(No Model.)

J. J. McTIGHE.

METHOD OF TRANSFORMING HEAT ENERGY INTO MOTIVE POWER.

No. 411,605. Patented Sept. 24, 1889.

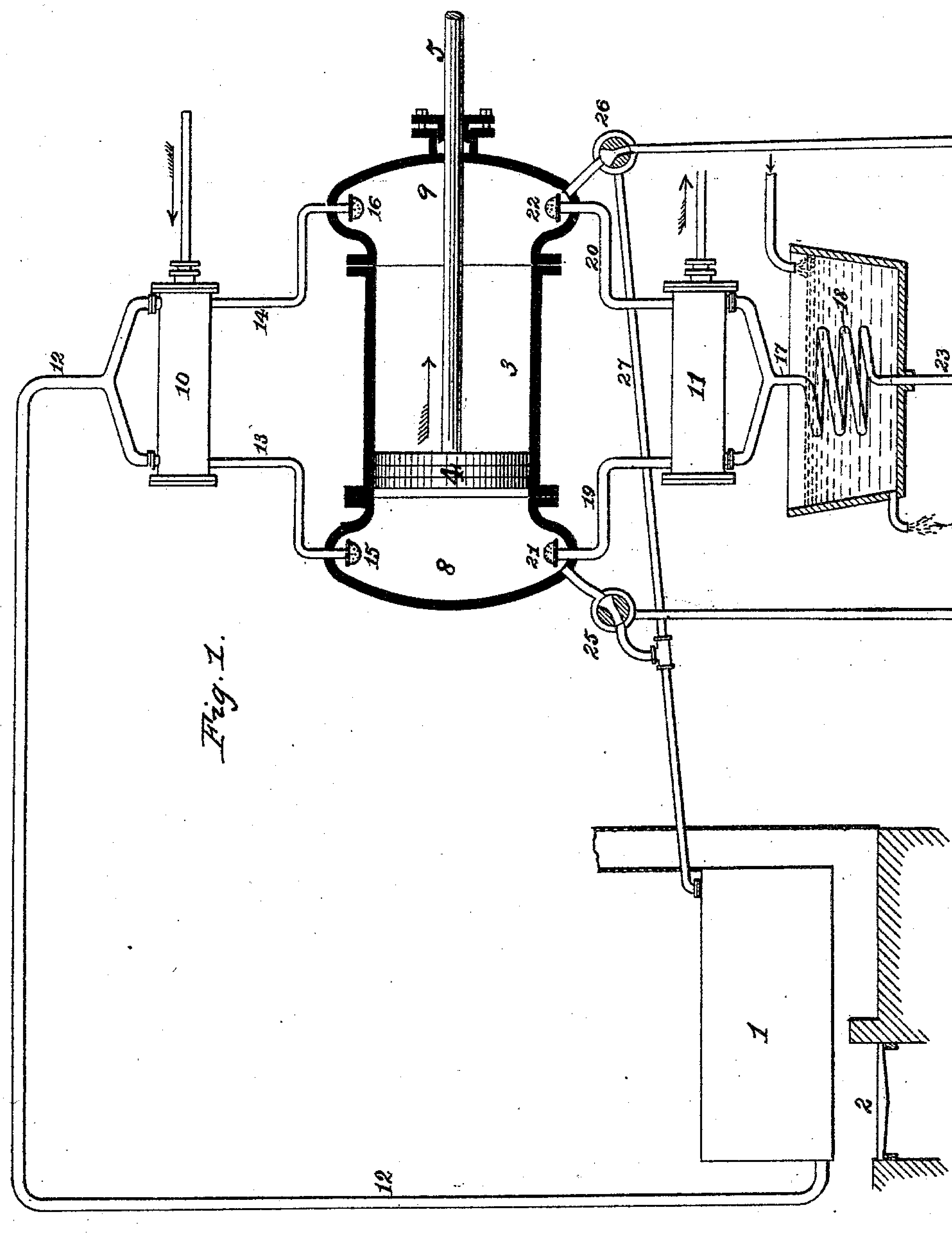

Fig. 1.

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METHOD OF TRANSFORMING HEAT ENERGY INTO MOTIVE POWER.

SPECIFICATION forming part of Letters Patent No. 411,605, dated September 24, 1889.

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To all whom it may concern:

Be it known that I, JAMES J. McTIGHE, a citizen of the United States, residing at Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in a Method of Transforming Heat Energy into Motive Power; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention relates to a novel method of transforming the potential energy of heat into motive power, whereby the energy stored in the ordinary form of fuel may be utilized under conditions of high efficiency. For a complete comprehension of the manner in which this transformation can be effected I deem it proper to lay down some well-known principles.

First. If air at ordinary atmospheric pressure be heated, it will gain in potential energy, or, in other words, its pressure will be increased, and the rapidity of increase of pressure is in proportion to the speed of the rise in temperature. If air be first compressed and then heated, there will be not only a remarkable gain in pressure, but a large relative economy in the heat needed to increase the temperature.

Second. If the heated air be cooled, it will lose the pressure due to its former high temperature, and the rapidity of this decrease of pressure will be in direct ratio with the speed of the fall of temperature.

Third. Vapors, if heated considerably above the point of saturation, are practically subject to the same laws of expansion as air or gas.

Fourth. Air and other gases practically hold toward vapors the place of vacua—*i. e.*, a given space is capable of containing a certain quantity of vapor, no matter whether it be already occupied by a gas or be a perfect vacuum.

Fifth. According to Dalton's law, the amount of vapor which any certain space can receive depends solely on the temperature which the vapor will have when it occupies said space, irrespective of any gas which may already occupy the same. A vessel of the capacity of one cubic foot can hold only a single cubic foot of water or sand; but if a vapor be heated enough the same vessel can receive and contain as much vapor as would expand into an indefinite number of cubic feet, if not prevented by the walls of the vessel. In other words, the density and tension of a vapor depend solely on its temperature and the volume of space occupied by it.

Sixth. The capacity of air for absorbing vapor depends on the temperature of the air—the higher the temperature, the more vapor it absorbs. If the air lose heat, it deposits vapor as dew. The degree of temperature at which it deposits dew is its point of saturation—*i. e.*, at that temperature it can hold no more vapor.

Seventh. Air in expanding against resistance occupies a greater space and falls in temperature; hence, if the capacity for vapor of the increased volume do not increase in exact inverse ratio with the loss of capacity for vapor of the air, due to the fall of temperature, some of the vapor contained in the air will be deposited as dew; hence, also, if the temperature of the air be sustained during expansion not only no dew will be deposited, but the capacity for absorbing vapor will be increased.

Eighth. Vapor condensing to dew gives up its latent heat of vaporization to any body in contact with it.

Ninth. A liquid will have its boiling-point raised if the pressure on its surface be increased, whether such pressure be that due to its own vapor or to a superincumbent atmosphere of gas or other vapor.

Tenth. The vapor arising from a liquid has approximately the temperature of the liquid itself, and may thus serve as a carrier of heat from the liquid to a cooler body.

Eleventh. The pressure on the walls of a vessel containing air or other gas and one or more vapors is the sum of the pressure of all gaseous bodies and vapors within the vessel.

Twelfth. The compression of air or gas produces heat, while the compression of a saturated vapor coincident with a reduction of its volume reduces it to the form of mist and, if continued, to the form of liquid.

Thirteenth. The contact between the particles of air and an absorbed vapor is so intimate that it may practically be said to be a contact between the smallest particles—*i. e.*, between the respective molecules.

Fourteenth. If while in such molecular contact the vapor be either heated or cooled, the heating or cooling effect produced on the air will be practically instantaneous throughout the entire mass of the air.

Fifteenth. Air is heated very readily by contact with a hot body of some kind, scarcely at all by radiation, and only very slowly by conduction. Consequently the heating of a body of air will reach its maximum rapidity when its every molecule is in contact with a hot body.

Sixteenth. The more minutely the heating or cooling body is divided the greater will be its heating or cooling surface. A cube containing a pound of water is about three inches each way, giving an external surface of fifty-four square inches. Divided into drops .01 of an inch in diameter, it will make about fifty million drops, each having a surface of .00031416 square inch, thus giving a total heating or cooling surface of about fifteen thousand and seven hundred square inches, or about one hundred and ten square feet.

Seventeenth. *A fortiori*, the surface presented by the thousands of millions of molecules of a pound of water in the state of mist or vapor is enormously greater than and, in fact, may be said to be infinite compared with that of the same water in mass.

Eighteenth. When this mist or vapor returns to the state of liquidity, the enormous heating-surface practically vanishes.

Nineteenth. Water evaporates rapidly when wind blows across its surface, and of course it will evaporate very rapidly if it be cast in a minutely-divided condition—such as a fine spray—into a body of air.

Twentieth. Different liquids have different boiling-points, and a mixture of two liquids may be made such that in a closed vessel one will boil and vaporize before the other, and thus reacting by its pressure raise the boiling-point of that other.

Twenty-first. The cooling-surface of a spray of cold liquid is very much greater than when the liquid stands together as one body, and in returning to this condition the cooling-surface practically vanishes.

Twenty-second. The vapor that arises from any liquid below the temperature of its boiling-point is considered as a gas; it is called steam only when its pressure is equal to or above that of the superincumbent atmosphere. In other words, steam is the vapor that rises from a liquid in a condition of boiling.

My invention is based upon the foregoing principles; and it consists, fundamentally, in the method of converting the heat energy of fuel into the potential energy of air or other gas and vapor, and, further, in the particular steps of the method, all substantially as hereinafter fully described and claimed.

In the accompanying drawing, which forms part of this specification, the figure is an explanatory diagram, illustrating my invention graphically.

I use a heater of any suitable type—such as, for instance, the form designated by 1, having the furnace 2. I take an ordinary cylinder 3, having a piston 4, whose rod 5 is connected to the driving-shaft in the usual manner. The ends of the cylinder are closed by the globular heads 8 and 9, respectively.

In suitable proximity to the cylinder so as to be controlled by the shaft, I locate a hot-water pump 10 and a cold-water pump 11, whose respective plungers are operated by eccentrics on the shaft. Each pump has an inlet and an outlet at each end, and is provided with the usual check-valves. A pipe 12 connects the lower part of heater 1 with the two inlets of hot-water pump 10, whose outlets are connected by the respective pipes 13 and 14 to the globular heads 8 and 9, as shown, and terminate inside in suitable spray-nozzles 15 and 16. A pipe 17 connects the outlet of a hot-water cooler 18, with the two inlets of the cold-water pump 11, whose outlets are connected by the respective pipes 19 and 20 to the globular heads 8 and 9, as shown, and terminate in suitable spray-nozzles 21 and 22. The inlet 23 of cooler 18 has a connection 24 branching to the two respective three-way cocks 25 and 26. These cocks are connected, respectively, to the globular heads 8 and 9, and are adapted to be connected to a pipe 27, leading back by gravity to heater 1, according to the position of the parts, which is automatically effected by mechanism of suitable character connected with the shaft. Now let it be supposed that the apparatus, including pumps, cylinder, heater, cooler, and connections, is so charged with air under pressure that there are twenty atmospheres behind the piston, or, say, three hundred pounds per square inch, and ten atmospheres ahead of it, or one hundred and fifty pounds. Assuming that the initial movement to be given piston 4 is to be in the direction of its arrow, (to the right,) the shaft-connections will be such as to move the piston of the hot-water pump 10 to the left and that of the cold-water pump 11 to the right. Fire being started under the heater 1, the contained water can be safely raised under said pressure to a temperature of at least 350° Fahrenheit without boiling. Suppose the proportions are such that the cylinder contains one pound of air on each side of the piston, and that the pumps 10 and 11, respectively, spray into it one pound of hot water behind the piston and one pound of cold water ahead of it at each stroke. Now, as the piston moves to the right pump 10 sprays water at said temperature of 350° into globular head 8 and pump 11 sprays cold water into the globular head 9. The hot-water spray heats by direct contact nearly every particle of the air behind the piston, and does so at a speed which is very rapid. This heating of the air enables it to absorb hot vapor from the immense surface of the numberless drops of hot water at a very high rate of speed, and this vapor, being yet of about the same temperature as the hot water, assists by its molecular contact in making the heating of the air practically instantaneous. Now, applying the formula for common temperature of a mixture of fluids of different temperatures—viz., $MS(T-x)=M'S'(x-T')$, in which MM′ are the weights, SS′ the respective specific heats, TT′ the temperatures, and x the resultant temperature, we find, supposing the air to be at 100° Fahrenheit, that it is instantaneously heated to a resultant temperature of 315°. At this temperature the pressure of the air has increased about forty per cent. above its initial pressure, this being, as before stated, three hundred pounds. The pressure will now be four hundred and twenty pounds per square inch. To this must be added, as a working element, the pressure of the vapor absorbed by such heated air, which at said common temperature of 315° is nearly one hundred pounds per square inch, thus making a total initial pressure behind the piston of five hundred and twenty pounds per square inch. The initial effective pressure will then be the difference between this and the pressure ahead of the piston. Therefore, the resultant initial pressure will be about $520-150=370$ pounds per square inch. Under this pressure the piston moves forward, and the loss of pressure due to the loss of heat consequent on expansion as the piston moves is, by a complex series of condensations of the vapor and re-evaporations of the same and surrender of the latent heat of vapor to the air, partly compensated. At the same time in front of the piston the cold spray is entering and cold vapor is being absorbed, and therefore the heat due to compression as fast as generated is abstracted from the air. The position of valves 25 and 26 remains during this time, and the hot water leaves the cylinder and returns by gravity to the heater, and, similarly, the cold water leaves the other end of the cylinder and by gravity returns to the cooler. During the stroke of the piston the pressure behind it eventually decreases; but by proportioning the volume of air to the stroke the decrease of pressure may be predetermined, so as not to fall below that necessary to prevent the water from boiling in the heater. By making this proportion such, for instance, as 1:2, the final pressure behind the piston will be in the case given about two hundred and sixty pounds per square inch. Therefore, the mean pressure behind the piston will be $\frac{520+260}{2}=390$ pounds per square inch. The rate of decrease of volume in front of the piston being inversely 2:1, the final pressure will be three hundred pounds. The mean resistance ahead of the piston will therefore be $\frac{150+300}{2}=225$ pounds; hence the total mean effective pressure on the piston will be $390-225$, or 165 pounds, and this pressure will in the given case result from the loss of only a few degrees of temperature from the hot water, which returns to the heater while still very hot. Conversely the cold water ahead of the piston is heated only a few degrees, gaining even less than the hot water loses, the difference being spent in useful work. On completion of the stroke the pumps 10 and 11 and cocks 25 and 26 are reversed from the shaft, so that the hot spray is now thrown into globular head 9 and the cold spray into globular head 8. Instantaneously the pressure at the right of the piston rises to five hundred and twenty pounds and the pressure at the left falls to one hundred and fifty pounds per square inch, and for the stroke again the mean effective pressure is as above shown. The remaining hot water now returns to the heater through cock 26 and the cold water returns to the cooler through the cock 25, as before, and this return of the hot and cold water to their respective reservoirs or supply-points is invariably effected by gravity. Economy is thus secured by the small amount of fuel required to heat water through a differential temperature of 35°, instead of, as is usual in steam-engines, wasting nine hundred and sixty-six heat-units per pound of water before the working-fluid can be obtained at all. Economy is also secured by the small amount of running water around the cooler required to abstract the small amount of heat imparted to the cold spray by the hot air and vapor.

For the sake of clearness I have purposely omitted from the drawing certain valve arrangements automatically operating from the shaft to prevent the hot water from being sprayed ahead of the piston, as such features of mechanical construction do not form any essential part of the present application. It is to be noted that the air has the hot water sprayed into it when the air itself is at its point of maximum density; and it is further to be noted that since the working-body of air is confined within the cylinder on each side of the piston, when the spray of hot water is pumped into the globular head the entire body of air which is to be heated becomes heated at once.

Instead of water, other liquids may be used in the heater, and other gases may be used instead of air, or two liquids of different boiling-points—one of which is by the high heat of the other to be first turned into the working-fluid—may be adopted without departing from the spirit of the invention.

Obviously the operation of the engine may require a means for preventing excessive accumulation of condensed vapor in the cooler. This can be done by a pump or other device, which takes the excess accumulating and returns it to the heater, as required.

It is evident that an air-pump may be used in connection with the apparatus for the purpose of compressing the air and compensating for leakage.

I do not herein lay any claim to the special form of apparatus or engine which I have contrived for the purpose of carrying out the foregoing method of conversion of energy in a practical way, as such will form the subject of other applications.

In using the expression "liquid" throughout this specification, I desire to be understood as including not merely ordinary liquids—such as water, various kinds of oil, &c.—since in some cases it will be found that the purposes of the invention can be accomplished by using the heater for the purpose of therein melting various normally-solid substances, whether the same be in the form of metals or otherwise. In such modifications it will be necessary to take the precaution to substitute, instead of air, a gas of such character as would not abstract energy from the liquid by chemical union therewith. In other words, the gas should be chemically inert, in any given case, with reference to the liquid with which it would come in contact in the apparatus. The substance used for cooling in such cases must likewise be chosen with a proper discretion.

The method of heating and cooling hereinbefore set forth has an additional feature of distinction and advantage, in that the heating and cooling surfaces both change in amount between the limits of the stroke. At the beginning of the stroke the heating and cooling surfaces are both at a maximum, at the end of the stroke both are at a minimum, and between these two limits both decrease in extent. This reduction of surface takes place in a way which does not detract from the economic efficiency of the conversion, but rather assists it, since the reduction of surface takes place just in proportion to the decreasing need of heat or cold; and further, considering only the space on one side of the piston during an entire stroke, the heating-surface gradually reduces and finally vanishes the instant it meets the cold spray, whose surface is then maximum, and it in turn reduces and vanishes in presence of the next hot spray.

By a proper arrangement of slide-valves, cut-offs, &c., usually adopted in the best steam-engines, the times for spraying both hot and cold liquid can be so nicely governed that an engine constructed and working according to the methods above explained will prove to be very econominal in the expenditure of heat. In addition its size will be very small for a given power, and since only a few gallons of water will be needed in the heater, should explosion occur the dreadful accidents and great loss of life due to the sudden liberation of many tons of boiling water needed in the present forms of motive power from steam will be entirely avoided. Finally, there being no escape of steam, the engine will be nearly noiseless.

What I claim as my invention is—

1. The method of transforming heat energy into the energy of tension of a vapor, consisting in heating a liquid and pumping it in a divided state into a body of air or other gas or vapor of lower temperature.

2. The method of transforming heat energy into the energy of tension of vapor, consisting in heating a liquid under pressure and pumping it in a subdivided state into a body of air or gas or vapor also under pressure, but of lower temperature.

3. The method of transforming heat energy into the energy of tension of a vapor, consisting in heating a liquid under pressure sufficient to prevent ebullition and pumping such liquid in an atomized form into a body of air, gas, or vapor.

4. The method of transforming heat energy into the energy of tension of a vapor, consisting in heating a liquid under pressure independent of that due to its own vapor and sufficient to prevent ebullition, and injecting such liquid into a body of air, gas, or vapor having a pressure above that of such boiling-point of said liquid.

5. The method of transforming heat energy into motive power in a piston-engine, consisting in maintaining a working-body of air, gas, or vapor behind the piston in said engine and injecting at once into the whole body of such air, gas, or vapor a liquid heated to a higher temperature, and thereby increasing the tension of such atmosphere and moving the piston.

6. The method of transforming heat energy into motive power in a piston-engine, consisting in maintaining a working-body of air, gas, or vapor behind the piston in said engine and injecting at once into the whole body of such air, gas, or vapor a liquid heated to a higher temperature and in a subdivided state.

7. The method of transforming heat energy into motive power in a piston-engine, consisting in maintaining a working-body of air, gas, or vapor behind the piston in said engine and injecting at once into the whole body of such air, gas, or vapor a spray of liquid heated to a higher temperature.

8. The method of transforming heat energy into motive power in a piston-engine, consisting in maintaining a working-body of air, gas, or vapor under pressure behind the piston in said engine and injecting at once into the whole body of air, gas, or vapor a spray of liquid heated to a higher temperature.

9. The method of transforming heat energy into motive power in a piston-engine, consisting in maintaining two separate working-bodies of air, gas, or vapor—one ahead of the piston, the other behind it—and injecting into

the body of air, gas, or vapor behind the piston a spray or stream of heated liquid and into the body of air, gas, or vapor ahead of the piston a spray or stream of cooler liquid.

10. The method of transforming heat energy into motive power in a piston-engine, consisting in maintaining two separate working-bodies of air, gas, or vapor—one ahead of the piston, the other behind it—and injecting into the body of air, gas, or vapor behind the piston a spray or stream of heated liquid and into the body of air, gas, or vapor ahead of the piston a spray or stream of cooler liquid, and then reversing the hot and cold sprays relatively to the two bodies of air, gas, or vapor on the respective sides of the piston.

In testimony whereof I affix my signature in presence of two witnesses.

JAMES J. McTIGHE.

Witnesses:
R. J. STONEY, Jr.,
T. H. LEWIS.