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PROVISIONAL SPECIFICATION.

Improvements in or relating to Fluid Pressure Thermo-dynamic Engines.

I, JACOB TRIPLER WAINWRIGHT, Civil Engineer, of 2103, Wabash Avenue, Chicago, State of Illinois, in the Republic of the United States of America, do hereby declare the nature of this invention to be as follows:—

I have invented a new and useful art, an apparatus, and a method of operation, all of which pertain to said new art.

This new and useful art consists in utilizing as a source of energy heat that is common to terrestrial matter and manifested as temperature condition. A rationalle and description here follows.

Heat engines which operate by the varying condition of a working fluid, as regards pressure, volume, and temperature, have properly been divided into two classes.

1st. Those known as heat motor engines, and which by their operation transform or convert heat into dynamic energy or work. 2nd. Those known as heat pumps, and which are merely motor engines with a reversed cycle of operation, and consequently transform dynamic energy into heat.

Heretofore, an essential to the operation of such motor engines has been the maintenance of a refrigerator or medium of heat reception to receive the accumulation of unconverted heat after passing through the engine.

Whereas, the object of my invention is to dispense with this refrigerator, either wholely, or partially.

Also, heat engines heretofore made exemplified the following principles, first enunciated by Sadi Carnot, and now commonly known as the second law of thermodynamics.

1. "All heat motor engines are similar in that they receive heat from some source, transform part of it into work, and deliver the remainder to a refrigerator."

2. "In the thermo-dynamic sense, a heat motor engine is perfect only when the cycle is reversible, and the efficiency of such an engine is expressed by an average ratio of loss of temperature to initial absolute temperature of the heat applied.

Although these two principles or laws apply with correctness to heat engines heretofore made, I have discovered or observed that they are not correct for a broader and more comprehensive treatment of the subject. In fact, they apply only to a specific type of engine, have not the broad scope of a general nature, and do not apply to all heat engines. However, they disclose the present state of the art.

Also, I have discovered or observed that the two above mentioned laws should be revised so as to read as follows.—

1. All heat motor engines are similar in that they receive heat from some source; transform this heat into work, wholely, or partially; and deliver what remains to a refrigerator.

2. In the thermo-dynamic sense, a heat motor engine is perfect only when

the cycle is reversible, and the efficiency of such an engine is expressed by a ratio of loss of heat to quantity of heat applied.

An application of my invention consists in combining a heat motor engine with a novel apparatus which is merely a part of my invention and is herein called a potential transformer; in a manner to intercept the transfer to a refrigerator unconverted heat that has passed through the motor engine; and return such intercepted heat to its source, or to the motor engine, by the expenditure of less dynamic energy than is generated by the motor engine.

When the heat from a heat motor engine is thus intercepted, and returned, a supply of heat can be utilized at a comparatively low temperature and from some convenient source such as the atmosphere, or a body of water, because it is not necessary to maintain a refrigerator for the reception of an accumulation of ejected heat.

The above rationale of the matter is simple and explicit but necessitates an explanation in regard to the nature and properties of the potential transformer.

For a potential transformer; I have invented a new kind of heat engine which I term potential transforming engine.

When perfect and reversible in a thermo-dynamic sense; this kind of engine can transform a fluid from one potential condition to an other, without changing the intrinsic or total contained energy of the fluid; and consequently at no cost, nor gain, as regards external work or dynamic energy. Also, its operation can be regulated so as to transform the potential condition of the fluid either with cost, or gain, as regards external work; and consequently with a corresponding changed condition as regards the intrinsic energy of the fluid.

My invention is based on the feasibility of transmuting or transforming the fluid from a lesser to a greater potential condition, accompanyed by but a meager increase in intrinsic energy, for the purpose of affording means to manipulate for a transmutation of its contained energy into dynamic energy or work; all in accord with the first law of thermodynamics; and with the second law, as hereinbefore revised by myself.

In a generic sense; my preferable process or method of operation for transforming a fluid from a lesser to a greater potential condition; consists in densifying the fluid by abstracting heat or energy therefrom while maintaining it at conveniently low pressure, transferring this heat to the thus densified fluid while maintaining it at higher pressure, by or through a medium which is adapted to cause a greater increase in potential condition than increase in intrinsic energy considered proportionately respectively as regards total potential condition and total contained or intrinsic energy.

A perfect transformation is effected when there results no change in intrinsic energy. With regard to most fluids; it may be remarked that such transformation of the potential condition results at a corresponding temperature which does not differ from that corresponding with the initial potential condition, when the fluid is a perfect gas; and at a changed temperature when the fluid is in the condition of a mixture of liquid and saturated gas. With such a mixture, a change in potential condition corresponding with no change in intrinsic energy necessitates a change in the relative proportion of liquid to gas, and consequently a change in its temperature because the values for specific-heat respectively for the liquid and gas are not equal.

Referring to the accompanying drawings. For the purpose of simplicity, these drawings have been made in a conventional manner, and refinements in matters of detail and scale have been purposely omitted because the specified parts when taken separately are well known devices and may be constructed in any manner that is suitable and known.

Figure 1 shows an elementary type of potential transforming engine which approximates an ideal in a thermo-dynamic sense, but is not so efficient in a mechanical sense. A diaphram capable of a ready conduction of heat therethrough is shown at A, it separates the interior of a non-conducting cylinder into the two parts B and B B, each of these cylindrical parts are provided with a non-conducting piston respectively indicated by C and C C, these pistons are moved to and from the diaphram A by means of separate racks and pinions respectively shown at D and D D. For explanatory purposes, crank arms indicated at G and G G are here shown for operating their respective pinions; and for the purpose of avoiding prolixity, mechanism for operating these crank arms has been purposely omitted because such explanation is not essential to a proper understanding of the particular principles and operation herein involved.

Preparatory to operating; a permanent charge of working fluid is charged through the conduit E and opened cock F and into the cylinder B while partially withdrawing the piston C; the cock F is then closed to put the engine in condition for operation. This fluid is only a working fluid and not the fluid to be treated or transformed. It is preferable that this fluid shall be the same kind as that which is to be treated. Also, it is essential that this cylinder shall now be only partially expanded and thereby permit ample room for subsequent expanding and contracting of the piston C.

Preferably, a cycle is effected by the following successive operations.—

1. Starting with the pistons placed as shown in Figure 2. Through the conduit E E and opened cock F F and while withdrawing the piston C C to its full extent; a charge of vaporous, or gaseous fluid to be operated upon or transformed is received into the cylinder B B. The cock F F is then closed. The pistons have now acquired the positions shown in Figure 3.

This fluid is thus received in a certain condition as regards its contained or intrinsic energy, also in a certain potential condition.

This operation causes the piston C C to effect external work or dynamic energy by reason of its withdrawal with the fluid pressure thereon.

2. The piston C C remaining stationary; the working fluid in the cylinder B is expanded and cooled by a partial withdrawal of the piston C; at a slow rate of speed so as to make efficient the accompanying transfer of heat through the diaphram A, from the fluid in the cylinder B B to the fluid in the cylinder B. This operation causes the fluid in the cylinder B B to lessen its pressure by reason of its loss of heat, while the fluid in the cylinder B effects work by reason of its expansion and pressure. The pistons have now acquired the positions shown in Figure 4.

3. With the piston C slowly continuing its course of withdrawal; the cylinder B B is contracted by forcing the piston C C towards the diaphram A, preferably at constant pressure. The pistons have now acquired the positions shown in Figure 5. This operation causes the fluid in the cylinder B to be further cooled and continue its production of work by reason of its expansion; while the fluid in the cylinder B B is caused to contract by reason of the application of external work thereon, and loss of the heat transferred to the contents of the cylinder B.

4. Wth the cylinder B B contracted, and the piston C C remaining stationary, the cylinder B is contracted by slowly forcing its piston C back to its initial position. This operation causes the fluid in the cylinder B B to acquire temperature and pressure by reason of the compression of fluid in the cylinder B. The pistons have now acquired the positions shown in Figure 6.

5. The piston C remaining stationary, the fluid in the cylinder B B is removed in a transformed condition through the conduit E E, by opening the cock F F and forcing the piston C C to its initial position; the pistons have again acquired the positions shown in Figure 2, and the cycle is completed.

The relative extent of the successive operations which make up a cycle can be regulated so as to produce any desired degree of change in potential condition. The degree of change in intrinsic energy is dependent upon the degree of pressure under which the treated fluid is densified, and is an increasing function of this pressure.

This transforming engine posesses the following objectionable features.—1st. The process is not continuous. 2nd. The engine is not highly efficient, in a mechanical and constructive sense.

To overcome these objectionable features; I have invented the type of transforming engine herein shown by Figures 7[A] and 7[B], taken together as a whole. I prefer to operate this engine so as to effect a process or method of operation that is less generic than that hereinbefore mentioned, which consists in liquifying the fluid by abstracting heat or energy therefrom while maintaining it at a relatively low pressure, and transferring this energy to the liquified fluid while maintaining it at a higher pressure. With this particular apparatus; this process or method of operation is effected in the more specific manner which consists in liquifying the fluid by abstracting heat therefrom, while maintaining it at a relatively low temperature and pressure by a regenerative action; and transferring this heat to the liquified fluid while maintaining it at a higher pressure.

A regenerative action is herein understood to be an action in which there is an interchange of heat between working fluid that precedes and working fluid that follows in the same routine.

Referring to Figures 7[A] and 7[B]. In order to clearly show the operation of this engine and the principles involved; in a conventional manner the apparatus is shown by these two figures, when they are taken together as a whole; certain conduits shown in one figure connect with and continue as the same conduit in the other figure, these conduits are respectively indicated by the same reference letter in each figure, and are the conduits Z, Y, X, and W; the direction which the fluid is caused to pass through the various conduits is indicated by conventional arrows. Figure 7[A] is a sectional-elevation and shows that portion of the apparatus where manipulations are effected, as regards regeneration of heat. Figure 7[B] is a plan and shows the dynamic mechanism. In a conventional manner, and where desirable, the conduits and engine cylinders are shown to be surrounded by suitable insulating material to prevent thermal inefficiencies by reason of external radiation.

In operation, preferably, the fluid to be treated or transformed is received in a gaseous condition by the conduit U and passes therethrough into the conduit Y which extends from the pressure reducing-valve V to the compression cylinder C1. This fluid enters the conduit Y, therein mixes with the current of fluid passing therethrough from the valve V, passes from this conduit into the compression cylinder C1, is compressed in this cylinder and delivered therefrom into the conduit Z and passes therethrough until the valve V is reached at the end of this conduit Z, by passing through this opened valve it again enters the conduit Y to again pass therethrough to the compressor C1. Through the conduit X, and as explained later, a portion of the fluid is withdrawn from this circuit.

A diaphram or siding capable of a ready conduction of heat therethrough is indicated by D, and separates the above mentioned conduits Y and Z. The above mentioned compression effected by the compression cylinder C1 causes a changed condition to the fluid, as regards pressure and temperature; thereby the fluid pressure is increased and also the temperature of the fluid is increased.

The above mentioned passage of this fluid through the conduit Z, in this compressed and heated condition, causes an efficient regenerative interchange of heat through the diaphram D, and with the colder fluid passing in an opposite direction in the adjoining conduit Y.

This regenerative interchange of heat effects a self-intensifying frigefactive effect, culminating at the valve V, and causing the fluid in the thus frigefied end of the conduit Z to condense to the liquid condition. By reason of gravitation, this frigefied liquid fluid collects in the trap or upturn at the bottom of the conduit Z, from whence it is forced through the upward turn of this trap until it reaches the valve V at the top of this upturn in the conduit. By passing from thence through the orifice or opened pressure reducing-valve V, the culminating frigefaction is then effected by reason of the evaporation of this liquid due to its entry into the conduit Y wherein a lesser pressure is maintained by the combined action of the valve V and the compressor C1.

For the purpose of effecting an efficient regenerative interchange of heat to condense the fluid in the conduit Z; the frigened end of the conduit Y and the adjoining branch from the conduit Z are purposely extended upwards and separated by the heat conducting diaphram, in order that the released liquid from the valve V may gravitate along the diaphram and toward the warmer portion of the conduit and thus insure a rapid evaporation and thus prevent an accumulation of this liquid after passing through the valve V.

Through the conduit X, a portion of the liquid fluid is withdrawn from the conduit Z. This withdrawn liquid passes through the conduit X and enters the pressure pump P 3 wherein it is put under pressure and ejected therefrom into and through the conduit W wherein this increased pressure is maintained. The conduit W is separated from the conduits Z and Y by the diaphram or siding F which is capable of a ready conduction of heat therethrough.

For a normal working of the apparatus; the weight of the liquid fluid thus withdrawn from the conduit Z and forced through the conduit W, and therefrom from this apparatus, is equal to the weight of gaseous fluid received into the apparatus through the conduit U. Through the diaphram F, there is an efficient interchange of heat between the frigefied liquid passing through the conduit W and the warmer and gaseous fluid passing under a lesser pressure and in an opposite direction through the adjoining conduit Z. Thus; the gaseous fluid to be treated or transformed is received into the apparatus, through the conduit U; is condensed to the liquid condition when it reaches the frigefactive end of the conduit Z; is kept in a liquid condition and under a greater pressure after passing through the pump P 3; and while under this pressure and passing through the conduit W along the diaphram F, it receives heat abstracted from the gaseous fluid in the adjoining conduit, for the purpose of aiding the condensation in the conduit Z.

The circuit through the valve V is maintained for the purpose of producing the self-intensive frigefactive effect, and should be operated with sufficient flow, but with little difference in pressure through this valve; because the efficiency of a reducing-valve or orifice for this purpose, in a thermodynamic sense, is affected by this difference in pressure and is a decreasing function thereof.

The counter shaft T is driven by any suitable source of dynamic-energy. By means of suitable regulating devices such as the belted sprocket cones shown at R 1 and R 3, the counter shaft T actuates the compressor C 1 and the pressure pump P 3 by means of their respective crank shaft and piston shown at S 1 and S 3. These sprocket cones or an equivalent regulating device afford suitable means for regulating the relative flow through the compressor C 1 and the pressure pump P 3. The pressure reducing valve V is of the type used on self-intensive frigefactive apparatus, and can be readily adjusted to effect any desired change of pressure.

Thus. As presented a description of a type of potential transforming engine that receives a continuous flow of gaseous fluid to be treated; ejects the same in a continuous flow, and in a changed potential condition in the same sense as hereinbefore mentioned and described in connection with the apparatus shown by Figure 1.

Figures 8A and 8B, taken together as a whole, show a preferable manner of combining the type of potential transforming engine shown in Figures 7A and 7B with an ordinary type of heat motor engine. In order to clearly show the operation of this combination and the principles involved; in a conventional manner the apparatus is shown by these two figures, when they are taken together as a whole; certain conduits shown in one figure connect with and continue as the same conduit in the other figure, these conduits are respectively indicated by the same reference letter in each figure, and are the conduits Z, Y, X, W, U, and L; the direction which the fluid is caused to pass through the various conduits is indicated by conventional arrows. Figure 8A is a sectional elevation and shows that portion of the apparatus where manipulations are effected, as regards regeneration, and interchange of heat. Figure 8^B is a plan and shows the dynamic mechanism. For the purpose of convenience, the various parts of the transforming engine, where shown in this combination, are respectively indicated by the same reference letters that are used in Figures 7^A and 7^B. In a conventional manner and where desirable, the conduits and engine cylinders are shown to be surrounded by suitable insulating material to prevent thermal inefficiencies by reason of external radiation.

The object of this combination is to effect an interception of the ejected low pressure fluid from the heat motor engine, transform the potential condition of this ejected fluid by passing same through the potential transforming engine, return this transformed and high pressured fluid to the heat motor engine, increase the intrinsic energy of this returned fluid by raising its temperature to that of available terrestrial atmosphere, pass this comparatively heated fluid through the working cylinder of the heat motor engine, and thus complete the cycle in accordance with the principles hereinbefore explained in the rationale of the matter as regards utilizing heat that is common to terrestrial matter for the purpose of transmuting same into dynamic energy.

In operation, the low pressure gaseous fluid is ejected from the working cylinder E 2 of the heat motor engine, it is also ejected from the working cylinders of the auxiliary motor engines E 1 and E 3, which are directly attached respectively to the compression cylinder C 1 and the pressure pump P 3 for the purpose of supplying the necessary dynamic energy to operate same. This ejected low pressure fluid is received in the conduit U and therefrom passes into and through the various conduits of the transforming engine in identically the same manner as was described for Figures 7^A and 7^B. The transformed and comparatively cold fluid, under high pressure, and in liquid condition, passes from the conduit W into a continuation of this conduit shown at K which is separated from the conduit H by a diaphram or siding J capable of a ready conduction of heat therethrough. Through the conduit H; preferably; is forced a current of air taken directly from the atmosphere, or a current of water taken from some large body of same, by means of a suitable fan or circulating device which it is not necessary to show here, and is purposely omitted in order to avoid prolixity. Through the diaphram J, the current of atmosphere passing through the conduit H effects an exchange of heat with the current of colder fluid passing in an opposite direction in the adjoining conduit K; thereby, the high pressured liquid fluid is heated and evaporated at high pressure and is forced through the continuation of this conduit shown at L. From thence, this high pressure gaseous fluid is withdrawn to operate the before mentioned motor cylinders E 1, E 2, and E 3. From these motor cylinders, this fluid is ejected at low pressure into the conduit U, and thus the cycle is completed.

In order to renew the working fluid lost by leakage, and to maintain a proper quantity of fluid in the conduit system, the pump P 4 forces a supply through the conduit N and from thence into the conduit W. The fluid is supplied to this pump in a liquified condition, and by means of the conduit M which leads from some suitable reservoir containing a supply thereof. It is desirable that this liquid shall be volatile, cheap, readily available, and non-corrosive. Consequently, I prefer to use liquid carbonic acid, or liquid air.

The current of atmosphere passing through the conduit H is the source from which heat is supplied for actuating this whole system of mechanism. If it were possible to construct the apparatus so that a perfect efficiency would be obtained from all of its parts; the heat that disappears or is abstracted from the current of atmosphere would represent the surplus of dynamic or mechanical energy developed by the whole apparatus; in other words, all of the heat taken from this current would be transmuted into dynamic energy available for any purpose. In a practical apparatus; the difference between the actual available dynamic energy and the heat abstracted from the current of atmosphere represents that portion of the abstracted heat that is not transmuted into dynamic energy but is dissipated; consequently, it is desirable that the various parts shall be constructed so as to effect the greatest possible degree of efficiency, particularly as regards fluid expansion and fluid compression. From the pulley O on the shaft of the motor engine E 2, all available dynamic energy can be taken by means of a belt or other suitable device and applied to any desired purpose. For the purpose of effecting a suitable regulation of the relative flow through the various conduits; the various pistons are connected one to the other by means of the counter shaft T and the several belted sprocket cones connecting this counter-shaft with the crank shafts that operate with these pistons, and shown respectively at R 1, R 2, R 3, and R 4. For convenience in starting and stopping the apparatus; valves for stopping the supply of motive fluid from the conduit L to the engine cylinders E 1, E 2, and E 3, are shown respectively at L 1, L 2, and L 3; clutches for disconnecting the torsional action of the shaft T in regard to the several sets of sprocket cones are shown respectively at T 1, T 2, T 3, and T 4. In like manner the clutch T 5 disconnects the pulley R 5 which is used only when starting the apparatus, and as a means for then connecting some suitable steam engine or other convenient source of dynamic energy for the purpose of actuating the counter shaft and thereby actuate the mechanism of the apparatus until a normal working is effected; when the apparatus has acquired a normal working condition, this pulley is disconnected from the shaft T by this clutch T 5, the auxiliary starting engine is stopped, and the apparatus continues by its self operating action.

By utilizing the cooled current of atmosphere ejected from the conduit H, for frigefactive purposes, the apparatus becomes a self operating frigefactive engine.

In order to make clear the principles involved; in Figures 7^A and 8^A, it was necessary to adopt a conventional manner of showing the conduit system. In practice, it is desirable to adopt an annular spiral coil system.

Preferably; this coil system consists of a continuous series of flat spirals placed one over the other, separated into successive layers by horizontal partitions of non-conducting material; and between these horizontal partitions, a spiral partition of the same material is arranged to form a flat spiral conduit in each layer, and so as to continue successively through the series of layers, and to conduct the current of low pressure fluid; in and along this insulated conduit containing the current of low pressure fluid, are placed conduits or pipes containing respectively the several high pressure fluid currents, these pipes are made of material which is capable of a ready conduction of heat therethrough.

Figures 9 and 10 show a spiral coil constructed on this system, Figure 9 is a sectional plan, Figure 10 is a sectional elevation, and the same reference letters are used in both of these figures to indicate the same parts. In the interior of the hermetically closed casing C, the high pressure fluid pipes or conduits 2 and 3 are contained in the insulated spiral conduit 1 and there surrounded by the current of low pressure fluid contained in this conduit 1.

Thus, is presented a description of an operative and practical apparatus for effecting the purpose of my invention.

It is herein understood that any operation mentioned in connection with my invention may be performed in any manner that is suitable and known. Also, my invention is not limited to the use of any particular material in the construction of the various parts, nor to the use of any particular working fluid. Also, the application of a multiplex method of combination, which consists in effecting the same cycle of operation by means of inter-dependent action between two or more apparatus, shall be considered as a mere equivalent of the simple single apparatus shown.

Dated this 1st day of February 1900.

JACOB TRIPLER WAINWRIGHT.

COMPLETE SPECIFICATION.

Improvements in or relating to Fluid Pressure Thermo-dynamic Engines.

I, JACOB TRIPLER WAINWRIGHT, Civil Engineer, of 2103, Wabash Avenue, Chicago, State of Illinois, in the Republic of the United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

I have invented a new and useful art, an apparatus, and a method of operation, all of which pertain to said new art.

The purpose of this art consists in utilizing as a source of energy heat that is *common to terrestrial matter* and manifested as temperature condition. A rationale and description here follows.

Heat engines heretofore made which operate by the varying condition of a working fluid, as regards pressure, volume, and temperature; have properly been divided into two classes. 1st. Those known as heat motor engines, and which by their operation transform or convert heat into dynamic energy or work. 2nd. Those known as heat pumps, and which are merely motor engines with a reversed cycle of operation, and consequently transform dynamic energy into heat

Heretofore, an essential to the operation of such motor engines has been the maintenance of a refrigerator or medium of heat reception to receive the accumulation of unconverted heat after passing through the engine. Whereas, the purpose of my invention is to dispense with this refrigerator, either wholely, or partially.

Also, heat engines heretofore made exemplified the following principles, first enunciated by Sadi Carnot, and now commonly known as the second law of thermodynamics.

1. "All heat motor engines are similar in that they receive heat from some source, transform part of it into work, and deliver the remainder to a refrigerator."

2. "In the thermo-dynamic sense, a heat motor engine is perfect only when the cycle is reversible; and the efficiency of such perfect engine is expressed by the difference between the respective temperatures of heat reception and heat rejection, divided by the absolute-temperature of heat reception, taken as an average with respect to the units of heat applied and the portions of these units which are rejected."

Although these two principles or laws apply with correctness to heat engines heretofore made, I have observed that they are not correct for a broader and more comprehensive treatment of the subject. In fact, they have not the broad scope of a general nature, do not apply to all heat engines, and merely apply to that particular type in which all portions of the working fluid progress through the same temperature changes with common-to-all corresponding rates of change in potential condition.

Also, I have observed that the two above mentioned laws should be revised so as to read as follows.—

1. All heat motor engines are similar in that they receive heat from some source; transform this heat into work, wholely, or *partially*; and deliver what remains to a refrigerator.

2. In the thermo-dynamic sense, a heat motor engine is perfect only when the cycle is reversible, and the efficiency of such perfect engine is expressed by a ratio of loss of heat to quantity of heat applied.

A preferable application of my invention consists in combining a heat motor engine with a novel apparatus which is merely a part of my invention and is herein called a potential transformer; in a manner to intercept the unconverted heat that has passed through the motor engine, and prevent the transfer of same to a refrigerator; and return such intercepted heat to its source, or to the motor engine, by the expenditure of less dynamic energy than is generated by the motor engine. When the heat from a heat motor engine is thus intercepted and returned, a supply of heat can be utilized at a comparatively low temperature and from some convenient source such as the atmosphere, or a body of water, because it is not necessary to maintain a refrigerator for the reception of an accumulation of ejected heat.

The above rationale of the matter is simple and explicit but necessitates an explanation in regard to the nature and properties of the potential transformer.

For a potential transformer, I have invented a new kind of heat engine which I term potential transforming engine. Its function, as applied to my invention in a preferable manner, is to transform or transmute the potential condition of the working fluid after passing through the motor engine, and thus dispense with the necessity of maintaining an external refrigerator for receiving the accumulation of such ejected heat. The preferable manner in which this result is attained consists in reducing the potential condition of the fluid to be treated, by abstracting heat from same; when this fluid has thus acquired a comparatively low potential condition and consequently is not capable of developing much latent heat by a change in condition as regards density and pressure, its condition is then caused to be changed by a meager external application of dynamic energy or work; the above mentioned abstracted heat is then returned to the thus densified fluid held under an increased pressure and thereby causes a transmutation to the condition of greater potential by reason of the returned heat existing in the same but more densified fluid; and effecting this abstraction and return of heat by a regenerative action which is made effective by causing different portions of regenerative fluid to progress through the same temperature changes with corresponding rates of change in potential condition that differ.

When perfect and reversible in a thermo-dynamic sense; this kind of engine can transform a fluid from one potential condition to an other, without changing the total contained energy of the fluid; and consequently at no cost, nor gain as regards external work or dynamic energy. Also, its operation can be regulated so as to transform the potential condition of the fluid either with cost, or with gain, as regards external work; and consequently with a corresponding changed condition as regards the total contained energy of the fluid.

My invention is based on the feasibility of transmuting or transforming the fluid from a lesser to a greater potential condition, accompanied by but a meager increase in total contained energy, for the purpose of affording means to manipulate for a transmutation of its contained energy into dynamic energy or work; all in accord with the first law of thermodynamics; and with the second law of thermodynamics, as hereinbefore revised by myself.

In a generic sense; my preferable process for effecting such transformation consists in lessening the potential condition of the fluid by abstracting heat from same; when the fluid has thus acquired a lowered potential condition, effecting a changed condition by increasing its density, or fluid pressure, or both, by an external application of force; returning said abstracted heat to the thus densified fluid held under increased pressure; and effecting this abstraction and return of heat by a regenerative action in which different portions of regenerative fluid are caused to progress through some identical temperature changes with corresponding rates of change in potential condition that differ.

A perfect transformation of the potential condition is effected when there results no change in the total contained energy. With regard to most fluids; it may be remarked that such transformation results at a temperature which does not differ from that corresponding with the initial potential condition, when the fluid is a perfect gas; and at a changed temperature when the fluid is in the condition of a mixture of liquid and saturated gas. With such a mixture, a change in potential condition corresponding with no change in total contained energy necessitates a change in the relative proportion of liquid to gas, and consequently a change in its temperature because the values for specific-heat respectively for the liquid and gas are not equal.

The drawings filed with my Provisional Specification are herein referred to in all cases. For the purpose of simplicity, these drawings have been made in a conventional manner, and refinements in matters of detail and scale have been purposely omitted because the specified parts when taken separately are well known devices and may be constructed in any manner that is suitable and known.

Figure 1 shows an elementary type of potential transforming engine which approximates an ideal in a thermo-dynamic sense, but is not so efficient in a mechanical sense. Figures 2, 3, 4, 5, and 6, are merely of the nature of a diagram, and are for the purpose of explaining the successive operations that make up a cycle. A diaphram capable of a ready conduction of heat therethrough is shown at A, it separates the interior of a non-conducting cylinder into the two parts B and B B, each of these cylindrical parts are provided with a non-conducting piston respectively indicated by C and C C, these pistons are moved to and from the diaphram A by means of separate racks and pinions respectively shown at D and D D. For explanatory purposes, crank arms indicated at G and G G are here shown for operating their respective pinions; and for the purpose of avoiding prolixity, mechanism for operating these crank arms has been purposely omitted because such explanation is not essential to a proper understanding of the particular principles and operation herein involved.

Preparatory to operating, a permanent charge of working fluid is charged through the conduit E and opened cock F and into the cylinder B while partially withdrawing the piston C; the cock F is then closed to put the engine in condition for operation. This fluid is manipulated as a portion of the working fluid and is not the fluid to be treated or transformed. It is preferable that this fluid shall be the same kind as that which is to be treated, but in a more densified condition. It is essential that this cylinder shall now be only partially expanded and thereby permit ample room for subsequent expanding and contracting by means of the piston C.

Preferably, a cycle is effected by the following successive operations.—

1. Starting with the pistons placed as shown in Figure 2. Through the conduit E E and opened cock F F and while withdrawing the piston C C to its full extent; a charge of vaporous, or gaseous fluid to be operated upon or transformed, is received into the cylinder B B. The cock F F is then closed. The pistons have now acquired the positions shown in Figure 3. This operation causes an interchange of heat through the diaphram A until a common temperature is acquired in both cylinders, and also causes the piston C C to effect external work or dynamic energy by reason of its withdrawal with the fluid pressure thereon.

2. The piston C C remaining stationary; the working fluid in the cylinder B is expanded and cooled by a partial withdrawal of the piston C; at a slow rate of speed so as to make efficient the accompanying transfer of heat through the diaphram A, from the fluid in the cylinder B B to the fluid in the cylinder B. This operation causes the fluid in the cylinder B B to lessen its pressure by reason of its loss of heat, while the fluid in the cylinder B effects work by reason of its expansion and pressure. The pistons have now acquired the positions shown in Figure 4.

3. With the piston C slowly continuing its course of withdrawal; the cylinder B B is contracted by forcing the piston C C towards the diaphram A, preferably at constant pressure. The pistons have now acquired the positions shown in Figure 5. This operation causes the fluid in the cylinder B to be further cooled and continue its production of work by reason of its expansion; while the fluid

in the cylinder B B is caused to contract by reason of the application of external work thereon, and loss of the heat transferred to the contents of the cylinder B.

4. With the cylinder B B contracted, and the piston C C remaining stationary, the cylinder B is contracted by slowly forcing its piston C back to its initial position. This operation causes the fluid in the cylinder B B to acquire temperature and pressure by reason of the compression of fluid in the cylinder B. The pistons have now acquired the positions shown in Figure 6.

5. The piston C remaining stationary, the fluid in the cylinder B B is removed in a transformed condition through the conduit E E, by opening the cock F F and forcing the piston C C to its initial position; the pistons have again acquired the positions shown in Figure 2; and the cycle is completed.

The relative extent of the successive operations which make up this single cycle can be regulated so as to produce any desired degree of change in potential condition. The degree of increase in total contained energy is dependent upon the degree of pressure under which the treated fluid is densified, and is an increasing function of this pressure.

A more controllable result can be attained by a cycle which consists in one or more repititions of such single cycle modified by retaining the fluid in the cylinder B B for the repeated treatment. The relative extent of the successive operations can be regulated to produce any desired change in potential condition, and any desired change in total contained energy.

This transforming engine posesses the following objectionable features.—1st. The process is not continuous. 2nd. The engine is not highly efficient, in a mechanical and constructive sense.

To overcome these objectionable features; I have invented the type of transforming engine herein shown by Figures 7[A] and 7[B], taken together as a whole. I prefer to operate this engine so as to effect a process or method of operation that is less generic than that hereinbefore mentioned, which definiteness consists in liquifying the fluid by abstracting heat or energy therefrom while maintaining it at a relatively low pressure, and transferring this heat to the thus liquified fluid while maintaining this liquified fluid at a greater pressure. With this particular apparatus; this process or method of operation is effected in the more specific manner having definiteness as regards the liquifaction of the fluid by abstracting heat or energy therefrom while maintaining it at a relatively low temperature and pressure by a regenerative action, and transferring this heat to the thus liquified fluid while maintaining this liquified fluid at a greater pressure.

Referring to Figures 7[A] and 7[B]. In order to clearly show the operation of this engine and the principles involved; in a conventional manner the apparatus is shown by these two figures, when they are taken together as a whole; certain conduits shown in one figure connect with and continue as the same conduit in the other figure, these conduits are respectively indicated by the same reference letter in each figure, and are the conduits Z, Y, X, and W; the direction which the fluid is caused to pass through the various conduits is indicated by conventional arrows. Figure 7[A] is a sectional-elevation and shows that portion of the apparatus where manipulations are effected as regards interchange of heat. Figure 7[B] is a plan and shows the dynamic mechanism. In a conventional manner, and where desirable, the conduits and engine cylinders are shown to be surrounded by suitable insulating material to prevent thermal inefficiencies by reason of external radiation.

In operation, preferably, the fluid to be treated or transformed is received in a gaseous condition by the conduit U and passes therethrough into the conduit Y which extends from the pressure reducing-valve V to the compression cylinder C1. This fluid enters the conduit Y, therein mixes with the current of fluid passing therethrough from the valve V, passes from this conduit into the compression cylinder C1, is compressed in this cylinder and delivered therefrom into the conduit Z and passes therethrough until the valve V is reached at the end of this conduit Z, by passing through this opened valve it again enters the conduit Y to again pass therethrough to the compressor C1. Through the conduit X, and as explained later, a portion of the fluid is withdrawn from this circuit.

A diaphram or siding capable of a ready conduction of heat therethrough is indicated by D, and separates the above mentioned conduits Y and Z. The above mentioned compression effected by the compression cylinder C 1 causes a changed condition to the fluid, as regards pressure and temperature; thereby the fluid pressure is increased and also the temperature of the fluid is increased.

The above mentioned passage of this fluid through the conduit Z, in this compressed and heated condition, causes an efficient regenerative interchange of heat through the diaphram D, with the colder fluid passing in an opposite direction in the adjoining conduit Y.

This regenerative interchange of heat effects a self-intensifying frigefactive effect, culminating at the valve V, and causing the fluid in the thus frigefied end of the conduit Z to condense to the liquid condition. By reason of gravitation, this frigefied liquid fluid collects in the trap or upturn at the bottom of the conduit Z, from whence it is forced through the upward turn of this trap until it reaches the valve V at the top of this upturn in the conduit. By passing from thence through the orifice or opened pressure reducing valve V, the culminating frigefaction is then effected by reason of the evaporation of this liquid due to its entry into the conduit Y wherein a lesser pressure is maintained by the combined action of the valve V and the compressor C 1.

Through the conduit X, a portion of the liquid fluid is withdrawn from the conduit Z. This withdrawn liquid passes through the conduit X and enters the pressure pump P 3 wherein it is put under pressure and ejected therefrom into and through the conduit W wherein this increased pressure is maintained. The conduit W is separated from the conduits Z and Y by the diaphram or siding F which is capable of a ready conduction of heat therethrough.

For a normal working of the apparatus; the weight of the liquid fluid thus withdrawn from the conduit Z and forced into the conduit W, is equal to the weight of gaseous fluid received into the apparatus through the conduit U. Through the diaphram F, there is an efficient interchange of heat between the frigefied liquid passing through the conduit W and the warmer and gaseous fluid passing under a lesser pressure and in an opposite direction through the adjoining conduit Z. Thus; the gaseous fluid to be treated or transformed is received into the apparatus, through the conduit U; is condensed to the liquid condition when it reaches the frigefactive end of the conduit Z; is kept in a liquid condition and under a greater pressure after passing through the pump P 3; and while under this pressure and passing through the conduit W along the diaphram F, it receives heat abstracted from the gaseous fluid in the adjoining conduit, thereby aiding the condensation in the conduit Z.

The circuit through the valve V is maintained for the purpose of producing the self-intensive frigefactive effect, and should be operated with sufficient flow, but with little difference in pressure through this valve; because the efficiency of a reducing valve or orifice for this purpose, in a thermo-dynamic sense, is affected by this difference in pressure and is a decreasing function thereof.

The counter shaft T is driven by any suitable source of dynamic energy. By means of suitable regulating devices such as the belted sprocket cones shown at R 1 and R 3, the counter shaft T actuates the compressor C 1 and the pressure pump P 3 by means of their respective crank shaft and piston shown at S 1 and S 3. These sprocket cones or an equivalent regulating device afford suitable means for regulating the relative flow through the compressor C 1 and the pressure pump P 3. The pressure reducing valve V is of the type used on self-intensive frigefactive apparatus, and can be readily adjusted to effect any desired change of pressure.

Thus is presented a description of a type of potential transforming engine that receives a continuous flow of gaseous fluid to be treated; ejects the same in a continuous flow, and in a changed potential condition in the same sense as hereinbefore mentioned and described in connection with the apparatus shown by Figure 1. Also, it may be remarked that with each of these devices it is desirable to densify the treated fluid at a degree of pressure that is below but somewhat near its critical-pressure.

Figures 8^A and 8^B, taken together as a whole, show a preferable manner of combining the type of potential transforming engine shown in Figures 7^A and 7^B, with an ordinary type of heat motor engine. In order to clearly show the operation of this combination and the principles involved; in a conventional manner the apparatus is shown by these two figures, when they are taken together as a whole; certain conduits shown in one figure connect with and continue as the same conduit in the other figure, these conduits are respectively indicated by the same reference letter in each figure, and are the conduits Z, Y, X, W, U, and L; the direction which the fluid is caused to pass through the various conduits is indicated by conventional arrows. Figure 8^A is a sectional elevation and shows that portion of the apparatus where manipulations are effected as regards interchange of heat. Figure 8^B is a plan and shows the dynamic mechanism. For the purpose of convenience, the various parts of the transforming engine, where shown in this combination, are respectively indicated by the same reference letters that are used in Figures 7^A and 7^B. In a conventional manner and where desirable, the conduits and engine cylinders are shown to be surrounded by suitable insulating material to prevent thermal inefficiencies by reason of external radiation.

The object of this combination is to effect an interception of the ejected low pressure fluid from the heat motor engine, transform the potential condition of this ejected fluid by passing same through the potential transforming engine, return this transformed and high pressured fluid to the heat motor engine, increase the total contained energy of this returned fluid by applying heat taken from available terrestrial atmosphere, pass this comparatively heated fluid through the working cylinder of the heat motor engine, and thus complete the cycle in accordance with the principles hereinbefore explained in the rationale of the matter as regards utilizing heat that is common to terrestrial matter for the purpose of transmuting same into dynamic energy.

In operation, the low pressure gaseous fluid is ejected from the working cylinder E 2 of the heat motor engine, it is also ejected from the working cylinders of the auxiliary motor engines E 1 and E 3 which are directly attached respectively to the compression cylinder C 1 and the pressure pump P 3 for the purpose of supplying the necessary dynamic energy to operate same. This ejected low pressure fluid is received in the conduit U and therefrom passes into and through the various conduits of the transforming engine in identically the same manner as was described for Figures 7^A and 7^B. The transformed and comparatively cold fluid, under high pressure, and preferably in liquid condition, passes from the conduit W into a continuation of this conduit shown at K which is separated from the conduit H by a diaphram or siding J capable of a ready conduction of heat therethrough. Through the conduit H; preferably; is forced a current of air taken directly from the atmosphere, or a current of water taken from some large body of same, by means of a suitable fan or circulating device which it is not necessary to show here and is purposely omitted in order to avoid prolixity. Through the diaphram J, the current of atmosphere passing through the conduit H effects an exchange of heat with the current of colder fluid passing in an opposite direction in the adjoining conduit K; thereby, the high pressured fluid is heated and expanded, or evaporated, at high pressure, and is forced through the continuation of this conduit shown at L. From thence, this high pressured gaseous fluid is withdrawn to operate the before mentioned motor cylinders E 1, E 2, and E 3. From these motor cylinders, this fluid is ejected at low pressure into the conduit U, and thus the cycle is completed.

In order to renew the working fluid lost by leakage, and to maintain a proper quantity of fluid in the conduit system, the pump P 4 forces a supply through the conduit N and from thence into the conduit W. The fluid is supplied to this pump in a liquified condition, and by means of the conduit M which leads from some suitable reservoir containing a supply thereof. It is desirable that this liquid shall be non-corrosive, cheap, readily obtained, and possess a critical-temperature and a critical-pressure that are conveniently low. Consequently, I prefer to use liquid air, or liquid carbon monoxide.

The current of atmosphere passing through the conduit H is the source from which heat is supplied for actuating this whole system of mechanism. If it were possible to construct the apparatus so that a perfect efficiency would be obtained from all of its parts; the heat that disappears or is abstracted from the current of atmosphere would represent the surplus of dynamic or mechanical energy developed by the whole apparatus; in other words, all of the heat taken from this current would be transmuted into dynamic energy available for any purpose. In a practical apparatus; the difference between the actual available dynamic energy and the heat abstracted from the current of atmosphere represents that portion of the abstracted heat that is not transmuted into dynamic energy but is dissipated; consequently, it is desirable that the various parts shall be constructed so as to effect the greatest possible degree of efficiency, particularly as regards fluid expansion and fluid compression. From the pulley O on the shaft of the motor engine E 2, all available dynamic energy can be taken by means of a belt or other suitable device and applied to any desired purpose. For the purpose of effecting a suitable regulation of the relative flow through the various conduits; the various pistons are connected one to the other by means of the counter shaft T and the several belted sprocket cones connecting this counter shaft with the crank shafts that operate with these pistons, and shown respectively at R, R 2, R 3, and R 4. For convenience in starting and stopping the apparatus; valves for stopping the supply of motive fluid from the conduit L to the engine cylinders E 1, E 2, and E 3, are shown respectively at L 1, L 2, and L 3; clutches for disconnecting the torsional action of the shaft T in regard to the several sets of sprocket cones are shown respectively at T 1, T 2, T 3, and T 4. In like manner the clutch T 5 disconnects the pulley R 5 which is used only when starting the apparatus, and as a means for then connecting some suitable steam engine or other convenient source of dynamic energy for the purpose of actuating the counter shaft and thereby actuate the mechanism of the apparatus until a normal working is effected; when the apparatus has acquired a normal working condition, this pulley is disconnected from the shaft T by this clutch T 5, the auxiliary starting engine is stopped, and the apparatus continues its action by reason of the self operating feature.

By utilizing the cooled current of atmosphere ejected from the conduit H, for frigefactive purposes, the apparatus becomes a self operating frigefactive engine.

In order to make clear the principles involved, in Figures 7^A^ and 8^A^ it was necessary to adopt a conventional manner of showing the conduit system. In practice it is desirable to adopt an annular spiral coil system.

Preferably; this coil system consists of a continuous series of flat spirals placed one over the other, separated into successive layers by horizontal partitions of non-conducting material; and between these horizontal partitions, a spiral partition of the same material is arranged to form a flat spiral conduit in each layer, so as to continue successively through the series of layers, and to conduct the current of low pressure fluid. In and along this insulated conduit containing the current of lower pressured fluid are placed conduits or pipes containing respectively the several higher pressured fluid currents, these pipes are made of material which is capable of a ready conduction of heat therethrough.

Figures 9 and 10 show a spiral coil constructed on this system. Figure 9 is a sectional plan, Figure 10 is a sectional elevation, and the same reference letters are used in both of these figures to indicate same parts. In the interior of the hermetically closed casing C the higher pressured fluid pipes or conduits 2 and 3 are contained in the insulated spiral conduit 1 and there surrounded by the current of lower pressured fluid contained in this conduit 1.

Thus, is presented a description of an operative and practical apparatus for effecting the purpose of my invention.

A self-intensifying heat engine is herein understood to be a heat engine in which the action of the cycle tends to intensify or extend the limit of the working range of temperatures, when interchange of heat with external sources is dispensed with. A regenerative action is herein understood to be an interchange of heat between fluid that precedes and fluid that follows in the same routine, or the abstraction and subsequent return of heat to and from the same fluid.

Also, it is understood that any operation herein mentioned in connection with my invention may be performed in any manner that is suitable and known. Also; my invention is not limited to the use of any particular material in the construction of the various parts; any particular working fluid; nor any particular type of engine or device for converting fluid pressure and expansion into dynamic energy, or for *vice-versa*, particularly as regards the application of fluid jets and turbines to such purposes. Also, the application of a multiplex method of combination, which consists in effecting the same cycle of operation by means of inter-dependent action between two or more apparatus, shall be considered as a mere equivalent of the simple single apparatus shown.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is:—

1. The art, which consists in combining things in the manner by which they are adapted as a means for converting into available energy heat that is common to terrestrial matter and manifested as temperature condition; all as a manner of new manufacture.

2. A heat engine adapted as a means for converting into available energy heat that is common to terrestrial matter and manifested as temperature condition, all as a manner of new manufacture.

3. A fluid pressure heat engine adapted as a means for converting into available energy heat that is common to terrestrial matter and manifested as temperature condition, all as a manner of new manufacture.

4. A fluid pressure regenerative heat engine adapted as a means for converting into available energy heat that is common to terrestrial matter and manifested as temperature condition, all as a manner of new manufacture.

5. A fluid pressure regenerative self-intensive heat engine adapted as a means for converting into available energy heat that is common to terrestrial matter and manifested as temperature condition, all as a manner of new manufacture.

6. In a fluid pressure heat engine; a motor engine in combination with an other engine, adapted as a means to receive ejected unconverted heat from the motor engine and return this unconverted heat to the motor engine's heat supply by the expenditure of less dynamic energy than is generated by the corresponding conversion of heat in the motor engine; all as a manner of new manufacture.

7. In a fluid pressure regenerative heat engine; a motor engine in combination with an other engine, adapted as a means to receive ejected unconverted heat from the motor engine and return this unconverted heat to the motor engine's heat supply by the expenditure of less dynamic energy than is generated by the corresponding conversion of heat in the motor engine; all as a manner of new manufacture.

8. In a fluid pressure regenerative self-intensive heat engine; a motor engine in combination with an other engine, adapted as a means to receive ejected unconverted heat from the motor engine and return this unconverted heat to the motor engine's heat supply by the expenditure of less dynamic energy than

is generated by the corresponding conversion of heat in the motor engine; all as a manner of new manufacture.

9. In the operation of a fluid pressure heat engine, the method of manipulating the working fluid; which consists in actuating such fluid through a range of temperatures and return through the range, in a manner to cause different portions of the fluid to progress through some identical temperature changes with corresponding rates of change in fluid pressure that differ; all as a manner of new manufacture.

10. In the operation of a fluid pressure heat engine, the method of manipulating the working fluid; which consists in actuating such fluid through a range of temperatures and return through the range, in a manner to cause different portions of the fluid to progress through some identical temperature changes with corresponding rates of change in fluid density that differ; all as a manner of new manufacture.

11. In the operation of a fluid pressure heat engine, the method of manipulating the working fluid: which consists in increasing its density by abstracting heat therefrom and externally applying force, returning said abstracted heat to the thus densified fluid held under increased pressure, and effecting this abstraction and return of heat by a regenerative action in which different portions of regenerative fluid are caused to progress through some identical temperature changes with corresponding rates of change in fluid pressure that differ; all as a manner of new manufacture.

12. In the operation of a fluid pressure heat engine, the method of manipulating the working fluid; which consists in increasing its density by abstracting heat therefrom and externally applying force, returning said abstracted heat to the thus densified fluid held under increased pressure, and effecting this abstraction and return of heat by a regenerative action in which different portions of regenerative fluid are caused to progress through some identical temperature changes with corresponding rates of change in fluid density that differ; all as a manner of new manufacture.

13. In the operation of a regenerative heat engine; the method substantially as herein shown and described for converting heat into dynamic energy or work; taken with respect to the features that are essential to effect the purpose of my invention, as said purpose is herein set forth; all as a manner of new manufacture.

14. A regenerative heat engine adapted substantially as herein shown and described for converting heat into dynamic energy or work; taken with respect to the features that are essential to effect the purpose of my invention, as said purpose is herein set forth; all as a manner of new manufacture.

Dated this 8th day of September 1900.

JACOB TRIPLER WAINWRIGHT.

Redhill: Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1900.

SHEET 1

Fig. 1.

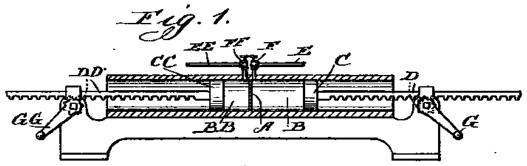


Fig. 2.

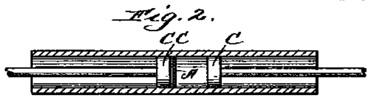


Fig. 3.

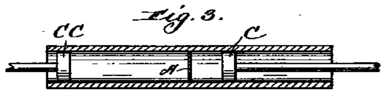


Fig. 4.

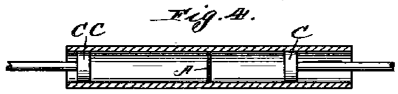


Fig. 5.

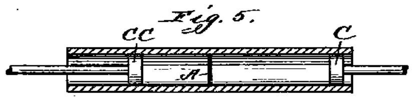
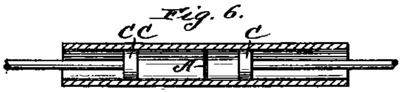
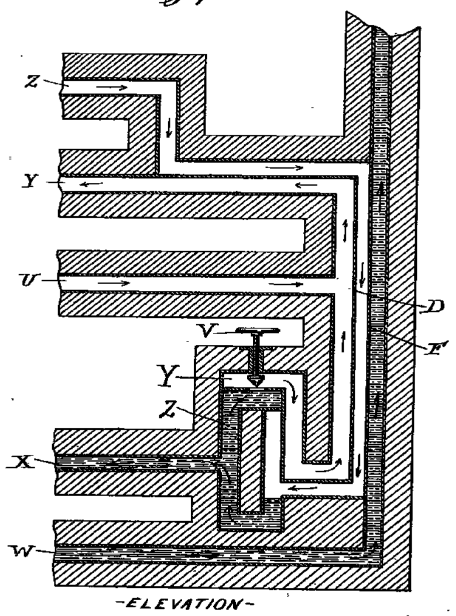


Fig. 6.



SHEET 2

Fig. 7.A.



-ELEVATION-

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Fig. 1.

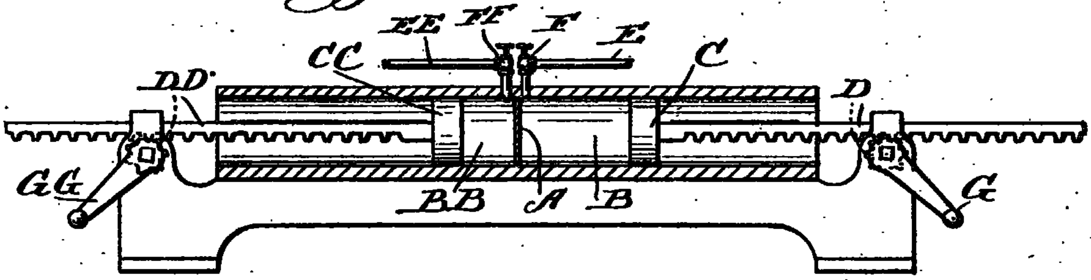

Fig. 2.

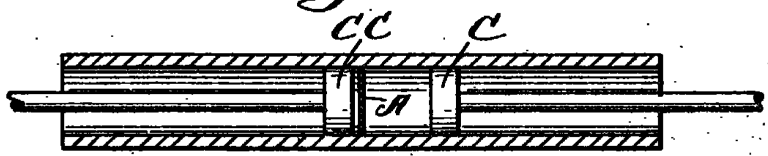

Fig. 3.

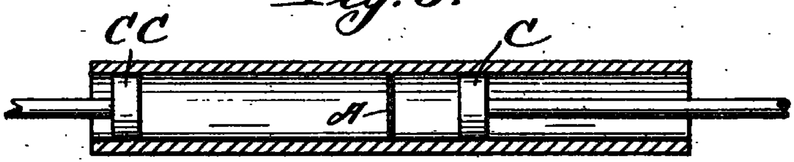

Fig. 4.

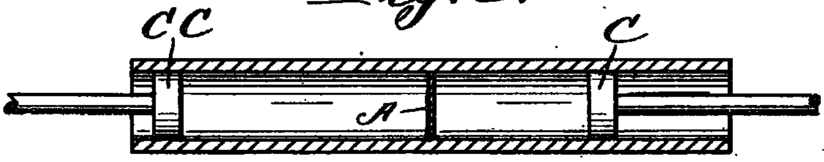

Fig. 5.

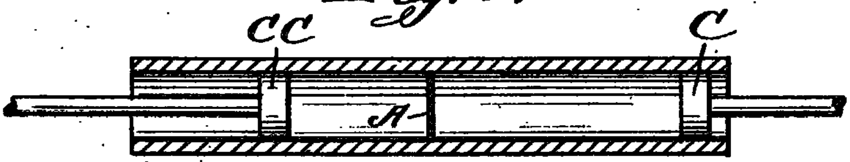

Fig. 6.

Fig. 7. A.

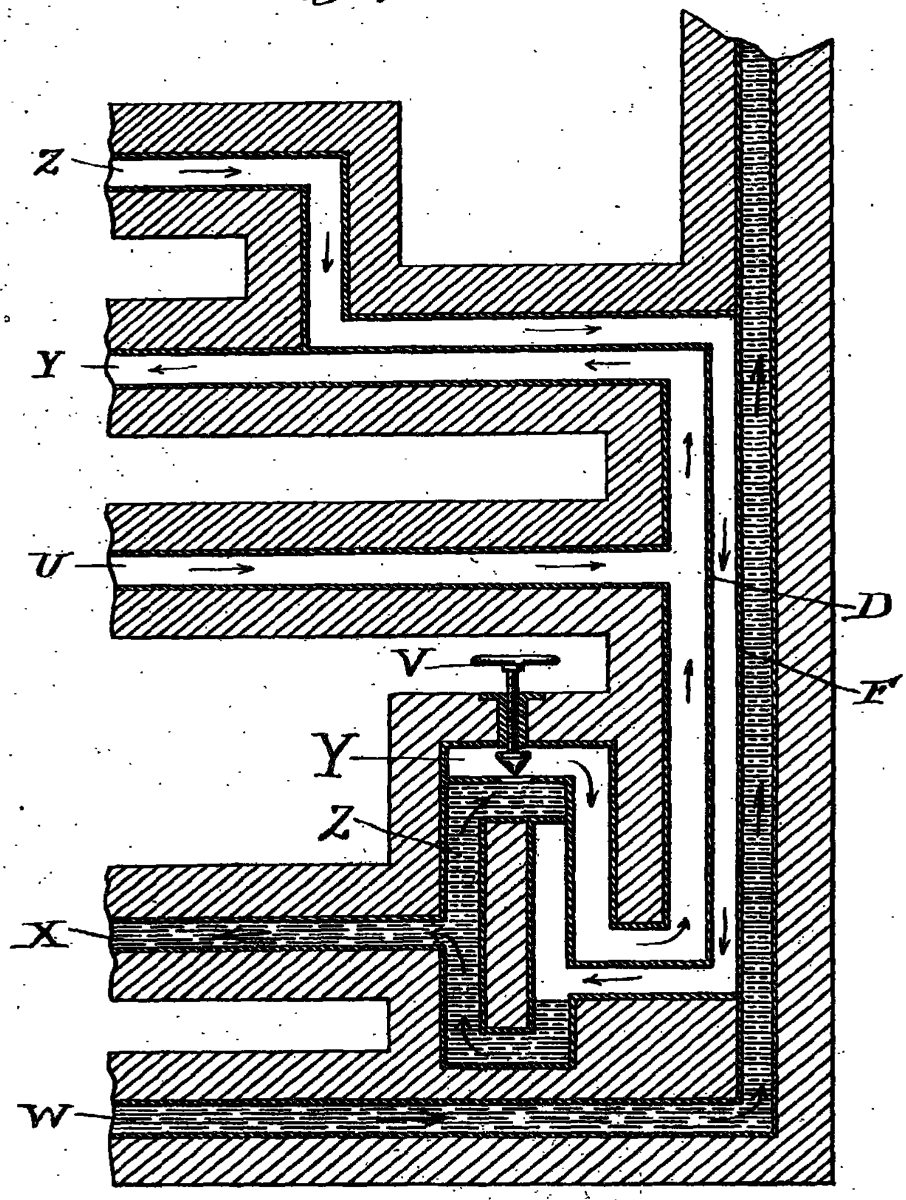

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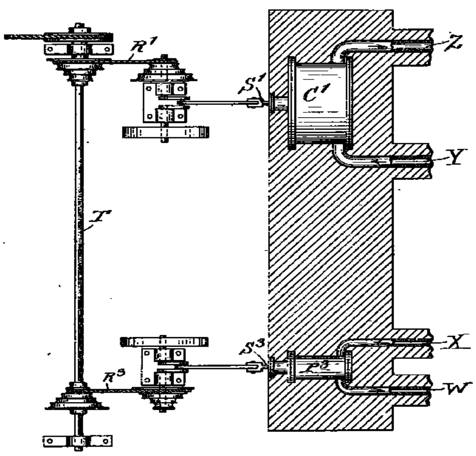
Fig. 7B.



- PLAN -

Fig. 8. A.

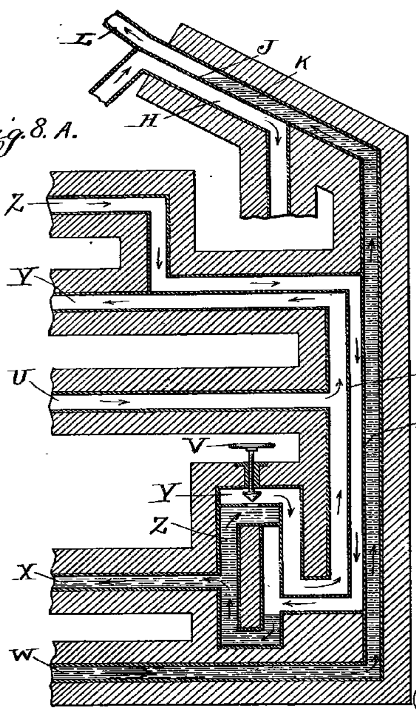


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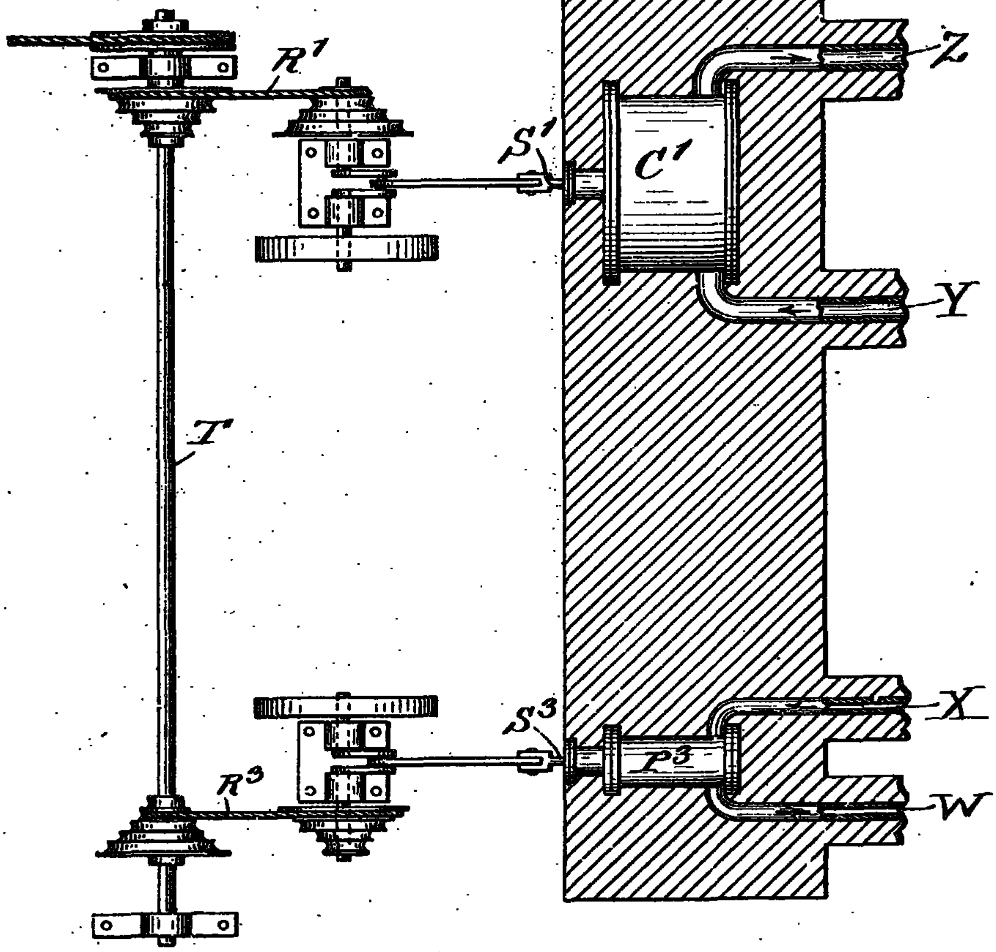
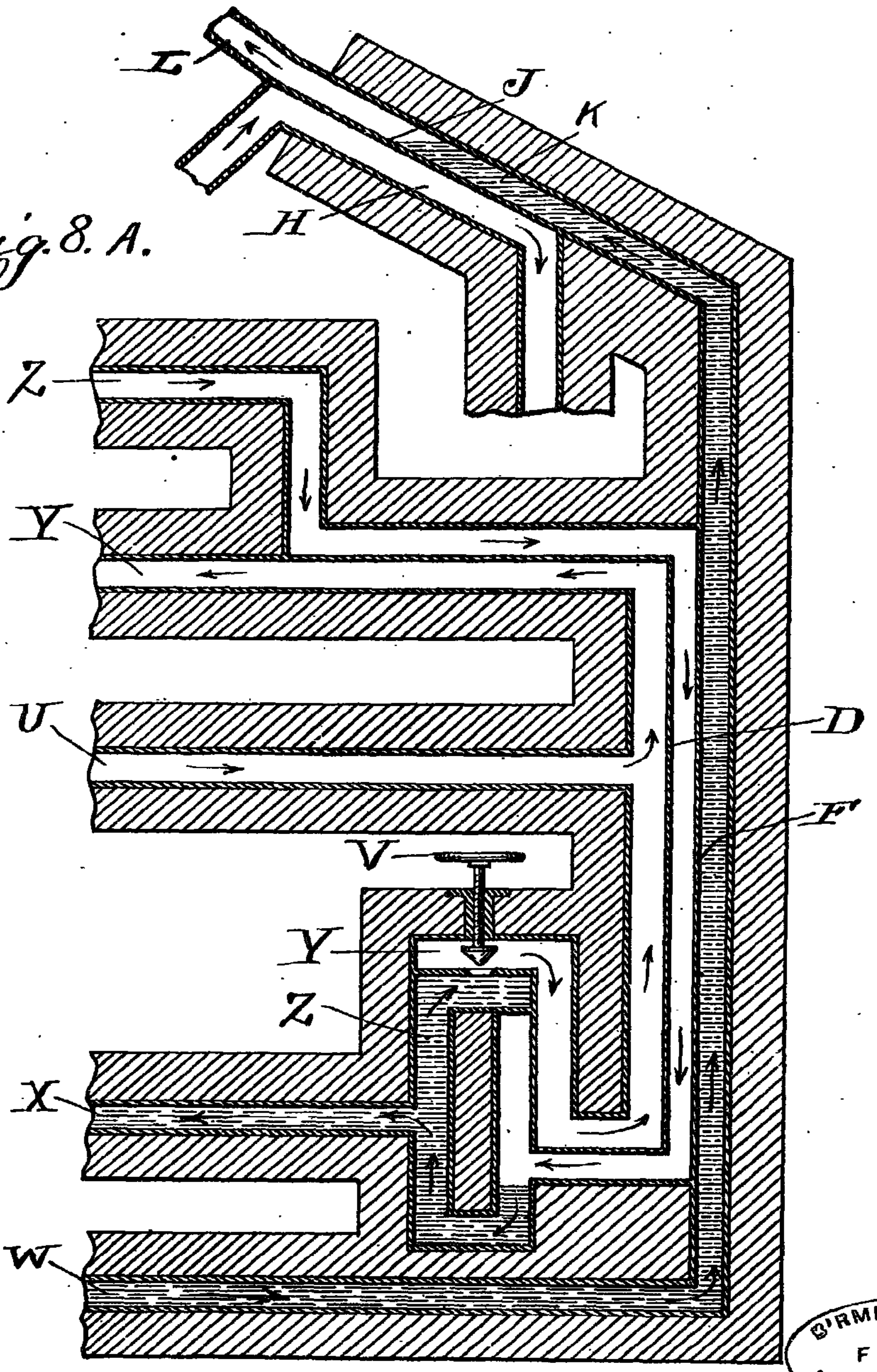
Fig. 7B.



-PLAN-

Fig. 8. A.



-ELEVATION-

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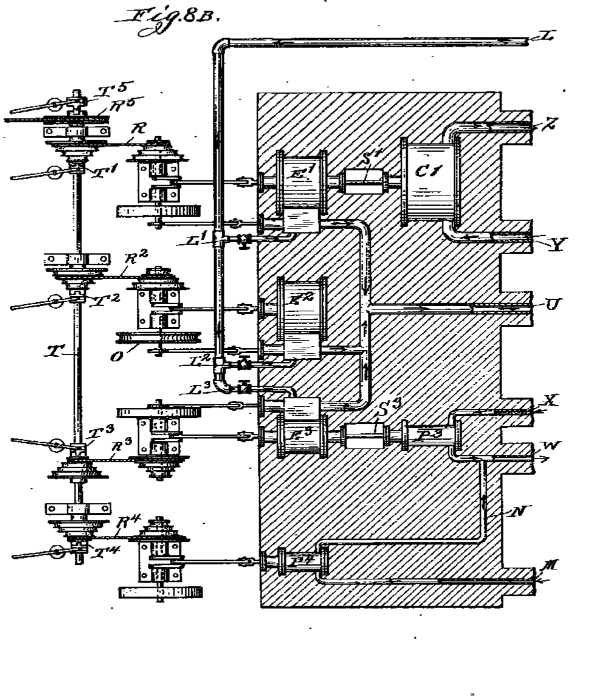
(6 SHEETS)

SHEET 5

Fig. 8B.



SHEET 6

Fig. 9.

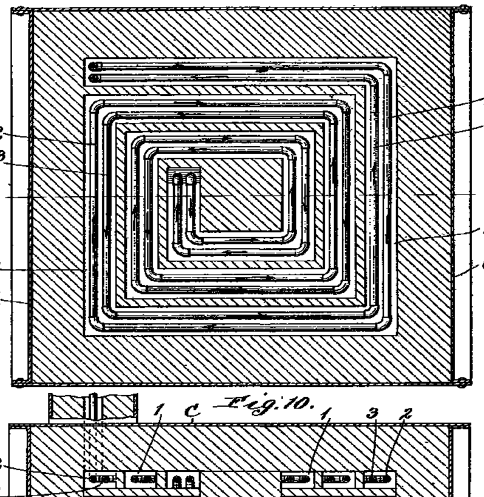
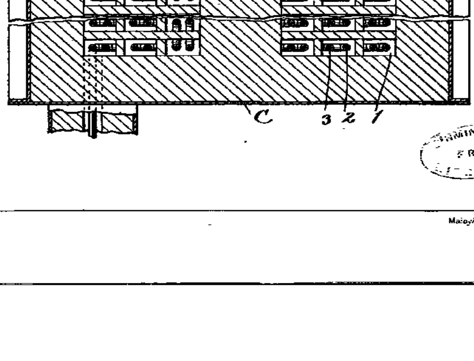


Fig. 10.



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SHEET

Fig. 8B.

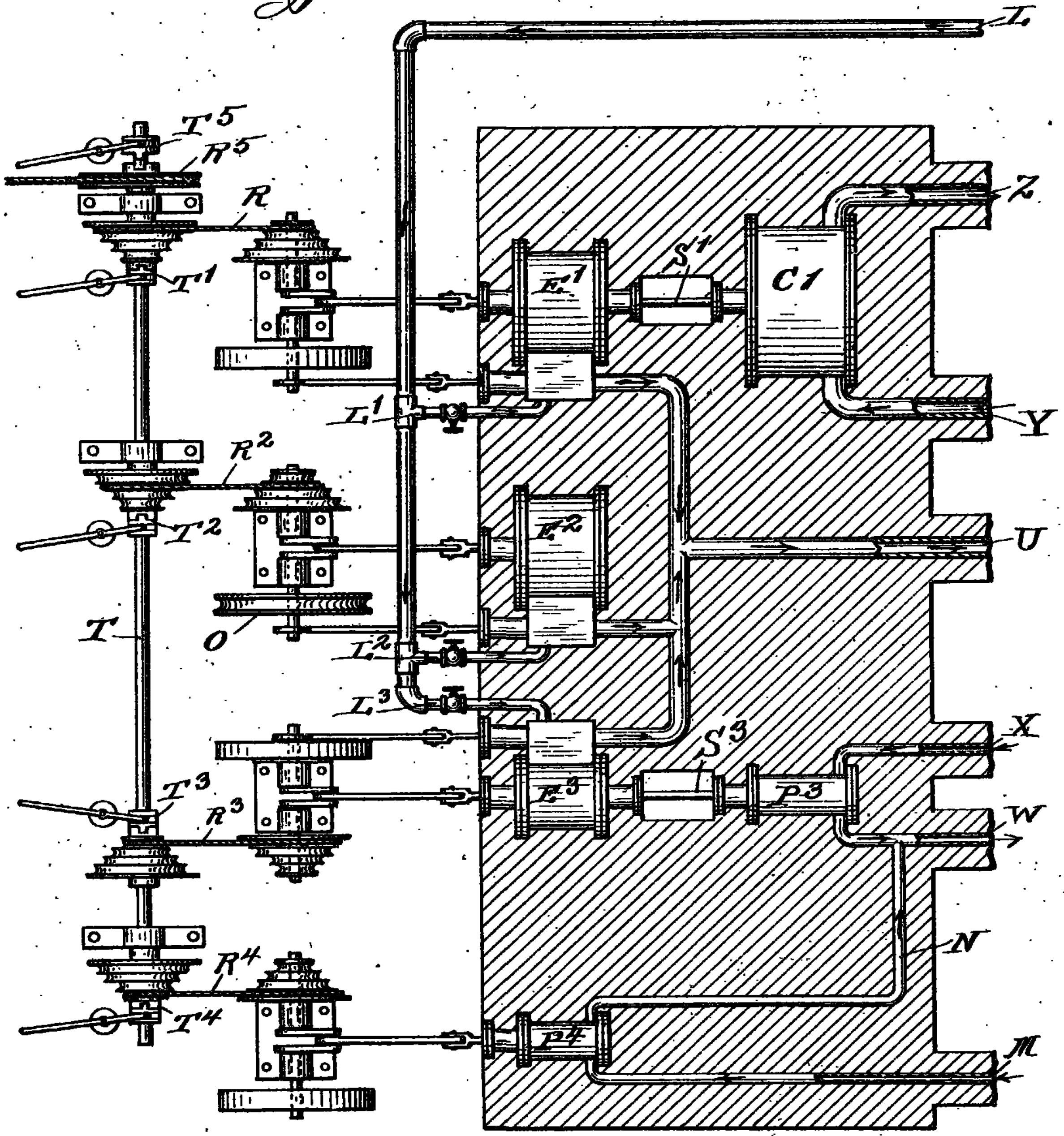

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Fig. 9.

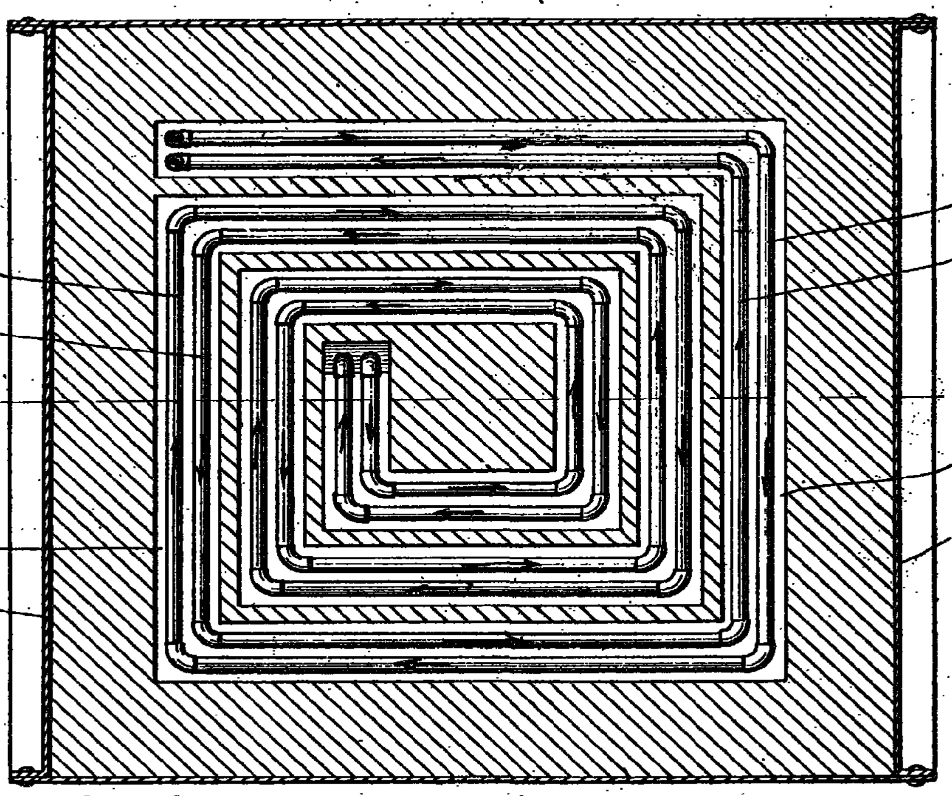
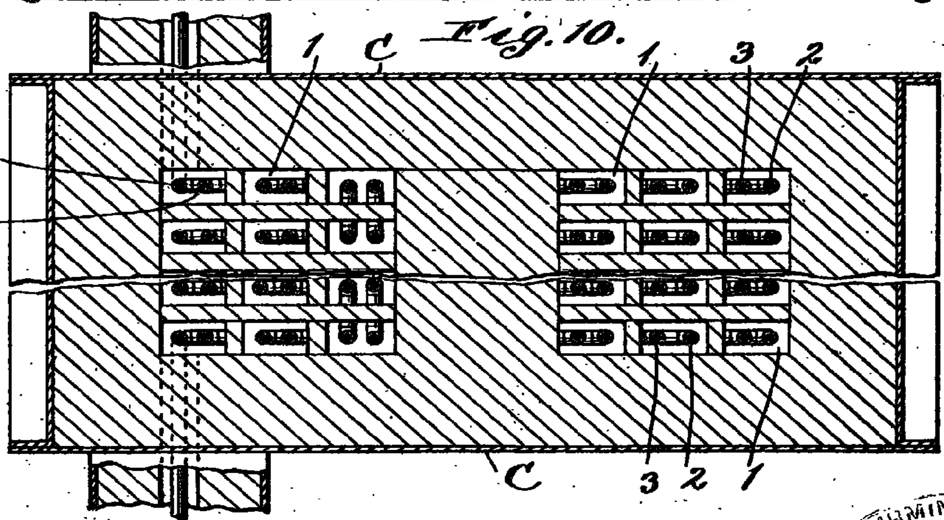


Fig. 10.



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