G. HILDEBRANDT.

REFRIGERATING OR COOLING APPARATUS.

APPLICATION FILED DEC. 20, 1907.

963,555. Patented July 5, 1910.

2 SHEETS—SHEET 1.

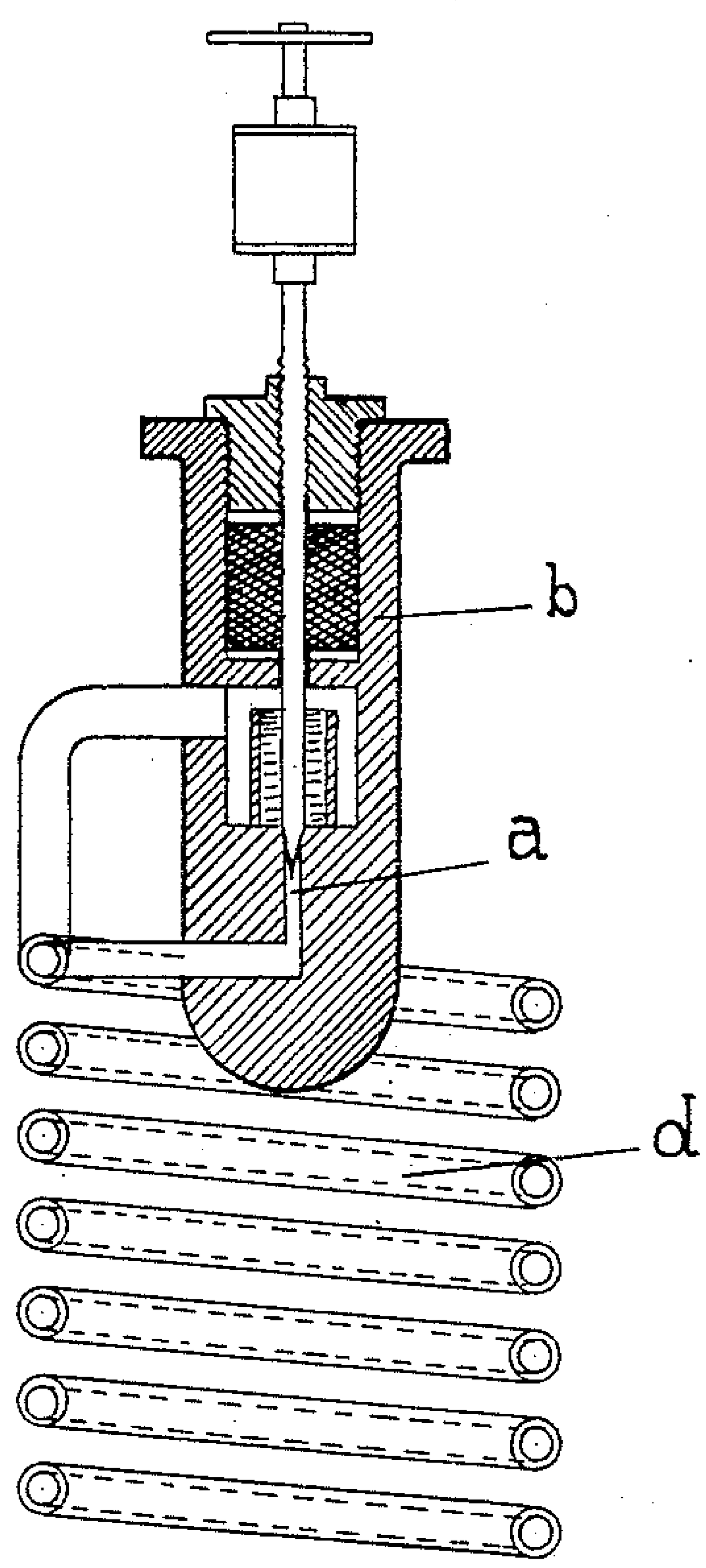

Fig. 1

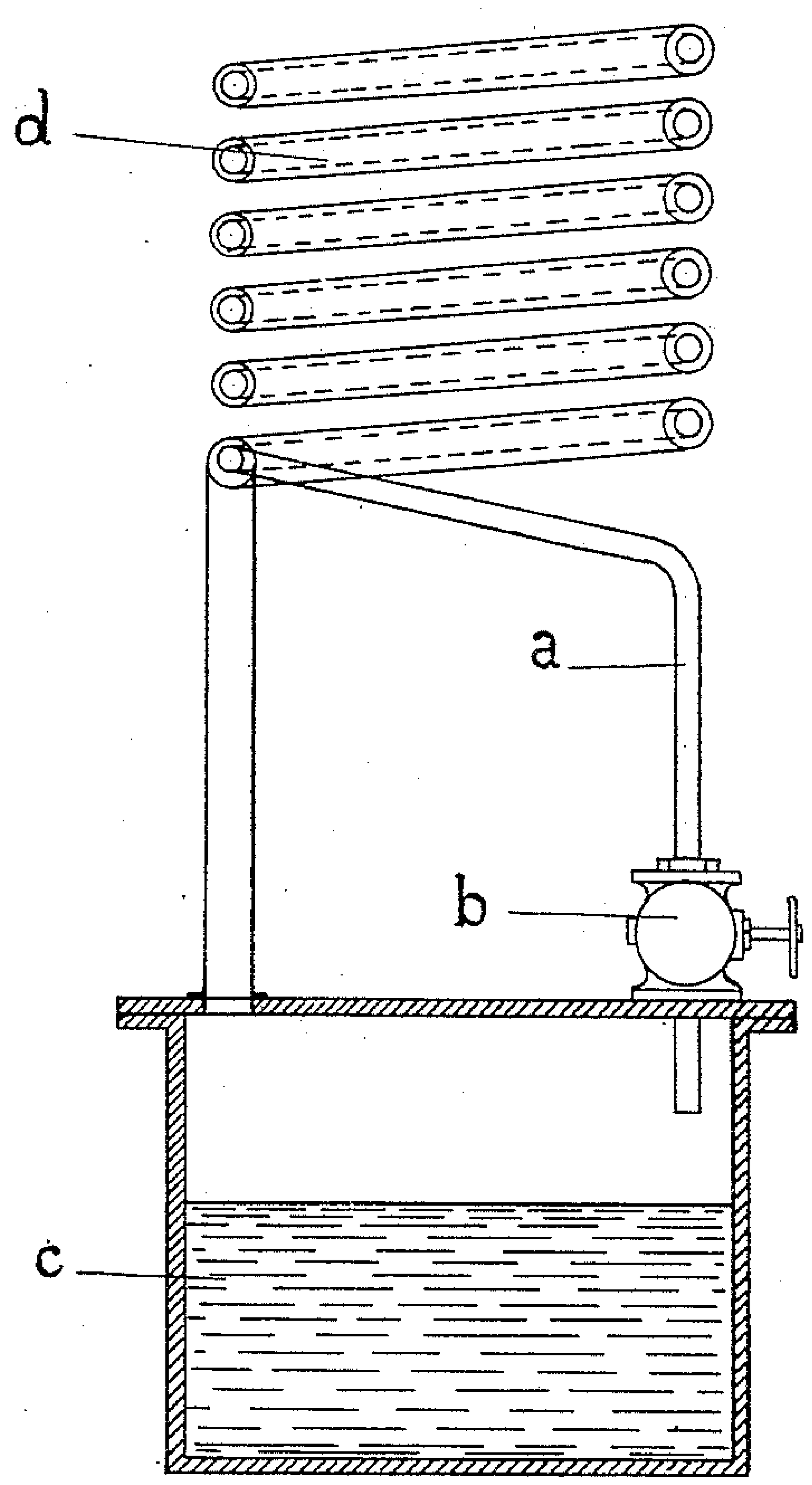

Fig. 2

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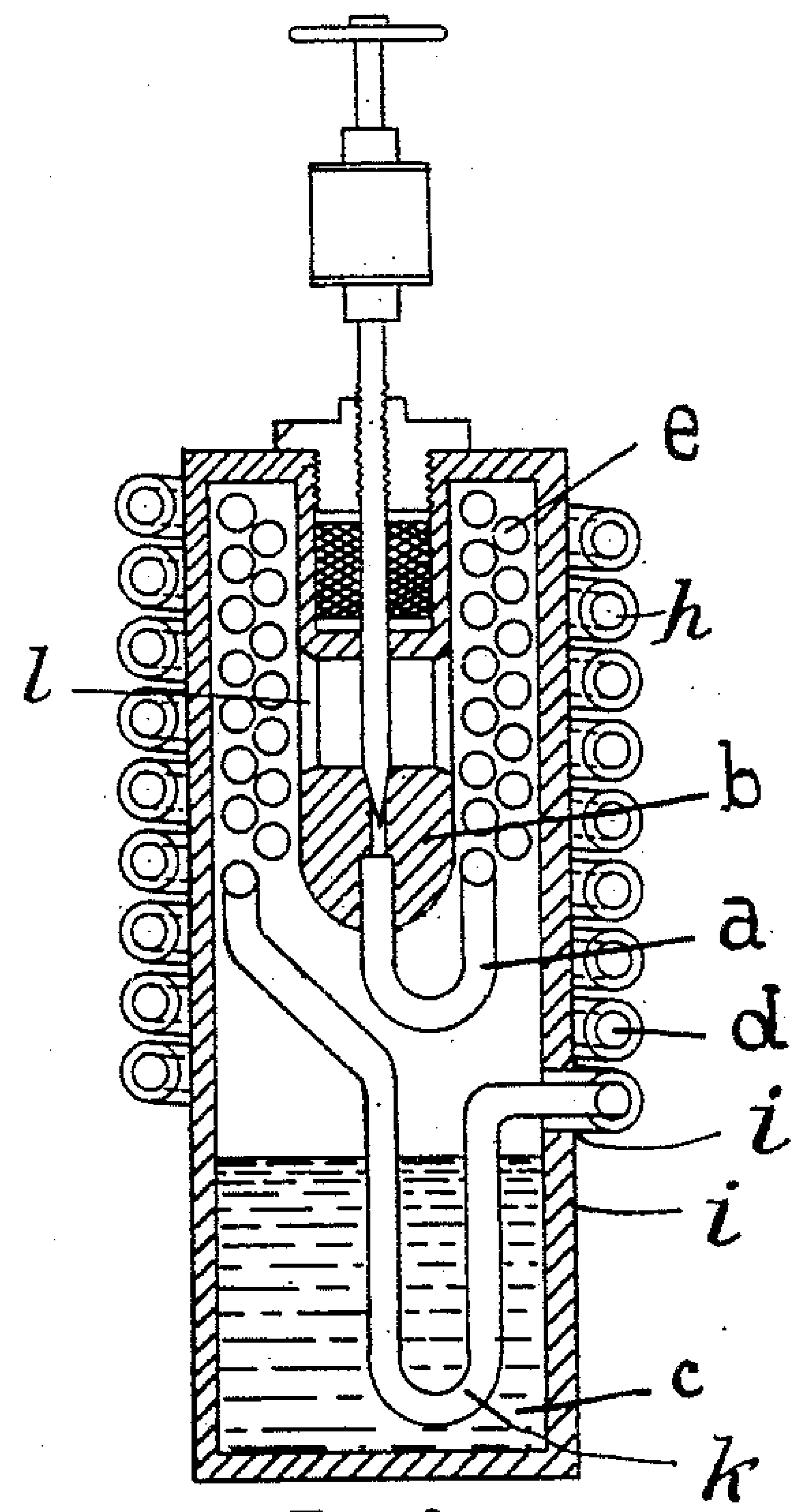

Fig. 3

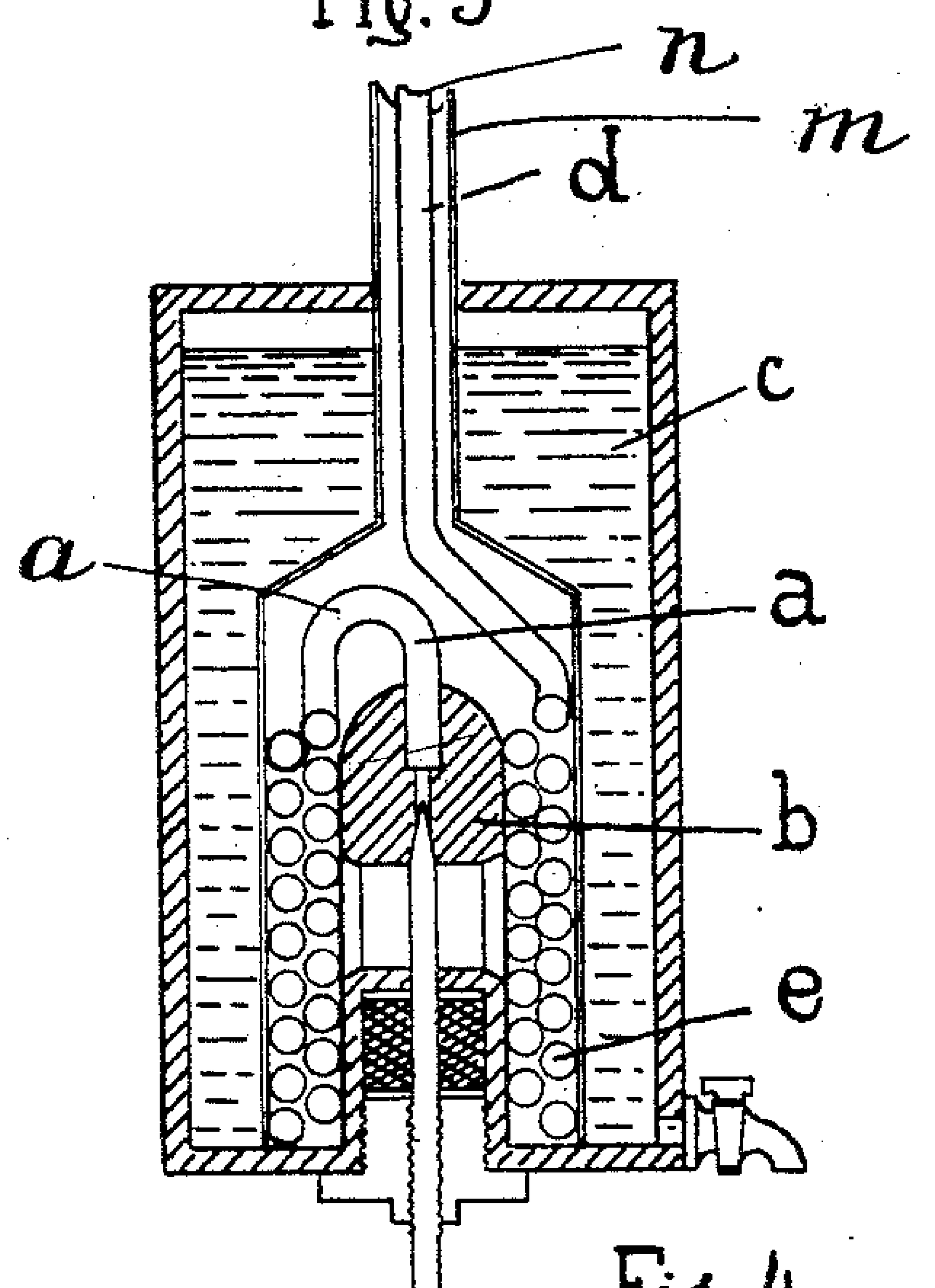

Fig. 4

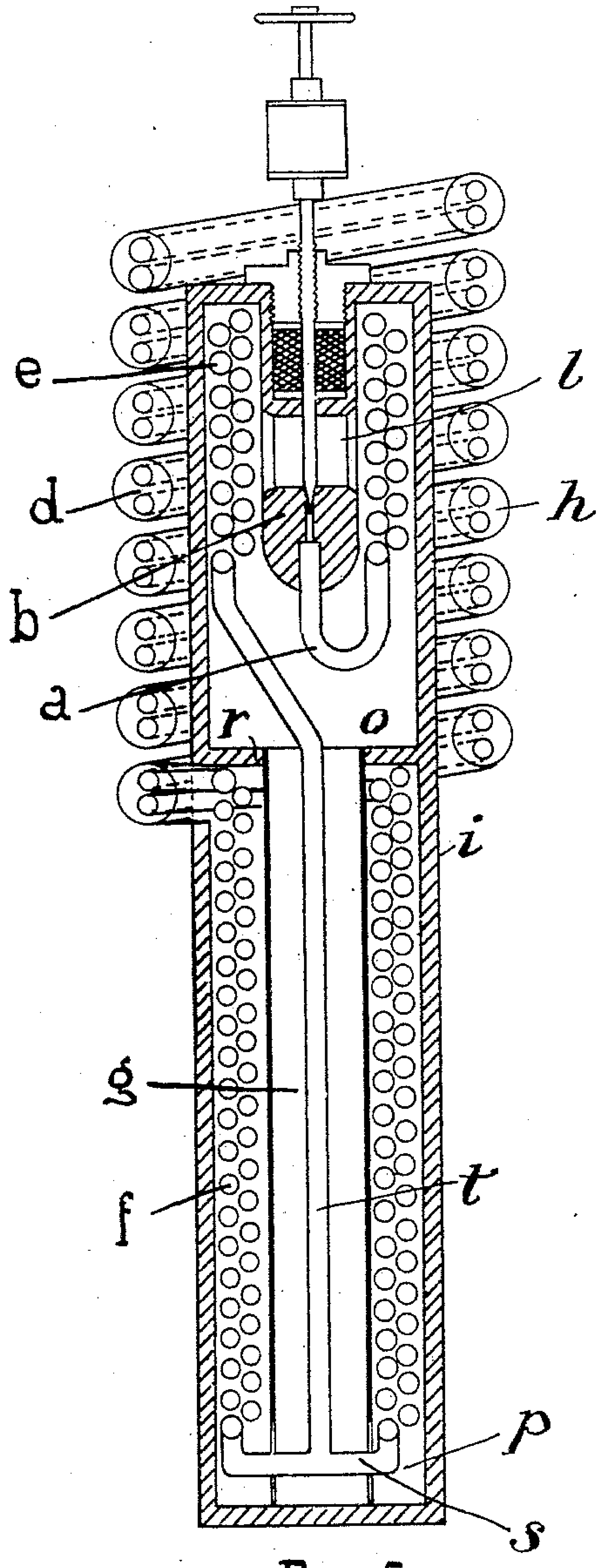

Fig. 5

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REFRIGERATING OR COOLING APPARATUS.

963,555. Specification of Letters Patent. Patented July 5, 1910.

Application filed December 20, 1907. Serial No. 407,356.

To all whom it may concern:

Be it known that I, GOTTHOLD HILDEBRANDT, a subject of the Emperor of Germany, residing at Berlin, Germany, have invented an Improvement in Refrigerating or Cooling Apparatus, of which the following is a specification.

This invention relates to refrigerating or cooling and final liquefaction of gases by means of the expansion of compressed gases and apparatus therefor, and has particular reference to an apparatus whereby gases with low boiling points, such, for example, as atmospheric air, can be utilized for this purpose as efficiently as can gases with higher boiling points such, for example as ammonia, carbonic acid or the like.

Hitherto owing to the small heat-capacity of air and other gases having low boiling points, they have not been able to be used with economy for the purposes of refrigerating and liquefying gases owing to the fact that the compression cylinder had necessarily to be very large compared to that used with, say, ammonia.

According to this invention the gas is compressed and cooled in any well known way, but instead of then being allowed to expand through a regulating valve directly into a refrigerator or "counter-current" apparatus, it is first caused to effect a preliminary cooling of the compressed gas flowing toward the valve.

As is well known, theoretical calculations give a much greater fall of temperature due to the expansion of compressed air than can be obtained in practice, that is to say, the expanded air from cold air compression machines is considerably warmer than it ought to be in accordance with theory. For this reason the use of air and other gases with low boiling points for the purposes of refrigerating or cooling and liquefying gases has been largely abandoned in favor of refrigerating compression machines employing gases such as ammonia, carbonic acid, sulfurous acid, etc. Or when for special purposes air or other low boiling point gas has been used, the final low cooling or liquefying has been only attained by the consumption of a greater amount of energy.

In the drawing, Figure 1 is a central longitudinal cross section and Fig. 2 is a similar view showing diagrammatically, forms of refrigerating or cooling apparatus which are well-known in the art. Figs. 3, 4 and 5 are central longitudinal sections illustrating modified or different forms of a refrigerating or cooling apparatus made in accordance with my present invention.

With reference first to Figs. 1 and 2, air expanded from the high-pressure pipe *a* through the valve *b* and thus cooled is admitted by way of a liquid-separator *c* into a closed counter-current apparatus or refrigerator *d* where it cools the compressed air admitted in the opposite direction, so that the air thus cooled arrives at the expansion valve *b* with a gradually decreasing temperature. In such apparatus, which may be taken as typical of that hitherto used, the important cooling action of the expanding gas on the outlet nozzle itself has been neglected, and importance attached chiefly to the cooling effect of the expanded gas in the counter-current apparatus alone. It is neglect of this cooling action on the nozzle itself which accounts in great measure for the difference between the theoretical and practical results above mentioned.

At the moment of the expansion of the highly compressed air, heat is absorbed, for the gas itself being cooled tends to absorb heat from the nearest heat-containing body, that is the expansion valve or the outlet nozzle, which in its turn draws heat from the surrounding insulating material and from the adjoining metal-supply pipe, and even from the refrigerator to which that pipe is connected. This action necessarily renders the temperature produced by the expansion of the compressed gas considerably higher than it should be. It may be said that the expansion of the compressed gas results in two distinct cooling effects, one that produced in the surrounding air at the moment of expansion which may be termed the "primary effect," and the other that produced in the regulating valve or in the expansion nozzle, which may be termed the "secondary effect." In apparatus hitherto used, the secondary effect has not contributed to the end in view, for example refrigerating or cooling or liquefying another gas—but has simply been wasted by conduction and radiation in the apparatus.

For efficient working it is necessary to prevent the lowering of temperature due to the secondary effect from becoming distributed over large areas of the material or substance cooled. That is to say, this secondary effect must be localized in order to obtain greater difference of temperature compared to the outer air, as such differences of temperature react more quickly and reduce to the lowest possible extent the unavoidable loss by radiation. For example, in order to manufacture ice, the water used must be cooled considerably below zero for the purpose, not merely of attaining the desired freezing temperature, but also of absorbing its latent heat. If the cold produced by the secondary effect be distributed over large areas, then although it may be possible to cool the water, it is impossible to freeze it in a sufficiently short time, as owing to conduction and radiation, the losses increase with the increase of time occupied by the process. The efficiency of the process is quite different when the cold produced by the secondary effect is concentrated in a small space and caused to act first on the freshly supplied compressed air. In that case the supply of water nearest to the source of cold is very quickly frozen before the intensity of the action is lost.

In order to liquefy gases with low boiling points in a reliable manner, the cold produced by the expansion should be so concentrated that, for example, in the liquefaction of atmospheric air, the temperature should be at any rate as low as 140 C. If the temperature be even a few degrees higher, it is insufficient for obtaining the result desired. But on the other hand, if this low temperature be obtained even if it be but temporarily so as to effect at one time but a very small quantity of gas in a very small space, it is possible to liquefy in consecutive steps and to accumulate any desired quantity of air, while otherwise the liquefaction either does not take place at all, or takes place only after a long time, during which a large proportion of the piping and apparatus have been cooled in a useless manner to a very low temperature.

The present invention consists, therefore, in localizing or concentrating the secondary cooling effect produced in the expansion nozzle, so that it acts in conjunction with the primary cooling effect produced in the gas itself. For this purpose the gas at the moment of expansion is caused to act upon a small hollow body such, for example, as a small coiled pipe *e* which, as shown in Figs. 3, 4 and 5, surrounds the expansion valve or an outlet nozzle so closely that the gases escaping must first come into contact with it before they are admitted into counter-current apparatus. The pipe bringing the supply of compressed air is connected to this low cooling coil *e* instead of being joined directly to the expansion valve *b*. The coil *e* thus placed is subjected to both the primary and secondary cooling effects of the expanding gas, and owing to this double influence the freshly admitted compressed gas passing through the coil is cooled more energetically than by methods hitherto known. The smaller and more compact the arrangement of the low cooling coil, the more sudden and lower is the fall of temperature obtained, and the less the possible loss by radiation.

The expanded gas which has thus cooled the coil *e* may then pass by way of a refrigerator or a counter-current apparatus to other compressed gas or to other substances such as brine, etc. which it may be desired to cool or to use for cooling purposes, and the whole cooling process may be divided into stages of which the first is represented by that which takes place in the above described low cooling coil *e*, and the second by a repetition of similar apparatus or by the counter-current apparatus. This idea of cooling in stages may be further developed by dividing the counter-current apparatus itself into separate stages or sections as, for example, in the manner illustrated in Fig. 5. One section is formed by the coil *e* arranged as previously described with reference to Fig. 3, and another by the coil *f* situated in the lower part of the casing. These two sections are connected by a supply pipe *g* which is of comparatively small cross section so that the losses through conduction along the metal pipe are very small. The expanded gas first impinges upon the coil *e* and then passes down the central space around the small pipe *g* and enters the annular space in the lower casing which contains the coil *f*. From the upper part of this space it enters the coils *d* of the counter-current apparatus proper.

The arrangement shown in Fig. 4 illustrates an apparatus suitable for the manufacture of ice or the cooling of brine, the low cooling coil *e* arranged between the counter-current pipe *d* and the expansion valve *b* having the effect of producing a greater cooling of the casing which transmits the cold to the liquid by freezing, the time of freezing being therefore considerably reduced.

As will be seen by reference to the drawing, the apparatus constructed in accordance with my present invention may comprise a vessel having a single compartment as indicated in Figs. 3 and 4, or two compartments as indicated in Fig. 5.

Referring particularly to Fig. 3, the counter current coil indicated at *h* surrounds the vessel *i* and enters the same at any suitable point as indicated at *i'*. The inlet coil *d* for the compressed air is preferably made concentric with this counter current coil *h* passing from the same into the vessel *i* forming a loop *k* therein and passing upwardly and surrounding the valve *b* in the outer inlet coil *e* and the inner inlet coil *a* which latter leads to the inlet orifice of the valve *b*, the valve *b* being provided with apertures *l* in such a position that the expanding gas as the same passes through and escapes from the valve, impinges against the outer surface of both the coils *a* and *e*.

A somewhat similar structure is shown in Fig. 3, with the exceptions that the valve *b* is inverted and the counter current tube is a straight pipe *m* instead of a coil, necessitating of course an inlet connection pipe *n* of the same shape; the valve *b* in both instances being contained within the compartment formed by the walls of the vessel.

Referring to Fig. 5, the vessel *i* is provided with two compartments indicated respectively at *o* and *p*, having a dividing wall *r* in which there is a centrally disposed aperture to receive one end of the tube *g* which extends therefrom to a point adjacent to the opposite end of the compartment *p* as hereinbefore described. In the construction shown in this figure, the inlet pipe *d* is arranged in a double coil which extends through the convolutions of the counter current coil *h*, closely surrounding the walls of the compartment *o* and these inlet coils *d* enter the compartment *p* through the connection therewith for the end of the counter current coil *h* preferably at a point adjacent to the partition wall *r*.

The inlet tube *d* extends through the compartment *p* in a double coil indicated at *f* to a point adjacent to the end opposite the partition wall *r* at which point the coils *f* are united as indicated at *s* in a pipe or tube indicated at *t*, which pipe *t* extends through the tube *g* into the compartment *o* and closely surrounds the valve *b* in the coils *e* and *a* in exactly the same relationship as those hereinbefore described in connection with Fig. 3.

In the use of the apparatus shown in Fig. 5, the compressed air or other gas is supplied to the pipes or double coils *d* passing through the same within the counter current coil *h*, passing thence through the double coil *f* to the pipe *t* and thence through the coils *e* and *a* to the valve *b* where the gas is expanded, it being liberated to pass through the valve *b* and in so doing escapes through the apertures *l* in the walls of the valve, impinging on the outer surface of both coils *e* and *a*, the liquefied portions of the gas passing by way of the tube *g* to the compartment *p* and the remaining gaseous portions thereof escaping by way of the counter current coil *h* to the atmosphere or a receptacle provided therefor.

It will be noted by reference to Fig. 1 that the compressed air after being admitted to and passing through the valve *b* or so much thereof as is still in the vapor form passes directly to the counter current coil and does not impinge previously to so doing on any part of the inlet pipe for the compressed air, whereas in Fig. 2, after passing through the valve *b*, the compressed air is conveyed to the tank *c* from which so much of the compressed air as is still in a gaseous condition, passes from the tank *c* to the counter current coil.

What I do claim, and desire to secure by Letters Patent, is—

1. In an apparatus for refrigerating or cooling by means of the expansion of compressed gases, the combination with a regulating valve or expansion nozzle, of separate coil sections *e f*, a pipe of relatively small cross section connecting the said coils *e f*, and a casing having separate compartments in which the said separate coil sections are placed, one of said coils surrounding the said regulating valve or expansion nozzle and there being provided a means of communication between the said compartments and through which the expanded gas flows.

2. An apparatus for refrigerating or cooling by means of the expansion of compressed gases, comprising a vessel, a valve or expansion nozzle located within the said vessel and being provided with apertures through which the expanded gas escapes after passing through the said valve, an inlet pipe for compressed gas leading to the said valve closely surrounding the same and against the exterior of which double coil the expanded gas impinges after passing through the said valve, and a counter current coil leading from the said vessel.

3. An apparatus for refrigerating or cooling by means of the expansion of compressed gases, comprising a vessel, a wall within the said vessel dividing the same into two compartments, a valve or expansion nozzle located within the first of said compartments and being provided with apertures through which the expanded gas escapes after passing through the said valve, a coil inlet pipe for compressed gas leading to the said valve closely surrounding the same and against the exterior of which double coil the expanded gas impinges after passing through the said valve and a counter current coil leading from the said vessel.

4. An apparatus for refrigerating or cooling by means of the expansion of compressed gases, comprising a vessel, a wall within the said vessel dividing the same into two compartments, a valve or expansion nozzle located within the first of said compartments and being provided with apertures through which the expanded gas escapes after passing through the said valve, a tube passing through the said partition wall of the vessel and extending from the same to a point adjacent to the opposite end of the said second compartment, a coil inlet pipe for compressed air surrounding the said tube within the said second compartment

extending through the said tube and terminating in a double coil closely surrounding the said valve to which the said inlet pipe leads, and a counter current coil leading from the said second compartment.

5. An apparatus for refrigerating or cooling by means of the expansion of compressed gases, comprising a vessel, a wall within the said vessel dividing the same into two compartments, a valve or expansion nozzle located within the first of said compartments and being provided with apertures through which the expanded gas escapes after passing through the said valve, a tube passing through the said partition wall of the vessel and extending from the same to a point adjacent to the opposite end of the said second compartment, a counter current coil leading from the said second compartment and closely surrounding the wall of the said first compartment, and a double coil inlet pipe extending through the convolutions of the said counter current coil into the said second compartment at a point adjacent to the said partition wall, the said double coil inlet pipe closely surrounding the said tube and extending to a point adjacent to the opposite end of the said second compartment where these coils are connected to a common pipe extending through the said tube into the first compartment where the said pipe is connected to a double coil closely surrounding the said valve and leading thereto.

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