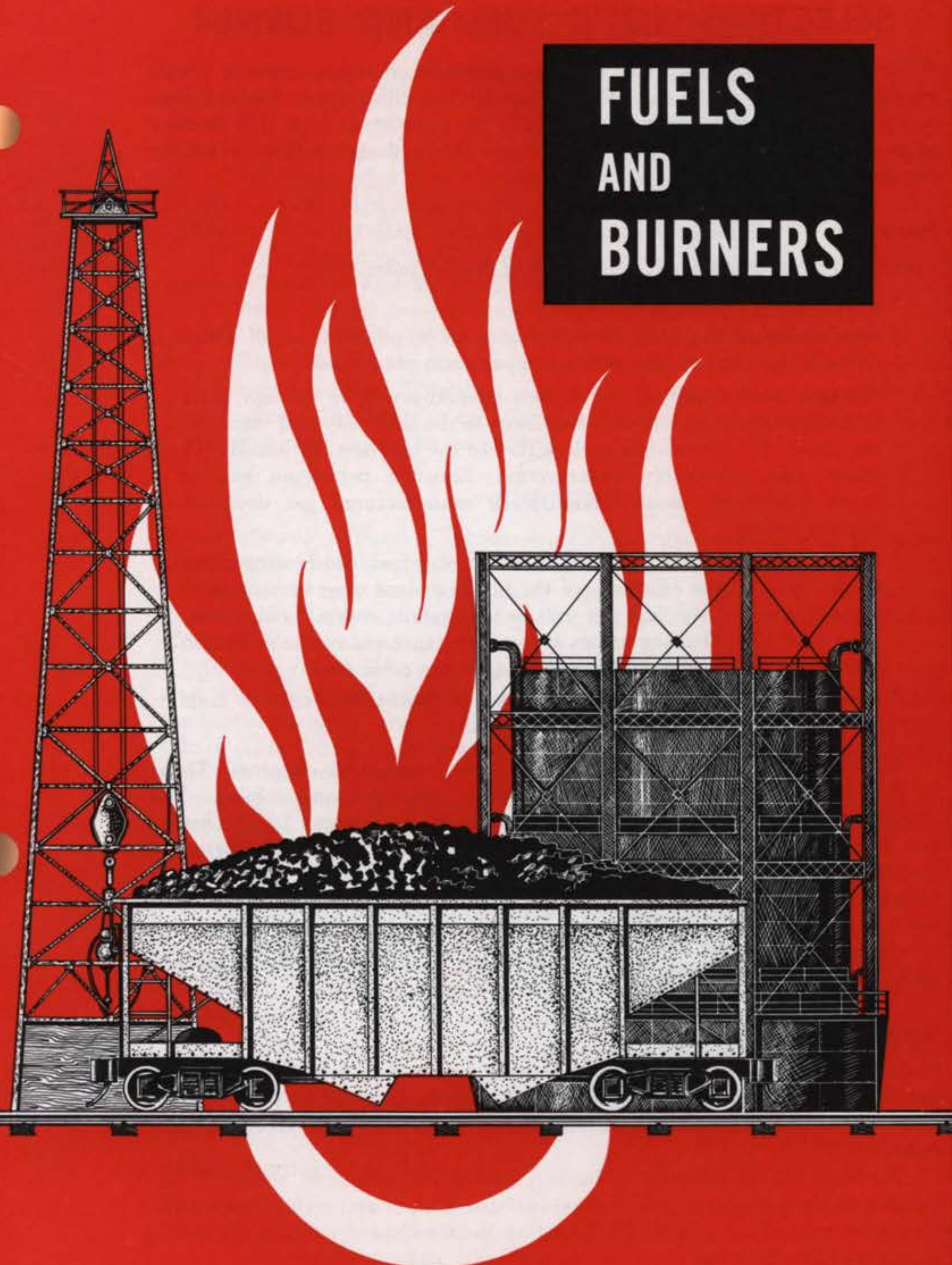
CIRCULAR SERIES

INDEX NUMBER G3.5

FUELS AND BURNERS



FUELS AND BURNERS
SMALL HOMES COUNCIL G3.5

ISSUED BY THE SMALL HOMES COUNCIL

UNIVERSITY OF ILLINOIS BULLETIN

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REVISED EDITION, 1953, BY J. R. FELLOWS, DEPARTMENT OF MECHANICAL ENGINEERING

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SELECTING YOUR FUEL AND BURNER

Before you purchase any home heating equipment, it is important to decide on what fuel you want to use. The highest heating efficiency is obtained from fuel-burning equipment designed especially for a particular fuel. The decision as to fuel should be made while the house is being designed because storage requirements for a fuel may affect the plan.

Fuels

Factors which will influence your choice of fuel include:

- **Convenience offered by the fuel.**
- **Availability of the fuel.** Not all fuels can be obtained in all areas. Consult fuel dealers and utility companies in your locality.
- **Storage space required.** Solid fuels generally require storage space within the house at a point convenient to the driveway and the heating plant. Oil is stored in tanks either in the basement or outside the house area, preferably underground; liquefied petroleum gas, in tanks outside the house. Natural or manufactured gas does not require storage.
- **Cost of fuel.** To determine the true cost of a fuel, the heating value of the fuel and the efficiency of the heating plant must be related to the sale price of the fuel per unit — ton, gallon, therm,* cubic foot. (See page 12.) Heating values are usually expressed in Btu's (British thermal units*) per pound, per gallon, or per cubic foot.
- **Cost of the heating plant.** As in other equipment, maintenance costs must be considered as well as initial cost.

All the different fuels contain the same three combustible elements. These, in the order of their importance, are carbon, hydrogen and sulphur. The heating values in Btu per pound for these elements are carbon, 14,540; hydrogen, 62,000; and sulphur, 4,050. Solid fuels contain the greatest proportion of carbon, and natural gas, the smallest proportion. While the sulphur contributes to the heating value of a fuel, its presence is undesirable because the sulphur dioxide formed by its combustion is irritating to humans, detrimental to vegetation, corrosive to exposed metals, and harmful to the strength of mortar in unlined brick chimneys.

Burners

Burners have been designed for the various types of fuels — coal, coke, oil, gas, liquefied petroleum gas. These burners can be installed in furnaces (for warm-air heating systems) or in boilers (for hot-water or steam heating systems).

To help you in selecting a burner, safety and efficiency standards for equipment have been set up by several fuel associations and technical societies. Seals of approval are frequently placed on the equipment to show that these standards have been met.

To give the most efficient service, a fuel burner should be:

- **Purchased in the correct size.** For a house under construction, the heat loss should be estimated by a competent person before the burner is selected. In replacing a burner in an existing house, the performance of the old burner can be used as a guide to size. If its performance has been satisfactory, buy a new one having the same capacity.
- **Competently installed.** No equipment can perform efficiently unless it is correctly installed.
- **Properly maintained.** The life of mechanical equipment depends largely on careful maintenance. Equipment should be inspected and cleaned annually. Do not tamper with the equipment or controls — call a service man when something goes wrong.

* A British thermal unit is the heat required to raise the temperature of one pound of water one degree Fahrenheit. A therm is equivalent to 100,000 Btu.

OIL AND OIL BURNERS

Fuel oil is commercially available in five grades, numbered 1, 2, 4, 5, and 6. (No. 3 oil has been discontinued as a separate grade.) No. 1 oil is a transparent fluid similar to kerosene. It is more expensive and has a lower heating value per gallon than the other grades. As the classification number increases, the oil becomes darker and less fluid, and the heating value per gallon increases — from 136,000 Btu for No. 1 oil to 152,000 Btu for No. 6 oil. Oils numbered 4, 5, and 6 are used only in industrial burners.

Oil tanks should be installed in accordance with recommendations of the National Board of Fire Underwriters and local ordinances. Tanks are commonly located in the basement above the level of the burner. These tanks should not exceed 275-gallon capacity and should be 7 feet or more from any flame. They should be vented to the outside and should have an outside fill-pipe connection. Two 275-gallon tanks are the maximum storage allowed in the basement. For larger installations, tanks must be outside the area of the house, preferably buried in the ground.

BURNERS

Three types of oil burners are manufactured — the pressure-type, the rotary type, and the vaporizing type.

The burner you buy should carry the seal of approval of the National Board of Fire Underwriters showing that it has met safety standards. Use oil of the grade shown on that label.

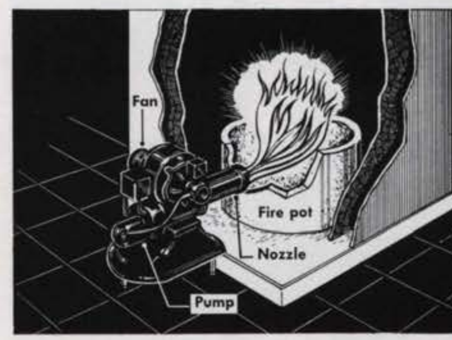
All burners should be installed by an experienced service person in accordance with the manufacturer's instructions. He should also inspect and clean the burner annually, and should be called on to make any adjustment of the rate of oil-feed or air supply which is necessary to provide a non-smoky flame free from soot and odors.

All oil burners (particularly the vaporizing type) require a small but steady draft. This should be provided by an automatic draft regulator installed in the vent pipe.

Pressure-Type Burner

The pressure-type burner consists of 1) a pump and a nozzle which spray the oil into a fine mist, and 2) a fan which provides a stream of air which mixes with the oil before it enters the firepot. This mixture of oil and air is ignited by an electric spark when the burner is turned on. The burner is not operated continuously but is turned on or off in accordance with the demands of a room thermostat.

This type of burner usually projects outside of the furnace or boiler, making it readily accessible for servicing. Oil as heavy as grade No. 2 may be used.

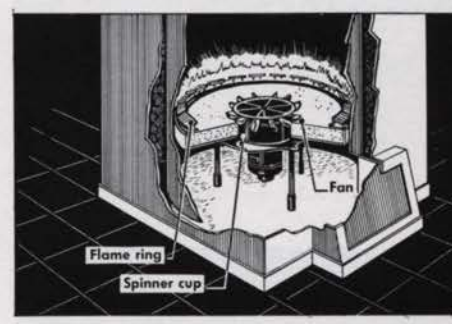


Pressure-type oil burner

Rotary Burner

The rotary burner consists of a horizontally spinning cup (or a set of tubes) which sprays the oil by centrifugal force. The oil spray is further broken up and mixed with air by a fan which is attached to the underside of the spinner. As in the pressure-type burner, the mixture is ignited by an electric spark when the burner is turned on. The burner is turned on or off in accordance with the demands of a room thermostat.

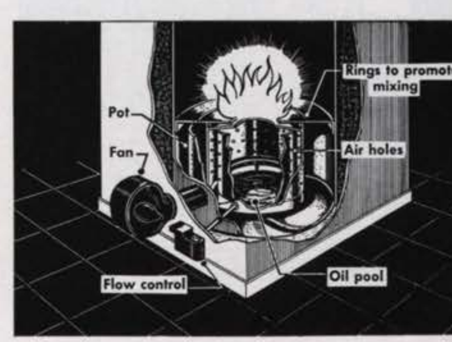
As the entire unit is located inside of the furnace or boiler, this type occupies less floor space than the pressure-type but is not as accessible for servicing.



Rotary oil burner

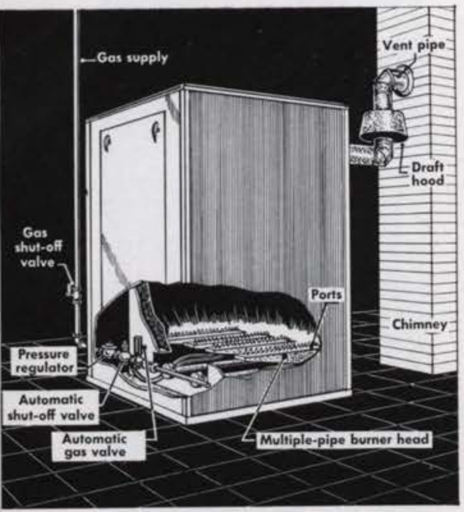
Vaporizing Burner

The vaporizing or pot-type burner consists of a pot containing a pool of oil and a control which regulates the oil flow. Heat from the burning process vaporizes the oil. The air necessary for burning is drawn into the vapor above the oil pool by natural draft or is forced in by a very small fan. There are few moving parts, and the burner operates quietly. The fire is started manually with oily waste, after which a low pilot flame keeps the fire alive. When heat is needed, more oil is fed into the pool and a hot flame results. Careful adjustment of both fuel and air is necessary in order to avoid a smoky, sooty flame. The initial cost of this burner is lower than for other types.

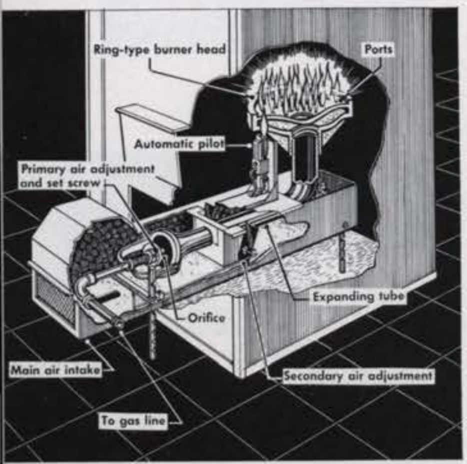


Vaporizing oil burner

GAS AND GAS BURNERS



Gas burner with multiple-pipe burner head



Detail of ring-type gas burner

When gas is used as a fuel, gas pressure is maintained by a central gas plant, and no storage facilities are necessary on the customer's premises. The cost to the homeowner of installing gas pipe from the street mains to the burner depends upon local utility practice, and on the distance between the main and the burner. Consult your utility company for an estimate of these piping costs.

Natural Gas

Natural gas has a heating value ranging from 960 to 1550 Btu per cubic foot depending on the location of the wells from which it is obtained.

In some areas, bills for natural gas are rendered in terms of therms (100,000 Btu). The number of therms of gas used is obtained by multiplying the number of cubic feet consumed by the accepted heating value per cubic foot and then dividing this product by 100,000.

Coke Oven Gas

Gas for domestic and industrial use in communities which are not served by pipe lines from gas wells can be produced locally in special plants by heating bituminous coal; coke is produced as a by-product of the process. The heating value of manufactured gas varies from 460 to 650 Btu per cubic foot, the average value being approximately 565.

BURNERS

Practically all gas burners for homes operate on the same principle. Gas fuel is supplied at low pressure into the burner where it is mixed with the air required for burning. The combustion forms hot gases which pass through the furnace or boiler and give up heat to the air or water to be circulated in the heating system. The gases then pass into the vent pipe and the chimney.

The design of burner heads varies. Some are made up of multiple rows of straight pipe with slots or with holes (ports) spaced at regular intervals. Others are ring-type with either ports or slots.

The rate at which gas is supplied to the burner head is controlled by an automatic gas valve and an orifice (a small opening in the plug at the end of the supply pipe). The gas valve operates in accordance with heat demands of the room thermostat.

The pressure of the gas is controlled by an automatic pressure regulator which reduces the gas pressure from the main supply lines to the exact amount needed in the burner.

In most models, a pilot burner is lighted at the beginning of the heating season and this flame is maintained continuously. When a demand for heat occurs, a large gas flow is introduced automatically to the main burner through the gas-control valve and a large fire is obtained. If the pilot flame is extinguished, an automatic cutoff shuts off the flow of gas.

A draft hood is required in the vent pipe to prevent excessive draft and also to prevent air currents from coming down the chimney and blowing out the pilot flame. The hood also helps to keep moisture from condensing in the chimney or in the vent pipe by introducing air which dilutes the water vapor formed during the combustion of the gas.

Aside from the operating controls, a gas burner has no moving parts. Gas burners are quiet in operation, and relatively long in service life.

Conversion gas burners can be installed in existing boilers and furnaces. These installations should be made by a competent installer in strict accordance with instructions of the burner manufacturer. Furnaces and boilers designed especially for the use of gas are usually more satisfactory than conversion installations. The initial cost of a furnace or boiler designed for use with gas is relatively low.

Gas-burning equipment should bear the American Gas Association's seal of approval. The final adjustment of the various valves and controls should be either made or checked by a service man from the gas company.

LIQUEFIED PETROLEUM GASES — BUTANE AND PROPANE

Fuels of the butane and propane types are transported, sold and stored under pressure in the liquid state, but they are burned as a gas. They bring the convenience offered by gas to homes not served by pipe lines.

Two types of service are available to customers using this fuel.

In one type, two small tanks are installed. Gas is drawn from one tank until it is empty. The connection to the burners is then switched, either manually or automatically, to the other tank. (In the latter case, a signal indicates the switch.) The customer notifies the dealer when a switch has been made, and the empty tank is replaced without any interruption of the service. The fuel supplied this way is usually sold by weight.

In the other type of service, a much larger tank is installed, and the liquid-fuel level is indicated by a float-operated gage. When the gage shows that the level is low, the customer notifies the dealer and the tank is refilled by pumping liquid fuel into it from a special tank truck. When liquefied petroleum gas is so supplied, the fuel is usually sold by the gallon, and the amount supplied is measured by a meter installed on the tank truck.

The heating value of these liquefied gases ranges from 21,000 to 22,000 Btu per pound and from 90,000 to 105,000 Btu per gallon. The heating value per gallon is considerably lower than that of fuel oil.

BURNERS

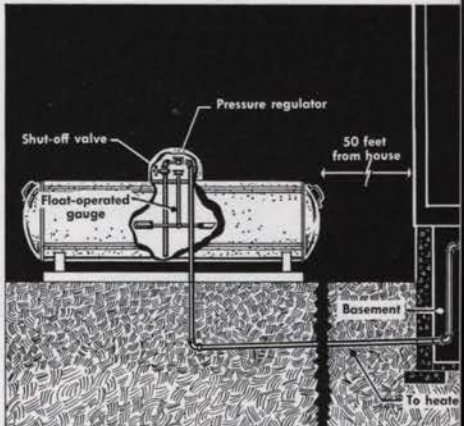
Burners for liquefied petroleum gases are similar to those used for burning other kinds of gas, the principal differences being:

- The pipe bringing the fuel to the burner is attached to a storage tank instead of to a gas main.
- The pressure regulator is usually required to operate against a much higher pressure in the pipe line than is the case with natural and manufactured gases.
- The orifice, which feeds the fuel into the air-mixing chamber of the burner, must be a smaller size. (See page 4.)

The compressed liquefied gases are delivered to the burner from the bottle-shaped metal tank stored outside the house.

Gas pressure in the upper part of the tank is maintained by evaporation of liquid in the lower part. When gas is drawn from the top of the tank for use in heating (or cooking appliances), the pressure is momentarily reduced, but some of the liquid then automatically evaporates and the original pressure is restored. When all of the liquid has evaporated, the tank must either be refilled or replaced. If an installation is correctly made, the available pressure is always more than is needed as long as any liquid fuel remains in the tank. A pressure regulator installed between the tank and the burner maintains a constant pressure at the burner orifice.

Warning: Liquefied petroleum gases are heavier than air and are not easily vented from basements in case of a leak. If the pilot flame should go out, it should be relit only by a competent service man who should determine with instruments whether the air is free enough from gas to permit relighting without an explosion.

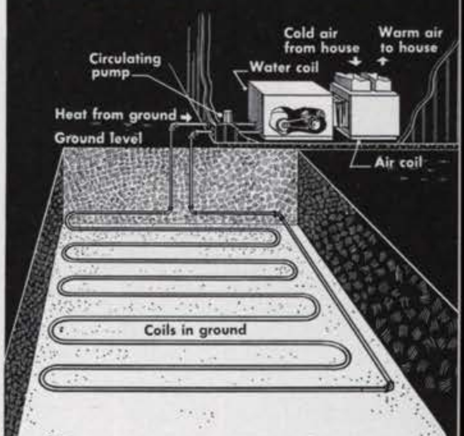


Liquefied gas hook-up

ELECTRICITY FOR HOME HEATING

Electricity, while not a fuel, is sometimes used to heat houses in regions where electrical rates are low. In ordinary electric heaters, the electricity heats a grid in front of a reflecting surface to a red heat. In electrical panels, the electricity heats relatively large glass or rubber surfaces, but the temperature is not nearly as high as in the electric heaters.

Electricity is also used to provide energy for the heat pump now in the developmental stage. The heat pump is a special application of a mechanical refrigeration system in which the refrigerant absorbs heat from such sources as outdoor air, the ground, or wells, rivers or lakes. It gives up this heat at a higher temperature level to air or water circulated in the heating system. The equipment can also be used in the reverse — to "pump" heat out of the house during hot weather. The heat pump requires less electricity than electric heaters or panels to deliver an equivalent amount of heat.



Heat pump for extracting heat from ground

COAL AND COKE

Anthracite Coal

Anthracite coal (hard coal) produces little or no smoke in burning. It is well adapted for use in automatically-fired furnaces and boilers, and also in hand-fired heaters which are equipped with self-feeding supply chambers (magazines), because it does not soften and fuse together in the burning process. As a result, the coal flows readily by gravity action. Automatic ash removal is possible with anthracite coal because, in burning, large hard clinkers are not formed.

This fuel is sold in several sizes: broken, egg, stove, chestnut, pea, No. 1 buckwheat, No. 2 buckwheat (rice), No. 3 buckwheat, and No. 4 buckwheat. The broken is the coarsest (3¼″ to 4⅜″) and the No. 4 buckwheat is the finest (3/64″ to 3/32″). The smallest sizes are the least expensive, but special grates and fans to provide a forced draft are needed to burn them.

Anthracite coal produces an even heat. Its heating value is usually between 12,000 and 13,000 Btu per pound.

Bituminous Coal

Bituminous coal (soft coal) is sold in a wide variety of types, preparations and qualities. It is found in more areas of the country than anthracite and hence is less expensive in most regions because of lower transportation costs.

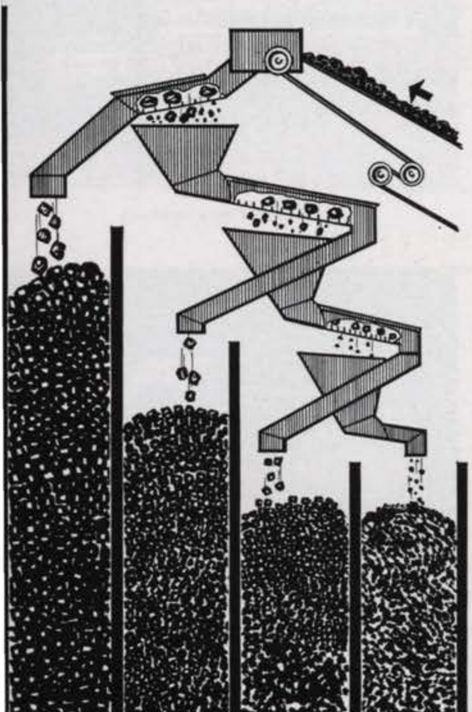
Some of the bituminous coals are nearly as hard as anthracite when handled or stored at outdoor or room temperatures, but they all soften and the lumps fuse together to a varying extent when heated in a fuel bed. They are, therefore, not well adapted for use in hand-fired furnaces or boilers having a magazine to feed the fuel to the fire by gravity. Most bituminous coals burn well in underfeed stokers. (See page 9.)

Objectionable smoke is produced when this fuel is burned in ordinary hand-fired heaters unless the methods of firing described on page 8 are used.

Sizing practice in the bituminous coal industry has not been standardized as in the anthracite industry. Typical sizes of bituminous coal are run of mine (no separation of the different sizes), 5″ lump (all large lumps, each big enough to pass over a shaker screen having holes five inches in diameter), 5″ x 2″ egg (passes through 5-inch holes and over 2-inch holes), 2″ x 1¼″ nut, 1¼″ x ¾″ stoker, and ¾″ screenings. Bituminous coal should be oil-treated for the elimination of dust.

The screenings contain all of the small particles and coal dust which are created by the mining process. They are considerably less expensive than any of the other sizes but are not used for home heating since special burning equipment is required. Some mines produce stoker coal for household use by removing all of the extremely small particles from the ¾″ screenings.

Some of the best grades of bituminous coals have higher heating values and lower ash contents than any of the anthracites. Heating values of bituminous coals range from less than 10,000 Btu per pound to nearly 15,000 Btu per pound.



Bituminous coal-sizing machine

Coke

Coke is a hard, gray-colored fuel made from high-grade bituminous coal. The coal is heated in a chamber from which air is excluded until all of its moisture and most of its volatile matter (portion which becomes gaseous when heated) has been driven out. The red hot residue is then removed and sprayed with water, after which it is crushed and separated into different sizes.

Coke is used principally in blast furnaces, but when available in sizes ranging from 1 to 5 inches, it can be used in homes as a smokeless fuel in hand-fired heating plants.

The ash content of coke is always higher than that of the coal from which it was made, but the heating value is usually about the same.

Petroleum Coke

Petroleum coke is the final residue in the distillation of crude petroleum. It is similar to coke made from coal except that the ash content is much lower and the heating value is usually higher.

HAND-FIRED FURNACES AND BOILERS (Coal and Coke)

Hand-fired furnaces and boilers are less expensive than those designed to automatically feed the coal or coke to the fire. Most hand-fired furnaces and boilers can be converted to automatic firing by installing conversion burners at a later time if the homeowner wishes to do so. Such conversion units are available for gas, oil and coal.

In all conventional hand-fired furnaces and boilers, the coal or coke is burned on top of a grate which is over the ashpit. The fuel is consumed by a process known as "up-draft" burning. The air necessary to make the fuel burn (the "primary" air) enters the ashpit through an opening in the ashpit door which is provided with a damper. The air then rises through the grate.

Additional air ("over fire" or "secondary" air), which enters above the fire through the over-fire damper, is needed to complete the burning of gases released from the fuel.

The hot gases, which are the products of combustion, flow through passages where the heat is transferred to the air or water in the heat circulating system. These gases then go into the smoke pipe and the chimney.

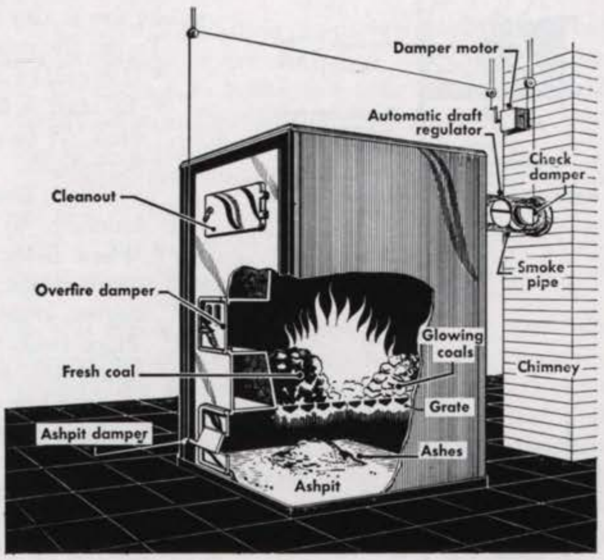
The chimney must furnish enough draft 1) to cause the air to flow through the fuel bed, and 2) to remove the burned gases. The check damper in the smoke pipe controls the draft and, together with the ashpit damper, regulates the amount of air passing through the fuel bed. When more heat is desired, the draft damper should be opened and the check damper closed; when less heat is needed, the positions of the dampers are reversed. Although these dampers can be operated manually, an automatic damper regulator controlled by a room thermostat is recommended since it helps to maintain a uniform temperature.

Excessive draft wastes fuel and may cause the furnace or boiler to be overheated. The installation of an automatic draft regulator, often called a barometric damper, prevents excessive drafts. One special design of barometric damper operates also as a check damper.

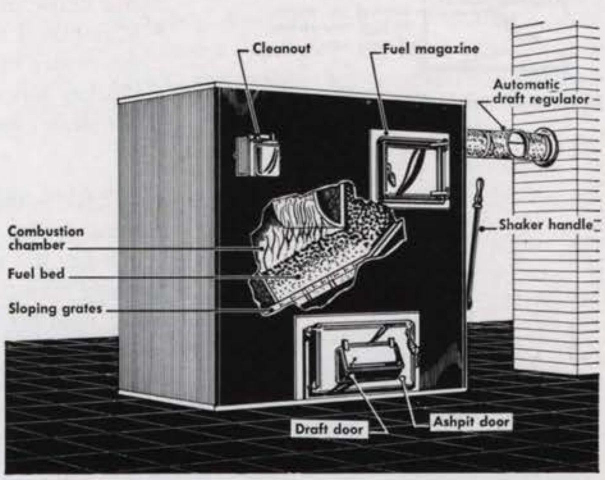
Safety controls should be installed to prevent overheating. (See Small Homes Council circular G3.2, "Controls for Central Heating Systems.")

Storage Chambers for Anthracite

Some hand-fired boilers and furnaces designed for anthracite only are provided with a fuel storage chamber (magazine) which automatically feeds the anthracite to the fuel bed to replace the coal burned. This magazine-type heater has an advantage over other heaters in that it permits a larger charge of anthracite to be placed in the unit without completely covering the hot coals at the top of the fuel bed.



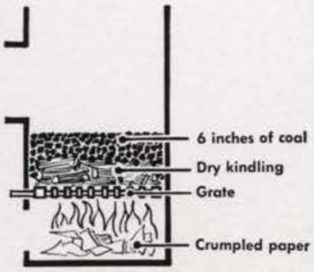
Hand-fired furnace



Hand-fired anthracite heater with magazine

Hand-Firing of Coal and Coke

Satisfactory results can be obtained with hand-fired furnaces or boilers if instructions for firing the specific type of fuel are followed.



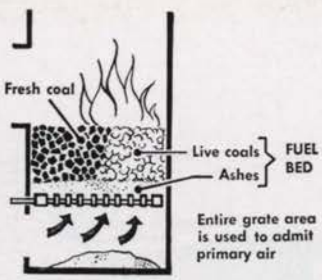
Anthracite fire is started by igniting crumpled paper in ashpit

Anthracite Coal

The preferred sizes of anthracite coal for use in hand-fired furnaces and boilers are egg, stove and chestnut.

When starting a fire, place a generous amount of dry kindling on a clean grate; cover it with about six inches of coal; then ignite the kindling by burning crumpled papers in the ashpit. After the initial charge has been heated to a red glow, the fire pot can be filled. When adding anthracite to an established fuel bed, shake the grates until sparks appear in the ashpit; level the hot coals; then place fresh fuel on top of them, leaving a small area at the front of the fuel bed uncovered so that the gases released by the coal can be ignited. (In units having a magazine, place the anthracite in the magazine instead of directly on top of the hot coals.)

An anthracite fuel bed responds more slowly to a demand for additional heat than a bituminous one, especially after a long period of low heat output.



Bituminous fuel bed for cold weather

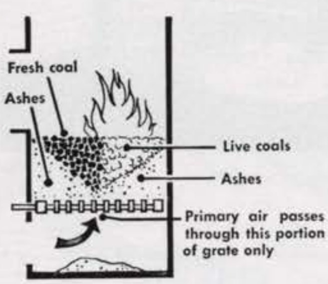
Bituminous Coal

Smoke, which is commonly associated with soft coal, results when the gases contained in this fuel are not completely burned. Since nearly one-half of the heating value of many types of bituminous coal is contained in the gases, a smoky fire is also a wasteful one.

To get the most satisfactory results in hand-firing bituminous coal*:

- Use coal of egg, nut, or stove size — about 2 or 3 inches in diameter.
- **To start a fire,** follow these suggestions: 1) Clear one-half of grate area. 2) Cover the other half with a 6-inch layer of ashes or with old periodicals. 3) Place a charge of coal on the clear portion of grate. 4) Place kindling *on top* of coal. 5) Put crumpled papers on top of kindling. 6) Ignite papers with a match. 7) Close firing door.
- **When firing,** follow these suggestions: 1) Shake the grates gently until a faint glow appears in the ashpit. 2) Use a poker bent to a 30-degree angle to push any scattered coals to the heap of live coals. Place fresh fuel *at the side* of the live coals — not on top. 3) If a flame does not start immediately after firing because the live coals are not hot enough to ignite the gases, use crumpled papers and, if necessary, kindling to start a blaze. (Failure to establish a flame after firing coal is likely to cause a minor explosion.) 4) To achieve maximum efficiency, leave the over-fire damper open just enough to avoid "puffing."
- Do not disturb partly burned soft coal unless it is necessary because of serious underheating. To do so causes gases to be released very rapidly and dense smoke results.
- Maintain a thick fuel bed. In mild weather, keep only a small fire in the center of the fire pot, leaving ashes around the edges.

  Placing ashes on top of the fuel bed to bank a fire is not good practice since clinkers will be formed. Do not burn garbage in the furnace.



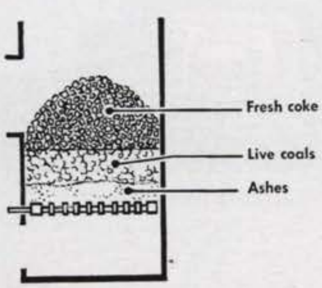
Bituminous fuel bed for mild weather

Coke

Because coke is difficult to ignite, use the procedure recommended for starting an anthracite fire. After the initial charge of coke has been heated to a red glow, the fire pot can be filled. Thereafter it should be kept well filled during the heating season.

Coke requires very little draft, and careful draft control is necessary to avoid overheating. The ashpit door and ashpit damper should be well fitted so that the heating plant is practically "airtight." As a further means of control, a cross damper should be installed in the smoke pipe between the heating plant and the check damper (or draft regulator).

While allowing ashes to accumulate in the bottom of the fuel bed will help control the fire during mild weather, this is not a satisfactory method of control in cold weather nor when petroleum coke is burned since such coke is practically free from ash.



Coke fuel bed immediately after firing

* For more information, see University of Illinois Engineering Experiment Station Circular No. 46, "Hand-firing of Bituminous Coal in the Home."

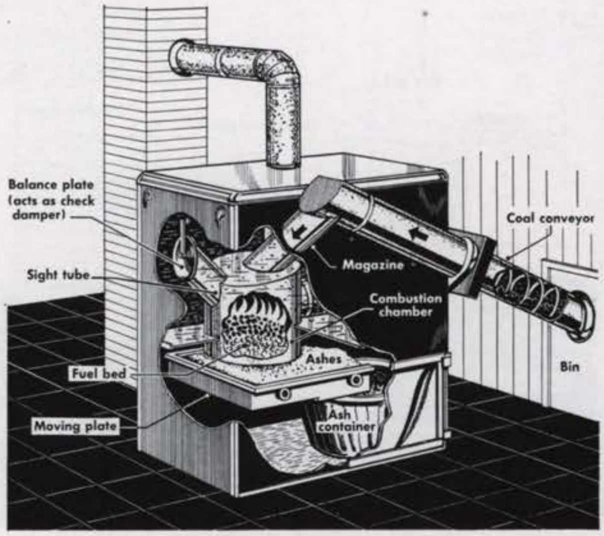
AUTOMATIC BURNERS FOR COAL

Anthratube

The anthratube is a completely automatic anthracite burner which utilizes a vertical tube as the combustion chamber. So far, the anthratube has been applied only to boilers.

The coal is fed into the top of the tube by gravity action from a magazine automatically kept full by a special coal conveyor (an "archimedes" screw). This conveyor with its special spiral ring works on a principle completely different from that of an ordinary coal screw.

The combustion air is drawn through the vertical tube by a fan located at the outlet of the boiler. The fan is controlled by the room thermostat. Combustion of the fuel progresses as it moves down through the tube. A plate located directly below the combustion chamber moves back and forth in such a way that the ashes are automatically removed and placed in a container.



Anthratube

STOKERS

Stokers — automatic burners for coal — have a steel screw to bring coal to the firepot (the retort). Air needed to burn the coal is forced by a fan through openings (tuyeres) in the retort. An electric motor drives both the coal screw and the fan. The maximum capacity rating of stokers in pounds of coal fired per hour is indicated on the seal of the Stoker Manufacturers Association.

The coal screw determines one classification of stoker types — "hopper" or "binfeed."

In the hopper stoker, the coal screw feeds fresh coal into the fire pot from a storage box (hopper) which must be filled by hand. The hopper should always be kept at least half full.

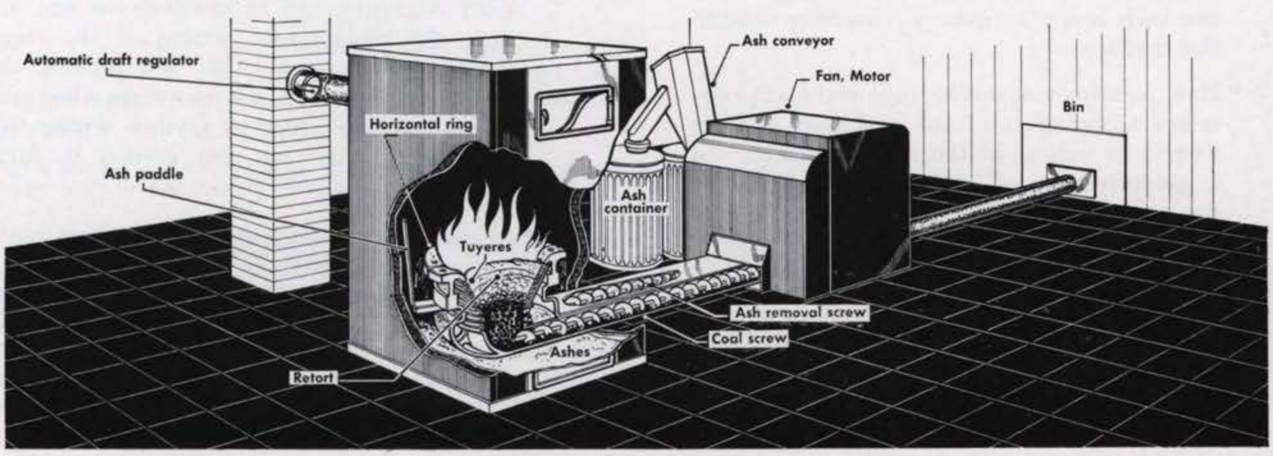
If the coal screw is extended, a stoker can feed the coal to the fire pot directly from the coalbin. This is the "binfeed" stoker. With automatic ash removal, binfeed stokers provide completely automatic service except for the occasional emptying of the ash container. (The screw for a binfeed stoker cannot remove all of the coal from the bottom of the bin. For information on bin construction, see Small Homes Council circular G3.61, "Homes Planned for Coal or Coke".)

Correct installation is necessary for any coal screw. It may be installed at the front, side or rear of the furnace or boiler, but sufficient room should be provided in front so that the operator can clean the heating plant.

Stokers are also classified according to type of burner.

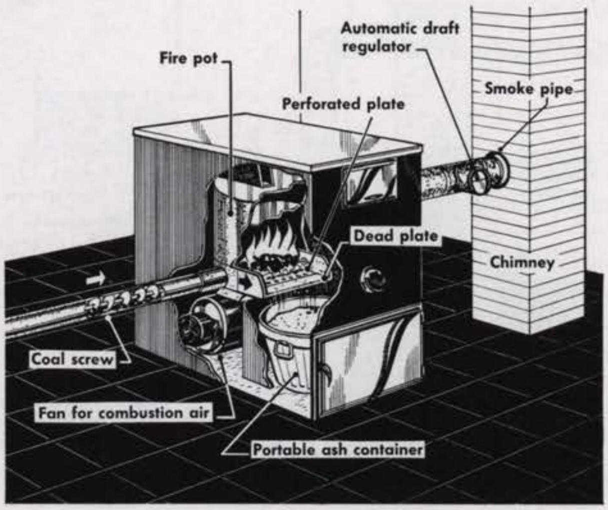
Anthracite Underfeed Burner

In this stoker, the coal screw carries the coal into the bottom of a cone-shaped retort. Air necessary to burn the fuel is supplied to the retort through small holes (tuyeres) by a fan. The rates of coal feed and of air supply are both adjusted so that the fuel is completely burned by the time it reaches the horizontal ring at the top of the retort. The ashes are pushed off the edge of the ring by the hot coals which are forced up by the fresh fuel fed into the bottom. The ashes fall either into a large sealed storage chamber, designed to hold a season's accumulation, or into a small receiver from which a conveyor carries the ashes to a covered portable container.

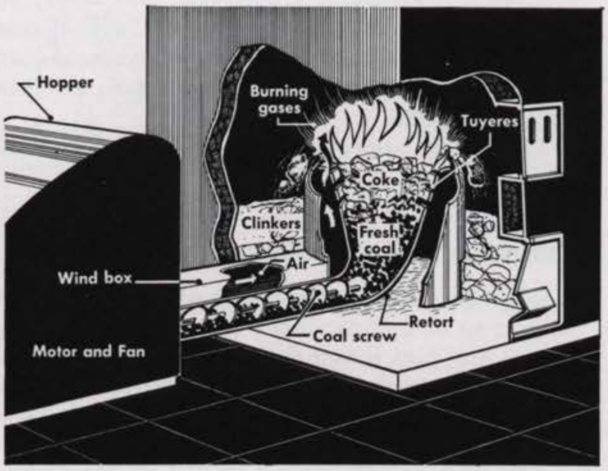


Anthracite underfeed burner

AUTOMATIC BURNERS FOR COAL — STOKERS



Anthracite cross-feed burner



Bituminous stoker

Anthracite Cross-Feed Burner

In this stoker, the anthracite is fed by a coal screw into one edge of a rectangular fire pot. The screw forces the coal across a plate which is perforated with small holes. Air from a fan is forced through the holes and produces a hot fire. The rates of coal feed and of the air supply are coordinated so that the fuel is completely burned by the time it reaches the edge of the horizontal perforated plate. The burning coal pushes the ashes ahead of it over a narrow "dead" plate (corresponding to the horizontal ring at the top of the underfeed stoker) from which they drop either into a large ash storage bin or into a portable container.

Bituminous Stokers

Stokers for bituminous coal employ the underfeed principle of burning. They burn bituminous coal smokelessly when properly adjusted. This is possible because the fresh coal is fed into the burning zone at a controlled rate; the gases released are mixed with air from the openings in the retort; and the mixture is passed through the hot coke at the top of the fuel bed where ignition is assured.

The fire is started with kindling and is maintained by a hold-fire control. This control automatically keeps the fire alive in mild weather when the thermostat makes infrequent demands for heat.

The hot fire fuses the ashes into clinkers which can be removed with tongs.

Automatic ash removal can be incorporated in the stoker design, but its use is successful only with certain types of bituminous coals — the ashes of which do not melt at the normal fuel-bed temperatures. The ashes must remain in a loose form so that they can be carried by a conveyor from the edge of the fuel bed to the ash container.

INSTALLATION AND CARE OF STOKERS

Stokers require reasonable care:

- Use a size and type of coal recommended by the stoker manufacturer. Coal should be one inch in diameter or smaller. Coal larger than one inch is apt to make a crunching noise in the coal screw.
- Have a competent service man make any necessary adjustments of the coal feed and air supply, as well as of the control settings. In a properly-adjusted stoker, the thickness of the fuel bed will be about equal to the diameter of the retort. If the type of coal is changed, readjustments may have to be made by the service man.
- If the stoker is of the clinkering type, use a bar to loosen clinkers from the fuel bed. They can then be removed by means of clinker tongs.
- Do not disturb the fuel bed any more than necessary. Remove only large-sized clinkers. In mild weather, these may take several days to form. If clinkers are not formed and difficulty is experienced in cleaning the fire, reduce the temperature setting of the room thermostat at night. This will prolong the stoker operation in the morning when the thermostat is returned to daytime setting and will produce the hot fire needed to form clinkers.
- At the end of the heating season, all coal, ash, and clinkers should be removed. The coal screw, the retort, and the inside surfaces of the hopper should be coated with oil to prevent rust.

An automatic draft regulator in the smoke pipe is required for stokers.

HEATING EFFICIENCIES

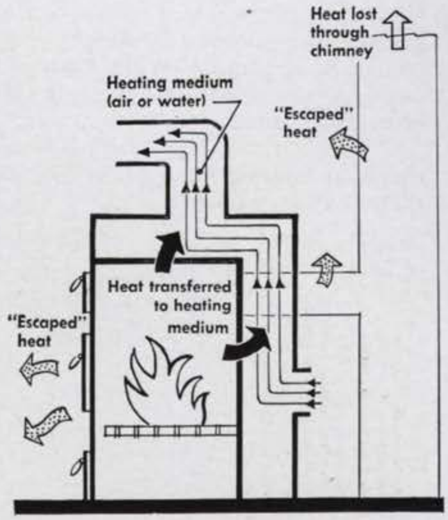
The amount of fuel you need to keep your house at a desired temperature depends on the house construction, the weather (outdoor temperature, wind velocity, clear or cloudy sky), and heating efficiencies. Reference is frequently made to two types of efficiencies:

- **The efficiency of the heating plant by itself** as tested in the laboratory. In other words, how much of the heat given off by a fuel is transferred to the heating medium (air or water circulating in the heating system)?

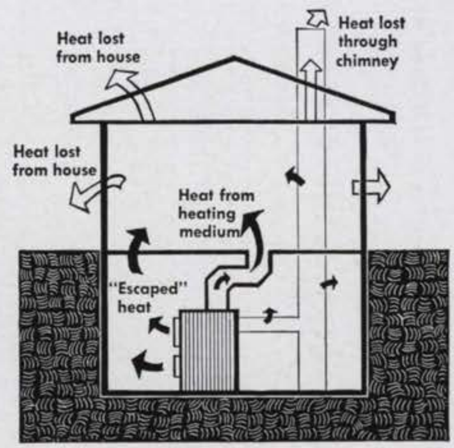
  Much heat never reaches the heating medium because it escapes through the front of the furnace or boiler, through the smoke pipe, and up the chimney. There is also a heat loss when fuel is unburned since the heat in the fuel is never released.

- **The over-all efficiency.** How much of the heat in the fuel is used to warm the house?

  Over-all efficiency considers not only the heat transferred to the air or water but also that part of the "escaped" heat which is actually within the house and is eventually used in heating the house. (This includes the heat which escapes through the front of the furnace or boiler, and through the smoke pipe. Heat which goes to the outdoors through the chimney is not included, nor is the heat lost due to unburned fuel.) The over-all efficiency, therefore, indicates how well the heating plant and the house utilize the heat in the fuel.



Heating plant efficiency



Over-all heating efficiency

Heating plant and over-all efficiencies are affected by the type of fuel used. Comparative values of over-all efficiency with different fuels can be obtained by testing in the same house all of those fuels to be considered. Each fuel should be tested for a period which includes all of the different climatic conditions of a typical heating season.

The table below presents assumed values of over-all efficiency as determined at the University of Illinois. These are based on an analysis of data taken in two research homes over a period of many years. These research houses had furnaces and boilers located in full basements. While the actual efficiencies would be different for other houses, the ratio of the over-all efficiency with one fuel to that with another fuel would probably be about the same for any house.

Type of Fuel	Method of Burning	Assumed Over-all Efficiency
Anthracite coal or coke	Hand-fired without controls	65%
Anthracite coal or coke	Hand-fired with controls	80%
Anthracite coal or coke	Stoker-fired	80%
Bituminous coal	Hand-fired without controls	55%
Bituminous coal	Hand-fired with controls	65%
Bituminous coal	Stoker-fired	65%
Oil	Units designed for oil burning with exception of vaporizing type without fan	80%
Oil	Vaporizing-type units without fan, and units converted to oil burning	70%
Gas (all types)	Any properly designed burner	80%
Electricity*		100%

* While electrical current is not a fuel, it is sometimes used to supply heat and for this reason is included in the table for comparison purposes.

ADJUSTING BURNERS FOR MAXIMUM EFFICIENCY

Too little or too much air entering the combustion chamber will reduce the efficiency of any fuel-burning unit. The higher efficiencies which are usually assumed in the case of automatic fuel-burning may not be achieved if the burners are not properly adjusted.

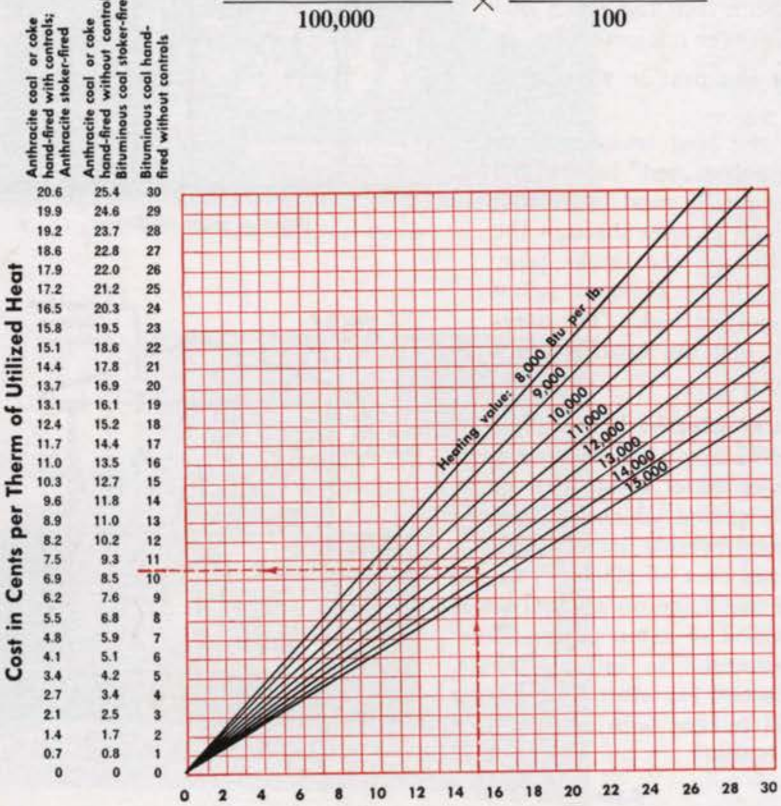
The amount of carbon dioxide in flue gas samples indicates whether a satisfactory air-fuel ratio is being maintained. Such analysis requires the help of a heating engineer.

HOW TO COMPARE FUEL COSTS

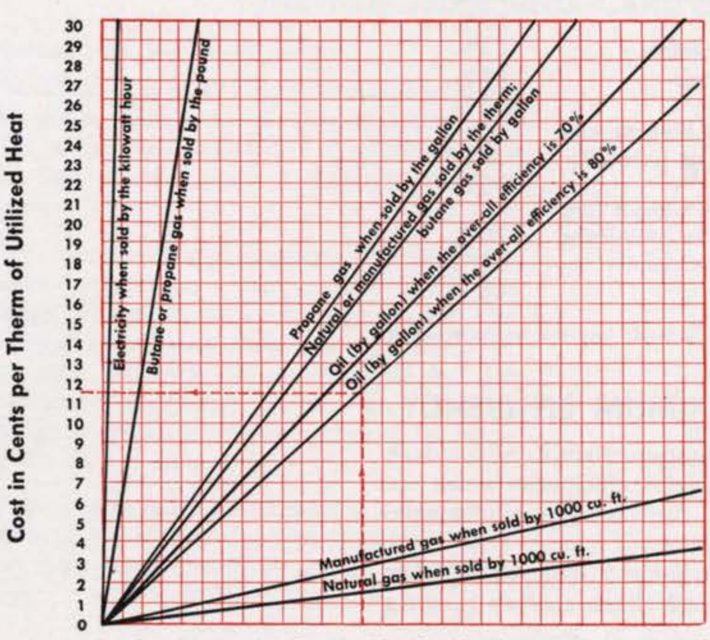
Coal and coke are sold by the ton, oil by the gallon, gas by either the cubic foot or the therm, and liquefied gases by the gallon or by weight. Because of these various units of measure, the cost of different types of fuels cannot be compared on the basis of the usual price quotations. The prices must be converted to a common basis. A convenient way of doing this is to compute all costs in terms of **cost in cents per therm (100,000 Btu) of heating value.**

To determine the most economical fuel, the over-all efficiency must be considered. The **cost in cents per therm of heating value** should be divided by the **over-all efficiency.** (See page 11.) This gives the **cost per therm of heat utilized.**

$$\text{Cost per therm of heat utilized} = \frac{\text{Price in cents per sale unit}}{\dfrac{\text{Heating value per sale unit in Btu}}{100{,}000} \times \dfrac{\text{Assumed efficiency in per cent}}{100}} \quad or \quad \frac{\text{Price in cents per sale unit} \times 10{,}000{,}000}{\text{Heating value per sale unit in Btu} \times \text{Assumed efficiency in per cent}}$$



Price of Coal or Coke in Dollars per Ton



Price in Cents per Sale Unit

The charts were developed from this equation. Heating values assumed are:

Coal or coke — obtain from dealer along with price.

Oil — 140,000 Btu/gal.

Natural gas — 1000 Btu/cu.ft.

Manufactured gas — 565 Btu/cu.ft.

Propane gas — 92,000 Btu/gal. and 21,680 Btu/lb.

Butane gas — 100,000 Btu/gal. and 21,330 Btu/lb.

Electricity — 3415 Btu/kw-hr.

The first chart is for coal and coke; the second is for other fuels. The costs obtained for fuels in the two charts* are comparable.

To use the charts, find on the horizontal scales, the price of fuel per sale unit; move up to the line in Chart I representing the heating value of the coal or coke concerned — or the line in Chart II representing the fuel concerned; then move horizontally to the cost per therm of utilized heat on vertical scale at left. In using Chart I, select the appropriate vertical scale.

Example: Bituminous coal costing $15 per ton and having heating value of 13,000 Btu per pound is to be stoker-fired. (Vertical scale 2.) Cost per therm of utilized heat, as indicated by the broken line, is between 8.5 and 9.3 cents or approximately 8.8 cents.

If price of any fuel in Chart II is beyond range of horizontal scale, divide the price by 2, 3 or 4; use the chart; then multiply the answer by the same number used for division. **Example:** If manufactured gas costs 75 cents per 1000 cu. ft., divide by 3 and use "25 cents" on the horizontal scale. Cost per therm of utilized heat at 25 cents per 1000 cu. ft. is 5.5 cents. The cost at 75 cents per sale unit would be 5.5 x 3 or 16.5 cents per therm of utilized heat.

* Comparison of coal and coke costs requires a different chart because 1) the heating value of these fuels varies, and 2) the customary price quotation for coal in terms of "dollars per ton" instead of "cents per pound," makes the horizontal scale used in the second chart unwieldy for coal and coke.