac{3}{10}$ inch, this would leave a pressure of $\frac{5}{10}$ at the burner, which is about right for flat-flame and Argand burners, while incandescent burners require a little higher pressure.

It is a popular fallacy that gas companies willfully put on a high pressure at the works in order to make the consumers' meters go faster. A moment's reflection ought to convince any fair-minded person that this is not the case. If the above supposition were true, the gas companies would be the losers in two ways, viz.:

(1) A high pressure leads to a larger loss by leakage at the joints in the street mains, a loss usually estimated at from

seven to ten per cent of the total gas output, but often largely in excess of this amount.

(2) An excessive pressure would mean an increased consumption, or rather waste, of gas in all street lamps having ungoverned burners and not supplied through a meter, for which gas companies are paid a fixed sum per lamp per year.

It is, nevertheless, true that it is impracticable for gas companies to maintain a constant pressure in the street mains.

In a town of small extent, with absolutely level districts, and with centrally located gas works, a gas pressure of 10/10 inches of water in the mains would be ample to supply all consumers. Such conditions, however, are quite exceptional, and as a rule, owing to variations in levels of various districts, owing to various diameters of the gas-supply mains and submains, owing to the unavoidable friction in the pipes and the extreme distances to which gas has to be conducted from the works, the gas works are obliged to put on a high initial pressure in order to insure a sufficient supply to the most distant consumers and to those located in low-lying districts. Again, no matter how well the gas distributing pipes in a house may be proportioned and adjusted, it is impossible to maintain an even pressure at the gas burners, for the pressure in the house pipes and at the burners changes continually with the varying number of burners lit at one time in a dwelling, and also, and to a higher degree so, with the varying consumption in a street or in a district. These unavoidable fluctuations of pressure range from 10/10 to 40/10 inches of water pressure.

The evils of high gas pressure have long been recognized, and efforts have been made to avoid the same. An excess of pressure at the gas burner means imperfect combustion, loss of illuminating power, vitiation of the atmosphere, blowing and hissing gas jets, and a wasteful use of gas. In speaking of burners, I have already stated that a high pressure and small burners are not to be recommended; that, on the contrary, ample volume of gas, issuing at a low pressure, from large burners, are desirable conditions for successful gas illumination.

The following results of experiments, taken from an able paper by Mr. Butterworth, the general manager of the Columbus (O.) Gas Company, exhibit clearly the evil effect of over-pressure at the burner:

TABLES I.

(A)	Common 3-Cubic-Foot-per-Hour Burner Tip.				
Pressure	10/10	15/10	20/10	25/10	30/10
Consumption in cubic feet per hour	5.70	7.55	9.15	10.40	11.45
Candlepower	13.36	16.62	17.64	18.88	17.08
Candlepower per cu. ft. per hr. of gas consumed	2.344	2.201	1.917	1.815	1.492

(B)	Common 5-Cubic-Foot-per-Hour Burner Tip.				
Pressure	10/10	15/10	20/10	25/10	30/10
Consumption in cubic feet per hour	7.45	9.70	11.50	13.15	14.20
Candlepower	16.32	21.96	23.28	21.80	20.28
Candlepower per cu. ft. per hour of gas consumed	2.191	2.264	2.025	1.658	1.428

These experiments demonstrate the enormous waste of gas occurring with common burners, where no attempt is made to regulate the pressure. They also show that high pressure means a loss in candlepower; for, whereas the consumption of gas doubled, the efficiency of the burner decreased 57 per cent, for the 3-cubic-foot-per-hour burner, and 53 per cent for the 5-cubic-foot-per-hour burner, showing a slight advantage in favor of the larger burner.

There are various ways in which the gas pressure in the house pipes or at the burners may, up to a certain extent, be controlled and checked. One rough method consists in throttling the main gas-cock at the gas meter, and another in turning the gas keys at each fixture, *i.e.*, at the burners. Sometimes both methods are jointly used, the meter-cock control to cut down wider fluctuations of pressure and the burner key to effect a finer regulation. Such methods, however, are unsatisfactory and unreliable, because the control of pressure is not automatic, and because it would obviously be impracticable to require the consumers to devote care, time, and almost constant attention to the frequent manipulation and adjustment of the burner keys, made necessary by the constant fluctuations in the pressure. Indeed, this would prove to be such a troublesome and annoying proceeding that it would be likely to be overlooked or forgotten.

A multitude of check burners have been devised, all having in view a retardation of the velocity with which gas escapes at the burners. This they accomplish to a certain extent, but as the obstructing material is, as a rule, fixed in the burner and cannot be adjusted, whereas the pressure fluctuates constantly, it is obvious that check burners can not and do not attempt to regulate the flow of gas or govern the pressure. Even the best check burners, having adjustable checks, would require a frequent adjustment during the evening hours and, therefore, would have no advantage over the simpler method of checking the flow by turning the gas keys. All that can really be said in favor of check burners is that they are better than the common gas burners and that they are somewhat cheaper than automatic governor burners. The Empire burner, the Young America, the Broenner, Leoni, and Bray burners, Sugg's "Winsor" burner, Gregory's mica-check burner, and Silber's bat's-wing burner, having a lower chamber in which the gas expands and thus escapes at the slit of the burner tip under diminished pressure, are examples of this class.

From Mr. Butterworth's paper I quote again two tests of consumption and efficiency, made with a 5-cubic-foot-per-hour Empire check burner and a No. 6 Bray special burner:

TABLES II.

(C)	5-Cubic-Foot-per-Hour Empire Check Burner.				
Pressure	10/10	15/10	20/10	25/10	30/10
Consumption in cubic feet per hour	3.10	4.05	4.85	5.50	6.05
Candlepower	9.24	12.44	15.18	16.74	18.04
Candlepower per cu. ft. per hour	2.981	3.071	3.129	3.044	2.982

(D)	No. 6 Bray Special Burner.				
Pressure	10/10	15/10	20/10	25/10	30/10
Consumption in cubic feet per hour	6.10	7.75	9.10	10.25	blowing
Candlepower	15.60	18.56	20.74	22.72	...
Candlepower per cu. ft. per hour	2.557	2.395	2.279	2.216	...

It is evident from the above observations that check burners do not prevent wasteful use of gas, that they do not control gas pressure, and that the gas consumption of check burners necessarily varies with the pressure. In the above tests the consumption of the Empire burner was nearly doubled when the pressure increased from 10/10 to 30/10, whereas the candle-power per unit of gas consumption remained the same.

While the gas works may, by using station and district governors, reduce, or control to a certain extent, the pressure in the street mains, it is obviously desirable that the consumers should use means in their houses for controlling the gas pressure automatically. Gas companies long ago recognized the evils of excessive pressure, and also the fact that economy in lighting depends upon its efficient control. Where they undertake to furnish public illumination of streets and squares by contract with the city for a stated fixed annual sum of money for each street lamp, they, therefore, applied to the burners automatic means for controlling the pressure and thus preventing waste of gas.

Two efficient methods, each one of them only applicable under certain conditions, may be adopted by the consumer to effect an automatic control of the gas pressure; gas governors are accordingly of two entirely different kinds. One may apply an automatic gas governor on the house service-pipe at the meter, which will regulate and reduce the pressure in the whole house-pipe system, and maintain a practically constant pressure at the level of the meter, or else one may use automatic gas governor burners, which control the rate of gas supply to each burner separately, establishing a constant consumption at each burner, while leaving the full pressure in the house pipes. By the use of governor burners higher results are attained in pressure regulation than by the use of pressure regulators.

There are a large number of gas-pressure regulators in the market, and as it is the chief object of this chapter to point out to the consumer that there are means available for efficient control of the gas pressure, rather than to offer a detailed description of these devices, many of which are quite similar in principle and in construction, I will simply state that there are two kinds of pressure regulators, namely, the dry and the wet regulators, the former using a leather diaphragm, whereas the latter uses a float, cup or bell, dipping either in glycerine or else in mercury.

The Sugg and the Peebles diaphragm pressure regulators are examples of English devices of the first class, whereas the Scott, Shaw, Sugg, Bower, Ewart, Brown's "Excelsior" and Peebles' mercury, are English pressure regulators belonging to the second class.

The "National" automatic and the Amick gas regulators are American liquid governors, having a brass globe floating in a seal of glycerine, and the Beattie, O'Gorman, and Patterson regulators are examples of American mercury-seal regulators. Some of these are obtainable for sale, whereas others are only placed on a rental basis in the houses of consumers by companies obtaining a revenue from the saving effected as shown by the monthly gas bills.

It is an essential condition, where pressure regulators are applied, that the house pipes be made very ample in size, that there be as few elbows or bends in the pipes as possible, and that the tubing of gas fixtures, the aperture of gas keys, and the slits of the burners be large; in other words, that the volume of gas supplied to the burners be ample, otherwise the inevitable result of a control of pressure is a loss of light, or reduced illumination. Therefore, such pressure regulators should never be used by consumers where the above conditions are not complied with, otherwise the remedy might prove worse than the evil complained of. It is equally useless to apply pressure regulators to houses in low-lying districts where the pressure is already low. In all cases the saving in gas consumption, which is the result of a reduction in gas pressure, should be effected without any loss of illuminating power.

A pressure governor or regulator placed on the service pipe of a house reduces an excessive gas pressure and secures a tolerable uniformity of pressure and supply at all burners; but this is only true of buildings with small floor area and of few stories in height. For large factories and halls, with many lamps on the same level, where the whole number is always lighted, a pressure regulator will answer.

In the case of large buildings and in all buildings of many stories, on the other hand, an absolutely uniform pressure is not attained, because no matter how well the distribution pipe system may have been calculated and arranged, there is necessarily some loss of pressure through friction in long pipes and at elbows, so that the gas at burners situated at a distance flows at a lower pressure. Owing to its specific gravity, which is not quite one-half that of air (about 0.45), gas tends to gain in pressure with increased elevation, each rise of ten feet vertically adding one-tenth inch of water pressure. If the governor is adjusted so as to give a pressure of 6/10 inches on the ground floor, the pressure on a floor ten feet higher would be 7/10 inches and so on. This explains why, in high buildings, even with a pressure regulator at the meter, the gas pressure increases for each floor, causing the burners in the upper stories to "blow." Therefore, the better method in such cases is to provide a governor on each floor.

It is sometimes feasible in cases where the number of burners lighted remains constant, and where the pressure varies only slightly, to control and reduce the pressure on each floor level by a governor, and in addition to use a good check burner at the fixtures. Sugg's "Winsor" screw-regulating burner has been devised with this special object in view.

The best and surest remedy, undoubtedly, consists in the use of automatically acting governor burners at all fixtures. Governor burners must not be confounded with check burners, which only retard, whereas governor burners regulate, the flow of gas in such a way that, as the pressure increases, their regulating action increases, and vice versa. Such governor burners cause the gas to issue at the burner in a constant volume, no matter what the pressure in the service pipe may be, hence the name "volumetric" burners is sometimes applied to them.

The first automatic regulating burners were devised for street lamps, and they were sometimes very clumsy in shape, casting large shadows downward. They have been much improved of late years, and now there are several good governor burners obtainable which are compact in shape, not unsightly on the gas fixture, and which act almost perfectly in regulating the supply to the burners, and in preventing gas from flowing out under excessive pressure. Even governor burners, however, may in time clog up, and will require occasional cleaning.

There are many different makes of volumetric burners, and it is not my intention to describe any of them in detail. Briefly stated, the flow of gas is controlled in them by a light cup, cone, or disk, placed in an enlarged chamber of the burner, which floats up or down as the gas pressure increases or diminishes, and being connected with a valve at the entrance to the burner, it opens or closes the same, and thus causes more gas to be admitted when the pressure falls, and when the pressure rises reduces the supply.

Volumetric governor burners are equally applicable to flat-flame, round-flame, regenerative, and incandescent burners. The best regenerative lamps are always fitted up with such a regulator, and likewise are the Argand and flat-flame burner lamps of the highest make always sold with them.

Among the best-known governor burners I mention those of Giroud, Wilder, Sugg, Peebles and Lux, the first one being a French burner, the second a burner of American make, the third of English, the fourth of Scotch make, and the last one being a German volumetric burner.

Other burners, not so well known or extensively used, are the Rappleys rheometric governor burner, endorsed in 1882 by the Committee on Science and Arts of the Franklin Institute; the Champion burner, patented by Van Wies in 1890; the Chamberlain, Boore and Jackson burners, all of American make; the Schuelke adjustable gas governor burner, of German make; and the Orme, Hawkins and Acme burners, of English make — the Hawkins burner, being the only governor burner with union jet tip known to me.

My list does not pretend to be exhaustive, and it is quite possible that I may have unintentionally omitted some good burners which have not come to my notice.

The Wilder volumetric governor burner is the invention of Moses G. Wilder, M.E., of Philadelphia, who obtained a patent for it in 1880. This burner is a good example of an American governor burner, and it is suitable not only for flat-flame and Argand burners, but also for regenerative lamps and for the Welsbach incandescent lamp. The maker, in describing it, states that it is not a pressure reducer or regulator, that the flow of gas through it is not changed by very wide variations of pressure, and that it secures a uniform rate of supply to the burner, with little or no reduction of pressure.

The inventor of the Boore burner, Mr. Lewis Boore, of Buffalo, N. Y., states that he endeavored to produce a reliable and simple automatic governor burner of low cost, which would indicate practically correctly for a very wide range of pressure, without having such an extreme accuracy or such close adjustment as to destroy its utility.

William Sugg & Co. make two kinds of volumetric burners, a steatite float governor and a leather diaphragm governor burner.

Sugg's patent "Alexandra" governor burners combine great economy with efficiency, and produce a brilliant, white, silent light. They are fitted with steatite float governor, and the superior light attained is also a result of adopting double annealed Albatrine globes with wide opening. An even better flat-flame burner by the same maker is Sugg's patent "Christiania" governor burner, fitted with a specially prepared leather diaphragm governor, with Sugg's patent table-top, circular-slit, steatite burner tip. Sugg's London improved Argand burner always has a governor burner attached to the fixture.

Mr. Wilder calls attention to the fact that his governor burner, to operate well, requires a full street pressure. This rule is applicable to all volumetric burners; hence, where these are used, a pressure regulator should not be used at the meter.

In order to show, by actual experiments, how nearly uniform the consumption of gas remains with governor burners, I refer the reader again to Mr. Butterworth's able paper on governor burners, wherein is published the following table, showing the gas consumption of a number of such burners under varying pressures:

TABLE III.

Pressure.	10/10	15/10	20/10	25/10	30/10	35/10	40/10	Type and Make of Burner.
	Cu. Ft. per Hr.	Cu. Ft. per Hr.	Cu. Ft. per Hr.	Cu. Ft. per Hr.	Cu. Ft. per Hr.	Cu. Ft. per Hr.	Cu. Ft. per Hr.	
6 cu. ft. per hr. governor burner	6.20	6.20	6.35	6.30	6.25	6.25	6.40	Sugg
6 cu. ft. per hr. governor burner	5.95	6.50	6.20	6.20	6.05	6.15	6.05	Peebles
5 cu. ft. per hr. governor burner	4.50	4.50	4.55	4.55	4.65	4.65	4.60	Chamberlain
5 cu. ft. per hr. governor burner	4.50	4.65	4.55	4.65	4.70	4.65	4.55	Rapplye
5 cu. ft. per hr. governor burner	4.90	4.95	4.95	4.95	4.90	4.90	4.90	Lux
Adjustable burner . .	5.60	5.50	5.40	5.30	5.07	4.80	4.60	Champion
Adjustable burner . .	4.96	5.97	5.21	6.19	6.05	5.89	5.69	Boore
Adjustable burner . .	4.95	4.95	4.95	4.95	4.95	4.95	4.95	Wilder

The last burner in the table showed a perfect uniformity of supply under the wide range of pressures used in the test. Some of these governor burners are adjustable, and if they are required to pass a certain quantity of gas per hour, a nice adjustment is necessary, which can only be accomplished if the candlepower and quality of gas, its pressure and specific gravity are known. A governor burner, adjusted for a gas of certain specific gravity, would not remain correct for a gas of different density, or for any temperature which would change the density.

Both the pressure regulators on the main service pipe and the governor burners render the gas-piping system independent of the unavoidable fluctuations of pressure in the street mains and accomplish a saving in gas consumption by preventing useless waste, amounting to a reduction of from twenty to forty per cent in the gas bills. Other incidental advantages gained are: A great improvement in the steadiness of a gas flame without regard to the number of burners lit or the constantly changing street pressure; the hissing or roaring noise, the blowing, and the flickering of the light is prevented; the illumination becomes stronger; the smoking of Argand burners is prevented, and the air of the room is vitiated to a much smaller extent by the products of imperfect combustion. With governor burners, however, these results are attained in a higher degree than with pressure regulators on the service pipe. All efficiently-acting gas governors should effect a saving in the consumption of gas without causing a diminution in the light.

In New York State the Legislature quite recently limited the maximum pressure of gas in the mains to that due to $\frac{25}{10}$-inches of a water column. While this law aims at correcting the evils of too heavy gas pressure, it is doubtful whether it is desirable to control the pressure in this way. It might have the undesirable effect that in some districts or streets consumers would suffer from *lack of pressure* and lack of a sufficient supply of gas.

While trying to comply, as far as possible, with the laws, the gas companies received hundreds of complaints daily that gas ranges would not burn properly, and that gas flames, left partly turned down, went out on account of lack of a gas supply.

As already mentioned, gas companies, in order to avoid excessive gas leakage in the street main, carry only a pressure at the works sufficient for efficient service, hence this question could well be left to their judgment. In many city districts, which have grown beyond anticipation, or where numerous high buildings are located closely together, the old gas street mains have become inadequate for the service to be performed, and hence a higher initial pressure must be put on to force sufficient gas through the pipes. A possible solution of the difficulty might be found in a division of a city into zones or districts, each district being provided with a suitable automatic pressure governor.

To sum up, practical considerations must decide which form of regulation it is best to adopt. In this connection the following rules are to be recommended, viz.:

(*a*) Where the street mains are large and the differences of level insignificant, use either check burners or volumetric burners.

(*b*) Where the street mains are small, or the pressure is low, or the house pipes insufficient in size, neither method of regulation should be employed, and the only remedy would be to put in not only large burners, but also large pipes.

(*c*) Where the town is hilly and there are reasonably large differences of elevation in the districts, a pressure regulator will answer in districts on a higher level than the gas works, provided the house pipes are large, the gas keys full bore, and the building only a few stories in height, and not of great extent laterally.

(*d*) Where in such districts the buildings are high or very large, a pressure regulator on each floor should be used, together with regulating check burners at the fixtures, but in such cases governor burners at the fixtures are a simpler remedy, and are, therefore, to be preferred.

(*e*) Never use gas pressure governors where the gas pressure is low, or where the house gas pipes are known to be insufficient in size in proportion to the gas consumption, as the results would be very unsatisfactory.

(*f*) Do not use gas pressure regulators on the main service where incandescent mantle burners are used, for these require a higher pressure than flat-flame burners.

(*g*) Do not use gas pressure regulators on the line supplying gas cooking fixtures, except where the pressure is unusually heavy.

CHAPTER XV.

GAS GLOBES AND GLOBE HOLDERS.

Flat-flame burners are, as a rule, surrounded with gas globes. Practical experience and observation have established the fact that if these are unsuitably arranged, or of improper shape, they constitute another factor, causing deficient illumination, imperfect combustion, and frequently a waste of gas and a corresponding increase in the gas bills.

Gas globes are devices, usually of glass, and used chiefly to protect open flames against draft, and thereby to prevent the annoying unsteadiness and flickering of the light, but also used as ornament to add to the external appearance of the gas fixtures. They are also employed to shade the eyes from the direct glare of the light, to diffuse and soften the light, and finally, gas globes are, for safety's sake, placed over naked burners to shield the flame from coming into direct contact with inflammable materials. Glass shades are used to reflect the light downward. From all of which it follows that gas globes are used for utility even more than for ornament, hence their design and construction should be based on sound principles.

In order to obtain good illumination, and to avoid the flickering of the light, the air necessary for combustion should be brought to the flame in a slow, uniform and steady current. If the air supply is insufficient, a flame is apt to smoke and will blacken ceilings and contaminate the air. If the air rushes to the flame in a violent manner, this will destroy the steadiness of the light, the light will flicker and jump, and it has the further detrimental effect of cooling the flame, and thereby reducing its brilliancy.

The old style glass globes were quite defective in shape, form, and material. They were made with very narrow top and bottom openings, or, if tulip-shaped and widening at the top, the bottom opening was extremely narrow, being often but one and one-half or two inches in diameter, and, where such globes were in use, the ceiling was often the only well illuminated place. The result was that, owing to the smallness of the bottom aperture, the contracted globe acted like a chimney, causing the sharp air current to impinge upon the flame to such an extent as to seriously disturb it, and thereby causing it to flicker in a distressing manner. Another defect of the old style globes is that they form dust traps, and that they are readily soiled in lighting.

If, in addition to this defect in the globes, the gas pressure at the burner was excessive, the resulting illumination necessarily was very imperfect. To determine the actual loss of light due to small openings in globes, Dr. Wallace made a series of experiments, which showed the following results:

A naked flame was tested and found to give 16.8 candlepower. The same flame, surrounded with a 7.5-inch diameter clear globe, with 2.375-inch bottom opening, gave 15.4 candlepower, or a loss of 8.3 per cent. The same flame surrounded with a 7.5-inch diameter clear globe, with 2.25-inch bottom opening, gave 15.2 candlepower, or a loss of 9.5 per cent. The same flame, surrounded with a 7.5-inch diameter clear globe, with 2-inch bottom opening, gave 13.6 candlepower, or a loss of 19 per cent. The same flame, surrounded with a 7.5-inch diameter clear globe, with 1.5-inch bottom opening, gave 13 candlepower, or a loss of 22 per cent. The same flame, surrounded with a 7.5-inch diameter clear globe, with 1-inch bottom opening, gave 12 candlepower, or a loss of 28.6 per cent.

All glass globes, moreover, absorb a certain amount of light, and the loss of light and corresponding waste of gas due to this cause increases the more opaque the glass tube is. It also increases with the soiling of the globes. Fancy "ruby" or other colored, etched, ground or otherwise decorated globes, in particular, absorb a large amount of light, and hence increase the gas bills by the necessity of keeping a larger number of lamps lighted on a chandelier. It is stated on good authority that the light is obstructed as follows:

	Per Cent.
By clear glass globes	10–15
By slightly ground globes	24
By globes ground all over	25–40
By opal, thick glass globes	64

Globes of thin, milk-white or opal glass, if made with bottom opening four inches in diameter, give a soft and mellow light.

Lastly, the globes with narrow bottom and wide top opening are objectionable, because instead of casting light outward and downward by reflection, they throw the greatest amount of light up to the ceiling, where it is not wanted.

It matters little how attractive in shape and artistic in outline such old style globes are; as long as they tend to disturb the flame they are clearly objectionable. These defects have been gradually recognized, and such globes with contracted openings are now happily being discarded. The new form of globes has wide bottom openings, which admit the air without causing a draft; the shape of the globe is designed more with a due regard to its proper functions than solely from a decorative point of view. Such globes induce a straight, upward, gentle current of air, and the flame remains steady and bright. All globes of modern construction have bottom openings, at least 4 and 5 inches in diameter, and have the incidental advantage that a portion of the light falls directly downward without being obstructed.

The Sugg "Alexandra" and "Christiania" burners are surrounded with globes of most desirable shape and material, in which the top and bottom are of the same size; the Broenner burners have similarly shaped "Cornelian" globes; and Wilder, in the description of his volumetric burner, recommends globes 4 5 inches in diameter at the bottom and 5.5 inches at the top.

Regarding the material for globes, clear, crystal glass is the best, because it absorbs the least light. Still, it oftentimes becomes desirable to render the light of a gas flame soft and mellow, and for such cases thin, milk-white, opal globes are best and quite effective. Sugg uses with his best flat-flame governor burners double-annealed, large-size globes, with wide bottom opening, which he calls "Albatrine" globes, and which give a particular softness to the light. The cheaper kind of opaque white glass globes should be avoided, as they intercept as much as from 70 to 80 per cent of the light.

In connection with globes, it is noteworthy that somewhat increased illumination is obtained by using globe holders which are as little light-obstructing as possible, *i.e.*, very thin sheet-brass or brass-wire globe holders. The old style fixtures had heavy and cumbrous cast-brass holders, or heavy disks, triangles, or rings, all of which are objectionable, because they intercept a portion of the light and cast a shadow downward, and thereby cause a loss of light. The new shadowless triangle globe holders, made of three simple prongs of brass wire, not more than one-eighth of an inch thick, and without any rims whatever, are recommended by all dealers in advanced gas-lamp fixtures.

Lastly, the position of the glass globe in reference to the gas flame is of a good deal of importance where it is desired to secure a steady, bright light. It has been found, long ago, by experiment, that by arranging a shadowless globe holder on the burner in such a manner as to place the level of the bottom of the flame in line with the bottom edge of the globe, the flame will burn very quietly and steadily, and will not be affected much, if any, by the ascending air current, whereas if the flame is set higher it is apt to flicker.

This correct position and shape of a glass globe has been pointed out repeatedly by such gas engineers as Wilder, Peebles, Sugg, Broenner, Silber, and others, in connection with their gas-burning appliances; but on the whole, in practice, little attention has been paid to this simple, yet efficient, rule.

At the annual meeting of the American Gas Light Association, held in Cincinnati, in October, 1877, Mr. James Somerville, now Chief Engineer and Superintendent of the Indianapolis Gas Co., read a paper on "The defects of the gas globe and holder," which contains criticisms so applicable to many of the holders and globes still in use that I quote the following extracts from the same:

"A gas globe ought to combine utility with ornament. As they are at present constructed, the utility is entirely left out. In rooms where gas is used the ceiling is often the only place well lighted. The gas flame inside the globe flickers, wavers, and dances, as the cold air rushes through the narrow orifice, impinging against the light, causing it to smoke at the points, and destroying half its value, while the agitated flame allows a portion of the gas to escape unburnt. It is to be hoped that the manufacturers of globes and holders may be induced to make them more adapted to the purpose for which they are intended, viz.: to impart steadiness to the flame, and to direct and allow the rays of light to reach that point where they are most required, and, at the same time, to be ornamental. The improvement or remedy needed is simple, effectual and inexpensive.

"The first and greatest defect of the ordinary globe is its 2-inch opening at the bottom. This diameter is just two inches too small, yet the maker of globe holders contrives still more to contract the opening and obscure the light by furnishing the globe with what is meant to be an ornamental holder, with the metal of the arms spread out at right angles to the light. A good globe-holder ought to be constructed only of three prongs of brass wire, not over 0.125 inch thick, and any additional strength required ought to be put parallel with the downward rays of light, so that it will cast no shadow. No rim whatever is required to the holder; the prongs ought to be so fashioned at the ends as to receive the rim of the globe and support same.

"The globe ought to be made with its bottom opening never less than 4 inches in diameter, and from 7 to 8 inches diameter at its widest part. These dimensions will allow the air ample passage through the globe, without striking against the flame, and will actually have a tendency to steady the light, which is the greatest desideratum. It will also allow the use of the best form of burner, and the rays of light will have ample scope to strike downward to the place where they are most required, and, in short, the consumer will get the full benefit of the light.

"All globes ought, furthermore, to have a space of 3 inches of clear glass around the bottom, and, in ornamenting and flowering, the maker ought to have this one end always in view, to intercept the rays of light as little as possible. Opal and ground glass globes ought to be entirely discarded, it being known that they obscure from 40 to 50 per cent of the light.

"If globes and holders are made and used as described, the gas companies will have far less complaints of bad gas and poor light, and it becomes more and more the duty of the companies to attend to the wants of the consumer. It is a common experience that it pays the gas engineer well, in every way, to see that the consumer gets the full benefit of the light which he is purchasing from gas companies."

CHAPTER XVI.

GAS FIXTURES.

Gas fixtures are devices or appliances, more or less ornamental, for burning illuminating gas, connected with the gas outlets in ceilings or on side walls, provided with stopcocks or gas keys to control the flow of gas, and carrying one or several gas burners. The term includes brackets, pendants, clusters, and chandeliers for indoor lighting. In a wider sense, it sometimes includes also the fixtures in which gaseous fuel is used for heating or cooking, such as gas stoves, gas logs, gas ranges, etc.

In this chapter, when speaking of gas fixtures, I refer to lighting devices only.

A few remarks regarding the choice of proper gas fixtures — not from the artist's or decorator's point of view, but from the gas engineer's standpoint — may prove useful to the gas consumer; for oftentimes ill-contrived, poorly constructed, or defective chandeliers or bracket fixtures are the cause of deficient interior illumination, and many gas leaks in rooms are due to a poor class of fixtures.

Manufacturers of gas fixtures, with rare exceptions, do not pay much attention to the essential requirement of correctness in mechanical execution. The designs of fixtures which they offer for sale may be exceedingly pretty, neat, artistic, and decorative, but fixtures with too much scroll work often turn out to be quite objectionable, where the gas supplied to the house is improperly purified, or where the distributing pipes for gas are pitched toward the chandelier or bracket, or where the drop is taken directly from the bottom of a line, in which cases the fixtures in a short time accumulate much watery vapor or naphthaline, which hardens in the tubing and obstructs the passages for gas.

Firms engaged in the manufacture of fixtures often employ artists at a high salary to design novel forms of expensive ornamental gas fixtures, but who has ever heard of a firm engaging a competent mechanical expert, or an "illuminating engineer," as the new profession is called, one thoroughly conversant with the requirements to be observed to obtain the best illumination and the highest degree of illumination, to make details for the mechanical execution of the work and to advise on the best kind of burners and globes to be used?

People building and fitting up houses generally select the gas fixtures according to their price and their more or less artistic shape, and seldom pay any attention to the question whether the shape of the chandelier or the gas bracket is well contrived and not light-obstructing, whether the tubing is ample in size, whether the fixtures have been tested for tightness, and whether the gas keys are free from defects. Such kind of fixtures, however defective they may be, are sold in great numbers and are rendered still more useless by unsuitable or bad burners, and by globes of improper shape and color, and with narrow-bottomed openings, causing the flames to flicker.

Faulty mechanical execution is by no means confined to the cheaper class of fixtures. Even the best and most expensive modern fixtures are susceptible of much improvement in these respects.

One serious fault is the use of too small gas tubing in the fixtures, through which the requisite flow of gas to supply the burners cannot be established. It is quite common to find large gas chandeliers with six or eight burners constructed of one-quarter-inch tubing. A simple calculation shows that a one-quarter-inch pipe, ten feet long, is only capable of supplying 5.7 cubic feet of gas per hour at a pressure of $\frac{4}{10}$ inches of water column; hence the tubing would be just large enough to supply one 5-cubic-foot-per-hour burner instead of six or sometimes eight burners per hour. It would be quite useless to use on such fixtures any type of improved governor burner.

It is obvious, that where pains are taken to pipe a house for gas with all service and distributing pipes of sufficiently large caliber, it is equally desirable to have the passages for gas in the fixtures of ample bore to get the required amount of light; in other words, the main tube of a chandelier should be of such a diameter as to be able to pass the necessary volume of gas required by the total number of burners on the fixture, all of which may be lighted at one time; and again, the side tube for each burner and the bore of the gas key should be of such a diameter as to afford passage for an adequate volume of gas to each burner.

All gas keys of fixtures should be made strong and of full bore; they should be ground with care, so as to be tight-closing, yet easily turned. A serious defect inherent to many fixtures is the leakage at the stopcock, caused either by defective workmanship or by keys getting worn out or becoming honeycombed or loose. It is, in most cases, a matter of impossibility to apply any pressure test to the gas-pipe system of a house while the gas fixtures are connected, as they usually leak at the fixture joints, at the swing joints of brackets, at extension pendants, and at the gas keys much more than at the pipe joints.

It should, therefore, be made a rule, that all large or heavy chandeliers should be tested before they leave the factory, and their tightness should be guaranteed by the makers when the fixtures are sold.

The hanging or putting in position of the gas fixtures should properly belong to the gas-fitter who piped a building for gas. The universal custom, however, is to leave this work to the gas-fixture dealer or manufacturer, and it is a common experience that after fixtures are hung or put up the fixture joints leak more or less when the gas is turned on for the first time at the meter. It would seem to me to be a great deal better and safer to have skilled gas-fitters do the work, and thus have one trade only responsible for any defects.

The mechanic who does this work should use the utmost care to make the joints absolutely tight, and he should furthermore see that the joints do not become partly obstructed by bits of white lead, squeezed out at the inside of the joint.

It is customary for the fixture dealer or manufacturer to provide the gas fixtures with burners, and from personal observation and experience I can state that gas-fitters and gas-fixture men take scarcely any interest whatever in the kind of burners which they put on fixtures, except that in some instances they may select burners, the flames of which will not crack the globes. The bulk of the gas-consuming public are indifferent to this matter, and so we find in practice that even the most elaborate and expensive gas fixtures are provided with only the cheapest and most ordinary kind of burners, and often with badly proportioned gas globes and cumbersome globe holders. The same size of burner tip is used without regard to the amount of light required in various rooms. The burners are carelessly put on and the gas passages are often partly choked with white lead, or the gas keys are not the full bore of the tubing.

It is far better to buy gas fixtures without gas burners and glass globes, and to purchase separately the very best kind and quality of burners, and to insist on the use of globes with wide bottom opening, supported by shadowless wire-prong holders. (See Chapter XV.)

Purchasers of gas fixtures are advised to stipulate, when buying, that the fixtures be tested separately at the factory, and again afterwards under a lighter pressure after they are hung.

Although good burners cost considerably more than the common bad ones, the extra price is more than compensated for by the yielding of a more satisfactory light, and by the saving in the gas bill. Some of the governor burners mentioned heretofore are the best obtainable burners and deserve unqualified commendation.

Old-fashioned gas fixtures are often quite defective, and may even become dangerous by reason of having so-called "all-round" keys or taps which are not made with stop-pins. It is a frequent experience, particularly in lodging houses and hotels, that gas leaks, or even cases of asphyxia by inhalation of escaping illuminating gas, are caused by the incomplete turning of these all-round keys, or by the accidental turning on of the gas after the extinguishing of the light.

Quite often in the course of my professional travels to other cities and towns, I have come across first-class hotels having gas fixtures in the guests' rooms which are dangerous on this account, and I likewise find such fixtures with gas keys without stop-pins in private houses, particularly in out-of-the-way places, in the cellar, in housemaids' closets, or in servants' bedrooms, where their use is attended with considerable risk. I have, years ago, argued that the use of such fixtures should be prohibited by act of legislature. It is at least to be hoped that when the time arrives, when building departments will look after the gas piping in houses and exercise a supervision over the gas fixtures, similar to the supervision now enforced in sanitary matters and about plumbing fixtures, they will pay some attention to the above-mentioned defects, with which underwriters have long been familiar.

The modern fixtures are always provided with stop-pins, but the metal of which they consist is often much too light, and after some use the pins crack off or bend out of shape. The remedy consists obviously in having all check-pins attached to gas keys made of good size and extra strong, and to have them well soldered on and fastened.

Gas escapes frequently occur with water-slide chandeliers, when the water which seals the joints evaporates. The leakage of gas can be avoided either by frequent additions of water, or by putting on the water some sweet oil or glycerine, which retards the evaporation. While water-joint pendants are quite common in England and on the Continent, they are not much used in our country, where either cork-slide pendants or telescopic extension-joint chandeliers are preferred, which dispense entirely with the chain and counterbalance weight and the water seal.

Gas fixtures may be divided into fixtures hung on side walls, or bracket lamps, fixtures hung from the ceiling, called drop-lamps, pendants, and chandeliers or gasoliers, and portable gas fixtures.

Bracket fixtures may be either stiff brackets or horizontal swing brackets, with one, two, or three joints, or brackets with parallel motion, as used for reading lamps, or for ophthalmoscopic purposes.

Drop lamps with one or two arms are usually called pendants, whereas the term chandelier (sometimes called gasolier) applies to pendant fixtures, usually ornamental, having three or more branches or arms fitted with gas-lamps. Drop lamps with single-center burners are sometimes termed " lyras " or hall lanterns. The ceiling joint of such fixtures may be a stiff joint, a hinged joint, or a swing joint. Larger and heavier fixtures are hung with universal ball-and-socket joints. Chandeliers are often provided with extension fixtures, to pull down, and the joint in these is either a cork or telescopic joint. If the whole chandelier can be lowered, the fixture is hung with counter-weights and the joint has a water seal (hydraulic gasolier).

Each burner is usually controlled by a separate gas key, except in rare instances, where cluster burners set close together are used, such as the incandescent " Beacon " lamps, the sun-burners and the multiple, high-power flame lamps.

The rules of the United Gas Improvement Co., of Philadelphia, are the only gas rules in which some consideration is given to the gas fixtures. They contain the following:

Requirements for Gas Fixtures.

1. All fixtures must be made so that at all traps there is provision for letting out water of condensation.

2. Tubing for chandelier arms, where of brass, must not be made of less than 0.375-inch brass tubing up to 24 inches spread, 0.45-inch brass tubing for up to 30-inch spread, and 0.5-inch brass tubing up to 36-inches spread.

3. Straight arms or straight pendants must have not smaller than 0.25-inch iron pipe in arms.

4. Stems to chandeliers and pendants up to 6 burners must have not less than 0.25-inch iron pipe, and from 6 to 12 burners not less than 0.375-inch iron pipe. All openings in keys or swing joints must not be less than 0.125 inch.

5. All keys must be well ground, and so fitted as to show no leak under 3-pound mercury gauge, when the keys can be turned by finger.

6. The opening in all globe rings must be a snug fit against the burner nozzle, and must flare out in an inverted cone shape, so that the burner, in screwing down, will not strike the knife edge of the flare, but hold the ring tight by binding against the sides of the cone, making at the same time a tight joint with the nozzle threads.

7. The company reserves the right to take fixtures apart at any time, and to refuse to pass them, if they are not constructed in accordance with good workmanship.

CHAPTER XVII.

GAS METERS AND GAS-METER STORIES.

In the early days of gas lighting, no means were available for measuring the quantity of gas which a consumer used. The only method of arriving at an approximate estimate of the consumption was to take into consideration the size of the house, the number and size of the gas burners and fixtures, and the duration of the gas lighting, which, as is well known, differs in the various seasons and months of the year. (See Tables in Chapter XXI.)

Such a system must necessarily have been very crude and unsatisfactory, for it did not and could not discriminate between the saving and the wasteful or dishonest consumers, both of whom had to pay the same amount.

The first gas meter, or apparatus for measuring the quantity of gas consumed in a given place and time, was invented by Samuel Clegg about the year 1815, or 23 years after gas was first manufactured. This was a wet meter, which was subsequently improved by John Malam and Samuel Crossley. Malam invented the dry meter in 1820.

The gas meter forms the connecting link between the gas company's service and the consumers' house pipes and fixtures. "It is at the meter," says Mr. Joseph Shaw, a noted British gas engineer, "where supplier and supplied meet and exchange congratulations or otherwise, and where originates that spring of difficulties and disputes between producer and purchaser, which frequently leaves anything but a good impression on the minds of either. That the meter plays a most important part in the supply of gas there can be no doubt whatever. Upon it rests the responsibility of dealing honestly with the gas consumer, and at the same time of not defrauding the company; equity should be its motto, and justice its constant practice. It is clear that an instrument, filling such an onerous position, should be constructed on the very best principle and of first-class materials."

The principal reason for the universally prevailing distrust of the gas meter is, doubtless, the fact that consumers, as a rule, do not know anything about its construction or operation. To the majority of householders the gas meter is nothing but a mysterious apparatus, which is supposed to register as the gas company wishes it to. "To lie like a gas meter" has become a popular expression of this distrust, and in the daily press the instrument has received more than ordinary attention, both from the editor of the "funny column" and from complaining correspondents.

Without going deeply into details, an attempt will be made in the following to explain the construction and internal mechanism of gas meters.

There are, broadly speaking, two principal kinds of gas meters, namely the *wet* and the *dry* gas meter. The wet meter was the first one to be invented and has held its place in some countries up to the present day, while in others preference is now given, for reasons which will appear further on, to the dry meter.

The wet meter is so called because of the fact that water must be used up to a fixed level in its interior chambers to seal the measuring compartments. A wet meter is practically an iron or tin box, either cylindrical or rectangular, containing on the inside a peculiarly constructed measuring drum. This drum is divided into chambers or compartments containing a measurable fixed volume of gas; the drum rotates and its chambers are alternately filled with gas and emptied. The rotations of the drum are recorded by means of a proper gearing on the dials of an index. These dials do not register the number of revolutions, but indicate the gas consumption in cubic feet. The drum is made to revolve by the pressure of the gas upon its sides and upon the surface of the body of water; the gas itself, therefore, furnishes the motive power as it passes through the meter.

It is clear that the essential thing in a wet meter is the establishment of a *permanent water line;* when this water line is lowered from any cause, the cubic contents of the measuring compartments become larger, and hence a volume of gas in excess of the quantity registered is passed, and therefore the meter registers "slow" or against the company.* Leakage and

* A gas meter is designated "slow" when it registers a less volume of gas than actually passes through it; it is called "fast" when the recorded consumption is in excess of the amount actually passing.

evaporation of water in a wet meter are therefore in favor of the gas consumer. A tilting of the wet meter also leaves insufficient water to seal the wings of the drum, and thus some gas may pass through unregistered. If, on the other hand, the water line should vary by being increased, the cubic capacity of the chambers of the drum is reduced; in this case a meter registers "fast," or in favor of the company. To guard against slow registration it is necessary for the gas company to refill the meter from time to time, and in order that the water line may not be too high, a permanent overflow is established, which with a wet meter, set level, protects the consumer against any wrong registration. To guard against the other danger, *i.e.*, that the water line should be lowered, a float is introduced which closes a supply valve in the meter when the water should be too low, and thus makes the meter cease to operate. In some meters a double-acting valve, operated by a float, is used, which protects the consumer by shutting off the meter, in case the water line should be too high. It is obvious that a wet meter, containing water, is liable to freeze, and for this reason its location should be selected with care. It sometimes becomes necessary to fill the compartment with a mixture of water and glycerine to prevent freezing. The difficulties mentioned led to the invention of the second type of gas meter, namely the *dry* meter.

The interior working mechanism of dry meters is entirely different from that of wet meters. As its name indicates, a dry meter does not require any water in its working compartments. The outer casing of dry meters is usually of tinned iron, and is sub-divided by an interior central partition. On each side of this partition there are one, or sometimes two, movable diaphragms consisting of flexible leather sides. These leather diaphragms form compartments, which perform the same service as those of the drum of the wet meter. The gas is made to enter and leave these compartments alternately by means of slide valve movements.

The action in the dry meter resembles somewhat that of a number of bellows, the pressure of the gas causing alternate inflation, expansion, or filling, and contraction or discharge. These expanding and contracting movements are transferred by means of cranks, levers, or connecting rods to the wheel work of the meter index. The compartments formed by the diaphragms have each, when these are new, a definite measurable capacity; in this way the quantity of gas which passes through the meter is recorded in the meter index.

The leather partitions or diaphragms are subject to deterioration: they harden and sometimes crack after use. When they become less flexible, the cubic capacity of the measuring compartment becomes reduced, and a meter in this condition registers against the consumer. On the other hand, it frequently happens that the diaphragms become so badly cracked as to have perforations, in which case gas may pass into the house pipes without causing the reciprocating motion of the diaphragms, or, in other words, without being registered on the counting mechanism; in this way the consumer may burn considerable gas without having to pay for it.

Regarding the *comparative advantages* of wet and dry meters, the following may be said: The dry meters cost more to manufacture, but are easier handled, cause less trouble to the gas company, are cheaper to maintain, and need not be set absolutely level. They require no water for their action and hence the danger of freezing is minimized, though even dry meters may freeze up, in case a large amount of watery vapor, condensed in the street pipes, flows into them. This amount of condensation is the same, whatever kind of meter is used. Dry meters also do not cause so much trouble to the gas company by reason of requiring to be refilled with water, as in the case of the wet meters, and there is no sudden stopping of the gas supply, as may happen with the wet meter when the float drops. Hence such meters would be preferred by the consumers if they had any voice in the matter.

The apparatus for counting and registering the number of revolutions or of reciprocating motions of the meter is the same in either case. The interior mechanism of the dry meter is more complicated, more delicate, more liable to wear and to require repairs; dry meters are also said to be more liable to corrosion. The wet meter is much the simpler of the two, has no valve mechanism liable to derangement, and is more accurate. On the whole, however, gas companies are nearly unanimous in preferring the dry meter, and in the United States and in England it is used much more frequently than a wet meter.

It is doubtless true that the dry meter requires a good deal of attention on the part of the gas companies. The dry meter, in the author's judgment, is more liable to register in favor of the gas company, for the reason that the diaphragms will harden and stiffen some time before they crack. If cracked, they do permit gas to pass through without being registered, but the gas company's inspector would find this out at the next meter reading, whereas he would not know when the diaphragms are merely stiffened or contracted. The wet meter is simple and more accurate if properly attended to, and in some countries of the Continent, such as Germany, and a few others, it still seems to be preferred, particularly as it is found to be more accurate.

Recently, the Sprague Manufacturing Company, of Bridgeport, Conn., has introduced a new meter, which is practically the first American-made meter for artificial gas, made of cast-iron instead of tin. The advantages claimed for it are increased durability, less costly repairs, simple and compact construction. The case of cast iron is necessarily more durable than one of flimsy tin, which corrodes and rusts quickly. The new meter can be taken apart for inspection and repairs by the simple manipulation of a screw driver. The diaphragms can thus be readily examined for cracks, and being made in one piece of leather without seams, they last longer. The Sprague meter also occupies considerably less space than an old-fashioned tin meter of same capacity; another advantage is that all parts of the inside mechanism are made interchangeable.

Another new meter, with a cast-iron body, is the rotary meter, introduced here from England. It was invented in 1902 by Thomas Thorp, who also invented the prepayment meter, mentioned further on. This meter is manufactured for artificial as well as for natural gas, for low as well as high pressure. Its working parts consist of a turbine wheel with vanes set at angles of 45 degrees. These parts are interchangeable, and can be easily removed and examined. The meter is not affected by differences in temperature, specific gravity, or pressure.

It is not necessary to give a detailed description of the different types of gas meters made by manufacturers, but a few special kinds deserve a brief mention. The troubles caused by the variation in the water level of wet meters caused the invention and introduction of so-called "compensating meters," which are constructed with a special water reservoir within their case, and which have automatic contrivances, by means of which a part of this water is transferred to the regular water in the drum in order to make up for losses by evaporation or leakage.

Every gas company has at the works a large meter, which measures and records the total output of the works; this meter is called a station meter. It is usually of the *wet* meter type, which fact might possibly be interpreted to indicate that gas companies consider the wet meter as being more reliable in its measurements. In the case of the station meter the fluctuations in the water level are compensated by supplying a small continuous stream of water, and at the same time providing a fixed overflow point, which prevents the water from rising beyond its normal level. Recently a rotary *dry* station meter, invented by Thorp, and claimed to fulfil the three requirements of accuracy, durability, and compactness to a remarkable degree, has been introduced in England and America.

About fifteen years ago a special form of meter called the "prepayment meter," coin or slot meter, was introduced, and very soon became quite popular, notwithstanding that the newspapers were at first inclined to treat the innovation in the nature of a joke. In England alone, there were said to be about 2,000,000 of these in use in 1906. This ingenious type of meter is provided, in addition to the regular mechanism, with a special attachment similar to the one found in the nickel-in-the-slot machines. Its purpose is to enable small consumers to obtain a measured, limited quantity of gas, equal to the value of the coin deposited, by a prepayment, made by dropping the coin into the box. As soon as this is done, a certain volume of gas is permitted to flow into the house pipes. When this measured fixed volume of gas has been consumed, the meter shuts off the gas automatically until another payment is made, and then the gas again begins to flow. When the price of gas is changed, the interior mechanism of such meters has necessarily to be altered to conform in the supply it yields to the quantity of gas, which should be obtained for a definite sum. The prepayment meters are fairly reliable in action but their use involves some slight danger, and some cases of asphyxiation by gas have been caused by them. For this reason they should never be placed in sleeping apartments, nor is it desirable that they should supply burners located in bedrooms.

In some cities, gas used for lighting is charged at a different price from that used for cooking, heating, or power purposes, and special forms of meters, with double recording mechanisms, are sometimes used.

The ordinary gas meter does not register when the flow of gas is smaller than about 3 cubic feet per hour, and a smaller flow of gas, as, for instance, 0.5 cubic foot per hour, might pass through the meter without causing it to register. The acetylene gas burners have a very much smaller consumption than ordinary burners. Accordingly, when town or village lighting by central acetylene plants was introduced, it became necessary to manufacture special meters, which measure accurately small volumes of gas, and such meters are used, to a limited extent, where buildings in the country take their supply of gas from a general acetylene lighting plant.

The *essential requirements* of all gas meters are the following: they must be absolutely tight and not leak any gas; they must register fairly accurately, and they must not require too much pressure of gas to overcome the friction of the interior mechanism or the stiffness of the leather diaphragms.

Gas meters are manufactured in a large variety of sizes, and they are designated according to the number of burners which they supply, each burner being rated at usually 6 cubic feet of gas per hour. The smallest size of meter is a two- or three-burner meter (usually called two- or three-light meter), and the larger sizes are intended for 5, 10, 20, 30, 45, 60, 80, and 100 burners, but meters of even larger capacity then these are manufactured.

In determining upon the size of the meter required, it is necessary to take into consideration the size and consumption of each lighting burner and of each gas cooking burner, or gas heating stove. A gas meter should be adequate in size for the *maximum* consumption for both lighting and other purposes. It is a mistake to use a meter of too small a size, as it must be obvious that the quantity of gas required cannot be passed through it at the necessary rate, and hence an insufficient capacity of the meter is often the cause of a poor gas illumination. It is a popular fallacy that gas companies sometimes put in larger meters than required for the sake of having a larger consumption registered. This is evidently an impossibility, for a meter can only register the exact quantity of gas which passes through it, whether consumed or wasted by leakage or otherwise. The usual sizes of gas meters used in dwellings are the 10-, 20-, 30- and 45-burner meters.

It is usual to connect the house pipes with the gas meters by means of lead pipe connections. These are often wrongly bent, or bent flat, or kinked in the process of bending and then pass a smaller volume per unit time than is intended. It is advisable to use, at least for all larger meters, only the iron meter connections and couplings. The lead connections are undesirable from the point of view of safety from fire, because both lead and solder melt in a strong heat, and the escaping gas would only feed the flames of a fire.

"In most buildings," says a writer, "designed for multiple tenancy, like great apartment houses and the capacious office buildings, which comprise so large a part of the business portion of a city, it is customary to provide a separate gas meter for each room or suite of rooms. These meters are commonly placed in closets and out-of-the-way corners, and are very apt to be surrounded with much combustible matter. The connections of meters with the gas pipes are usually, if not always, of lead, a metal that is easily fusible, and the solder with which the plates of the meter are joined together yields even more readily to heat. Let a fire break out in a building containing, as many buildings do, a score or more of these fragile fire-feeders, and the hot air sweeping in advance of the fire will quickly melt the lead or solder. The outpouring gas fills the building with the explosive atmosphere which hastens the spread of the flames and keeps up an inexhaustible supply of fuel. Such burning of gas jets, sometimes of great size, is to be seen after almost every city fire, when nothing is left of a building but blackened and broken walls. The gas poured into burning buildings through such openings doubtless helps materially to account for the surprising suddenness with which many great buildings have been swept by flames, and in all cases the outflow of gas most seriously counteracts, if it does not altogether thwart, the efforts of firemen. The remedy for this great evil is not so easy to point out. It is obvious that, where a multitude of meters are to be distributed through a building, they should be more securely encased and provided with infusible connections, or some means should be devised whereby the gas supply shall be automatically shut off whenever the temperature rises, so as to imperil the integrity of the meter. There should also be near the door and readily accessible to firemen some means by which the connection of the house with the gas main in the street can be quickly closed." It is, perhaps, better to set all meters together in a special vault, which should have ample ventilation to outdoors.

Gas meters should be located in a place where there is a uniform temperature, neither very high nor very low. They should neither be exposed to a freezing temperature nor to the direct rays of sunlight. This is necessary for several reasons, one being that it prevents a dry meter from getting out of order quickly by reason of the diaphragm hardening, shrinking, and cracking. It is likewise in the consumer's interest that a meter should not stand in too warm a place, for gas expands by the heat, increases in volume, and consequently the meter will register "fast." The standard temperature for meters is taken usually at 60° Fahrenheit, and when the temperature of the room is much higher, a fixed volume of gas will be registered higher in proportion to the raise in the temperature. This means that the consumer pays for more gas than he actually consumes. The contraction of the diaphragm causes, as we have already mentioned, a scant measurement, and this is another reason why a warm place should be avoided. It is, therefore, a rule, in locating a meter, to avoid the proximity of the furnace, the steam boilers, and of the steam pipes. As heat ascends, and accumulates at the highest point, a place near the ceiling is particularly objectionable and dangerous in case of fire.

A very cold place is equally undesirable, for a wet meter would freeze, but even with the dry meter the moisture in the gas condenses, fills the meter with water, and then the water may freeze; moreover, the leather diaphragm is apt to get hard and cease to work. This condensation of watery vapor occurs whenever the gas meter or the house service is colder than the protected street main. The fact that a dry meter has water in it may be noticed by the jumping of the gas flames. It is also a notable fact that gas subject to a low temperature deteriorates in illuminating power. In dry meters the leather diaphragms become stiff from the cold and cease to work properly. When in wet meters the water freezes the drum ceases to revolve.

Owing to its moderate temperature, and for other reasons, the cellar of the house is usually chosen as the place for the gas meter. It should not be set in a dark, out-of-the-way corner, where its reading is accomplished with difficulty, nor under the cold air duct, nor anywhere where it may be accidentally injured. The meter should be set level, and at such a height that the index can be properly read. It should be isolated from fire, frost, dampness, and be kept away from electric wires. The meter should be kept clean and free from dust and the glass over the index should be frequently cleaned to enable the accurate reading of the meter. It is best to choose in a cellar an easily accessible well-lighted place, which is dry, cool, without draft, and where the meter would not be affected by the vibration due to passing vehicles. If meters are located where they are unduly exposed, they should be protected against injury.

All dry meters last longer and better if continually kept in use. The impurities in the gas are the principal causes of the wearing out of meters; thus the tar stiffens the diaphragms and clogs the valve movements, the ammonia causes the diaphragms to rot, and in the wet meter it may cause rust holes, the result being that gas passes through unrecorded.

In a new gas meter all dial hands point to zero. The index of a connected meter begins to register as soon as gas passes through it, whether consumed, or wasted, or leaking. When all the burners in the house are shut off, the hands of the meter should stand still, provided the pipe system is tight.

Householders should practice reading the meter index which is easily learned,* and they should keep a record of the readings. It is advisable to read the meter at least once a week and oftener if a careless use or waste of gas in the house is suspected. If possible, the meter should be read on the day when the gas inspector calls. All this will give the consumer an opportunity to check the monthly bill, for a very little figuring will enable anyone to tell exactly how much or how little gas he has been using.

The small or top circle of the meter index is *not* read in taking the meter's registration. This circle is usually subdivided into single cubic feet, and it is useful in testing the consumption of a burner, or of a gas cooker, or other gas appliance. Its principal use is to discover that there is a leak. The reading of the meter is also useful in helping to discover when a meter has got out of order.

* See Gerhard, Gas Lighting and Gas Fitting. Science Series No. 111.

In Europe, the accuracy of gas meters is tested and attested by an official commission. Meters are stamped "correct" in England when they do not vary from the true measure more than 2 per cent in favor of the company, and 3 per cent in favor of the consumer. In the United States, gas meters, after being first adjusted by the manufacturers, are tested by state inspectors. While on the one hand we find a considerable distrust of the gas meter by the public, we find on the other hand that gas companies and gas engineers are apt to exaggerate the claims for their accuracy. The statement of a practical gas engineer, which I found in a book on gas lighting, that "the gas meter is an almost infallible instrument with accuracy greater than almost any other measuring machine" is absurd and not true. Like all other machines, gas meters are not absolutely accurate, but they are as a rule *fairly* correct, as numerous tests indicate, and when it is taken into consideration that gas meters are cheaply manufactured and are subject to wear and to deterioration much more than other measuring machines, it may be truly stated that their accuracy is on the whole quite satisfactory. As we have seen above, this accuracy changes in time; in the wet meter, except it has a compensating reservoir or is refilled, the accuracy of registration changes against the company; with dry meters, when the diaphragm has begun to harden, the stroke is shortened, and the accuracy changes against the consumer, because the meter goes fast, but if cracks appear and allow the gas to pass through, the gas company loses.

Meters are tested by passing a certain measured number of cubic feet of gas through them and comparing the amount registered on the dials with the known quantity passed through.

The author has searched vainly for any records of experiments giving the comparative accuracy of wet and dry meters as ascertained by such testing. Such experiments would, however, at this date, have largely a theoretical interest, for the reason that wet gas meters have gone almost entirely out of use, at least in the United States. It is to be assumed, therefore, that any reports published in this country on the testing of meters refer to the dry meters only.

Some years ago, the State Inspector of gas meters in Ohio tested 2122 old meters; out of this number he found 34 per cent registering fast, 55.7 per cent registering slow, and 12.5 per cent registering correct. Eighteen meters failed to register.

The average rate of the fast meters was 2.88 per cent, and that of the slow meters was 2.76 per cent. The total average error was 0.47 per cent slow.

Similar results were obtained by the State Inspector of Meters for Massachusetts, who tested 11,309 meters, of which only 148 failed to come within the 3 per cent error against the company; 85 averaged 4.50 per cent against consumers.

In another test made in Massachusetts on 1917 suspected meters,

671 were found to be 2 per cent fast;
950 less than 2 per cent;
278 were more than 2 per cent slow;
18 did not register at all.

The average error in this case was 0.35 per cent fast.

"Complaint meters" are those, which, while being in use, are suspected of registering incorrectly.

According to a report by Charles W. Hinman, State Gas Inspector of Massachusetts, 231 complaint meters, nearly all of which were dry meters, were tested in 1891. Of these, 52 were found too fast, with an average error of 4.74 per cent; 144 were found within the legal limit, 2 per cent fast or slow; 34 were found too slow, the average error being 10 per cent; 1 meter did not register. Mr. Hinman compiled the following interesting table, extending over 20 years:

Year.	Fast Meters.		Number of Correct Meters.	Slow Meters.		Total	Percentage of Error.	Fast or Slow.
	Number.	Per Cent.		Number.	Per Cent.	Number.		
1872	87	4.30	81	32	9.55	202	0.32	Fast
1873	100	5.43	95	40	6.61	238	1.18	Fast
1874	101	4.76	131	51	6.22	285	0.57	Fast
1875	123	5.99	142	39	8.17	314	1.33	Fast
1876	148	5.19	179	53	9.17	381	0.74	Fast
1877	93	4.79	125	34	11.00	257	0.28	Fast
1878	111	5.34	180	44	9.51	343	0.63	Fast
1879	83	5.00	91	18	16.20	193	0.64	Fast
1880	48	4.54	52	22	6.59	122	0.52	Fast
1881	41	5.68	72	28	6.44	141	0.33	Fast
1882	41	4.10	62	21	11.30	127	0.43	Slow
1883	11	4.25	15	12	13.12	38	2.76	Slow
1884	51	4.22	100	25	5.02	176	0.58	Fast
1885	44	5.09	74	21	11.50	139	0.08	Slow
1886	38	4.55	64	22	12.43	124	0.79	Slow
1887	23	4.29	63	8	5.69	94	0.62	Fast
1888	56	5.22	109	17	8.71	182	0.82	Fast
1889	42	5.65	121	16	15.41	179	0.05	Slow
1890	64	5.32	134	20	23.60	218	0.60	Slow
1891	52	4.74	144	34	10.03	230	0.41	Slow

He calls attention to the increased proportion of correct meters, which shows a gradual improvement in their accuracy. During the first five years, 44 per cent were found to be correct, during the next 10 years 50 per cent, during the last five years 64 per cent.

In 1903, 1200 complaint meters were inspected, of which 5 did not register, while the 1195 meters had an average error of 1.28 per cent fast. 45.1 per cent of the total number were fast, the average error being 10 per cent, while 44.6 per cent of the total number were correct (*i.e.*, not over 2 per cent fast or slow).

In 1906, the Gas and Electric Light Commissioners of Massachusetts reported the testing of 424 complaint meters. Of these —

6 meters passed gas without registering;
1 meter passed no gas;
1 meter passed gas, and registered 155–305 per cent slow.

Omitting these 8 very defective meters of the 416, the average error was 1.82 per cent fast.

212 or 51.2 per cent were fast, average error 4.82 per cent.
25 or 6.01 per cent were slow, average error 7.4 per cent.
178 or 42.79 per cent were correct (no more than 2 per cent fast or slow).

Of the fast meters —

143 registered 2 to 5 per cent fast;
63 registered 5 to 10 per cent fast;
5 registered 10 to 15 per cent fast;
1 registered 17 per cent fast.

Of the slow meters —

14 registered 2 to 5 per cent slow;
8 registered 5 to 10 per cent slow;
1 registered 14 per cent slow;
1 registered 30 per cent slow;
1 registered 35 per cent slow.

Out of 187 complaint gas meters, tested in Brooklyn some years ago,

21 were found to be correct

114 were found to be fast, with an average error of 3 per cent	3 more than 10 per cent. 42 between 3 and 10 per cent. 69 less than 3 per cent.

52 were found to be slow, with an average error of $2\frac{1}{4}$ per cent.	0 more than 10 per cent. 13 between 3 and 10 per cent. 39 less than 3 per cent.

As a rule, more meters are found to be fast than slow, yet regarding serious errors the opposite is true. In Massachusetts, any gas consumer may have his meter tested; if it is found to register correctly, or within the allowed error, the consumer has to pay the cost of the test; if found to be incorrect, the consumer is furnished with a new tested meter. In New York City, every gas company is required by law to keep on their premises an apparatus for testing meters. Any consumer has a right to request that his meter be tested, and should it be found to be slow or correct, he has to pay a reasonable fee for the removal, the testing, and the replacing of the meter.

It is of importance that all State gas-meter inspectors should be in the service of the State, and they should not receive their salary or any fees from gas companies.

A greater accuracy in the records of meters would doubtless be secured if the meters were tested periodically, but gas companies, as a rule, neglect to do this. Consumers may test their own meter on the premises by obtaining a so-called test burner, known and regulated to burn a certain volume of gas per hour under a constant pressure. Such volumetric burners may be constructed and adjusted accurately if the specific gravity of the gas is known.

Regarding the period of usefulness of a gas meter, this depends somewhat on the care taken at the gas works in purifying the gas. If the purification is well carried out, the gas meter will sometimes remain accurate for ten or fifteen years.

Gas bills are made out from the monthly readings of the meter, and their size or amount depends solely upon the quantity of gas consumed. Unless the meter inspector reads the meter wrongly, or purposely makes false entries, the bills should be approximately correct. A mere error in the reading of the meter corrects itself on the next monthly bill. When the gas bill rendered appears to the consumer to be unusually large, there must be some good reason, and some satisfactory explanation can usually be found. Before questioning the accuracy of the bill the consumer should try to remember whether there has been more than the usual company in the house, whether there was sickness requiring a greater amount of light, or perhaps gas used at extraordinary hours for preparing patients' meals or warming water for a bath. He should also try to remember what the weather was, whether the same was not unusually dark or cold, for if so more gas must have been used for lighting and for warming by means of gas heaters and gas logs. Consider also any other possible occurrences which might help to explain the bill. As a last resort, bring a complaint at the company's office. If the company's officers are considerate and anxious to keep a customer, they will help him to find either the error or the cause of the increased bill. Mistakes may and do happen, and the gas company's clerks should be careful not to offend a consumer, but they should cheerfully and courteously correct an error when found.

Concerning gas complaints, the following extract from the annual report of the inspector of gas meters and illuminating gas of the City of Boston, dated, January, 1899, is of interest:

"As usual, there have been complaints received of large gas bills, which to the consumer were unaccountable; in such cases a little time devoted to reading the meter and looking after the burners might satisfy the consumer.

"It ought to be a common acquirement to read a gas meter, and for this purpose meters should be set in light, easily accessible places, and not higher than six feet. It is a simple matter to read a meter, as it is only necessary to read, from left to right, the figures, which the hands have passed. Adding two ciphers to these figures gives the reading in cubic feet; subtracting from this reading the previous one gives the amount of gas that has passed in the interval.

"The gas meter has no power of itself to register; it cannot register unless gas goes through it; if gas goes through the meter, the gas must be either leaking, unconsumed, through the fixtures or pipes, or be burning, either economically or wastefully.

"By keeping account of the number of burners and number of hours used day by day, the monthly amount of gas can be estimated, if the gas consumed per hour by each burner is known. To find this, the same experiment or testing hand is used, and the time to make a revolution of two or more feet is noted, and the rate per hour calculated. It is a most satisfactory method of checking the amount of gas used to read the meter at regular intervals, as daily or weekly, thus keeping track of the rate at which the gas is being used and registered."

Many of the popular fallacies on gas lighting, spoken of in Chapter II, concern the gas meter and its registration, so that a few words only may be devoted to this subject. "Consumers," says *Progressive Age*, "cannot understand what causes their bills to vary, and many understand it on no other hypothesis except that the 'confounded old meter,' being the child of the company, is naturally in league with it. Else, why should one quarter's bills be larger than another when the same amount of gas has been burned, as far as the consumer can see?"

It is a mistake to suppose that a gas meter of larger size than required will lead to a larger consumption of gas. Meters, no matter what their size or capacity, only register the volume of gas which passes through them. It is the opinion of experienced gas men and of the author that a large meter does its work more easily and steadily, and for this reason they are sometimes used. On the other hand, if a meter is chosen too small, the supply of gas in a house will be insufficient, and the effect will be apparent both at the lighting flames and at the heating and cooking appliances.

It is an error to suppose that gas bills are made out regardless of the amount of gas consumed. The popular belief that a gas company likes to render a large bill is a mistake, for it is to the interest of the gas company to have the consumer pleased and satisfied, and this they are much more apt to accomplish when the bill rendered is reasonable. Too high gas bills drive some customers to the use of electricity where this is available, or to a change in the gas service where there are two or more companies in the same street. (I do not refer to New York City, where the several gas companies have now combined.)

It is a popular error to think that a meter index moves at the will of the company; this is absurd, for the dials cannot move except when gas passes through the meter. The statement that increased gas pressure makes a meter go round faster, and hence causes exorbitant bills, is often met with. It is true, in a sense, because more gas is delivered under a higher pressure, but the consumer can and should regulate his pressure, and, *if he does this*, the effect of an increased pressure on consumption is neutralized.

Where both dry and wet meters are used, the popular fallacy is often met with that the dry meter registers more correctly than the wet meter, or vice versa. Of course, if both are kept in working order and periodically tested, one kind is as good as another as far as accuracy goes.

Various circumstances occur in connection with gas meters which appear at first sight mysterious and give rise to complaints about "the vagaries of gas meters." One instance of this kind is when a connected gas meter persists in registering a large consumption though all the burners in the house are turned off. Another example is that of the gas bills of persons, who after being absent for a length of time, find on their return a bill showing that gas had been burned. As a rule, investigation will show that some gas burners had been accidentally left lit during the absence of the owner. Mysterious gas bills are sometimes explained by gas leaks at the fixtures or in the piping, and at other times the servants in a house may, without the owner's knowledge, burn gas in an extravagant manner.

I introduce in the following a number of "gas-meter stories" gathered from various sources and nearly all based upon actual experiences of gas inspectors or superintendents. These stories will tend to explain the above-mentioned occurrences and will also, it is believed, assist in establishing faith in the apparatus used for measuring the consumption of gas.

GAS-METER STORIES.

No. 1. A gentleman, well known in the gas world, having commenced business, was anxious to economize in every possible manner; his consumption of gas exceeded considerably what he estimated it should be, so he resolved to test his meter during the night. To his surprise the following morning, although all the lights were turned off, he found that 300 cubic feet had passed the meter. The experiment was repeated two or three times with the same result, and without the slightest odor of gas on the premises. Puzzled beyond description, and knowing that, if the meter indicated, the gas must have passed, he examined all gas-fittings. Outside the attic window he found a pipe which conveyed the gas to a room below, cut as with a chisel. From this aperture the gas had escaped for months. Of course, the escape being outside the house was not detected by the odor, and would probably have continued for years. If the cause had not been discovered, it would have been numbered among the vagaries of gas meters.

No. 2. Enormously heavy gas bills were presented quarterly to a gentleman, to which he protested as utterly impossible, and refused to pay. The meter indicated incessantly night and day. All the pipes throughout the house were examined — the flooring being taken up for the purpose — but no signs of escape or odor were found, and still the meter went on. The engineer of the company was then referred to to solve the difficulty; and as he knew it could only arise from an escape, and the loss was considerable, he had every foot of gas pipe, that was embedded in the walls, uncovered. At last, to the surprise of all, immediately over the mantlepiece and at the back of the looking glass, a small pipe was found carried directly into the chimney, where the gas escaped without giving any odor. This had been done by some malevolent workman.

No. 3. It is not only from escapes that such incidents arise, for many years ago an inspector went to take the index of a meter at an establishment, and on stating the quantity consumed the owner protested that no gas had been burnt, that it was a fraud, and that he would not pay. The following quarter the same inspector went for the same purpose, when he was asked blandly the question, " How much have I burned this quarter ? " "None," was the reply. " None," said the proprietor, " then I have more faith in your meter than in the word of my servant; for I took away the key of the main, and only replaced it when I knew you were here." The servant had been in the habit of burning the gas in the absence of the master, but denied it.

No. 4. A gentleman and his family who had occupied a " flat," shut their house and left to visit some friends in a distant part of the country. At the end of six months they returned. A few days afterward the gas company sent in a heavy account — indeed, for a much larger quantity of gas than would have been consumed had they remained in their home. The gentleman, believing it be to an error, went to the gas office and showed the receipt for gas consumed up to the day of his departure, but was informed that the account was for gas consumed since then. " But," said he, " we have been away all the time, and the house shut up; consequently no gas could possibly have been required." This was met by the reply that the meter indicated that the gas had been consumed, and that he must pay. This certainly appeared a vagary of the meter to which no explanation could be given or reason assigned. The gentleman, much exasperated at the apparent extortion of the gas company, went home and informed his wife of the circumstance, when she, after a little hesitation, said: " Well, now I remember; how very silly of me; just as I was on the point of leaving I returned for something I had forgotten, and lighted the gas to get it and omitted to turn it off again." The gas had been constantly alight during the six months, and was of course indicated by the meter.

No. 5. Mr. X, a merchant, converted some time ago from electricity to gas complained of high gas bills. The meter was read again and again, the second reading developed no error, and the consumer was still unsatisfied, so the meter was tested. In case the meter was " fast " proper allowance was to be made, but the meter on test showed to be correct, and Mr. X. said " don't care what the meter says." The meter was read daily and a postal card sent the owner showing each day's consumption, meanwhile advising economy but not pressing collection. This course was followed for a year and the gentleman was kept as a customer. Such a course is troublesome, and the foreman or meter reader may call Mr. X. (and truthfully) " a blamed crank," but there is a pleasure in handling successfully such a case and bringing the objector to practically disavow his spoken objections.

No. 6. Mr. Y., another merchant, used gas at his residence. During the summer, while the family were all away except a woman left in charge, the house bill instead of decreasing showed a marked increase. This case could be diagnosed by the gentleman's own statement. The caretaker, a poor, little, lone, frightened woman, worrying through sleepless nights and in fear of her life, kept three or four jets lighted for company and protection. Fearful of reproof, she would not, when the bill came in, acknowledge the facts, and Mr. Y., having known her as a faithful and truthful servant, could not doubt her word. The Gas Company was obliged to collect the amount called for by the bill. Mr. Y. acknowledged that the company had at least seemed to try to be fair, and that possibly the cause for the trouble had been in his household.

A newspaper contributor some time ago described in rhyme a case of this kind, as follows:

"TWO SIDES TO IT."

" How sweet to roam by the sad sea waves,
While no cares your mind harass,
And what joy to think as you watch the stars,
That you are paying no bill for gas!
But, oh, what grief when you travel home
And the meter your sad eyes meet:
You find that the cook has been holding soirées
And has burned ten million feet."

No. 7. Mr. YY., a wealthy business man of standing in the community and prominent in a church, pays promptly, seldom complains, and hence is one of the great and good majority who rarely come especially to notice in a gas company's office. After the price of gas was reduced, Mr. YY. expressed the opinion that, instead of reducing the price of gas, it would have been better to improve its quality, which, at his home, had for some time been poor. This was the first intimation of his having been dissatisfied, and a letter was written him thanking him for having mentioned it, stating that the gas was of good quality and that his trouble must be entirely local. In a day or two he came to the office and, after a pleasant talk, it was concluded that the fault in his light was from want of pressure due to the clogging up of a rather old service pipe. A remedy was promised to him and his service pipe renewed. After the service was relaid the light, of course, became good.

No. 8. Mr. ZZ. keeps a small restaurant and pays gas bills weekly. He works hard, and with the assistance of wife and family, is trying to get on in the world. As he is kept awake until late every night and rises early in the morning, he is, when he calls to pay his little bill, apt to be crusty and faultfinding, and inclined to quit gas and use oil. His daily experience, with some who would sell him bad eggs for fresh, rank butter for gilt-edged, or cheat him regarding other food supplies on the one hand, and on the other with those who try to pay a twenty-five cent check with a dime, or try to forget to pay at all, makes him suspicious of all, even of the gas company. But, by patience with his complaints, and attention when necessary, reading his meter every day for a while, and then teaching him to read it himself, and keeping him well supplied with burners and tips, he has been kept a consumer and taught to believe in the gas company.

No. 9. No man can please everybody, and some folks are best pleased in being displeased, so there are sometimes " kickers " who refuse to be reformed. For example, Mr. X.Y.Z. is a learned and estimable gentleman, with a character in many respects lovely and lovable, but his monthly payments for gas are invariably accompanied by some caustic comment or expression of distrust. He stated that owing to his residence being out of the electric company's territory, and owing to his wife's fear of kerosene, he is obliged to use gas, and, in general, has, up to date. refused to be placated. He surely does the gas company no good among his friends, but even he has not been given up, and if he lived long enough, the gas company would find an opportunity to show him that it is not as black as he thinks.

No. 10. A large house had for more than a year been unoccupied and shut up, so that the meter could not be seen for reading. At last the house was rented, the new tenants moved in, and the state of the meter was taken. Compared with the last reading it called for a bill of nearly $20, which was duly presented to the owner. As the last bill had been paid up to the day the previous tenant had moved out, it showed something wrong, for investigation showed no leak. The owner happened to be a large holder of gas stock, so he went quietly to the office and read somebody a lecture none the less emphatically indignant from being, so to speak, *sub rosa.* The matter was placed in the hands of an inspector, who gave it extended and exceedingly puzzled attention. Suffice it to say that he at length found out that four months' gas had been burned in an upper room by a party of "crap" players, who had obtained entrance through a rear door, a panel of which they had broken out. The bill was paid without further protest against the meter or the company. Suppose the "crap" players had not been discovered? The meter would have been charged with inaccuracy, or the company with dishonesty.

No. 11. In a double house, one half only had been piped for gas when the house was built, while the other half was piped some years afterwards, by simply extending into it the pipes from the other half. This made the gas for both houses pass through one meter, and the plan worked all right as long as the original owner retained the property and attended to the paying of the gas bills. After a time the property changed hands and was rented. The tenants in both houses began to use gas, but one found that his bills were out of all proportion to the quantity of gas he consumed. He even found that his bills would come in just the same, whether he used any gas or not. He thought he had a clear case of robbery against the company; but an investigation was instituted which resulted in the discovery that his neighbor had all the time been enjoying the gas lighting at his expense.

No. 12. The following story is introduced, not to explain the mysterious reading of meters, but to show how some people get into the habit of distrusting any bill rendered by a gas company, and how they become accustomed to question its accuracy. In Bradford, England, an old man was about to step in front of a steam tram going at full speed, when a hand seized him and flung him back. It was a narrow shave, and as soon as the old man realized it he exclaimed: "You have saved my life, and I can never repay the debt." "I deserve no thanks," was the modest reply. "But you deserve my thanks, I am a rich man, and I want to give you some substantial token of my gratitude. Here — let me write you a check —" "I couldn't accept anything — really I couldn't," protested the other; "but there is something you might do for me, all the same." "Speak and it shall be done." "You are a rich man, and I know your name. I am secretary of the gas company. Every month when you come in to pay your bill you make a tremendous row for half an hour, and declare that we are highway robbers. If you would only agree —" "Not to make a row over my gas bill? Never, sir; never. You saved my life, and I am ready to draw a check for $10,000; but as for foregoing a privilege granted only to free-born Britons, I can't surrender it — couldn't do it if you saved my life a dozen times over."

No. 13. An instance occurred at a large wholesale warehouse, where gas was being consumed during the whole of the twenty-four hours daily; but in the day time, as at night after business hours, only a small number of burners were used. The principal of the establishment found the consumption very excessive, and complained to the company. The meter was accordingly tested for his satisfaction, in the presence of his representative, and found correct. Subsequently, renewed and continuous complaints were made, when an officer of the company went to investigate the affair, and a simple observation of a few minutes convinced him that there was an important escape of gas somewhere; pursuing the inquiry, he found a defective pipe on the roof of a detached building, which at once accounted for the complaint and loss. The isolated position of the place where the defective pipe existed prevented the escape of the gas being detected by the smell; and the loss, being continuous, made it of very serious importance.

Had the principal, or the persons in his employ, understood the construction of the meter, they would have done precisely the same as the gas inspector — turned off all the taps on the premises, leaving the main tap open, and then noticed the drum or dial, which shows the units of feet passing and would have observed this to revolve, clearly proving the gas was *passing*, although none was *used.*

Stories similar to those mentioned are a daily occurrence in a gas company's office. In nearly all cases of this kind the gas consumer at once blames the "lying gas meter," the instrument against which there exists such universal prejudice. Examples might be multiplied, but it is believed that those quoted will suffice to point out a lesson, and to prove that very often — indeed, nearly always — there is some good and sufficient reason why a gas meter has registered in spite of the loud protest of the gas consumer that he has not used any gas.

CHAPTER XVIII.

THE ILLUMINATION OF INTERIORS WITH GAS LIGHTS.

MUCH of our life is necessarily spent by artificial light, in business, social, and educational pursuits. In dwelling houses, in particular, much of the home comfort, after darkness sets in, will depend upon the arrangement and distribution of the gas lamps. I, therefore, intend to give in this chapter some advice regarding the types of gas fixtures to be used, and how best to locate them in the average dwelling house.

"Let it be borne in mind," says the London *Journal of Gas Lighting*, in commenting upon a paper by R. A. Briggs, Architect, "that houses are used as much by night as by day, and that consequently the artificial lighting is as important a consideration as the size and disposition of the windows.

"The architect should come to an understanding with his client about the artificial lighting, which should not be left to chance. If only portable illuminants are to be used, such as lamps and candles, the architect may be pardoned for not thinking about them. If, on the contrary, either gas or electric lighting is to be adopted, the architect ought to know how to make the necessary provision. Yet how often is the lighting of a dressing-room intelligently arranged? Attention should also be given to the lighting of the kitchen and service apartments, and to the corridors, staircases, retiring-rooms, etc.

"Whenever gas can be had, it should be installed to facilitate the getting about in, and doing the work of a house during the dark winter days, and to this the architect should see. What ever may be the occupant's taste in regard to the lighting of the drawing-room, or even the dining-room, there can be no question of the superiority of gas for the purposes above-named, as well as for the hall, the vestibule," etc. . . . "The architect who cannot dispose of a gas fixture so as to obtain a good effect from it had better get himself a tie-wig and a sword, and forswear railway travelling and the use of the penny post and telegraph until he is sure of his epoch."

At an early stage of the construction of the building, it is well to begin by marking all the desired outlets on the house plans. It is also advisable to show all doors on the plans and the direction in which they swing when opened, so as to avoid the frequent mistakes of placing gas fixtures where the doors necessarily open up against them.

It is well to fix at once, when locating the gas outlets, upon the height of the same above the floor level. This depends to some extent upon the design of the fixture used. Where fixtures are intended for gas only, it is usually safe to place the side outlets at a height of five and one-half feet from the finished floor in all rooms, and six and one-half feet in all halls and passages, except where the ceilings are very low, in which case there should be at least two feet between a gas flame and the ceiling (three feet would be still safer). Where combination electric and gas fixtures are used, the gas burner is always placed uppermost, while the electric glow lamp hangs down or is placed inclined and pointing downwards. In that case the gas outlet requires to be put higher than usual to avoid exposing the electric lamp to breakage.

It is equally important not to place the burners on chandeliers too high, as it is not the purpose to illuminate the ceiling. In those rooms where a large center table is placed permanently under the chandelier, such as the sitting room or the library, the chandelier should be hung low so as to obtain a concentrated illumination on the table for reading, writing, or working. The usual height of gas burners on such chandeliers is from five and one-half to six feet from the finished floor. In dining rooms, the burners should be at such a height that they will effect a good illumination of the table, thus rendering it more pleasing and attractive to the house occupants and their guests. In all other cases, chandeliers must be so hung that their lowest point is located well above the head of persons passing underneath.

Regarding the size of the burners to be chosen, it may be stated in general that for average-sized rooms it is much better to have a few large burners lighted than a larger number of smaller burners.

For lighting hallways, staircases, passages, servants' bedrooms, and the servants' department in the basement, plain, durable fixtures, with little ornamentation, should be chosen; but in the principal rooms of a house, the fixtures should be selected with a due regard to the dimensions of the rooms, the style and scheme of decoration, the colors of the wall paper, the furniture, and the purposes of the rooms.

In locating the gas-lighting fixtures on the plan or at the building, the following general points should be constantly borne in mind:

Center lamps on chandeliers are more efficient in lighting up a room than side lamps because the former can radiate the light in all directions, whereas much of the light from brackets is absorbed by the walls, particularly if these are tinted a dark color.

Place the lights where they will light up the room, or else the special parts of a room, for instance the reading desk, the dining table, the steps of the stairs, etc., to the best advantage. Also place the fixtures in such a position that there will be no danger from fire from them.

In locating gas fixtures on the house plans, mark not only the outlets where wanted with a star (*) or by any other convenient and easily intelligible symbol, but indicate also the number of burners for each outlet; also, where this is practicable, indicate on the plan the height of side-wall fixtures above the finished floor.

To avoid accidents on stairways from persons stumbling, see that no light is so placed that it may throw an objectionable shadow.

Avoid locating a fixture directly at the foot of the cellar stairs, where it may become accidentally hit.

In hallways avoid the use of side or bracket fixtures, as these may interfere seriously with the placing of hall furniture.

In locating side fixtures always make sure that no door would swing against them.

Avoid placing gas burners where they would be located in a strong draft.

Do not place any gas lamps in small closets.

Never place gas outlets vertically over hot-air registers or over steam radiators, for light from burners so placed will give constant annoyance by flickering.

Do not place gas jets so low that persons sitting in a room would be obliged to look directly into the glare of the flame. This causes an injurious eye strain. Flames so placed must be covered with opaque shades.

Avoid the use of swinging side fixtures as much as possible, chiefly so at curtained windows, near door portières or window drapery of any kind. Swing fixtures are equally bad in halls, passages, and stairs, or near woodwork of any kind. Use stiff brackets, or, where light may be required sometimes at the left or at other times at the right of the fixture, use two or more stiff arms and several burners.

In bathrooms set the fixtures high, so as to be out of the way of persons dressing in a hurry.

In hallways, put the pendants so high that they cannot be accidentally hit by persons putting on their overcoats.

. . . . .

The following suggestions may serve as a guide in locating the outlets in the different rooms.

Beginning in the cellar, there should be a burner near the foot of the cellar stairs, also one or several in the cellar passages, a burner in the wine cellar, and one near the furnace, steam boiler, or other house-heating apparatus. Where there is a steam boiler, there should be a burner near the same with a polished metal reflector, so placed as to throw the light on the water glass tube and on the steam gauge. The side brackets should be plain, stiff brackets, and the burners should be three-foot burners, preferably surrounded with large wire cages.

In larger kitchens there should be a two-burner pendant with 3-cubic-foot-per-hour burner over the center table, the pendant preferably to be hung with a swivel joint, so it can be placed out of the way whenever the table is removed. There should be a bracket lamp fixture at the kitchen range, and in large kitchens another lamp over the kitchen sink, each of these to have a 3- or 4-cubic-foot-per-hour burner. In smaller kitchens provide only side lamps, one to the left of the sink, one at the range or stove, and one at the side table.

If there is a separate servants' sitting room or dining hall, there should be a two-lamp pendant over the table, with 3-cubic-foot-per-hour burners.

In the laundry there should be a fixed center fixture, where the ceiling is high, or a hinged pendant in case of a low ceiling, also one stiff side bracket at the washtubs, with a 4- or 5-cubic-foot-per-hour burner, and possibly one at the left-hand end of the ironing table. All the burners should be surrounded with well-fastened large wire cages to protect the flame.

In the kitchen storeroom there should be a single-lamp pendant, the drop type being preferred, because it does not interfere with shelves.

There should be a bracket fixture at the refrigerator, and one in the scullery at the sink.

In the butler's pantry a side bracket over the pantry sink is desirable, in addition to a center fixture; but as a rule one two-lamp pendant with 3-cubic-foot-per-hour burners is ample.

Continuing the consideration of the servants' department, there should be one side bracket with a 3-cubic-foot-per hour burner, and with large wire globe or cage in each housemaid's closet or at the housemaid's sink. In the linen closet, the light should preferably come from a pendant with a wire cage.

The servants' bathroom should have a side bracket with a 3-cubic-foot-per-hour burner, and there should be in each servant's bedroom one lamp, not placed near the bed or near window curtains. These lamps should be supported on stiff brackets, and they should be surrounded with wire cages. Three-cubic-foot-per-hour burners will give ample light, and it is particularly desirable, if the servants' bedrooms are on the top floor of the house, where the gas pressure is highest, to use automatic governor burners.

The servants' stairs and rear halls should have a sufficient number of single stiff-bracket lamps, with 3-cubic-foot-per-hour burners and wire cage to light them up well. As a rule, one light on each floor landing will be sufficient. The use of polished reflectors to light up dark passages is much to be recommended.

Turning now our attention to the front portion of the house, there should be a center drop fixture or a hall lamp with one 4- or 5-cubic-foot-per-hour burner, in the outer vestibule, and this lamp should be so placed, if practicable, as to light up the house number over the front door. Outside lanterns, though not much used except for large mansions, form a very useful feature and are a great protection against burglaries. It is essential that they should be provided with holophane globe or other reflector, throwing the light downward, so that they will light up well the steps leading up to the main porch in front of the house.

There is generally a center lamp in the front hall near the inner vestibule door, or directly opposite the hatrack; also one or more bracket lamps in the main hall passageway.

A bracket lamp, coming through a mirror, is sometimes placed on the upper stair landing, and stiff-bracket side lamps with one or two arms are located in the center of each staircase hall. Lamps on the stair newels are not used at the present time as much as in former days.

In the drawing room, reception room or parlor, a better, more uniform, and more diffused illumination can be obtained by discarding the cumbersome center chandelier, with its cluster of lamps all concentrated in one place, and placing instead numerous side lamps around the walls. These will prove efficient wherever the walls are decorated in a light color. In rooms decorated in dark colors and in all those exceeding eighteen feet in width, however, both side brackets and chandeliers should be used. Brackets may also be placed at the sides of the fireplace, or upright lamps on the mantlepiece. If other side lamps are required they should be placed with reference to the position of the furniture and the wall pictures.

The drawing room, above all other rooms in a house, requires a brilliant illumination in order to light up effectively the faces, the dresses, and the jewelry of the company, and therefore large, 5- or 6-cubic-foot-per-hour burners should be used. The new incandescent mantle burners in candle form, made by the Enos Co., of New York City, are particularly attractive as well as effective in lighting up the room. It should also be borne in mind that the color of the walls and ceiling, and of the draperies and furniture, has considerable bearing upon the question of lighting up such rooms properly. Light colors reflect the light, and are, therefore, better than dark colors, which absorb it. Dark-colored rooms require more lamps and larger burners to be effectively lighted.

A flood of warm and soft light may be obtained by using sun burners in the ceiling, and this is much to be preferred to the direct glare from ordinary chandeliers. Owing to the difficulty of placing gas lamps close up to the ceiling, it must be admitted that for ceiling illumination of drawing rooms the electric lamp offers a more promising field to the decorative artist. The electric incandescent lamp is also much to be preferred from a decorative point of view for lighting up cosy corners, recesses in bay windows, etc.

Regarding the lighting of dining rooms, however individual tastes may differ, the chief problem is, without question, to light up the dining table brightly and artistically, yet not too brilliantly. A center chandelier, with four, six, or eight arms, and 5-cubic-foot-per-hour burners, should be the chief feature, to which is sometimes added an extension or slide pendant with Argand or with Welsbach burner. There should be side fixtures at or on the sideboard, and sometimes side brackets at the mantlepiece. Where there are fine paintings on the wall, side brackets should be suitably arranged so as to display these to the best advantage. A side bracket at the carving table may also prove a great convenience.

As the dinner table is the chief feature of the dining rooms, so are the reading table and the writing desk the chief features of the library and the sitting room. Where there is a fixed center table a chandelier with extension lamp may be used, together with side lamps at the reading table or reading chair. The light in this room should not be too brilliant, except at the writing desk or the reading table, where an Argand or Welsbach mantle table-lamp, or a bracket Argand burner of strong candlepower should be fitted up so as to concentrate the light. The library requires in addition one or more bracket fixtures for reading besides the center chandelier already spoken of.

The billiard room requires a drop over the center of the billiard table, with from four to six large burners; also a side bracket at the lavatory.

The boudoir of the lady of the house, and the den of the master of the house may be treated differently in each case according to the taste of the occupant, and side illumination will generally be used, together with a strong and powerful light at the reading desk or writing table.

The sewing room should have a side bracket at the sewing machine, with a 5-cubic-foot-per-hour burner; the nursery should also have one or two side lamps, and may be treated much like the bedrooms.

Bedrooms, as a rule, should not have ceiling fixtures. There should be a bracket fixture at the wall against which the head of the bed stands, near the bedstead, and another near the washstand. The toilet table or bureau generally has two stiff side brackets, one on each side of the looking glass, to which, for ladies' dressing tables, a mirror light, suspended high or dropped from the ceiling in center and placed high in front of the mirror, is sometimes added. Near the fireplace there may be a bracket fixture for a reading lamp.

According to its size and the number of fixtures, the bathroom may have one or two stiff side brackets with 4- or 5-cubic-foot-per-hour burners, generally one lamp at the wash basin and another at or near the water-closet. It is desirable to have a side bracket at the shaving mirror, if this is placed in the bathroom.

Provide against the frequent and objectionable discoloration of ceilings by the gas flames by placing these not closer than 3.5 feet to ceilings, and where this is impracticable on account of low ceilings, use deflectors, or else ventilating hoods over the burners.

In bathrooms, hallways, pantries, and stairs, lights which are used only a short while at a time should be provided with the so-called "self-igniting" burners, which can be turned down during the intervals when not wanted, and normally burn only a small pilot flame.

The hints thrown out in the foregoing paragraphs may be useful as a general guide in locating the gas outlets of a house; they also serve to illustrate the wide adaptability of gas lighting in the home. As regards the large rooms, no hard and fast rules can be given, as so much depends upon the individual taste of the owner or his decorative artist, and upon the decorative features of the house in general.

. . . . .

In addition to the outlets required for illumination by gas, there should be provided the necessary outlets for gas cooking and gas heating fixtures. Beginning in the kitchen, if there is to be a gas range, this should have an entirely separate supply pipe, with a 1- or 1.25-inch outlet according to the number of gas burners in the gas range.

If the heating of the sad irons in the laundry is to be done by gas, there should be a separate supply pipe for these. Should there be a gas plate warmer in the butler's pantry an outlet from the separate line should be provided for it.

In some of the living rooms grate fires or gas logs may be fitted up in the fireplaces; they always require separate and independent supply lines from those lines which supply the lighting fixtures. This also applies to any gas warming stoves. In the bathroom, for instance, outlets are wanted for a gas stove or for a gas fireplace heater, or a gas water-heater, also sometimes for a gas jet in local ventilating flues.

Sometimes houses are fitted up with a larger gas water-heater in the cellar, in which case this requires a large outlet, not less than 0.75 inch, from the separate line which supplies the fixtures intended for cooking or heating.

CHAPTER XIX.

THE LIGHTING OF COUNTRY HOUSES.

In the case of houses in the country, and not within reach of either the city gas mains, or of a central electric-lighting plant, it is an interesting problem how to dispel the darkness and how to light up the dwellings in evening hours by means of artificial light.

In discussing this matter, a brief transgression from the subject indicated by the title of the book may be pardoned, because of the fact that other illuminants, besides artificially made gas, play an important rôle in the lighting of country houses.

The following may be said to be general requirements of artificial illumination:

(*a*) The light should be moderate in cost and safe and convenient to manage.

(*b*) It should be abundant for the purposes for which it is required.

(*c*) It should be as near to daylight or sunlight, as to quality and color, as possible.

(*d*) The light intensity should not be injurious to the eyes, and the illumination should not be too concentrated.

(*e*) The objectionable or harmful elements of illumination, such as the radiant heat from the flame, the contamination of the air by products of combustion, the possibility of explosions, or of bodily injury by coming in contact with live electric wires, should be excluded, or at least the danger therefrom should be reduced to a minimum.

The production of all artificial light is based upon the property which some substances have of becoming incandescent, and in nearly all illuminants it is the carbon which becomes incandescent and thereby gives a flame, though there are also other light-giving substances, such as platinum, magnesia and others, like the Welsbach gauze mantles impregnated with rare earths. As a rule, the material used for lighting is consumed by the flame, as for instance in the candle, in the oil lamp, in the gas flame; but there are exceptions, for instance, the carbon filament of the electric incandescent lamp, and the mantle burner of incandescent gas lamps. Wherever the material used in lighting is consumed in the flame, the combustion forms an oxidation process and plenty of air is required to make the same successful.

We may distinguish solid, liquid, and gaseous illuminants, of which the candle (animal substance), the oil lamp (vegetable substance), and the gas flame (mineral substance) are representative examples.

Among solid illuminants we make use of tallow, stearine, wax, paraffine, and spermaceti; the liquid illuminants comprise rape or colza oil, solar oil, olive oil, linseed oil, kerosene, benzine, and alcohol; gaseous illuminants are the coal gas, water gas, oil gas, gasoline and acetylene gas.

All these illuminants are but different forms of hydrocarbons; and in all of them, the hydrogen (H) and the carbon (C) must unite in combustion with oxygen (O), forming water (H_2O) and carbon oxide (CO) as well as carbonic acid (CO_2).

When solid or liquid illuminants are used, the gas required for combustion in the flame is generated only as fast as wanted; in other words, there is no surplus or storage of gas as in the case of gas illumination. In the form of the candle the illuminant requires the greatest transformation up to the flame. It may be said in general that the solid illuminants are the most expensive, and also the least desirable from a hygienic point of view. (See the table of cost of illuminants at the end of this chapter.) Their flames are injurious to the eyes because of the flickering of the light.

After this introduction, I will now discuss very briefly the various methods available for the lighting of country houses. These comprise chiefly the following:

First: Candle illumination.

Second: Illumination by lamps burning vegetable or mineral oil, and in some instances by lamps burning alcohol in connection with incandescent mantles.

Third: Illumination by gas, which may be either:

(*a*) Gasoline or air gas.

(*b*) Acetylene gas. The latter gas is sometimes burned in portable acetylene lamps.

Fourth: Illumination by electricity.

Candles. Candles give a subdued and pleasant, but not a brilliant illumination. The old-fashioned tallow candles are very unsatisfactory, as the flame is apt to flicker and smoke; they are made from the fat of animals, such as muttons; spermaceti candles are made from fat of the sperm whale; stearine candles are better, but the best light is obtained from hard paraffine and from wax candles, which burn more slowly and with a more perfect combustion. At the present day all candles are manufactured by casting them in forms, with the exception of the wax candles, which are drawn or rolled. The wick used in the candle must be treated chemically, so that it will twist when burning and fall off, thus not requiring the snuffing of the candle, as in the tallow candles formerly used. The objection to paraffine candles, which give a brilliant light, is that they are soft and become bent in summer time from the heat. The wax candles, which are made in all shapes and of all colors, plain, fluted, or otherwise decorated, are superior in appearance, give a most beautiful and soft mellow light, have no bad smell, are clean, firm, hard, and slow burning, and for decorative purposes are quite effective, but they are not cheap. In fact, candlelight is very inadequate as far as lighting up large living rooms is concerned, or if made adequate, it is very costly. The intensity of the light cannot be regulated in candle illumination, except by reducing or increasing the number of candles burnt, and in this respect the illumination is also less satisfactory than illumination by lamps.

One advantage of candles should be mentioned, namely, that they are safer to carry about in a house than oil lamps.

Illumination by Oil Lamps. Lamp illumination is much older than that by means of candles, but the ancient lamps, consisting of open earthen or bronze vases, filled with olive oil, into which a wick of flax or oakum dipped, were rather crude devices, which did not give much light and emitted more or less smoke. The scientific principles of proper combustion were apparently unknown to the ancients.

All lamps which use fluid illuminants require storage reservoirs for the fluid; they also require a wick, which may be either flat or round, single or double, and a chimney to furnish a draft and thus to supply plenty of air to the flame, which will otherwise flicker and smoke.

Lamps are either suction or pressure lamps; the former burn the lighter and more volatile oils, such as kerosene, while the pressure lamps burn the heavier vegetable oils or whale oil.

In modern lamps the wick is made movable to reduce or increase the flame at will. Before the introduction of the use of mineral or kerosene oil, fat or vegetable oil was burnt in lamps, and inasmuch as this fluid ascended but slowly into the wick, it became necessary to use some device to force or press the oil up to it; in the so-called "moderator" oil lamps, for instance, a piston was operated by a spring which had to be wound up several times during an evening.

In the more recent kerosene lamps the wick draws the light oil up by capillary action and no complicated mechanism of any kind is required to force the oil up to the flame.

Some of the advantages of lamps are that they are a reasonably cheap form of illumination, and that in their best forms they give a very steady light. The illumination obtained from a good lamp is very restful to the eyes and is particularly adapted for reading, writing, or sewing. Being portable, lamps are very conveniently moved from one place to another where wanted, but this very portability also involves the danger from explosions and possible fires resulting therefrom.

Among the disadvantages I mention the great care required in handling the lamps, the large amount of heat given off, particularly by the "duplex" style of lamps and all those having a large round wick; the vitiation of the atmosphere, the bad odors nearly always present where kerosene lamps are used, and the annoyance and bother of the daily cleaning and filling of the lamps, of the cleaning and trimming of the wick, of the cleaning of the chimneys, not to mention the trouble incident to the breakage of lamp chimneys, and of the wick mechanism getting out of order, or of the wick hardening.

The requirements of a good oil lamp are:

First: A regular and plentiful supply of oil to the wick.

Second: A supply of air adjusted to the quantity and character of the oil burned.

Third: Simple-acting and properly devised means for regulating the height of the wick, and consequently the size of the flame.

Fourth: The location of the oil storage reservoir in such a position relative to the flame as not to obscure the same or cast a shadow.

To insure safety from explosions it is necessary that the kerosene used in the lamp should be tested for its flash point. It is further advisable to use only lamps with a metal reservoir, as those having glass reservoirs are somewhat dangerous in use. Benzine oil is always dangerous and cannot be recommended.

Incandescent Alcohol Lamps. In recent years the manufacture of denatured alcohol has increased largely, and use is made, particularly in Germany, of the alcohol by burning it, with the aid of incandescent mantles, in portable lamps. Denatured alcohol is domestic alcohol rendered unfit for use as a beverage or as a liquid medicine by mixing with it certain denaturing materials, or substances soluble therein, either of a bad taste, or of a bad odor, or both. German denatured alcohol contains 2 per cent wood alcohol, 0.5 per cent pyridins and some rosemary oil. It is sometimes called "industrial alcohol."

The alcohol flame does not in itself possess any illuminating power, but its heat is used to bring the gas mantle to incandescence. The light of alcohol incandescent lamps is brighter and whiter than that of kerosene lamps; it does not vitiate the air, and heats it less than the oil or kerosene oil lamps; the lamp and burner require but little attention. The use of such lamps has been steadily increasing in Germany in the past years and quite recently they have appeared on the American market.

Gasoline Gas Lighting. For many years country houses have been lighted by means of gasoline gas machines, and while the results were formerly unsatisfactory, due to the crude and unimproved type of machines, the more recent applications give a quite satisfactory illumination.

In all these machines the gas is manufactured from gasoline, which is a colorless volatile inflammable fluid, the product of distillation of crude petroleum or naphtha. Its specific gravity is from 0.63 to 0.67 (that of water being 1.0).

The vapor of gasoline has a pungent odor; the fluid is readily evaporated under ordinary temperatures, and it is somewhat analogous to kerosene, but contains elements of greater danger. This danger lies chiefly in its tendency to vaporize and permeate the air at ordinary temperatures, thus forming an explosive gas. Any approach to it with fire or light is dangerous, and it requires great care in handling. "We find gasoline in use in the hands of hundreds of persons", says a report of the Michigan State Board of Health, " who do not know that the vapor arising from it when mixed with the atmosphere in a proper proportion forms one of the most dangerous explosives." For this reason gasoline should never be allowed in a building.

The process of making gasoline, or air gas, is quite simple and consists in forcing a current of atmospheric air over the liquid gasoline. The vapor which arises from coming in contact with the fluid impregnates and saturates the air and thus produces carburetted air gas, which is a mechanical (not a chemical) mixture of air and vapors of hydrocarbons of a specific gravity greater than that of air. The gas has no corrosive effect on iron pipes, but it is liable to condense.

The machine used for producing carburetted air gas is called a gas machine, and of these there are several types. The majority of machines are operated by a blower or an air pump, which is run by a weight, which requires winding up, or sometimes by a water wheel. The generator, which contains the gasoline, is always separate from the blower and should be placed underground, or in a vault at a distance of from 50 to 70 feet from dwellings and lower than the connecting air pipe. The air pump or blower, on the other hand, may safely be put into the cellar so as to be conveniently operated, as it requires daily attention. It should be placed in an accessible and dry place, so that the pulleys and moving parts will not rust. The air pump contains water and must be kept from freezing. As a rule, the gas so generated is heavy and is apt to smoke when burning, and in order to prevent this, special air mixers are attached to the machine in the cellar, intended to produce a gas of a more uniform quality and a better and steadier flame.

The air gas requires special open-flame burners, but even then the flame is not very steady, and in recent years it has been found best to burn it in connection with incandescent Welsbach mantles. Even the latest improvement, namely, the inverted incandescent gas lamp can be used in connection with gas machines, and has the advantage that it throws the light downwards and casts no shadows. In general, however, the light is somewhat inferior to that produced by acetylene gas machines.

Air-gas machines are cheaply installed and maintained, are easily manipulated and reliable in operation. The disadvantages are the necessity of attending to the blower and the occasional refilling of the generator with gasoline, which is always attended with some danger. An incidental advantage is that the manufactured gas can be used, not only for lighting, but also for cooking, heating, and for running engines.

Since air gas is much heavier than ordinary illuminating gas, its specific gravity being higher than air, it requires somewhat larger pipes, and the pipes must be well run and jointed. Otherwise the gas-piping scheme is quite the same as that for city gas. (See Chapter IX.)

On account of the dangers connected with the use of gasoline, the underwriters have from time to time framed stringent rules and regulations regarding the installation of gasoline machines, and the substance of these is given further on in this chapter. But beyond the danger incident to the gasoline itself, gas-machine lighting is really safer than lighting by lamps; for small houses it is more economical than the lighting by means of a special electric-light plant.

Acetylene Gas Machines. A new illuminating agent for country houses is acetylene gas, which is produced in special apparatus from the union of calcium carbide and water. Acetylene gas burns with a steady, white, open flame, which is many times more powerful than the flame produced from an ordinary open-flame burner, and which is said to cause a lessened strain on the eyes. In the use of this gas special acetylene burners are required and are made with very small openings, consuming from one-half to three-quarters of a cubic foot of gas per hour. The acetylene flame does not require any globes and it causes less vitiation of the air, and likewise less heat. The gas is explosive when mixed with air in certain proportions. Caution is required in the storage of the cans of carbide, which must be kept in an absolutely dry place.

A very large number of acetylene generators are sold in the market and it requires careful judgment and expert knowledge to select a suitable apparatus. Those intending to purchase acetylene generators are earnestly advised to communicate with the National Board of Fire Underwriters and to obtain from them their list of approved generators, which is revised annually.

All generators consist of a mixing chamber or generator and a receiver; in some machines water is fed to the carbide, whereas in others small carbide lumps are fed to the water, and these in general are very much preferable. The machine requires re-charging every few days and the waste residue must be safely disposed of. The machine itself occupies comparatively little space, and requires no special skill in attendance.

While the acetylene apparatus is cheaper in first cost than a good gasoline gas-machine of the same capacity, acetylene lighting is more expensive than gasoline gas lighting, owing to the cost of the carbide. (See the table at the end of this chapter.) The light given off by an acetylene burner is more brilliant than that produced by the best gasoline machine.

Underwriters recommend that the acetylene generating machines be placed in an out-building, which must be protected from freezing in winter time, and here is where one difficulty arises. A few underwriters have approved of the location of the generators in the cellar or basement of a building, but if so located, acetylene machines cannot be considered as safe as gasoline gas machines. The lighting of entire villages or small towns by acetylene gas has been tried and is working quite successfully. In such a case, service pipes are branched from the street mains to the houses and no individual acetylene generators are required.

The specifications for piping for acetylene gas have been given in Chapter X, and further on in this chapter are given the rules and regulations of the Board of Underwriters regarding such apparatus. All piping for acetylene gas should be most carefully tested so as to avoid the danger of leaks, and all fixtures must be made and kept absolutely gas-tight.

Both the acetylene machines and the gasoline machines have the advantages that they require little attention, that they are always ready for use, and that the intensity of the light can be regulated. Both types of apparatus are cheaper than an apparatus for generating electric light, but, on the other hand, both of them are more expensive than lamps.

Portable Acetylene Lamps. It should be mentioned that in recent years portable acetylene lamps have been put on the market, which give a very pleasing, steady, white light, which is almost as efficient as sunlight. In these lamps a carbide, ground specially fine, is dropped automatically from a chamber above into the water reservoir below. If the dropping of carbide is stopped, the production of gas ceases. The charge in the lamp is sufficient for burning it ten hours. Owing to the necessity of providing a large water reservoir for the carbide, the lamps necessarily become bulky and clumsy, and attempts to make them ornamental have not been altogether successful. The burners are special 0.5- or 0.75-cubic-foot-per-hour acetylene burners.

If I am correctly informed, one or two forms of such lamps have met the approval of the Board of Underwriters, but great care would seem to be necessary at all times in the manipulation of such lamps. The manufacturers, on the other hand, state they are not only durable and simple to manage, but absolutely safe, and even less dangerous than kerosene lamps. There is no odor from the lamps and no smoke, and they give a light of 36 candlepower, or over two times the light of an ordinary 5-cubic-foot-per-hour, open-flame gas jet of 16 candlepower. While they require no chimney, a glass shade is generally used for ornament.

Electric Lighting. — Country houses may finally be lighted by electricity, the electrical energy being generated in a special plant. Little need be said in this place about the many advantages of electric lighting, but for summer houses the fact that the light gives off comparatively little heat should be specially mentioned. There is very little danger of breakage of the lamps and no danger of an explosion. No matches are required to make a light, as is the case with all other illuminants mentioned. Very unique lighting effects may be obtained, because electric lamps can be placed in almost any position. It is usually stated that there is very little danger from fire where electric lighting is used, but recent statistics would seem to disprove this assertion.

The wiring of a building is quite an expensive affair if properly done, and so is the installation of a lighting plant, particularly for the smaller houses.

The electric-lighting plant may consist of a dynamo, run by a gasoline or kerosene engine; in other cases a steam engine or water-power are used. A great economy can be effected by combining the electric-lighting plant with the water-pumping plant of a country house.

On account of the vibration or noise of the engine it is better to put it outside of the house, either in a special building or in the barn. It is also desirable to provide storage batteries or accumulators, in order to keep up the lighting for some hours after the engine has stopped running.

While some electric-lighting plants have recently been installed which are so simple that a coachman, gardener, or man-servant may run them, it must nevertheless be said that electric lighting is still so expensive a method of illumination that it can only be adopted by the wealthy people.

The portability, which was mentioned as an incidental advantage of oil-lamp illumination, may be attained in electric illumination, by the simple method of providing plugs at numerous points to which the electric lamps can be attached.

Summing up what has been said, we may state that candle and lamp illumination are comparatively little used for the lighting of country houses, and the choice usually rests between a gasoline gas machine, an acetylene gas machine and an electric-lighting plant.

In building new houses, it is always advisable to install both gas piping and electric wiring.

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The following statement as to the relative cost of gasoline and acetylene gas lighting and the tables, giving the comparative cost of equivalent illumination by means of different illuminants, will be of interest:

Cost of Gasoline and Acetylene Gas Lighting.

The cost of gasoline machine-made gas depends primarily upon the price charged for gasoline. This varies considerably, and at the present time may be said to fluctuate between 15 and 23 cents per gallon.

It is sometimes claimed by manufacturers of gasoline gas machines that 4.5 gallons of best quality gasoline are sufficient to make 1000 cubic feet of air gas, but estimating more liberally, it may be said to require six gallons of the gasoline fluid to saturate air so as to produce 1000 cubic feet of gasoline gas.

Hence the price of 1000 cubic feet of gas would run from $6 \times 15 = 90$ cents to $23 \times 6 = \$1.38$.

The cost for attendance of a gas machine is almost nothing, involving merely the daily winding up of the drum and the occasional refilling of the generator with gasoline. In the newer forms of gas machines, which are run by a water wheel instead of by a drum, the water supply required is stated to be about 2 gallons per burner per hour. If 10 burners are kept lighted for 5 hours per evening, this would mean $2 \times 10 \times 5 = 100$ gallons of water, which probably would not cost over 1 or 1.5 cents per day.

Burning the gasoline gas in an incandescent mantle burner, which consumes 3 cubic feet of gas per hour, and gives, say, about 40 candlepower, we have the cost per candlepower-hour equal to

$$\frac{3 \times 90}{1000 \times 40} = 0.0065 \text{ cent (if gasoline costs 15 cents)}$$

and

$$\frac{3 \times 1.38}{1000 \times 40} = 0.01035 \text{ cent (if gasoline costs 23 cents),}$$

or an average of 0.0084 cent per candlepower-hour, or 0.84 per 100 candlepower-hour. But burning the same gas in flat-flame burners, we find the cost to be much higher. Gasoline gas, costing \$1.20 per 1000 cubic feet, costs in a flat-flame burner, using 4 cubic feet of gas per hour, and giving not more than 12 candlepower,

$$\frac{4 \times 120}{1000} = 0.5 \text{ cent per hour,}$$

or $\frac{0.5}{12} = 0.04$ cent per candlepower (4 cents per 100 candlepower-burners).

If gasoline gas costs 75 cents per 1000 cubic feet, the cost per 100 candlepower-hour would be 2.5 cents.

The cost of acetylene gas lighting is somewhat higher than gasoline-machine gas lighting, as the following calculation shows:

One pound of calcium carbide yields on the average 4.5 cubic feet of gas and costs 4 cents (when one ton of carbide is sold at \$80.00, which is approximately the present price).

An acetylene burner uses per hour from 0.5 to 0.7 cubic foot of gas, and gives a light of about 25 candlepower, hence the cost per candlepower-hour is equal to

$$\text{from } \frac{0.5 \times 4}{4.5 \times 25} \text{ to } \frac{0.7 \times 4}{4.5 \times 25}$$

or from 0.017 to 0.0248 per candlepower-hour or 2.48 cents per 100 candlepower-hour. In other words, acetylene gas costs from 2 to 2.5 times as much as light from gas machines, always supposing equal illumination.

Irrespective of the candlepower developed, acetylene gas costs, according to Dr. Pond,

0.5 cent per hour, if carbide costs 5 cents per lb.
0.45 cent per hour, if carbide costs 4.5 cents per lb.
0.4 cent per hour, if carbide costs 4 cents per lb.

For comparison, give the cost of city gas, burnt in an open 5-cubic-foot-per-hour flat-flame burner, which is,

0.5 cent per hour, when gas costs $1.00 per 1000 cu. ft.
0.625 cent per hour, when gas costs $1.25 per 1000 cu. ft.
0.75 cent per hour, when gas costs $1.50 per 1000 cu. ft.

According to the same authority, the following are the average costs for different illuminants, viz.:

City gas, burnt in Argand burner, 3.9 to 4.2 cents per 100 candle-hours with gas at 1.25 per 1000 cubic feet.

Gasoline gas, burnt in Argand burner, 3.1 cents per 100 candlepower-hour.

Electric incandescent lighting, from 3.1 to 6.2 cents per 100 candlepower-hour.

Acetylene lighting from 1.5 to 2.0 cents per 100 candlepower-hour.

Cost of Various Illuminants.

All tabulated statements regarding the cost of various methods of lighting must, in the nature of things, be only approximate, first, on account of the cost of the crude material used as illuminant, which fluctuates in different cities and countries; second, on account of the varying estimated intensity of the flames, and thirdly, because of the fact that there are several units used in determining illumination. The most common modern standard is the Hefner lamp, which is equivalent to 0.817 normal candlepower as formerly in vogue.

According to a German publication, called "Gas Light," the different usual illuminants range in the following *relative* order of cost, the one on top of the list being the highest, and the one at the bottom the lowest:

Stearine candle.
Oil lamp with round wick.
Flat-flame gas burner.
Electric incandescent carbon lamp.
Argand gas burner.
Alcohol incandescent mantle lamp.
Electric incandescent lamp with metallic filament.
Acetylene gas flame.
Electric arc lamp.
Benzine lamp.
Mercury vapor lamp.
Incandescent Welsbach gas lamp.

Professor D. E. Jones, quoted in O'Connor's "Gas Engineer's Pocketbook," gives the following table of relative cost of different illuminants, stated in the number of candlepower-hours which can be provided at the same cost, viz.:

	Candlepower-hours
Wax candle	33
Stearine candle	77
Incandescent electric lamp	440
Coal gas in slit burner	625
Acetylene and air slit burner	716
Oil gas	1660
Water gas and benzine	1666
Large petroleum lamp	2250
Welsbach burner with coal gas	2300
Electric arc light	2322
Welsbach burner with water gas	4350

In order to compare different illuminants, it is necessary, not merely to take the cost of the light per hour, but to consider the intensity of light, or the candlepower obtained per hour. According to Professor Leonhard Weber, Professor Fischer and D. Beutsch, three German authorities on illumination, the following table of the cost of various illuminants has been compiled by me:

TABLE OF COST OF ILLUMINATION PER 100 CANDLEPOWER-HOUR.

	Cents per 100 candlepower-hours
Wax candles	from 77 to 118
Sperm candles	from 38 to 67.5
Tallow candles	from 40 to 58
Stearine candles	from 41.5 to 50.5
Paraffine candles	from 17.5 to 34.75
Colza oil	16.8
Colza oil burnt in Carcel lamp	10.3
Aerogen gas	12.5
Coal gas burnt in union-jet burner	from 9 to 36 (or from 10 to 15, according to some)
Benzine lamp	7.5
Kerosene Argand lamp	6.00
Argand gas burner	from 3.6 to 9
Coal gas burnt in bat's-wing burner	from 3 to 6.25
Incandescent electric lamp	from 3.75 to 5.45 (also from 6.2 to 7.5)
Kerosene lamp, small	3.00
Coal gas, in Siemens regenerative burner	from 1.6 to 2 and 2.5
Kerosene lamp, large, burning solar oil	from 1.1 to 1.5 and 2
Acetylene gas lamp	from 1.63, 1.92, 2, up to 3
Electric arc lamp	from 1.0 to 1.5 and even 3
Wolfram incandescent electric lamp	1.1
Alcohol incandescent lamp	from 1.25 to 2.25
Incandescent mantle lamp	0.9 (also as low as 0.65)
Inverted incandescent gas lamp	0.4

The cost of incandescent electric lighting, derived from a *central station*, not from isolated plants, is about as follows:

A 16-candlepower lamp uses 55 watts; 1000 watt-hours, or 1 kilowatt-hour, cost at present in New York 10 cents, or 50 watt-hours 0.5 cent; therefore 100 candlepower-hours cost 3.1 cents; if 1 kilowatt-hour costs 20 cents, 100 candlepower-hours cost 6.2 cents.

Illumination with the incandescent carbon filament lamp costs, therefore, 1.5 to 7 times as much as gasoline gas, and 5 to 6 times as much as incandescent gas lighting.

In this connection, however, it should be remembered that the improved electric incandescent lamps, such as the Nernst, Tantalum, Osmium, Wolfram, and Tungsten lamps use a much smaller amount of current.

While 1 kilowatt gives 300 candlepower-hours in carbon incandescent lamps (3.5 watt-hours per candlepower-hour), it gives:

600–620 candlepower-hours in the Nernst lamps 600–620 candlepower-hours in the Tantalum lamps; 660–670 candlepower-hours in the Osmium lamps;	About 1.5 watt-hours per candlepower-hour.

910 candlepower-hours in the Wolfram lamps;
1000 candlepower-hours in the Tungsten lamp.

REQUIREMENTS OF NATIONAL BOARD OF FIRE UNDERWRITERS TO INSURE SAFETY IN THE USE OF GAS MACHINES.

First. The vault or gas house to be removed from the premises insured the distance required, viz., from 40 to 50 feet for small buildings, and from 50 to 70 feet for large structures.

Second. The machine and all the apparatus to be made of good materials and in a substantial and workmanlike manner.

Third. All the apparatus containing gasoline or other inflammable fluid, or any gas holder, is to be placed in a vault outside the building or premises to be insured.

Fourth. Stopcocks must be placed on both the gas and air pipes near the machine in the vault, and also on the gas pipe within the building, and on the air pipe near the air pump when the pump is in the cellar of building.

Fifth. The vent pipe and the filling pipe are to be so arranged that one cannot be opened without opening both.

Sixth. All the main gas pipes leading to the premises lighted must have an inclination towards the gas machine, so as to return all the condensation that may take place in the pipes.

Seventh. The premises to be lighted must be securely piped, the pipes thoroughly tested by competent persons before the gas is let on, and the pipes so put up as to avoid, as much as possible, all accumulation of any condensation that may occur inside the building lighted.

Eighth. Particular inquiries are to be made as to the competency of the persons who are to have charge of filling the machine, and to ascertain if they are informed as to the importance of having the vent open and the air pump shut off whilst the machine is being filled with fluid, or of the great danger of using a light in or near the gas house or vault.

Ninth. No barrels containing gasoline or other like fluid, or from which gasoline has recently been emptied (yet full of vapor), are to be allowed to be kept in any cellar, barn, shed, or outbuilding where other property is kept, or where there is a liability to use a fire or light.

Tenth. In case the air pump of the machine is placed in the cellar of the building, an automatic check valve is to be inserted in the air pipe to prevent the backward flow and escape of gas through the pump into the cellar, or the pump is to be constructed and set so that the air supplying it is drawn through an induction pipe leading from without the building.

REQUIREMENTS OF NATIONAL BOARD OF FIRE UNDERWRITERS FOR A STANDARD ACETYLENE GENERATOR.

First. The generator and gas holder must be constructed either of iron or steel capable of resisting an internal pressure of twenty pounds to the square inch, and if of wrought iron or steel they must be constructed with lapped joints double riveted. Wrought iron or steel must be used for the construction of the gas holder. It shall be permissible for generators to be made of cast iron when from their design wrought iron or steel cannot be used.

Second. The generator and gas holder must be so arranged as to be entirely freed of air before the gas is turned into the service pipe.

Third. The generator must be so designed that it can be supplied with calcium carbide, and the residuum be withdrawn without the escape of gas or the admission of air.

Fourth. No device or attachment facilitating or permitting mixture of air with the gas prior to consumption shall be allowed.

Fifth. The generator must be so arranged that gas will be automatically produced, and only in such quantities as immediate consumption demands. The gas holder must be limited in its capacity to meet these requirements.

Sixth. The generator and gas holder must be provided with a water seal having an automatic attachment to the water supply, insuring a constant level of the seal.

Seventh. Apparatus in which gas is generated by a small quantity of water falling upon calcium carbide must be so arranged that not more than five pounds of calcium carbide can be in contact with water at the same time.

Eighth. All apparatus must be so arranged that it cannot generate gas at a pressure in excess of that due to a five-inch column of water. A safety water seal, which shall not exceed that limit, and also a pressure gauge, must be attached to the generator. An escape pipe of not less than one and one-half inches in diameter must be connected with the water seal, and discharge into the open air above the roof of the generator building. The water seal of the gas holder must not be less than nine inches.

Ninth. Each gas holder must be connected by at least one and one-half-inch escape pipe, through which the gas holder can be freed of air, and through which the gas can be conveyed and discharged with safety into the open air above the roof of the generator building. The escape and gas service pipes must be connected by means of a two-way cock located at the gas holder. A stop valve must be placed on the supply pipe at the place where it enters the inside of the building to be lighted. No stop-cock or shut-off valve other than the two-way cock above provided for shall be placed in the gas pipe between the generator and the service pipe, except at a point between the safety water seal and the gas holder.

Tenth. The generating and gas-holding apparatus and the surplus of calcium carbide must, in all cases, be placed in an outside building, built and located as prescribed in the requirements for their installation.

Eleventh. To be approved, acetylene generators must conform to the foregoing standard, and plans and specifications in detail of such apparatus must be submitted to the insurance organization having jurisdiction over the territory in which such apparatus is to be installed, for approval by an inspector duly authorized by the National Board of Fire Underwriters, with whom a copy of such plans and specifications must be filed. If the plans are approved, a special examination of the generating apparatus will be made (at the expense of the applicant), and if it is found to be in compliance with the standard, a certificate of approval will be issued.

PERMIT FOR THE USE OF ACETYLENE GAS.

Permission is hereby granted for the use of acetylene gas on the premises described in this policy, provided the apparatus for generating the same has been first approved by . . . . ., the duly authorized inspector of the National Board of Fire Underwriters, and is installed in accordance with the following requirements:

REQUIREMENTS FOR THE INSTALLATION AND USE OF ACETYLENE GAS.

First. The generating and gas-holding apparatus, when installed for lighting buildings in the closely built-up portions of towns and cities, must be located in an outside, fireproof, and well-ventilated building. In constructing said building, its floor must be raised above the grade upon which it is located, and suitable drainage be provided. Ventilation is to be obtained by air passing from the outside of the building through suitable inlets in the floor, and by a pipe not less than six inches in diameter, at the roof, into which the escape pipes from the gas holder must discharge. The said ventilating pipe must extend at least four feet above the roof of the generator building, and must be topped with a guard cap, and if there be any building within ten feet of said pipe, then the ventilating pipe must be carried four feet above the roof of the higher building.

Second. The dimensions of the generator building must be confined to the requirements of the apparatus and a limited surplus supply (hereinafter mentioned) of calcium carbide, and the building shall be located as follows:

(*a*) For generators having a capacity of not over twenty-five pounds of calcium carbide, and, in addition, one hundred pounds of surplus calcium carbide — not less than ten feet from other buildings.

(*b*) For generators having a capacity not exceeding one hundred pounds, and, in addition, not over five hundred pounds of surplus calcium carbide — not less than twenty-five feet from other buildings.

Third. When the installation is to be used for lighting detached or isolated property, it must conform to the above requirements in all respects, save that the generator and its attachments may be placed in a non-fireproof building, which shall be located not less than twenty-five feet from insurable property, except by special permission to the contrary in any case.

Fourth. A special permit must be obtained from the authorized inspector of the National Board of Fire Underwriters for the installation of generating apparatus, having a capacity in excess of one hundred pounds of calcium carbide, and for the keeping of a surplus supply of calcium carbide in excess of five hundred pounds.

Fifth. Generators must be supplied with calcium carbide and the residuum be removed without the use of artificial light. All acetylene gas generating apparatus should be in charge of persons properly instructed in their management.

Sixth. No artificial light shall be used inside of the building in which the gas is generated, and no heat except steam.

Seventh. The residuum of the calcium carbide, when removed from the generator, must be deposited outside of the building remote from all combustible material.

Eighth. Calcium carbide must be packed in screwed-top, air- and water-tight metal packages of not over one hundred pounds each, and each package must be conspicuously marked " Calcium Carbide, Keep Dry." The packages must be of sufficient strength to insure the handling of the same without rupture, and they must be kept under cover at all times.

Ninth. Bicycle and other portable lamps, in which acetylene gas is generated, and supplied direct to burners, unless in compliance with foregoing requirements, are prohibited, and will not be approved until such lamps are so constructed that they will cease to generate gas immediately upon the extinguishment of the flame, thereby securing a safeguard which is absolutely necessary; the keeping on insured premises, or immediately adjacent thereto, of calcium carbide, either in the crude state or in cartridges for portable lamps, will not be approved unless same is kept in hermetically sealed metal packages, and in quantity not to exceed two pounds in all.

In considering the specifications herewith submitted for the construction of a " Standard " acetylene generator, the committee has so framed the stipulated conditions as to cover the essential of safety as a fire-hazard, and yet leave such wide scope as to the form and design of any such device, as to avoid imposing upon the manufacturer of the same any unusual mechanical or structural difficulties, or in any marked degree to restrict the range of the type or class of such apparatus.

CHAPTER XX.

THE RELATIONS BETWEEN GAS COMPANIES AND GAS CONSUMERS.

ONLY a little over a century has passed since the birth of the gas industry, yet we already find gas lighting, in some instances, being supplanted and displaced by the electric lighting. Even a casual observer cannot fail to notice the fact that electric illumination has recently become very popular; but does this mean that gas lighting is entirely doomed? Has not, on the contrary, the gas industry profited by the advent of the new system, and is it not a fact that the consumption of gas has increased in recent years instead of diminishing?

At the time when the electric lighting was first brought to public notice, Mr. W. H. Preece, in a lecture on "Recent Wonders of Light," delivered in 1880 before the London Society of Arts, uttered the following prophetic words: "Gas is a magnificent thing in itself, but one of the great advantages of gas has been that it has driven the candle makers and oil-lamp manufacturers to give us hundred-fold better things than they did before, and so the introduction of electricity, if it does nothing else, will compel our gas engineers to produce gas-lighting apparatus as far superior to those of our youth as these ordinary lamps are to the oil lamps of the Greeks."

Gas lamps took the place of candles and oil lamps, and are now, in some cases, replaced by electric arc and incandescent lamps, yet in each case the older illuminant has profited instead of suffered. Doubtless, one result of the improvements in methods of illumination has been a more lavish use of light, and the setting up of a higher standard in street as well as in domestic lighting. With the increased requirements, therefore, each kind of artificial light benefited by the advent of its successor, competitor and rival.

Electric lighting, in particular, awakened the managers of the gas industry to activity, and a higher quality of gas at reduced cost, better gas-fittings, more efficient gas burners and gas lamps have been produced, demonstrating to a greater extent than ever before the possibilities of the "light without a wick," created from "the spirit of coal."

Gas lighting has in the past been of incalculable benefit to mankind; its many advantages are at present more than ever enjoyed in the household, in the office, and in the workshop, and notwithstanding contrary statements by those interested in the development of the rival system, it is my belief that for a long time to come, gas will not only hold its own, but make still further progress. The twentieth century will, doubtless, ultimately become the age of electricity, but the present is the era of gas.

Having thus briefly glanced at the past, present, and future of gas lighting, let us consider what should be done to strengthen the future position of gas lighting in view of the rapid strides made by its chief rival, electric lighting.

An impartial observer cannot help admitting that the future of the gas industry must, to a great extent, depend upon the relations between gas companies and gas consumer, which, as is well known, are not always as pleasant as they might be.

The gas companies are corporations formed for the purpose of manufacturing and selling illuminating or fuel gas to a community or to consumers; the gas works are establishments or works for the manufacture of illuminating and fuel gas.

The bulk of the gas-consuming public is lamentably indifferent or ignorant, or both, about the subject of gas manufacture and gas lighting; hence, the proper use of gas in the household is little understood. A few commendable instances excepted, gas companies have made no effort whatever to keep householders and gas consumers informed on the subject. Instead of trying to gain the consumer's confidence, many gas companies and their employees have persistently pursued the erroneous policy of surrounding themselves and everything pertaining to their business with an air of profound mystery. Worse than this, in many instances those employees of a gas company who come into closer contact with the public, often throw a veil of secrecy about the subject with a view only of hiding their own ignorance. All this is much to be deprecated, for as a natural result the consumer, already full of prejudices and dissatisfaction, becomes still more suspicious and biased. It would seem to me as if the best interests of gas companies demand that they enlighten the public, and that they help them in every possible way to consume the product of the gas works in the best manner.

I quote in full a recent editorial from the *New York Times*, which is to the point:

"Gas companies do not understand, and have never understood how to deal with the general public, or appreciated the value of trying to satisfy the consumer. They receive complaints with indifference and protests with something very like insolence.

"Even when they know, or have good grounds for suspecting, what the trouble is which causes dissatisfaction, they seem to think it beneath their dignity, as a great corporation, to do anything or say anything satisfactory. The clerk behind the grilled window who is the recipient of a complaint that the bills are increasing without greater satisfaction to the consumer in added illumination, quickly falls into the attitude of his employers and feels perfectly at liberty to be insolent, if not deliberately insulting.

"The tardy zeal which some of the local offices of the gas combine show in investigating complaints of consumers, and the discovery that most of them can be remedied by a little intelligent attention to conditions existing in the pipes or at the burners of the dissatisfied consumer comes too late to quickly undo the cumulative grievance of years of neglect."

Why gas companies should not make efforts to establish, or to maintain, pleasanter relations with their consumers has often been a matter of wonder to me. The interests of the gas manufacturers and of the gas consumers are mutual and should go hand-in-hand; therefore, companies should constantly strive to dispel any bitter feeling, to remove all prejudices, and to avoid as far as possible all friction. The welfare of gas companies demands that they should not be indifferent to the wishes of the consumer. It is a fact, capable of easy demonstration, that where a company or its employees have taken the trouble to instruct the consumer how he can make the best possible use of gas, or how he can obtain a maximum amount of illumination from the burning of a given quantity of gas, an increased consumption of gas resulted for the company.

What then can gas companies do to bring about a better feeling between themselves and their consumers? First of all, gas companies should attend to the complaints of the consumers. Nothing within the bounds of reason should be left undone to satisfy them and thereby to retain or regain their confidence.

By far the majority of complaints are, first, about bad gas or deficient light, and second, about excessive gas bills. The latter are invariably attributed to the inaccuracy of the company's gas meters, or to errors of the clerks in making out the monthly gas bills, while the deficiency of light is usually laid to the bad or poor quality of the gas or to lack of pressure in the gas mains. Occasionally, consumers grumble about the flickering of the light, about hissing and noisy flames, about the breaking of gas globes, caused by gas flames with ragged edges, about the vitiated air, about immoderate heat and the injurious effects of gas lighting upon health and comfort, and about the destructive effects of gas upon the decorations, pictures, books and furniture, the walls and ceilings of rooms.

In some cases, no doubt, there is just ground for these complaints. The gas company should then endeavor to remove the causes, if practicable, and should make constant efforts in the interest of the consumer. But, as often as not, the complaints of consumers arise from their own lack of knowledge, or carelessness, or indifference. Very frequently, too, the troubles complained of are a result of the stupidity or cupidity of the gas-fitter or the builder, and an impartial investigation would demonstrate that the complaints can easily be traced to one or more of the following defects, over which the gas company seldom has any control, viz.: the use of gas piping of inadequate size, the improper running of gas pipes, the use of bad, cheap, or unsuitable burners, or good burners becoming obstructed or worn out; the use of ill-contrived and light-obstructing brackets and chandeliers with tubing of insufficient size; the use of globes, with narrow bottom opening, made of light-obstructing material, and supported by heavy globe holders; or the failure of the gas light may be due, in districts where a high pressure necessarily prevails, to the omission of pressure-reducing appliances.

Consumers of gas should inquire into the subject of gas lighting without bias, and gas companies should endeavor to remove all manner of prejudices generally arising from ignorance or suspicion. Among misconceptions of consumers, the most difficult to deal with is the prejudice against the "lying gas meter." This is largely due to want of knowledge as to its construction and mode of operation. It is increased by the many stories of the vagaries of gas meters, disseminated by the daily press. Many consumers imagine that they are completely at the mercy of the gas meter, or that gas companies charge them whatever they see fit to charge. It is needless to say this is a great mistake. To remove this deeply rooted prejudice, gas companies should endeavor to teach the householder how to become familiar with the gas meter, and to encourage his frequent reading of the index, as many a serious misunderstanding may thereby be prevented.

As a matter of fact, the size of a consumer's gas bill is dependent upon the quantity of gas consumed only, and with this a gas company has very little to do. As regards gas bills, wrong statements are rendered much less often than the average gas consumer supposes. The process of making out the bills is about as follows: Once a month the meter inspector calls at the consumers' houses, takes the readings of the meters, enters the date and the state of the meters in his record book, and returns the same to the gas company's office. Then the clerks in the office make out the bills by putting the last statement just taken at the top, and the reading of the previous month under it. The latter amount is then deducted from the former, and the difference obtained is the last month's gas consumption. Errors of calculation can be prevented by checking the figures, and errors in the figures by a careful comparison of the previous and the present meter reading. Errors made in reading the meter are, as a rule, discovered at the end of the next month, it being then found that the consumer has either paid in advance or else too little, generally by an even 1000 cubic feet. By reading his own gas meter every month, or every week, or daily, a consumer has in his hands a perfect check against fraud or mistakes.

Again, a great deal of good might be accomplished if managers and officers of gas companies would endeavor to correct and dispel the numerous popular errors or fallacies regarding gas lighting. Still more good could be accomplished if gas companies would undertake to give direct advice and practical instruction on the details of domestic gas-burning appliances, and thereby spread the knowledge of the correct principles of gas consumption. Some topics of interest and practical value to gas consumers are, to begin with, the gas meter, its construction and arrangement, with explanations of how to read the index of the same. If once the householder becomes familiar with reading the gas meter, misunderstandings or disputes about the gas bill would in the majority of cases be prevented. Then there is the gas piping of buildings. It has been said that a bad system of internal gas piping is the arch enemy of every gas undertaking; therefore, gas companies should, in the case of all new buildings, see that architects, builders and gas-fitters follow the best rules on gas piping. It would certainly lead to good results if gas companies would distribute rules and regulations on the best mode of doing gas piping, on the methods of running the distribution pipes, on the sizes of pipes, and the proper manner of testing gas pipes.

Gas companies should in this way try to exercise some supervision over the consumer's fittings, and also insist upon the employment of responsible and qualified gas-fitters. Regarding gas burners, the gas companies should remind consumers, that even the best of burners wear out, and that worn out burners mean a waste of gas, also that burners become obstructed and need periodical cleaning. They might, with advantage, go a step farther and give to the householder information regarding improved burners, or supply the consumer, either free or at a nominal charge, with the best kind of burners rather than see him at the mercy of the burner quack. Many consumers, without doubt, would welcome any judiciously thrown out hints about burners and lamps. Information about gas lamps and gas fixtures, gas globes, globe holders, shades, and reflectors would also be useful, particularly a demonstration of the advantages arising to householders from the use of gas globes of clear glass with wide bottom openings, supported in shadowless triangles made of thin wire.

Gas companies should explain the object and use of gas pressure regulators and of volumetric governor burners. In districts with excessive gas pressure they should teach the gas consumer the proper remedy for " blowing " burners. It is much to be regretted that, as a rule, gas companies are opposed to the use, by the consumers, of pressure regulators of any kind, except the ordinary check burners which are notoriously unreliable, while they themselves make extended use of the best volumetric governor burners on their street lamps. The use of pressure regulators should be discouraged only where the house piping is quite insufficient in size.

Much may be accomplished by employees of the gas companies giving instruction to consumers about the proper management and use of gas. Gas is wasted in houses in many ways, and children as well as servants are proverbially careless or thoughtless in the use of gas, keeping gas burning many times when not wanted. Again, the householder's attention should be called to defective gas keys, such as the "all around" keys without stop-pins, which often cause escapes of gas and may lead to serious accidents. There is not a gas consumer who would not thankfully accept advice upon such points, if it were given conscientiously and in a proper manner.

Many hints may be thrown out regarding the maintenance of gas-fittings, the cleaning and renewal of burners, the cleaning of chimneys and globes, the greasing and tightening of the gas keys, the refilling of the water joint in hydraulic gasoliers, and kindred subjects. The annoying and aggravating irregularities sometimes occurring in the gas supply, and the proper way to remedy each trouble, should be lucidly explained. The consumer's attention should be called to objectionable gas leaks, whether in the pipes and fittings, or in the fixture joints, the gas keys, or the burners, and the remedy should be given. All necessary and usual precautions against danger from fire should likewise be explained and commented upon.

Useful hints may be given regarding the advantage, economy, and convenience of gas cooking and gas heating appliances. The revenue of a gas company will be increased where the day use of gas is encouraged. In all these matters gas consumers must be aided and guided, and gas companies should not lose the opportunity of doing this, as the continued welfare of their business depends upon it. Many a grumbling consumer may be turned into a friend of the company by timely advice, given in a discreet manner. Gas managers, gas inspectors, and the gas-fitters employed by the gas company should be well informed on these topics, so as to be able to give intelligent advice to the consumer.

While there are several ways in which gas companies may educate the consumers, one of the best consists in the arrangement by the gas company, at their office, of a general exhibition of gas apparatus. In this exhibition should be included a collection of the best gas-lighting burners, also samples of governor burners, of well-shaped glass globes and shadowless globe holders, of improved modern regenerative and incandescent gas lamps, etc.

A good gas-pressure regulator should be shown in practical operation, likewise an exhibition meter, constructed of glass, so as to show the interior construction and working mechanism of the gas meter. Finally, there should be exhibited the best examples of gas cooking ranges, of apparatus for heating water, for heating laundry irons, also gas heating stoves, incandescent fireplace heaters, and terra cotta gas logs. All of these appliances should be fitted up with gas connections ready for lighting up, in order to show to the public their mode of operation, and their advantages and utility.

There can be no question that a well-arranged show room, containing a judiciously selected stock of the best domestic gas appliances, must have a powerful influence in popularizing the use of gas. Manufacturers of gas apparatus should aid the gas companies in this matter, as such a display would tend to create an increased demand for improved gas appliances. In connection with such exhibitions, popular lectures might be arranged on various subjects, such as the use of gas for lighting, cooking by gas, with demonstrations of practical cookery, on gas heating appliances, on gas motors, and the like. The gas exhibitions would prove a useful medium for distributing to consumers tracts or pamphlets upon the advantages of gas for light, fuel, and power purposes, and containing just such hints and general information as the public is most in need of. A liberal dissemination of such pamphlets must eventually result in a large reduction in the number of common complaints. It is likewise desirable that printed rules for gas piping in new buildings be circulated by gas companies amongst those who are chiefly interested, *i.e.*, architects, builders, plumbers, and gas-fitters.

The question is often asked, if it would not be advantageous to have the gas piping in new buildings done by the gas companies. After a careful consideration of this matter, I fail to see what material advantage, if any, could be derived therefrom. Gas companies necessarily must rely just as much as other contractors doing gas piping, upon the honesty, practical skill, and ability of the mechanics, and in not a few instances have I found fully as much ignorance and carelessness among gas companies' fitters as among fitters in the employment of the trade. Whether the householder gives his gas-piping work to the gas company or to a tradesman, a plumber or gas-fitter, his chance for securing perfect work lies mainly in paying a fair price for it and insisting upon the employment of only competent fitters. Here, as elsewhere, the best results may be secured by proper supervision.

Not a little of the ill-feeling existing between gas companies and gas consumers is due to the disrespectful treatment which consumers occasionally receive in some gas offices. Employees of gas companies, and in particular the inspectors of gas meters and those clerks in the office who come into more frequent contact with the public, should be required to be courteous and polite in manner and speech. After all, the public have a right to demand at least the same fair treatment in a gas office which they receive by clerks or salesmen in stores, in which they make the purchases of the sundry necessaries of life, and where, as a rule, they are shown that they are valued customers. Fully aware of the fact that the position of the clerks in the gas office, who receive the customers' complaints, must often be a very trying one, I still hold that the ill-temper of the clerk should never be vented upon an unoffending customer. Here, as in other lines of business, it pays to be patient, obliging, and polite, and nothing is gained by showing even the slightest sign of irascibility. Customers, on the other hand, ought to bear in mind that very often the clerks and inspectors of gas companies are abused by the suspicious, the ignorant, the ill-mannered people, necessarily forming a portion of the customers of a gas company, and they should, therefore, condone a clerk's offense of sometimes appearing gruff, impatient, and uncivil.

In short, gas companies would undoubtedly be on better terms with consumers if they had not, in too many cases, disregarded their wishes. The enlightenment of the gas consumer is of importance, for even well-educated men often display a very deplorable ignorance and bias as regards the use of gas. The public should be taught that a gas company's business is legitimate and that their dealings are just as honest and upright as the transactions of other business concerns. And, lastly, the consumers who go to the gas company's office for advice should have confidence in the suggestions made by the company. A proper observance of what has been herein stated would undoubtedly pave the way toward better relations between gas companies and gas consumers.

CHAPTER XXI.

PRACTICAL HINTS FOR GAS CONSUMERS.

1. The numerous advantages which gas offers, and the fact that it is both an economical and a convenient source of light, heat, and power, are in themselves sufficient reasons for advising its introduction into all buildings, old as well as new, wherever a supply of gas is available.

2. Whenever a new building is erected, provision should be made for a gas service, for it is cheaper to put in the gas connection during the construction of the building. Notify the gas company and send in a written application for a gas service-pipe. In the majority of American cities gas companies tap their street mains and run the service into the houses free of charge. They do not do any of the piping for gas in the building; their service pipe stops at the place where the gas meter is to stand.

3. Pipe the entire building for gas when the house is built. This will surely enhance the value of the building, particularly if you provide a separate supply pipe for a kitchen gas range. Select a gas-fitter, or a well-recommended and trustworthy plumbing firm, to do the piping in the house. Before letting the work by contract, decide upon the position of the gas meter in the cellar, and locate the main gas riser or risers as well as the required gas outlets for light and for other uses.

Even when you do not contemplate burning or using gas, put in the main distributing lines in the floors to avoid future annoying and troublesome cutting of floors and partitions.

Wide-awake landlords having apartments and dwellings to let know from experience that one of the questions asked by prospective tenants is whether provision is made for a gas range, for gas fireplace heaters, for bath water-heaters, etc.

4. If you give out the work of piping the building by contract, use a good form of gas-piping specification as a guarantee for a good character of the workmanship, for a satisfactory quality of pipe and fittings, and for the proper adjustment of the pipe sizes and their proper running and distribution.

Unless some one qualified to do so superintends the work of the gas-fitter, it is more than likely that inadequate gas piping will be put in, which surely sooner or later will lead to frequent complaints regarding the deficiency of the gas illumination.

5. Locate the gas meter in an easily accessible place, not subject to dampness or to extremes of temperature, and where the meter will not be subject to accidental or malicious damage. The gas meter remains the property of the gas company; it is solely under their control, and the gas consumer should under no circumstances meddle with it. If he suspects anything to be wrong with the meter, he should at once notify the company.

Do not object if the gas company sends you a gas meter of what looks to you like an over-generous size. No possible harm to you can result from this; on the contrary, it may insure to you a full supply of gas to the lighting fixtures and to the gas cooking range, while it will *not* increase your gas bills, provided you exercise care and judgment in the management of gas.

6. In piping a building for gas, do not be afraid to have your gas-fitter put in pipes of generous size. It is an error to suppose that this leads to increased gas bills. The gas piping, if done with pipes of ample size, will remain adequate, even if additions are made to the building. But even where the pipes are larger than actually necessary, no harm can result, nor will the gas bill be increased unduly, whereas piping which is too small is always detrimental and the direct cause of an insufficiency of gas pressure in the house pipes.

7. Have your gas piping tested after completion to make sure that there are no leaks. A comparatively small leak, amounting to one cubic foot per hour, will in the course of a year cost you

$ 7.00	when gas costs	$0.80	per 1000 cubic feet.
8.76	when gas costs	1.00	per 1000 cubic feet.
10.95	when gas costs	1.25	per 1000 cubic feet.
13.14	when gas costs	1.50	per 1000 cubic feet.
15.33	when gas costs	1.75	per 1000 cubic feet.
17.52	when gas costs	2.00	per 1000 cubic feet.

Gas consumers may inform themselves about the tightness of their gas piping by the following simple and easily applied method: Close all burners in the house and watch the small index hand of the meter for an hour. If the hand moves during this time, it is evident that there must be a leak somewhere, which may be either in the piping or in the fixtures. Do not neglect a gas leak however small it may appear. If the leak asserts itself by a strong odor of gas, open at once all windows and do not permit the use of open flames anywhere until after the leak is located and remedied. It is a good plan to have the gas piping in a building re-tested periodically.

Iron rust, watery vapor and naphthaline accumulate in the gas pipes and lodge particularly at the foot of risers and vertical branches. Thus they become the cause of the obstructions in the pipes and of deficient illumination or gas supply to the fixtures. Gas consumers are advised to have their gas pipes blown out and cleaned from time to time. Corrosion takes place in the gas burners, and the tips break or wear out. From time to time the burners should be cleaned or, where necessary, replaced by new ones. Unfortunately, not one gas consumer in a hundred will think about such matters, nor will he think it worth while to take care of his gas fixtures.

9. When extensions or additions are made to a building, it is best to put in additional risers, and also additional supply lines in the cellar. Additional outlets should never be taken from the existing gas pipes except where the gas pipes were originally put in with this in view. As a rule, it is advisable also to increase the size of the gas meter.

10. Should the pressure of gas be excessive, the gas consumer can improve the illumination, secure steadier flames, and at the same time keep the gas bill down by using a pressure regulator at the meter, or by adopting improved burners (see Chap. XIV). But one should be careful not to use pressure regulators where the house pipes are too small. The disastrous effect of excessive pressure is illustrated by the following experimental results: A burner using 3.9 cubic feet of gas per hour under $\frac{5}{10}$ inch gas pressure will use

5.6 cubic feet per hour of gas under $\frac{10}{10}$ gas pressure;
8.5 cubic feet of gas per hour under $\frac{20}{10}$ " "
10.5 cubic feet of gas per hour under $\frac{30}{10}$ " "

11. Consumers using flat-flame burners should from time to time study the appearance and shape of the flames. Flames with ragged edges, uneven or unsteady flames, singing, blowing, or hissing flames mean a wasteful burning of gas. Flames which appear to be divided indicate that the burner requires cleaning.

See that the flame from bat's-wing burners is not too wide, as it is liable to crack the glass globes. Use globes of wide bottom diameter, and set the bottom edge of the globe level with the point at which the gas issues from the burner. The flame will be a great deal more steady in this way.

If they wish a bright illumination, gas consumers should replace their flat-flame burners by the incandescent mantle burners, which give more light and at the same time use less gas.

12. Modern incandescent mantle burners require some care in their use and management. It is best to light them from the top, but before applying the match or the taper the gas cock should be turned on for some seconds. Care should be taken not to have burnt fragments of the match or the wax from the taper drop on the mantle.

A self-lighting attachment is used much in Europe and tends to protect the mantle. Should the flame jump back, the gas should be turned off and relit. In portable desk lamps care should be taken not to break the mantle in handling the lamp.

13. Where a strong light is required for a work table, a drawing table, for reading, sewing, etc., consumers are advised to make use of glass or mercury reflectors, or of some of the excellent holophane glass shades. Care should be taken, however, in all cases where a strong light is used, to protect the eyes from the direct rays of the light, by encasing the flame with frosted glass.

14. Gas consumers are advised to study the manner of reading the index of the gas meter. The regular reading of the meter index at periodical intervals will inform a householder whether gas is used in a wasteful manner. The reading of the small index on the meter serves also to determine the hourly gas consumption for any burner, lamp, or for the gas cooking stove, the gas water-heater and the fireplace gas-log.

The reading and watching of the small index hand, when all gas keys are kept turned off, will show whether there are leaks, and not only this, but it will also indicate the size of the leak by the volume of gas registered in a given time.

15. Consumers, who unexpectedly receive a very high gas bill, are prone to blame at once the "lying" gas meter and to claim that it must register incorrectly. The better way would be for them to calmly inquire from the household whether any reasons have existed for consuming more gas, to investigate

whether children or servants have not been careless in using gas wastefully; whether there has perhaps been more company than usual, or whether perhaps sickness was the cause for burning more than the regular amount of gas. If all such inquiries fail to give an explanation, it is well to search for hidden gas leaks. Should none be found, notify the gas company, and request that the gas meter be removed and retested.

16. The following two tables, one an English one, and probably correct for the latitude of London, the other an American one, presumably calculated for the latitude of New York, will be found extremely useful in calculating and checking what the average gas-lighting bill each month in the year should be, when the number of burners nightly in use are noted. A careful use of the tables will also lead to a saving of gas.

TABLE OF NUMBER OF HOURS GAS IS BURNED IN EACH MONTH DURING THE YEAR.

(From Newbigging's English Gas Handbook.)

Burning from	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Total.
Dusk to —													
" 9 o'clock	13	71	82	124	152	173	158	117	93	58	29	8	1078
" 10 o'clock	44	102	112	155	182	204	189	145	124	88	60	38	1443
" 11 o'clock	75	133	142	186	212	235	220	173	155	118	91	68	1808
" 12 o'clock	106	164	172	217	242	266	251	201	186	148	122	98	2173
All night	217	307	345	421	473	527	512	411	382	295	242	195	4327

II. — YEARLY TABLE OF GAS-BURNING HOURS.

(From American Meter Company's Pocketbook.)

Number of Hours from Sunset to 10 P.M., with Average for Each Month.

			Average Daily Number of Hours.		Comparative Length of Evenings.
	Hrs.	Min.	Hrs.	Min.	
June	76	55	2	34	100
July	83	52	2	42	109
May	88	38	2	51	115
August	99	16	3	12	132
April	102	47	3	25	134
September . . .	115	24	3	51	150
March	127	06	4	06	165
February . . .	132	59	4	25	172
October	140	14	4	31	182
November . . .	153	35	5	07	199
January	163	16	5	16	212
December . . .	168	25	5	24	218

Precautions to Render Gas Lighting Safe from the Danger of Fire.

17. The majority of dwelling-house fires are due to defective or improperly managed lighting and heating apparatus. Both fires and gas explosions may result in consequence of leaky gas pipes. Hence make sure that all gas piping is absolutely tight, and do not permit even the smallest leaks to remain unattended.

Do not permit the search for a leak with an open light, a taper, candle, or even a match. The escaping gas may become ignited without your noticing it. This in turn may set woodwork on fire. Some of the fires, the origin of which remains a mystery, may be attributed to this cause. Electric candles are much the safest devices to use in locating gas leaks.

18. Consider carefully the location of the gas fixtures. Swinging gas brackets are particularly dangerous, and often set woodwork of doors or windows, or curtains, portières, shades, or wall shelves on fire. The remedy consists in protecting the open flame with a wire cage of large diameter, or in using stiff brackets in such places. Unguarded, open gas flames in a building are always dangerous and should be carefully watched at all times, and kept away from inflammable material. Gas flames should not be nearer to a ceiling than three feet, otherwise use some form of protection, either a metal or glass shield, a bell hung over the flame, a deflector or a ventilating hood.

19. In case of regenerative or other ventilating gas burners, the exhaust flues must be of metal, and should not be in direct contact with woodwork.

20. Glass shades or globes should be used to protect open flames from drafts. Wire cages are particularly necessary in the servants' department of a house; in the cellar, basement, and attic; in the laundry, the ironing room, the linen and storage closets.

21. Use only metallic reflectors; paper or pasteboard reflectors or shades are dangerous to use.

22. The very common practice of using rubber hose of any kind for the connections between a gas outlet and a gas stove, radiator, cooking plate, or even for a drop fixture is very dangerous. The cheaper grades of hose soon deteriorate in use, become leaky and are easily inflammable. Metallic hose is infinitely better though more expensive.

23. A stiff iron pipe connection between the gas supply and

the gas fixture is much more preferable and safe. It should always have a stopcock or valve to control the supply of gas.

24. Fires have been caused by the setting up of small gas cookers or laundry iron heaters on a wooden bench or table. The better way is to line the tables so used with bright tin.

25. Great care must always be observed in the use of matches. They not infrequently cause a fire if they are thrown away carelessly while still glowing. Always put burnt matches into earthen or metal receptacles. Keep fresh matches away from mice and rats. Do not leave matches exposed to the sun's rays. Wax and parlor matches are more dangerous in use than the so-called Swedish or safety matches.

26. In all large buildings the lighting up should be in charge of a special responsible man. He should be instructed to use care in the means for lighting the gas flames. He should not be permitted to use alcohol torches as they are dangerous for indoor use; electric torches or lighters are much better.

27. Broken or cracked lava burner tips in combination with a sudden increase in the gas pressure may cause a gas flame to flare up unduly and sometimes ignite nearby woodwork. Sudden changes in gas pressure are very undesirable in this respect.

See that the gas meter is located in a ventilated place, which, if practicable, should be open to the outer air.

Asphyxiation by Illuminating Gas.

28. It is a dangerous practice to accustom oneself to sleep in an unventilated chamber with the gas left burning low. A reduction in the gas pressure, which may happen at any time of the night, may cause the light to go out. If, later on, the gas pressure again becomes stronger, the gas will escape from the open burner, gradually fill the room and endanger the life of the occupant.

29. Carbon oxide, which is colorless, odorless, tasteless, and very poisonous, is the constituent of gas which causes asphyxiation. It begins by causing a ringing in the ears, headache, dizziness, heart palpitation, drowsiness, confusion of the mind, lowering of the pulse, loss of feeling in the extremities, and finally loss of consciousness. As a rule, the person so exposed is unconscious of any danger.

30. Hæmoglobin is the scientific name of the red coloring matter in the blood; this normally absorbs oxygen from the air

which enters the lungs while breathing. The poisonous carbonic oxide has a greater affinity for the hæmoglobin than the oxygen. Asphyxiation results because the carbon oxide renders the hæmoglobin incapable of taking up oxygen in the lungs.

31. Persons who have been exposed to carbonic oxide should be removed to the open air; their clothing should be opened, and breathing should be restored by artificial respiration movements. Rubbing the person with warm cloths, and applying electricity are also useful.

32. Make it a rule never to neglect even the slightest gas leak. While the smell of gas sometimes gives a warning, it does not do so where gas has been filtered through the soil, and thereby has lost its odor. All such gas leaks constitute grave dangers to health, as well as fire hazards. This danger became more serious at the time when gas companies began the manufacture of the cheaper water gas, having about 30 per cent of CO, and abandoned the making of coal gas, which had only from 6 to 7 per cent CO.

33. Accidents with gas arise in general in one of the following ways:

(1) By suffocation, as in the case of workmen working in trenches of broken or leaky gas mains.

(2) By the formation of an explosive mixture of gas and air.

(3) By asphyxiation during sleep, when gas escapes from a burner or from defective fixtures; asphyxiation is often due to ignorance in gas matters; in some cases it is due to accident, in others to intention.

(4) By slow and obscure poisoning caused by the cumulative effect of a number of small leaks in the house pipes.

(5) By gas escapes from broken street mains into the soil, thence into cellars of houses, and up through the house. These cases are particularly frequent and dangerous in winter time. Such accidents can even occur in such houses which have no gas supply whatever. The soil is apt to absorb the odor of the gas and becomes impregnated by it, whereas the escaping gas itself loses its peculiar odor.

Gas Consumers' Complaints.

34. Consumers' complaints may be summed up as follows:

(1) The gas pressure is insufficient.
(2) The gas pressure is too high.

(3) The quality of the light is bad; there is less light than formerly.

(4) The gas flames burn irregularly or jump.

(5) The gas bill is much higher, although no more gas than formerly is burnt.

35. Gas should, of course, always be supplied by the company to the consumers under a sufficient pressure to give a maximum of illumination, or, where gas is used as fuel, to give a maximum calorific effect.

Consumers should remember that a moderate pressure of gas and a burner of large size give the best results. They should also take into consideration that different kinds of gas burners require different pressures; thus an Argand burner requires less pressure than a flat-flame burner; this in turn requires less pressure than an incandescent burner; the greatest pressure is required at cooking burners and heating stoves.

36. Insufficient gas pressure is generally due to local causes, such as too small piping; piping partly stopped up with rust, tarry matter or naphthaline; gas meter of insufficient size; service pipe obstructed and requiring cleaning out.

37. The increasing number of complaints of loss of light is largely due to the fact that builders furnish buildings with defective, inferior, and inefficient gas-fittings. In many buildings, even in modern and new ones, and not merely in houses erected by the speculative builder, but also in those of a higher grade and selling at high prices, the gas piping is improperly done, and the pipes throughout are too small, causing a loss of pressure in the system. Thus it happens that the gas company, or sometimes the manufacturers of gas fixtures, receive blame for poor illumination, when the trouble is really due to the bad piping done by the builder or his gas-fitter or plumber.

38. In a few cases the trouble with the illumination is due to the gas company's fittings, which comprise, as we have seen, the service pipe and the meter. The service pipe may be too small, and in other cases the meter may be of insufficient capacity. The gas company usually will remedy both defects promptly if notified, and it is not often that gas companies deny an application for a larger meter.

39. The most common fault is the insufficient size of the house pipes for gas. One frequent cause deserves special mention, *i.e.*, the supplying of a gas log, a gas fireplace heater, or even of a

gas range from the same riser which feeds the lamps. Gas fires and gas cooking stoves are often installed and supplied from services originally intended for only a few flat-flame burners. The gas fires are often used simultaneously with the lamps.

In other houses, gas flames giving only a dismal illumination jump up suddenly to a satisfactory brilliancy when some of the burners are turned off. This conclusively shows that the house piping is insufficient in size, and the remedy is, of course, to put in larger pipes. But the consumer or the house owner may be shy to apply the only right remedy, because it involves a good deal of tearing up of floors and ceilings as well as the cutting of plastering. And so, rather than cure the evil, the consumer goes on grumbling about his poor light.

40. There are many cases where the same gas, used in a number of adjoining houses, produces in one house a good illumination, whereas the adjoining house may suffer from poor light. In such case the conclusion is unavoidable that the quality of the gas furnished by the company cannot be at fault, and that the whole trouble must necessarily be in the system of gas piping or in the burners of the badly-lighted-up house.

41. Irregular or jumping gas flames are nearly always due to local causes, such as the accumulation of water either in the gas meter, or in some low and defectively-run piping in the house.

42. Troubles with poor light are not always due to insufficient size of house pipes, or to partly-stopped-up pipes, or to too many fixtures being taken off from one riser, or to an obstructed service. There are numerous cases where a street gas-main has outgrown its usefulness in consequence of a sudden increase in the number of gas consumers in the district which the main supplies. In such a case, the remedy should be applied by the gas company, and consists in replacing the street main by one of larger capacity or else in putting in an additional main.

43. The above explanations will suffice to indicate that it is unwise and usually wrong, for consumers to jump at the conclusion that the quality of gas supplied by the gas company is inferior. There *may be* and there usually *are* other reasons for the consumers' complaints.

" A gas company may in all sincerity send out gas of even better quality than standard, yet be accused of supplying 'bad gas'" (*London Journal of Gas Lighting*). To assume, as many consumers do, that the gas companies persistently violate the requirement of a standard quality of gas is erroneous and unwarranted; for all manufactured gas is frequently tested by official municipal inspectors. As a matter of fact, the records of testing stations show that the gas seldom falls below the standard requirements.

44. To explain the fact that gas consumers quite often obtain a very unsatisfactory supply of gas, which fact is true beyond doubt, it is necessary to look to other causes, such as those mentioned above, to explain it.

45. Consumers who wish to have a good illumination should avoid cheap gas fixtures and cheap gas burners; they should use only the best burners and efficient globes or shades.

They should also remember that the modern higher requirements regarding the illumination of interiors are at the present time fulfilled in the best manner by the use of the incandescent gas lamps.

A Word to the Gas Consumer about the Price of Gas.

46. A mistake too frequently committed by the gas consumer is to judge the cost of gas by the price charged per one thousand cubic feet, without considering the candlepower of the gas. Without a knowledge of the latter, it is really impossible to tell whether a gas is cheap or expensive. Gas at $1.00 per 1000 cubic feet, and giving 16 candlepower is actually dearer than gas of 22 candlepower at $1.25. Burnt in a 5-cubic-foot-per hour, flat-flame burner, the former gas costs 3.12 cents per 100-candlepower-hour, whereas the latter costs 2.84 cents.

47. High candlepower gas is only needed for flat-flame and Argand burners; it is no longer required where incandescent mantle burners are used. In fact, a gas of low candlepower, so burned, gives better results than a high candlepower gas.

48. Speaking of the price of gas, the *London Journal of Gas Lighting* says: "The public generally resents more strongly an increase in the price of gas than a proportionate or even a greater rise in the price of other commodities. So many people speak as though they were the victims rather than the customers of their gas company, as though, in fact, they got nothing for their money, that it seems clear that this idea, carefully fostered

by the so-called comic paper, with its antique gibes at the accuracy of the gas meter, lies at the root of much of the hostility sometimes displayed towards gas undertakings."

49. The question, so frequently asked by gas consumers, appears justified: — "Why are the gas bills higher at present than in former years, for the same number of fixtures in the house, notwithstanding the fact that the unit price of gas has been reduced?"

It is difficult to frame an intelligent answer to this question. Gas companies, without exception, seem to have evaded the question. The following would seem to me to be a fair answer. If a consumer's gas bill is larger than formerly the gas meter must have passed more gas than formerly. Assuming that there are no leaks, the following are some reasons which may explain the matter. The candlepower of gas has been reduced recently. Unless the consumer has substituted incandescent mantle burners for his flat-flame burners he must necessarily use more burners on the same fixtures to get the former degree of illumination. This means increased gas consumption. Another explanation is that the consumer, tired of his poor light, may have been misled to buy new types of flat-flame burners, which often, though marked to burn only 3 or 4 cubic feet per hour, in reality pass per hour from 5 to 10 cubic feet of gas, particularly where the pressure is excessive, and unchecked by pressure regulation. A third reason is that in districts where the gas mains have become insufficient in capacity, the gas company carries more pressure of gas in the evening hours. Unless the consumer checks this by pressure-regulating devices, he will burn more gas, although perhaps not using a larger number of burners.

Others have endeavored to explain the increased gas bills by calling attention to the fact that the specific gravity of the gas supplied at the present time has been reduced. The reduced specific gravity, combined with increased pressure, causes more gas to flow through the gas meter in a given time. This explanation appears reasonable enough, but I am not prepared to confirm it.

Various Household and Commercial Uses of Gas.

50. Consumers should bear in mind that at the present greatly reduced prices for gas there are numerous uses of gas in the household other than for light, combining convenience as well as economy.

(*a*) Gas may be used in the kitchen for the various cooking processes. There is a large variety of excellent gas cooking stoves and ranges in the market from which one can select apparatus suitable to one's needs. Remember that the gas companies willingly assist the consumer in the selection of appliances adapted to their individual requirements.

(*b*) Gas may be conveniently used in gas stoves, gas logs, and gas fireplace heaters for the occasional warming up of a room.

(*c*) In the laundry the use of gas sad irons will be found extremely convenient, and with proper care also quite economical.

(*d*) When drying of clothes has to be done indoors, the installment of a clothes dryer heated by gas will be found advantageous. These clothes dryers are made in all sizes, adapted to the needs of large as well as small families.

(*e*) Gaseous fuel is of the greatest convenience in heating water for the kitchen, for the bathroom, for shaving, etc., in one of the modern gas water-heaters, which are made in a variety of styles and capacities.

(*f*) Finally, there are numerous commercial uses of gas, other than for lighting, which it is well to consider. Owners of small workshops will find it of advantage to look into the merits of the small gas engine for power use.

. . . . . .

"DON'TS" FOR GAS CONSUMERS.

Don't think if your gas gives a poor light that the gas company is letting down in the quality of gas. Your pipes or burners may be at fault. The gas furnished you is the same as that furnished to your neighbor, who has good light.

Don't put in too small pipes when building your house. You cannot get a big stream, even of gas, through a small hole.

Don't put in too small burners. It will be poor economy, for more jets will have to be lighted to get enough light.

Don't expect your gas bill in December to be as small as in July; it is not possible, if you want to have light in dark hours.

Don't expect children and servants to be as economical of gas as you are; it isn't their nature.

Don't leave your gas burning full when it ought to be turned out; you will be irritated by the sight of the next gas bill.

Don't forget to keep your burners cleaned out.

Don't use globes with too small opening at the bottom; the light will be cut off by them.

Don't allow the gas to flutter and blow as it burns; it is simply wasting, making heat but no light.

Don't leave your house alone and shut up a great length of time without notifying the company to remove the gas meter or shut off the gas. Some one else may get in and burn gas for you to pay for.

Don't fail to go to the gas office when anything is wrong with your light, instead of complaining to your family or to your neighbor.

(*From the Columbus Gas Company's Book.*)

Don't look for a gas leak with a match or other open light.

Don't fail to keep your burners clean. Gas companies furnish cleaners free of charge.

Don't put on too small burners; it is poor economy.

Don't use globes of too ornate pattern, or with too small openings at bottom; they cut off light. The plainer the globes the better.

Don't forget that gas as a fuel for cooking is cheaper than coal.

Don't allow your gas-range burners to become foul.

Don't fail to turn off your gas-range burners when not in actual use, or to turn them down to just the efficiency required when in use. It is very easy to waste gas.

Don't fill your oven with gas and apply a match or light. Any self-respecting gas will explode under these conditions.

Don't forget to read your meter occasionally.

Don't expect your bill for lighting to be as small in winter as in summer.

Don't blame the gas company if you receive a bill which seems unduly large. Remember that you control the gas consumption, the meter records it, and the company only reads the meter which you can do also.

Don't be too sure that you did not use the gas as billed. Consumers are sometimes mistaken in this respect, and if you think your gas meter registers fast, the company provides a remedy.

Don't fail to notify the gas company of any defects in the gas service. They will be promptly attended to.

(*From Cicero Gas Company's Book.*)

Don't call an unbiased and fair-minded observer or counselor, who attempts to explain to you the mysteries of the gas meter, and who endeavors to show you why your meter is not at fault and points out to you the real cause for your high gas bills, a " champion of the gas meter."

(The Author.)

A FEW POINTERS ON GAS.

Have your gas meter placed in a convenient location, and where it will be least affected by outside changes of temperature, and keep your service pipe protected from frost.

Use a little patient effort to learn the manner of measuring gas. Then you can read your meter every week, or oftener if desired, and have in your own hands a perfect check against fraud, or against waste on the part of your employees or servants.

Carelessness or waste in using more burners a longer time or under a heavier pressure than necessary, is the main cause of high bills.

The time has gone by when gas companies should desire the lighting bills of their consumers to be as large as possible. Their true interest lies in furnishing perfectly satisfactory light for the least possible money.

Remember that the gas meter registers all that gas which is burnt unnecessarily or wastefully, or which escapes through leaks in the house pipes or at the fixtures.

(*Compiled from various sources.*)

CHAPTER XXII.

SOME FACTS ABOUT THE GAS SUPPLY.

(*A*.) *The Quality and Price of Gas.* From time to time the public and the newspaper press indulge in complaints about the "exorbitant" gas bills and the poor quality of the gas manufactured by gas companies.

To an impartial observer both complaints appear generally to be without foundation in fact. While there is scarcely another private manufacturing industry in which the general public is so much interested as that of the supply and distribution of gas, because it is a commodity in very general use, I venture to assert that nowhere else are so much ignorance and misconception of facts prevailing. This may be partly explained by the well-known truth that it is human nature to be suspicious and sceptical of anything which one does not understand. Of the making and selling of gas the public knows very little indeed, few people care to take the trouble to inquire at all into the subject, and many erroneous ideas and prejudices exist.

Notwithstanding the fact that gas companies have in more recent years exerted much effort in trying to educate and enlighten the gas consumers about the mysteries of gas making and gas burning, by freely given advice, by remedying unfavorable conditions in cases where these, upon investigation, were found really to exist, by popular lectures on the use of gas, by exhibitions of gas appliances, for lighting, cooking, and heating, etc., much still remains to be done in these directions to clear up popular fallacies and prejudices.

Concerning the price at which gas is sold to consumers, it is doubtful if it ever occurs to the grumbling consumers to consider that the cost of manufacturing gas must necessarily depend upon three principal factors; namely, upon the cost of the raw materials (coal and oil), upon the freight rates from the coal regions to the gas works, including the cost of loading and unloading and trucking, and upon the cost of the labor engaged in the manufacture and distribution of gas. It is unavoidable, therefore, that the cost of production of gas must change, and vary with the price paid for the two chief items entering into its manufacture, viz., coal and labor. The cost of coal at the mines is always subject to fluctuations, caused by strikes, and its transportation is greatly affected by the prevailing freight rates, which are generally high, owing to railroad combinations, and only fall when a contest between competing railroad lines takes place.

The other item, the cost of labor, depends upon the rate of wages paid, and includes not only the wages of the laborers in gas works but such items as salaries, expenses of the distribution department, cost of meter reading, expenses for testing and repairing meters, for altering or repairing street gas-mains and street surfaces; for lighting, extinguishing, cleaning, or repairing street lamps, etc.

It is fair to assume that gas consumers must be aware of the fact that the cost of coal has in recent years gone up; that a few years ago, for instance, the price of coal, owing to the prolonged coal strike, was extraordinarily high, in fact, almost prohibitive; that the freight rates have increased owing to railroad combines, and that the wages of laborers have also increased instead of diminishing.

Notwithstanding these facts, gas companies in New York, for instance, are held, by an Act of Legislature, to a fixed price, namely of $0.80 per 1000 cubic feet of gas, irrespective of the future cost of coal, of oil, or of the rates of wages.

It is well to remind consumers that when gas was first introduced (about 80 years ago) the price charged was ten dollars per 1000 cubic feet. This price was adhered to for many years, but it subsequently dropped to $7, $5, and $4 successively. Only twenty years ago the price was $2.50, which was gradually cut down to the 80-cent gas of to-day. From the fact that for a short period of time, during the war between the rival gas companies in New York, who have since consolidated, the gas was sold at 65 cents per 1000 cubic feet, a popular fallacy arose that the recent charge of $1.00 was an *exorbitant* one. This being the case, it seems proper to remind the public of the former charges as mentioned above.

When a consumer discusses the price of gas, he is very apt to make comparisons with actual prices charged in other cities. Such general comparisons are, however, often extremely incorrect, and, to say the least, unfair. Cities situated in the coal or oil regions must necessarily enjoy the advantage of cheaper gas rates, as the item for transportation of the raw material is very much reduced in comparison with cities located remote from these regions.

In no other branch of commerce or industry are comparisons made from the actual price per unit only, without taking the *quality* of the product sold into consideration. For example, a poor quality of paper, sold at one dollar a ream, may in reality be a great deal more expensive than a good quality of paper sold at the rate of two dollars a ream. The same applies to the cost of gas sold to consumers. Without a consideration of either the candle or illuminating power and the heating power, it is impossible, in comparing two kinds of gas, to say which of the two is the cheaper and which the more expensive. Is it not a fact that gas sold in London at 3 shillings, or about 75 cents, is dearer than gas sold at $1.00 in New York, when it is borne in mind that London gas is of 16 candlepower, whereas New York gas is from 22 to 26 candlepower?

Take again the City of London as an example: Would it not surprise gas consumers to learn that in London the companies were some years ago obliged, and received parliamentary permission, to raise the price of gas, because of the growing scarcity of coal and the consequently higher price charged for same, and also because of the higher value of other materials and of labor. Yet, according to the *London Journal of Gas Lighting,* this is a fact, not only in London, but in many other English towns as well.

In the State of New York, too, several instances have occurred, where, owing to the increased price for coal and higher freight rates, the price of gas was raised. The Mohawk Gas Company of Schenectady, for instance, announced recently an increase of 10 cents (from $1.20 to $1.30 net) per 1000 cubic feet, and as this company has, from time to time, voluntarily reduced its price, whenever the state of the coal market permitted, fair-minded consumers probably did not seriously object to the trifling advance.

The cost of gas in London at the present time is nearly as high as in New York City, yet the item of laborers' wages alone is vastly higher here than there. Moreover, gas companies here are expected to do a great deal more for the public than in England or on the Continent of Europe. For instance, American gas companies always run the service from the street main to the building free of charge, and often are asked to do even some piping inside of the building, whereas in Europe it is the rule that the gas consumer must pay for every foot of service pipe laid for him. Again, here gas companies are expected to furnish the gas meter free, and to set and connect the same, whereas in London and other European cities the house owners must pay for this work and even for the meters.

Compare again the gas service with the water service of cities. The house owner must defray all expenses connected with the introducing of water, for service, taps, shutoffs, and for the water meter where this is used. Not so for the gas service, which he expects to get, and does get, entirely free of charge, including the gas meter.

Again the public should bear in mind how, in innumerable instances, gas companies are called upon, where there is trouble in the gas supply, and complaint made at the gas company's office, to look into the question of the house piping, fittings, and even the gas appliances, all of which is never expected from them in London or in Continental cities.

(*B.*) *The Candlepower of Gas.* When gas burns poorly, it is usual for people to complain at once about the inferior quality, or the low and insufficient candlepower of the gas. Not many persons will stop to consider first, whether other causes might not exist to explain the poor illumination.

It is desirable that the general public should know that the candlepower of the gas furnished to consumers is tested by officially appointed gas examiners regularly, not at the gas works, but at gas-testing stations located in different parts of the city. The published records of these gas tests offer sufficient proof that it is a rare occurrence to find the quality of the gas falling below the established standard.

In Greater New York the charter requires that gas should be of at least 20 candlepower. In the month of September of the year 1900, the records of the gas-testing stations showed the illuminating power to have been from 22 to 26 candlepower, in other words always from 2 to 6 candlepower higher than required by statute, yet articles appeared in the daily press giving a list of the results of the monthly gas tests, with words like the following " gas somewhat improved in quality," thus indirectly implying that the gas had before that time been below standard, whereas in reality it had always been kept more or less *above* the legal requirement.

It is a fact, not well known to consumers of gas, that even a gas of high candlepower will not give a good illumination when it is burned under unfavorable conditions, such as poor, worn out, or corroded burners, insufficient size of the piping of the houses, or badly arranged gas pipes, or clogged services, or in cases where too many fixtures are being supplied from a small riser or service. Take the case, for instance, where gas burns well on the lower floors of a house, but gives dim flames on the upper floors: common sense should tell the occupants that it cannot be the candlepower of gas which is at fault, for the same gas is supplied to all parts of the house. There must, in such cases, be local causes affecting the lighting; for instance, the gas riser from the lower to the upper part of the house may be stopped up with rust. These matters are spoken of more in detail in other chapters of this book.

I must, however, dwell further on the requirement of the candlepower of gas. It should be borne in mind that the expectations of consumers with regard to illumination have in recent years been increased, partly, no doubt, by the advent of electric lighting.

On the other hand, it cannot be denied that the progress made in the last decade in the art of illumination by gas has been somewhat in the nature of a complete revolution. This came about largely through the introduction of the incandescent gas lamp. An excellent illumination is now obtainable with gas of low candlepower by burning it with the incandescent or Welsbach mantles. But more than this, scientific men have discovered that a gas of low candlepower, burned with the incandescent mantle, gives actually far better results than does a high candlepower gas.

No less an authority than Professor Dr. H. Bunte, of Carlsruhe, speaking of the conditions prevailing at this date in Germany, states that " incandescent gas lighting, as opposed to the older lighting by flat-flame and Argand burners, has assumed a predominant position. . . . The fundamental factors, by which gas is valued, and the properties and manufacture of gas, have been entirely altered."

Formerly illuminating power was regarded as the principal criterion of the value of gas, but this has now become of secondary importance as compared with heating power. A large part of the gas used for lighting, and nearly all gas used for heating and cooking is mixed with air in the Bunsen burners (giving the well-known bluish or greenish flame); this destroys the illuminating constituents of flames and only the calorific (or the heating) value of the gas is of any importance. Hence there should be substituted for the present illuminating candlepower standard a standard calorific value of the gas.

The Boston Herald, under the heading of "A Standard of the Past," discusses this phase of the gas question in its issue of May 1, 1907, in the following words:

"In discussing the various plans that have been put forward for governing the supply of gas furnished the consumers in this city, it should not be forgotten that in one respect at least we are behind the gas users of Europe. This is in regard to "candlepower." We still stick to a high candlepower for our gas, measuring it by the old-style fish-tail burner, a burner that in some European cities is as hard to find as would be a hen's teeth. For burning with mantles, for heating purposes and engines, high candlepower gas is not only wasteful, but for some reasons, at least, it is not so good as that with fewer illuminative units when measured by the old-fashioned standard. Throughout the United Kingdom the tendency has been very marked both with the municipal-owned and private plants to lower the standard of candlepower demanded, and in Germany they have gone so far that candlepower is no longer mentioned, and gas is furnished *capable of supplying a certain number of heat units.* While the use of mantles has increased wonderfully in this city during recent years, we are still far behind our friends across the sea in this respect. In London, gas lighting in the streets is being steadily extended, even where there is keen competition with municipally-owned electric plants. Any basis of settlement, sliding scale or otherwise, for the Boston gas question should be with some provision for a reduction in the future of the number of lighting units supplied by a given amount of gas. By that change we would bring ourselves in line with progress in the business as it has been developed for use in stoves and engines. The fish-tail burner is as much out of date in comparison with the mantle burner as is a tallow candle in comparison with a kerosene lamp."

In incandescent gas lighting the quantity of the illumination is dependent primarily upon the quality and nature of the mantle. At the present time every opportunity is offered to the gas consumer, who wishes a brilliant illumination, to get it, without an increase in the candlepower of gas and also without an increase in the amount of gas consumed, by simply making use of the incandescent gas lamp in one of its many improved forms. Indeed, there is as a rule a reduction rather than an increase in the gas consumption, and, owing to their efficiency, the gas mantle burners are in some cases successful rivals to the electric lamp.

It is to be regretted that nearly all cheap mantles at present sold are bad, and that the good mantles are rather expensive, but is not this equally true of many other commodities or articles sold to the public? Doubtless this state of things will be remedied in the near future by the manufacturers of incandescent gas mantles and burners. It will, furthermore, be of interest to gas consumers, who are inclined to complain about the insufficient candlepower of the gas, to learn that in London one of the three large companies obtained about eight years ago a concession from Parliament, reducing the illuminating power by two candlepower, so that now Londoners burn 14-candlepower gas (see the *London Journal of Gas Lighting* of October 9, 1900). The granting of this reduction in illuminating power was largely due, no doubt, to the increasing use of incandescent gas burners, and of gas heating and gas cooking appliances. Close observations show that similar conditions prevail in the United States, and the time is probably not far distant when photometer or candlepower tests will be superseded by calorific tests or tests of the heating value of the manufactured gas.

CHAPTER XXIII.

ACCIDENTS WITH GAS.

THE records of the coroners' offices in every large city show each year a list of fatalities due to the use of illuminating or fuel gas in buildings. The thirteenth annual report of the Board of Gas and Electric Light Commissioners of the Commonwealth of Massachusetts, published in January, 1898, enumerates 105 instances of gas escapes which happened during the year 1897, and which caused the death of 60 persons and injury to 74 others. A few of these cases were due to intended suicide, but the larger number were clearly *accidents.* In the city of New York, 388 deaths were traced by the coroner's office in 1903 to illuminating gas. Of these 130 were considered to be "suicide" cases, and 258 "*accidental*" cases. The casualties occurring in other states are undoubtedly equally large in proportion, and perhaps even exceed the above figures in the case of seaboard cities where a vast number of immigrants land every year, many of whom are not familiar with the management of gas.

As is well known, many gas companies now manufacture water gas which they enrich with naphtha. This gas contains a much larger percentage of carbonic oxide than coal gas, and since carbonic oxide forms the principal poisonous constituent of illuminating gas, a greater number of fatalities result in those cities where water gas is used. The percentage of carbonic oxide in gas varies from 6 per cent in coal gas to as much as 25 or even 30 per cent in water gas. Carbonic oxide is strictly odorless, and therefore pure water gas would be very dangerous to use. Fortunately, it cannot, *per se*, be used for lighting purposes, and must be mixed, or "enriched," with coal gas or naphtha to make it suitable for illumination. This admixture imparts to the gas the peculiar strong and pungent odor, by means of which it is readily detected, when it escapes unburned in even small quantities. Notwithstanding this fact, the numerous accidents point to the necessity of diligent care in the use of gas fixtures and fittings; they also emphasize the need of popular instruction in the management of gas, and finally they tend to show that an official supervision of gas piping and gas-fitting in all classes of buildings would be as desirable as the official regulation of plumbing and drainage now enforced in a large number of cities.

Illuminating gas (both coal and water gas) possesses another quality making it dangerous under certain conditions, *i.e.*, when mixed in a certain proportion with atmospheric air (from 13 to 20 per cent) it becomes a highly explosive compound. Ignorance of this fact is a prolific source of accidents and explosions. When gas escapes, it is imperative that one should not search for the leak with an open flame. Yet even the employees of gas companies frequently come to grief by a disregard of this simple rule. Witness the following account, taken from the columns of a daily paper:

"Because of the repeated complaints of the odor of escaping gas being in evidence in the neighborhood of —— Street, a gang of men was sent down there by the —— Gas Company to locate the supposed leak. After a hole had been dug near the curb in front of the house, the foreman went down, *with a lighted lantern*, to examine the pipes. The escaping gas was ignited by the flame, and an explosion followed, throwing the man out of the trench. The occupant of the ground floor was knocked down by the force of the explosion, and all the windows of his place shattered. The explosion also caused a fire."

Similar severe accidents happen when an escape of gas occurs in the cellar of a building, or when a gas meter springs a leak. In all such cases the safe rule to follow is *never to search for the leak with an open flame or lantern*, nor to strike a match near the gas meter, nor even to handle any tool or instrument which may cause a flying spark.

Many cases of gas asphyxiation arise from the ignorance of persons who have never used gas. Immigrants and travelers from remote country towns constitute a large percentage of these cases. Persons who have never lighted a gas flame before in their life, are apt, upon retiring at night, to blow out the flame in the same way as they would a candle or oil lamp, and the next morning they are found asphyxiated in their bed. Intoxicated persons sometimes commit the same fatal mistake.

The Massachusetts Board of Gas and Electric Light Commissioners considered several expedients to guard against this accident. They suggested that a legislative act might be passed requiring in the sleeping rooms of cheap hotels and lodging houses the use of some kind of gas burner from which gas cannot escape except when lighted. At the gas exhibition held in New York some years ago, several inventions tending to accomplish this object were shown, and some types of gas burners are now manufactured which automatically shut off the supply of gas when the burner is blown out, either by design or by accident, as, for instance, from a draft of air passing over a flame which has been turned down low. The danger in relying upon such safety burners arises from the fact that these appliances may not always prove to be reliable and durable, and may refuse to work at the proper moment. It is not denied that it is within the range of mechanical possibility to construct a device of this kind, which would be simple, safe, durable and at all times efficient. Encouragement should therefore be offered to inventors of this line of appliances.

Another frequent source of accidents by asphyxiation is found in gas keys, which are worn out and have become so loose that they turn too easily. It frequently happens with such fittings that upon retiring for the night, persons turn out the gas, and accidentally or carelessly re-open the burner enough to cause a dangerous escape of gas. Many cases of fatalities recorded in official statistics are due to this cause. The remedy is too obvious to require any further description. Other accidents arise from fixtures which are defective by reason of the stop-pin being either absent (so-called "all-around keys" which persons unconsciously may turn too far), or because of its having fallen out. Such old-fashioned fixtures are, unfortunately, often to be found in hotels and lodging houses. Many years ago, the author suggested that the use of such dangerous fixtures should be prohibited by legislative act. The law should also provide for an efficient inspection of the gas fixtures in hotels, lodging houses, and similar buildings. The above-named commission proposed as a further safeguard a law prohibiting the use of gas in sleeping rooms containing less than a definite number of cubic feet.

Fatal accidents occur through the stupid custom, still existing in some hotels, of turning off the gas at night from the bedrooms. Occupants often leave their gas flame turned down low, on retiring, and by reason of the practice mentioned, the flame becomes extinguished without the burner cock being turned off.

When the gas is again turned on early in the morning, it escapes through the partly open burner and asphyxiates the occupants before they awaken. This bad practice is not confined to hotels and lodging houses, but it also occurs in boarding schools, in apartment and dwelling houses. Equally bad is the practice of turning off the gas at the main service during the day, as it leads to similar dangers, by reason of people leaving gas cocks open when they attempt to light the gas early in the evening, before it has been turned on at the meter. Two cases in point were related in the daily papers not long ago, as follows:

Case 1. "Yesterday the body of E. S. was found in his apartments. He had seemingly been asphyxiated with gas, which was issuing from a *jet not turned off*. S. went to bed sick at an early hour, leaving the burner turned down low. His brother-in-law always turned off the gas in the cellar so that no accidents would occur during the night. Early in the morning he used to turn it on again so as to make the gas available in the gas stove which his wife used in preparing the morning meal. This practice resulted in the death of his boarder."

Case 2. "T. C. was found in his rooms overcome by gas, and died later at the hospital to which he had been removed. He was in the habit of sleeping with his gas burning. That night the gas in the lodging house had been turned off for only a few minutes to make certain repairs. No one thought of the habit of the man sleeping with his gas burning. The turning out of the gas had, of course, extinguished the gas flame in the man's room, and when the gas was again turned on full force, it escaped into his room while he lay in bed sleeping and caused his death by inhalation."

Gas explosions may also occur when attempts are made to thaw out a frozen gas meter with the heat of a flame.

In this connection, the following extract from the report of the Inspector of Plumbing of Washington, D. C., of August 26, 1897, is interesting:

"Some study was given, during the winter 1894–95, to determine the best practical method of obviating the dangers of accidental asphyxiation through the escape of illuminating gas, due to defects in old fixtures and pipes, and that investigation has been continued during the period covered by this report.

"The coroner expressed an opinion that the deaths which took place in January, 1895, at 922 G street S. W. and 33 H street N. E., were due entirely to defective gas fixtures. He at that time recommended that a thorough inspection of all buildings, especially sleeping apartments therein, be made relative to the condition of the gas fixtures. Two similar instances were brought to public notice in December, 1896, and January, 1897, the two deaths being directly caused by accidental opening of seriously defective keys.

"In February, 1897, a list of the principal hotels and boarding houses was prepared and sent to the commissioners with a request that it be determined if authority existed to make inspection of the gas appliances in these buildings. The opinion rendered by the attorney was an adverse one and no further action was taken. I consider that the conditions justify the enactment of a statute, allowing the entrance of my assistants for such examination, and compelling repairs after due service of notice.

"That this subject is deemed of pressing importance in other municipalities is evidenced by the report made to the Massachusetts legislature by the Board of Gas and Electric Light Commissioners of the city of Boston (February 10, 1897). This report states that four propositions have been considered, viz.:

1. "To require the use, in the sleeping rooms of hotels and lodging houses, of some kind of burner from which the gas cannot escape except when lighted.

2. "To prohibit the use of gas in sleeping rooms which contain less than a definite number of cubic feet.

3. "To provide for the systematic inspection of gas fixtures and piping by some duly authorized public official.

4. "To define by statute the amount of CO or other ingredient which may exist in the gas, and to prohibit the distribution of gas containing an excess of such ingredients.

"The apparent conclusion reached by this board respecting the third proposition is that the number of fixtures (estimated at 1,200,000 burners in Boston) is prohibitive of the proposed inspection. I do not agree with this conclusion, but consider it entirely feasible to make periodic inspection of the condition of a very large number of gas fixtures if the requisite authorization can be secured."

A still more serious matter is the frequent escape of gas into houses from breaks or leaks in the street mains. These escapes may occur into houses which are not provided with a gas service. As long as the pungent odor of the gas warns the occupants of the leak, the danger of an accident may be averted. Unfortunately, the gas, after filtering through the soil, loses sometimes its peculiar odor, and cases of entire families being asphyxiated from the escape of gas are by no means uncommon. Very often such escapes merely cause sickness or headache, and, the true cause not being at once apparent, the gas company is not notified and the leaks are not immediately repaired. Such escapes are particularly dangerous in winter time, when, by reason of being heated, the houses act like huge chimneys in drawing up the gas-polluted air. Where the street surface is paved with impermeable pavements like asphalt, and in winter when other kinds of street surfaces are frozen hard, the escape into the interior of houses is much more likely to occur than where the pavement is an old-fashioned loosely jointed cobblestone pavement. The report referred to states that from 1889–1896, 13 cases of this kind occurred, in which 75 people were rendered unconscious.

Finally, the air of houses may be continuously contaminated by slight escapes due to leaky house gas pipes, or to defective fixtures, loose bracket joints, or worn-out gas keys. The leaks may be so slight as to be hardly noticeable. In many cases of headaches, languor, nausea, drowsiness, prostration, or loss of consciousness, the cause is to be sought in a slight escape of gas. The public is generally inclined to attribute such illness to "sewer gas" entering the house through defective plumbing, and the true cause is seldom thought of. A writer in a recent issue of the New York *Evening Post* speaks about the danger as follows:

"A frequent cause of neuralgia and headaches is the poison of illuminating gas. When the house is supplied with what is known as 'water gas' a recurrence of such maladies should prompt a very careful investigation of the fixtures. Water gas contains a poison of admitted virulence, and the fact that it is colorless, tasteless, and odorless makes its power for evil the greater. Absolutely tight fixtures are the only protection. . . . Periodical examination is essential, for what seems secure to-day may be insecure to-morrow. Old fixtures are likely to be loose in screws or joints, the threads of the thumb screw may be worn out and turn at a touch to let the poison escape with no one the wiser, or in moving furniture the arm of a chandelier or side bracket may be wrenched enough to permit its escape. A safe plan is to have each fixture put through what is called the pressure test. This properly done by a good plumber will show quickly any defects or chances for leakage."

Not long ago, the writer had in his own house a case in point. When the gas was lit in the evening, a peculiar odor arose, which caused severe headache, but for which the reason could not be immediately ascertained, as the odor ceased completely in day-time, when the gas fixtures were turned off. The house gas pipes were tested and found in a tight condition. The gas fixtures also showed no leaks. The gas company was sent for to clean out the main service, it having occurred to the writer that an accumulation of naphthaline in the meter or the house pipes or the service might cause the gas, when burning, to smell in the way it did. The service was thoroughly cleaned out; the meter was removed, emptied, and cleaned; the house pipes were blown out by means of a pressure pump, but all to no avail; the odor returned in the evening when the gas was burning. After much searching, the cause was at last found in slight leaks at the burner joints, which permitted an escape of unburnt gas only when the keys were open and the flames lit. These joints were then made tight with white lead and the odor immediately ceased.

In the statistics of gas accidents, other less frequent causes appear, among which I mention the following:

(*a*) Gas and electric fixtures so constructed that the gas key may be accidentally turned in the dark instead of the electric key.

(*b*) Gas escaping from the gas cooking stove by reason of the water boiling over and extinguishing the gas flame.

(*c*) The breeze from an open window blowing out a gas flame which has been turned down low, the gas then escaping unburnt and causing an accident.

(*d*) A flame turned down low for the night being extinguished by a sudden reduction in the gas pressure.

(*e*) The connecting rubber hose of a gas heating stove becoming either loose in the joint or completely detached and causing an escape of unburned gas.

(*f*) Two gas keys, one for light, the other for a gas stove, being placed so near together that one might be mistaken for the other and turned on unintentionally.

(*g*) The tubing of a gas chandelier or other fixture becoming split and permitting escapes of gas.

(*h*) Disarranged electric gas-lighting fittings intended by the pulling of a chain to open a valve, letting out the gas, and at the same time to light it by a spark.

(*i*) Finally, gas leaks may cause headaches or loss of consciousness, where gas escapes from the rubber hose connection to a table gas lamp.

The majority of cases quoted are clearly due to lack of a reasonable and ordinary care on the part of the gas consumers. What is much needed is the giving of plain instructions to gas users. Emphasis should be laid on the fact that illuminating gas is a highly dangerous substance, and that due care is required in its use. The danger of asphyxiation is somewhat greater where water gas is manufactured and distributed, for reasons explained heretofore.

It is not the author's intention to create a prejudice by these notes against the use of lighting gas or gaseous fuel, for as long as it is confined in tight pipes, gas is perfectly harmless, and if burnt properly, or used with reasonable care, there is not the slightest danger connected with its use. Even the fire risk is comparatively small. Statistics gathered by German fire insurance companies show that in the five years from 1881–1885 14.7 per cent of the fires caused by lighting were due to gas, whereas 85.3 per cent were due to the use of kerosene and oil lamps. In 1892, 1089 fires arose from kerosene and oil, and only 80 fires from gas.

CHAPTER XXIV.

DANGERS TO THE PUBLIC HEALTH FROM ILLUMINATING AND FUEL GAS.

THE American Public Health Association, some years ago, appointed a committee of which the author was a member, to investigate the subject of illuminating gas in relation to health, and at the annual meeting of the association, held at Minneapolis, in 1899, the author submitted a paper bearing the title of this chapter, which paper is reprinted herewith in revised form.

Owing to recent progress in the art of manufacturing gas, the subject is now much more difficult to treat than it was twenty or thirty years ago, when scarcely anything else but the ordinary lighting gas, manufactured by a process of distillation from coal, was known. About thirty years ago gas companies began the manufacture and introduction of the so-called water gas, and several investigations were conducted and reports made at that time * with regard to the dangers involved in the new gas. Still more recently, not more than sixteen years ago, the manufacture of acetylene gas from calcium carbide began. While the use of acetylene gas is, at present, largely confined to isolated buildings not in reach of city gas works (see Chapter XIX) it promises a rapid development within the next decade.

To discuss intelligently a subject of such great importance, and to make the work of a committee investigating the subject

* See Dr. Samuel W. Abbott. "The relation of illuminating gas to public health," Sixth Annual Report Massachusetts State Board of Health, Lunacy and Charity, 1885.

See Professors Sedgwick and Nichols, "A study of the relative poisonous effects of coal and water gas," same report, 1885.

Prof. Edw. S. Wood, "Illuminating gas in its relation to health." Vol. III. (Trans. A.P.H.A., 1877.)

Dr. Jos. H. Raymond, "Illuminating gas; its history and its dangers." Tenth Annual Report, State Board of Health of New Jersey.

William Paul Gerhard, "Accidents with gas." *Amer. Arch.*, Aug. 6, 1896.

Report of the Commissioner of Health of Brooklyn on Illuminating Gas, 1883.

effective, an intimate knowledge and practical experience in the manufacture and distribution of gas, in the work of piping houses for gas and in the different uses of gas, are necessary. It would, therefore, seem best to place on such a committee a chemist or chemical technologist, acquainted with modern methods of generation, purification, and analysis of gas; a gas engineer or a sanitary engineer, who has made a specialty of the entire subject of domestic and street gas-piping and gas lighting; and finally a physician, health officer, or sanitarian, who should be well acquainted with the sanitary features and requirements of lighting, with the unhealthful effects due to the combustive processes, and with the dangers due to gas escaping unburned.

The aëriform mixture, commonly known as gas, is nowadays used not only as an illuminant, but also as fuel (for heating, cooking, and industrial purposes); in a few cities a special quality of gas, not fit for illumination, is distributed to consumers for use as gaseous fuel; in other cities what is known as natural or rock gas is introduced into houses for like purposes (see Chapter VIII). Hence the scope of the inquiry would, perhaps, be enlarged by either omitting the word "illuminating" before the word "gas," or else using the term "illuminating and fuel" gas. For other reasons it seems advisable to omit the words "leakage from" and to call the subject "Dangers to the Public Health from Illuminating and Fuel Gas."

By way of introduction, the different known kinds of gas, their manufacture and composition, will be briefly reviewed; likewise the usual impurities found in them, and in particular their dangerous or poisonous ingredients.

From a sanitary point of view, it is important to consider not only the danger incident to gas escaping unburnt, but also the effects upon health due to the burning of gas. Gas escapes and leaks may occur at the place of manufacture or the gas works, in the distributing system in the public streets, and finally at the places of consumption, — in the houses, offices, or shops. The last subject is of particular importance, and hence will be more fully discussed under the headings of dangers due to the gas service pipes in houses, to the gas fixtures, and to the use and management of gas. Following this, it is desirable to review the remedies and precautions suggested or enacted for the lessening of the dangers and fatalities due to gas.

Different Kinds of Gas — Their Manufacture and Composition.

At the present time, we may distinguish the following kinds of gas, viz.:

1. Natural gas.
2. Coal gas.
3. Water gas.
4. Carburetted or luminous water gas.
5. Air or naphtha gas.
6. Acetylene gas.
7. Gas from oil, wood, resin, etc.

Natural or *rock gas* consists of an accumulation of hydrocarbons found in nature below the surface of the earth. It sometimes flows freely at the surface, like the eternal gas fires at Baku, Russia, or else it is liberated by boring. It is really the same as marsh gas or light carburetted hydrogen, known in mines as fire damp. In burning it usually produces little light, the flame being bluish yellow, and is therefore suitable principally as fuel gas, though some natural gas contains illuminating or heavy hydrocarbons, and can be used for lighting. Mixed with ten times its volume of air, this gas ignites with a violent explosion, when a light is applied. The composition of natural gas varies, as seen from the following three analyses:

	I.	II.	III.
Marsh gas	49.58	75.16	60 to 89
Hydrogen	35.92	14.45	4.79 to 22.5
Ethylhydride	12.30	4.80	4 to 18
Ethylene	0.60	0.60	0.56 to 2.94
Oxygen	0.40	1.20	......
Carbonic oxide	0.40	0.30	traces to 0.26
Carbonic acid	...	0.30	0.28 to 0.66
Nitrogen	...	2.89	......

Coal gas is made from bituminous coal, by a process of distillation in closed retorts. It may be termed the ordinary illuminating gas, as it was the first lighting gas manufactured and distributed on a large scale. Such coal gas is really a more or less purified mixture of a number of distinct gaseous combustible substances, of which some are luminous, while others burn with a non-luminous flame. Its manufacture embraces three principal processes, viz., the distillation, the condensation, and the purification of the gas. When coal gas is distilled in retorts, the resulting vapors which contain hurtful impurities are first condensed, and tar and water is thereby removed; the subsequent processes of condensation in condensers remove carbonic acid and some ammonia; in the washers and scrubbers ammonia is removed, while the purifiers free the gas of carbonic acid, sulphuretted hydrogen, and other gaseous sulphur compounds, by means of lime and oxide of iron. The composition of purified coal gas is about as follows:

	I.	II.	III.
		(Pettenkofer)	
Hydrogen	50.2	49	40 to 50
Marsh gas	29.8	36	35 to 45
Carbonic oxide	7.9	7	4.5 to 7.5
Heavy hydrocarbon	4.3	8	......
Nitrogen	7.8	......	......
	100.0	100.0	Olefiant gas, small amounts carbonic acid.

A few actual analyses of coal gas are here quoted, the differences in them being due to the kind of coal used in the manufacture of the gas.

Boston Coal Gas. (Nichols.)			London Coal Gas. (Letheby.)	
Marsh gas	40.0	37.41	Light carburetted hydrogen	39.5
Hydrogen	34.8	46.38	Hydrogen	46.0
Nitrogen	14.2	3.72	Condensible hydrocarbons	3.8
Carbonic oxide	7.0	5.53	Carbonic oxide	7.5
Illuminants	3.4	6.19	Aqueous vapor	2.0
Oxygen	0.5	0.25	Oxygen	0.1
Carbonic acid	0.1	0.52	Nitrogen	0.5
			Carbonic acid	0.6

Water gas or *hydrogen gas* is made by passing steam over incandescent carbon or glowing coals. The resulting gas is odorless and non-luminous, but owing to its large amount of hydrogen it burns with great heat, hence this gas is excellent for fuel purposes. The coal used in the process is anthracite coal. Theoretically, water gas is composed of 50 per cent hydrogen and 50 per cent carbonic oxide. It should be pointed out that pure water gas contains a very large proportion of carbonic oxide, which is the dangerous element in all gas.

Carburetted or *luminous water gas* is a mixture of pure water gas and petroleum, naphtha or cannel gas, the latter gases being heavy hydrocarbons mixed with it to give it luminosity, to render it fit for lighting purposes and to give it a distinct odor. This is done by the so-called carburetting process. Since about thirty years a great many gas works (nearly two-thirds in United States, according to Professor Bunte) manufacture and supply this composite gas, the chief reasons for preferring this process being the reduction in first cost of the works, the easier purification, the smaller area required for manufacturing, the possibility of using coke, the doing away with some of the side products or residues, and the cheapening in the cost of manufacturing the gas.

There are many different processes in use for making carburetted water gas (Lowe, Strong, Gwynne-Harie, Harkness, Tessie de Motay), and the composition of the manufactured gas, as well as its lighting qualities, vary greatly. A few analyses are quoted as examples:

Composition of Water Gas. (Remsen.)	Water Gas of Municipal Gas Light Co. (N. Y.) (Wurtz.)		
	I.	II.	III.
Hydrogen	30.3	38.05	36.34
Marsh gas	21.45	11.85	20.55
Carbonic oxide	28.25	29.40	27.46
Carbonic acid gas	0.3	0.10	0.35
Oxygen	...	0.10	0.26
Nitrogen	6.85	3.71	2.56
Olefine	...	9.29	...
Paraffines	...	7.50	...
Illuminating hydrocarbons	12.82	...	12.48

Air or machine-made gas, or *carburetted air gas*, is a simple mixture of atmospheric air with the vapor of naphtha, benzol, petroleum, or gasoline. The use of such gas is largely confined to the lighting of isolated buildings not in reach of gas works. The apparatus for its manufacture consists, in its simplest form, of a blower and a generator. The latter is placed in a brick vault, at a good distance from a building, and is filled with refined gasoline, which is a very volatile inflammable liquid. A blower or air pump is placed in the cellar of the building; this is operated either by a suspended weight (which must be wound up same as the weights of a clock) or by a wheel driven by water. It forces air into the generator, which here takes up the vapors of the naphtha and so enriched is delivered to the house to be consumed (see Chapter XIX).

It burns with a tolerably good, luminous flame; the gas being very heavy flows comparatively slowly, hence large pipes and burners are required. The flame is seldom free from smoking.

The gasoline itself, from which the gas is made, is a very volatile and highly inflammable liquid, which gives off vapors at ordinary temperature. Mixed with a certain proportion of air, the machine or air gas is very explosive.

Acetylene gas is the latest comer in the field of gas manufacture. This gas has been known chemically since 1836 (Edmund Davy, chemist) as the most brilliant of illuminating gases. In 1861, the chemist Woehler, and in 1862, Berthelot, prepared the gas in the laboratory from calcium carbide and water. In the latter part of the year 1892, the French chemist, Henri Moissan, made small quantities of calcium carbide in a laboratory furnace. But the commercial manufacture of crystalline carbide on a larger scale in electric furnaces was discovered accidentally in May, 1892, by an electrician, Thomas L. Willson, of Canada. Before that time, calcium carbide was a very expensive chemical, costing about $2000 per ton; after Willson's discovery its price immediately dropped to $70.

Acetylene gas has a very peculiar, easily detected garlic-like and unpleasant odor; it is an ignitible gas, rich in hydrocarbons, and is generated by bringing calcium carbide in contact with water. It is composed of 92.3 parts by weight of carbon, and 7.7 parts of hydrogen. When mixed with air, in a proportion from 1 to 4 up to 1 to 20, acetylene gas is very explosive, its explosive force being much stronger than that of coal or water gas. The more the gas is condensed, the more explosive it becomes, and in its liquefied form it is so dangerous that its use is at present everywhere prohibited.

The purity of acetylene gas depends upon the purity of the raw material from which it is made. Calcium carbide always contains phosphorus, sulphur, and nitrogen, and unless purified the resulting acetylene gas will contain phosphoretted hydrogen, sulphuretted hydrogen, and ammonia. The improved processes of manufacture of calcium carbide do away with these impurities. Purified acetylene is not as dangerous to breathe as coal or water gas; it takes also, in burning, less oxygen from the atmosphere, and creates much less carbonic acid in combustion than the ordinary gas. It is, too, of a much higher luminosity than ordinary gas, burns with a white flame, and owing to its richness in hydrocarbons, special burners, with small orifices or jets, and burning only 0.5 cubic foot of gas per hour, must be used; these give about 25 candlepower light against 16 candlepower of the ordinary 3- to 6-cubic-foot-per-hour burners.

The ammonia contained in acetylene gas will form a chemical explosive combination with copper, hence copper gas-fixtures, piping, or generators should not be used.

Numerous forms of apparatus for making acetylene gas have been devised. Practically, they all belong to one of the following three types of generators:

(*a*) Those in which a measured quantity of water is supplied gradually to a large volume of calcium carbide, contained in a closed vessel.

(*b*) Generators in which the carbide is immersed in water and then withdrawn, the action being repeated from time to time.

(*c*) Generators arranged so that a measured quantity of carbide is dropped into a large volume of water.

The generator and the gasometer may be fitted up separately or together. From the point of view of safety, it is advisable to place the generator in a brick vault outside of a building (the same as with air-gas machines).

Owing to the necessary use of very small burners, it will take a much longer time before a room, in which a gas cock is left open, will hold a mixture dangerous to health. The odor of acetylene being very peculiar and distinct, a small leak is rendered very noticeable.

Quite recently a new lighting gas made from pure acetylene gas by dilution has been used, as the following item from the *London Daily Mail* shows:

"The first place in the United Kingdom to be illuminated with the bright white light of 'Electroid Gas' is Hunmanby, a Yorkshire village near Scarborough. This new illuminant is composed of acetylene with the admixture of inert matter and a proportion of oxygen. Its manufacture is claimed to be of the simplest nature. The gas can be delivered through any ordinary gas main at the ordinary pressure, measured by means of gas meters, and charged for in the same way as is the custom where ordinary coal gas is used. The light is described as perfectly white, and equal to 250 candlepower, as against the average 17 candlepower of coal gas."

According to an article by Dr. Paul Wolff in a recent issue of Glaser's *Annalen für Gewerbe und Bauwesen*, the town of Schönsee, in West Prussia, is now supplied with acetylene gas from a large plant, designed for 2000 burners (*Eng. Record*, October 21, 1899).

Finally, gas is made from oils, melted fat, resin, petroleum, peat, and from wood. Owing to the cost of these materials, only few oil or wood gas-works are in existence. Gas is made from petroleum or from naphtha by decomposing the same in heated retorts. Such gas requires no purification, is very rich in heavy hydrocarbons, but is too expensive to be sold in a commercial way. It is used more as a means to enrich the non-luminous water gas, and to render the same less dangerous in use by imparting to it a distinct smell.

Impurities in Gas. — Tests for Impurities.

The gaseous impurities of ordinary coal gas are sulphuretted hydrogen, vapor of carbon disulphide, carbonic acid and ammonia. These reduce the lighting qualities of the gas, and the sulphuretted hydrogen, in burning, produces sulphurous and sulphuric acids, which are destructive to metallic articles, plants, and generally injurious. Sulphuretted hydrogen can be traced by holding a strip of paper, dipped in sugar of lead, which, in the presence of this impurity, becomes discolored and turns brown, the intensity of the latter color being an indication of the degree of impurity.

Carbonic acid can be detected by leading the gas through lime water, which thereby becomes cloudy or white. The presence of ammonia is indicated by dipping a glass rod in muriatic acid and holding it over an open gas burner, when a white fog will form.

The purification processes remove all but a small quantity of these gaseous impurities.

Dangerous or Poisonous Ingredients in Gas.

While sulphuretted hydrogen is a poisonous ingredient, the quantity contained in well-purified gas is so small that it may be disregarded. From a health point of view, the really dangerous poisonous ingredient of both coal and water gas is the carbon monoxide. This is present in both kinds of gas, the amount in coal gas being from 7 to 10 per cent, and in carburetted water gas from 25 to 40 per cent. Chemistry teaches that carbon monoxide, or carbonic oxide, is a colorless and tasteless gas, a little lighter than air, which burns with a bluish flame, forming carbonic acid. It acts as a strong poison, producing asphyxia and often death when inhaled in small quantities. Its toxic effect is due to a combination with the hæmoglobin of the blood, which is thereby rendered unfit to take up oxygen in the lungs.

In coal gas as well as in carburetted water gas the carbonic oxide is simply a diluent, the same as the marsh gas. It does not appear to be practically possible to remove it from ordinary coal gas, though it is stated that a part of it can be removed from water gas.

As regards the danger from explosions, the light carburetted hydrogen, and to some extent the olefiant gas or the heavy carburetted hydrogen, are the dangerous elements, for these mixed in certain proportions with atmospheric air, form a mixture which explodes when ignited.

Dangers in the Use of Gas.

When lighting gas was first made, objections were raised against its use, because of the products of illumination, when the gas was burnt. But nowadays it is a well-established fact that no serious danger to health, beyond the mere contamination of the air, results from the burning of purified illuminating gas. The contamination of the atmosphere can, of course, be counteracted by proper and sufficient ventilation. Theoretically the products of burning gas are water and carbonic dioxide.

Unburned gas, however, is dangerous, no matter how made. Escapes of unburned gas are therefore to be avoided. The dangers are twofold, viz., first, asphyxiation, and second, explosions; the latter sometimes accompanied by fire. The danger of asphyxia is greatest with pure water gas; next comes carburetted water gas; then gas made from wood, coal gas, and finally natural gas. Neither the air gas nor the acetylene contain carbonic oxide, though the breathing of such gas may be injurious for other reasons. The danger of gas explosions, caused by mixtures of gas and common air becoming ignited, is present with all kinds of gas, though the proportions between gas and air, which are explosive, differ somewhat with the different kinds of gas.

Escapes or Leaks of Gas.

Dangerous escapes of gas may occur either at the works, where the gas is manufactured, or in the distribution system in the streets, or finally in the houses when the gas is consumed as fuel or as illuminant, or for power purposes. Gas escapes in buildings are either due to leaks, or to carelessness or ignorance in the use of gas, or to accidents.*

Dangers Incident to the Manufacture of Gas.

At the gas works, where either coal or water gas, or carburetted water gas is manufactured, the workmen are to some extent exposed to the danger of explosions due to escaping gas, and on the other hand they are liable to suffer from breathing gas which may escape from the retorts, the gas-holder, or other points in the works. It is stated on good authority that accidents at gas works from the inhalation of coal or water gas are comparatively rare. Where water gas is manufactured, there is of course a greater danger than with coal gas, owing to its larger percentage of carbonic oxide. Good ventilation in the gas works is always an essential condition. The workmen in gas works are also liable to suffer from exposure to the heat and from sudden changes of temperature. The ammonia of unpurified gas attacks the mucous membrane of the respiratory organs. Besides this, the workmen may suffer from the vapors caused by the extinguishing of the burning cokes, and, in the purifying department, workmen who clean and empty the lime boxes are liable to inflammation of the eyes from the gases and odors.

Dangers Incident to the Distribution of Gas.

The gas distribution system embraces the street mains, the house and lamp services, and the gas meters. Gas leaks caused by a break of a street main are generally noticeable by the intense smell of gas, and in the case of smaller gas works by the sudden falling of the station gas-holder.

There is always some leakage of gas connected with the distribution mains, the gas escaping either at the joints or from imperfect pipes, or finally from breaks in the mains. From 7 to 10 per cent of the daily output is estimated to be lost by leakage

* See Gerhard, W. P. Accidents with gas — *American Architect,* August 6, 1898.

from the gas mains. In 1894 the gas leakage per mile of main in Philadelphia amounted to the enormous volume of 871,000 cubic feet per annum. Cases of asphyxiation occur when workmen make connections with the gas mains (so-called "tapping"), or when they go into trenches, in which a broken gas main is to be repaired.

The chief danger connected with escapes of gas under the street surface is that the gas will often find its way through the soil and escape into the houses located along the street. When such gas leakages occur, the characteristic pungent odor of the gas is sometimes partly or completely lost by filtration through the soil. Where this is the case, it is much more difficult to detect a leak or break, and the buildings and their occupants along the line of such defective or broken gas main become exposed to two grave dangers, namely, the danger of explosion and of asphyxiation. Many cases are on record of people having become asphyxiated in houses not provided with any gas service. This danger, as was first pointed out years ago by Professor von Pettenkofer, is particularly great in winter time, and this for two reasons: first, the street surfaces are apt to be frozen hard and will not permit the gas to escape upwards where it would do no harm and where it might be quickly noticed; then again it is well known that houses in winter time act like chimneys by reason of the temperature inside being higher than that outside. They, therefore, draw in the ground air, as it were, and with it the gas which has leaked into the soil. The dangers are, of course, aggravated by the fact that at night, and in winter particularly so, the doors and windows of bedrooms are usually kept closed. Professor von Pettenkofer relates a great number of instances where not only one person, but sometimes entire families, have been found in the morning asphyxiated by gas which entered houses in this manner. Sometimes the gas escaping from the main will follow along the line of house sewers and will thus gain entrance to the cellars; in other instances it follows the tubes or conduits which enclose the electric light wires. Professor Wolffhügel has drawn attention to the fact that coal gas may also lose its peculiar odor in passing through floor deafenings and plastered ceilings.

Where no asphyxiation occurs, dangerous explosions may happen by reason of the escaping gas mixing with the air. The striking of a match, or the bringing down into the cellar of an open flame will speedily cause this result. Only recently, a fatal gas explosion occurred in a residence street in New York City, in a house which had not been occupied for the entire summer, but where a workman had entered in the morning to make some improvements. Five minutes after he was seen to enter the house, an extremely violent explosion occurred, which blew out the entire front and rear walls of the three-story brick and stone building, causing a fire in this and several adjoining houses, and resulting in the death of the unfortunate workman. The cause in this instance was a broken gas main, from which the gas had been escaping into the cellars of the houses along the street for probably many days or weeks.

The danger of being asphyxiated is in all such cases much greater where the gas manufactured is the so-called carburetted water gas. Where otherwise healthy persons, living in houses not supplied with gas, awake in the morning with persistent headaches or nausea, it is always well to bear in mind the possibility of carbonic oxide poisoning from gas escaping in the manner described above.

In case of a break of a street gas main, the most important thing to do, until the gas company can shut off the gas and reach the leak, is to keep open all windows of the cellar and basement, also to avoid having any open light.

It is difficult to suggest a remedy for the conditions named, except that wherever an escape of gas is noticed in a street it should be immediately reported to the gas company and it should act promptly in the matter, and, if necessary, cut off the gas from the entire street rather than continue to expose the houses to such dangers. A German chemist, Professor Bunte, has suggested a ready method for testing the tightness of gas street-mains. Small holes from 12 to 16 inches deep are bored, at intervals of 6 to 10 feet along their line, and in each opening an iron tube 0.5 inch in diameter is placed, which has within it a glass tube containing a roll of test paper. This paper is dipped into a solution of palladium chloride, and any trace of gas escaping from the main at once acts upon the paper, coloring it a slight brown or even black, according to the extent of the leak. If, on the other hand, after, say, ten minutes, the paper remains white, it is a safe indication that at the point tested there is no escape of gas.*

* Another method is suggested in Hartenfels' patent gas-leak indicator.

To the distribution system belong also the house and lamp services and the gas meter. The house service should be laid with the same care as is required for the inside gas-piping system. The tapping with the main should be done carefully with a good ratchet brace and hard steel drills. In certain soils, it is advisable to protect iron service pipes against corrosion by painting them.

A leak which shows itself in the cellar at the point where the service enters should be at once repaired by notifying the company to whom the piping belongs. Breaks in services to street lamps are sometimes indicated by the fact that a street lamp suddenly burns very dimly.

The consumers' gas meters, which form the connecting link between the house service and the house pipes for gas, should also be tight and all connections made with the greatest care. Connections with iron pipes and fittings are preferable to those of lead.

Accidents sometimes occur to workmen of the gas company when replacing a defective gas meter or cleaning out house services that have become stopped up. In all such cases, the greatest care should be observed to avoid asphyxiation.

Dangers Incident to the Gas Piping in Houses.

In piping houses for gas it is always well to bear in mind the dangerous nature of the gas to be carried in the pipes. Of whatever kind the gas may be with which the house is to be lighted, whether natural gas, coal gas, air gas or acetylene gas, the piping should be absolutely tight in the joints and the tightness should always be ascertained by carefully testing the gas-piping system after completion. (For a description of how to test the gas piping, see Chapter XI.) It has been pointed out by scientific investigators, that even slight gas leaks in houses, when going on for a long time, will have an ill effect upon the health of the inmates. They will suffer not only from headaches, vertigo, and nausea, but also in some cases from sore throats.* Quite often such gas leaks and their effects are erroneously attributed to "sewer gas." Larger leaks of gas are dangerous, first, by reason of persons becoming asphyxiated, and second, because the gas when mixed with air and brought in contact with a flame will cause explosions or a fire. Many

* See Gerhard's "Gas Lighting and Gas Fitting."

accidents are annually recorded where persons have searched for a gas leak with an open flame, and even mechanics, who should know better, at times risk their lives by this bad practice.

In laying out the gas-piping system for a building, it is therefore obviously of the utmost importance to so arrange the pipes, in size and manner of distribution, as to avoid at any point in the system the possibility of a sudden reduction in the gas pressure, for, where this happens, a flame which has been turned down low is liable to go out, and when the pressure is re-established death, by asphyxiation, may result through the escape of the gas. Although this matter was not unknown, it has been pointed out, for the first time, I believe, by Mr. Faxon, an architect, of Boston. The matter will be referred to again under the heading of "Management of Gas." (See also Chapter V.)

A few points of caution may be useful: First, in piping a house, always keep the gas pipes away from bell wires, for cases are on record when such bell wires in constant contact with the gas pipes have gradually cut the pipe, causing a hidden leak of gas which was often extremely difficult to find. Second, gas pipes should always be kept away from steam and hot-water pipes, and also from hot-air flues, smoke pipes, and from electric service wires.

Where small leaks of gas in the pipes of a house are suspected, a very simple method for detecting these is to watch the small index hand of the gas meter. Wherever this moves, when no gas is burning and no gas is used in the house, there must be somewhere a gas escape. Sometimes a gas leak may be noticed by a rumbling sound in the gas meter when all the burners are closed.

Dangers Incident to the Gas Fixtures.

In the gas fixtures, where gas is either burned for illumination or else for cooking or heating purposes, there are a number of points which require serious attention. First, there is the joint where the fixture is attached to the gas piping or to the gas outlet. Except for the few temporary connections by means of rubber tubing, this joint is nearly always a fixed joint. It, therefore, should be made with the same care as any other joint in the pipe system, but the makers of gas fixtures, who usually attach the latter, are very often guilty of carelessness or bad workmanship.

Next come the fixtures themselves. Of whatever material they are made, the tubing through which gas is conveyed to the point where it is burnt, should be absolutely tight. It would be well if all the gas fixtures were tested before leaving the factory, for owing to the fact that the gas keys are seldom absolutely tight, it is a difficult matter to test the gas fixtures in a house after they are once connected.

The gas keys, which govern the flow of gas, are very often found to be loose in the joint or else worn out, and in that case a constant, though small, escape of gas may result. Keys which turn too hard are equally bad, as accidents may happen by reason of the gas not being entirely shut off. Numerous fixtures have either folding or extension or telescopic joints. All such joints constitute places where an escape of gas may occur. Particular attention should be called to the danger of old-fashioned gas fixtures with so-called "all around" cocks, that is, having keys without stop pins. The writer has held long ago that the use of such fixtures should be prohibited by legislative act. Where the keys are provided with pins, these are often made of too light material and break or snap off. The joints of extension fixtures should be watched with particular care. So-called water-joint pendants are liable to have the water evaporate, and it is best to substitute glycerine for the water. Very often the tubing of chandeliers corrodes or splits and gas leaks result. Where portable table lamps are used, the rubber tubing may become worn out or cracked, and permit the gas to escape.

All gas keys should be properly greased and loose keys should be tightened to avoid the slightest smell of gas. The joint where the gas burner is attached to the fixture should also be made tight, as it otherwise may leak gas when the latter is turned on.

Accidents may occur from all the causes named. In the Massachusetts statistics of deaths from asphyxiation, a few other causes are pointed out, of which the following may be mentioned: Combination gas and electric fixtures in which the gas key may be turned on, being mistaken for the electric lamp key. The use of the so-called independent cocks is also somewhat dangerous when the two keys are placed together, one of them controlling the lamp and the other a connection to a gas stove, as the one may be turned open by accident when the other is closed.*

* See "Accidents with Gas," by William Paul Gerhard, *Amer. Arch.*, Aug. 6, 1898.

Heating and cooking fixtures should also be connected with care and should not have any leaky places. Where rubber tubing is used for temporary connections, accidents may occur from the tubing slipping off the joint or becoming sufficiently loose to permit an escape of gas.

Where gas pressure regulators are used at the meter to control the gas pressure, they should be carefully examined for tightness, for very often slight leaks are found in such appliances.

Each single leak may be ever so small, yet the aggregate of leaks in a house may lead to a serious contamination of the air and to bad effects on the health of the occupants, due to slow poisoning.

Dangers Incident to the Use and Management of Gas.

Numerous accidents occur annually in the use of gas for lighting, cooking, or heating, through either carelessness or ignorance. The largest number of accidents, probably, occurs from ignorant persons blowing out the gas, or from turning it off and subsequently turning the cock on sufficiently for the gas to escape unnoticed. This is particularly liable to happen in hotels and lodging houses, where persons from remote country districts, or emigrants, who have never used gas before, take rooms; but it also happens now and then in private families, in the bedrooms of servants, not acquainted with the use of gas. Fatal accidents usually occur in small rooms having no ventilation, while the occupants are asleep.

Other accidents are the result of the bad practice of turning a gas flame down low, particularly in bedrooms. This is always ill-advised, for such a turned-down flame may be either blown out by a draft of air from an open window, or else it may be extinguished by a sudden variation or reduction in the pressure. When this happens in a small bedroom without ventilation there is great danger of persons becoming asphyxiated, particularly so if water gas is used. Much can be done to avert this danger by a proper arrangement of the gas piping in houses.

Another dangerous custom is to shut off the gas at the main service, or at the gas meter during the night, and numerous accidents, some of them fatal, have resulted from it. It is almost equally bad to turn off the gas at the meter during the day.

Notwithstanding the universal introduction of gas lighting, there are still many persons who would be benefited by receiving plain instructions on the use of gas in the household. Gas companies would benefit themselves and the public by paying more attention to this matter.

Among the statistics already quoted may be found numerous deaths or accidents due to a faulty management of gas. Among the more remote causes the writer finds the following mentioned: In one of two adjoining rooms supplied with gas from one so-called prepayment gas meter, a man retired for the night when the gas supply from the meter was exhausted, but forgot to close his gas burner. The occupant of the adjoining room came home late at night, dropped a coin in the slot of the gas meter and got a fresh supply of gas, which meanwhile also escaped in the adjoining room, killing the occupant.

The danger incident to the use of automatic or quarter-in-the-slot gas meters is also illustrated by the following recent occurrence in New York City, which caused the death of two victims:

" An automatic gas meter ran out in an apartment after the majority of the household had gone to bed. In the early morning hours some one of the household, after rising, put a quarter in the meter and the gas began to flow through the gas jet in a bedroom, the occupant of which had left the burner open when the gas went out the night previous. Gas filled the room, and the occupant was found unconscious, and after being removed to the hospital, died after several hours. A lady, occupying an adjoining bedroom, was also overcome by the gas, and likewise died from the effects of gas poisoning."

Escapes of gas and explosions have also happened in the use of gas cooking stoves, where the boiling water, running over the vessel, extinguished the flame. It has already been mentioned that the so-called independent gas connections, with two keys, may lead to accidents by the wrong one being turned by mistake.

Where the gas in the cellar freezes in winter time, it is dangerous to attempt to thaw out the gas meter or the gas service with a flame. A gas meter should never be examined with a burning light, nor should any tools be used near a gas meter which is known to be leaky, on account of the danger of flying sparks.

Remedies Suggested.

According to the official statistics of the Board of Gas and Electric Light Commissioners of the State of Massachusetts, 105 gas accidents occurred in the year 1887, causing 60 deaths and 74 injuries. In the year 1898, 101 accidents occurred, causing 77 deaths and 45 injuries. While some deaths were due to suicidal intent, the majority of cases were accidents which might have been prevented by a stricter inspection of the gas piping and fixtures.

It cannot be overlooked that the danger is a serious one, and one that is sure to increase as the use of carburetted water gas becomes more universal. Leaks of coal gas produce unpleasant symptoms and sometimes cause loss of consciousness, but an exposure to the more dangerous water gas would, under similar circumstances, result in the death of the victim. Without a desire to draw comparisons as to the relative dangers from sewer air and from illuminating gas poisoning, the writer has always held the view that both are equally preventable by proper supervision of buildings, old and new.

In recent years, the supervision of gas piping and gas-fittings has been agitated in numerous places, among others in Boston, New York, Philadelphia, and in Washington. In the first-named city this agitation has resulted in the enactment of laws governing gas piping and the inspection of such work in all new buildings. A similar law was introduced years ago in Albany, but for reasons difficult to explain the bill was killed. At present, however, the gas piping of all new buildings in New York City is inspected and tested before use by the municipal building department.

Among the safeguards to be applied, I mention the following:

First. The enactment of official regulations regarding the arrangement of the gas pipes in buildings and the provision for official municipal inspection and for testing all work in connection with it. It is advisable that all manufacturers of gas fixtures should test their output at the factories.

Second. The periodical inspection of gas-lighting fixtures and other gas appliances in hotels, lodging houses, and tenements by the municipal authorities. Precautions against gas asphyxiations are particularly necessary in the case of cheap hotels and lodging houses, frequented by people unacquainted with the use of gas.

Third. The prohibiting of the use of gas in all sleeping rooms without proper provision for ventilation, and in bedrooms of less than a stated number of cubic feet capacity. The danger of exposure to escaping gas becomes aggravated by sleeping in very small bedrooms.

Fourth. The use of so-called automatic burners in the sleeping rooms of hotels and lodging houses. The term "automatic" in this connection is intended to designate a gas burner from which gas cannot escape without becoming immediately ignited. Several ingenious so-called "self-lighting" burners have been patented within a year or two and are now placed on sale. If a person should blow the gas out where these burners are used the gas will become automatically lighted and no asphyxiation can result.

Fifth. It has also been repeatedly suggested to restrict by law the amount of carbonic oxide in gas and to prohibit the distribution of any gas containing more than a stated quantity of this poisonous ingredient. In the writer's judgment, it will be a difficult matter to enforce such a statute, and managers of gas companies may surely be expected to oppose any such measures, as in recent years they found it to their advantage, on account of lessened cost of production, to manufacture a carburetted water gas instead of the coal gas.

Under all circumstances, diligent care should be exercised in the use of gas fixtures and gas fittings. This, together with an official supervision of the gas piping, and with popular instructions disseminated by gas companies to their customers, would accomplish much good in preventing fatal accidents in the future.

CHAPTER XXV.

DANGERS OF GAS LEAKAGE (continued).

In the preceding two chapters the author has given his own views and observations on the dangers from gas leakage. The subject has become one of vast importance, and may be viewed from two different points, namely:

1. From the standpoint of the sanitarian, who looks upon it chiefly as a serious danger to health and life.

2. From the point of view of the underwriter, who sees in the frequent gas escapes and leaks dangers to property and risks of fire.

The following quotations, drawn from the various sources indicated, are given in order to emphasize the absolute necessity of taking efficient steps to eradicate the evil, or at least to reduce it to a minimum. I should, perhaps, point out that with the exception of the first report quoted all others appeared after my own paper on the subject was prepared.

From a pamphlet published in September, 1897, by the City Club, of New York, I quote the following sentences:

"The enormous leakage loss of gas from mains is not only a public nuisance; it is in a high degree dangerous to life and property. . . . Explosions in sewers, subways, and in manholes, of gas which has leaked from the gas mains are of frequent occurrence, entailing much public inconvenience and great expense for repairs. . . . Notwithstanding the repairs constantly in progress, the leakage of gas from street mains and defective service connections is enormous. . . . Experiments should be undertaken to determine whether some reasonable means of abating this nuisance, with all its attendant evils, is not available. The danger from these leaks is materially enhanced by the increase in the area of asphalt pavements.

"The occurrence of a number of fires and explosions, studied in the light of these facts, may be assumed to be due to the gas leakage, and warrants the belief that this important subject should be further investigated."

The Committee on Lighting and Heating of the National Board of Fire Underwriters, issued a Report dated December

28, 1899, on "The Fire Risk of Gas Main Leakage under Impervious Street Mains," from which the following is quoted:

" From the insurance standpoint, gas leakage from mains in asphalted or other impervious street pavements is important, as it increases the fire risk of buildings fronting on such streets.

" The leakage from gas mains, service connections, and service pipes is much greater than is generally known. It is asserted on good authority that the normal leakage of 6-inch gas mains averages 225,000 cubic feet per mile per annum; that of 12-inch gas mains averages 450,000 cubic feet.

" From reports received from fifteen American gas companies, large and small, the leakage appears to be vastly greater, in some instances nearly three times as much as the above figures indicate.

" In Massachusetts the leakage is somewhat smaller, viz., 202,475 cubic feet for an average diameter of 6 inches.

" This is a matter of grave concern to the fire underwriters. Leakage which formerly escaped gradually upwards, now follows the paths of least resistance, when street surfaces are practically air-tight; it follows spaces around gas services, escaping into coal cellars and vaults, while some reaches either the sewers or the subways."

In the *Scientific American* of 1904, I find the following:

" Whereas water leakage is chiefly a question of municipal extravagance, gas-main leakage is a much more serious matter, especially when it occurs under asphalt or other practically gas-tight pavements. Of the gas thus lost, some is held in the superficial earth strata and creates the familiar nuisance in connection with street excavations. Some leaks into subways and sewers, and is occasionally heard from in explosions which hurl manhole covers high into the air and rip up sections of streets. (Such explosions are usually recorded by the reporters as 'sewer gas' explosions.)

" Most of the gas leakage, however, follows along the mains and works its way into cellars and coal vaults following the soft and pervious filling around gas and water services. This constitutes a very serious menace to life and property.

" The case of the Hotel Windsor Fire in New York a few years ago is now assumed to have been due to an escape of gas, and the cause of many mysterious and costly fires may be looked for in the same direction.

" Can we afford to put down impervious pavements until we learn how to minimize gas-main leakage?

" Gas leaks are caused largely by expansion and contraction of the pipes. The total movement due to the range of summer and winter temperatures exerts such power that the strongest materials cannot resist it, those irresistible forces therefore cannot be disregarded.

" Wrought-iron pipes with steam-tight screw joints have been tried in place of cast-iron pipe with caulked joints. But even with wrought-iron pipes the threads are stripped, the joints are pulled apart, and rigid connections are broken.

" Gas mains are also subject to the jar of the surface traffic, and to unequal settlement; excavations near them increase the leakage.

" In underground mains, rigidity is fatal to tightness and durability, and elasticity as well as flexibility should be secured.

" The first cost of mains per unit of length is of vastly less consequence than freedom from leakage and repairs."

An editorial in *The Metal Worker* of 1904, on "Tightness in Gas Mains," contains the following sentence:

" It is said that possibly as much as 50 per cent of the gas generated at the works is lost before the consumer is reached. The consumer must necessarily pay a price sufficiently high to cover the loss. . . . The public utility corporation supplying gas should be forced to exercise the utmost care in laying its system of mains. . . . Possibly, when the gas company is made to feel that there is talk of restricting the retail price of gas, it will take measures to reduce to a minimum the losses which now seem to be regarded as unavoidable. From the standpoint of economizing . . . and from the standpoint of sanitation, in preventing the dissemination of a poisonous gas, the question of tightness in gas mains is one of no little importance."

In *Insurance Engineering*, a well-informed monthly magazine of New York City, occurs the following:

" Who can tell how many fires, in New York and other cities, whose origins are reported as ' unknown,' are really due to gas leakage? From one to two hundred recorded gas fires occur in New York City alone each year. It is an alarming question of the first magnitude.

" Gas-saturated buildings and streets constitute a menace of the most dangerous description. . . . The perils against which people require insurance are largely of their own making, or exist on account of their ignorance or tolerance. . . . The gas-leakage peril, with its retinue of variegated calamities, can be regulated and reduced, if not eliminated wholly."

The *Philadelphia Medical Journal*, of March 4, 1899, brought the following article, headed "The Increasing Dangers of Illuminating Gas."

" The occurrence, only a few days apart, of three instances of asphyxiation in this city by the accidental escape of illuminating gas should direct public attention to the dangerous character of the illuminant. In the instances alluded to no less than sixteen persons were overcome and five deaths resulted. In this number are not included cases of attempted or successful suicide, by this agent, of which also several have been reported.

" A point of danger, concerning which knowledge is not general, is the fact that, since the lease of the Philadelphia Gas Works, by the United Gas Improvement Company, an increasing quantity of water gas is being mixed with the coal gas, which many suppose constitutes the sole illuminating agent dispensed. Water gas is distinctly a more lethal agent than the ordinary illuminating gas, possesses no noticeable pungent odor, is particularly penetrative, and not only acts much more rapidly in producing asphyxiation, but produces effects far more difficult to overcome than does coal gas. Even when resuscitation and apparent recovery is made, the action of water gas upon the blood is such that an impaired state of health, temporary or permanent, according to the degree of asphyxiation, must inevitably result.

" For the protection of the public, this important matter of the constant supply of so dangerous an agent should be hedged about with more safeguards than at present exist. Among the more obvious protective measures that should be recommended is the requiring of all companies manufacturing and selling illuminating gas, to give public notice of the use of any kind of water gas, such statement, with a caution as to the danger of the illuminant, forming part of every bill for service sent out by the company. In addition, municipal legislation should regulate the proportion of carbon dioxide † in the gas supplied, at least in the resident sections during what may be called the ' sleeping hours,' limiting such proportion to about 12 per cent. The character of the gas burners and fittings and their testing would also seem appropriate matters for regulation by the city government. Observance of such laws could be enforced by appropriate penalties. The concomitant possibility of civil suits for damages, in the event of death or injury, resulting from violation by the gas companies of any of the provisions having public safety in view, would also, doubtless, have effect in producing some degree of caution in the observance of legal points of liability.

" The gas companies seem to have three malevolent aims: 1. To ruin our eyes by gas which does not illumine. 2. To ruin our bank accounts by compelling us to burn great quantities of gas, in the hope of lighting our rooms. 3. To ruin our health by vitiation of our atmosphere. If we are rebellious, they propose actual death by asphyxiation.

"*Note.* — In the above editorial a slip of the pen made us say, ' carbon dioxide ' instead of ' carbon monoxide.' The latter is the gas present in water gas; it is the more dangerous of the two forms because it has the greater combining power with oxygen; hence the statement in the

† See explanation in the Note.

Press, by a gas official, apparently in reply to the editorial, that in the illuminating gas of this city far less than 12 per cent of carbon dioxide is used while there is a larger percentage of carbon monoxide, is most applicable to the contention by this *Journal* that cautions concerning the dangerous character of the illuminant should form part of the gas company's service. The statement in the same interview, that the two gases are ' almost equally fatal,' is fallacious. Carbon monoxide is not only more surely fatal, but its after-effects, particularly upon the oxygenating power of the red corpuscles, are far more lasting, a condition of permanently impaired health usually resulting when resuscitation from the immediate severe effects of the gas is had. Since the last writing two more deaths from this cause have been reported. Is it not time some step should be taken? "

Commenting on this article, the *New York Tribune* wrote:

" For the protection of the public against the dangers of illuminating gas, the *Philadelphia Medical Journal*, in a vigorous editorial, urges the absolute necessity of more safeguards than at present exist. Among the more obvious measures, with this end in view, it recommends requiring all companies manufacturing and selling such gas invariably to give public notice of the use of any kind of water gas, such statement, with an explicit caution as to the danger of the illuminant, forming part of every bill for service sent out by the company. In addition to this, the *Journal* emphasizes the necessity of municipal regulation, of the proportion of carbon monoxide in the gas supplied, at least in the resident districts, during what may be called the ' sleeping hours,' limiting such proportion to about 12 per cent. Nor should the character of the gas burners and fittings be neglected in such supervision. That such regulations are of immediate importance is evident."

Again, we find the subject mentioned in *The American Architect* of July 26, 1902:

" An interesting discussion on gas leakage and its possible effect upon health was held at a recent meeting of the New York County Medical Society. Annually in the large cities the gas companies expect to have a leakage of over one thousand millions of cubic feet of gas. In recent years this has become much more dangerous in its possible effects than in the early days of gas lighting when ordinary coal gas was employed. The gas produced in closed retorts by the destructive distillation of coal contained only a very small amount of the most poisonous ingredients, the carbon monoxide, or blue gas. Since water gas has come to be employed almost exclusively for illuminating purposes the percentage of carbon monoxide present in illuminating gas is over 30 per cent. There has been a suggestion in recent years that pure water gas should be employed in cities for heating purposes. In order to be useful for illumination, water gas must be carburetted — that is, saturated with certain naphtha derivatives. It is these substances which give the water gas, as made at present, its characteristic penetrating odor. They also somewhat dilute the more poisonous gases which are present. The gas expert who discussed the subject at the meeting referred to said that 'if pure water gas was to be supplied for heating purposes, the only safe place to live in New York City would be outside of it.' Present conditions in our large cities add to the dangers of gas leakage. Our pavements, especially in quiet residence streets, are usually asphalt, and are thoroughly impermeable. Gas that escapes from the mains is confined beneath the streets until it finds its way into the houses or into the sewers. There is no doubt that severe anæmias are becoming more frequent in city life. Dr. Lloyd pointed out at this same meeting that some of these anæmic conditions, associated with febrile temperature, malaise, and headache, are traceable almost directly to sewer gas. As it is well known that ordinary sewer gas does not affect the health of workmen who are many hours each day engaged in the sewers, it would seem that only when large amounts of carbon monoxide find their way into the sewers, and thence into the houses, for the gas is highly diffusible, that so-called sewer gas takes on such pathogenetic influence." (From *American Medicine.*)

Finally, I quote from *The Metal Worker* these sentences:

"The leakage of gas in dwelling houses and other buildings is a source not only of annoyance, but frequently of disaster. The experience of Pittsburg with leaky natural-gas pipes and burners has been especially unfortunate and has led to the utmost precautions being taken to prevent the escape of gas from its proper channels. In the case of natural gas, however, the danger is very much greater than with the ordinary illuminating or coal gas, which possesses a decided odor that permits of its presence being readily discovered. The first intimation that natural gas gives of its escape is quite likely to be an explosion.

"Notwithstanding the fact that coal gas has so marked a smell that the average nose will quickly detect it and if properly directed trace it to its point of escape, there appear to be many who seem to think they can see the gas more distinctly than they can smell it, and, therefore, whenever a gas leak occurs they go hunting for it with a light. It must be confessed that this method is apt to be successful so far as revealing the presence of gas is concerned, but, unfortunately for the investigator as as well as the house in which the gas is escaping, an explosion, sometimes little and sometimes great, usually precedes the finding of the leak. It is so natural to pick up a light when looking for anything, never mind what it may be, that the danger of doing so in the case of escaping gas when the point of leakage is the object of search is too frequently missed sight of until the explosion calls it to mind. The first thing to do when a strong smell of gas is noticed in a house is to extinguish all the lights, and if possible intrust the search to some one who has had experience in the matter and knows what is best to be done. This advice, of course, should not be followed strictly when the gas is only smelt in one room, for then a little common sense applied to a search will often discover a gas burner turned on or something out of order that can be easily set to rights".

A writer in a recent issue of the Boston *Journal of Commerce* gives some valuable suggestions on gas leaks, their repair and detection, from which we quote as follows:

"A leak may be occasioned from a variety of causes, such as a fracture in the pipe from imperfect welding, from corrosion, bad fitting couplings, sprung joints in the gas meter caused by wrenching and twisting in attaching a regulating device by an amateur 'wrench fiend,' a leaky dome or gas-holder in a regulator attached to the meter, etc. When a leak is discovered, if in the pipe or couplings, it can be temporarily stopped, until a plumber's service can be obtained, by covering or filling the aperture with white or red lead, or with sealing wax or beeswax, and, as a last resort, a cloth can be saturated with molasses or any sticky substance and wound about the leak. The locality of a leak may be determined at times by taking a sponge and saturating it with a solution of strong soapsuds and applying it to pipe, couplings, etc., upon which it will form a thin film which the escaping gas will blow up into a soap-bubble. A leak may also be determined by passing the hand, if warm, over the pipe, as the gas, being of a cold nature, produces a sensation of chilliness when coming in contact with a warm hand. The writer then refers to the trouble occasioned by leaks between ceilings which are not readily located, and when found are not easily reached. The danger of investigating with a flame is illustrated by a case that actually happened where a man looking for a leak mounted on a step-ladder, and against the advice of others, proceeded to light a match in the hope of setting fire to the gas where it escaped from the pipe, and thus locating the source of the trouble. The result, as expected, was an explosion, and the writer closes with the wise remark: 'Like many another fool, he did not believe it was loaded until the mischief was done.' Mixed within an iron cylinder and exploded with a flame, illuminating gas and air are the source of power in a gas engine, and if when used in such small quantities they have to be confined in an iron chamber to prevent damage, it is little wonder that a room, full, not to say a house full, of the mixture when exploded, should do considerable harm."

CHAPTER XXVI.

HISTORICAL NOTES ON THE DEVELOPMENT AND PROGRESS OF THE GAS INDUSTRY.

In the following I shall not attempt to give a complete history of the gas-lighting industry. Those who are interested will find ample material of this character in the bibliography on gas lighting following this chapter. I shall confine myself to a sketch of the development of gas lighting in Greater New York, with brief notes interposed relating to other cities.

In the early days of the Dutch settlements of New Amsterdam and Breuckelen, as New York and Brooklyn were then called, the "burghers" or citizens, who went about the streets after dark, carried their own lanterns with them. Later in the history of both cities, the lighting of the streets was made a duty of the citizens. In 1697, the first street-lighting ordinance was passed in New York, which ordained by decree of the Corporation that "every 7 householders should unite to pay the expense of burning a candle in a lantern, suspended on a pole from the window of every seventh house on nights when there was no moon."

In New York City, public street lampposts of wood were first erected and maintained, at the expense of the city, in the year 1762; these posts carried lamps which burned oil, and oil lamps were continued in use up to the year 1823, when gas lighting was first introduced. "The street oil lamps of New York were tended by a regular force of lamp lighters who went about every morning with a can of oil, scissors, and a supply of wicks, and carried a small ladder, mounted on which they blew out and trimmed the lamps for the next night's service. At dusk the same perambulation occurred when the lamps were lit by means of torches." (John T. Doyle, "A Boyhood in old New York.")

Contrasting the present manner of lighting street gas lamps with the former primitive methods, the late Mr. Charles H. Haswell, C.E., in his "Reminiscences of an Octogenarian," states that " the lighting of the oil lamps involved the use of a ladder, a vessel of spirits of turpentine, a lantern, and a torch, and if by the severity of the weather the torch was extinguished, the relighting of it, before friction or "locofoco" matches were known, was a dilatory matter.

In Brooklyn, now a borough, and once a sister city of New York, it is related, that owing to the increase of vice and crime on the streets at night, householders were recommended, in 1800, " to put candles in their front windows on dark nights as a convenience to those having to be upon the streets, and that was the genesis of street-lighting in Brooklyn," as related in the *Brooklyn Eagle* " History of the City." In 1820, the streets of Brooklyn were for the first time lit up by means of street posts carrying oil lamps.

The lighting of the interiors of houses, stores, theaters, and churches was accomplished, prior to the advent of gas lighting, by means of both oil lamps and candles, the candles being made of spermaceti or tallow.

" It was so different and attended with so many difficulties and inconveniences, compared with the facilities we now avail ourselves of, that it is worthy of record. The instruments of illumination were oil lamps and spermaceti or tallow candles. The lamps required attention to trimming of their wicks and to guard them from smoking, and the candles required repeated "snuffing" and would occasionally run or drip, as it was termed, frequently involving damage thereby, as in ballrooms, dancing parties in dwellings, etc., as such places were illuminated by chandeliers with a great number of candles thereon, some one or more of which would drip, and fortunate were the parties who did not receive drops of spermaceti upon their dresses." (Chas. H. Haswell, " Reminiscenses of an Octogenarian.")

About the facilities of procuring a light at that period in the history of the two cities, when phosphor matches were as yet unknown, the same author relates the following: " The question has frequently been put, how we put up with such inconvenient methods? The only reliable artificial method was that of the construction of a tinder box, filled with tinder of well-scorched rags, a flint and a suitable piece of steel; or by the rapid operation of a steel wheel rotated by drawing a long cord previously wound around its axis; to the face of this was applied a flint, the sparks elicited by it falling upon the tinder, to which, when ignited, a sulphur or bituminous match, as it was termed, was applied and lighted. French phosphoric matches carried in a case with a vial of a phosphoric mixture and matches were altogether unreliable." Owing to the difficulties involved in these inconvenient methods, it became customary to keep tapers floating in oil lighted in bedrooms, sickrooms, in the city fire-engine houses, and other places where light might be quickly wanted at night time. Later on (about 1830), a brimstone match was introduced and soon became universally used.

Gas lighting was introduced in England in the beginning of the nineteenth century. A London theater is said to have been lighted by gas in 1803; in 1807 Pall Mall was lighted by gas lamps, and street lamps, placed on the Westminster Bridge, were lit by gas in 1813. In 1823, twenty-three cities in England had gas illumination.

Paris adopted gas lighting in 1816, Vienna in 1818, Berlin in 1826, Dresden in 1828. In 1850, twenty-six German cities had introduced gas lighting.

Some early experiments with gas were made in New York in City Hall Park in 1812, and continued the next years, while Baltimore had some gas light in 1807, and Philadelphia in 1807. New York City was the third city in the United States to introduce gas lighting more generally, Baltimore having adopted gas in 1816 and Boston in 1820. The first steps to make use of the new method of illumination were taken in New York in 1823 and in Brooklyn in 1825. The city of Cincinnati adopted gas lighting in 1841 and New Orleans in 1835. In other countries, the use of gas did not begin until after the first half of the last century. Thus in Japan, Yokohama, in 1868, was the first city to use gas lighting.

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In 1823 the New York Gas Light Company was incorporated with a capital of $100,000 and its first president was Mr. Samuel Leggett. The company was given the exclusive privilege, for thirty years, of laying gas pipes in the streets in that part of the city lying south of Grand Street.

In September, 1823, some gas mains were laid in the principal streets, and in the same month the president of the gas company gave a reception in commemoration of the event, and his house at No. 7 Cherry Street. is said to have been the first New York residence in which illuminating gas was introduced. In 1825 gas mains were laid in Broadway from the Battery to Canal Street, consisting like the water mains of wooden bored logs, tapered at the ends.

The first gas made by this company was distilled from resin, which was at that time obtained in large quantities from the South. Coal, although known before this time, was not much in use for domestic purposes, and the heating of dwellings, stores, and factories was usually accomplished by means of wooden logs; wood was also the fuel used in the kitchen stove. Coal was at that time being imported from Liverpool and Newcastle, and was accordingly very expensive. The American anthracite coal was used in the districts where it was mined, and though some of the coal was shipped to the Eastern States by way of the canals, it was only after the advent of the railroads that coal was transported in large quantities and became cheaper in price.

Between the years 1825 and 1830, illuminating gas came more and more into general use. In 1827 the former wooden lamp-posts were replaced by cast-iron lamps, and street gas-lamps were first lit in the month of June, 1827. In as late a period in the history of New York as 1858 or 1859, the street gas-lamps, which were then rather far apart, were not required to be lighted on moonlight nights, and as a result, when the calendar indicated moonlight, there was often no light in the streets although the sky was cloudy, overcast, and dark. When the complaints from citizens about this became too loud, it was changed to the present practice.

It may also be of historical interest to mention that gas fixtures, gasoliers, and even the gas burners were formerly imported from England. On October 23, 1826, the New York Theater, afterward known as the Bowery Theater, was opened and was the first theater building in New York City lighted by gas. The price charged at that time for 1,000 cubic feet of gas was ten dollars, which has gradually dropped to the present price of eighty cents per 1,000 cubic feet, this price being fixed by Act of Legislature.

In 1830 the second gas company, viz., the Manhattan Gas Light Company, was incorporated with a capital of $500,000, and was given the privilege of supplying the territory of the city lying north of Grand Street. Thus Grand Street formed the boundary line between the two gas companies then doing business in the city. The Manhattan Gas Company began the manufacture of gas from coal. The price of gas at this time dropped to $7.00 per 1000 cubic feet.

While street illumination with gas lamps was regarded as a great improvement, the introduction of the use of gas in houses was rather slow in the first years. It is stated that, not unlike the experiences in London, many householders and landlords of New York protested at first against the introduction of gas lighting into dwellings, for fear of explosions, and continued to use oil lamps and wax candles by preference.

The New York and the Manhattan Gas Light Companies were the two original companies in Manhattan Island. Since their incorporation, a large number of other companies have been started, some of which have again become absorbed by the consolidation of several companies, so that their original name has disappeared.

The third company in New York was the Metropolitan Gas Company, organized in 1853, which also began manufacturing coal gas. A keen competition was carried on for years between the Manhattan and the Metropolitan Gas Companies, until they finally mutually agreed to divide the territory, the Manhattan Company supplying the territory between Grand Street and 34th Street, and the Metropolitan Company that above 34th Street. The independent settlements of Manhattanville and Yorkville (subsequently called Harlem) were about this time supplied by another gas company, the Harlem Gas Company. In 1848 the price of gas fell to $3.50, and in 1855 it was fixed at $2.50, but the companies at that time charged in addition a rental for the gas meter. This meter rent was abolished in 1867.

In 1870 still another company, the Mutual Gas Light Company, was incorporated, and met at first considerable rivalry from the three oldest companies. This company was the first to make coal gas enriched with naphtha, and furnished gas of 20 candle-power.

In 1876 a French gas engineer, Tessie de Motey, introduced in New York a process for making hydrogen gas, and the resulting brilliant gas light, made under his process, was much admired and sought for. This system, however, required the laying of two separate mains, one for oxygen gas, the other for hydrogen gas, which were brought together at the burner and created a very white light not unlike the lime or calcium light. Capitalists became interested in this process and organized the Municipal Gas Light Company, with works at 46th Street. Subsequently, this company made a kind of water gas enriched by naphtha, by a process suggested by Tessie de Motey, modified by Mr. Wilkinson and now known as the Wilkinson process. This gave a light of great illuminating power.

Another gas company was started in 1876, viz., the Knickerbocker Gas Company, with works at 99th Street. The price charged for gas in 1878 was $2.00.

In the year 1880, New York City was supplied by nine gas companies, viz., the New York, Manhattan, Mutual, Municipal, Metropolitan, Knickerbocker, Harlem, Central, and Northern Companies. Soon after this date a consolidation of companies took place, and six companies, the New York, Manhattan, Metropolitan, Municipal, Knickerbocker, and Harlem, became thereafter known as the "Consolidated Gas Company." The price of gas was fixed at $2.25. The Mutual Gas Light Company was the only company on Manhattan Island which remained opposed to the Consolidated Company. There were in 1880, in New York City, about 860 miles of gas mains in the public streets, and 23,231 street lamps. In 1899 there were more than 1300 miles of gas mains and over 27,000 gas lamps. More than 531 miles of city streets and 70 acres of parks and public squares are lighted by gas, the annual cost per lamp to the city varying from $12 to $28.

Stockholders from the old Municipal Company started, in 1882, the Equitable Gas Light Company, which built new works in 1884. Still later the Standard Gas Light Company was organized with works in 115th Street, and made gas from oil. This was the first company to lay a large number of miles of wrought-iron gas mains with screw joints, the intention being to avoid the large amount of leakage of gas from cast-iron gas mains with lead-caulked joints. Still later, the East River Gas Company was organized with works located at Ravenswood, L. I., and it built a tunnel under the East River to supply New York.

In 1898, the Equitable and the East River Gas Light Companies combined under the name of the New Amsterdam Gas Company. In 1900, there were four principal Gas Light Companies in the Borough of Manhattan, viz., the Consolidated, the Mutual, the Standard, and the New Amsterdam Companies. In many cases mains of different companies are located in the same street, thus giving the consumer the choice between several gas companies. In 1899 there was a "rate war," and since 1900 all companies have combined so that at the present time there is practically no competition. The last step in the organization movement was the acquisition by the Consolidated Gas Company, in 1900, of all competing plants, and furthermore the merging of the gas and electric lighting interests of New York City under one ownership and management.

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The Brooklyn Gas Light Company was the first company to be incorporated, in 1823, in Brooklyn, the population numbering then only 9000 inhabitants. Notwithstanding this early incorporation, gas was not introduced for street lighting until the year 1848 or 1849, but from this period on, gas lighting grew rapidly in favor, so that in 1852 there were 50 miles of gas mains laid and 1200 gas lamps put up in the streets.

The second gas company to be incorporated was the Nassau Gas Light Company, which began to supply gas in May, 1873. A third company, the Fulton Municipal Gas Light Company, commenced operations in 1880, and besides supplying its own district, furnished also gas to the Metropolitan, the Citizens', and the People's Gas Companies. Another company was the Williamsburg Gas Company, which supplied gas to the Eastern District. In 1893 there were eight gas companies in Brooklyn, with a total of about 600 miles of street mains. About the year 1896 all these companies consolidated under the name of the Brooklyn Union Gas Company.

Besides the large companies mentioned, there are in Greater New York a number of smaller companies, supplying the outlying or newly annexed districts.

The quality and candle-power of the gas supplied by the gas companies is controlled and tested in the Boroughs of Manhattan and Brooklyn by officially appointed gas testers and examiners. The many complaints made from time to time by gas consumers about the poor quality of the gas supply are, as a rule, not due to any wilful reduction in the quality of the gas by the companies. Such complaints generally arise from insufficient size or defective arrangement of the gas piping in buildings, or else from the fact that in many streets the gas mains have become too small to supply the district.

Many years ago, when there was but a single gas company in a district, the running of gas pipes in houses was controlled by the companies, and the regulations for interior gas piping and for the distribution of gas, as issued by them, had to be strictly followed before the company would set a gas meter in a house. Each building, after being completely piped for gas, was rigidly inspected and the piping tested by an inspector from the gas company. This practice, owing to the sharp competition between the different companies, has in recent years been given up, and the quality of the gas piping work done in the common and cheaper classes of buildings has rapidly deteriorated. Many dwelling houses now exist which have gas pipes of insufficient size, and where gas log fires and gas stoves are supplied from small risers or branches intended originally for but a few lighting burners. In many houses the gas burns dim when lamps are turned on simultaneously on different floors, and the flames begin to burn with more brilliancy whenever some are turned off. In all such cases the main service pipe, or the house pipes, or both are too small. In other instances, the fault is due to obstructions in the service pipe by tarry matter or naphthalene.

For all these reasons, it became quite desirable that there should be a similar supervision and control of the work of gas fitters as was practiced by the Department of Buildings over the plumbing work in new houses. A few years ago laws were passed embodying this feature, and nowadays the Building Department exercises control, not only over the drainage and plumbing but also over the gas piping. A similar inspection of the gas piping exists in Boston.

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Until about the year 1878, gas lighting was the only means of lighting, from one central source or station, the streets and squares, and the interiors of small as well as large buildings. At this time appeared the first electric arc lamp, giving a white light of great intensity, which, however, could be used only outdoors or at railroad stations, in large exhibition halls, factories, halls of audience, and in big commercial stores.

The years 1881 and 1882 mark the advent of the Edison electric incandescent lamp. It was this which gave the first real impetus to the competition between gas and electricity.

The electric lamp was at first expected to interfere seriously with the business of the gas companies. Up to that date, gas burners had been used chiefly in the form of either flat-flame or Argand burners. The Siemens and other forms of regenerative gas burners, in which both the gas and the air are heated before combustion, were now put on the market as new forms giving more concentrated and stronger light.

The electric lamp, however, was much more expensive in use than these gas lamps, and gradually gas companies began to feel safe again. It was later on found that the introduction of electric lighting had in reality a most beneficial effect upon the gas industry. Yet the electric incandescent lamp had some intrinsic advantages, such as greater safety from fire, less heating of the surrounding air, less vitiation of the air by products of combustion, and more convenient control of the lighting and turning off of the lamps.

These palpable advantages caused further improvements of gas lights. About the year 1886 some improved and more economic regenerative lamps appeared, and soon afterwards came an invention, which was destined to revolutionize gas lighting: namely, a burner in which a non-luminous flame raised a specially prepared mantle to incandescence. This lamp became known as the Auer or Welsbach lamp from the name of its inventor. It used very much less gas for the same intensity of illumination, but was at first somewhat imperfect. It was much improved during the years 1887 to 1892 by the original inventor as well as by others. The improved lamp gave a light that was much more agreeable to the eyes, and gave three times the amount of light with only half the consumption of gas.

The fact that in recent years the annual output from gas works has steadily increased is partly explained by the increasing use of gas as fuel, but it was also largely due to the improvements effected in gas burners.

Dr. C. W. Siemens predicted this for the gas industry when in 1882 he said: "I venture to think that gas lighting will hold its own as the poor man's friend, and the time is not far distant when both rich and poor will largely resort to gas as the most convenient, the cleanest, and the cheapest of fuels."

From an interesting paper on "Incandescent Gas Lighting," by Professor Dr. H. Bunte, read some years ago before the International Gas Congress at Paris, I quote the following:

"Incandescent gas lighting, as opposed to the older lighting by flat-flame and Argand burners, has assumed during the past decade the predominant position in Germany. The Welsbach lamp is now the recognized form for both public and private use; the older types of flames are continually losing ground. It has thus effected a complete revolution, not merely in regard to the illuminating effect and the economy of gas lighting, but even the fundamental factors by which gas is valued, and the properties and manufacture of gas have been entirely altered.

"Formerly 'illuminating power' was regarded as the principal criterion of the value of gas. Now by far the greater part of the gas, whether it is used for lighting or for heating, is first of all mixed with air in the Bunsen burner. By this means the illuminating constituents of flames are completely destroyed and the heating effect of the Bunsen flame alone comes into play.

"The quantity of light yielded is, in incandescent lighting, no longer directly dependent on the quality of gas as made in the works and distributed to the consumer. It is primarily dependent on the nature of the mantle which is brought to the luminous state in the Bunsen flame. It is, therefore, a matter of prime interest to the gas industry to follow the improvements in the manufacture of Welsbach burners, and the efficiency of the mantles on the market.

"The incandescent gas lighting owes its illuminating power and brilliancy entirely to the high temperature of the flame, therefore the grounds on which the properties of illuminating gas are estimated, and the methods used in its manufacture, must be modified, because since the introduction of Welsbach burners the production of light has resolved itself simply into a question of heating.

"Under the former regime of flat-flame and Argand burners the greatest value attached to the production of a gas, rich in the so-called heavy hydrocarbons (etylene and benzine); the lighting effect of the flame depended entirely on the presence of these constituents. But as incandescent lighting and the use of non-illuminating gas for heating and cooking continue to spread, these illuminants — formerly so essential — become less and less valuable.

"For the determination of the quality of gas a photometric test of the illuminating power with a bat's-wing or Argand burner can no longer form a proper criterion. It is the *calorific value of the gas* which now plays the most important part.

"When the gas industry is freed from the antiquated control of tests of lighting value in flat-flame and Argand burners, it at once acquires a freedom in the selection, both of raw material and methods of manufacture, which is of supreme significance in respect, not only of its whole future development, but also of the supply of towns with light, power and heat by means of gaseous fuel."

In the course of time, mantles of increased luminosity, which were at the same time less destructible and fragile, were manufactured, and simultaneously the cost of good mantles was reduced somewhat.

The latest development in gas lighting is the inverted incandescent gas lamp, which gives a much better downward distribution of light, with shorter and therefore less breakable mantles, and which also permits the designing of more artistic forms of gas fixtures. Simultaneously herewith, the upright or vertical incandescent gas lamps were much improved by the use of specially ground prismatic globes or shades, the so-called "holophane" globes, which enable the throwing of the light where most wanted, *i.e.*, either outward, upward or downward as may be desired.

Another improvement, introduced since 1898, was the use of an artificially increased gas pressure in the incandescent lamps.

In a comparatively short period of time great and wonderful improvements have been made in the construction of gas burners, gas lamps, gas fixtures, and gas globes. These important improvements, and similar ones in electric lighting devices, to which I cannot refer as it would be exceeding the subject matter of this book, have brought about a vast change in the appearance at night of our streets and squares, of our dwellings, stores, factories, theaters, and numerous other buildings.

Thus we see that during the last two decades gas lighting and electric lighting have become close competitors. Great progress has been made in both forms of illumination and the advantages which always follow in the wake of a sound competition are exemplified in this friendly battle between the two rival modern modes of lighting. This competition will doubtless be kept up, the development of the art of illumination will make further strides, and the public will be ultimately benefited, while the question: "gas *or* electricity?" will lose much of its former importance.

. . . . .

The increasing use of gas as fuel for both heating and cooking leads naturally to a brief consideration of the kind of fuel used in the household in former times. At the beginning of the nineteenth century, wood was the common fuel used in New York for heating and cooking. The wood was largely oak and hickory, which were considered the best, though chestnut and gumwood were also used. The wood came to the city on sloops or schooners, and the cargo was, on arrival of the vessel, purchased by cartmen in such quantities as they desired. They then drove through the streets selling their entire load or portions to customers. The carts were generally accompanied by men who sawed and split the wood, and put it into the bins in cellars. Very little coal came to New York in the days before the advent of the railroads, as has already been told. Only the rich could then afford the luxury of burning in their parlor grates bituminous coal, shipped to the United States from Liverpool and Newcastle. Many of the cooking operations were universally performed in open fireplaces, fitted up with large iron cranes, swung on hinges, which ran across the back of the chimney, and from which the cooking pots were suspended by iron chains or hooks. The roasting of meat was accomplished in what was called a "Dutch oven" or else in a "roasting jack," or spit. When coal from the mines in Pennsylvania began to be shipped to the Eastern States, first by way of the canals and then by rail, the use of coal in kitchens became more popular, and some kitchens were fitted up with closed fire or coal ranges in place of the open flames. Thus it came about that the modern kitchen coal range gradually superseded the former primitive devices. But in recent years, prudent, and economical housekeepers have not been slow in recognizing the many advantages of cooking by means of gaseous fuel. This is clean, labor saving, of the utmost convenience, and economical, if properly managed. In these days when gas is constantly becoming reduced in price, owing to improved methods of manufacture, while coal is getting scarcer and at the end of each winter or during miners' strikes becomes higher in price, gas cooking ranges are rapidly gaining in favor. Householders who have provided their kitchen with a modern gas range, who also have an auxiliary apparatus, using gas to heat the water in the kitchen boiler, and who have in the laundry the convenient gas sad irons for ironing, need no longer lay in a large supply of coal for the winter and pay the coal bill before the fuel is used; they can save the bother and annoyance of handling and storing their kitchen fuel.

Numerous are the advantages of gas ranges: a gas range requires no coal to be carried up from the cellar, and no ashes to be carried away. A gas range saves time, because it is instantly lighted, the fire is under perfect control, it is quickly adjusted and regulated, it is always ready for use, and no fuel is wasted, for by the turn of a stopcock the gas flame is entirely put out. Gas fuel is also safer than kerosene oil or gasoline. Kitchens fitted up with gas ranges are kept cleaner; there is no soot nor dirt, and in summer time the kitchen can be kept cool and pleasant. Gas ranges also require fewer repairs than coal ranges, and not the least advantage is that they do better cooking, roasting, and broiling. To all these reasons is due the recent great activity in the gas stove business, by which the gas companies are profiting Many of the modern apartment houses in New York City, in Brooklyn, and in other cities have now kitchens fitted with gas instead of coal ranges.

. . . . .

But even for heating, gas is convenient and offers many advantages, particularly in the autumn and spring of the year, when only a moderate heat is wanted, but likewise in zero weather, at which time gas logs in fire places, incandescent gas heaters, gas stoves, gas radiators, etc., are used advantageously to increase or supplement the heat obtained from furnaces or steam boilers.

A successful and novel form of gas-heating stove has recently been introduced in Germany, the inventor and manufacturer of which is Professor Junkers, of Aix-la-Chapelle, and Dessau, in Germany.

"Should a heating stove necessarily stand on legs?" asked Professor Junkers in one of his interesting pamphlets, describing the new device. He draws attention to the fact that it is difficult to conceive objects, which one has been accustomed from childhood to see in a certain form, being made differently. Whoever thought until now of constructing a gas heating stove of a different form and to place it in a position other than on the floor? True, as long as one was obliged to use heavy and compact fuel for heating one could not very well dispense with the solid and strong legs, embodied in the construction of the usual forms of heating stoves. Since however wood and coal are being more and more replaced by gaseous fuel, it does seem unreasonable to hold fast to old traditions and to the clumsy forms of our heating stoves.

The Junkers gas-heating stoves are of such form and construction that they may be attached to the gas-supply pipe along the wall at any height instead of being placed on the floor.

In these stoves cold air is drawn in from the bottom, or from very near the floor line, and passes upward at the rear behind a reflector and thence through a number of flat tubes ascending towards the front of the stove, and after being heated by these tubes, which are surrounded by the hot gases from the burner, the warm air passes out into the room vertically upwards and also forward at the front of the stove. This secures a strong circulation of the air of the apartment, while the downward rays from the reflector tend to warm the floor and the lower strata of air. In this way, a room may be quickly and uniformly heated. There is a complete combustion of the gas, the heat units generated are utilized to best advantage in the heating surfaces, and a very intense heat is produced. The heated gases, after having done their work round the air tubes, pass out at the top through a flue which is connected with some available chimney flue. These stoves are odorless and perfectly sanitary, because there is no chance for products of combustion to escape into the room. The wall, or the wall paper at the back of the stove, do not become warm, because cold air ascends at the back of the stove.

The stoves are quickly and easily installed by connecting a gas coupling at the top of the stove with a gas pipe dropped from the ceiling along the wall. The stove may be placed at any height usually from 12 inches to 20 inches above the floor, and no other wall clamps or fasteners are required.

Gas-heating stoves attached to a wall secure a number of advantages compared with the usual forms of gas stoves. In the first place, the installation is simple, and easily and cheaply made. In connecting the old forms of gas-heating stoves it was necessary to cut the gas pipe to exact measure, because the heating stove had to stand on the floor. In passing, it may be remarked that a permanent connection by means of wrought-iron piping is much preferable to a temporary gas-hose connection. The new wall stoves are attached only at a single point of the gas service and it is not necessary to measure exactly the distance of the coupling from the floor, because the stove does not stand on the same.

Another advantage of considerable importance lies in the saving of floor space. All old forms of gas-heating stoves require a floor space proportionate to their size, and the space between the floor and the stove is rendered useless. The wall stove does not occupy any valuable space in the room, but can be attached at any part of the wall wherever desired, and while it gives a large amount of heat the size of the stove is comparatively small.

Another advantage of wall stoves is one of sanitary importance. With the old forms of gas stoves the floor underneath them could not readily be cleaned. Dust and dirt and unhealthful matters accumulated beneath them, and yet the old form of stove draws the air from the very part of the floor which cannot be cleaned, causing the dust to be drawn up and burned on the surface of the stove, producing an annoying odor, which cannot help being disagreeably felt by the occupants of the apartment, and which is surely unhealthful. By hanging the stove against the wall at some height above the floor, it is possible to clean the entire floor and therefore accumulations of dirt and dust cannot occur.

A further advantage consists in the more uniform warming of the apartment. With all forms of stoves which stand on legs, the floor underneath and at the sides of the stove does not receive any heat radiation and therefore remains cold. The reflector of the wall stove causes the floor near and in front of it to be warmed, and in this way the lower strata are also warmed. This in turn has a tendency to warm the air of the room more uniformly. The appearance of these new stoves is quite different from that of the older gas stoves standing on a floor, and it is possible to design and construct a large variety of quite ornamental, novel, and pleasing forms.

Gas-heating stoves, in general, have the following advantages as compared with coal stoves. They require no attendance, are quickly lit by the use of a match and can be quickly and easily regulated after being lighted. The full heat production is utilized almost immediately after lighting the stove so that the room can be quickly warmed, whereas in using a coal stove a great deal of time must necessarily pass before it gives off a good heat. When the room is sufficiently warm, the production of further heat may be quickly and completely stopped in a gas-heating stove, while this cannot be done with any coal or wood stove. Relatively speaking, the running expenses are lower for gas-heating stoves, because the heat produced by the burner is very largely utilized, whereas much of the heat generated in coal stoves is lost by going directly up the chimney. For temporary use gas heating may be cheaper than heating by coal, even where the price of the fuel is higher. Many drawbacks and disadvantages of coal stoves are done away with by using gas stoves, such as the creation of dirt, smoke, soot, the cleaning of the stoves and chimneys, the storing and transportation of the fuel, and the removing of the ashes.

Another recent invention in which gas instead of coal is used as fuel is a gas-burning furnace.

Finally, gas is advantageous as fuel for operating small motors, such as house pumps, etc., and it is likewise used for clothes dryers, for heating laundry irons, and for warming the water used in lavatories and bathtubs, as well as in kitchen and laundries, not to mention innumerable minor industrial purposes, in which gas is used, partly for fuel and partly for power purposes.

CHAPTER XXVII.

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