

Aug. 30, 1932.

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METHOD OF AND APPARATUS FOR USE IN BURNING SOLID FUEL

Filed May 12, 1928

2 Sheets-Sheet 1

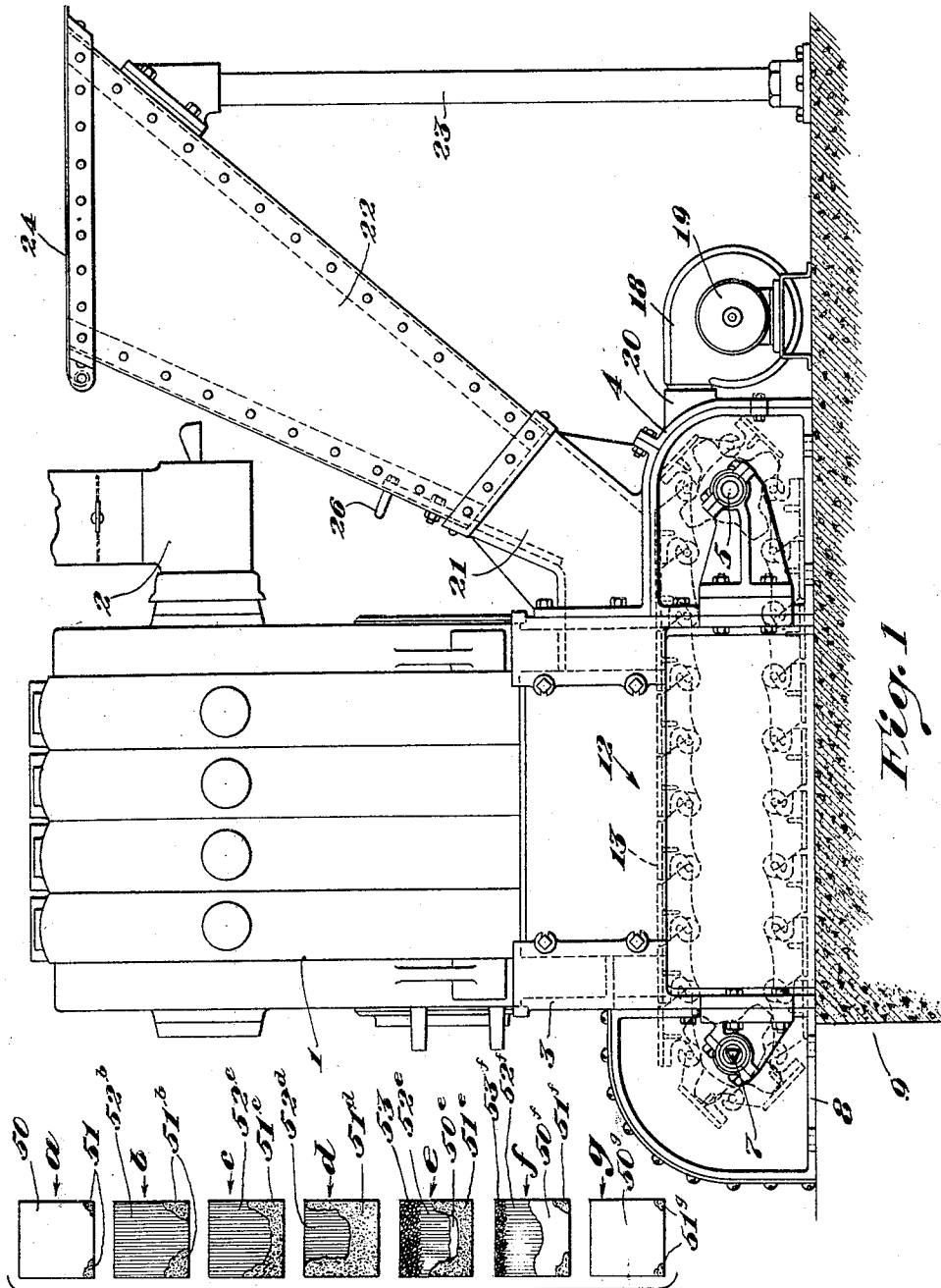


Fig. 1

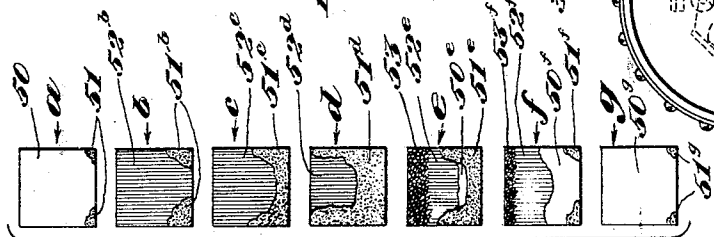


Fig. 5

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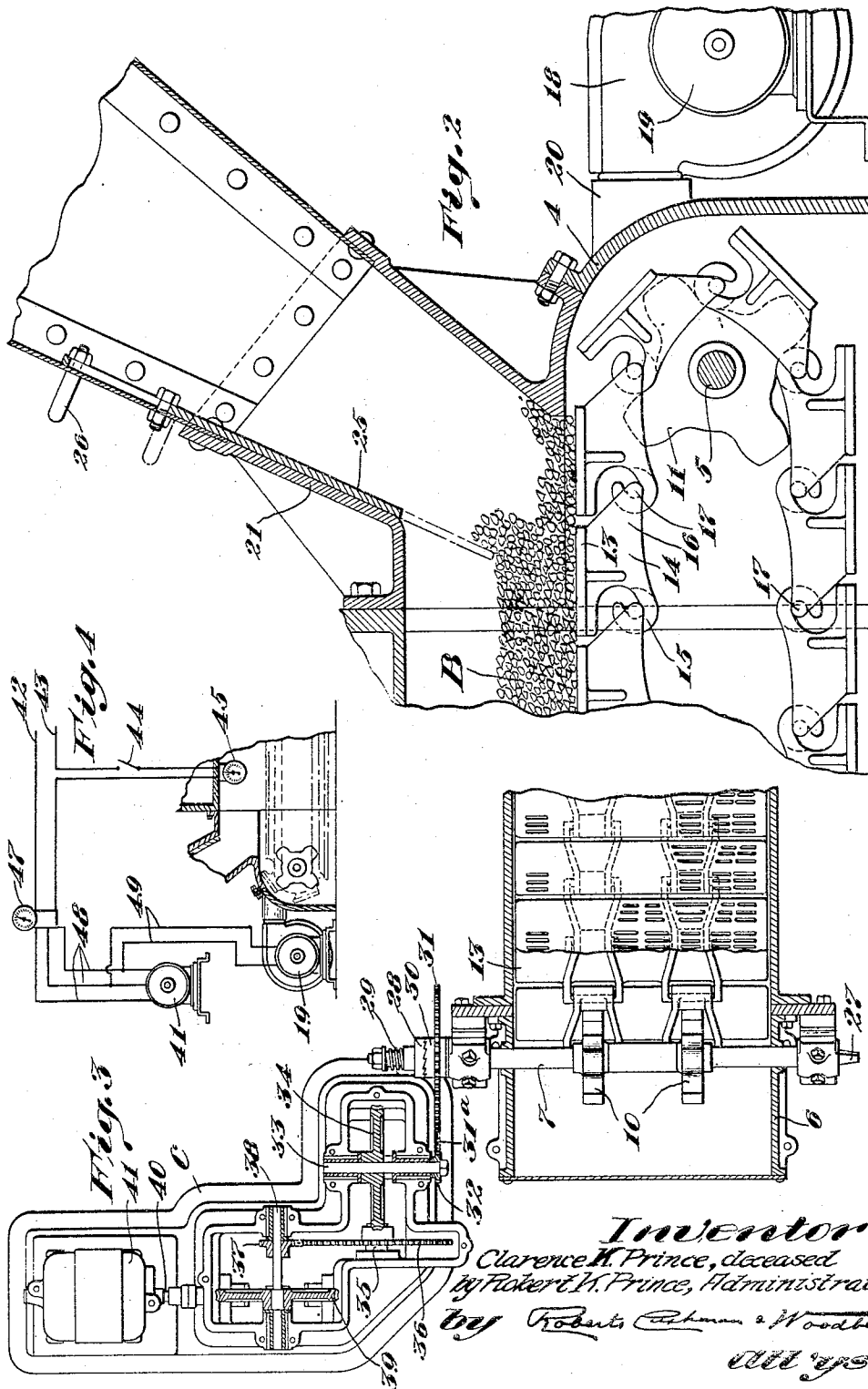
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UNITED STATES PATENT OFFICE

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METHOD OF AND APPARATUS FOR USE IN BURNING SOLID FUEL

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This invention pertains to a method of and apparatus for use in burning solid fuel and finds especial utility in the use of the smaller and cheaper grades of anthracite coal for domestic heating purposes, although in its broader aspects it is applicable to the burning of solid fuels of other kinds, for example, soft coal, coke, etc., and to furnaces other than those employed for domestic heating.

In heating dwellings, apartment houses and the like by means of apparatus employing a fluid heating medium such as steam, hot water, etc. three factors must be considered with reference to the heat supply;—first, radiation,—that is to say the area and efficiency of the device by which the heat from the heating medium is transferred to the air of the room; second, the heat absorption at the boiler,—that is the area and efficiency of the means by which the heat of the fuel is transferred to the water or other heating medium; and thirdly, the heat production,—that is the rate and efficiency of the conversion of the combustible elements of the fuel into available heat units.

Much experimental and practical work has been done to determine the best conditions for radiation and heat absorption, and, as a result of this work, radiating and absorbing means of highly efficient character have been devised, but with respect to heat production, particularly in connection with domestic heaters, comparatively very little advance has been made in the efficiency of burning solid fuel, at least.

Theoretically, for most efficient heat production and absorption, the combustion of the fuel should take place as rapidly as possible in order to produce a maximum temperature, since in accordance with Newton's law of cooling the quantity of heat given up by the fire to the water in the boiler is proportionate to the difference between the temperature of combustion and that of the water. Thus, if it were possible to burn the fuel in a powdered or vaporized form in an atmosphere of pure oxygen, the most intense heat and thus the most efficient use of the fuel would be obtained, but of course, as a prac-

tical matter, such a mode of burning fuel is impossible, and in dealing with fuels containing ash it is also necessary to take into consideration the fusing temperature of the ash, since the ash, when heated beyond this point, fuses and produces clinkers, which interfere with the orderly burning of the fuel and may cause damage to the grate and other portions of the furnace. Thus from a practical standpoint the maximum rate of combustion of solid fuel containing ash is that at which the temperature produced is just below that required to fuse the ash into clinkers, and any decrease in rate of burning below this point means a substantial loss in efficiency.

While the above conditions for high efficiency have long been recognized, there has apparently been no real attempt to construct domestic heaters in such a manner as to approach this ideal. Thus it has been common with most manufacturers to make the fire box of such a size and so to proportion the drafts that the rate of combustion will only approach a maximum under the lowest temperature conditions which will ever be met, and this means that in average and mild weather the drafts must be closed and the large area of fuel in the fire box kept alight, but at a temperature far below that for most efficient combustion. Some manufacturers have recognized this error in construction and have designed their heaters with reference to average rather than extreme weather conditions, but in this way an equally undesirable result is obtained since in extremely cold weather the heating plant is entirely inadequate, and requires constant attention and frequent firing in order even to approach conditions of comfort in the house, while in very mild weather combustion is inefficient for the reasons above described.

Apparently, without any clear conception of the underlying difficulty, but with the object of fitting fuel consumption to varying demands for heat, certain impractical attempts have been made to improve existing conditions by the use of endless moving grates or their equivalent, fed with fuel at one end and dumping the ash from the other

end. Providing the fuel is all burned while traveling from one end of such a grate to another, the quantity of fuel burned per unit of time varies with the speed of the grate, and it has been suggested that by progressively
 5 varying the speed of such a grate from high to low, as for example by placing the driving mechanism under the control of a thermostat, located either in the combustion space
 10 of the furnace or in the apartment to be heated, more economical combustion of the fuel could be obtained. Obviously such arrangements are mere makeshifts, accomplishing but little more than the automatic regulation
 15 of dampers, since at best there can be only one speed of grate travel at which the fuel is burned at highest efficiency, while at any lower speed the fuel burns less rapidly and thus efficiency of heat transfer to the water
 20 in the boiler is impaired.

For domestic heating, as distinguished from most power boiler conditions, the amount of heat required from the burning fuel varies rapidly and decidedly even from
 25 hour to hour. For example, when the sun is shining the heater may not be required to deliver nearly as much heat as when the sky is overcast; variations in the direction of the wind and in its velocity also makes appreci-
 30 able differences in the temperature of the ordinary house; while during the night hours, although the outside temperature may fall, it is usual to permit the temperature within the house to drop below the level maintained
 35 in the daytime.

As already pointed out, maximum efficiency of combustion requires a maximum rate of combustion and if for the minimum heat delivery the grate and draft are calculated for
 40 a maximum rate of combustion, it is obvious that since the rate of combustion can not further be increased, the obvious way to obtain more heat for transfer to the heating medium is to increase the grate area. Thus theo-
 45 retically an elastic grate capable of expanding and contracting as rapidly as required to meet varying demands for heat would be a satisfactory solution of the problem, but obviously the construction of such an elastic
 50 and expansible grate capable of burning solid fuel is a difficult and from a practical standpoint, an almost impossible accomplishment.

While prior investigators have apparently attempted to solve this problem, either by
 55 varying the rate of combustion, or possibly in some instances by attempting to vary the area of the grate, as just suggested no one previously has taken into consideration the time factor, that is to say, the length of the
 60 period during which maximum combustion takes place. The problem has now been approached from this angle, taking advantage of the fact that the heating medium, usually water, in the boiler constitutes a heat reser-
 65 voir of large capacity. With these consid-

erations in mind provision has been made for maximum rate of combustion of fuel during a given period of time, which period may be varied in length at will, and which if desired
 70 may be under the automatic control of a thermostat or similar instrument, and in the intervals between such periods of maximum combustion the rate of combustion is reduced
 75 to a very low point, which theoretically should be zero, although from practical considerations, particularly the necessity for rekindling the fuel at the beginning of a subsequent period of maximum combustion, it is preferred to maintain a low rate of combustion
 80 sufficient to prevent extinguishment of the fire.

In practicing this method of burning solid fuel, it is preferred to employ an endless moving grate, such as above described or its equivalent, automatically feeding solid fuel (usually anthracite coal of the size commercially
 85 known as buckwheat) to one end of the grate, and delivering the ash at the other end of the grate to an ash pit or other disposal means. Provision is made for delivering air under pressure into the space beneath the grate, and the grate is driven by suitable motive means
 90 at such a rate, taking into consideration the conditions of use, the character of the fuel employed, and the available draft, that the fuel is burned at as near maximum speed and efficiency as is possible, without fusing the
 95 ash or injuring the grate or other parts of the furnace. The high temperature thus obtained results in a rapid and efficient transfer of heat from the fuel to the water in the boiler, which in turn carries the heat units to the radiators where it is delivered to the surrounding air.

So long as the room temperature remains
 105 at or below normal, this high rate of combustion is maintained, and it is contemplated that in determining this high or operative speed of the grate, the total heat units delivered to the water per unit of time under continuous
 110 operation of the grate will be at least equal to the total heat units per similar unit of time necessary, under the most extreme conditions of outside temperature, to provide the desired
 115 degree of indoor temperature.

With the high or operative speed of the grate thus adjusted it is simply necessary, when the indoor temperature rises above that desired, to stop the grate and cut off the air pressure, whereupon the feed of fresh fuel
 120 ceases and the rate of combustion drops to a very low point. As above stated, as a practical matter it is preferred not to stop the grate entirely but instead to cut down its speed abruptly and to a definite point, as deter-
 125 mined by experiment, such that just sufficient fresh coal is fed to provide an area of smoldering fuel upon the grate, adapted, upon resumption of the operative speed and forced draft, rapidly to attain maximum combus-
 130

tion temperature and to serve as a means for quickly kindling the new fuel which is now fed at normal speed to the grate. This system, involving intermittent periods of maximum combustion and near extinction of the fire, thus differs materially from prior methods of progressively varying the fire intensity, since the heat units are delivered to the boiler at maximum efficiency, and the total quantity of heat delivered is substantially a function of the time during which the grate is driven at high speed, while in the intervals between periods of maximum combustion the quantity of fuel consumed is but very small compared with the amount usually burned when a heater is run with closed drafts.

As a safeguard to prevent waste of unconsumed fuel, if for any reason the fire should actually go out during an unusually long period of low combustion, it is proposed to provide automatic means, for example a thermostat located in or near the fire box, for completely stopping the grate driving motor when the fire box temperature drops below a predetermined point, and it is also contemplated the provision of a time controlled mechanism for stopping the grate after a low combustion period of excessive length.

Since with this method of burning fuel, combustion takes place under conditions of maximum efficiency, the grate area may be made relatively small as compared with ordinary constructions, while at the same time the rate of such a heater, as referred to the arbitrary system of rating heaters in accordance with the amount of radiation surface which they will supply will be very high, and yet will represent a true rating, whereas certain types of heaters, particularly those which are based upon radiation requirements for average temperature conditions, are misleading and unfair. In accordance with the present invention, a rating based upon grate area would be definite and dependable, for the reason that under standard conditions a definite quantity of heat units at a definite temperature would be delivered from each unit area of grate.

In the accompanying drawings one desirable embodiment of apparatus for practicing the improved method has been illustrated by way of example, and while this apparatus is practical and eminently suitable for the purpose, it is to be understood that the method is not dependent upon this specific apparatus, but may be practiced by the use of other apparatus or by other means wholly unlike that herein specifically illustrated.

In the drawings,

Fig. 1 is a side elevation, with certain parts in section, illustrating heating apparatus designed for use in the practice of the invention;

Fig. 2 is an enlarged fragmentary vertical

section showing the rear part of the heater of Fig. 1, with details of the fuel feed hopper;

Fig. 3 is a horizontal section partly in plan illustrating the forward portion of the heater shown in Fig. 1 together with mechanism for driving the grate;

Fig. 4 is a diagrammatic view illustrating one arrangement of electrical wiring suitable for use in controlling the operation of the mechanism herein disclosed; and

Fig. 5 is a diagram illustrating the appearance of the fuel bed of the heater at various stages in the operation.

The numeral 1 designates a boiler of any suitable construction adapted to contain water or other liquid constituting the heat transfer medium. This boiler is supplied with a smoke pipe 2 and with a fire-box 3, the latter having a rear extension 4 furnished with bearings for a horizontal shaft 5 and having a front extension 6 provided with bearings for a horizontal shaft 7. The front extension 6 is provided with an ash discharge opening 8 in its lower part adapted to deliver ashes into an ash pit 9 or to any other suitable ash disposal means such, for example, as a conveyor adapted to remove ashes from the vicinity of the heater.

The shaft 7 is furnished with one or more sprocket wheels 10 and the shaft 5 is furnished with corresponding sprocket wheels 11, and these sprocket wheels support an endless chain grate 12. This grate may be of any desired and usual construction, but is here shown as comprising a series of connected grate bars 13, each bar having a pair of downwardly projecting webs 14 and terminating at its front end in wide hooks 15 and at its rear end in a tail member 16 supporting a transverse pintle bar 17 which engages in the hooks of the next adjacent bar.

A blower 18, driven by means of an electric motor 19, delivers the air under pressure through a pipe 20 into the lower part of the fire-box and beneath the upper or active run of the grate. There is thus produced a plenum pressure in the space beneath the grate so as to provide a forced draft upwardly between the grate bars.

A hopper-like delivery nozzle 21 forms the upper part of the extension 4 of the fire-box and constitutes the lower part of a magazine 22 for the reception of fuel. This magazine may, if desired, be additionally supported by means of a post or posts 23 and is provided with a cover 24 which may be opened for filling the magazine but which is normally closed to exclude air. Preferably the lower part of this magazine is furnished with a sliding regulating plate 25 (Fig. 2) having an actuating handle 26. The lower part of this regulating plate 25 may be placed at various distances above the upper surface of the active run of the grate, and its lower end determines

the depth of the bed B of fuel upon the grate surface.

One of the shafts 5 or 7, here shown as the shaft 7, is furnished at one end with a polygonal portion 27 adapted to receive a shaker bar by means of which the shaft may be turned manually for advancing the grate if desired. A clutch collar 28 is splined to the opposite end of this shaft 7 and is normally forced by means of a spring 29 into engagement with a corresponding clutch member 30 forming the hub of a sprocket wheel 31 turning freely upon the shaft 7. Normally the clutch members 28 and 30 are engaged so that the wheel 31 drives the shaft 7, but the clutch elements are so shaped that upon application of a shaker bar to the end 27 of the shaft, the latter may be turned forwardly without turning the sprocket wheel 31.

The sprocket wheel 31 is driven very slowly by means of suitable reduction gearing from any desired source of power, such reduction gearing being here shown as comprising a chain 31^a engaging the wheel 31 and a sprocket wheel 32 on a shaft 33. The shaft 33 carries a worm wheel 34 meshing with a worm (not shown) mounted upon a shaft 35 at right angles to the shaft 33. The shaft 35 carries a sprocket wheel 36 which is driven by means of a chain from a sprocket wheel 37 on a shaft 38. The shaft 38 carries a worm wheel 39 meshing with a worm on the shaft 40 of an electric motor 41. Conveniently this motor and the several shafts of the reduction gearing may be mounted in a casing C provided with a cover, not shown, and which is filled with oil so that the parts may be constantly lubricated. With such an arrangement it is possible, while employing a motor of commercial type running at high speed to produce the desired slow movement of the chain grate 12. For example, with a motor speed of 1140 R. P. M. it is quite possible to so reduce this motion as to obtain a speed ratio of 320,000 to 1, thus bringing the linear speed of the grate down to 3.8 inches per hour. While such reduction is mentioned as a possibility well within the bounds of practical limitations, the invention is not intended to be confined to this particular reduction ratio or to the employment of a motor of this particular speed or even to an electrical motor of any type, nor is the invention limited to the employment of this particular reduction gearing.

The motor 41 is a two-speed motor, that is to say, when running at load it has two definite speeds, one of which is substantially greater than the other; for example, such speeds may be in the ratio of 6 to 1.

This motor may receive its actuating current from mains 42 and 43, and a manually operated switch 44 is provided by means of which the circuit may be broken if desired,

for example, when the heater is not in use. A thermostatic switch 45 is provided in this motor circuit, such switch 45 being located preferably within or adjacent to the fire-box and in such a position that it is exposed to the heat from the central part of the grate. This thermostat is so set that so long as any substantial amount of fire exists on the grate the circuit from the mains to the motor will remain closed, but when the fire is actually extinguished upon the grate, this switch will operate to break the circuit.

At some suitable point in the motor circuit a thermostat 47 is provided, preferably disposed in the apartment to be heated by the steam or other heat transferring medium from the boiler 1. This thermostat 47 is arranged to determine the speed at which the motor 41 shall operate, and is so set that so long as the temperature of the apartment is below or at a predetermined point the motor will run at the higher of its two speeds, but as soon as the temperature exceeds such predetermined normal point the thermostat will immediately shift the connections so as to cause the motor to run at its lower speed.

Connections are also provided 49 which are under control of the thermostat 47 for determining the operation of the motor 19 which drives the blower. These connections 49 are so arranged that when the motor 41 is running at its higher speed, current is furnished to the motor 19 to actuate the blower and thus provide a forced draft under the grate, but when the motor 41 is running at its lower speed the motor 19 of the blower is stopped.

In designing the apparatus, the kind of fuel, the draft and the grate area are taken into consideration and the high speed of the motor and the corresponding high speed of the grate is so determined that with forced draft the fuel upon the grate is burned with maximum speed, that is to say, as fast as is permissible without fusing the ash or injuring the heater. The fuel feeds down automatically by gravity from the magazine 22 beneath the lower end of the regulator plate 21 and forms a bed B of desired thickness upon the grate, and in traveling from the magazine to the forward end of the fire-box this fuel is wholly consumed and the ash is dumped from the forward end of the grate through the opening 8 into the ash box. During this high speed travel of the grate the fire upon the grate surface usually has the general appearance indicated at *a* in Fig. 5 wherein almost the entire surface of the grate shows an intense white heat, as indicated at 50, with only slight areas of ash 51 at the extreme forward corners of the grate. If after a certain period of operation at maximum rate of combustion the temperature in the apartment to be heated rises above normal, the thermostat 47 immediately operates to stop the blower 18 and to reduce

the speed of travel of the grate to its low and predetermined speed which, as above noted, is much slower than its maximum speed. Within a very few minutes after this operation of the thermostat the grate surface is found to exhibit the appearance somewhat as in *b* of Fig. 5 wherein the area 52^b is a dull red and the ash areas 51^a at the forward corners have increased substantially in size.

After a short further interval the grate surface appears as indicated at *c* in Fig. 5, wherein the dull area 52^c has decreased in size, whereas the ash area 51^c has correspondingly increased, extending across the front of the grate. After a short further interval the dull area 52^d as indicated at *d* in Fig. 5 has shrunk and the ash area 51^d has become so great as substantially to enclose three sides of the smoldering fuel.

Assuming that at this time the temperature in the apartment falls below the normal point, the thermostat 47 will reverse its former action, starting the blower 19 into action and causing the grate to resume its high speed of travel. The immediate effect of this is illustrated at *e* in Fig. 5 wherein it will be seen that fresh and unconsumed fuel 53 is moved forwardly over a substantial area of the grate, and the smoldering area 52^e also moved forwardly as well as the ash area 51^e, but at the forward portion of the smoldering area 52^e the fire will have become brighter, as shown at 50^e. After a few moments of operation of the blower the grate will show the appearance indicated at *f* in Fig. 5 wherein the dull area 52^f will have increased in size, some of the fresh fuel has kindled, the area of unconsumed fuel 53^f will have become smaller, the area of intense burning 50^f will have increased very substantially, and the ash area 51^f will have become quite small. At *g* in Fig. 5 the appearance of the grate is shown after a slight further period of operation of the blower, the fire 50^g being intensely bright with very small areas of ash 51^g at its corners, this condition being substantially the same as at the beginning of the operation.

With this arrangement the heating period constitutes that period at which the grate is running at high speed and the blower is in operation and during substantially all of this period, except at the very beginning and end thereof, the fuel is being burned at the highest permissible speed and thus at the nearest possible approach to maximum efficiency. On the other hand, in the intervals between such periods of maximum combustion there is but slight consumption of fuel, the movement of the grate at this time being just sufficient to keep the fire from actually going out, although it may be desired to run the grate at a little higher speed than this in order that there may be a reasonably large area of smoldering fuel to produce a quick heat when the blower

is again started. However, during such intervals, between periods of maximum combustion, there is but little heat given off and but little fuel actually consumed. Thus while the heater is operated at maximum efficiency when called upon to deliver heat, its consumption of fuel is very economical and very low as compared with the ordinary heater.

Moreover, by the employment of the present method of burning fuel it is possible to use a grate area much smaller than usual since this grate area may be calculated for continuous operation at maximum efficiency in producing the necessary amount of heat to meet the most adverse temperature conditions, while at the same time this area thus calculated is only operative during such periods as may be necessary to produce the actual amount of heat required for heating the apartment. In other words, the present system of heating is based upon a variable time factor rather than upon the usual method of attempted variation in rate of fuel consumption, and much more accurate and uniform results are secured and a far higher economy of fuel than has been possible in any construction previously known.

While a desirable form of apparatus has been disclosed for practicing the above method and while certain desirable steps in the practice of the method have been set forth, it is to be understood that the apparatus here disclosed is merely by way of example and is not restrictive of the invention and that the various steps of the method described need not necessarily be followed in the exact order pointed out and that certain of such steps may be omitted or others substituted therefor as occasion may indicate to be desirable.

Claims:

1. That method of burning solid fuel which comprises burning a bed of fuel at the maximum practical rate of combustion with the assistance of a forced draft while moving the fuel bed bodily toward ash receiving means and feeding fuel at such a rate as to maintain combustion over substantially the entire surface of the fuel bed, and suddenly cutting off the forced draft and reducing the rate of movement of the fuel bed.

2. That method of burning solid fuel which comprises feeding fuel to one end of a movable grate to form a fuel bed, burning the fuel upon the grate at the maximum practical rate with the assistance of a forced draft, moving the fuel bed away from the feed point at such a rate that the fuel is substantially consumed before reaching the opposite end of the path of travel, and abruptly shutting off the forced draft and reducing the speed of the fuel bed to a predetermined fixed rate substantially less than its original rate.

3. That method of burning solid fuel which comprises alternatively moving a bed of fuel

bodily at one of two predetermined speeds, burning the fuel at the maximum practical rate while the bed of fuel is moving at the higher rate of speed, suddenly shifting to the lower rate of speed, and burning the fuel at a rate just sufficient to support combustion while the fuel bed is travelling at the lower speed.

4. That method of burning solid fuel under a boiler for domestic heating which comprises feeding fuel at a relatively high and predetermined rate to a grate, burning the fuel with the aid of forced draft at the maximum practical rate so long as the temperature in the apartment to be heated remains at or below a predetermined normal, and upon rise in temperature above said normal, abruptly cutting down the rate of fuel feed to a relatively low point of positive feed and stopping the forced draft.

5. Apparatus of the class described comprising means for moving a bed of fuel bodily in a given direction at either of two predetermined rates, means for supplying solid fuel to one end of said bed and for receiving ash from the other end of the bed, means for supplying a forced draft for burning the fuel at a maximum practical rate while the bed of fuel is moving at the higher of said speeds, and means automatically responsive to temperature variation for suddenly shifting from one of said speeds to the other.

6. Apparatus of the class described comprising means for moving a bed of fuel bodily in a given direction at either of two predetermined rates, means for supplying solid fuel to one end of said bed and for receiving ash from the other end of the bed, means for supplying a forced draft for burning the fuel at a maximum practical rate while the bed of fuel is moving at the higher of said speeds, and thermostatic means responsive to rise in temperature above a predetermined normal for abruptly shifting from the higher to the lower speed and for concomitantly cutting off the forced draft.

7. Apparatus of the class described comprising a boiler, a fire box, moving means constituting a grate, a magazine for solid fuel arranged to deliver fuel to one end of the grate surface, a two-speed motor for moving the grate, reduction gearing for transmitting motion from the motor to the grate, a blower for delivering air under pressure to the grate whereby to burn the fuel upon the grate with maximum practical rapidity when the grate is driven at the higher of its two rates of travel, and means simultaneously stopping the blower and causing the motor to shift from its higher to its lower speed.

8. Apparatus of the class described comprising an endless movable grate, a magazine for delivering solid fuel to the grate, motor means for moving the grate at either of two definite predetermined speeds, and a thermo-

static control device for the motive means adapted at a predetermined temperature to cause the motive means abruptly to shift from one speed to the other, the higher speed of grate travel being such that the fuel is fed from the magazine at a rate for burning with maximum practical rapidity, and the lower speed being such as to provide fresh fuel from the magazine at a rate such as merely to prevent extinction of the fire.

9. Apparatus of the class described comprising an endless chain of grate bars, means guiding said chain to provide a run forming the active grate surface, a magazine for delivering solid fuel to one end of the active grate surface, motive means for moving the chain of grate bars at either of two definite predetermined speeds, and means for delivering air under such pressure and in such volume to the under side of the active grate surface as to cause the fuel to burn with maximum practical rapidity when the chain of grate bars is moving at the higher speed.

10. Apparatus of the class described comprising a boiler, a fire box, a chain grate normally moving from the rear to the front of the fire box, a magazine for feeding solid fuel to the rear end of the grate, means at the front of the fire box for receiving ashes from the grate, a two-speed electric motor, reduction gearing for transmitting motion from the motor to the grate, a blower for delivering air below the grate, and means responsive to room temperature for simultaneously changing the speed of the grate driving motor and for starting or stopping the blower.

11. Apparatus of the class described comprising means for feeding solid fuel at two different predetermined rates, means supplying a forced draft for burning the fuel with maximum practical rapidity while the fuel is fed at the higher rate, and means for abruptly shifting from the higher rate of fuel feed to the lower rate and concomitantly cutting off the forced draft.

Signed by me at Westfield, Massachusetts, this 24th day of April, 1928.

ROBERT K. PRINCE,
Administrator of Clarence K. Prince, Deceased.