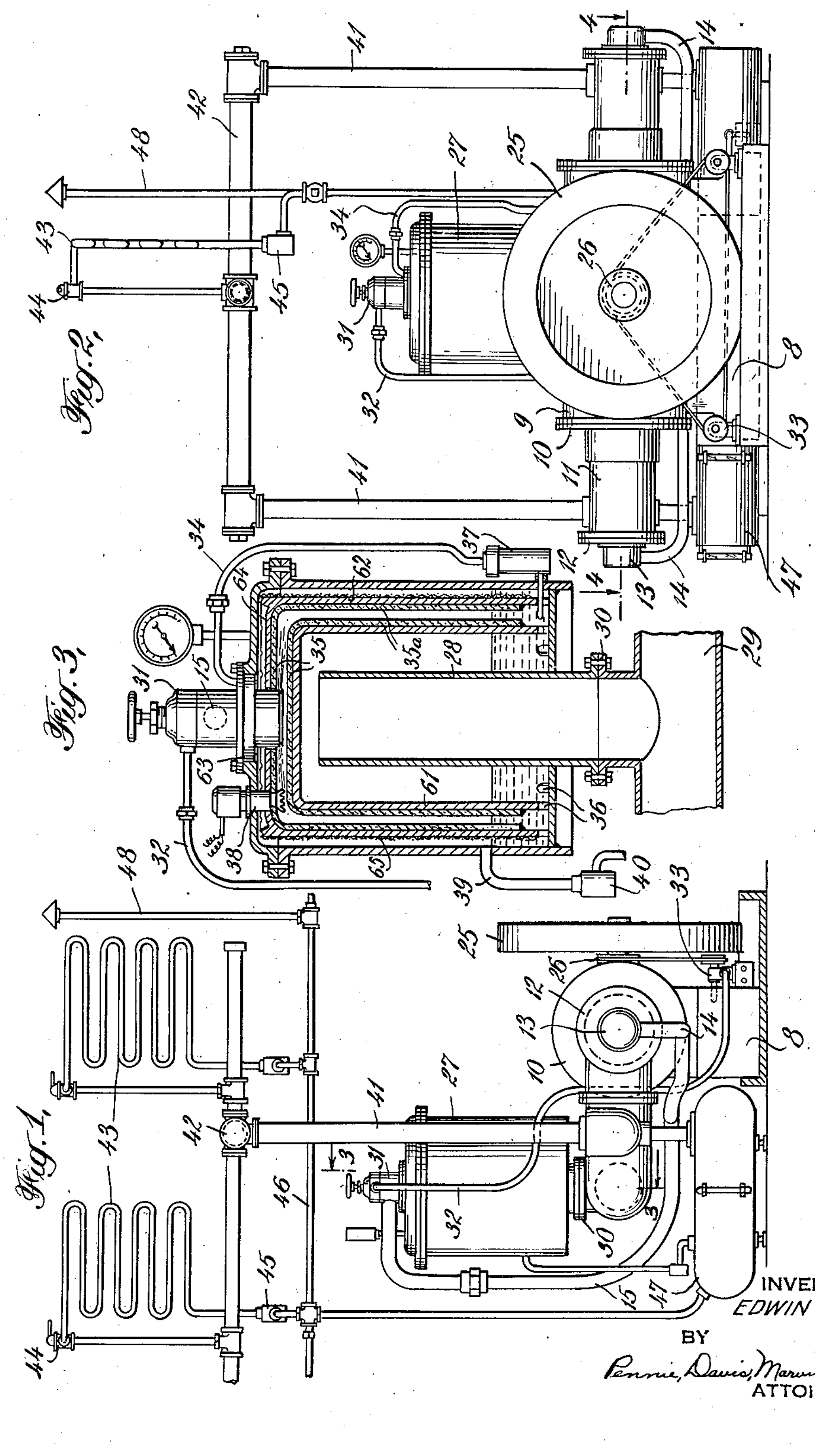
Oct. 14, 1941. **E. TAYLOR** **2,259,012**

HEATING SYSTEM

Filed May 24, 1939 3 Sheets-Sheet 1



INVENTOR
EDWIN TAYLOR
BY
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

Oct. 14, 1941. E. TAYLOR 2,259,012

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Filed May 24, 1939 3 Sheets-Sheet 2

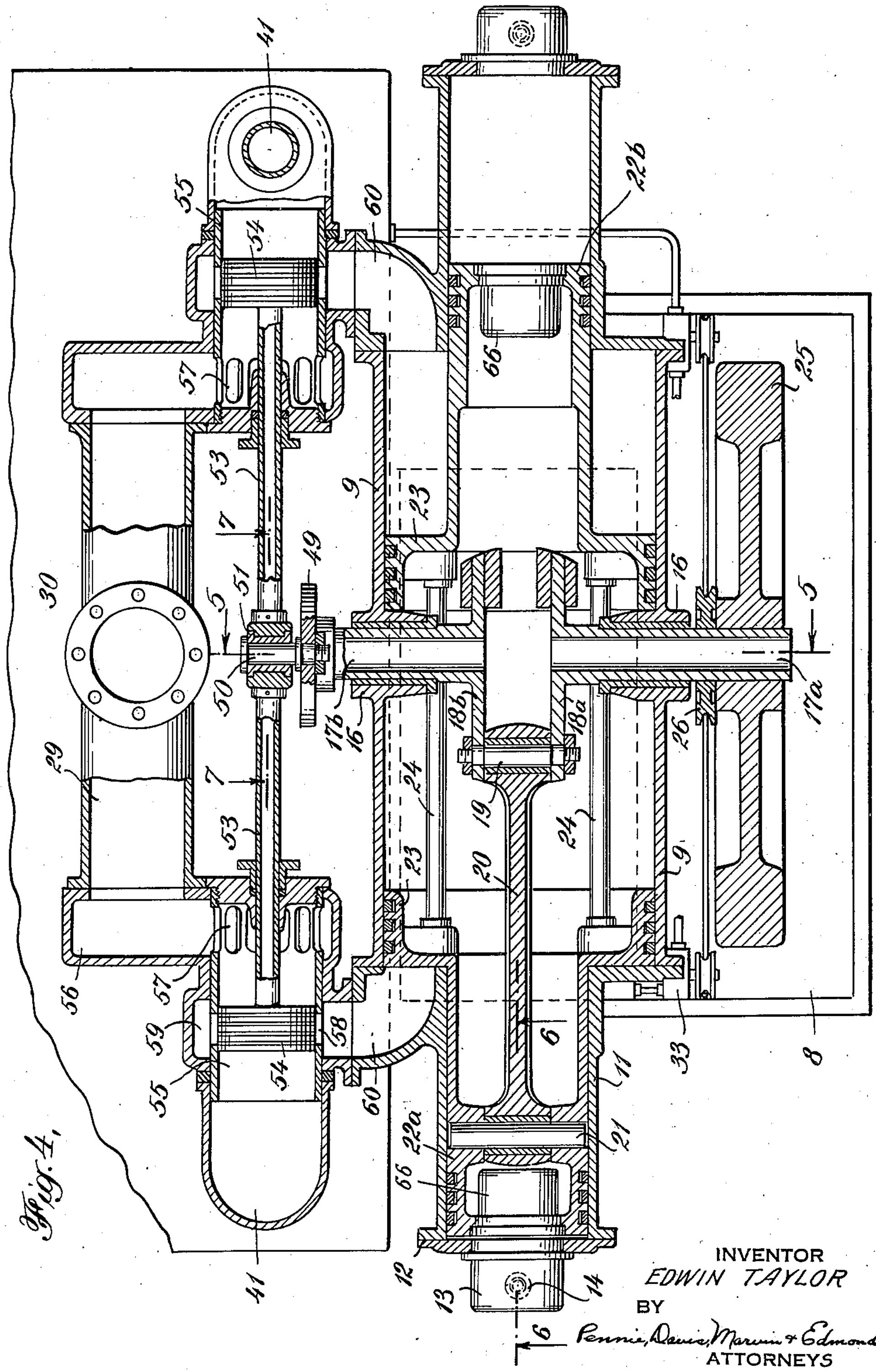


Fig. 4.

INVENTOR
EDWIN TAYLOR
BY
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

Fig. 5.

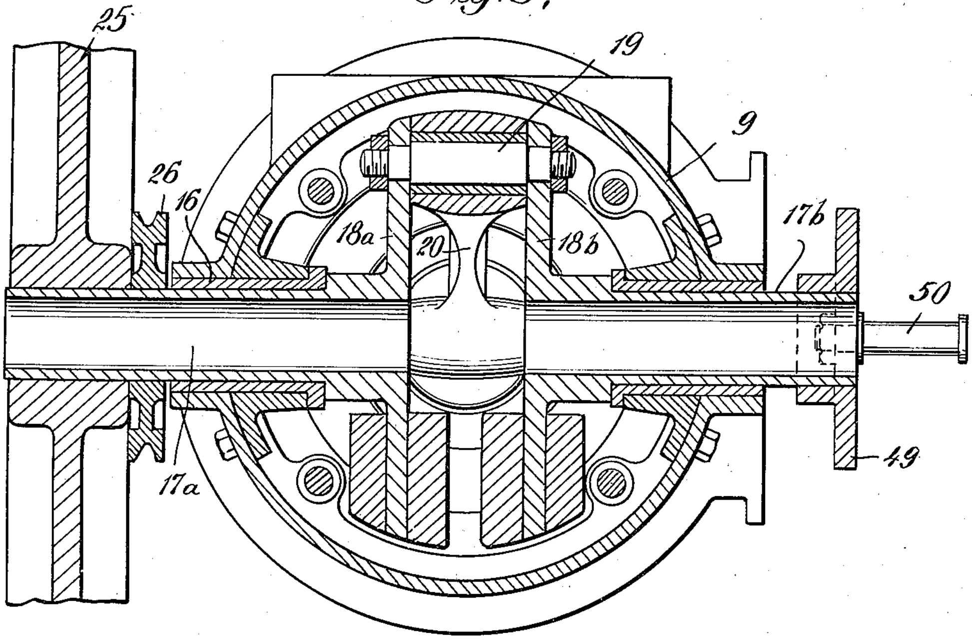


Fig. 6.

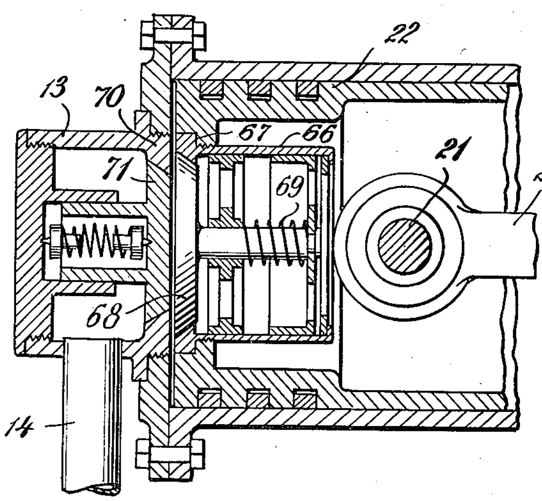
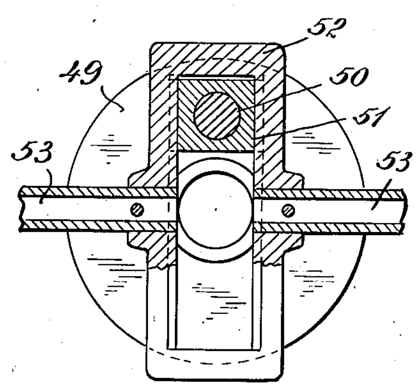


Fig. 7.



INVENTOR
EDWIN TAYLOR
BY
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

Patented Oct. 14, 1941 2,259,012

UNITED STATES PATENT OFFICE

2,259,012

HEATING SYSTEM

Edwin Taylor, Brooklyn, N. Y., assignor of two-fifths to William F. Doyle, Summit, N. J.

Application May 24, 1939, Serial No. 275,464

9 Claims. (Cl. 237—2)

This invention relates to an improved method and apparatus for the radiation of heat. More particularly the invention relates to a heat-radiating system comprising a particularly effective generator for the production of a heat-conveying fluid medium of any desired temperature and pressure by the substantially complete combustion of a fluid fuel, and a heat-radiating system for the radiation of the heat contained in said fluid medium and present partially in the form of sensible heat and partially in the form of latent heat of vaporization of at least one of the components of the medium. In a particularly advantageous embodiment, the invention provides a method and means for the production and discharge to a heat-radiating system of a heat-conveying fluid medium at a rate automatically and responsively regulated by the amount of heat radiated from the system.

The hitherto suggested methods of heating and, particularly the currently successfully employed methods, have involved the combustion of a gaseous, liquid, or solid fuel in a fire-box or combustion zone adjacent to but not in open communication with a boiler or equivalent confined space containing a heat-conveying medium. For example, in household heating systems, whether they be air, hot water or steam, the air or water to be heated is present in or circulated through a mechanism separate from the combustion zone. In spite of the fact that signal advances have been made in the art of heating, the efficiencies of the systems employed, expressed in terms of the potential heating power of the fuel compared to the heat units actually radiated or available for the desired heating operation, have remained at a relatively low figure. Such prevailing low efficiencies are primarily attributable to two causes: first, current methods of combustion invariably fall short of attainment of complete oxidation of the fuel, thus precluding from the outset the possibility of utilizing substantial proportions of the theoretically possible heat-generating power of the fuel; and second, the transfer of heat from the hot products of combustion to the heat-conveying medium even under the most favorable circumstances is limited, and as a result a large proportion of the heat developed during the oxidation remains with the products of combustion and is passed to the atmosphere through a flue or stack.

In spite of extensive development work on methods of combustion, oil and gas burners produce substantial quantities of products of incomplete combustion, such as carbon monoxide and carbonaceous sooty material. One method of minimizing the production of such incompletely oxidized products has been to employ an excess of air in the combustion. Such an expedient, however, serves to produce a higher velocity of gaseous flow in the combustion chamber and the hot products of combustion are in heat-transfer relationship with the heat-conveying medium for a shorter period of time. As a result, in actual practice it has usually been necessary to effect a compromise between the degree of combustion attained and the added proportion of heat lost through the use of such excess air. The use of combustion catalyzers variously disposed in combustion zones for accelerating the oxidation has frequently been proposed. The effectiveness of such substances as finely divided platinum and palladium, or metallic oxides such as copper, nickel, lead, cobalt, chromium, thorium and uranium oxides, is well known. It is equally well known, however, that few if any of such proposed methods, except in very special circumstances, have been successful in avoiding the presence of large proportions of incompletely burned material in the flue gases. In order to make use of the salutary effects of such catalytic substances to the best advantage, many and varied expedients have been resorted to in the disposition of the material in the combustion chambers and in the arrangement of the chambers themselves. Although some of these arrangements and methods represent substantial advances in the art of combustion, they have failed to provide a method for completely burning a fluid fuel to produce a gaseous mixture substantially free of products of incomplete combustion.

Regardless of the extent to which complete combustion is achieved, however, the primary loss of heat in the methods employed in the heating art today is to be found in the excessive amounts of heat, in many household heating systems as high as 50% of the potential fuel output, discharged to the atmosphere and frequently referred to broadly as "stack losses." Due primarily to practical limitations in transferring the heat to the heat-conveying medium, the products of combustion discharged will usually have a temperature ranging from 400° to 600° F., thus introducing a very considerable loss in the form of sensible heat. There is an additional loss which is unavoidable where the products of combustion escape, as they do in most cases, at a temperature in excess of 212° F. Hydrogen, a constituent of most fuels, burns to form water which passes off with the other products of combustion in the form of steam. The additional and necessary loss here involved in the form of heat of vaporization of the water is considerable. For example, if pure hydrogen is burned under a boiler with twice the amount of air needed for theoretical combustion giving exit gases of 550° F., the heat loss due to the discarded steam is 30%. With ordinary fuel oils this loss approximates 8 to 10%. Because of the fact that a loss due to this cause has been considered inevitable. it has become the practice to refer to the heating value of an oil as the value obtained after subtracting the heat to be lost through this usually inevitable cause. This value is the "lower heating value." For instance, a certain fuel oil containing 13.7% hydrogen has been rated as having a heat content of 19,210 B. t. u. per pound. Theoretically this same fuel should release 20,889 B. t. u., an increase of nearly 9%. This latter value constitutes the "higher heating value" of the fuel.

In an attempt to eliminate the second of the above discussed causes of inefficiency, it has been proposed to subject hot products of combustion to contact with water, usually in a packed tower, and to pass the hot gases commingled with steam to a heat-radiating system. In such a process, although the temperature of the hot gases is lowered to a more suitable working temperature, the heat given up in the cooling is not lost, but is transformed to latent heat of vaporization, in which form it also passes to the radiating system and is given up when the steam is condensed to water. Furthermore, the heat contained in the steam resulting from the combustion itself is also passed to the radiating system. Heating systems attempting to eliminate "stack losses" by the application of the just recited basic idea have failed in practical operation, and have, therefore, not achieved commercial significance. The failure of the proposed methods has been due to such factors as difficulty of control and maintenance on an automatic basis and particularly to their inability to effect complete combustion of the fuel. Incomplete combustion in such systems results not only in low efficiencies, but also gives rise to circumstances making the process inoperative either from mechanical causes or due to necessary safety precautions. Carbon monoxide and soot or similar carbonaceous material are two particularly deleterious products of incomplete combustion, one or both of which are present in the combustion gases of all of the referred to proposed methods with which I am familiar. The danger of passing hot carbon monoxide through a radiating system is obvious. Soot very quickly clogs passageways and valves, preventing their continued operation. Furthermore, the combustion gases usually contain unburned hydrocarbon fuel and this, when traversing a packed tower at high temperatures through which water is also passed, breaks up to form a carbonaceous deposit which completely clogs the packing in a very short time.

The present invention affords a process and apparatus for the production and radiation of heat which overcomes or eliminates the disadvantages and difficulties encountered in the operation of the above discussed currently employed and hitherto proposed heating systems.

In accordance with my invention an intimate mixture of a fluid fuel and a combustion-supporting medium is injected between a plurality of heated, uniquely arranged contact surfaces of refractory material to permit the attainment of complete combustion of the fuel during the free expansion of the mixture. The resulting hot gases, substantially free of products of incomplete combustion, are subjected to contact with a volatile medium to transform a substantial portion of their sensible heat to latent heat of vaporization, and the thus formed heat-conveying mixture is discharged to a heat-radiating system.

In a preferred embodiment the invention comprehends a mechanism intermediate the means for generating the heat-conveying fluid medium and the radiating system, capable of delivering said fluid medium to the radiating system in an amount and at a rate regulated by the amount of heat discharged from the radiating system. This responsively regulated means may also be adapted to control the generation of the heat-conveying medium by supplying the combustion-supporting medium to the generator at a rate responsive to the amount of heat dissipated from the radiating system. My invention thus provides a method and apparatus for producing a heat-conveying fluid medium containing substantially all of the heat units resulting from complete combustion of a fluid fuel, and for supplying this heat-conveying medium to a radiating system in response to the heat demand of such a system.

The generator unit of the heat-radiating system of my invention comprises the following elements. An injection means is suitably positioned for injecting an intimate mixture of a fluid fuel and a combustion-supporting medium, for example air, between a plurality of closely spaced, heated, combustion-catalyzing contact surfaces of refractory material at a pressure in excess of the pressure in the remainder of the system. These surfaces should be spaced approximately ¼ to ⅜ inches apart, and may advantageously have incorporated therein a combustion-catalyzing substance, such as for example an oxide of chromium or other appropriate metal. The fluid fuel may be a gaseous or liquid fuel, and it is to be understood that the term "fluid fuel" as used herein has such a connotation. Any liquid fuel capable of being burned and possessing a viscosity appropriate to permit pumping and atomization at reasonably low temperatures is suitable for use in such a generator. Of the appropriate liquid fuels, various petroleum products, ranging from kerosene to heavy fuel oils, are most suitable. As a result of the high efficiency of oxidation achieved by such a generator, many gaseous as well as liquid fuels which in the past have been of little or no commercial value may be completely burned therein to produce with substantially theoretical efficiencies, a valuable heat-conveying medium. The catalytic contact surfaces should be so constituted and arranged that their areas adjacent the point of injection of the fuel-air mixture increase outwardly therefrom at a rate substantially in excess of a linear rate. By this novel arrangement the said areas, and also the space between the plates increase outwardly from the point of injection at an even higher rate than the rapidly expanding heated fuel-air mixture. As a consequence there is no back pressure created by the inability of the products of combustion to escape from the combustion area, as is the case in other methods of combustion, and there is little or no tendency for the completely oxidized products to circulate in the said area to prevent unburned gas from coming in contact with the catalytic surfaces where substantially all of the combustion occurs. The contact surfaces adjacent the point of injection may comprise two substantially flat horizontal circular surfaces through the upper of which extends the fuel injection means, as described below in connection with the drawings attached hereto, or the said contact surfaces may comprise a plurality of superimposed coaxially aligned closely spaced substantially bell-shaped surfaces providing a plurality of substantially bell-shaped passages. In the latter type of generator the tops of the bell-shaped surfaces, other than the innermost surface, are provided with coaxially aligned openings preferably having progressively smaller diameters approaching the inner surface. A fuel-air mixture is injected into the well formed by such openings and is equally distributed to the passages between the contact surfaces whose areas adjacent said openings expand at a rate in excess of a linear rate. Various other arrangements of contact surfaces may be employed within the scope of the invention, provided they involve closely spaced surfaces whose areas increase outwardly from the point of fuel injection at a rate substantially in excess of a linear rate. The generator further comprises means for cooling the products of combustion to any desired operating temperature by transforming a portion of their sensible heat to latent heat of vaporization by subjecting the hot gases to contact with a volatile liquid such as water. This may be accomplished by passing the hot gases from between the contact surfaces into and through a volatile liquid, or by other means such as spraying a volatile liquid into or across the path of the hot gases. The mixture of products of combustion and vaporized condensable liquid, together with any inert constituents of the combustion supporting medium, at a temperature substantially less than the combustion temperature, constitutes the heat-conveying medium supplied to the radiating system. Suitable generators for producing such a heat-conveying medium are described and claimed in my co-pending application for Letters Patent Serial No. 275,462 filed of even date herewith.

The heat-radiating system may be of any conventional type suitable for use with a heating medium containing a vaporized condensable liquid. It is in fact one of the advantages of the invention that an already installed radiating system may be directly incorporated in the novel co-operative combination of elements of my invention without substantial alterations or change in capacity. It is to be understood that while the heat-radiating system is described and illustrated herein with respect to its use in maintaining the temperature of a room, house or similar interior space within a desired range, the method and apparatus of the invention are equally effective in supplying heat for other purposes, such as for example the operation of a steam table or drying oven.

The means for controlling the generation of the heat-conveying fluid medium responsively to the amount of heat radiated, i. e., the amount transferred to the surrounding atmosphere or objects to be heated, in accordance with my invention may comprise a simple and effective prime mover mechanism which regulates the passage of the heat-conveying medium to the radiating system and which concurrently supplies the combustion-supporting medium to the injection means of the generator at a rate appropriate to satisfy the demand of the radiating system. Such a prime mover mechanism in addition to supplying a combustion medium to the generator at an automaticaly controlled rate may be in operative relationship with pumping means for supplying the fluid fuel to the injector means at an appropriate rate and for supplying the volatile liquid to the generator at a rate appropriate to maintain the desired temperature of the heat-conveying medium. A mechanism of this type, hereinafter more fully described, transfers the heat-conveying medium from the generator to the radiating system, as well as performing the just mentioned functions with a minimum loss in the form of work. Such a mechanism, in accordance with the embodiment to be described, is in effect a slow speed engine operated by virtue of the difference in pressure between the generator outlet and the heating line, and not primarily by the expansive force of the heating medium, as will be apparent from the fact that the gas-steam mixture is fed to the cylinder during the entire piston stroke. The speed of such an engine need not exceed 160 R. P. M. The performance of the above mentioned functions constitutes a very small load on such a device.

A more complete understanding of the process and apparatus of my invention may be had by reference to the accompanying drawings which illustrate one form of construction arrangement in accordance with my invention.

In the drawings in which like reference numerals designate similar parts:

Figure 1 is an end elevation of the generating and transmission unit which is represented diagrammatically as attached to a heat-radiating system.

Figure 2 is a side elevation of the unit and radiating system as shown in Figure 1.

Figure 3 is an enlarged axial section of the heating fluid generator taken on the line **3—3** of Figure 1, parts being broken away and parts being shown in elevation.

Figure 4 is an enlarged horizontal section taken along the line **4—4** Fig. 2, and showing the prime mover means and air compressor portion of the unit shown in the lower parts of Figures 1 and 2, portions being broken away and other portions shown in plan.

Figure 5 is an enlarged transverse section on the line **5—5** of Figure 4, with the crank shaft displaced 90° from its position as shown in Figure 4, parts being broken away and parts shown in elevation.

Figure 6 is an enlarged fragmentary section on the line **6—6** of Figure 4, parts being broken away and parts shown in elevation.

Figure 7 is an enlarged fragmentary sectional elevation taken on the line **7—7** of Figure 4.

As shown in Figures 1 and 2, an appropriate pedestal or base **8** supports an enlarged prime mover cylinder **9** whose ends are partly closed by annular plates **10**, connecting with which are coaxially aligned air compressor cylinders **11** of reduced diameter. To the outer end of each compressor cylinder is attached an annular cap **12** to each of which is secured a delivery valve housing **13** shown in detail in Figure 6. From the valve housings **13** lead delivery pipes **14** which discharge into a common air delivery pipe **15** supplying air under pressure to the generator. Midway of main cylinder **9**, as best shown in Figure 4, are bearings **16** for journaling a hollow horizontal drive-shaft through which air may be introduced into the compression chambers. This drive-shaft consists of axially spaced sections 17a and 17b, whose inner opposing ends are provided with crank arm sections 18a and 18b. Between the outer ends of these crank arm sections is disposed a crank pin 19, which in turn is pivotally connected with one end of a connecting rod 20. The opposite end of the connecting rod is pivotally connected to a wrist pin 21 carried by an air compressing piston 22a, which reciprocates in the compression cylinder 11 to compress air admitted through the main horizontal drive-shaft structure, or through openings in the wall of main cylinder 9 positioned beyond the limits of movement of pistons 23, for example peripherally spaced in alignment with main shaft 17. Enlarged oppositely faced pistons 23 which are rigidly connected by connecting rods 24 reciprocate in the main cylinder 9 and are integrally connected with the smaller diameter air compressor pistons 22a and 22b, which reciprocate in the smaller terminal cylinders 11 in unison with the large pistons. Mounted on the outer end of shaft 17a is a flywheel 25, inside of which may advantageously be placed a power take-off pulley 26.

The heat-conveying fluid medium is produced in generator 27, shown in Figures 1 and 2, and in detailed axial section in Figure 3. The fluid medium passes through downcomer pipe 28 into manifold 29, provided with an upwardly presented connection flange 30 for seating the downcomer pipe, which is in turn rigidly connected with generator 27. The fuel to be burned is supplied to an appropriate inlet nozzle or atomizer 31 through fuel pipe 32. This may be accomplished by fuel pump 33, which may be run by power derived from take-off pulley 26. Air under pressure enters through pipe 15, and water is introduced through pipe 34. The atomizer, here shown in elevation, may be of the type described and claimed in my co-pending application Serial No. 275,463, and should be effective in injecting a substantially flat disc-like sheet of atomized liquid fuel outwardly toward the periphery of circular closely spaced contact plates 35. These contact plates, containing a catalytic material, and extensions thereof 35a forming an annular cylindrical space, define a combustion zone in which complete combustion of the fuel occurs. The extensions 35a are immersed in a volatile liquid, preferably water, in a manner such that the hot products of combustion will pass through the water, being themselves substantially cooled and concurrently volatilizing a portion of the water to form steam. The hot products of combustion pass through the ports 36, situated adjacent the bottom of one of the inner of two cup-shaped supports 61 and 62 for the contact surfaces 35, into a central annular space and together with superheated steam are removed from the generator through the down-comer pipe 28.

The flow of water into the system from supply tank 47, through pipe 34 is with advantage automatically regulated by a thermostatic control valve 37 which operates responsively to the temperature of the water in the bottom of the generator. The water may with advantage be introduced at the top of the generator through annular space 63 and by holes in the bottom thereof to basin 64 formed by the top of support plate 62. The water overflows through peripherally spaced notches and passes over the cylindrical portion of support 62. The distribution of the water over this surface may be improved by supplying a cylindrical mesh screen 65. The introduction of the water in this manner serves to partially cool the hot combustion surfaces and effect a preheating of the water. There is indicated in Figure 3 an ignition device 38 which may be of the hot wire type or of a jump spark type. A particularly efficient form of ignition device is a circular hot wire extending circularly through the flat combustion zone defined by contact surface 35 and intermediate the atomizing head and the periphery of the said plates. The maximum permissible water level in the generator is governed by an overflow pipe 39 through which the escape of hot gases is prevented by means of a thermostatically acting valve 40.

The mixture of partially cooled products of combustion and steam from the generator is passed from manifold 29 into main prime mover cylinder 9. After performing auxiliary functions as described below, it is subsequently forced into the heat-radiating system by the action of the main pistons through outlet pipes 41, which lead to a manifold supply pipe 42 from which radiators 43 disposed at suitable points to provide the desired degree of heating, may be supplied through connection pipes in accordance with conventional practice. The radiators are equipped with Sylphon control valves 45 connected to return manifold 46 which in turn is connected with the water supply tank 47. Cut-off valves 44 of standard type serve to remove individual radiators from the system. In this way there is returned as water suitable for reuse the greater part of the steam produced in the generator, both by vaporizing the water and as a product of combustion. Return manifold 46 is also connected with a pipe 48 which leads by means of a vent to the outer atmosphere. Through this vent at atmospheric pressure and substantially atmospheric temperature passes the noncondensable portion of the heat-conveying fluid. This gas is composed primarily of carbon dioxide and nitrogen, and small amounts of water vapor and oxygen. This noncondensable portion, due to the complete combustion effected in the type of generator used in the heating system of my invention, contains no obnoxious or dangerous products of incomplete combustion, and the disposition of the vent, therefore, involves little difficulty.

Referring now in greater detail to the portion of the apparatus illustrated in Figures 4 to 7, which is effective in discharging the gas-steam mixture into the heat-radiating system at a rate responsively regulated by the amount of heat radiated, and in regulating the mixture of fuel and air injected into the generator responsively to the amount of gas-steam mixture discharged to the radiating system, it will be seen that the inlets from the manifold 29, the outlet pipes 41, the main pistons 23 reciprocating in cylinder 9, and the smaller air compression pistons 22a and 22b are so arranged as to bear an operative relationship with each other. Secured to the outer end of drive-shaft 17b is a crank disc 49 provided with a laterally presented pin 50. This pin, as shown in Figure 7, rotates in a bearing block 51, which during the rotation of the main shaft 17a, 17b reciprocates within a valve operating yoke 52. Connected to yoke 52 and extending therefrom in a direction perpendicular to the axis of the main shaft 17 are valve rods 53 which are in turn connected to valve pistons 54 which reciprocate in chambers 55 to control the alternate admission and exhaust of the heating fluid into and from the main cylinder 9. Each end of the manifold

29 opens into chambers 56 each of which connects through a circular series of port openings 57 with valve cylinders 55. Midway of its length each cylinder 55 is provided with port openings 58 which communicate with a substantially annular chamber 59 providing an inlet communication for the hot gases passing through port openings 57 and valve cylinder 55, through passage 60 into the main cylinder 9. In a similar manner the substantially annular chamber 59 provides an exhaust communication through passage 60 and subsequently cylinder 55 to connection pipe 41. Referring now to Figure 6 in connection with Figure 4, air is drawn into the inner portion of the piston structure through hollow shaft 17a by the displacement of compressor pistons 22. In the surface of each of piston heads 22 is mounted a cylindrical check valve housing 66, which is provided with a frusto-conical valve seat 67. Engaging this valve seat is an outwardly opening check valve 68, carried by valve stem 69, suitably supported and movable in the valve housing 66. The delivery valve 13 is provided with valve seat 70 for a compressed air delivery valve 71, which is provided with a hollow stem slidable in a cylindrical guide under the bias of a compression spring, which tends to hold the valve against its seat. From this description it will be understood that as compressor piston 22a moves from left to right in Figure 4, valve 68 will open under the bias of the spring on valve stem 69, valve 71 being held to its seat by the pressure of its spring. Air is thus permitted to enter the air compressor cylinder between the said valves, and as the compressor piston begins its return movement the check valve 68 will close, the trapped air being thereupon compressed and forced outwardly past valve 71, which opens when the desired pressure, determined by the attached spring, has been reached. This compressed air passes into delivery pipe 14 and thence to the air inlet of the atomizer 31.

From the above description it will be understood that in an apparatus of the type illustrated, it is possible to generate the maximum possible amount of heat from a given quantity of fluid fuel at its "higher heating" value, to convey substantially all of the thus produced heat to a desired point, and to automatically control and regulate both the generation of the heating medium and its transfer to the radiating system. The proper functioning of such a combined operation depends primarily on the maintenance of small pressure differentials between the various parts of the system. Thus if a pressure of 3 lbs. is maintained in the radiating system, 5 lbs. pressure will be sufficient to activate the prime mover mechanism, and the fuel and air may be supplied to the atomizer at a pressure approximating 7 lbs. The steam being continuously condensed to water as its heat is radiated causes a corresponding continuous reduction in pressure, which is compensated for by the admission of additional fluid medium. A decreased condensation is accompanied by the creation of a back pressure in the prime mover, thereby decreasing its speed and in turn cutting down on the gas-steam mixture produced by the generator. A greater heat discharge on the other hand will tend to increase the pressure differential between the line and the generator, causing the prime mover to run faster in order to maintain an equilibrium. Such a change concurrently compresses more air and produces additional gas-steam mixture. The effective areas of the piston surfaces are so proportioned that a volume of gas-steam mixture suitable to fill the cylinder with each stroke, and to supply air to the atomizer at a pressure 1½ to 2 lbs. in excess of that in the generator. I have found that a ratio of effective piston areas approximating 2.71:1 will accomplish this result. It will thus be seen that the prime mover mechanism and associated valve cut-off means operate to supply gas-steam mixture to connecting pipes 41 without involving any substantial expansion of the fluid medium within the cylinders, and that the operation of the entire assembly is governed by the heat demand on the radiating system.

The temperature of the gas-steam mixture discharged to the radiating system may have any desired value in excess of about 212° F. I have found that temperatures within the range 250° to 350° F. are in general satisfactory, although higher temperatures may with advantage be employed under some conditions. The temperature of the gas-steam mixture is controlled by the rate of admission of water to the generator, and it is an important feature of the invention that any desired temperature may be produced without entailing a corresponding change in the pressure of the system.

The water which is condensed in the radiating system and returned to the generator comprises both the original water added to the generator and that produced by the combustion of the fuel. The water so produced is in most cases sufficient to counteract the moisture carried to the atmosphere with the cooled gases through the vent, and as a result the system is capable of operating for extended periods of time without the addition of added water.

The present method of heating, as distinguished from other methods, does not require any substantial excess of air during combustion, an excess of about 10% being ample to attain complete combustion. However, if excess quantities are employed, there is no increased loss in heat efficiencies due to the fact that the heat units carried by the excess air are all delivered to the radiating system.

In operating a household heating system of the type here described any desired temperature may be maintained in each of a plurality of rooms by supplying each individual radiator with a Sylphon valve of standard type which is operative to reduce the amount of heat supplied to the radiator and the amount of water returned to the reserve tank. When the amount of heat radiated to the surrounding atmosphere is substantially lessened or when radiators are completely shut off, the piston mechanism will operate more slowly. When the heat demand on the system, determined by the settings of the referred to valves, is greatly decreased, the prime mover mechanism and generator will stop, but may be started again by an auxiliary thermostatic control system such as is now in common use. In response to the action of such a system, fuel and air will be supplied to the generator and ignited, after which the generator and discharge means operate responsively to the amount of heat radiated. A complete heating installation adapted to operate in this manner may involve various additional automatic control features. For example an auxiliary air tank supplied with a suitable valve may be attached to store air under pressure for starting the generator and continuing its operation for the few seconds necessary until the air compressor is functioning. Alternatively a small air compressor operated by a battery driven motor may be used for this purpose.

I claim:

1. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for transforming a part of the sensible heat of said products of combustion into latent heat whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover means, said prime mover means comprising a chamber and a double faced piston movable within the chamber and adapted to be driven from both ends of the chamber by substantially all of the heat-conveying fluid medium in passing from the generator to the heat-radiating system, and means associated with the prime mover means for compressing the combustion-supporting medium and supplying it to the mixing and injection means of the generator.

2. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for transforming a part of the sensible heat of said products of combustion into latent heat whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover means, said prime mover means comprising a chamber and a double faced piston movable within the chamber and adapted to be driven from both ends of the chamber by substantially all of the heat-conveying fluid medium in passing from the generator to the heat-radiating system, means associated with the prime mover means for compressing the combustion-supporting medium and supplying it to the mixing and injection means of the generator, and means associated with the prime mover means for supplying the fluid fuel to the injection means of the generator.

3. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for transforming a part of the sensible heat of said products of combustion into latent heat whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover means, said prime mover means comprising a cylindrical chamber having a common intake and exhaust port near each end thereof, and a double headed piston movable within the chamber adapted to be driven by substantially all of the heat-conveying fluid medium introduced from the generator alternately through each of said ports, and adapted to discharge the fluid medium from the chamber to the radiating system through the same port on the return stroke, and means associated with the prime mover means for compressing the combustion-supporting medium and supplying it to the mixing and injection means of the generator.

4. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for transforming a part of the sensible heat of said products of combustion into latent heat whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover means, said prime mover means comprising a chamber and a double faced piston movable within the chamber and adapted to be driven from both ends of the chamber by substantially all of the heat-conveying fluid medium in passing from the generator to the heat-radiating system, and compression means for supplying the combustion-supporting medium to the injection means of the generator comprising chambers positioned terminally of the prime mover chamber having substantially smaller diameters than said chamber and coaxially aligned therewith, and pistons movable in the said terminal chambers, attached respectively to each end of the double piston.

5. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for transforming a part of the sensible heat of said products of combustion into latent heat whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover means, said prime mover means comprising a cylindrical chamber having a common intake and exhaust port near each end thereof, and a double headed piston movable within the chamber adapted to be driven by substantially all of the heat-conveying fluid medium introduced from the generator alternately through each of said ports, and adapted to discharge the fluid medium from the chamber to the radiating system through the same port on the return stroke, compression

means for supplying the combustion-supporting medium to the injection means of the generator comprising chambers positioned terminally of the prime mover chamber having substantially smaller diameters than said chamber and co-axially aligned therewith, and pistons movable in the said terminal chambers, attached respectively to each end of the double piston, a drive shaft journalled in the cylinder wall of the prime mover chamber midway of its length, and a connecting rod connecting said drive shaft with one of the compressor pistons.

6. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for transforming a part of the sensible heat of said products of combustion into latent heat whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover-compression means, said prime mover-compression means comprising axially spaced compressor cylinders separated by a prime mover cylinder of substantially larger diameter coaxial therewith, two rigidly joined axially spaced oppositely faced piston members, each having a prime mover portion movable in the prime mover cylinder and a compressor portion movable in the adjoining compression cylinder, said prime mover cylinder having a common intake and exhaust port near each end thereof adapted to deliver substantially all of the fluid medium from the outlet of said generator thereto to drive the rigidly joined piston members in unison and adapted to deliver the fluid medium from the cylinder to the heat-radiating system on the return stroke of the piston, and a hollow drive shaft comprising axially spaced sections journalled in opposing midlength positions in the wall of the prime mover cylinder with crank-arm sections attached to each of the shaft sections and connected by a crank pin, the drive shaft being connected with one of the compressor pistons by means of a connecting rod attached to the said crank pin and to a wrist pin associated with said compressor piston.

7. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for introducing a volatile liquid therein in a regulated quantity and for subjecting the hot products of combustion to contact therewith whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover means, said prime mover means comprising a chamber and a double faced piston movable within the chamber and adapted to be driven from both ends of the chamber by substantially all of the heat-conveying fluid medium in passing from the generator to the heat-radiating system, means associated with the prime mover means for compressing the combustion-supporting medium and supplying it to the mixing and injection means of the generator, and means associated with the prime mover means for supplying the volatile liquid to the liquid introduction means of the generator.

8. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, associated means for intimately mixing the fluid fuel with a combustion-supporting medium and for injecting the mixture intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for introducing a volatile liquid therein in a regulated quantity and for subjecting the hot products of combustion to contact therewith whereby a heat conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a prime mover means, said prime mover means comprising a chamber and a double faced piston movable within the chamber and adapted to be driven from both ends of the chamber by substantially all of the heat-conveying fluid medium in passing from the generator to the heat-radiating system, means associated with the prime mover means for compressing the combustion-supporting medium and supplying it to the mixing and injection means of the generator, means associated with the prime mover means for supplying the volatile liquid to the liquid introduction means of the generator, and means associated with the prime mover means for supplying the fluid fuel to the injector means of the generator.

9. An apparatus for producing and radiating heat by the combustion of a fluid fuel which comprises a generator having a plurality of closely spaced combustion-catalyzing contact surfaces of refractory material defining a combustion zone, means for injecting an intimate mixture of the fluid fuel and a combustion-supporting medium intermediate the contact surfaces, the areas of said surfaces adjacent the point of injection of the fuel mixture increasing outwardly therefrom at a rate substantially in excess of a linear rate, said generator further having means for transforming a part of the sensible heat of said products of combustion into latent heat whereby a heat-conveying fluid medium is produced, a heat-radiating system connected to the outlet of said generator by a double-acting prime mover means operative to discharge substantially all of the heat-conveying fluid medium to the radiating system at a rate responsive to the amount of heat radiated from the said system, and compression means operatively associated with said prime mover means for supplying the combustion-supporting medium to the injection means at a rate and under a pressure responsive to the amount of heat radiated from said radiating system.

EDWIN TAYLOR.