

[54] **SYSTEM FOR CONVERTING HEAT TO KINETIC ENERGY**

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[58] **Field of Search** .....60/108; 122/11, 451

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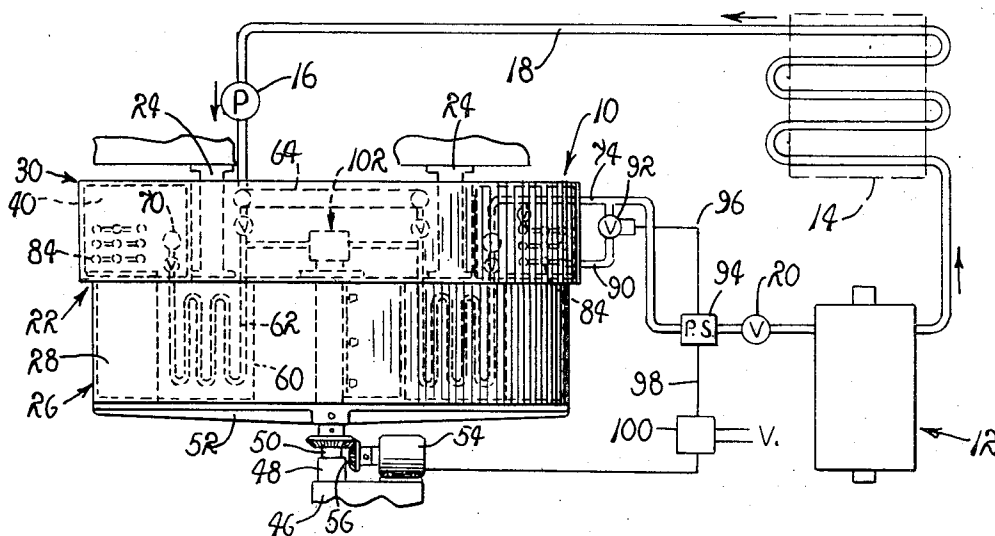
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[57]

## ABSTRACT

A system for converting heat to kinetic energy, characterized by a fluid-driven motor responsive to an introduction of high-pressure fluid for driving a selected power train, and a pressure generator for introducing the high-pressure fluid to the motor. The pressure generator includes a plurality of boiler tubes for receiving low-pressure fluid, a fire-box for successively transferring heat to the boiler tubes, and a pressure equalizer for incrementally equalizing pressures within boiler tubes, whereby an introduction of low-pressure fluid, followed by an efficient conversion to a high-pressure fluid, is facilitated within the system.

### 13 Claims, 10 Drawing Figures



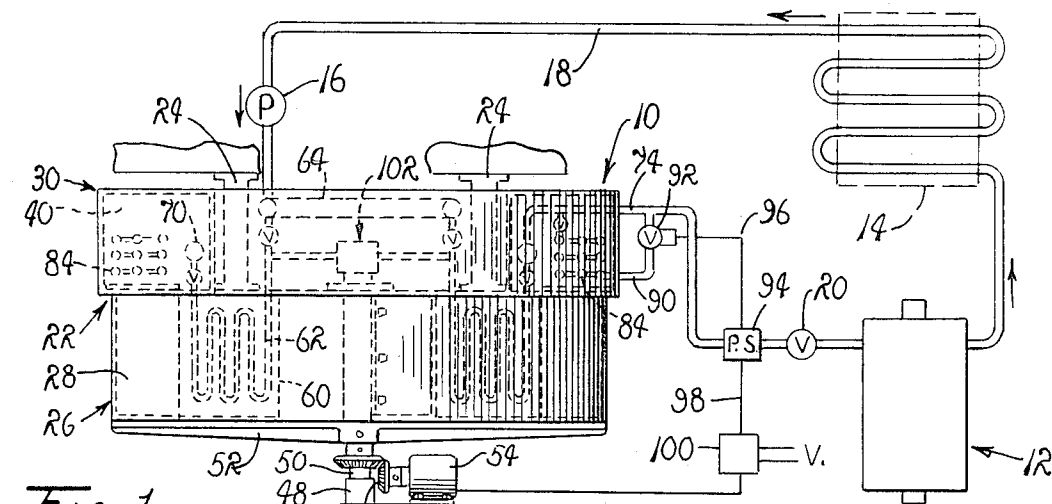


FIG. 1.

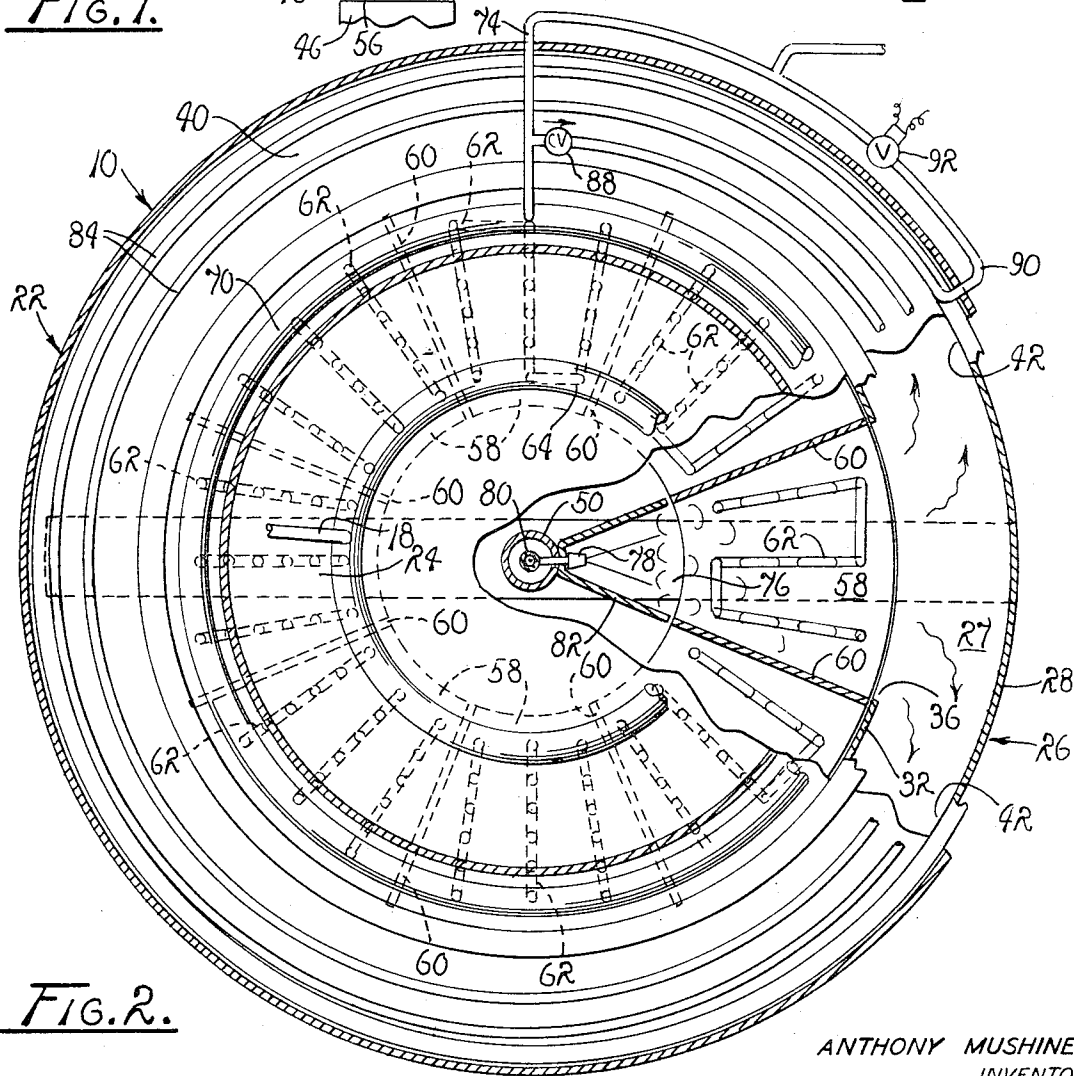
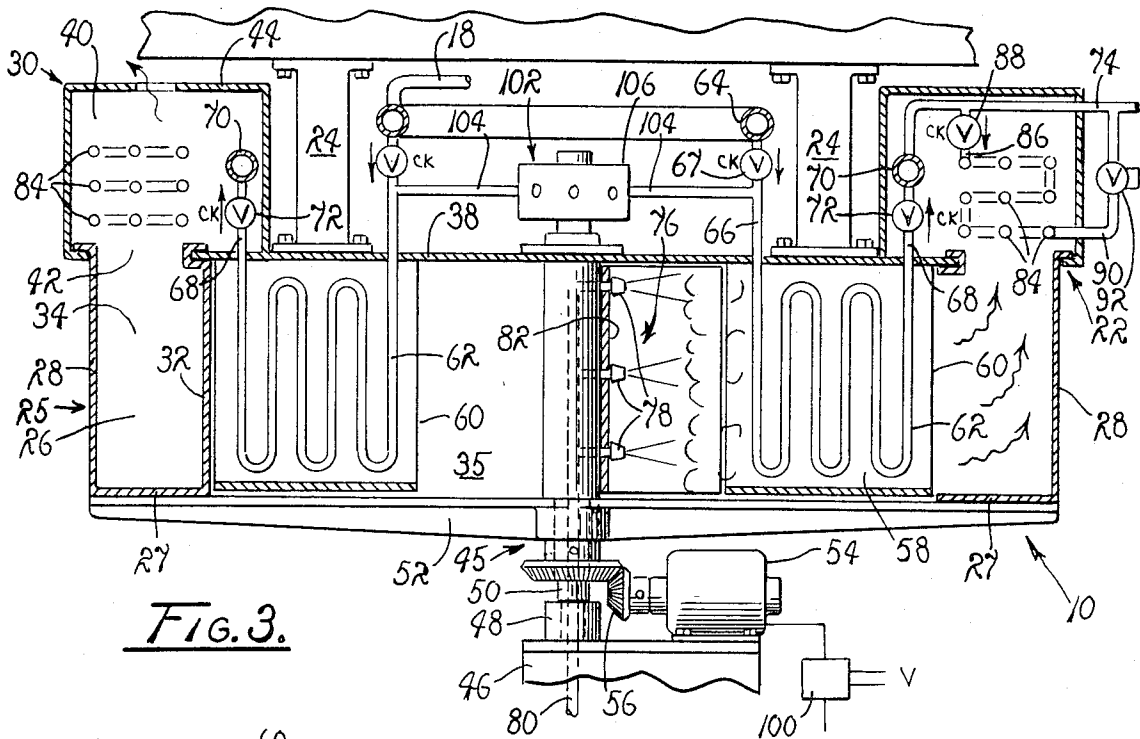
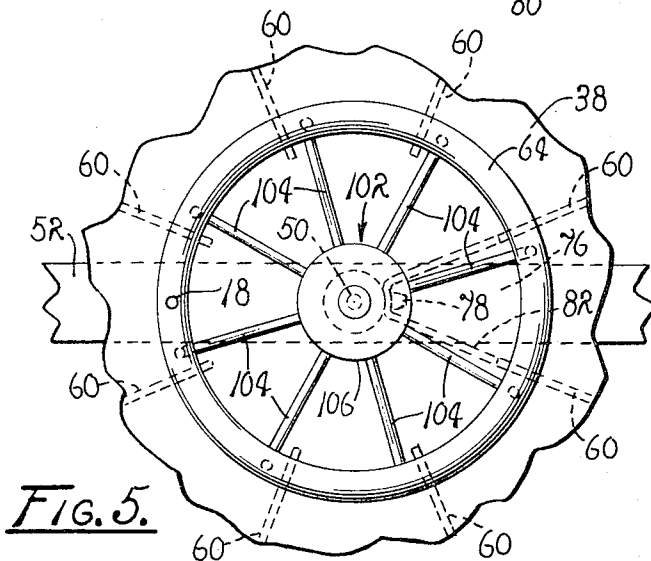
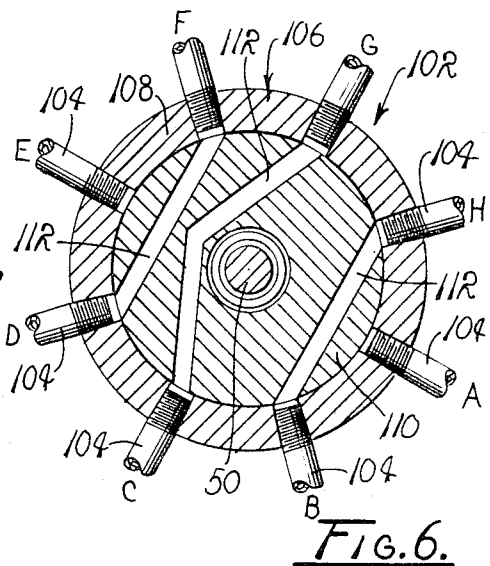
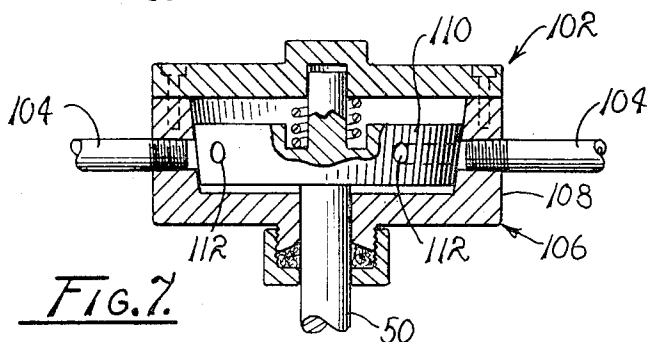


FIG. 2.

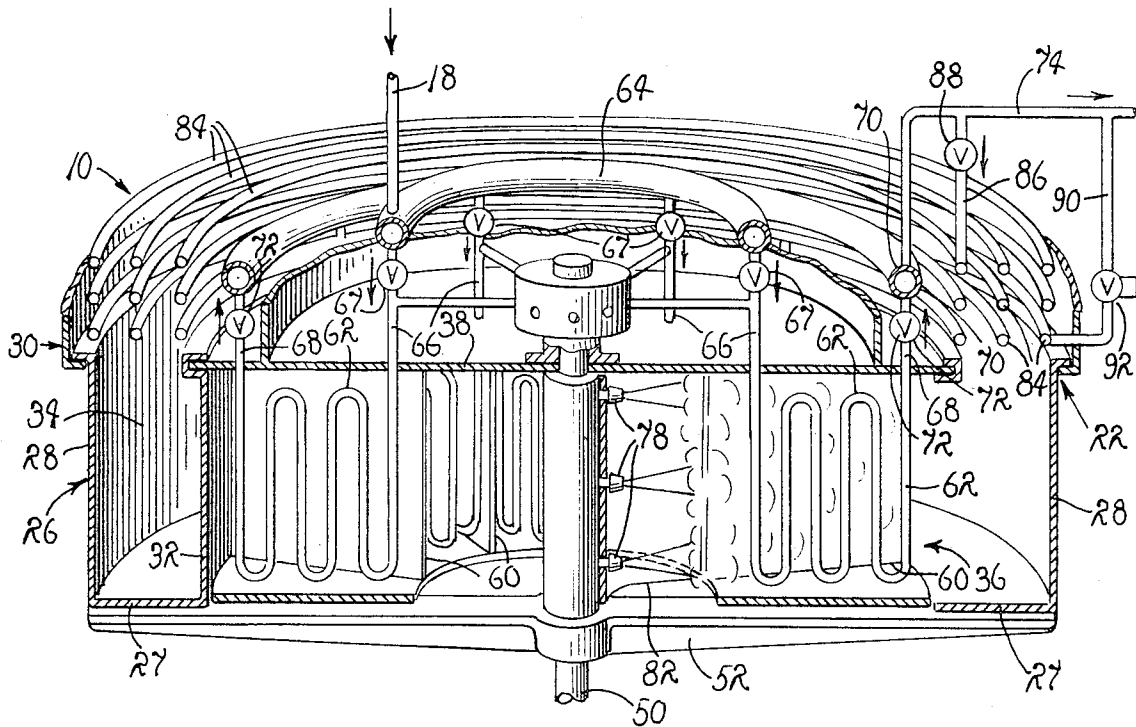
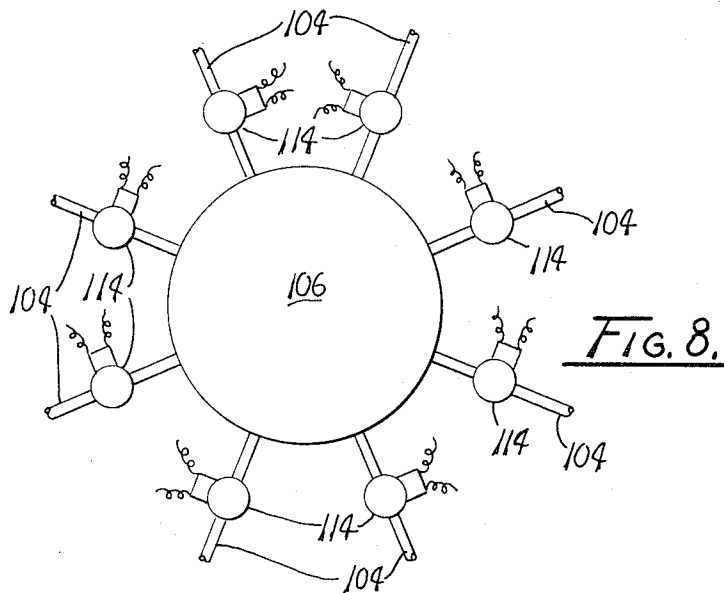
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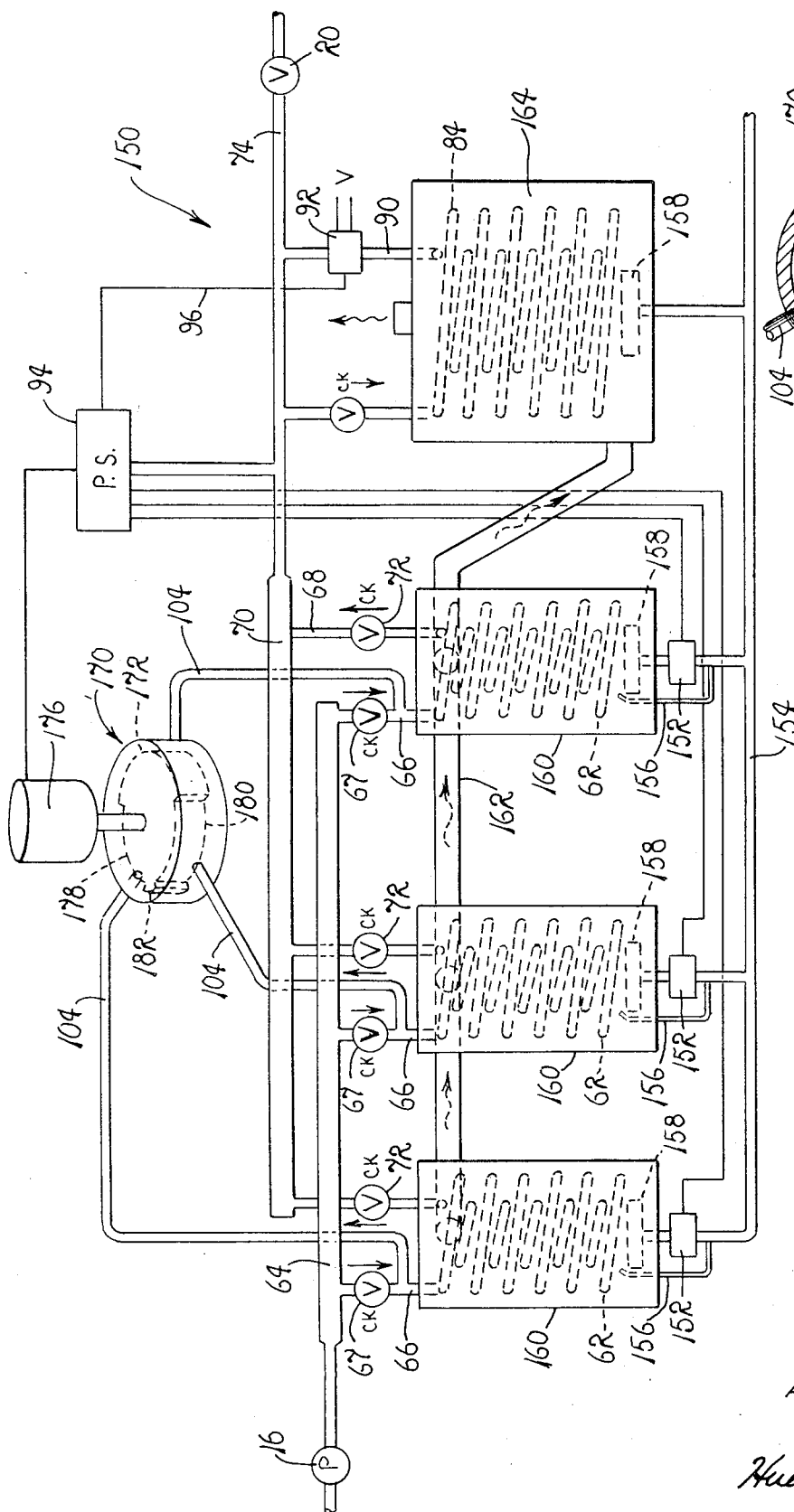


FIG. 9.

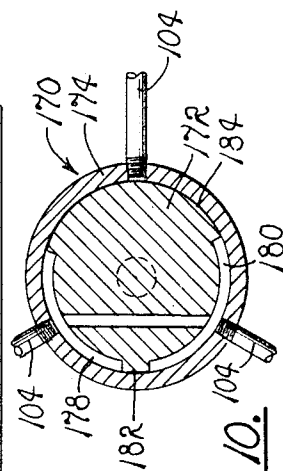


FIG. 10.

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# SYSTEM FOR CONVERTING HEAT TO KINETIC ENERGY

## BACKGROUND OF THE INVENTION

The invention generally relates to an energy conversion system and more particularly to an improved system for converting heat to kinetic energy.

Numerous systems heretofore have been employed in converting heat to kinetic energy. Normally, such systems include a steam boiler wherein a liquid is converted to a vapor and admitted to a cylinder of a piston-type motor, or to a turbine, where it expands against the piston, or against turbine blades, as the case may be, discharged therefrom and thence returned via a feed pump to the boiler.

In employing systems of known designs, difficulty often is encountered in introducing the working fluid in its liquid phase, into a boiler preparatory to its being converted to its vapor phase in response to an application of heat. This results from system back-pressure which normally attends the introduction of the fluid into the boiler. Consequently, numerous and complex systems hereto have been utilized in an effort to overcome this difficulty. Of course, where a conversion system is employed with a prime mover of a type utilized in an environment which imposes design limitations on both the mass and bulk of the system, simplicity attains a particular place of prominence among prevailing design parameters.

Attending the increased use of working fluids employed in the field of cryogenics is the prevailing interest in the development of conversion systems which can be employed efficiently in driving vehicles including automobiles and the like. However, systems employed for this purpose necessarily must be substantially simplified.

## OBJECTS AND SUMMARY OF THE INVENTION

It is therefore an object of the instant invention to provide a simplified system for converting heat to kinetic energy.

It is another object to provide an improved system which employs energy of heat for imparting driven motion to a selected power train.

It is another object to provide in a system for converting heat to kinetic energy an improved pressure generator wherein substantial effects of back-pressure are eliminated as a working fluid is introduced into the generator.

It is another object to provide in a system for converting heat to kinetic energy a pressure generator for simultaneously receiving a working fluid in a liquid phase, heating the working fluid to effect a phase change, and pressure equalizing means for incrementally elevating the pressure of the working fluid in its liquid phase, preparatory to its achieving a vapor phase, while circumventing deleterious effects of system back-pressure.

These and other objects and advantages are achieved through the use of an energy conversion system which utilizes a pressure-responsive motor and a pressure generator having a plurality of sequentially heated boiler tubes interconnected through a rotating pressure-transfer valve through which the boiler tubes sequentially are connected in variable pairs, so that as a working fluid is introduced pressures simultaneously are developed and reduced within the generator

through a continuous exchange of pressures between boiler tubes for thereby avoiding the effects of system back-pressure.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view, not to scale, of a system embodying the principles of the instant invention, including a vapor generator, a turbine associated with the generator, and a condenser for converting a working fluid to its vapor phase.

FIG. 2 is a fragmentary plan view of the vapor generator shown in FIG. 1.

FIG. 3 is a sectioned elevation of the vapor generator shown in FIGS. 1 and 2.

FIG. 4 is a partially sectioned, perspective view of the vapor generator shown in FIGS. 1, 2 and 3.

FIG. 5 is a fragmentary plan view of a pressure equalizer employed by the vapor generator.

FIG. 6 is a sectioned plan view of a valve employed by the pressure equalizer.

FIG. 7 is a sectioned elevation of the valve shown in FIG. 6.

FIG. 8 is a schematic view of a modified form of a pressure equalizer employable with the generator.

FIG. 9 is a schematic view of a further embodiment of the instant invention.

FIG. 10 is a sectioned elevation of the valve employed in equalizing pressures developed in the system shown in FIG. 9.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

### (GENERAL DESCRIPTION)

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1 a system which embodies the principles of the instant invention.

The system includes a vapor generator, generally designated 10, coupled with a prime mover, such as a turbine, generally designated 12. A condenser, generally designated 14, is coupled between the output side of the turbine 12 and the input side of the vapor generator 10. Where so desired, a feed pump 16 is interposed between the condenser and the vapor generator for assuring that a flow of working fluid therebetween is maintained for insuring a constant delivery of working fluid to the generator 10. While various substances can be employed as a working fluid, Freon functions satisfactorily for this purpose. It is, however, to be understood that the working fluid must be capable of undergoing phase changes between a vapor and a liquid with minimal heat exchange.

As a practical matter, a plurality of conduits 18 formed of any suitable material and of a size sufficient for delivering the working fluid, in its liquid phase, as well as in its vapor phase, is employed in coupling the vapor generator 10, the prime mover 12, and the condenser 14 into an integrated and operative system.

As a practical matter, the particular prime mover 12 employed is a matter of convenience, therefore, a detailed description of the turbine 12 is omitted in the interest of brevity. Similarly, since the condenser 14 and the feed pump 16 are well within the purview of the art, a detailed description thereof also is omitted. It is to be understood, of course, that the vapor generator 10 serves as a source of heated fluid, preferably a vapor,

which is directed through the prime mover 12 for imparting motion thereto. From the prime mover, the vapor is delivered to the condenser 14 whereupon the working fluid is converted to its liquid phase and returned to the vapor generator 10 via the pump 16.

The rate at which motion is imparted to the prime mover 12 is dictated, in part, by the pressure of the working fluid as it is delivered thereto. Where so desired, a throttle valve 20 is provided for controlling the rate of flow of fluid, and thus its pressure, as it is delivered from the vapor generator 10 to the prime mover 12. The valve 20 is of a commercially available and suitable design which serves to control the flow of fluid as it is passed therethrough. Accordingly, it is to be understood that once the system of the instant invention is rendered operative, a vapor, under pressure, is delivered via the valve 20 to the turbine 12, whereupon the turbine's output shaft, not designated, is driven in rotation in a manner and at a determinable rate consistent with the operation of commercially available turbines. Hence, it will be appreciated that by manipulating the valve 20, the rate of rotation imparted to the output shaft of the prime mover 12 accurately is controlled.

As a practical matter, the condenser 14 serves to transfer heat from the working fluid, prior to its delivery to the feed pump 16. While the condenser 14 is illustrated as including a serpentine conduit, it is to be understood that conduits of any configuration including helical coils and the like can be employed equally as well for transferring heat from working fluid as it is conducted therethrough for undergoing conversion to its liquid phase. Similarly, auxiliary cooling devices, such as fans and the like, also may be employed for transferring heat from the working fluid to a flowing stream of air passed through the condenser 14.

The pump 16 is capable of establishing a standing flow of working fluid at selected pressures. Since the fluid being delivered from the condenser 14 to the pump 16 frequently is a mixture of gas and liquid, the pump 16 preferably is of a type suitable for accelerating the fluid in either of its phases as it passed therethrough. Since such pumps are well known, commercially available, and well within the skill of the art, a detailed description of the pump employed in the system is omitted.

In view of the foregoing, it should readily be apparent that the working fluid employed in driving the prime mover 12 is converted to its vapor phase and pressurized within the vapor generator 10, directed through the prime mover 12 for imparting motion thereto, cooled within the condenser 14 and reintroduced into the vapor generator, in its liquid phase. Thus, the heat applied to the working fluid in the vapor generator is utilized as a source of kinetic energy.

#### VAPOR GENERATOR

##### (First Form)

As illustrated in FIGS. 1 through 8, one form of the vapor generator 10 includes a housing 22 of a generally circular configuration supported by a plurality of mounting brackets 24. These are employed in supporting the housing 22 in suspension from any selected structure or vehicle. It is to be understood that the housing 22, of course, can be supported at locations other than as illustrated in FIGS. 1 and 3. Accordingly, the particular mounting structure for the housing 22 is deemed a matter of convenience, dictated by the na-

ture of the structure with which the system of the instant invention is employed.

Similarly, the particular materials employed in fabricating the housing 22 also is a matter of convenience and can be varied in accordance with the parameters imposed by the environment within which the system is employed. As a practical matter, stainless-steel serves quite satisfactorily for this purpose. If so desired, a layer of asbestos, not shown, also can be employed for controlling the transfer of heat within the housing 22.

As shown, particularly in FIG. 3, the housing 22 includes a base shell 25 having a peripheral portion 26 of an open top configuration. This portion of the base shell is defined by an annular bottom wall 27 and an annular outer wall 28. The base shell 25 is closed by a cover shell, generally designated 30.

Within the peripheral portion 26 of the base shell 25 there is provided a second annular wall 32 spaced from and circumscribed by the outer wall 28 for defining therebetween an annular heat duct 34 circumscribing the central portion, designated 35, of the base shell 25. As best illustrated in FIG. 2, the annular wall 32 is interrupted at a passageway 36 established between the heat duct 34 and the central portion 35 which accommodates a flow of heat to the heat duct 34, for reasons which will hereinafter be more fully understood.

The cover shell 30 includes a disk-shaped cover plate 38, which serves to close the central portion 35 of the base shell 25, circumscribed by an annular compartment 40 which functions as a closure member for the annular heat duct 34. The compartment 40 also is of an annular configuration and opens downwardly into the heat duct 34, communicating therewith through an annular passage 42. As a practical matter, the cover shell 30 can be fabricated in any suitable manner, and preferably includes a plurality of angularly related wall segments 44 welded, or otherwise integrated, and similarly secured to the peripheral portion of the disk-shaped cover plate 38. The walls 28 and 32 are coupled with the wall segments 44 through a plurality of interlocking lips, not designated, having bearing surfaces mated in a face-to-face engagement, whereby sliding motion therebetween is facilitated. It is to be understood that the heat duct 34 and the annular compartment 40 are in continuous communication through the annular opening 42 so that a flow of heat therebetween can be sustained in a continuous fashion.

As best illustrated in FIGS. 1 and 3, the brackets 24 are fixedly coupled with the cover plate 38. Accordingly, the cover shell 30 is suspended in a stationary condition. However, for reasons which will hereinafter be more fully understood, the peripheral portion 26 of the base shell 25, namely the heat duct 34, is supported for rotation about an axis of symmetry passing vertically through the generator 10. To achieve this, there is provided a rotating spider 45 mounted on a stationary base 46. The base 46 is coaxially related to the housing 22 and through suitable bearings 48 serves to support the spider 45. The spider 45 includes a drive-shaft 50, extended through the housing 22, from which there radially is extended a plurality of coplanar arms 52 upon the distal ends of which there is seated the annular bottom wall 27 of the base shell 25. Consequently, the peripheral portion 26 of the base shell 25 of the housing 22 is supported for rotation, by the spider 45, relative to the cover shell 30.

Rotation is imparted to the base shell 25 by an electrically energizable stepping motor 54 coupled to the shaft 50 through a meshed set of bevel gears 56. Hence, by electrically energizing the motor 54, rotation relative to the cover shell 30 is imparted to the peripheral portion 26 of the base shell 25 through the set of bevel gears 56 and the shaft 50.

The central portion 35 of the base shell 25 is subdivided into a plurality of wedge-shaped compartments 58, best shown in FIG. 2. These compartments are formed by a plurality of vertically extended planar walls 60 extended inwardly along the radius of the base shell 25 from a point adjacent the annular wall 32 toward the center of the base shell 25, terminating at equidistances therefrom. Hence, as shown, the compartments 58 are arranged in an annular array of eight converging compartments open at both the innermost and outermost ends thereof. As a practical matter, the walls 60 are suspended from the cover plate 38 and are mutually spaced at equidistances with the opening at the outermost end being equal to the width of the passageway 36.

Within each of the compartments 58 there is provided a plurality of boiler tubes 62. Preferably, the boiler tubes 62 are tubular conduits of preferred dimensions configured into a bank of series-connected boiler tubes of a serpentine configuration. The number of boiler tubes employed in each compartment 58 is deemed a matter of convenience and is determined in accordance with prevailing operational conditions.

Each of the boiler tubes 62 receives the working fluid from an intake manifold 64 coupled therewith through a feeder tube 66. The manifold 64 is coupled with the pump 16 by a length of conduit 18, while each of the feeder tubes 66, in effect, is an extension of one of the boiler tubes 62. A suitable one-way check valve 67 is interposed in each of the feeder tubes 66 for assuring that unidirectional flow characteristics are imposed on the working fluid as it is delivered from the manifold 64 to the boiler tubes 62.

The manifold 64 preferably is formed of tubular stock material into an endless or ring-shaped configuration and is supported externally of the housing 22. Hence, the feeder tubes 66 are extended through the cover plate 38. The intake manifold 64, the feeder tubes 66, and the boiler tubes 62 are united by any suitable technique, including braising, silver soldering and the like.

Each of the boiler tubes 62 further is provided with a discharge tube 68, also extending through the cover plate 38, coupled with a discharge manifold 70, also of an endless or ring-shaped configuration. Preferably, a one-way check valve 72 is interposed between the boiler tubes 62 and the discharge manifold 70 for imposing unidirectional flow characteristics also on the working fluid as it is discharged from the boiler tubes 62 to the discharge manifold 70.

In view of the foregoing, it should readily be apparent that the working fluid is delivered by the pump 16 to the vapor generator 10 at the intake manifold 64, passed through a plurality of one-way check valves 67 into the boiler tubes 62, thence through the boiler tubes 62 to the discharge manifold 70, via the plurality of one-way check valves 72.

From the discharge manifold 70 the working fluid, in its vapor phase, is delivered, via a delivery conduit 74, to the throttle valve 20. It is important here to note that

the plurality of boiler tubes 62 of the compartments 58 is coupled with a single intake manifold 64 and a single discharge manifold 70. Hence, a single delivery to the generator 10, from the pump 16 is accommodated through a length of conduit 18 while a single delivery conduit 74 is provided for delivering the fluid, in its heated condition, from the vapor generator 10 to the throttle valve 20. Furthermore, it is important to understand that the heating coils 62 are suspended from the cover plate 38 in any suitable fashion so long as the feeder tubes 66 and the discharge tubes 68 are extended through the cover plate 38 and communicate with the manifolds 64 and 70, respectively.

Heating of the working fluid, prior to its being delivered to the throttle valve 20, is achieved by means of a rotating fire box, generally designated 76. The fire box is concentrically related to the base shell 25 and is supported for rotation by the drive shaft 50.

The fire box 76 includes a plurality of vertically aligned gas jets 78 projected from the surface of the drive shaft 50, as the shaft extends through the housing 22, and coupled with a suitable source of fuel, preferably a combustible gas, not shown. The jets are connected with the source of fuel by a tubular conduit 80. As a practical matter, the conduit 80 is concentrically supported within the drive shaft 50 and includes a swivel coupling, not shown, which permits the conduit 80 to rotate relative to the source of gas. Since such couplings are well known, a description thereof is omitted. In any event, it is to be understood that as the base shell 25 is driven in rotation, rotation also is imparted to the jets 78 of the fire box 76. Hence, upon lighting the gas delivered from the jets, rotation of the shaft 50 causes the jets sequentially to be directed into each of the compartments 58 whereby a flame of burning gas is caused to heat each bank of the boiler tubes 62 in succession.

As best shown in FIG. 2, the fire box 76 also includes a V-shaped heat shield 82 fixed to the drive shaft 50 and radially extended to points immediately adjacent the innermost ends of the walls 60. As a practical matter, the gas jets 78 are radially extended through the heat shield 82 and are outwardly directed toward the peripheral portions of the base shell 25 whereby heat generated at the jets is directionally confined. The outwardly directed opening of the heat shield 82 coincides with the innermost or inwardly directed opening of each of the compartments 58 so that, in effect, the heat shield 82 serves to complete the innermost portion of each of the compartments 58, for thus isolating each of the compartments 58 as the bank of the boiler tubes 62 therewithin is heated. Accordingly, it is to be understood that as the drive shaft 50 is driven in rotation, successive compartments 58 are caused to communicate with the gas jets 78 and, when the fuel delivered thereby is ignited, a plurality of radially projected flames is caused to heat boiler tubes 62 within each of the compartments 58.

It is important to understand that the heat shield 82 and the opening 36 are in radial alignment. Due to the fact that the heat shield 82 and the annular wall 32 are fixed to the shaft 50, a fixed positional relationship is maintained between the heat shield 82 and the passageway 36. Thus the passageway 36 continuously is supported opposite the fire box 76 so that a continuous passage of heated air from the fire box to the heat duct 34 continuously is provided through each of the com-

partments 58 as it is caused to communicate with the fire box.

Since the compartment 40 communicates with the heat duct 34, it is to be understood that the compartment 40 also continuously is in communication with the fire box 76 through the opening 36 aligned with the fire box 76 through one of the compartments 58 being heated. Accordingly, the compartment 40 continuously is heated as rotation is imparted to the drive shaft 50, by the motor 54 and the fire box 76 is advanced in rotation in unison with the annular wall 32.

Within the compartment 40 there is disposed a reserve boiler tube 84. Preferably, the boiler tube 84 is of a helical configuration, however, other configurations can be employed equally as well. This boiler tube, of course, continuously is subjected to heat developed within the fire box 76 so that fluid confined therewithin continuously is heated. As a consequence, the reserve boiler tube 84 is particularly suited as a standby boiler tube which affords the system with an auxiliary source of heated working fluid in order to preclude an introduction of an oscillating rate of motion at the output of the prime mover 12.

In practice, the boiler tube 84 includes an intake portion 86 coupled with the delivery conduit 74 through a one-way check valve 88, FIG. 4. The boiler tube 84 further includes a discharge lead 90 also coupled with the delivery conduit 74. Hence, it should readily be apparent that so long as the pressures of the fluid confined within the reserve boiler tube 84 are maintained at or above the level of the pressure of the working fluid being delivered through the delivery conduit 74, the one-way check valve 88 is non-conductive. However, in the event the pressure of the fluid confined within the reserve boiler tube 84 drops below that of the working fluid being delivered by the delivery conduit 74 the check valve 88 is rendered conductive for delivering fluid from the conduit 74 to the reserve boiler tubes 84.

The working fluid delivered to and confined within the reserve boiler tube 84 is isolated from the conduit 74 by a selectively actuatable valve 92 interposed in the discharge lead 90 of the reserve boiler tube 84, preferably mid-way between the boiler tube 84 and the delivery conduit 74. This valve is of any suitable design and is opened and closed in response to an electrical signal delivered thereto from a pressure switch 94, FIG. 1. The pressure switch 94 is interposed in the delivery conduit 74 and is coupled with the solenoid-operated valve 92 through a suitable electrical lead 96. Since pressure switches are well known, a detailed description is omitted. In the event a pressure drop of a predetermined magnitude is experienced within the delivery conduit 94 it immediately is detected by the pressure switch 94 with a resulting signal being delivered to the solenoid-operated valve 92, whereupon the valve 92 is opened for conducting heated fluid from the reserve boiler tube 84 to the throttle valve 20, via the delivery conduit 74. Since the reserve boiler tubes 84 continuously are in communication with the fire box 76, the fluid within the tube continuously is heated. Accordingly, fluid of a predetermined pressure continuously is available for use by the prime mover 12 in the event a pressure drop is experienced in the delivery conduit 74.

The pressure switch 94 also is coupled with the stepping motor 54 through a suitable control circuit including a lead 98 and a solenoid-activated switch 100. The

switch 100 functions to couple the motor 54 with a suitable source of voltage, not shown, in response to a signal received from the pressure switch 94. Therefore, this circuit serves to assure that a pressure above a minimal level continuously is imposed on the fluid being delivered through the delivery conduits 74 to the throttle valve 20 by advancing the drive shaft 50 through a predetermined increment of rotation for thereby bringing the fire into operative communication with the next-in-line compartment 58 and simultaneously opening the valve 92 for supplying heated working fluid to the conduit 74 from the reserve boiler tube 84.

As should readily be apparent, when the fire box 76 is brought into operative communication with the compartment 58, the working fluid confined within the boiler tube 62 disposed within the compartment is heated for thus elevating the temperature thereof, preferably to its phase-change temperature. As a phase change occurs, from a liquid to a vapor, the discharge manifold 70 responsively is pressurized through the one-way check valve 72. Upon opening the throttle valve 20, the working fluid, in its vapor phase, is delivered through the prime mover 12 whereupon a pressure drop is experienced in the boiler tube 62 being heated. Once a pressure drop of a predetermined magnitude is experienced within the delivery conduit 74, it is detected by the pressure switch 94. A signal responsively is delivered to the stepping motor 54, through the lead 98 and solenoid-activated switch 100, whereupon the motor 54 is energized for advancing the fire box 76 to the adjacent, next-in-line compartment 50 for initiating a heating of the bank of boiler tubes 62 arranged therewithin. The fluid within the bank of boiler tubes is heated and subsequently delivered to the throttle valve 20, in the aforementioned manner. This cycle, of course, is repeated for each of the compartments 58. Of course, during the interval required for heating a boiler tube 62, for thereby developing the required pressure level, a signal responsively is delivered from the pressure switch 94 to the solenoid-operated valve 92 so that working fluid, under pressure, is delivered from the reserve boiler tube 84, through the valve 92, to the prime mover 12 through the throttle valve 20.

For reasons which should readily be apparent, as the working fluid is delivered to the intake manifold 64, it normally is maintained in its liquid phase under a pressure substantially less than the pressure developed within the heated boiler tubes 62. Consequently, it is necessary to effect a charging of the depleted boiler tubes 62 subsequent to a cooling thereof. Due to the fact that the fire box 76 is advanced in an indexing progression, a substantial lapse of time is experienced between the heating intervals for the boiler tube within a given compartment. Accordingly, cool-down time is experienced so that charging of the boiler tubes 62 in a cooled condition is facilitated.

However, and quite importantly, it is to be understood that the conservation of heat also is deemed highly desirable in order to increase the total efficiency of the system. Thus the vapor generator 10 is provided with a pressure balancing system, generally designated 102, which employs residue pressures for achieving pre-pressurization for facilitating an efficient operation of the system.

The pressure balancing system 102 includes a plurality of bleeder tubes 104 coupled in a communicating relationship with the plurality of banks of boiler tubes

62. In practice, each of the bleeder tubes 104 is coupled with one of the feeder tubes 66 at a point between one of the check valves 67 and the associated boiler tube 62. Thus, the bleeder tubes 104, in effect, serve as conduits for exchanging pressures between the various boiler tubes 62.

As a practical matter, the plurality of bleeder tubes 104 radiates from a pressure balancing valve 106 coaxially related to the fire box 76 and supported at the uppermost or distal end of the drive shaft 50.

The purpose of the pressure balancing valve 106 is to achieve a rapid exchange of pressures between selected boiler tubes of the various compartments as indexing of the fire box 76 occurs. Therefore, the valve 106 includes a cylindrical housing 108, FIGS. 6 and 7, which receives therein the adjacent end of the bleeder tubes 104. Within the housing there is seated a valve plug 110 which is fixed to the drive shaft 50 and supported for rotation within the housing 108. The plug 110 includes a plurality of transverse bores defining therein a plurality of fluid delivery channels which extend through the plug and terminate in suitably spaced relationship for accommodating coupling of pairs of the bleeder tubes in communication. Thus, the boiler tubes 62 are caused to communicate through the plug 110 in a paired relationship. Of course, each of the boiler tubes 62 is paired with another in accordance with the instantaneous position of the plug.

It is important to note that each of the diametrically opposed bleeder tubes 104 is sealed against communication with any of the other boiler tubes 62. Consequently, a flow of working fluid through these bleeder tubes 104 is interrupted. The purpose for this relationship is to assure that pressure cannot be delivered through the pressure balancing valve 106 to or from the associated boiler tubes 62. Thus, one of the boiler tubes is prepared for heating while the diametrically opposed boiler tube is prepared for charging by a delivery of working fluid from the intake manifold. Since the boiler tube 62 being heated always is positioned at 180 degrees with respect to the boiler tube being charged, charging occurs while the tube is cooled to a maximum extent and therefore is charged without encountering substantial back pressure.

Accordingly, it is to be understood that where a given vapor generator 10 includes eight compartments, the associated pressure balancing valve 106 will include three channels for simultaneously coupling six boiler tubes 62 in a paired communication, while communication with diametrically opposed bleeder tubes 104 is interrupted, so that a charging of one boiler tube 62 is accommodated while a heating of the diametrically opposed boiler tube 62 is accomplished. Thus, reduction in the temperature and the attendant pressures of the working fluid confined within the boiler tube 62 being charged is maximized in order that the effects of back pressure be avoided.

For the sake of illustration, during an operational cycle, the bleeder tubes 104 can be considered coupled with the pressure balancing valve 106 at eight positions designated A through H, as shown in FIG. 6. Further, assume that the fire box 76 has been indexed for heating the boiler tube associated with the bleeder tube 104 terminating at position A. Thus the channels 112 couple, in a paired relationship, the boiler tubes 62 associated with the bleeder tubes 104 terminating at positions B and H, C and G, and D and F. Hence, a balanced con-

dition for pressures within the pairs of the thus paired boiler tubes is established. If desired, additional channels 112 having lengths sufficient only to extend between adjacent bleeder tubes 104 can be included in the plug 110 so that adjacent bleeder tubes are brought into momentary communication as the plug 110 is indexed to its next position, whereby the most recently heated boiler tube 104 momentarily communicates with the next boiler tube 104 to be heated.

As heat is applied, the pressure is increased in the boiler tube 62 connected with the bleeder tube 104, terminating at position A. Simultaneously, a charge of fluid is delivered to the boiler tube 62, via a feeder tube 66, coupled with the bleeder tube 104 terminating at the position E. Once the boiler tube 62 is heated sufficiently for boiling-off and thus substantially depleting the working fluid from the boiled tube, the motor 54 is activated for again indexing the fire box 76. As the fire box is indexed, a rotating motion concurrently is imparted to the plug 110 of the pressure balancing valve 106 for thus causing the plug to rotate through a distance sufficient for bringing the bleeder tube 104 terminating at position A into direct communication with the bleeder tube 104 terminating at position C. Of course, the boiler tube 62 now being heated is associated with the bleeder tube 104 terminating at position B so that no fluid flow is afforded through this bleeder tube.

Of course, a pressure balance now is established between the paired boiler tubes 62 associated with the bleeder tubes 104 terminating at positions A and C, D and H, E and G, respectively, while a charge of working fluid is being introduced into the boiler tube 62 associated with the bleeder tube 104 terminating at position F. Thus, a pre-pressurization of the previously charged boiler tube 62 connected with the bleeder tube 104 terminating at position C is effected as a pressure reduction occurs in the most recently heated and depleted boiler tube 62 associated with the bleeder tube 104 terminating in position A. Since the boiler tube associated with the bleeder tube 104 terminating at position H has been pressurized more recently than the boiler tube 62 associated with the bleeder tube 104 terminating at position D, a pressure balance is established therebetween by permitting the pressure of the boiler tube associated with position H to bleed into the boiler tube 62 associated with position D. In a similar fashion, the boiler tube 62 associated with the bleeder tube terminating at position G is permitted to bleed into the most recently charged boiler tube 62 associated with the bleeder tube terminating at position E. This variable pairing of boiler tubes 62 is repeated as the fire box 76 is indexed to communicate with each of the compartments 58 for thereby achieving a stepped pre-pressurization for the charged boiler tubes 62, preparatory to heating, and a stepped de-pressurization, preparatory to charging depleted boiler tubes 62, is achieved. Thus by employing the pressure balancing valve 106, an encounter with back-pressure substantially is avoided and the interval required for achieving a phase change for the working fluid within the boiler tube 62 is substantially reduced, while a maximum use of the heat generated at the fire box 76 is experienced.

In some instances, the pressures developed within the boiler tubes may be such as to initiate an escape of gas at the peripheral surface of the pressure balancing valve 106. Accordingly, if so desired, a solenoid-

operated valve 114 is included in the bleeder tubes 104, FIG. 8, so that an escape of gas from the bleeder tubes 104 is restricted to selected intervals substantially less than the interval required in achieving a phase change of the working fluid in a single boiler tube 62 disposed within one of the compartments 58. Control is achieved for the valves 114 by coupling these valves with the switch 100 so that the valves 114 are actuated once for each step of rotating motion imparted to the fire box 76.

#### OPERATION OF THE SYSTEM EMPLOYING THE FIRST FORM OF THE VAPOR GENERATOR

With the system of the instant invention assembled in the manner hereinbefore described, it is to be understood that the prime mover 12 is driven through a delivery of the working fluid, as a vapor, from the vapor generator 10 through the throttle valve 20. As the vapor escapes from the prime mover 12, via a conduit 18, residual heat is given up and condensation occurs in the condenser 14, whereupon the working fluid undergoes a phase change to a liquid phase. The working fluid now is conducted through the conduit 18 to the pump 16 and thence returned to the vapor generator 10. The pump 16 is operated at a rate sufficient to support an adequate flow-rate for the working fluid as it is delivered to the intake manifold 64. As the fire box 76 heats a given boiler tube 62 a phase change for the working fluid again occurs, resulting in a pressurized vapor being delivered to the discharge manifold 70 through the one-way check valve 72. The thus pressurized fluid is then conducted via the delivery conduit 74 to the throttle valve 20 and thereafter again conducted to the prime mover 12. By controlling the flow-rate of the working fluid through the throttle valve 20, the rate of operation of the prime mover 12 is varied.

As the vaporized working fluid is depleted from a given boiler tube 62, as it is heated, a pressure drop is experienced in the delivery conduit 74 and detected by the pressure switch 94, whereupon the motor 54 is activated for indexing the fire box 76 to the adjacent compartment 58, while the solenoid-activated valve 92 is open for delivering heated fluid from the reserve boiler tube 84, for thus assuring a continuous flow of pressurized working fluid within the system.

Prior to indexing the fire box 76 for thus heating the next-in-line boiler tube 62, within the adjacent compartment 58, the next-in-line boiler tube is prepressurized by a delivery of residual pressure acquired from the immediately preceding boiler tube through a channel 112 of the plug 110, while a charge of fluid, in its liquid phase, is introduced into the boiler tube 62 associated with the bleeder tube 104, diametrically opposed to the bleeder tube 104 associated with the boiler tube 62 now being heated. Once the temperature of the fluid confined within the boiler tube now being heated attains a predetermined level, the working fluid therewithin undergoes a phase change to a vapor and is delivered via the check valve 72 to the discharge manifold 70 for thus elevating the pressure of the working fluid within the delivery conduit 74.

As the pressure of the fluid within the delivery conduit 74 is elevated to a predetermined level, the pressure switch 94 initiates a closing of the solenoid-operated valve 92. Of course, once the working fluid within the boiler tube 62 being heated is boiled-off and thus depleted, so that a pressure drop is experienced

within the delivery conduit 74, the cycle again is repeated with the pressures developed within the boiler tubes being balanced as they successively are connected in variable pairs of boiler tubes through the bleeder tubes 104.

#### VAPOR GENERATOR

(Second Form)

Turning now to FIGS. 9 and 10, therein is depicted a second form of a vapor generator, which readily can be employed in a system embodying the principles of the instant invention.

The vapor generator, as illustrated in FIG. 9 and generally designated 150, functions in a manner and for a purpose quite similar to that of a vapor generator 10 hereinbefore described in detail.

However, as shown in FIG. 9, the boiler tubes 62 of the second form preferably are of a helical configuration and are arranged in a mutually spaced relationship. A gas burner 152, also connected with a source of combustible gas, not shown, through a conduit 154 is provided for heating the boiler tubes 62 in succession. As a practical matter, each of the burners 152 is provided with a suitable pilot light 156 in order to assure a cyclic relighting of the burners 152 is achieved during the operation of the generator 150. The intake manifold 64, shown in FIG. 9, while normally not of an annular configuration, performs the functions hereinbefore described, namely that of delivering working fluid to the boiler tubes 62 by way of the feeder tubes 66, in the manner hereinbefore described. Similarly, the discharge manifold 70 also serves to couple each of the boiler tubes 62 with the throttle valve 20 in the manner hereinbefore described.

The vapor generator 150 also is provided with a reserve boiler tube 84. As shown in FIG. 9, this reserve boiler tube is of a helical configuration and is associated with a gas burner 158, coupled with the conduit 154 for continuous operation. Since the gas burner 158 is a continuously operating burner, no control is required therefor.

If so desired, a tubular housing 160 can be provided for enclosing of the boiler tubes 62 and 84 whereby collection of surplus heat generated by the burners 158 is collected for delivering a tubular heat duct 162 away from the housing 160.

As a practical matter, the reserve boiler tube 84 is housed within a cylindrical housing 164 coupled in communication with the heat duct 162 so that a discharge of heat into the housing 164 is accommodated for thereby achieving a conservation of energy of heat which normally would be discharged to atmosphere during the operation of any of the boiler tubes 62.

The vapor generator 150 also includes a pressure balancing valve 170 quite similar in design and function to the pressure balancing valve 106 hereinbefore described. However, the valve 170 includes a rotatable plug 172 seated within a cylindrical housing 174 and driven by a shaft, not designated, extended from a stepping motor 176 for thereby performing a function similar to that of the pressure balancing valve 106.

The plug 172 includes a pair of relieved peripheral sections forming pressure chambers 178 and 180 adjacent the peripheral surface of the plug. The pressure chambers 178 and 180 are separated by a first land 182 of a minimal length while a second land 184, diametrically opposed to the land 182, serves to separate the

chambers 178 and 180 at substantially the opposite side of the plug 172. However, the second land 184 is of a substantially greater length than the land 182. Accordingly, the pressure chambers 178 and 180 are eccentrically related to the axis of rotation of the plug 172.

As illustrated in FIG. 10, the bleeder tubes 104 terminate at three positions spaced at equidistances about the periphery of the valve so that while one of the boiler tubes is being heated the adjacent boiler tubes 62 are brought into direct communication through a single channel 112 provided for the plug 172. As the motor 176 is activated for driving the plug 172 in rotation, the boiler tubes 62 associated with a pair of communicating bleeder tubes 104 are brought into communication for achieving a pressure balance therebetween. However, as the first land 182 traverses the surface of the valve housing 174, adjacent the bleeder tube 104, a charging of the boiler tube 62 is effected through a delivery of working fluid from the manifold 64 so that as the plug 172 is rotated to its next position, the next-in-line boiler tube is coupled in direct communication through the channel 112 with the previously heated and pressurized boiler tube. For reasons hereinbefore discussed, this cycle is repeated as often as is necessary for pre-pressurizing the next-in-line and previously charged boiler tube, prior to its being heated to effect a pressurization and subsequent depletion of the working fluid from therewithin.

The pressure switch 94 is in direct communication with the fluid delivery conduit 74, in the manner hereinbefore described with regard to the vapor generator 10. However, as employed with the vapor generator 150, the switch 94 serves to deliver a signal to each of the burners 152 in succession, as a pressure drop is experienced within the conduit 74, whereby operation of the burners is initiated in succession for successively heating the boiler tubes associated therewith.

Simultaneously, with the successive initiation of the burners, an indexing of the pressure balancing valve 170 is accomplished by energizing the motor 176, as hereinbefore discussed. The pressure switch 94 also serves to activate the solenoid-control valve 92 coupled with the reserve boiler tube 84 for effecting a delivery of working fluid under pressure from the reserve boiler tube 84 to the throttle valve 20 via the delivery conduits 74, for reasons hereinbefore fully described.

While not shown, it is to be understood that a lock-out circuit can be employed for rendering the pressure switch 94 inactive during the initial phase of operation of the vapor generator 10 so that a proper heating of the boiler tubes 62 is achieved without experiencing a recycling initiated through a constant low-pressure present within the delivery conduit 74. Where so employed, such a lock-out switch serves to stabilize operation of the vapor generator until proper temperatures have been achieved for the system.

#### OPERATION OF THE SYSTEM EMPLOYING THE SECOND FORM OF THE VAPOR GENERATOR

With the pump 16 operating in the manner hereinbefore described, fluid, preferably Freon, in its liquid state is delivered to each of the check valves 72 interposed in the feeder tubes 66 in the manner hereinbefore described. Assuming that a charged boiler tube 62, associated with the bleeder tube 104 at a first position of the valve 170, is being heated, the remaining two

boiler tubes are in direct communication by way of the pressure chambers 178 and 180 and the interconnecting channel 112 so that a pressure balance is established therebetween. Once depletion of the working fluid from the boiler tube being heated is experienced, a pressure drop is experienced in the conduit 74 and is detected by the pressure switch 94. Upon detecting the reduced pressure, the switch 94 delivers an initiating signal to the motor 176 for imparting rotation to the plug 172 causing the land 182 to traverse the opening to the preceding bleeder tube 104. At this point, the pressure within the boiler tube 62 associated with the preceding bleeder tube 104 is minimized so that a charge of working fluid is delivered thereto. Continued rotation of the plug 172 causes the pressure chamber 178 to be positioned adjacent the bleeder tube 104 communicating with the now depleted boiler tube while the pressure chamber 180 is positioned adjacent the bleeder tube 104 most recently charged so that a pressure balance is achieved between the boiler tube 62 previously heated and the boiler tube previously charged through the bleeder tubes 104 and the channel 112. At this juncture, the remaining boiler tube associated with the pressure balancing valve 170 by the bleeder tube terminating at the second land 184 is subjected to heat delivered by one of the burners 152.

In order to initiate a cyclic heating of the boiler tubes 82, the pressure switch 94 sequentially activates the burners 152 in a timed sequence with the operation of the pressure balancing valve 170 so that heating to depletion of given boiler tubes is initiated only after the land 184 separating the pressure chambers 178 and 180 is positioned so as to close the bleeder tube 104 associated with the boiler tube being heated.

In a manner also quite similar to that hereinbefore discussed, the pressure switch 94 serves to deliver a control signal to the solenoid-control valve 92 for delivering a flow of pressurized fluid from the reserve boiler tube 84 to the throttle 20 via the conduit 74 during the intervals between delivery of heated vapor from adjacent boiler tube 62.

In view of the foregoing, it should readily be apparent that the system of the instant invention provides a practical solution to the problem of economically converting heat to kinetic energy with utmost efficiency.

Although the invention has been herein shown and described in what are conceived to be the most practical and preferred embodiments, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the illustrative details disclosed.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An improved system for converting heat to kinetic energy comprising:

A. means including a fluid-driven motor responsive to an introduction of fluid under an elevated pressure for imparting driven motor to a selected power train;

B. fluid control means for introducing to said fluid driven motor fluid at a first given elevated pressure including,

1. a pressure generator comprising, means defining a succession of fluid intake ports, a succession of fluid output ports, and a plurality of boiler tubes, each of which serves to couple a fluid output port in direct communication with a fluid intake port,

2. fluid delivery means coupled with said intake ports for successively delivering to said boiler tubes fluid at a second given pressure,
3. means for heating the boiler tubes in succession, whereby the pressure of the fluid within successive boiler tubes is elevated to said first given pressure, and
4. fluid transfer means for conveying heated fluid from said output ports to said motor at said first given pressure; and
- C. fluid return means for returning the fluid from said fluid driven motor to said fluid control means at said second given pressure.
2. The system of claim 1 wherein the fluid delivery means includes:
  - A. a condenser coupled with said motor for cooling the fluid, subsequent to an introduction thereof to said motor and prior to a delivery thereof to said boiler tubes;
  - B. a manifold coupled with said condenser;
  - C. a plurality of feeder conduits associated with each intake port for coupling the intake port with said manifold; and
  - D. a one-way check valve interposed in each of said feeder conduits for imposing unidirectional flow characteristics on the fluid as it is delivered to the boiler tubes.
3. The system of claim 2 wherein said means for successively heating the boiler tubes includes:
  - A. a heat generating fire box supported for stepped progression into a heat-exchange relationship with each of said boiler tubes for thereby successively heating the boiler tubes;
  - B. intermittently activated drive means coupled with said fire box for imparting thereto said stepped progression;
  - C. pressure responsive means interposed in said fluid transfer means and coupled with said drive means for detecting pressure changes occurring in said fluid transfer means; and
  - D. means coupled with said pressure responsive means for activating said drive means in response to selected pressure changes as they occur in said fluid transfer means.
4. The system of claim 3 further comprising:
  - A. means including a reserve boiler tube having opposed ends coupled with said fluid transfer means, for receiving from and discharging to the transfer means heated fluid, supported in a continuous heat-exchange relationship with the fire box, whereby heat continuously is transferred to the reserve boiler from the fire box;
  - B. a one-way check valve for imposing unidirectional flow characteristics on the fluid as it is received by said boiler; and
  - C. a solenoid controlled valve, interposed between the reserve boiler and the fluid transfer means, coupled with said pressure responsive means for limiting discharge of the heated fluid from said reserve boiler to the fluid transfer means.
5. The system of claim 4 wherein said fluid transfer means includes a manifold and means including a plurality of one-way check valves for coupling each of said output fluid ports with the manifold.
6. The system of claim 5 further comprising:
  - a pressure exchange system coupled with each of said boiler tubes, including means for developing in

- stepped progression a third and a fourth pressure within each of said boiler tubes.
7. The system of claim 6 wherein the pressure exchange system includes means defining a plurality of bleeder tubes, each communicating with one of said boiler tubes, and a multi-ported valve operatively coupled with said bleeder tubes in a variable relationship for simultaneously coupling selected bleeder tubes in variable pairs, whereby the boiler tubes are caused to communicate in a variably paired relationship for thereby selectively accommodating a pressure exchange between selected boiler tubes.
8. The system of claim 7 further comprising a solenoid controlled valve interposed in each of said bleeder tubes.
9. The system of claim 8 wherein said second pressure is greater than said third pressure, and said first pressure is greater than said fourth pressure.
10. In a system for converting heat to energy including a motor responsive to a flow of heated fluid for providing an output of mechanical energy, the improvement comprising:
  - means for establishing a flow of heated fluid including a high-pressure manifold coupled with said motor for delivering to the motor a flow of fluid at a first pressure; a plurality of mutually spaced boiler tubes the first ends thereof being coupled in direct communication with said high-pressure manifold for serially delivering thereto fluid at said first pressure; a low-pressure manifold coupled in direct communication with said plurality of boiler tubes at the second ends thereof for delivering thereto fluid at a second pressure, lower than said first pressure; means for controlling the delivery of fluid between said plurality of boiler tubes and said manifolds; and pressure control means including means for serially heating said plurality of boiler tubes in stepped progression for elevating the pressures of the fluid delivered to the boiler tubes, prior to its delivery therefrom.
11. The improvement of claim 10 wherein each of said boiler tubes is of a serpentine configuration and said plurality of boiler tubes are arranged in an annular array, with each tube of said array being extended radially from the center thereof, and said means for serially heating said tubes includes a concentric burner coupled with a source of combustible fluid and supported for rotation in stepped progression.
12. The improvement of claim 10 wherein said pressure control means further includes a pressure exchange system coupled with each of said boiler tubes including a plurality of bleeder tubes, each bleeder tube being coupled in a communicating relationship with one of said boiler tubes, and a multi-ported valve operatively coupled in a variable relationship with said plurality of bleeder tubes for simultaneously coupling selected bleeder tubes in variable, communicating pairs, whereby the boiler tubes are caused to communicate in a variably paired relationship for accommodating an exchange of pressure therebetween.
13. An improved system for converting heat to kinetic energy comprising:
  - A. means including a fluid-driven motor responsive to an introduction of fluid under an elevated pressure for imparting driven motion to a selected power train;

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- B. fluid control means for introducing to said fluid driven motor fluid at a first given elevated pressure including,
1. a pressure generator comprising, means defining a succession of fluid intake ports, a succession of fluid output ports, and a plurality of boiler tubes, each of which serves to couple a fluid output port in direct communication with a fluid intake port,
  2. fluid delivery means coupled with said intake ports for successively delivering to said boiler tubes fluid at a second given pressure,
  3. means for heating the boiler tubes in succession, whereby the pressure of the fluid within succes-

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- sive boiler tubes is elevated to said first given pressure, and
4. fluid transfer means for conveying heated fluid from said output ports to said motor at said first given pressure;
  - C. fluid return means for returning the fluid from said fluid driven motor to said fluid control means at said second given pressure; and
  - D. a pressure exchange system coupled with each of said boiler tubes, including means for developing in stepped progression a third and a fourth pressure within each of said boiler tubes.

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