U.S. DEPARTMENT OF COMMERCE
BUREAU OF MINES

QUESTIONS AND ANSWERS
FOR THE
HOME FIREMAN

FOREWORD

The desire to save on household fuel bills and to enjoy the best in heating satisfaction and convenience is universal. Many instructions covering operating moves are issued to guide the householder in the use of equipment and fuel. He usually ends by working out a system of his own that seems best fitted to his case. The "Questions and Answers" that follow attempt to present a few of the fundamental reasons "why" that may better fit the householder to solve his firing problems along correct and natural lines.

QUESTIONS AND ANSWERS FOR THE HOME FIREMAN[1]

By J. F. Barkley[2]

1. What kinds of household furnace fuels are there?

Coal, coke, manufactured briquets, wood, oil, and gas.

COAL

KINDS OF COAL

2. What kinds of coal are there?

Anthracite, semianthracite, semibituminous, bituminous, subbituminous, and lignite.

3. What is anthracite?

Anthracite is hard coal. It is delivered screened, the pieces or lumps are all of about the same size, and there is very little coal dust. It is free-burning; that is, the pieces of coal do not soften, swell, or cake together. It burns

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with a blue flame without smoke. It has very little "volatile" or smoky gases that are given off when the coal is heated.

4. What is semianthracite?

Semianthracite is almost as hard as anthracite. It is delivered screened but contains more coal dust. Having more volatile or smoky gas than anthracite, it burns at first with a yellow flame which changes finally to a blue flame. It kindles more readily than anthracite.

5. What is semibituminous coal?

Semibituminous coal is high-grade soft coal. It has the lowest amount of volatile of the soft coals and is sold as "smokeless coal." Much of this coal is low in ash and easily broken to the finer coal sizes.

6. What is bituminous coal?

Bituminous coal is a soft coal containing considerable volatile, which is given off as a smoky gas when the coal is heated. It includes most soft coals. The ash content ranges from a low to a high amount.

7. What is subbituminous coal?

Subbituminous coal is a lower-grade bituminous coal which contains considerable water "combined" with the coal substance. Such water is not seen in the coal and does not wet its surface. Subbituminous coal tends to

slack or break down on exposure to the air. It is sometimes called black lignite.

8. What is lignite?

Lignite is a brownish to black coal, frequently of a woody appearance and lower in rank than subbituminous coal. It is generally more than one third water. When exposed to the air it loses water easily and "slacks" or breaks down to fine sizes.

SIZES OF COAL

9. What are the commercial sizes of anthracite?

Anthracite is sold in the following sizes:

	Round-mesh screens	
	Through (inches)	Over (inches)
Broken	4 3/8	3 1/4
Egg	3 1/4	2 7/16
Stove	2 7/16	1 5/8
Nut	1 5/8	13/16
Pea	13/16	9/16
Buckwheat	9/16	5/16
Rice	5/16	3/16

10. What are the commercial sizes of semianthracite?

Semianthracite is usually sold in about the same sizes as anthracite.

11. *What are the commercial sizes of the soft coals?*

Soft coal as broken in the mine without any screening is called "run-of-mine." The amount of lump as delivered will vary and depends upon how easily the coal breaks with handling and the amount of the handling. Soft coal is also screened to various sizes and called lump, egg, stove, nut, pea, stoker, slack, etc. These sizes are not well standardized. Slack is all the coal passing through a screen of a given mesh. It is usually named by the screen size, as ¾-inch slack, 2-inch slack, etc.

COKE

KINDS OF COKE

12. *What kinds of coke are there?*

High-temperature and low-temperature coke, made from coal, and petroleum coke.

13. *What is high-temperature coke?*

High-temperature coke results from heating coal to a temperature high enough to drive off practically all its smoky gases or volatile. High-temperature cokes, although varying somewhat in appearance and color, generally have a grayish luster and a fairly hard, abrasive surface. The ash content of different cokes varies considerably.

14. *What is low-temperature coke?*

Low-temperature coke results from heating coal at relatively low temperatures insufficient to drive off all the volatile. Low-temperature cokes contain a small amount of volatile, are blacker, and have a softer, less abrasive surface than high-temperature cokes.

15. *What is petroleum coke?*

Petroleum coke is a product of oil-refining processes. It contains a small amount of volatile and practically no ash and ranges in color from dark gray to black. Only a limited amount of petroleum coke is available for household use.

SIZES OF COKE

16. *What are the commercial sizes of coke?*

Coke is sold for household use in screened sizes usually called lump, egg, nut, and pea. The exact sizing of the screens is not well standardized.

MANUFACTURED BRIQUETS

17. *What kinds of manufactured briquets are there?*

Briquets can be classified according to the type of fuel from which they are made, as anthracite fines, semianthracite, mixtures of either of these with semibituminous or bituminous coals, semibituminous, bituminous, low-temperature coke, etc.; these fuels are pressed with various binders into lumps sized for household use. Briquets from different plants vary widely in volatile or smoky gas and in ash content.

WEIGHT OF COAL AND COKE

18. Can the delivered weight of fuel be checked by measuring its volume?

The weight of fuel can usually be determined only roughly, say, within 10 to 15 percent, by measuring its volume. It is necessary to know the weight of a cubic foot of the fuel as piled in the storage place being measured. The weight per cubic foot varies with the fuel substance itself, with its moisture, and with the air spaces between the pieces as piled. The air spaces vary with the size of the fuel and the pressure packing down the fuel in the piling. The following figures give some idea of the variation in weight of the different fuels per cubic foot as piled:

	Pounds per cubic foot
Anthracite	50-58
Semibituminous coal	49-57
Bituminous coal, etc.	42-56
Coke	22-35

19. When coal or coke is delivered quite wet, what percentage of the weight may be surface moisture?

The percentage of the total weight that is surface moisture may range from a few percent to about 8 percent for anthracite or bituminous coal, depending upon the size. The smaller sizes, such as rice or slack, contain the higher percentages; pea or nut usually contains up to about 3 or 4 percent. Coke may absorb higher percentages of moisture because its structure is more porous. The amount of such moisture may be determined approximately by weighing a small quantity of the fuel as delivered, air-drying, then reweighing to find the loss. More time is usually required to dry coke than coal.

WOOD

20. What kinds of wood are used for household fuel?

Practically all woods are used. To burn readily wood should be seasoned—at least 3 to 6 months and preferably 12 months if air seasoned. Split wood seasons more rapidly than unsplit wood.

21. What is accomplished by the seasoning?

The wood in seasoning loses considerable moisture.

22. *Are all woods of equal value for fuel?*

Woods vary in their moisture content and burning characteristics. Moisture increases the weight and lowers the heating value. The greener the wood the harder it is to ignite and the slower it burns. More smoke is produced. A mixture of seasoned and greener wood frequently gives satisfactory results. The heavier hardwoods ignite and burn more slowly than the lighter softwoods. Some woods, such as spruce, "crackle" and throw sparks that might make them undesirable for open fireplaces.

23. *By what unit of measure is wood sold?*

Wood is sold by the cord, a measure of bulk.

24. *What is the cord?*

The standard cord is 8 feet long, 4 feet high, and 4 feet wide, or 128 cubic feet as piled. A "cord run," sometimes called a "cord," is 8 feet long and 4 feet high, with a width equal to whatever shorter length the pieces of wood are cut. For example, a cord run of 16-inch wood would be about one third of a standard cord.

25. *What are the commercial lengths of fuel wood?*

Wood is sold in various lengths, from about 1 foot to 4 feet; 16-inch wood is a convenient size and is called stove wood or block wood; and 4-foot wood is generally called cordwood.

26. *How do the different woods vary in heating value per cord?*

For dry wood, in general, the heavier the wood the higher the heating value. Resins and gums increase the heat content. Woods having high values per cord include black locust, hickory, and white oak; those having medium values include beech, ash, and sugar maple; and those having low values include chestnut, cedar, white pine, and hemlock.

OIL

27. *What kinds of domestic furnace-fuel oil are there?*

Domestic furnace-fuel oils are sold in three grades: No. 1, a light domestic fuel oil somewhat heavier than kerosene; No. 2, a medium oil; and No. 3, a heavy oil. These oils should meet the commercial standards published by the United States Bureau of Standards covering certain technical properties of the oils and assuring the grade of oil for each number. In general, the heavier the oil the higher its heating value per gallon.

GAS

28. *What kinds of household furnace-fuel gas are there?*

Natural gas and manufactured gas.

29. What is natural gas?

Natural gas is a gas found in the earth. It has a relatively high heating value.

30. What is manufactured gas?

Manufactured gas is made by various processes from coal, coke, oil, etc. The heating value can be varied considerably in the process of manufacture. The minimum heating value is frequently established by local law and generally is little higher than half the heating value of undiluted natural gas.

COMPOSITION OF FUELS

31. Of what are all these fuels composed?

All these fuels as used are composed of carbon, hydrogen, sulphur, oxygen, nitrogen, and ash.

32. What is carbon?

Carbon is a substance very common in living things, such as trees and plants. By itself, it is a solid, as lampblack or soot.

33. What is hydrogen?

Hydrogen is a very light gas present in nature generally combined with other substances.

34. What is sulphur?

Sulphur is an easily recognized yellow solid that occurs in nature both combined and uncombined.

35. What is oxygen?

Oxygen is a gas widely found in nature, both combined with other substances and uncombined. It exists in the air uncombined. Oxygen combined with hydrogen forms water.

36. What is nitrogen?

Nitrogen is a gas that does not readily combine with other substances. It exists in the air uncombined.

37. What is ash?

Ash is the unburnable mineral part of fuels. It is composed of earthlike minerals.

BURNING OF FUELS

38. When a substance burns, what is happening?

The substance is combining with oxygen. This action produces heat.

39. When a fuel burns, what is happening?

The burnable part of the fuel is combining with oxygen.

40. What is the burnable part of the fuel?

The burnable part is its carbon, the part of its hydrogen not already combined with its oxygen, and its sulphur.

41. What is formed when the carbon burns?

When there is plenty of oxygen a gas is formed called "carbon dioxide." When there is not enough oxygen, a gas is formed called "carbon monoxide." When carbon monoxide is formed much less heat is produced than when carbon dioxide is formed. Therefore, there is a loss in forming carbon monoxide instead of carbon dioxide. Unlike carbon dioxide, carbon monoxide is very poisonous and should not be inhaled. Carbon monoxide burns with a blue flame to form carbon dioxide. This blue flame can usually be seen at the top of a bed of burning coal or coke.

42. What is formed when the hydrogen burns?

Water is formed. Owing to the high temperature the water is in the form of a gas. When this gas cools it becomes liquid.

43. What is formed when the sulphur burns?

A gas called "sulphur dioxide" is formed. This gas has the familiar odor of burning sulphur.

44. Where does the oxygen needed for the burning come from?

The oxygen comes from the air.

45. What is air?

Air is a mixture of uncombined oxygen, uncombined nitrogen, and a very small amount of other gases. By volume it is about one fifth oxygen and about four fifths nitrogen.

46. What happens to the nitrogen of the air when the oxygen is used for burning?

The nitrogen mixes with the gases produced by the burning.

47. What is perfect burning of a fuel?

Perfect burning is obtained when the burnable part of the fuel is completely burned and only enough air is used to give the necessary amount of oxygen.

48. What difference does it make if more than enough air is used as long as the burnable part is completely burned?

Unnecessary air takes some of the heat produced by the burning and carries it out the stack as a loss. This means that more fuel must be burned to make up for this loss.

49. What must be done to burn completely the burnable part of the fuel?

The burnable part either as a solid or as a gas must be kept hot enough to burn, oxygen must be brought to it, and the gases formed from the burning must be carried away from it.

50. *What becomes of any burnable part that does not burn?*

Some of it goes into the refuse as coke or coal, some sticks to the boiler as soot, and some goes out the stack as burnable gases, smoke, soot, or coke.

51. *Is it possible to obtain perfect burning in the household furnace?*

No. It is necessary to use some excess air to burn the burnable part completely. The loss due to a small amount of excess air is not as great as that due to unburned fuel.

THE HOUSEHOLD FURNACE

52. *In what simple way may the household furnace be considered?*

From an operating standpoint the household furnace may be considered merely as a pipe extending from the basement floor to above the housetop. A jacket holding some medium such as water to be heated is placed around the pipe over part of its length. Fuel and air are brought together in the pipe to produce burning. For a solid fuel, a grate is placed in the pipe to support the fuel; usually three adjustable air inlets are provided, one beneath the grate, one just above it (usually in the firing door), and one beyond the jacket farther along the pipe (sometimes called the check damper). Generally a plate or damper called

the "stack damper" is also provided to swing in the pipe beyond the jacket as an adjustable obstruction to the flow of the gases.

53. *What causes the air to flow into the inlets?*

This cause is usually spoken of as the "draft." As the air or gas in the pipe is heated it becomes lighter than the outside air. This difference in weight causes an unbalanced condition, and the heavier cold air flows into the pipe causing the lighter hot air or gas to rise.

54. *Upon what does the amount of air flow depend?*

The amount of air flow depends upon the difference in temperature between the air or gas in the pipe and the outside air, the height of the pipe, any wind action at the top of the pipe, and the amount of obstruction the air or gas meets entering and flowing through the pipe. This means that the "draft" would be less when the pipe is not hot; when it is warmer outside; when cold air enters the pipe above the jacket either through the top air inlet or leaks of any kind; when the top of the pipe is below some nearby roof, etc., that would cause the wind to oppose the flow; when the air inlets or dampers are closed; or when any other obstructions, such as pipe bends, fallen brickwork, soot piles, a thicker bed of fuel, etc., are met.

55. *When burning anthracite, a typical noncaking fuel, how should the furnace be operated?*

In general, the fuel bed should be kept thick and about level with the firing door for both heavy and light loads. The ash should be shaken into the ash pit as often as necessary to keep a good bed of coal. The ash should be shaken down until a few red particles drop from the grate. The air flow should be controlled to suit the load, as the amount of coal burned depends upon the amount of air allowed to pass through it.

56. *How should the air flow be controlled by the various inlets or dampers?*

The air flow can be controlled by various combinations of settings of the inlets or dampers which act as variable obstructions to the flow. The main point is to be able conveniently to control the air from practically no flow—a banked condition—to as great a flow as is required to meet the heaviest load. In working out settings that seem best suited for a given coal, furnace, and fireman, the following factors should be considered. Opening the check draft at the top of the furnace to permit the air in the basement to flow into the stack so as to lower the draft on the furnace has two

disadvantages. It causes a relatively large amount of air to flow, most of which usually comes from the house rooms above, thus robbing them of their heat; also, it may lower the draft so much that gases, usually poisonous, given off from the hot coal will come out the furnace door.

Use of the check damper, then, is usually best confined to warmer weather when loss of heat is of little consequence and the fire cannot be checked any other way. To control the flow of air entirely by the plate or stack damper, leaving the check damper closed, would be ideal, if always possible. It is seldom possible, however, to regulate the air flow closely enough by this means at the low loads. Shutting this damper too tightly may also cause gases to come out the furnace door. Opening the furnace firing door to lower the air flow through the fuel bed has disadvantages. The colder air entering an open firing door cools the boiler in addition to wasting the house heat. It is, therefore, generally necessary to obtain some of the air regulation by adjustment of the dampered air inlet under the fire. For close regulation under the fire it is desirable to close all leaks as much as possible.

It is seldom realized what a large amount of air in relation to the air actually used for burning will flow through a very small leak. Leaks may be discovered with a candle flame and may be closed with furnace cement. A little steel wool stuffed around the shaker rod where it passes into the ash pit will usually cut down undesirable air leakage at that point.

Still another way to adjust the air flow is by choice in the size of the anthracite. Small sizes require more draft than large sizes. Where there seems to be a superabundance of draft a size such as pea coal can be used advantageously and at lower cost. To use a still smaller size such as buckwheat it is generally necessary to force the air through the fire with a blower.

57. What use should be made of the dampered air inlet in the firing door?

The dampered air inlet on this door has the definite use of supplying some of the air over the fire that is actually needed to complete the burning of certain gases given off by the fire. How much air to let in over the fire usually is a matter of guesswork. Much, if not all, of this needed air reaches the top of the fire through small openings where the fuel lies against the sides of the furnace, through leaks at the furnace door, etc. A little air can be let in over the fire through the air inlet in the firing door when there is much flame, particularly when small anthracite, such as pea, is used.

58. Does all anthracite as sold have the same burning characteristics?

No. Some anthracites burn much freer and faster than others. A fast-burning anthracite will not bank over long periods or hold a good depth of live coal as well as medium- or slow-burning anthracite. Some householders use more of the fast-burning anthracite than of a slower-burning one during a season. On the other hand, the fast-burning anthracite will bring up the load much quicker. The burning characteristics are affected by the amount of the "volatile," the amount and nature of the ash, the temperature at which the ash melts, etc.

59. Is there any possibility of an "explosion" or fire puff when the air over the fuel bed combines with the unburned gases given off by the fire?

Yes. Such "explosions" or fire puffs can and do occur under certain conditions. Their severity practically never is sufficient to do any material damage, rarely blowing open the fire door. The fire puff is due to sudden ignition of a mixture of unburned gases and air. If a hot bed of fire is completely covered with cold fuel, especially of a small size, the gases rising from the hot fuel beneath may be so cooled that they will not burn above the fuel bed, and all flaming will cease. Sooner or

The slower it is heated the slower it gives off the gas. The problem is to burn this gas, as it contains an appreciable amount of the heat of the fuel.

If not completely burned soot is deposited on the heating surfaces, lowering the efficiency of the heater. Firing instructions for such fuels are varied. All involve firing the fresh fuel into one spot of the fuel bed, leaving a considerable area of lively burning coke around or to one side of the fresh fuel. The fresh fuel thus heats more slowly than if it is scattered thinly over the top of a hot fuel bed. The hot gases from adjoining coke help to burn the smoky gases as they are given off by the fresh fuel. This also helps prevent any fire puffs or explosions from sudden ignition of gases in the furnace. More use should be made of the dampered inlet in the firing door with higher- than with lower-volatile coals. The amount of opening must be judged by the amount of flame and gases at the time. No air for burning the burnable gases above the fuel bed can come through a perfectly formed bed of burning coke with no breaks or air holes.

Such a bed is seldom formed, however, in an ordinary househeating furnace. An adjustment of the air damper over the fire that would be correct for a heavy load would admit too much air, greatly lowering the efficiency for light loads. Another factor affecting furnace

operation for many coals is the caking together in the fuel bed of the coke formed from the fuel. This caking must be broken up at times to let the air evenly through the bed and thus maintain efficient burning. In so doing, care should be taken not to get ash up into the fuel bed.

63. What automatic devices may be installed when solid fuels are used?

The automatic devices are designed mainly for two purposes: (1) To reduce the labor or trouble of manual operation and (2) to improve efficiency. In manual operation of the hand-fired furnace the operator must adjust the various dampers for air flow through the fuel bed to suit the needs of the load to be carried, shovel fuel and maintain the fuel bed in proper condition, and remove ashes. The efficiency is greatly affected by the care given by the operator. The simplest to the most complicated devices are designed to do part or all this work automatically. The simplest types merely vary the dampers to suit the needs, the air flow being governed by the temperature in a room, the temperature of the water, or the pressure, etc. With a clock arrangement, the dampers may be moved at chosen times of the day, for example, early in the morning or late at night.

Stokers are designed for anthracite and for bituminous coal. Some merely shovel the coal, while others include the complete operation of shoveling, maintaining the fuel bed, and cleaning out and placing the ashes into a container, with automatic control to suit the needs of the load. Improvement in efficiency over that of ordinary manual operation should be expected with automatic control, and with stokers it is usually possible to use a cheaper and smaller sized coal. Automatic control is readily applied to the use of pulverized fuel for househeating.

64. What type of equipment is used to burn oil?

An "oil burner" is essentially a device to throw atomized oil and air. The burning occurs in the chamber formed usually by brickwork and part of the boiler. Oil can be atomized in many ways, and many different types of burners are used. Some burners can atomize the heavier, cheaper oils; others can use only the lighter oils. Control devices are readily adapted to oil-burner use. Due to the explosive nature of any atomized fuel, safety controls must be used to meet fire underwriter's regulations if fire insurance is to be carried.

65. What type of equipment is used to burn gas?

A "gas burner" is essentially a simple nozzle to throw gas and air. As with oil burners, the

burning occurs in a chamber. Hand regulation can be used, but control and safety devices usually are installed.

66. What factors should be considered in choosing the type of fuel-burning equipment for a house?

Each household must be considered as an individual case, the householder deciding the relative weight he places on the various factors. It is desirable, where possible, for him to inspect and get the local experience on the equipment he is considering with the type of fuel he expects to use, particularly if coal is to be used, due to its great variation. Equipment new to the market may require development changes before it reaches its full possibilities in giving satisfaction. Where claims are made as to saving fuel costs, the householder should determine if possible just why the saving can be expected. A list of factors with discussion follows:

1. The necessity for continuous service: The simpler the equipment the less chance there is for discontinuous service, and the better chance the operator has of being able to fix troubles himself.

Any equipment will get out of order or adjustment and need attention sooner or later. To meet the necessity for quick repair in the more complicated devices, service stations in the locality are usually maintained by the sellers. When purchasing a device for which the householder will require service, he may consider the purchase as one of heat engineering and service rather than of equipment. He should determine if the seller has a capable, trained service force and carries, or can quickly procure, spare parts, or if he is merely an overoptomistic merchandiser. Where operation of the equipment depends upon electricity, he should judge how long the current might be off due to line trouble and what the resulting effects will be. Where gas is to be used, he should determine if ample pressure will always be available, especially on the coldest days. He should also consider whether the equipment is so designed that some sort of heat can be maintained manually or otherwise when the equipment is out of regular working order.

2. The chores or troubles accompanying each type of equipment: This factor should be determined as closely as possible. Balanced with the cost, it usually determines the satisfaction or the disappointment of the purchaser. Consideration should be given to the dirt nuisance, the smoke and soot nuisance, the cleaning of the heating surfaces, the noise caused by the equipment—as motors, the fire and explosion hazard, etc.

3. The initial cost: In making economic comparisons of different types of equipment, each buyer should decide how he chooses to consider the initial cost. The point of view can vary widely. It may be considered part of the current house expense, to be forgotten, or as an expenditure requiring accurate cost accounting based on yearly interest and depreciation added to the yearly fuel bill.

The probable life of the equipment should be considered carefully. For example, to amortize in 10 years an expenditure of $1,000 at 6 percent interest compounded annually an annuity (which is also assumed to draw 6 percent interest compounded annually) of about $136 should be set aside each year. Certain equipment may become obsolete fairly soon due to constant changes and developments being made. If it is estimated that a given mechanism will last say,

8 to 10 years, it is necessary to be assured that spare parts can be obtained from some source for that period.

4. The yearly cost of service and maintenance: Included in this factor is the general overhauling service desirable once a year on most equipment.

5. The cost of operating power, gas for pilot, etc.: Operating cost can be expressed in several ways as cost per month or better as cost per unit of fuel used. Where the power is electricity the cost will vary with the price per kilowatt-hour of the current. Information is usually available on the kilowatt-hours per unit of fuel used for a given equipment.

6. The comparative cost for fuel: This factor is probably given most consideration by the householder. To arrive at a reasonable estimate a little relatively simple figuring is necessary, based on the delivered unit cost of the fuel, the total heat in the fuel, and the efficiency in the use of this total heat. The efficiency factor is that part or fraction of the total heat that is actually made useful.

Coal is usually sold by the short ton (2,000 pounds) or the long ton (2,240 pounds), oil by the gallon, and gas by the thousand cubic feet.

Each of these fuels when burning can develop a certain maximum quantity of heat. This heat is measured by a unit called the British thermal unit, usually abbreviated B.t.u. For example, a certain coal may contain 13,500 B.t.u. per pound, which means that when a pound is completely burned the amount of heat produced is 13,500 B.t.u. The householder, being interested in the cost of the heat rather than merely the cost of the fuel, its carrier, can determine the cost, say, per million B.t.u. It then becomes possible to compare the costs of the total heat of any fuels as received.

For example, to compare the following:

(1) A coal costing $8 per short ton that has 13,500 B.t.u. per pound as received;

(2) An oil costing 7 cents per gallon that has 138,000 B.t.u. per gallon as received;

(3) A natural gas costing 60 cents per 1,000 cubic feet that has 1,000 B.t.u. per cubic foot as received.

Coal:

$$\frac{\$8.00}{13{,}500 \text{ B.t.u.} \times 2{,}000 \text{ pounds} = 27{,}000{,}000 \text{ B.t.u.}}$$
$$= \$0.296 \text{ per } 1{,}000{,}000 \text{ B.t.u. "as received."}$$

Oil: $\frac{\$0.07}{138{,}000 \text{ B.t.u.}} = \$0.507 \text{ per } 1{,}000{,}000 \text{ B.t.u. "as received."}$

Gas:

$$\frac{\$0.60}{1{,}000 \text{ B.t.u.} \times 1{,}000 \text{ cubic feet} = 1{,}000{,}000 \text{ B.t.u.}}$$
$$= \$0.600 \text{ per } 1{,}000{,}000 \text{ B.t.u. "as received."}$$

Further comparison as to the actual "as received" total heat may be made if desired:

The ton of coal has 27,000,000 B.t.u.
The gallon of oil has 138,000 B.t.u.
The cubic foot of gas has 1,000 B.t.u.

$$\frac{\text{Coal}-27{,}000{,}000 \text{ B.t.u. per ton}}{\text{Oil}\ -138{,}000 \text{ B.t.u. per gallon}} = 196 \text{ gallons.}$$

$$\frac{\text{Coal}-27{,}000{,}000 \text{ B.t.u. per ton}}{\text{Gas}-1{,}000 \text{ B.t.u. per cubic foot}} = 27{,}000 \text{ cubic feet.}$$

$$\frac{\text{Oil}\ -138{,}000 \text{ B.t.u. per gallon}}{\text{Gas}-1{,}000 \text{ B.t.u. per cubic foot}} = 138 \text{ cubic feet.}$$

In other words, the ton of coal is equivalent to 196 gallons of oil or 27,000 cubic feet of gas, and the gallon of oil is equivalent to 138 cubic feet of gas. The B.t.u. content of the different fuels varies considerably. The correct value must be determined for each individual case. The "as received" B.t.u. content of coal, for example, is lower as the ash or moisture content is increased. The B.t.u. content in the trade is frequently expressed as the B.t.u. on a dry basis. This should be expressed on the "as received" basis to make correct comparisons, as some coals have 10 percent or more inherent moisture not discernible to the

eye. The B.t.u. value of oil usually varies with its heaviness; the heavier the oil, the more the B.t.u. per gallon. The B.t.u. value of gas depends upon its composition and the altitude of the locality at which it is measured. The following table gives some general values:

		B.t.u. "as received"
Anthracite; Semianthracite	per pound	11, 500–13, 300
Semibituminous	do	13, 000–14, 400
Bituminous	do	10, 500–14, 400
Subbituminous	do	7, 800–11, 800
Lignite	do	6, 500–8, 000
Coke (from coal):		
High temperature	do	12, 000–13, 300
Low temperature	do	12, 300–13, 600
Coke (from oil)	do	14, 500–15, 400
Manufactured briquets	do	11, 700–14, 400
Oil:		
No. 1	per gallon	133, 000–138, 000
No. 2	do	135, 000–141, 000
No. 3	do	138, 000–144, 000
Natural gas	per cubic foot	800–1, 150
Manufactured gas (as delivered in cities)	per cubic foot	450–600

The final step to be considered is the efficiency with which the total heat that has been received in the fuel can be transferred to the steam, water, or air that is to heat the house. The fuel bill depends upon the amount of "as received" heat actually made useful.

If an average of 700,000 of each 1,000,000 B.t.u. as received is made useful for heating purposes during the heating season, an efficiency of 70 percent is obtained. The remaining 300,000 B.t.u. may be lost out the chimney, lost out the ash pit, or radiated from the heater. This efficiency factor varies considerably. It depends upon the fuel, the design of the equipment, the care given by the operator—particularly for manually operated equipment, the adjustment of automatic equipment, the design and size of the heater in relation to the load, the cleanness of the heating surfaces, the leaks of unnecessary air into the gas passages, etc.

To figure the comparative cost of various fuels under conditions giving different efficiencies the efficiency factor must be used.

For example, to compare the following:

(1) A coal costing $8 per short ton that has 13,500 B.t.u. per pound "as received," used with an efficiency of 60 percent.

(2) An oil costing 7 cents per gallon that has 138,000 B.t.u. per gallon "as received," used with an efficiency of 70 percent.

(3) A natural gas costing 60 cents per 1,000 cubic feet that has 1,000 B.t.u. per cubic feet "as received," used with an efficiency of 75 percent.

Coal:

$$\frac{\$8}{13{,}500 \text{ B.t.u.} \times 2{,}000 \text{ pounds} \times 60 \text{ percent efficiency} = 16{,}200{,}000 \text{ B.t.u.}}$$
$$= \$0.494 \text{ per } 1{,}000{,}000 \text{ B.t.u. made useful.}$$

Oil:

$$\frac{\$0.07}{138{,}000 \text{ B.t.u.} \times 70 \text{ percent efficiency} = 96{,}600 \text{ B.t.u.}}$$
$$= \$0.725 \text{ per } 1{,}000{,}000 \text{ B.t.u. made useful.}$$

Gas:

$$\frac{\$0.60}{1{,}000 \text{ B.t.u.} \times 1{,}000 \text{ cubic feet} \times 75 \text{ percent efficiency} = 750{,}000 \text{ B.t.u.}}$$
$$= \$0.800 \text{ per } 1{,}000{,}000 \text{ B.t.u. made useful.}$$

Since these costs per 1,000,000 B.t.u. are the costs of the heat actually used, the yearly fuel bills for the different fuels would be in the same relative proportion. If the yearly gas cost in this case was $80 the oil cost would be $72.50 and the coal cost $49.40. If the yearly gas cost was $160 the oil cost would be $145 and the coal cost $98.80.

Further comparison as to the actual useful heat may be made if desired:

The ton of coal gave a useful B.t.u. of 16,200,000.

The gallon of oil gave a useful B.t.u. of 96,600.

The cubic foot of gas gave a useful B.t.u. of 750.

$$\frac{\text{Coal—}16{,}200{,}000 \text{ B.t.u.}}{\text{Oil— } 96{,}600 \text{ B.t.u.}} = 168 \text{ gallons.}$$

$$\frac{\text{Coal—}16{,}200{,}000 \text{ B.t.u.}}{\text{Gas— } 750 \text{ B.t.u.}} = 21{,}600 \text{ cubic feet.}$$

$$\frac{\text{Oil—}96{,}600 \text{ B.t.u.}}{\text{Gas— } 750 \text{ B.t.u.}} = 129 \text{ cubic feet.}$$

In other words, the ton of coal in actual use under these conditions of efficiencies is equivalent to 168 gallons of oil or 21,600 cubic feet of gas, and the gallon of oil is equivalent to 129 cubic feet of gas. Frequently fuel equivalents can be obtained in the locality covering certain conditions as a result of experience. It is usually desirable to check these by calculation.

The following table gives a general idea of the values of the over-all efficiencies usually found with domestic heating equipment. To obtain the highest efficiencies special boilers or furnaces are required. For example, installation of a gas burner in the ordinary coal boiler will not give as high an efficiency as installation of a special boiler and gas burner combined.

Over-all efficiencies, hand-fired equipment, percent

	High	Low		High	Low
Anthracite	70	50	Lignite	55	40
Semibituminous			Coke	70	50
Bituminous	65	40	Oil	75	50
Subbituminous			Gas	80	55

When the heat radiated from the heater or put into the house from the chimney masonry is useful in maintaining the desired temperature these figures may be somewhat higher.

The use of household stokers may increase the amount of coal over that used with hand firing about 5 percent or may decrease the amount as much as 15 percent or more, depending upon how poorly the hand firing was done. Sometimes the amount increases because better heat conditions are maintained in the house. There is more opportunity to decrease the amount where the householder has been using soft coal than where he has been using hard coal. The hand-fired efficiencies obtained with hard coal ordinarily are higher than those with soft coal, so that there is more opportunity for improving soft-coal burning. The efficiency of the average household boiler and stoker may be estimated as 55 to 65 percent.

67. Is much fuel saved by letting the house cool at night?

The resulting saving depends upon how low a temperature is reached in the house, how long this temperature is carried, the outside temperature, the type of fuel-burning equipment, etc. All the heat used for heating the house is given out by the house to the outside surroundings. When the house is held at a chosen inside temperature it is giving out heat at the same rate that it is receiving it. The lower the temperature of the house the less heat it gives out. When the house is allowed to cool at night by shutting off the supply of heat to it the total heat it gives out during the night must be put back into it to raise its temperature back to normal, but less heat is given off than if the house had remained all night at its higher normal temperature.

Part of the saving, however, may be lost by action of the equipment itself. Better efficiency is usually obtained when the equipment is under a steady normal load than when it is forced as is necessary during a morning heating-up period or when poorly banked at night. When no fuel is being burned, as happens when a gas or oil burner is off, any air passing through the heating equipment to the stack carries away heat that is lost. As a general example, tests have shown a saving from about 5 to 10 percent in total gas consumption by allowing the house to cool to 60° at night, the higher percentages saved being for the milder outside temperatures.

68. Can the heating surfaces of the equipment be cleaned of soot by using chemicals on the fire?

Certain chemicals sometimes cause the soot on the heating surfaces to burn. The chemicals vaporize when thrown on the fire and then deposit on the soot. The deposit causes the soot to ignite at a lower temperature than it would otherwise. To obtain this action very definite conditions are required in the furnace. The chemicals should be vaporized on hot coke with little load on the boiler, after which an attempt to ignite the soot should be made by getting a high-temperature fire (even burning papers if necessary). Common ice cream salt, or better, a mixture of five to one of salt and dry red lead, or white carbonate of lead, may be used. These chemicals do not remove the ash accumulated on the heating surfaces, which should be cleaned by brushing or its equivalent.

69. Can any use be made of chemicals on coal?

Considerable soft coal is now being treated with a water solution of certain chemicals, usually calcium chloride to which a small quantity of other chemicals is sometimes added. Such coal is sold as "dustless" coal. Calcium chloride collects moisture from the air and remains wet. This property is used to keep down the coal dust. A calcium chloride solution may give trouble by rusting any metal in contact with it. The weight of chemicals used is relatively very small. The weight of the water adds a little to the weight of the coal. Chemicals used in these small amounts have no observable effect on the burning of coal for househeating. "Tempering" of the coal by the water sometimes affects the burning advantageously.

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