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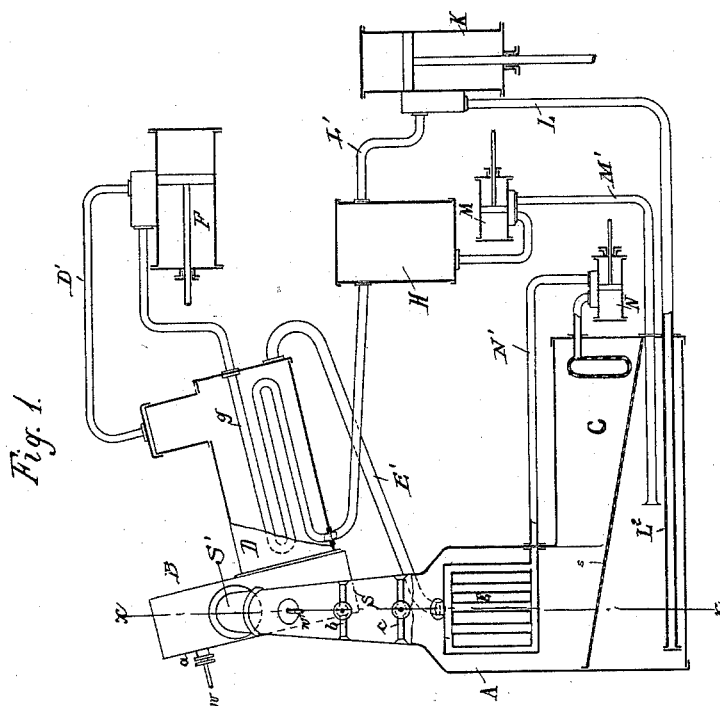
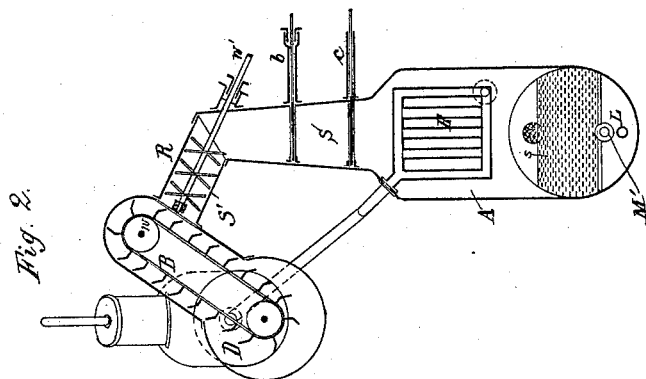
3 Sheets—Sheet 1.

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METHOD OF TRANSFORMING HEAT INTO MECHANICAL ENERGY.

No. 456,831.

Patented July 28, 1891.



Witnesses.  
C. Sedgwick  
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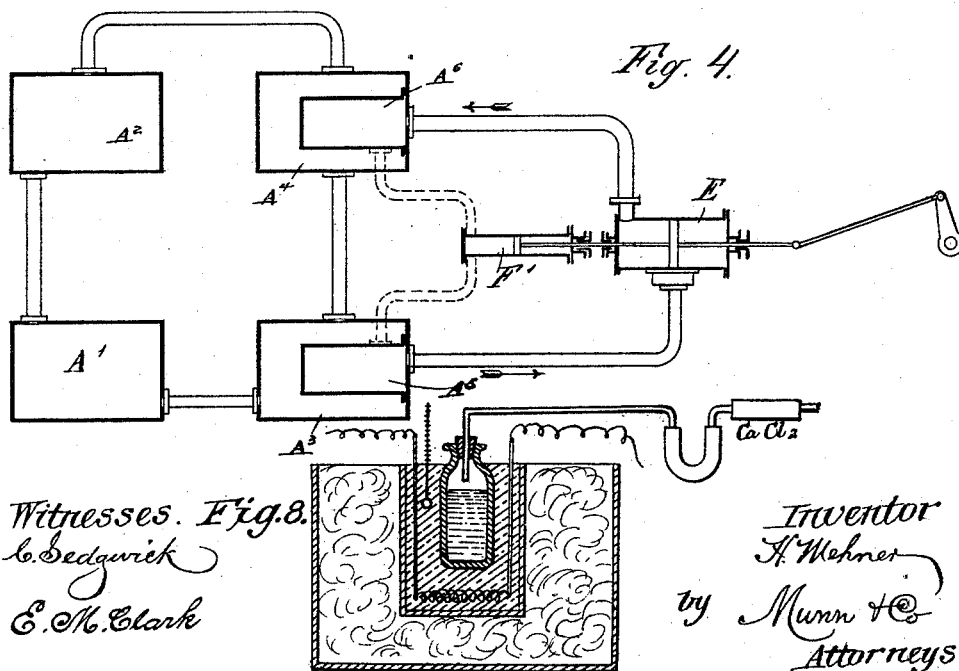
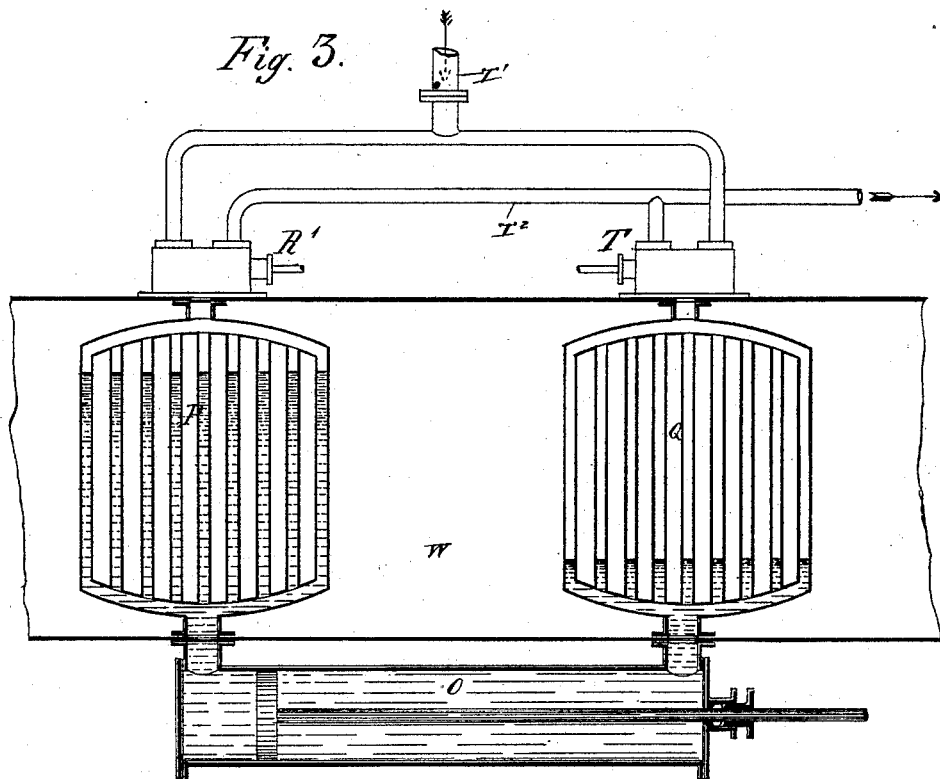
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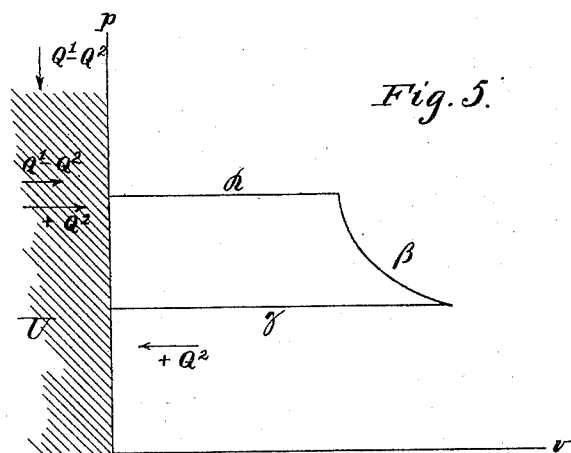


Fig. 5.

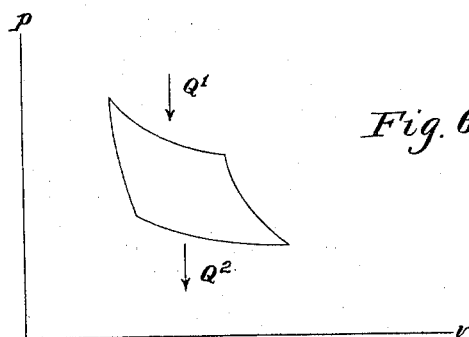


Fig. 6.

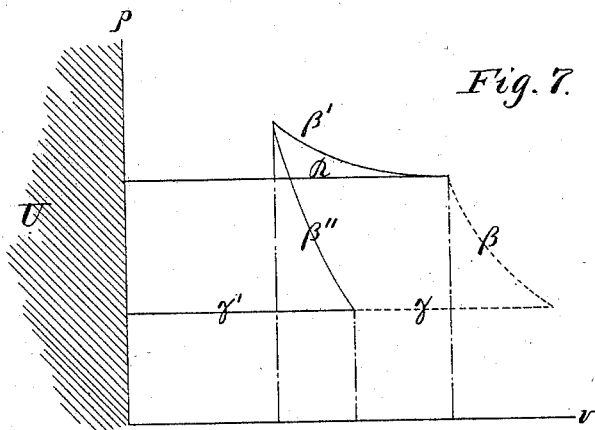


Fig. 7.

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# UNITED STATES PATENT OFFICE.

HERMANN MEHNER, OF HACKETTSTOWN, NEW JERSEY.

## METHOD OF TRANSFORMING HEAT INTO MECHANICAL ENERGY.

SPECIFICATION forming part of Letters Patent No. 456,831, dated July 28, 1891.

Application filed December 22, 1890. Serial No. 375,454. (No model.)

*To all whom it may concern:*

Be it known that I, HERMANN MEHNER, a subject of the Emperor of Germany, at present residing at Hackettstown, in the county of Warren and State of New Jersey, have invented a new and Improved Method of Transforming Heat into Mechanical Energy, of which the following is a full, clear, and exact description.

The invention relates to the dynamical theory of heat as expressed in the "Sadi Carnot engine" based on the thermo-dynamical cycle of operations by which a substance is finally brought to the same state in all respects as it had at the beginning.

The object of the invention is to provide a new and improved method for practically and economically transforming heat into mechanical energy without increase of entropy.

The method consists, principally, in changing the heat form of energy into the physico-chemical form, and vice versa.

In order to more fully explain the method, reference is to be had to the accompanying drawings, forming a part of this specification, in which similar letters of reference indicate corresponding parts in all the figures.

Figure 1 is a sectional side elevation of an apparatus for carrying out the method. Fig. 2 is a transverse section of the same on the lines  $xx$  of Fig. 1. Fig. 3 is a sectional side elevation of a modified form of compressor. Fig. 4 is a sectional side elevation of an apparatus for utilizing substances having a low expansive force for heating purposes. Fig. 5 is a diagram of my improvement. Fig. 6 is a diagram of the Carnot-Clausius theory. Fig. 7 is a diagram of a modified form of the improvement, and Fig. 8 is a sectional side elevation of an experimental apparatus for demonstrating parts of my method.

The method is carried out by the use of mixtures which bind heat, and are hereinafter called "freezing-mixtures."

Usually freezing-mixtures are produced by mingling any suitable solid substance in a solvent, usually water in fluid or solid state, but also with acids, alcohol, &c. I prefer for solvents the readily volatile fluids as facilitating the evaporation, and only make use of water in case common exhaust-steam from motors is to be condensed.

In order to demonstrate my process for the practical purpose of condensing exhaust-steam, I select as an example a mixture of water with saltpeter, more particularly as the characteristics of these two substances are very well known. First, I state that this common but not very effective freezing-mixture in my method of application becomes much better than it is ordinarily. This is owing to the fact that the binding of the heat in the process of condensing the steam can take place when changing the condition of a substance from solid to fluid at a temperature somewhat higher than the surroundings of the substance. By working at the common temperature of  $20^{\circ}$  to  $25^{\circ}$  Celsius a mixture of one kilogram of water with all the saltpeter that it can dissolve absorbs about twenty-six units of heat (kilogram calories) and at  $10^{\circ}$  Celsius more the amount is doubled. At about  $60^{\circ}$  Celsius the mixture binds about eighty units of heat at its boiling-point at a normal pressure in an open vessel. At  $113^{\circ}$  Celsius it absorbs more than two hundred units of heat, which is about one half of the latent heat of a kilogram of steam, and if the mixture is prepared with hot water and under pressure it is so effective that it absorbs as much heat as the kilogram of water it contains would consume if transformed to steam. This fact is the key of my invention.

For condensing waste steam in a suitable condenser I employ a cooling-mixture of saltpeter and water at from  $20^{\circ}$  to  $30^{\circ}$  Celsius above the boiling-point, the water being the waste steam, which is exhausted into the condenser and condenses in the saltpeter. One kilogram of steam in condensing yields about five hundred and twenty units of heat, and one kilogram of water of the condensation temperature mixed with saltpeter of the same temperature consumes the same amount of units of heat. Now by exhausting the hot steam into the hot salt a full condensation takes place without the help of any cool substance or body. As no heat is carried off, the entire amount is stored and locked up in the molten freezing-mixture. The latter is now transferred into a suitable boiler and transformed into steam at a somewhat higher temperature—say about twenty degrees more. In this manner steam of higher pressure is

made, and at the same time the saltpeter in a dry state is again obtained and also the absorbed heat. It will be understood that I heat with crystallizing-salt. The steam may now do its work, and its exhaust-steam is again condensed by the salt in the manner above described.

Heating by crystallizing-salts follows from the well-known process of cooling by dissolving-salts. In this connection it is stated that if work is needed or expended to separate molecules, as at present understood, it is given back (recovered) for bringing them together. If work is needed, for instance, to stretch a coil-spring, (separate the molecules,) it is gained for releasing it, bringing together the molecules. If work (heat) is needed to melt ice, it is gained in freezing it. The same is true in regard to the solution of salts. For illustration, a cylinder is selected containing in its bottom saltpeter or like solution and undissolved salt with steam above, the entire arrangement being in equilibrium—that is, the fluid being at a boiling-point. Now when the volume is decreased, the saltpeter dissolves by binding heat, (work separating-molecules,) the temperature not being changed. Now when the volume is increased, it appears to be reasonable to suppose that an exactly equal amount of heat (or work) will be given back in bringing the molecules together. If dissolving-salt and condensing-steam binds heat, it follows that if the conditions are reversed by a heat reaction, heat is liberated. The heat reaction is in quantity determined at the same temperature and changes only in quantity, not in quality, by raising the temperature previous to reversing the process,  $0.001^{\circ}$ ,  $0.01^{\circ}$ ,  $0.1^{\circ}$ ,  $1^{\circ}$ ,  $10^{\circ}$ ,  $20^{\circ}$  centigrade. It is the preservation of energy which produces the heating effect of the dissolving substance. An additional indication for the heat effect of the absorbed latent heat can be observed in the salt solutions prior to their crystallization. The specific heat of solutions, for example, of a saltpeter solution, is considerably lower than the specific heat of the salt plus that of the water. In derived solutions this specific heat is still less than the specific heat of the solvent itself, and in more concentrated solutions nearly equal to the last. This means that in order to raise an amount of saltpeter and water in combination to the boiling-point, it costs less heat than doing the same thing with the same amount of saltpeter and water separately. If the molecules are separated, a certain number of thermal units are not required, and can be spared to perform the work which is necessary for producing the temperature at which they come together. The full data for this can not at present be given, but attention is called to the advantage derived from the fact that the steam developed is not only saturated but superheated, as is well-known, notwithstanding the fact that less heat was given to the solution than the water should have required.

The heating effect of a desiccating freezing-mixture can be readily demonstrated in the following manner and by the use of an apparatus such as illustrated in Fig. 8: Between two large concentrically arranged jars is arranged a layer of cotton, and the inner smaller jar contains in its bottom a coil of German silver wire and is filled with paraffine. Through the coil of wire an electric current is passed and measured as to its energy (heat) developed inside of the inner jar, according to the usual methods. In the paraffine is held a thermometer and a small bottle fitted with a stopper and a glass tube. First, the bottle is left empty and the paraffine is heated to a suitable temperature, which is kept constant during each following measuring period. A suitable temperature is from about  $130^{\circ}$  to  $140^{\circ}$  centigrade. Further, the volt-ampères equivalent to the loss or radiated heat are noted. The small bottle is then filled with water and the electric current is regulated to bring the water to a boiling-point, while the thermometer in the paraffine shows a constant degree. After this the bottle is closed by a stopper carrying a pipe in order to condense the steam in the U-pipe and  $\text{C}^{\text{a}}\text{Cl}_2$  tube. The same experiment is repeated with a concentrated solution of saltpeter in the small bottle. Only about one-half of the amount of heat is required to form one gram of steam that is necessary to produce the same amount of steam from pure water. As by this method solid saltpeter salt is produced in the boiler it must be removed from the latter and carried back to the condenser to be again dissolved by the incoming exhaust-steam. This moving of the saltpeter can be carried out from time to time by hand or continually by mechanical means.

Owing to the great latent heat of the exhaust-steam, much salt has to be used in each operation of the process, and on account of the high temperature of the steam the loss of heat by radiation is considerable. If, however, ether is the solvent, then the latent heat of its vapor is only one-fifth of that of steam, and the ordinary boiling-point is  $35^{\circ}$  Celsius.

The physical constants for alcohols, aldehydes, benzol, naphtha, &c., are similar to those of the ether. All such fluids produce freezing-mixtures when dissolving the solid substances therein. For example, the ethyl ether mixed with crystallized acetic acid at  $15^{\circ}$  Celsius gives a fluid having a temperature lower by about  $20^{\circ}$  Celsius. When a freezing of such volatile substances is applied for condensing the vapors which have worked in a motor, then the favorable qualities of these substances render the mechanical motive power very cheap, provided the vapors are produced from volatile solutions, as demonstrated in the example of the saltpeter.

By the use of the most volatile solutions another result is obtained with the freezing-mixture—that is, the cooling of bodies below

the ordinary temperature of the surroundings or the production of ice.

If the solution of acetic acid in ethyl ether, mentioned above, undergoes my process of reproducing freezing-mixtures no pressure of practical value in evaporating is obtainable, because this ether has no remarkable expansive force below the melting-point of acetic acid. The motoric effect of this solution is therefore quite unimportant; but on the other side it is valuable with respect to the production of ice. As this appears not to differ from the ordinary use of cooling-mixtures, I point out more particularly the manner in which the cold is produced. My method does not use the cold arising during the formation of the cooling-mixture by the dissolving of a solid body, but the cold resulting from the decomposition of the mixture by evaporation. The principal amount of heat furnished for the formation of the vapor is derived from the crystallization, as shown in the example of the saltpeter, and only a relatively small amount dependent on the entire amount of heat (Zeuner's Gesamtwärme) of the vapor must be furnished from the outside, and if this small amount is taken from water, the temperature of which is nearly at the freezing-point, then a certain quantity of ice is produced. An apparatus which condenses vapor of ethyl ether by dissolving a solid substance and afterward reproduces the solid substances and the vapor by evaporating the solution at little below the freezing-point and deriving the necessary heat from freezing water is an ice-machine based on different principles from those now in use.

This machine, run with ethylic ether and based on excellent principles, has advantages resulting from the reproduction of freezing-mixtures, but also has the practical inconveniences of the old ethylic-ether ice-machine, on account of the large volume of gas encountered. This last mentioned use of freezing-mixtures, in connection with the first one described, produces a practical motive power, in case fluids are used which are more volatile than ethylic-ether solutions. The solution of the acetic acid in methylic ether, which boils at common pressure at  $23^{\circ}$  Celsius below zero, produces in evaporating a much higher pressure than the ethylic-ether solution, or solutions or combinations with ammonia, dioxide of carbon, (the so-called "fluid carbonic acid,") and other combinations of coercible gases having their boiling-point far below zero, are most effective in their motive power when evaporating below the ordinary temperature of the atmosphere.

There are combinations of ammonia-salts with ammonia-gas, like  $\text{NH}_4\text{Cl} + 3\text{NH}_3$  and  $\text{NH}_4\text{Cl} + 6\text{NH}_3$ ,  $\text{HBr} + 2\text{NH}_3$ ,  $\text{HBr} + 4\text{NH}_3$ ,  $\text{HBr} + 7\text{NH}_3$ , &c. The combination  $\text{HBr} + 7\text{NH}_3$  cannot exist in an open vessel at a temperature above  $-20^{\circ}$  Celsius, because it dissociates. Hence it is necessary to keep it in existence to subject it to a pressure of ammo-

nia-gas of somewhat more than one atmosphere at  $-20^{\circ}$  Celsius or to two atmospheres at  $-6^{\circ}$  Celsius or to about three atmospheres at  $5^{\circ}$  Celsius. At this temperature and at a pressure of one atmosphere the substance  $\text{HBr} + 4\text{NH}_3$  is a solid body. If this fluid substance is permitted to expand, it dissociates, at the same time producing ammonia-gas having a constant pressure of three atmospheres. This process continues until all is changed into the solid substance represented by the formula  $\text{HBr} + 4\text{NH}_3$ . In this process heat is used for the decomposition and the evaporation, and heat is produced by the solidification. The solid body  $\text{HBr} + 4\text{NH}_3$  at a temperature of  $-20^{\circ}$  Celsius has a pressure of about one-fourth atmosphere, and if placed in a vessel into which ammonia-gas of a little more than one atmosphere pressure is discharged, it becomes a fluid substance at the temperature mentioned. This fluid can dissolve a certain amount of the solid substance containing a lesser amount of ammonia. In this process heat is produced by the combination and the condensation, and heat is consumed or used by the liquefaction. Therefore if less ammonia is condensed, so that the heat of condensation and combination is less than the negatively-acting heat of liquefaction, then any one of these ammonia-salts can be used for producing a freezing-mixture which can be used in my method for condensing the exhaust-vapors of an ammonia-gas motor similar to the condensation of exhaust-steam by the saltpeter solution, but with the advantages pointed out above and derived from the low temperature of evaporation. A very important further advantage is that the freezing-mixture can be again used for ordinary cooling purposes at the evaporation temperature. A machine actuated in accordance with this process produces cold and power at the same time by simply changing heat into mechanical work. Like these ammonia freezing-mixtures, mixtures can be formed by other coercible gases and utilized and regained by my method, producing at the same time a reduction or lowering of temperature and mechanical work. It is well known that muriatic acid when employed for decomposing sulphate of sodium produces a fluid of a very low temperature. By heating this fluid to a high temperature the liberated or freed sulphuric acid expels the muriatic acid, as is now commonly done on a large scale in soda-factories, and the sulphate of sodium is again reproduced. Similar chemical reactions in either direction take place, according to the temperature, with weak acids. For instance, carbonic acid decomposes acetates, borates, &c., and even chlorides to a certain extent at a low temperature. These are salts the acids of which expel carbonic acid at a common and a high temperature, as is very well known. In case salts are used which liquefy in decomposing—as, for instance, salts containing crystal water, crystal alcohol, &c.—a freezing-mixture in

carbonic acid is obtained, which mixture gives a good practicable expansive force at the common temperature, and is therefore well adapted for condensing the exhaust vapor of carbonic-acid motors and for freezing purposes.

My process above described is capable of a modification that is most important and enlarges considerably the field of its practical use.

It will be understood from the foregoing that by using a freezing-mixture of saltpeter at the right temperature no cold water is required for condensing the exhaust or waste steam of an engine. The reason for this is that the disappearing latent heat of the liquefaction of the salt is at least equal to the appearing latent heat of the condensation of the steam. If such an equalized condition exists, then the condensing of the exhaust or waste vapor of any motor by a suitable freezing-mixture is possible and entirely independent of the temperature, which may be far below that of the surroundings; but even if the conditions are not quantitatively equal, but only partly, my process of applying freezing-mixtures is, notwithstanding, of a great advantage particularly in condensing steam and in general in all condensations which take place above the lowest temperature of the surroundings. The exhaust of other gas-motors at a still lower temperature can also be condensed, but only with the assistance of such means as are necessary to carry off that part of the latent heat of the vapor which the freezing-mixture does not absorb. If, for instance, one kilogram of a vapor needs four kilograms of a solid substance for neutralizing all latent heat in the solution and at the condensing-temperature the fluid generated by the vapor cannot dissolve more than one kilogram of the solid substance, then it is only necessary to produce in the boiler belonging to the motor four kilograms of vapor to separate in the manner described four kilograms of solid substance; but not all the vapor produced in the motor is permitted to work, but is compressed separately from the solution. Three kilograms of fluid are thus produced, and the other or remaining one kilogram of vapor passes into the motor to perform work. After that the four kilograms of solid substance, the three kilograms of fluid, and the one kilogram of vapor are mixed to form a freezing-mixture, which is sufficiently effective to take up all the latent heat of the vapor. The compressing of the vapor is performed as near to the temperature of the evaporation as possible, or at a lower temperature.

It is further to be understood that the reverse conditions may take place—namely, that the cooling-mixtures can absorb more heat than the latent heat of the vapor can introduce—so that a second motor can be actuated, which, for instance, is charged with carbonic acid, ( $\text{CO}_2$ ). The mechanical arrangement of such an engine is hereinafter more fully described.

Before more fully describing the various features and actions of the apparatus, I will first describe another feature of my method for using and regenerating freezing-mixtures. After the solid salt or a mixture of salts has been produced in the boiler it is brought back into the condenser, as above described. This salt or mixture of salts when entering the condenser has a considerably higher temperature than the freezing-mixture, and consequently carries a noxious heat into that mixture. In order to prevent this the salt or mixture of salts is previously cooled, and for this purpose the freezing-mixture already used and which goes to the boiler, after the principle of the counter-current cooler is employed, or a larger quantity of solid substance is used than is theoretically needed, or both methods may be employed at the same time. The apparatus for carrying out the method will now be described.

The accompanying drawings show only a diagram of the apparatus, the shape and whole arrangement of which may be modified in many respects to carry out the above-described method.

The motor K, in the form of an ordinary steam-engine, is connected by its steam-inlet pipe L' with the reservoir II and by its exhaust-pipe L with the condenser C, in which is arranged a transversely-extending sieve s, located above the perforated end L<sup>2</sup> of the pipe L. A suction-pump N is connected with the front end of the condenser C, above the lower end of the sieve s, and the said pump discharges into the pipe N', leading to a coil of pipes E, placed in the heater A, extending upward on the rear end of the condenser C. The coil of pipes E connects by the pipe E' with the upper end of the inclined boiler or generator D. The steam-dome of the boiler D connects with an inlet-pipe D', leading to a compressor F, in which the superheated steam from the boiler D is compressed, and then passes into the pipe g, which extends in the form of a coil in the boiler to finally pass out of the same to the reservoir H, from which the steam passes into the engine K to do its work. From the bottom of the reservoir H extends a pipe leading to a feed-pump M, which pumps the fluid for the freezing-mixture through pipe M' into the condenser below the sieve s. The pump M runs automatically, and can be used to only partly fill, when permitted to do so, by a suitable valve arrangement, for the purpose of cooling the fluid by expansion.

The heater A extends upward and connects at its upper end with a feed-pipe S, containing two horizontal valves b and c, through which the reproduced salt is charged back into the heater A and condenser C. The feed-pipe S is connected by a slightly-inclined pipe S', containing an agitator R, with the upper end of an elevator of any approved construction and inclosed in a casing connected with the lower end of the inclined

boiler D. The elevator is driven by a shaft *w*, extending through a suitable stuffing-box to the outside of the casing. The agitator R, previously mentioned, is provided with a shaft *w'*, carrying arms and also extending through stuffing-boxes to the outside. Both shafts *w* and *w'* are driven by suitable connections with the engine K or other devices. The salt or solid substance employed is discharged onto the sieve *s* in the condenser C, and there absorbs the exhaust-steam from the engine K and discharged into the condenser below the sieve and through the perforated end of pipe L.

The feed-pump N sucks up the fluid solvent in the condenser C and forces the liquid through pipe N' into the coil of pipes E in the heater A. In these pipes E the fluid freezing-mixture rises slowly and in the upper part of the said pipes reaches a boiling-temperature in case the salt has been sufficiently dried (in pipe S') to a temperature above the boiling-temperature of the solvent and at the time the salt passed onto the sieve and took up the steam. The liquid then passes through pipe E' into the boiler or generator D, which is heated so that the salt separates from the solvent and the latter appears in the state of vapor, (or steam,) and this vapor or steam passes through pipe D' to the compressor F.

It is understood that by the desiccation of the liquid in the boiler D heat is taken up from the outside so that the steam receives a higher pressure for working purposes. This exteriorly taken up heat is not very large and is only a part of the entire amount of heat for evaporation, the remaining or larger part of the heat being in the apparatus itself and becomes active by the solidification of the salt. The salt slides down to the lower end of the boiler D, is taken up by the elevator B, the buckets of which discharge the salt into the pipe S', in which the salt is agitated to dry as much as possible. The salt then passes onto the upper closed valve *b* and when a sufficient quantity has accumulated the valve *b* is opened to discharge the salt on the second valve *c*. The valve *b* is then again closed and the valve *c* is opened to discharge the salt into the heater A, onto the coil of pipes E, from which it finally passes onto the sieve *s* to take up the incoming exhaust-steam, as previously described.

The steam in the boiler D can be utilized in the usual manner, if desired. Often, however, in the cases when the insufficient solubility of the used solid substance requires an amount of liquid solvent outside of the exhaust vapor, then the superheated steam is passed to the compressor F, and is compressed therein, and then forced into pipe *g*, part of which is coiled and extends through the boiler D. In this part or coil of the pipe *g* in the boiler D, a part of the compressed steam is condensed into a fluid, giving off part of its freed heat to the boiler—that is, to

the fluid or liquid entering the boiler through the pipe E'.

The steam is condensed within the boiler D, as the condensation is preferably performed at as low a temperature as possible, and, also, as by the use of very volatile fluids the boiler has the lowest temperature of any part of the apparatus which would be used for this purpose. Furthermore, the coil part of the pipe *g* represents an economical steam-heater for fluids which boil above the mean temperature of the atmosphere.

In case the freezing-mixture to be evaporated contains a larger proportion of solid matter than fluid, then it is liable to change into a plastic or pasty state, which may operate injuriously in the boiler D. In order to prevent this, the boiler and elevator are entirely dispensed with, and a number of pipes, like pipe S', are employed, into the upper end of which the fluid is regularly injected in well-measured quantities. The same arrangement is used for liquids which have a higher dissolving power for the solid substance at the temperature of the boiler than at the temperature of the condenser.

If the boiler is dispensed with, then instead of using the coil *g* the tubes S' are preferred for producing liquid solvent, and for this purpose are provided partly with double walls and covered with a non-conducting material. The vapors to be condensed are passed through the space formed between the double walls.

From the foregoing it will be understood that the compression of the vapors in the cylinder F and the coil part of pipe *g* is only a practical arrangement for a complete theoretical process, and can only be used economically in case the steam is only sufficiently overheated, so that it enters at a slight compression into a saturated state. Each further reduction of the volume causes a precipitation in pipe *g*. Vapors can also be treated, such as carbon dioxide, in case it has a small expansive force and a temperature far above the boiling-point of fluid carbonic acid of the same pressure. In treating such substances a considerable increase in temperature in the cylinder F would take place, so as to prevent the successful operation of the apparatus. In order to obviate this the method and apparatus is somewhat modified in the manner presently to be described, reference being had to the typical apparatus shown in Fig 3.

In case of insufficient solubility of the substance, as mentioned above, it is necessary to reconstitute or impart to the evaporating fluid an amount of heat, which corresponds to the heat not absorbed by the solid substance in the dissolving process which takes place in the condenser. It is, however, not necessary to form a fluid solvent.

The cylinder O corresponds in size to the cylinder F, and is connected at its ends with the pipes P and Q, placed in a tank or vessel



W, containing a cooling-liquid, preferably the salt solution to be condensed. The upper ends of the pipes P and Q are connected by steam-chests R' and T, respectively, with an inlet-pipe T', leading from the cylinder F, and with an outlet-pipe T<sup>2</sup>, leading to the reservoir H. The cylinder O and parts of the pipes P and Q are filled with an indifferent liquid, such as mercury, paraffine, &c. The piston in the cylinder O moves in time with the piston in the cylinder F, and thereby alternately fills and empties the pipes P and Q with the indifferent liquid. The valves in the steam-chests R' and T permit the steam entering through pipe T' to pass alternately into that pipe P and Q, which empties on the return-stroke of the piston in the cylinder O. The steam thus admitted in the respective pipe P or Q is compressed on the forward stroke of the piston in cylinder O, the indifferent liquid being the piston. When the steam is sufficiently compressed before the piston is on the end of its stroke, the valve in the respective steam-chest R' or T establishes communication with the pipe T<sup>2</sup>, so that the compressed steam passes to the reservoir H, and from there to the motor K, the liquid being pumped by pump M back to the condenser C, as previously described.

In case the boiler D is omitted for the reasons above mentioned, then the liquid in cylinder O is passed into casings surrounding the pipes P and Q, and through the latter is passed a liquid which takes up heat, preferably the cold solution contained in the condenser C. With this modified form it is possible to obtain economical results with solutions which require compressing of the produced steam or vapor. It will be understood from the foregoing that I do not limit myself to the use of the particular substances mentioned.

By the above explanations, which also furnish a few typical examples of the new method for using and recovering freezing-mixtures, it has been proved that the quantity of heat which is now lost in operating motors can be economically utilized by an endothermo chemical reaction. In order to return this heat to the cycle of operations of the motor it is only necessary to proceed in reverse order as regards the said reactions.

In what manner the reversing of the physico-chemical reaction is to take place has been previously described and explained in connection with the freezing-mixtures—that is, the utilization for motoric purposes of vapors having a high expansive force and produced by certain chemical reactions.

In cases in which the expansive force of the vapor is not sufficient for motoric purposes, then the said vapors can be utilized for heating purposes. In order to accomplish this in an economical manner slight modifications (presently to be described) in the construction of the apparatus and the method are necessary, reference being had to Fig. 4.

Of the four connected receptacles A', A<sup>2</sup>, A<sup>3</sup>, and A<sup>4</sup>, the receptacles A' and A<sup>3</sup> have a higher temperature than the two receptacles A<sup>2</sup> and A<sup>4</sup>. In the receptacle A' say a solution is decomposed at 0° Celsius, so as to produce vapors of a low tension—say three-fourths atmosphere. These vapors are passed into receptacle A<sup>3</sup> to condense therein, thereby giving off their entire latent heat. In this receptacle A<sup>3</sup> is inclosed a second receptacle A<sup>5</sup>, in which, for example, fluid carbonic acid is evaporated. The carbonic-acid vapors pass from this receptacle A<sup>5</sup> into the working-cylinder E with a working pressure of about thirty-five atmospheres to actuate the piston therein. The thus utilized vapors condense at about -30° Celsius in the condensing-receptacle A<sup>6</sup>, located within the receptacle A<sup>4</sup>, for the reason that the latter receives the condensing-fluid from the receptacle A<sup>3</sup> and permits it to evaporate at a pressure of one-half atmosphere. The feed-pump F' returns the carbonic acid back to the receptacle A<sup>5</sup>, while the vapor passing from receptacle A<sup>4</sup> to the receptacle A<sup>2</sup> is condensed in the latter with a reaction which binds heat. In order to avoid undesirable complications in this process on account of lowering the temperature in receptacles A<sup>3</sup> and A<sup>4</sup> too much for the purpose of bringing down the tension of A<sup>3</sup> to that of A' and A<sup>4</sup> to that of A<sup>2</sup>, it is advisable to introduce into the said receptacles a substance (a lye for instance) which with an exothermal reaction dilutes in receptacle A<sup>3</sup> and concentrates in receptacle A<sup>4</sup>, thereby reducing the expansive force or tension. Otherwise the fluid in receptacles A<sup>3</sup> and A<sup>4</sup> would have a higher tension, as in receptacles A' and A<sup>2</sup>, if the receptacles A' and A<sup>3</sup> and receptacles A<sup>2</sup> and A<sup>4</sup> had a like temperature. In utilizing such low-tension vapors for actuating motors, a turbine would be the most desirable device to give a useful effect.

It remains to further describe the mechanical arrangement in case the freezing mixture is sufficiently strong to be used for removing the latent heat of a second vapor besides that of the original one used. This is also illustrated in Fig. 4, in which the parts E and F' are regarded as parts of a second engine, while A<sup>3</sup> represents the evaporator and A<sup>5</sup> the condenser of the machine shown in Fig. 1. The remaining working parts are represented by A' and A<sup>2</sup>. By the use of such efficient freezing-mixtures, it is even possible that the original machine A', A<sup>2</sup>, A<sup>3</sup>, and A<sup>5</sup> can also actuate with consumption of a certain quantity of mechanical energy. It is further possible that the vapor in the parts E' F' does not change its state, but that said machine is run as an air-engine. This outwardly entirely changed system of machines is only a slight modification of my system.

The several-times mentioned "latent heat" of the vapor must be regarded in the whole description as a shortened expression for the well-known quantity of heat which in the

perfect complete Sadi Carnot's engine is transferred to the cooler body for the purpose of bringing the working substance to the original (lower) isentropical curve.

5 It was not convenient to represent the invention by mere formulas in the beginning; but in the following I now give a concentrated recapitulation in the precise terms of modern thermo-dynamics as at present understood  
10 by me.

In Figs. 5 and 7 are represented diagrams of my improvement, and Fig. 6 is the well-known diagram of the Carnot-Clausius theory.

15 U in Diagrams 5 and 7 represents the internal energy. The working substance remains unchanged in Carnot's theory; but in my improvement this substance is repeatedly or periodically divided, and each part undergoes, independent of the other, thermo-dynamical changes, the parts to be brought together again for a time to again separate.

20 The thermal lines given in Figs. 5 and 7 represent an ideal indicator-diagram under the assumption that the change of volume of the salt solution, which is very small indeed, may be altogether neglected and considered as zero. The line  $\alpha$  gives the expansion of the system. (For example, salt-peter solution.)

25 This expansion line at a constant pressure is not always an isotherme, (as represented in the said figure,) as there are combinations possible, in which, for producing steam of constant pressure, the drying salt must become warmer and warmer in the pipe  $S'$  for the agitator R.  
35  $\beta$  means adiabatic expansion without presence of salt, a simple and common adiabatic line.  $\gamma$  means the absorption in the compressor, an isotherme illustrating the behavior of a gas when its volume is diminished in contact with  
40 its product of condensation, in which latter a salt is dissolved, it being assumed that the concentration of the liquid remains constant. So far this diagram is similar to the one of Carnot and Clausius; but the lines  $\alpha$  and  $\beta$  in  
45 my method must be considered in a different light, as the change of volume takes place in presence of a solid substance.

50 The transit of the vapor from the lower to the higher pressure takes place in combination with the salt and under a negligible change of volume and in a manner not yet fully investigated by physicists. The diagram closes in U, the details of which are as yet not known.

55 The most important heat reactions which signify the startling economical advantage of the new method do not appear in an indicator-diagram. They are sometimes given by arrows with lines, as in the typical Carnot diagram, Fig. 6. Corresponding to that Fig.  
60 5 will be readily understood. A horizontal arrow means a change of a quantity of heat within the system. Vertical arrows mean heat communication with the outside.

65 By consideration of the horizontal arrow  $Q_2$  under the line  $\gamma$  it will be seen that this line, which indicates an isothermal compression

in regard to the gas or vapor, means at the same time an adiabatic compression in regard to the whole system—that is, solid substance  
70 + liquid + vapor. A similar new view is induced by the two arrows near  $\alpha$ . The peculiar cycle with crossing adiabates is considered novel.

75 Fig. 7 gives the more complicated diagram for auxiliary compression in the case when part of the exhaust-heat cannot be bound, as previously described in reference to the compressor F, &c.  $\alpha \beta \gamma$  indicate the diagram as it would be ordinarily.  $\alpha' \beta' \beta'' \gamma'$  show the  
80 modified ideal indicator-line. The surface under  $\alpha$  is work first produced, the surface under the isotherme-line  $\beta'$  work consumed for compression, then the surface under the adiabatic line  $\beta''$  is work produced, and, finally, the surface under  $\gamma'$  is work consumed, as is the case  
85 in all diagrams.

It is understood that the given diagrams are mere types of my method. The diagrams may undergo innumerable variations in the  
90 practical workings of the motor, the same as the simple Carnot diagram undergoes changes in a triple-expansion steam-engine with receivers and dry, superheated, or wet steam.

Entropy is  $S = \int \frac{dQ}{T}$ , in which S is entropy, 95

Q quantity of heat, and T temperature. I am aware that entropy has been identified with unavailable energy. The energy, however, which is not available is generally TS, (for constant volume,) and the free energy is  $U - TS$ ,  
100 in which U is the internal energy, which is of the highest importance in a solution of salt and in solid substances. Science of the U is in the first dawn, and I claim to be the first  
105 to use it, so far as I know.

When in the Sadi Carnot cycle the working-substance undergoes the isothermic compression an amount of heat ( $Q_2$ ) leaves it with the temperature  $T_2$ . The entropy of this substance decreases therefore in the value  $-\frac{Q_2}{T_2}$ ,  
110

because the entropy is  $\int \frac{dQ}{T}$  in the same time the cool body takes up this heat and increases its entropy in the equal value  $+\frac{Q_2}{T_2}$ .  
115

This heat  $Q_2$  never enters the working substance again. It is and theoretically must be carried off forever. In the practical workings of Carnot's scheme the heat  $Q_2$  is dissipated, changed in heat of lower temperature  $T_2 - m$ , and therefore the entropy of the whole system is increased for the difference of the unequal values.  
120  
125

$$\frac{Q_2}{T_2 - m} \quad \frac{Q_2}{T_2}$$

(large)      (small)

130 In my cycle no heat  $Q_2$  is carried away. It liquefies a solid substance and thereby it disappears, vanishes in a manner named by scientists but not yet known. The solid sub-

stance which my process liquefies stands for Carnot's cooler body; but, theoretically, my solid substance can be and practically mostly will be of a higher temperature than  $T_2$  and the difference of the two fractions, which later measure the change of entropy therefore certainly will be zero at least. The entropy of the whole system cannot increase; but, on the contrary, it evidently decreases on account of the diminished volume and to a degree governed by the change in the solution. The quantity of heat  $Q_2$  with the temperature  $T_2$ , which caused the said liquefaction, is now some kind of energy called "latent" heat, physico-chemical energy, disgregational heat (die Disgregationswärme von Clausius.) Practically nobody knows what it is, but it is sure that it is no real heat. Therefore it does not behave according to the laws of heat, and theoretically it may be aimed at, and practically it is possible to transform this energy—the former heat  $Q_2$  of the temperature  $T_2$ —into heat of a higher temperature  $T_1$ . I transform it simply by adding a new quantity of heat to the liquid in some manner—for example, in the one described—and thus desiccating the liquid. This desiccating-liquid stands in the place of Carnot's warmer body, and it shows how heat can pass from a lower temperature  $T_2$  to a higher temperature  $T_1$  without expense of mechanical work or any "recompensation," as now held by modern thermo-dynamists.

In the explanation of my method I also mentioned that my machine can actuate a second common machine derived from Carnot's cycle. In this machine  $Q_2$  is composed of the heat of condensation of the dissolving exhaust and the common exhaust. The principle of the machines combined is the same as the principle for my simple machine, hence further consideration is deemed superfluous. The desiccating-liquid stands, indeed, in the place of Carnot's warmer body; but another body similar to Carnot's warmer body must be taken into consideration. This new body has to furnish the quantity  $Q_L$ , which comes from the outside.  $Q_L$  does not enter at once entirely into the gaseous part of the working substance. A part of it goes with the new-formed solid substance down into the regenerator E, and perhaps farther; but finally it comes up again with another part of the liquid. This part only travels around in the physico-chemical part of my combined cycle. Therefore as far as the calculation is concerned all of  $Q_L$  enters the gaseous part of the working substance in my cycle. In the Carnot cycle the same vapor ought to receive at this point the quantity of heat  $Q_1$  of the temperature  $T_1$ . This  $Q_1$  in my cycle is composed of the two quantities discussed before.

$$Q_1 = Q_2 + Q_L.$$

It is known that in the Carnot cycle the difference of the entering and leaving heat is

the equivalent of the gained mechanical energy  $L$ ,

$$Q_1 - Q_2 = L, \quad 70$$

( $L$  measured in calories.) In my cycle therefore this quantity is  $Q_L$

$$L = (Q_2 + Q_L) - Q_2 = Q_L. \quad 75$$

All heat which comes from the outside into my working substance is changed into mechanical work. The unchanged remainder  $Q_2$  travels around, as explained. Theoretically it is not necessary that my warmer body, which delivers the quantity  $Q_L$  should have the temperature  $T_1$ . It may have less. In this case the entropy of the whole system, even in the practical workings of this scheme, would not increase by this heat transfer.

In the cold-vapor machines my warmer body has the temperature of the surroundings the atmosphere and  $T'$  is consequently somewhat less. The heat transfer here increases the entropy for an amount due to  $Q_L$ ; but as  $Q_L$  is transformed into work the latter can give heat of any temperature, however high, and practically it produces, in some manner and at some future time, heat of the temperature of the surroundings. Thus it is shown that my cycle does not dissipate heat. It does not increase by any of its partial processes the entropy, the increase of which makes matter unpleasant from the point of view of the theoretical machinist.

By my cycle matter is kept in constant ability of mechanical reaction in eternal youth. I have invented, to give it in two words, an isentropical engine.

Having thus fully described my invention, I claim as new and desire to secure by Letters Patent—

1. The method of reducing the entropy of vapors, consisting of changing the heat form of energy into the physico-chemical form by dissolving solid substances in vapors or in their products of condensation, as set forth.

2. The method of guiding the increase of the entropy of vapors, consisting in changing the physico-chemical form of energy into heat by desiccating-liquids charged with substances which bind heat when combined with the said liquids at the same temperature, as set forth.

3. The method of transferring heat from a lower temperature to a higher temperature, consisting of liquefying a solid substance at a low temperature under the influence of chemical affinity and consuming heat and recovering the said substance in solid form from the produced liquid by subjecting the latter to a reverse physico-chemical reaction at a higher temperature, as shown and described.

4. The herein-described method for actuating a thermo-dynamical machine, consisting in regaining the original amount of entropy of the system of working vapors by changing the heat form of energy into the physico-chemical form after the entropy has been in-

creased and then changing the physico-chemical form of energy into the heat form, increasing at the same time the amount of entropy, substantially as set forth.

5 5. The herein-described method, consisting in compressing vapors to develop heat and at the same time transferring the heat thus developed into the liquid, substantially as described.

10 6. The herein-described method, consisting of compressing the vapors to develop heat and at the same time transferring the heat thus developed in the liquid, and also desiccating or decomposing the liquid by the heat, 15 substantially as shown and described.

7. The herein-described method of compressing unsaturated vapors without heating the same, consisting in forcing the vapors into a coil of pipe or vessel without change of volume and then compressing the vapors with a liquid and at the same time carrying off the heat, substantially as described.

25 8. The herein-described method, consisting in desiccating liquids to precipitate solid substances and to produce heat and at the same time adding an amount of new heat for actuating-motors or for cooling the source of the new heat, substantially as described.

30 9. The herein-described method for actuating a thermo-dynamical machine, consisting of first changing the waste or exhaust heat into the form of physico-chemical energy and then changing the physico-chemical form of energy into heat, substantially as described.

35 10. The herein-described method for actuating a thermo-dynamical machine, consisting

of first binding the waste heat of the machine by dissolving solid substances in vapors or in their products of condensation to form a liquid and then desiccating the liquid to recover the solid substances and the vapor containing the waste heat and the new heat introduced with the desiccation, substantially as described. 40

11. The herein-described method for actuating a thermo-dynamical machine, consisting of first binding the waste heat of the machine by dissolving solid substances in the vapors or their products of condensation to form a liquid and then desiccating the liquid at a low temperature for freezing or cooling purposes and to recover the solid substance and the vapors containing the heat and the new heat of a very low temperature and caused by the desiccation, substantially as described. 55

12. The herein-described method for actuating a thermo-dynamical machine, consisting of first binding the waste heat of the machine by dissolving solid substances in the vapors or their products of condensation to form a liquid and then desiccating the liquid at a high temperature to recover the solid substance and the vapor containing the waste heat and the additional new heat of a high temperature and introduced by the desiccation to form power for driving the machine, substantially as described. 65

HERMANN MEHNER.

Witnesses:

THEO. G. HOSTER,  
C. SEDGWICK.