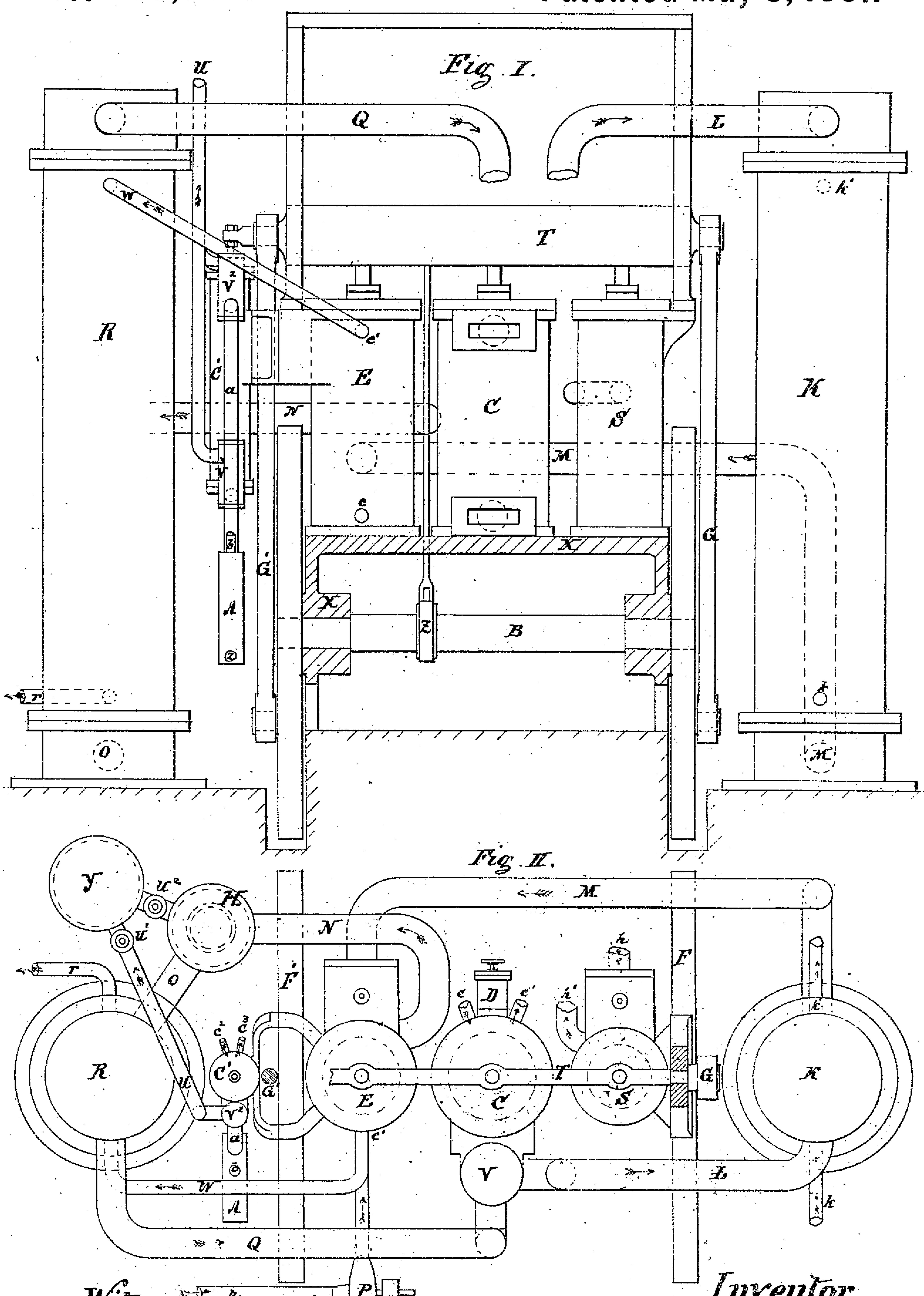
(No Model.) 2 Sheets—Sheet 1.

M. J. KLEIN.

Pneumatic Refrigerating Machine.

No. 240,830. Patented May 3, 1881.



Witnesses.
Louis Mayer
Max Strench

Inventor.
Mathias J. Klein

(No Model.) 2 Sheets—Sheet 2.

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Fig. III.

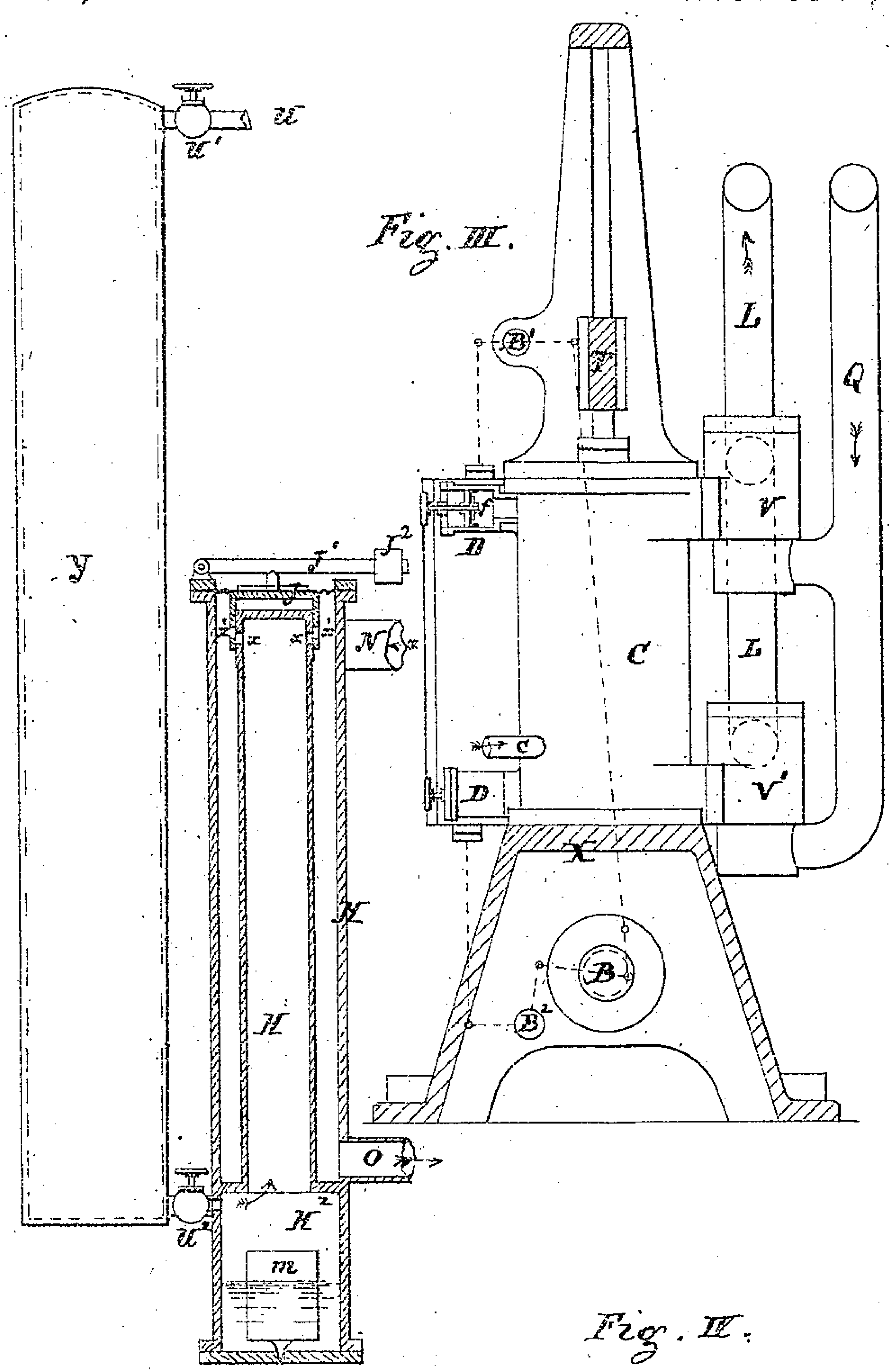
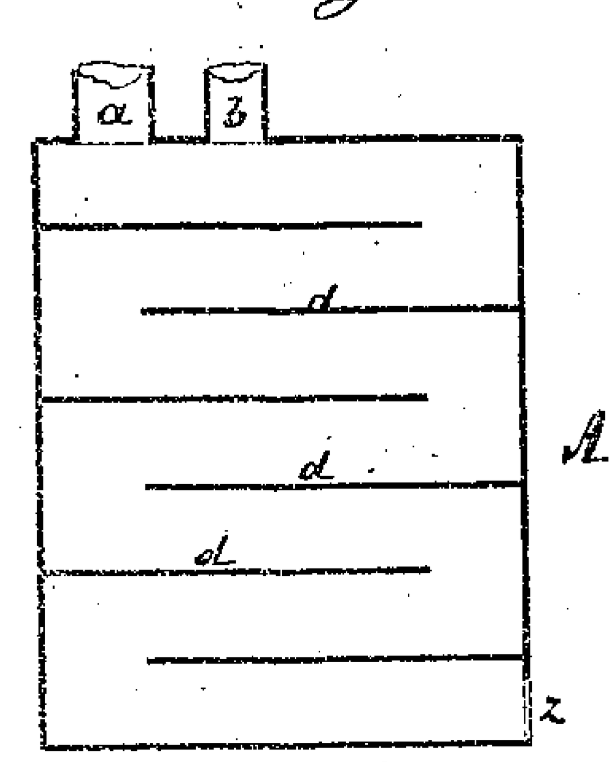


Fig. IV.



Witnesses
Louis Mayer
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UNITED STATES PATENT OFFICE.

MATHIAS J. KLEIN, OF NEW YORK, N. Y.

PNEUMATIC REFRIGERATING-MACHINE.

SPECIFICATION forming part of Letters Patent No. 240,830, dated May 3, 1881.

Application filed July 14, 1880. (No model.)

To all whom it may concern:

Be it known that I, MATHIAS J. KLEIN, of the city, county, and State of New York, have invented an Improvement in Pneumatic Refrigerating-Machines, of which the following is a specification.

This invention relates to that class of pneumatic refrigerating-machines in which the cold is produced by the alternate compression and expansion of one and the same body of atmospheric air. In such machines as have heretofore been produced, however, the minimum pressure of the air which produces the cold has been one atmosphere or less. Such machines, however, have the drawbacks of being of large dimensions and requiring great power to run them, and are, furthermore, more or less subject to difficulty on account of the moisture of the atmospheric air.

The object of this invention is to overcome these various objections; and my invention consists in the production of cold by the alternate compression and expansion of a confined body of purified and dry atmospheric air, which I call "working-air," under a minimum pressure always higher than one atmosphere. The waste through the stuffing-boxes and other leakages of this inclosed working-air on its circular course is supplied by other atmospheric air, which I call "feed-air."

My invention consists, also, in a new method of drying this feed-air perfectly, without the use of chemicals, before it enters into and becomes part of the working-air.

My invention consists, further, in the combination of parts designed to reduce the motive power required for the production of the cold to small limits as compared to the requirements of other pneumatic refrigerating-machines.

My invention consists, further, in purifying the feed-air, and in the automatic regulation of the minimum and maximum pressure of the inclosed working-air, which produces the cold.

By means of these several improvements I am able to produce a pneumatic refrigerating-machine of comparatively small dimensions, and which shall be serviceable within extended limits. Moreover, the internal parts of such a machine remain uninjured by the purified dry working-air, and remain free from dust, dirt, snow, and hoar-frost. A further advantage of such a machine is that comparatively little power is required to run it, and that it works economically.

My several improvements are more fully shown in the accompanying drawings, in which like letters indicate like parts, and in which—

Figure I, Sheet 1, is a front elevation of a pneumatic cold-producing apparatus with my improvements. Fig. II is a plan of the same. Fig. III, Sheet 2, is a vertical section of the same. Fig. IV is a vertical section of the air-purifier.

Upon a suitable frame, X, is mounted the steam-cylinder S, which may be of any suitable construction, the compressor C, and the expander E, which latter is provided with a variable cut-off. The small compressor C′—the air-feeder—is attached to the cylinder E. The piston-rods of the cylinders S C E C′ are connected to the horizontal beam T, which has a perpendicular reciprocating motion in ways in the upper frame, as shown. By means of two suitable pitmen, G G′, this beam T drives the two fly-wheels F F′ on the main shaft B, which rests upon bearings in the frame X, as shown. The expansion-cylinder E and steam-cylinder S have slide and cut-off valves, which are all put in motion by the eccentric Z, which rests on shaft B. The two slide-valves receive their motion from the shaft B′, and the two cut-off valves from the shaft B^2. The compressors C and C′ are surrounded by jackets, through which cooling-water is circulated by means of the supply-pipes c c^2 and discharge-pipes c' c^3. The expander E has a surrounding-jacket, through which, by means of the supply-pipe e and discharge-pipe e', a non-congealing liquid, or the water which is ultimately to be frozen, is allowed to circulate.

The air-cooler K is a surface-cooler, which may be of any suitable construction, and is connected with the valve-boxes V V′ of the compressor C and with expander E by means of the pipes L and M. It is provided with supply and discharge pipes k k', for the circulation of the cooling medium, which is usually water.

The refrigerator R, which may be of construction similar to the cooler K, is connected with the compressor C and the small surface-cooler H by means of the pipes Q and O, and is provided with supply and discharge pipes W and r, for the circulation of the non-congealable liquid, or whatever other medium may be chosen for transferring the cold. The air-feeder C′ is connected with the feed-air purifier A and the feed-air reservoir Y by means of the pipes *a* and U, as shown. The small surface-cooler H, with the water-vessel H^2 and pressure-reducing valve J on its top, is connected with the air-reservoir Y by the pipe U^2, with the expander E by the pipe N, and with the refrigerator R by the pipe O.

P is a pump designed to set in circulation the non-congealing liquid, or the water which is designed to congeal, and is connected at one side with the jacket of cylinder E, as shown, and at the other side, by means of pipe *p*, with the ice-making apparatus. (Not shown in the figure.)

The expander E, the refrigerator R, the small cooler H, the pump P, the pipes N O Q *r* W *p*, are all covered with non-conductors of heat.

The purified dry working-air, which produces the cold, is contained in N H O R Q C L K M E N, and during its circular course therein is compressed by the compressor C to its maximum pressure, and expanded by the expander E to its minimum pressure. This inclosed working-air is delivered and supplied by the air-feeder C′, which takes the feed-air from the atmosphere and conducts it through *z* A *a* U Y U^2 H^2 H′ and the ports *x x* to the working-air. The feed-air is in this way, before entering by *x x* to the course of the working-air, purified, compressed, and dried.

The feed-air purifier A—a small chamber—is provided at its bottom with an orifice, *z*, for the entrance of the atmospheric air, and is provided with a zigzag channel, formed through it from *a* to *z* by means of the series of horizontal partitions *d d*, as shown. Water is admitted through a pipe, *b*, at the top of the chamber, and flows through the channel and escapes at *z*. The atmospheric or feed air therefore enters at *z* and passes along the said channel to *a*, and delivers its dust and other impurities to the water with which it comes in contact in the chamber, and being thus purified and impregnated with water it passes into the air-feeder C′, in which it is compressed to the minimum pressure of the working-air, or to a higher degree of pressure, as may be desired. The warmth generated during this compression is partially absorbed in the evaporation of the water carried along from the purifier A, which has nearly the same effect as a spray of cooling-water thrown into the compressing-cylinder C′ during the compression of the feed-air. A further portion of this warmth is removed by the circulation of the cooling-water in the jacket of the cylinder C′. This water-impregnated feed-air renders unnecessary any lubrication of the piston of the cylinder C′, while the slide-valves and pistons of the cylinders E and C, into which only the dry working-air enters, must be perfectly lubricated. From C′ this very wet feed-air, which is now in a compressed state and a little heated, passes through the pipe U, the stop-valve U′ being open, into the feed-air reservoir Y. On the large surface of this reservoir the compressed feed-air will cool off to nearly the temperature of the surrounding atmosphere, and therefore a part of its moisture will be condensed in this reservoir and go with the feed-air through the discharge-pipe U^2, the stop-valve in U^2 being open, into the vessel H^2. If the feed-air is not cool enough upon entering H^2, the pipe U^2 may be increased in length, and cooled by a stream of cooling-water. The upright tube H′ is surrounded by the dry working-air, which, coming directly from the expander E, is at its lowest degree of temperature and at the minimum pressure. It enters at the top of H and escapes at O. From H^2 this now partially-dry feed-air passes up in the tube H′, and, through the ports *x x*, mingles with the working-air; but in the meantime it has been cooled off by the said working-air, which is passing downward in the jacket, between the tubes H H′, to the same or nearly the same temperature with itself—that is to say, the lowest temperature which exists in the machine. Now, since the feed-air in the tube H′ has the minimum pressure of the working-air, or a higher pressure, and because of the cooling above mentioned in this tube H′, nearly all the moisture still remaining in the said feed-air is condensed and drawn into the vessel H^2 in the form of condensed water and snow. The water in H^2 may be removed by a stop-cock or by a float-ing self-acting valve, *m*, as shown in the figure, or in any other way. The feed-air at the time of mingling with the working-air, and in consequence the working-air itself, is perfectly dry—that is to say, it is in such a degree or condition of dryness that not the least portion of the very small quantity of water-vapor which it still contains can become condensed into water or snow at any point upon its course; and it is quite obvious that this dry working-air remains in the same dry state, no matter how long the work of the machine is continued.

The ports *x x* in H′ will be regulated by the pressure-reducing valve J, which may be of any suitable construction. The working-air presses against the diaphragm of said pressure-reducing valve, which closes the tube H on its top. Said diaphragm is balanced by means of a weight, J^2, and lever J′, as shown. If the minimum pressure of the working-air is falling, the weight J^2 presses the diaphragm downward, and also the valve-ring *x′ x′*, and opens the several ports *x x*, near the top of tube H′, and the dry feed-air is allowed to escape by said ports and combine itself there with the working-air. The minimum pressure of the latter is now rising and will continue to rise until the correct minimum pressure of the working-air is reached, and thus will be relative to the position of the weight J^2. When this minimum pressure is attained, the weight J^2, together with the diaphragm, goes upward and closes the ports *x x*. The feed-air which is now coming from the air-feeder C′ must remain in the reservoir Y, and in consequence the pressure of the air in Y rises. By the continual escape of the working-air through stuffing-boxes and other leakages the pressure of the working-air decreases. This causes the pressure-reducing valve to open the ports *x x* and new feed-air to enter into the working-air. It is obvious that by these means the minimum pressure of the working-air is automatically regulated. Said minimum pressure may be varied by shifting the position of the weight J^2 upon the lever J′. The proportion of the maximum pressure to the minimum pressure of the working-air is relative to the proportion of the volume of the compressor C to that of the expander E and the position of the cut-off of the latter. If said cut-off be variable, the said proportion will be variable. The greater the ratio of said proportion, the lower will be the temperature reached by the machine.

The machine operates in the following manner, to wit: The necessary power for driving the machine may be delivered from the steam used in cylinder S or from any other motor. When the machine is started, the pressure of the air in the several parts of the machine is, of course, one atmosphere—that is, about fifteen pounds per square inch. The stop-valve U′ is opened and the stop-valve U^2 is closed. The air-feeder C′ first fills the reservoir Y with purified compressed atmospheric air until the pressure therein is a certain degree higher than the required minimum pressure of the working-air, and then the stop-valve U^2 is gradually opened. Thus all the moisture of the feed-air has time to condense in the tube H′ before this feed-air enters into the working-air. Having thus filled the machine with purified and perfectly-dry working-air, and the required minimum pressure of the working-air being reached, the minimum and maximum pressure of the working-air will remain constant, and will be automatically regulated by means of the air-feeder C′, the feed-air reservoir Y, and pressure-reducing valve J, as above described. Should the air-feeder C′ furnish more feed-air than required to counterbalance the loss by escape from the stuffing-boxes and other leakages, the surplus will remain in the reservoir Y, the pressure in the same in the meantime rising and continuing to rise until a safety-valve (not shown in the figure) upon said reservoir Y is opened and a portion of the confined air allowed to escape into the atmosphere. The same result may be attained by stopping the air-feeder C′ from time to time, similarly to the feed-water pump upon a steam-engine, or the amount of feed-air delivered may be reduced by enlarging the amount of waste space of the air-feeder, or by reducing its stroke, or by pressing its suction-valves by means of springs and screws, or in any other way. By stopping the machine for several hours the two stop-valves U′ U^2 may be closed, and the feed-air remaining in the reservoir Y may be stored for filling the machine for its next running. The purified and perfectly-dry working-air, which is in the minimum pressure state in the refrigerator R, passes through the pipe Q to the compressor C. It is here compressed to the maximum pressure and consequently heated. It next passes through the pipe L, and enters the surface cooler K, in which, by the aid of cooling water, air, or both, its temperature is reduced. It then passes through the pipe M to the expander E, in which it is expanded from its then maximum to the minimum pressure, and, as a resultant, cold and power are produced. The latter is utilized in compressing the working-air in C, and at the same time affords very great assistance to the steam-cylinder S. The working-air, as it emanates from the expander E through the pipe N, has reached its lowest degree of cold, and is in the minimum pressure state. It next passes into the upper portion of the jacket, between the tubes H and H′, thence downward, and cools off the feed-air contained in the tube H′ to its own temperature, as already described. From said jacket the cold working-air passes through the pipe O to the refrigerator R, in which it acts upon and refrigerates a non-congealing liquid, or air, or water, or freezes water to ice, the working-air in the meantime rising in temperature. From the refrigerator R said working-air passes through the pipe Q to the compressor C, where it is again compressed from the minimum to the maximum pressure, and repeats the circuit already described. This operation is continuous.

The more perfect the expansion of the working-air in E, the greater the reduction in the amount of power required to drive the machine, and also the greater the cold produced. In order to obtain a perfect expansion in the expander E through the different fillings of the latter, the capacity of the compressor C must be variable. This may easily be attained by varying its waste space. To effect this, two small cylinders, D D, are attached at the side of cylinder C, each of which has an air-tight movable piston, *f*, with a regulating-screw, as shown in the figure. The same effect may be obtained by other means. The motive power for driving the machine will also be reduced by circulating the non-congealing liquid, or the water which is designed to freeze to ice, in the jacket and cylinder-heads of the expanding-cylinder E. If the design be to use the refrigerating capacity of the machine for the production of ice, the water intended to be frozen will be allowed to circulate in the said jacket, where it is cooled off to nearly its freezing-point, and then it is allowed to escape into cans in the ice-producing apparatus. Said cans are immersed in the non-congealable liquid, which is circulated in said ice-producing apparatus and the refrigerator R by means of the pump P.

If the machine be not designed for the production of ice, the non-congealable liquid is allowed, in lieu of water, to circulate in the jacket of the cylinder E. Having here been cooled off to a certain degree, it is passed through the pipe W into the refrigerator R, where it is still further reduced in temperature.

Next it is allowed to pass through the pipe r to the apparatus or apartment where its cold is to be utilized. Having performed its refrigerating function, it next goes back to the pump, P, to repeat the circuit described.

If the machine be designed to produce cold water for any purpose, common water, in lieu of a non-congealable liquid, is allowed to make the circuit just described, and it may be used over and over again or not. In the latter case a continual stream of fresh water is allowed to circulate through the jacket of the cylinder E. The effect of said jacket in E will be increased if the liquid circulating through the same also circulate through the piston of cylinder E; and in the same manner the cooling effect of the jacket in the compressor C will be increased if the cooling-water is also allowed to circulate through the piston of the same.

The feed-air in drying, as above described, is cooled off in H′ to, or nearly to, the lowest degree of cold which exists in the machine by the direct operation of the cold working-air. The same effect may also be attained in H′ by means of a non-congealable liquid. In order to do this, the cold working-air is allowed to pass from expander E first to a small surface cooler of any suitable construction, in which it reduces said non-congealable liquid to, or nearly to, its own degree of cold, and goes then directly into the refrigerator R and not into H. Said non-congealable liquid goes from the small surface cooler just mentioned into the jacket between the tubes H and H′, and in the same manner reduces the temperature of the feed-air which is passing upward in tube H′. The non-congealable liquid, its temperature having, in the meantime, become slightly raised, returns to said small surface-cooler, where it is cooled off again by the cold working-air, and then it repeats the circuit described. If this modification be used, the upper portion of the jacket, between the tubes H H′, where the feed-air passes the ports x x, must be separated from its lower portion by an air-tight partition. From the said ports x x a pipe conducts said feed-air to pipe N or to any other place where the working-air circulates. If it be designed that the feed-air, after passing the ports x x, shall enter into the working-air at any point where it is in its maximum pressure state, the air-feeder C′ must, in this case, compress the feed-air to the said maximum or a higher pressure, and then the maximum pressure of the working-air will be directly and automatically regulated.

It is not necessary to cool the feed-air before it enters into the vessel H^2. The whole cooling of the feed-air could be done in H′ alone by the cold working-air or by said non-congealable liquid; but in such case, as it is easy to see, a part of the cold produced by the machine would be wasted, and therefore it is preferable to cool the feed-air, as above described, before it enters into vessel H^2.

My invention is not restricted to the arrangement shown in the drawings. The several parts of the machine may be arranged in any other position than that shown; and my invention is, furthermore, not confined to the special kind of constructions of the several parts shown in the drawings. Any kind of a double or single acting air-compresser, of a double or a single acting air-expander, any kind of a surface-cooler, refrigerator, air-purifier, or pressure-reducing valve, and any kind of an air-feeder, may be used. The compressor C and expander E may also be used in one cylinder, in one end of which the working-air shall be compressed, and in the other end of which it shall be expanded; and in lieu of one such cylinder two or more may be employed.

Instead of one cooler, K, and one refrigerator, R, two or more of each may be used. The refrigerator R may serve for several purposes at the same time. One part of it may be used for the production of ice, and another for the production of cold air, &c.

In lieu of the feed-air purifier A, an equivalent apparatus may be employed in which the feed-air must pass through a body or a spray of water, or through a mass of cotton or other fibrous material which is kept constantly impregnated with fresh water, &c.

The air-feeder C′ may be a double or a single acting air-compressor. It may consist of one compressor, in which the feed-air is compressed from the atmospheric pressure directly to the minimum pressure of the working-air or a higher pressure; or it may consist of two or more compressors in which the feed-air is first compressed from the atmospheric pressure to a medium pressure, and then further until the pressure required in the air-reservoir Y is reached.

As an equivalent apparatus for the air-feeder C′, there may be substituted a pulsometer, an injector, or any other apparatus or arrangement which is able to furnish compressed air of any desired degree of pressure; also, several of the apparatuses just mentioned may be employed at the same time. For instance, the feed-air may be first compressed by a pulsometer, and then further compressed by means of a piston-compressor to the required minimum pressure of the working-air or a higher pressure. The air-feeder may also be driven by a separate motor. In this case the air-reservoir Y may be filled with compressed air of the required pressure before the whole machine is started.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. In a pneumatic refrigerating-machine, the continuous use of a confined body of atmospheric air, called "working-air," which is alternately compressed and expanded, and the minimum pressure of which is higher than one atmosphere, substantially as and for the purpose described.

2. In a pneumatic refrigerating-machine, the combination of a small air-compressor or an

equivalent apparatus, which serves as an air-feeder, with an air-compressor and an air-expander in which the inclosed working-air operates, designed to maintain the working-air at a higher minimum pressure than one atmosphere, substantially as and for the purpose described.

3. In a pneumatic cold-producing apparatus or refrigerating-machine, the air-feeder C′ or its equivalent, in combination with the compressor C, cooler K, expander E, and refrigerator R, substantially as and for the purpose described.

4. The air-purifier A or its equivalent, designed to purify the feed-air and impregnate it with water, in combination with the air-feeder C′ or its equivalent, substantially as described.

5. The combination of the air-feeder C′ or its equivalent, the small surface-cooler H or an equivalent apparatus, and the vessel H^2, designed, in conjunction with the cold working-air or a non-congealable liquid, to reduce the feed-air, while in its compressed state, to, or nearly to, the lowest temperature which exists in the machine, and by these means to dry the feed-air perfectly, substantially as described.

6. The method of drying the feed-air, consisting in compressing the same before it enters into the circular course of the inclosed working-air to the minimum pressure of the latter or a higher pressure, and then cooling it off, while in this condition to, or nearly to, the lowest temperature which exists in the machine, and by this means, so far as possible, to condense all the water-vapor contained in he said feed-air to water or to water and snow, and remove the same, substantially as set forth.

7. In a pneumatic refrigerating-machine, the compressor C, in combination with the small cylinders D D, having air-tight pistons f f, with regulating-screws or their equivalent, substantially as and for the purpose described.

8. In a pneumatic refrigerating-machine, the expander E, in combination with a jacket provided with supply and discharge pipes, designed to circulate the non-congealable liquid or the water to be congealed, substantially as and for the purpose described.

9. The air-feeder C′ or its equivalent, in combination with the feed-air reservoir Y and pressure-reducing valve J, designed to regulate automatically the minimum or maximum pressure of the inclosed working-air, in the manner specified.

10. In a pneumatic refrigerating-machine, the combination of the air-feeder C′ or its equivalent, the feed-air purifier A or its equivalent, the feed-air reservoir Y, the small surface-cooler H or its equivalent, the vessel H^2, the pressure-reducing valve J, the compressor C, the cooler K, the expander E, and refrigerator R, designed and arranged to operate substantially as and in the manner and for the purpose set forth.

In testimony that I claim the foregoing I have hereunto set my hand this 2d day of July, 1880.

MATHIAS J. KLEIN.

Witnesses:
LOUIS MAYER,
MAX STRENCH.