NATURAL-GAS MANUAL
FOR THE HOME

BY
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CONTENTS.

PART I. Information about natural gas and prevention of waste.......................... 1
   Introduction ........................................................................................................... 1
   Acknowledgments .................................................................................................. 1
   Meaning of conservation......................................................................................... 2
   Source of natural gas............................................................................................. 2
   Necessity for conserving natural gas..................................................................... 2
      Limited quantity of gas available......................................................................... 4
      Increasing cost of supplying natural gas............................................................. 4
   Production, transmission, and distribution of natural gas.................................... 5
      Development and decline of gas fields................................................................. 5
      Gas wells.............................................................................................................. 6
      General features of natural-gas systems.............................................................. 10
   Effects of the removal of gasoline from natural gas............................................. 10
   Service involved in natural-gas distribution.......................................................... 11

PART II. Preventing waste in the use of natural gas................................................. 15
   Consumers' Interest in preventing waste.............................................................. 15
   Prevention of waste from gas leakage................................................................. 15
   Simple ways of saving gas..................................................................................... 15
   Preventing waste by efficient use of gas.............................................................. 16
      Conviction (burning) of gas............................................................................... 16
      Importance of ventilation and flues...................................................................... 17
      Principles of efficient use of gas......................................................................... 17
      Gas burners.......................................................................................................... 18
         Luminous-flame burners................................................................................. 18
         Blue-flame (Bunsen) burners........................................................................... 18
   House heating........................................................................................................ 21
      Furnaces and boilers......................................................................................... 21
      Incidental heating appliances............................................................................ 22
   Water heating......................................................................................................... 23
   Cooking................................................................................................................ 26
   Lighting................................................................................................................ 27
   Other uses of natural gas...................................................................................... 27
   Use of gas during periods of low pressure........................................................... 28
   Preventing waste by reducing distribution pressures.......................................... 29
   New houses and new equipment.......................................................................... 30
   Responsibility for efficient use of gas................................................................. 30

ILLUSTRATIONS.

PLATE I. Map of the oil and gas fields of the United States................................. 4
 II. Rig used in drilling for natural gas................................................................. 7
 III. A, Equipment used in the standard (cable-tool) method of drilling; B, Equipment used in the rotary method of drilling.................................................. 8
 IV. General features of a natural-gas system......................................................... 10
 V. A 20-inch natural-gas pipe line under construction........................................ 11
 VI. A 20-inch pipe line ready to be covered....................................................... 12
 VII. Exterior of a station for compressing natural gas........................................ 13
 VIII. Interior of a station for compressing natural gas........................................... 14

FIGURE 1. Generalized cross section through an oil and gas field.................... 3
  2. Value and volume of natural-gas output in Indiana...................................... 6
  3. Diagrammatical sketch of a section through a gas well.............................. 9
  4. Section reflector stove with luminous-flame burner.................................... 19
  5. A, Sketch of a blue-flame burner and a gas cock fitted with an adjustable spud; B, gas cock fitted with a spud having a fixed orifice; C, flames from a blue-flame burner.................................................. 20
  6. Construction and operation of a blue-flame heater...................................... 23
  7. Coil heater with features that make for efficiency....................................... 24
  8. Ordinary tank heater covered with an insulating jacket............................. 25
  9. Use of nails or pieces of sheet iron in burners for cooking at low pressure...... 29

II
PART I. INFORMATION ABOUT NATURAL GAS AND REASONS FOR PREVENTING ITS WASTE.

INTRODUCTION.

By using natural gas efficiently, consumers can do much to prevent its waste; and by saving for themselves they will help to increase the benefits to be obtained from the remaining supply, and will assist in delaying the exhaustion of this great national asset.

One of the duties of the Bureau of Mines is to publish information showing how efficiency in the production and utilization of fuels may be increased and waste prevented. In accordance with that duty, this manual has been prepared for distribution to those who use natural gas in their homes. Its purpose is to tell about the supply, production, and distribution of natural gas, so that the necessity for preventing waste will be better understood; also to make suggestions that will aid consumers in using the gas more efficiently.

ACKNOWLEDGMENTS.


MEANING OF CONSERVATION.

The natural resources of our country should be used to produce the greatest possible benefit to the public. Such use is true conservation. The meaning of conservation, as applied to natural resources, has been misunderstood, and some have interpreted it to mean hoarding; but the late Joseph A. Holmes, the first Director of the Bureau of Mines, defined conservation as "a wiser and more efficient use of natural resources."

In discussing the meaning of conservation, the late Franklin K. Lane wrote:

The word should mean helpfulness, not hindrance—helpfulness to all who wish to use a resource and think in larger terms than that of the greatest immediate profit; hindrance only to those who are spendthrift. A conservation which re-

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2 Lane, Franklin K., Conservation through engineering (excerpt from the annual report of the Secretary of the Interior for the fiscal year ended June 30, 1919): U. S. Geol. Survey Bull. 705, 1920, p. 3.
suits in a stalemate as between the forces of progress and governmental inertia is criminal, while a conservation that is based on the fuller, the more essential use of a resource is statesmanship.

To know what we have and what we can do with it—and what we should not do with it, also—is a policy of wisdom, a policy of lasting progress. And in furtherance of such a policy the first step is to know our resources—our national wealth in things and in their possibilities; the second step is to know their availability for immediate use; the third step is to guard them against waste either through ignorance or wantonness; and the fourth step is to prolong their life by invention and discovery.

**SOURCE OF NATURAL GAS.**

Natural gas is found compressed in the small cavities or pores in beds of sand or porous rock, called “gas sand” or “gas rock,” which lie under the earth’s surface between closer textured beds that prevent the gas from escaping. Natural gas is often associated with oil, but in many gas fields none has been found. Most deposits of gas occupy only the higher parts of porous beds, the lower parts usually being filled with salt water under pressure; and in many places oil containing absorbed gas fills a part of the bed below the gas and above the water. The reason for this relation of the three fluids is that they tend to sort themselves according to weight, gas being lighter than oil, and oil lighter than water. Consequently, the oil has risen above the water, gas has accumulated above the oil, and the gas has been forced by the pressure of the water into the higher parts of the porous beds. For this reason upfolds of the earth’s crust (as illustrated by Fig. 1) may be favorable places to drill for gas. Such folds are called anticlines and domes.

Figure 1 represents a generalized cross section through an oil and gas field, and shows features common to many fields. The reader’s attention is directed to the upper sands containing water, the lower sands containing gas, oil, and water, and the impervious beds of shale and lime that confine the oil and gas to the porous sands. The figure has been drawn to illustrate some of the conditions under which natural gas is found, rather than to represent any particular field, but the position of the beds and the relation of the gas, oil, and water are similar to those actually found in a very productive field where three different sands have produced oil and gas. In other fields conditions differ widely from those shown, and in many regions the beds are very irregular in position, thickness, and porosity.

**NECESSITY FOR CONSERVING NATURAL GAS.**

**LIMITED QUANTITY OF GAS AVAILABLE.**

Although there has been an energetic search for oil and gas throughout the United States, the areas that have produced gas are very small when compared with the total area of the country; and the important gas fields are confined to a few States. The total area of continental United States is 2,973,774 square miles, and of this
area only about 11,000 square miles, or less than one-half of 1 per cent, has produced natural gas, according to the United States Geological Survey.
Plate I is a map of the United States showing the oil and gas fields, including fields that have produced gas only, those that have produced both oil and gas, and others where oil has been the predominant product and the yield of gas has been unimportant. The total area of the fields is really less than is indicated by the map, as many of them are so small that their size must be exaggerated to show them on a map of this scale. However, the figure gives an idea of the geographical distribution of the gas fields, and indicates what a relatively small portion of the country has produced natural gas. There are, without doubt, other gas fields yet to be discovered, but geologic studies and prospecting indicate that only a small part of the United States will ever produce natural gas.

Only a limited quantity of gas can be taken from each field, for as gas is withdrawn from a producing bed, the pressure gradually decreases until the gas is exhausted or drowned out by water, so the deposit must be abandoned. Many of the fields shown have already been exhausted, while many others are approaching that stage. This decline and exhaustion of gas fields (explained more fully on pages 5–6) indicates that new gas is not formed to replace that withdrawn, and suggests that if natural gas is now being generated by nature, it certainly is being generated very slowly, and the quantity is negligible when compared with the amount being used. The inference to be drawn from the behavior of known gas fields is that—from a practical standpoint—the natural gas now being used has been generated by nature during past ages; a limited amount remains in the earth, and when this supply has been removed from the fields no more will be forthcoming.

The quantity of natural gas available to any community is determined by the resources of fields lying within a reasonable distance from that community, as the expense of transmitting gas for greater distances is prohibitive.

**INCREASING COST OF SUPPLYING NATURAL GAS.**

As the pressure of a field decreases and the wells become less productive, more wells are required to supply a given demand for gas, more pipe lines and equipment are required to gather the gas from the wells, and machinery must be used to compress the gas so that it will flow through the pipe lines. As near-by fields become less productive, the use of natural gas must diminish, unless it can be obtained from more remote sources; and if gas from such sources is available it can be obtained only by increased investment and other expenditures. The cost of supplying natural gas to any community must, therefore, increase as the reserve of natural gas available to that community is depleted.
MAP OF THE OIL AND GAS FIELDS OF THE UNITED STATES (AFTER U.S. GEOLOGICAL SURVEY, 1922). THE SIZE OF THE SMALLER FIELDS HAS BEEN EXAGGERATED TO SHOW THEIR LOCATION CLEARLY.
PRODUCTION, TRANSMISSION, AND DISTRIBUTION OF NATURAL GAS.

In order that natural gas may be utilized, wells must be drilled to find and develop the gas fields and the productive wells must be connected through transmission lines to distributing plants. The discovery, production, and delivery of natural gas are described in the following pages, that consumers may better understand the problems connected therewith and realize the necessity for preventing waste.

DEVELOPMENT AND DECLINE OF GAS FIELDS.

Prospecting for natural gas is usually based on geologic studies, for by these many factors of uncertainty can be eliminated, and the search limited to localities where general conditions are at least favorable to the occurrence of natural gas. When such conditions are found, the first step is to secure leases from landowners for the right to drill wells. No geologist can foretell that a well in any particular locality will yield gas and until wells are drilled nobody knows whether an area will be productive. Drilling for gas is always a venture and drilling the first well in a new locality, called "wildcatting," is especially venturesome. After gas has been found other wells may be drilled near the first with greater probability of success; but it is not unusual to drill unproductive wells or "dry holes" fairly near productive wells.

When a field is first discovered the gas is usually under high natural pressure, called "rock pressure," and each well has a high capacity. The capacity of a well is usually stated in terms of its "open flow"—the rate of delivery when the well is wide open and the gas is flowing against atmospheric pressure only. This gives a basis for comparing the capacities of different wells but does not indicate the rate at which they will deliver gas into the pipe lines. Gas usually flows into pipe lines against pressures considerably higher than atmospheric; therefore, the rate of delivery is usually much less than the "open flow." Furthermore, it has been found by experience that taking gas at a high rate may injure or even ruin a well; and in some localities the rate at which gas may be taken from a well is limited to one-fourth or one-fifth of its "open flow."

As gas is taken from a field the pressure drops, indicating that the quantity of gas in the beds is diminishing; this fall in pressure decreases the capacity of the wells. For a time the capacity of the field may be maintained by drilling additional wells; however, this can not be continued indefinitely, because each well drains gas from many acres, and spacing wells too closely is wasteful of money and may be injurious to the fields. Eventually the fall in gas pressure will decrease the productivity of the entire field; and this will continue until the field must be abandoned.
The decline and exhaustion of gas fields is illustrated by Figure 2, which portrays the growth and decline of natural gas production in Indiana. Development of natural gas began in Indiana in 1886, and production increased rapidly until 1893. From 1891 until 1902 it ranked second among States in the value of natural gas produced, and during the 11 years from 1893 to 1904 produced gas valued at over $65,000,000. Little of the gas was measured, hence the volume produced during these earlier years is not known; but as prices for gas were very low, the volume must have been large. In 1903 the production began to decline, and in 1906 the value of the gas produced during the year was only one-fourth of that produced during 1902. Since 1906 there has been a gradual decline in the production, so that by 1920 Indiana had dropped to fourteenth place in the rank of gas-producing States. In 1921 James P. Goodrich, ex-Governor of Indiana, said: 3

It is impossible to more than approximate the amount of natural gas used and wasted in the State since its discovery in 1886. In 1902 the production of natural gas, based upon the low price then charged and taking no account of the large consumption from privately owned wells, amounted to over $7,000,000, or 70,000,000,000 cubic feet. * * * The story is about finished, and the end of natural gas in Indiana is at hand. In 1902, 2,000,000 people were using natural gas; to-day not more than 200,000 are using gas from Indiana wells.

GAS WELLS.

The depth to which wells must be drilled to obtain gas varies greatly in different parts of the country. Although in some localities commercial gas wells are developed at depths of less than 1,000 feet, it is generally necessary to drill much deeper than this; depths of 2,000 to

3 Goodrich, James P., address before the sixteenth annual meeting of the Natural Gas Association of America, Cincinnati, Ohio, May 18, 1921.
3,000 feet are common. The shallow deposits are usually less productive than the deeper ones.

At the time of writing (September, 1922) the deepest producing gas well is 6,822 feet deep. The deepest well in the world was drilled to
7,579 feet (nearly a mile and a half) in search of gas, but was not productive.

Drilling machinery is shown in Plate II, a general view of a drilling rig; Plate III, A, equipment used in the standard (cable-tool) method of drilling; and Plate III, B, equipment used in the rotary method. Figure 3 is a diagrammatic sketch of a section through a gas well, showing typical formations encountered in drilling and illustrating material placed in gas wells. The formations encountered and the materials used vary in different wells.

Drilling is started with a large steel bit, which makes a hole of large diameter. When water sands or other troublesome beds are encountered, the water must be excluded from the well and the walls
of the hole must be prevented from caving in. To accomplish this, wrought iron or steel pipe, called casing, is placed in the drill hole. This is screwed together joint by joint as it is lowered and thus forms a long “string.” Drilling with a bit of smaller diameter is continued through this pipe until other troublesome beds are encountered and a smaller string of casing must be set in the hole. Drilling is then resumed through the second pipe with a bit of still smaller size. Other strings of casing are set, and the size of the hole again reduced whenever it is necessary. Many wells encounter several water-bearing beds or “cavey” formations; thus it is often necessary to insert several strings of casing before drilling is completed. Consequently the diameter of the hole at the bottom of a well may be considerably smaller than at the top. A producing well does not always contain all the casing inserted when the well is drilled, as the outer strings of casing may sometimes be removed from the well and salvaged after drilling is completed. However, this is not always possible.

The gas from the lowest producing bed is usually conducted to the surface through a pipe, called tubing, which is smaller than the smallest size of casing used in the well. (See Fig. 3.) The tubing is fitted with an expanding device, known as a “packer,” which expands to fit the walls of the hole just above the gas sand. The purpose of packers is (1) to prevent gas from escaping around the tubing and wasting into higher beds, and (2) to prevent water from entering the gas sands. Packers are some-

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Figure 3.—Diagrammatic sketch of a section through a gas well, showing typical formations encountered in drilling; also illustrating the use of casing, tubing, and packers. (The horizontal scale is greatly exaggerated.)
times used on casing for similar purposes. Gas from higher producing beds may be conducted to the surface between the tubing and the smallest casing or between two strings of casing. The fittings at the top of the well are so arranged that the gas from each producing sand is conducted through a separate pipe into the gathering line. These pipes are equipped with check valves, which prevent gas from flowing back into the well if the pressure in the gathering line is greater than that in any one of the producing sands.

It will be noted that in the condition represented by Figure 3 the gas from the lower gas sand is conducted to the surface through the tubing, and the gas from upper sand is conducted between the tubing and the $5\frac{1}{2}$-inch casing.

**GENERAL FEATURES OF NATURAL-GAS SYSTEMS.**

A complete natural-gas system consists of wells which supply the gas, the transmission system which carries the gas to the communities, and the distributing plants which deliver it to the consumers. As each system is planned to meet a different condition, types and arrangements differ widely, but certain general features are common to a majority of them. These features and the course of gas from the wells to consumers' appliances are shown in Plate IV.

The most important parts of a transmission system are the large pipe lines and the stations where the gas is compressed to smaller volume and higher pressure, so that it will flow through the lines. Main transmission lines are shown in Plates V and VI. An exterior view of a compressing station on a main transmission line is shown in Plate VII and an interior view of the same station in Plate VIII. See pages 13 and 14.

**EFFECTS OF THE REMOVAL OF GASOLINE FROM NATURAL GAS.**

Many natural-gas systems are equipped with absorption plants which recover gasoline and remove water from the gas, and consumers are more or less interested in the effect these plants have on the quality of the gas and service they receive. The Bureau of Mines has made a comprehensive investigation of this problem and has published the results of the study. Few readers of this manual will have seen the report, the conclusions of which may be summarized as follows:

The recovery of gasoline from natural gas is true conservation and a benefit to consumers. It saves yearly millions of gallons of gasoline that would otherwise be lost, reduces the heating value of the gas so little that it is impossible to distinguish the difference in ordinary use, and enables gas systems to give better service. Dow says:

There are advantages of utmost importance to gas producers in having gasoline plants located on their high-pressure lines, aside from the value of the

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gasoline recovered. Without gasoline plants, difficulty is experienced from condensation of gasoline and water in the lines: the gasoline condensate and vapor disintegrates the rubber gaskets in couplings with resultant large leakage of gas and lowering of pressure; the water frequently collects in low parts of the line and in cold weather freezes, forming constrictions that reduce the line capacity. These difficulties are met by the installation of traps, where gasoline and water are blown out after collecting. Blowing out, of course, represents waste of both gasoline and gas.

These disadvantages react not only against the producer but the consumer as well, because the best service is not assured when large leaks are continually cutting down the pressure and volume of gas. In conjunction with these disadvantages, the gasoline that has condensed in the line is a total loss both to consumer and producer, and represents a large part of the loss in heat units that a gasoline plant would remove from the gas.

SERVICE INVOLVED IN NATURAL-GAS DISTRIBUTION.

The distribution of natural gas involves the rendering of a service as well as the selling of a commodity, because the distributor is ex-
pected not only to furnish gas, but also to deliver the quantity the consumer wishes whenever he demands it. It is not always possible to fulfill expectations entirely since no more gas can be distributed than is yielded by the wells, and the company can only serve within the limits of supply, as explained on page 4. The demand for natural gas for household use is extremely variable—for example, the quantity of gas used by domestic consumers in January may be six or seven times the quantity used by these consumers in August—and
if good service is to be rendered at all times, the capacity of the wells and the transmission and distribution system must be sufficient to meet the maximum demand. This means that a natural-
gas system largely dependent upon domestic sales must work far below its capacity throughout most of the year. The cost of supplying natural gas includes the expense of standing ready to serve in
addition to the cost of the gas, and payment for natural gas should be on a basis that recognizes both the service and the commodity features and provides that each consumer shall carry his fair share of the burden of cost.

PART II. PREVENTING WASTE IN THE USE OF NATURAL GAS.

CONSUMERS' INTEREST IN PREVENTING WASTE.

Those who can be served with natural gas are fortunate, as this clean and convenient fuel is available only within limited areas and will eventually be exhausted. To make the most of natural gas while it lasts, consumers should avoid wasting it through leakage or inefficient use. Such economy will benefit consumers as saving gas means saving money. Moreover, users of gas can benefit others, because a collective effort to reduce waste will improve the quality of the service during cold weather, when natural-gas systems are working at full capacity. In addition, prevention of waste will help to postpone the depletion of gas fields, thereby delaying the rising cost of supplying natural gas and lengthening the time that it will be available.

PREVENTION OF WASTE FROM GAS LEAKAGE.

Small leaks in house piping and appliances waste more gas than is usually realized, as a leak wastes gas every minute of the day, and a leakage of 1 cubic foot per hour means 8,760 cubic feet per year. Such leaks are also a source of danger from explosions and fires. Most gas meters have a small dial indicating one-half, 1, or 2 cubic feet of gas per revolution of the hand, and one of the uses of such dials is to detect leakage. From time to time, consumers should shut off all appliances and note whether the hand on this dial moves during a period of two or three hours. Meters do not move unless gas is passing through them, hence if the hand continues to move it is conclusive evidence that gas is leaking somewhere on the premises. Gas leaks may be found by brushing the pipe and appliances with soapy water, as escaping gas will form bubbles. Fire should never be used in searching for leaks, as this is dangerous. Leaks may be stopped temporarily if they are covered with soap and the pipe wrapped with tape or a cloth bandage, but a pipe fitter should be called immediately to make permanent repairs.

SIMPLE WAYS OF SAVING GAS.

Users of natural gas should burn gas only when it does useful work. Gas may be saved in the following ways:

1. Correct temperature should be maintained by the aid of thermometers or thermostats, as keeping a house too hot is wasteful of gas and injurious to health. A thermostat is a device for the auto-

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6 For a discussion of safety in the use of gas, see Safety for the household: U. S. Bureau of Standards Circular 75, 1918, pp. 54–56.
matic regulation of temperature. Thermostats on gas appliances regulate temperature by controlling the flow of gas to the burners. The correct temperature for living rooms varies somewhat with individuals and conditions, but it is generally considered to be about 66° to 68° F.

2. Many families can save gas without inconvenience by using fewer rooms during cold weather than at other times.

3. A cooking utensil should be ready to be placed over the burner before it is lighted, and the gas should be turned off when cooking is completed.

4. When water has come to a boil, the fire should be turned down or the vessel moved to a smaller burner, and just enough heat should be supplied to keep the water boiling. Water can not be made any hotter than boiling, consequently violent boiling does not hasten cooking. It causes needless evaporation of water and thereby wastes gas.

5. Cooking utensils should be covered whenever practicable.

6. No more water should be heated than is needed.

7. The careless, wasteful use of hot water should be avoided, and leaky hot-water faucets should be repaired immediately.

8. Gas lamps should be burned only when they are needed.

**PREVENTING WASTE BY EFFICIENT USE OF GAS.**

**COMBUSTION (BURNING) OF GAS.**

When a mixture of gas and air is ignited, as by a flame or spark, the gas burns by uniting chemically with oxygen from the air, and this chemical action liberates heat. About 10 cubic feet of air is required to furnish enough oxygen to burn 1 cubic foot of natural gas. If the gas is completely burned, all of the available heat is liberated and only water vapor and a gas called carbon dioxide are formed.

If a gas flame is not supplied with a sufficient quantity of fresh air, or if the mixture of gas and air is chilled by coming in contact with a relatively cool surface before all of it has an opportunity to ignite, the gas is not completely burned. Incomplete combustion results in a loss of some of the available heat and is accompanied by one or more of the following conditions:

1. Part of the gas escapes unburned.

2. Soot (carbon) is deposited.

3. A very poisonous gas (carbon monoxide) is produced.

4. Disagreeable gases (aldehydes), especially irritating to the eyes and nostrils, are produced.

The poisonous gas, carbon monoxide, has no odor; but as this gas and the aldehydes are produced under similar conditions, appliances that give off bad odors are likely to be dangerous.

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The production of water vapor and carbon dioxide is not peculiar to the combustion of natural gas. These same substances are produced by the combustion of manufactured gas and other fuels, and are also exhaled from the lungs. Nor is carbon monoxide peculiar to the incomplete combustion of natural gas, for it is contained in manufactured gas and may be produced by the incomplete combustion of manufactured gas or solid fuels. Carbon monoxide is the substance that causes the most serious effects when one is asphyxiated by manufactured gas or "furnace gas." When manufactured gas is completely burned all the carbon monoxide it contains unites with oxygen from the air to form carbon dioxide.

**IMPORTANCE OF VENTILATION AND FLUES.**

All fires use oxygen, and as oxygen is necessary to life it is important that all rooms containing fires be so ventilated that the oxygen will be replaced. Small quantities of the carbon dioxide and water vapor produced by complete combustion are not particularly objectionable, but air containing a considerable quantity of carbon dioxide can not be breathed, and water vapor sometimes causes trouble by making the air too moist or by condensing to form water. Condensation of water vapor causes "sweating" of walls and windows, is injurious to glued furniture, and may cause rusting of appliances and fixtures. Gases produced by incomplete combustion are always objectionable and often dangerous.

Many gas appliances, including some well-constructed room heaters, are safe to use without flue connections in well-ventilated rooms. However, it is advisable that all appliances using gas in considerable quantities be connected to flues, to carry away the ordinary waste gases and to provide escape for unburned gas if the fire is accidentally extinguished or for poisonous and disagreeable gases if they are formed. Water heaters should always be connected to flues, for even the most efficient types may produce poisonous gas when the flame is first lighted.

In some cases a flue pipe from a gas appliance must be fitted with a damper to prevent excessive draft or interference with the draft for another appliance. Such a damper should fit the pipe loosely, or have holes through it, so that the flame will not be smothered if the damper is accidentally left closed when the appliance is lighted.

**PRINCIPLES OF EFFICIENT USE OF GAS.**

The principles of the efficient use of gas are:

1. "The gas must be completely burned.
2. The heat liberated must be transferred with the least possible loss to the air, water, food, mantle, or other substance that is being heated.
If gas is completely burned, all of the available heat is liberated, but this does not necessarily mean that the greatest possible benefit is being derived from the gas. Heat that goes out the chimney or escapes in other ways does not benefit the consumer; therefore such losses should be reduced as much as possible. Appliances should be so designed and operated that the gases from the flame will transfer their heat and be relatively cool when they leave the appliance.

Furnaces, furnace piping, water heaters, water tanks, and ovens should be properly insulated to prevent the escape of heat. The best insulating substance known is air confined in small pores or cells, so that heat can not be removed by air currents. No covering is better than that of perfectly still or "dead" air; and the value of most insulating substances depends upon the power of holding small quantities of air in such a manner that circulation can not take place. As a rule the gas companies will be able to inform consumers concerning proper insulation and where it may be obtained.

**GAS BURNERS.**

Gas burners are of two general types—luminous-flame burners and the more widely used Bunsen or blue-flame type. Although the latter are the more widely applicable, each type of flame has its own field of usefulness, and if combustion is complete, each generates the same amount of heat from a given quantity of gas.

**LUMINOUS-FLAME BURNERS.**

If gas is forced through a small hole into the atmosphere, the air required for complete combustion is drawn into the stream of gas and it can be burned with a large yellow flame. This is the principle of the luminous-flame burners used in open flame gas lamps and in several types of reflector stoves and grates. To obtain complete combustion with such burners the adjustment should be such that the flames do not come in contact with any solid body, and do not hiss and roar, but burn steadily and quietly. Figure 4 shows a section through a reflector stove equipped with a luminous-flame burner.

As the holes in luminous-flame burners must be small, they are not well adapted to appliances that burn gas in large volumes; and as carbon is deposited and disagreeable and poisonous gases may be formed when luminous flames touch solid bodies, these flames are not used in cooking stoves and similar appliances.

**BLUE-FLAME (BUNSEN) BURNERS.***

Blue-flame burners are well adapted to appliances that burn gas in large volumes, and to appliances in which the flames may come

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in contact with solid bodies. In such burners, some air (called primary air) is mixed with the gas before it reaches the flame, and the remainder of the air required to complete the combustion (called secondary air) is taken from the atmosphere surrounding the flame.

The operation of a blue-flame burner is illustrated by Figure 5, A, which shows a gas cock fitted with a common type of adjustable spud inserted into the mixer of a burner. When the gas cock is open the pressure in the gas pipe forces the gas through the small hole in the spud. In passing through this hole, the gas acquires relatively high velocity, which creates a sucking action that draws air into the mixer. The velocity of the gas carries the gas and air through the tube, where they are mixed before they pass through the burner ports to the flames. The heat generated by the combustion creates air currents which supply the secondary air.

Figure 4.—Section through a reflector stove equipped with a luminous-flame burner.
The adjustable spud may be turned with a wrench to bring it closer to, or farther from, the stationary cone on the end of the gas cock. With a fixed pressure in the gas line, turning the spud increases or decreases the quantity and velocity of the gas passing to the burner when the gas cock is wide open. The supply of primary air is regulated by turning the air shutter. The spud and air shutter should be adjusted so that the flame is of proper size and character when the gas cock is wide open. When a smaller flame is desired it can be obtained by partly closing the gas cock.

Figure 5, B, shows a gas cock equipped with a stationary spud. This spud can not be adjusted, but can be removed and replaced with one having a larger or smaller hole.

It will be noticed, especially at burners with long mixing tubes, that the gas does not ignite at the instant it is turned on. The
reason is that the mixing tube and burner are full of air, and this air must be forced out before the gas can be ignited.

Blue-flame appliances must be properly adjusted if gas is to be burned efficiently, and the burners and mixers must be kept clean. When a blue-flame appliance is in proper condition and correctly adjusted, the gas burns with a steady blue flame in which two distinct parts are visible—a pale blue inner part and an outer part of darker shade. If the holes in the burner are round, these two parts are seen as two cones, one within the other, as illustrated by Figure 5, C. Flames from a sawed or slotted burner show a thin pale-blue arch within an arch of darker shade. If the inner pale-blue part of the flame comes in contact with a relatively cool surface, such as a cooking utensil, the combustion is incomplete, and poisonous and disagreeable gases are formed. The position at which the inner part of a flame will touch a cooking utensil can not be determined by observing the flame before the utensil is placed over it, as the inner part often becomes larger when the flame is covered.

A yellow flame from a burner of the blue-flame type indicates that the supply of primary air is not sufficient. Such a flame is wasteful and deposits soot. The trouble can probably be corrected by opening the air shutter or cleaning the mixer. If the flames tend to blow away from the burner, they can usually be brought back by partly closing the gas cock or the air shutter. Flames that blow away from the burners of gas ranges will often return when cooking utensils are placed over them.

Burners of faulty design, or clogged with dirt, or too small for the amount of gas being burned, can not be adjusted to give correct flames. If appliances give trouble, the burners and mixers should be thoroughly cleaned, then if difficulty is experienced in obtaining the correct adjustment the gas company should be consulted.

HOUSE HEATING.

FURNACES AND BOILERS.

If natural gas is to be used in main heating appliances, it should be burned only in boilers or furnaces with correctly designed burners, air ports, and heating surfaces. Careful attention should be given to the adjustment of the air supply; if too little air passes to the flames the gas is not completely burned, while on the other hand excess air dilutes the products of combustion, reducing their temperature and decreasing the quantity of heat they give up to the water or air in the boiler or furnace.

When coal is burned, heat must be sacrificed to obtain sufficient draft to draw air through the fuel bed, and the flue gases are usually fairly hot when they leave the heating apparatus. Less draft is required for gas, therefore well-designed gas furnaces and boilers provide for close regulation of the air supply, and are built with long
fire travel," so that more of the heat is recovered and the flue gases are discharged at a lower temperature. The use of gas in the fire pots of ordinary coal stoves or furnaces is not recommended, because this method of burning gas is usually very wasteful when compared with burning it in well-designed gas appliances. If gas is burned in ordinary fire pots, great care should be taken to prevent dilution of the products of combustion by excessive supplies of air.

Those using gas in furnaces and boilers should give careful attention to the following suggestions:

1. Flues and chimneys should be unobstructed, and the latter should be high enough for proper draft. Flues should be fitted with some form of back-draft diverter. A back-draft diverter is a device for preventing "down drafts" from smothering or extinguishing the flames. The names "automatic draft regulator," "draft hood," "back-draft hood," and "safety collar" are applied to various forms of back-draft diverters. Some of these devices also aid in preventing excessive "up drafts."

2. All parts of the burners should be kept clean, and they should be adjusted to give steady blue flames.

3. The supply of air should be just enough to provide for complete combustion. An excessive supply of air causes loss of heat through the chimney.

4. Heating surfaces should be clean, as soot or dirt prevents the efficient transfer of heat.

5. The appliances and distributing pipes should be well insulated to prevent heat waste.

6. A thermostatic control saves gas and aids in maintaining proper house temperature.

INCIDENTAL HEATING APPLIANCES.

To use gas efficiently and safely in room heaters, it is necessary to secure complete combustion, provide for proper ventilation, and prevent unnecessary heat loss. Flue vents for room heaters are usually advisable, but heaters should be so designed and operated that the flue gases are relatively cool when they leave the rooms. When heaters with burners of the luminous-flame type are used (see Fig. 4), the reflectors should be bright, the burner tips should be unobstructed, and the burners and draft should be so adjusted that the flames do not touch any part of the heater and do not blow at the tips. When heaters with burners of the blue-flame type are used, all parts of the burners and mixers should be kept clean, and they should be adjusted to give steady blue flames.

Figure 6 illustrates the construction and operation of a type of blue-flame heater in which the flames burn within elements that radiate the heat. Most of these heaters are equipped with mixers that introduce a high proportion of primary air, and with grids or
screens which break up the flow of the mixture as it issues from the burners. The effect of these features is almost to eliminate the pale-blue inner parts of the flames. To use such a heater at its full capacity, the gas valve and needle valve should be adjusted to produce sharp blue flames that make the radiating elements incandescent throughout their length without burning above their tops. When less heat is desired, the gas should be turned down at the gas valve. Heaters of this type are usually vented to flues by setting them in fireplaces, but some are provided with flue-pipe connections.

**Figure 6.—Sketch illustrating the construction and operation of one type of blue-flame heater.**

**WATER HEATING.**

To use gas efficiently in heating water, it must be completely burned, and the heat must be transferred to and retained in the water. Figure 7 shows a coil heater, and illustrates some of the features that make for efficiency in water heaters of the circulating type. The arrangement may be quite different from that shown, but the principles are always the same. Attention is directed to the features which follow.

1. The size and design of the burner should be such that proper flames can be obtained at the maximum and minimum rates of gas consumption.

2. The coils or other heating surfaces should be such that the flue gases are relatively cool when they leave the heater.

3. The heater should be connected to a flue equipped with some form of back-draft diverter.
4. Both the heater and the tank should be insulated.
5. The cold water should be introduced near the bottom of the tank. If the cold-water connection is at the top of the tank, a cold-water tube should extend nearly to the bottom.

![Diagram of a heater system]

**Figure 7.**—Sketch of coil heater, illustrating features that make for efficiency in circulating-water heaters.

6. The hot-water connections should be at or near the top of the tank.
7. The lower connection to the heater should be a little above the bottom of the tank to prevent sediment from collecting in the pipe.
8. A thermostatic control valve on the gas supply is a gas saver and a great convenience.
Many ordinary hot-water tanks with ring burners underneath are still in use. These are usually inefficient and likely to produce poisonous and disagreeable gases. However, if such a heater is covered with a sheet-iron jacket, as shown in Figure 8, its efficiency is increased and the products of combustion are carried away. The inside diameter of the jacket should be about 2 inches larger than the outside diameter of the tank, leaving an annular space of about 1 inch through which the products of combustion pass to the flue. The jacket should extend below the burner, and be fitted with a bottom having shutters to regulate the supply of air. These shutters should be adjusted to admit just enough air to complete the combustion. Provision must, of course, be made for lighting and observing the flames. When a tank is covered in this way, the gases from the flames are conducted to the flue through the annular space around the tank instead of escaping into the room, and the heat transfer to the water is greatly increased. If the jacket is covered with insulating material (see Fig. 8), radiation is prevented and the heater is made still more efficient. When the flame is extinguished, the air shutters in the bottom of the jacket should be closed to prevent cooling of the stored water by currents of air passing through the annular space.

When water heaters are operated attention should be given to the following:

1. The burners and mixers should be clean and adjusted to give short blue flames. If the flames are long, so that the inner pale-blue parts are cooled by impinging upon the heating surfaces, the combustion is incomplete, and objectionable gases are produced.

2. In instantaneous heaters the flames should be as low as is consistent with rapid service at the faucets. Pilot lights may be yellow, but should be turned low, so that they do not deposit soot.

3. Soot on heating surfaces will prevent transfer of heat. Heating surfaces should be kept clean, and if soot is deposited the cause should be found and corrected.

4. Scale or sediment inside of heating surfaces will also prevent transfer of heat. Heaters should be drained frequently.

COOKING.

The following suggestions are presented to help consumers use gas efficiently in cooking:

1. The burners should be clean and adjusted to give short blue flames; yellow flames deposit soot.

2. If the tips of the flames are below the cooking utensil, the transfer of heat is not efficient. If the utensil is placed low on the flames, so that it touches the pale-blue parts, poisonous gases are produced. The best results are obtained when the outer parts of the flames touch the utensil and spread out slightly.
3. Most of the heat transferred to a cooking utensil comes from the higher parts of the flames; consequently, short flames use gas more efficiently than long ones. In order that short flames may be used, the burners should be close to the utensils. If the burners are more than 1 1/2 inches below the utensil, the gas company should be consulted about having them raised.

4. It is wasteful to allow the flames to lick up around the sides of the utensil. The size of the flames can always be reduced by partly closing the gas cock.

5. A solid lid between the flames and the utensil reduces the transfer of heat; consequently, gas ranges should be equipped with grid tops or skeleton lids, and the flames should be applied directly to the utensils.

6. Flames should be protected from side drafts.

A canopy over a gas range is a desirable feature, as it serves to remove the odors of cooking as well as the products of combustion. To serve its purpose a canopy must, of course, be connected to a flue.

Oven burners and vents should be so adjusted that the gas is completely burned and the products of combustion are carried away without unnecessary loss of heat. Closing the vent to an oven smothers the flames and may cause an explosion. On the other hand, an excessive quantity of air passing through an oven carries away heat. A thermostatic control saves gas and aids cooking. Condensation of moisture can be prevented by leaving the oven door slightly open for a few minutes after the burners are lighted. Ovens and burners can be protected from rust by applying oil or grease, free from salt, while they are warm.

LITHTING.

In an incandescent mantle lamp, a flame from a burner of the blue-flame type heats a mantle to incandescence, thereby producing light. Such lamps give the same amount of light with one-half to one-third the amount of the gas required by an open-flame burner. Most mantle lamps are equipped with a needle valve to regulate the gas and a shutter to regulate the air, and these should be adjusted to obtain maximum illumination and quiet burning. A hissing or roaring lamp wastes gas and destroys the mantle. When a mantle is replaced, all parts of the burner should be examined and, if dirty, cleaned.

OTHER USES OF NATURAL GAS.

Although this manual is written primarily for those who use natural gas in their homes, it may not be amiss to stress the necessity for the highest attainable efficiency in other uses of this gas. The larger consumers of gas usually have trained employees who burn gas more efficiently than domestic users; however, by proper care and adjustment of appliances many such consumers can obtain even
more service from the gas they use. All who use gas in large quantities should satisfy themselves that their appliances are of correct design, in first-class condition, and correctly adjusted; and they should not hesitate to make reasonable expenditures to attain these ends, as such expenditures will soon be returned in gas saved.

USE OF GAS DURING PERIODS OF LOW PRESSURE.

As the pressure in a distributing plant depends upon the quantity of gas in the pipe lines, normal pressure can not be maintained unless gas can be put into the plant as fast as it is taken out; therefore, if consumers try to use more gas than the wells or the transmission system can deliver, the pressure in the distributing mains must fall. In some localities the use of gas for heating creates a maximum demand that is greater than the available supply and in such places periods of low pressure will occur during cold weather unless gas is used more efficiently or other fuels are used in the main heating appliances. Such conditions can be improved by using appliances that can be adjusted to operate at low pressures, by using gas more carefully, and by substituting other fuels.

Reduced pressure in distributing plants does not change the quality of the gas and makes only a slight difference in the weight of gas contained in a cubic foot. It is likely that during cold weather a cubic foot of gas under a lower pressure may contain more heat units than a cubic foot of gas under higher pressure during warm weather, because the decrease of gas volume through lower temperature often exceeds the increase of volume through reduced pressure. As pointed out in other publications, changes in distribution pressure have no appreciable effect on the accuracy of gas meters. Therefore, if the gas is completely burned, changes in pressure make practically no difference in the amount of heat the consumer obtains from each 1,000 cubic feet registered by the meter.

The effect of reduction in pressure is to decrease the rate at which gas will issue through a hole of given size. Consequently, if no change is made in the adjustment of the burner, an appliance burns less gas at low pressure than at normal pressure, and therefore pro-

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9 At the pressures ordinarily carried in natural-gas distributing plants, the weight of gas in a cubic foot is decreased less than 1 per cent by a decrease of 2 ounces in gage pressure, and is increased about 1 per cent by a decrease of 5° F. in temperature. Therefore, a cubic foot contains a little more gas at a gage pressure of 1 ounce and a temperature of 45° F. than at a gage pressure of 3 ounces and a temperature of 50° F. A reduction in gage pressure from 8 ounces to zero will decrease the weight of gas in a cubic foot by about 31 per cent, whereas a fall in the temperature of the gas from 60° to 40° F. will increase the weight by about 4 per cent.

duces less heat. Furthermore, an appliance adjusted to use gas efficiently at normal pressure may be inefficient at other pressures.

It is evident that if the demand for gas is greater than the available supply, some consumers cannot get all the gas they want. However, with modern appliances adjusted for low pressure, they can usually get effective service from the gas they burn, even though it may not be sufficient to meet their needs or desires completely. To adjust appliances for low-pressure conditions, adjustable spuds (see Fig. 5, A) and needle valves (see Fig. 6) should be opened up to increase the flow of gas, and fixed spuds (see Fig. 5, B) should be replaced with others that have larger holes. The air shutters should

![Figure 9](image)

**Figure 9.—Sketches showing how nails or pieces of sheet iron may be placed in burners to bring cooking utensils to proper position for effective service at low pressure (after U. S. Fuel Administration).**

then be adjusted to give correct flames. The appliances must, of course, be readjusted when the pressure again becomes normal. Ordinary cooking operations can be carried on satisfactorily at pressures considerably lower than the normal pressure of most distributing plants if the tips of the flames are applied directly to the utensils. When the pressure is so low that the flames are very short, a utensil may be supported close to the burner by nails inserted in drilled burners or pieces of sheet iron placed in slotted burners, as shown in Figure 9. When this is done, the burners must be well supported so that they will bear the weight of the utensils.

**PREVENTING WASTE BY REDUCING DISTRIBUTION PRESSURES.**

On account of the large volumes of gas handled by natural-gas systems and the pressure necessary to transmit this gas, it has been the
practice to distribute natural gas at higher pressures than those usually carried in plants distributing manufactured gas. Natural-gas appliances have been adjusted for these pressures, and when the pressure is low consumers have difficulty in obtaining service. These high distribution pressures are conducive to waste, and with proper appliances correctly adjusted lower pressures give satisfactory service. Operating conditions make the regulation of pressure in natural-gas distribution more difficult than in manufactured-gas plants; but if (wherever economically practicable) the normal distribution pressures in natural-gas plants are reduced more nearly to those carried in manufactured-gas distribution, and appliances are adjusted to operate at these pressures, leakage will be reduced in the plants and on the consumers' premises, gas will be used more efficiently, and service will be more satisfactory and more uniform. Such a reduction in pressure makes little difference in the quantity of gas contained in a cubic foot. For example, with atmospheric pressure at 14.4 pounds per square inch, 1,000 cubic feet of gas at 6-ounce pressure contains the same weight of gas as 1,008½ cubic feet at 4-ounce gage pressure or 1,017 cubic feet at 2-ounce gage pressure.

NEW HOUSES AND NEW EQUIPMENT.

In many homes the house piping is too small for adequate service. Those building new houses should be sure that the piping is of adequate size and that proper flues are provided. In most localities it will be advisable to construct the flues so that other fuels can be used if the gas is exhausted or becomes too scarce for heating.

When new equipment is purchased, practical and efficient appliances should be selected. The burner is the most important part of any appliance, and to give satisfaction it should be of a type that can be adjusted to operate efficiently at low pressures. It should also give proper flames, without readjustment, over a considerable range of pressure.

RESPONSIBILITY FOR EFFICIENT USE OF GAS.

The responsibility for the efficient use of gas lies primarily with the consumers, for the use customers make of gas is beyond the control of the gas companies. However, the companies should always be ready to assist their customers in preventing waste of gas. For this purpose many of them maintain service departments, with trained employees whose duty is to advise and assist the customers. Consumers of natural gas should therefore ask their gas companies to show them how to get greater benefit from the gas they burn.