L. ALLEN.

Process and Apparatus for Cooling Air.

No. 231,886. **Patented Sept. 7, 1880.**

FIG. 1.

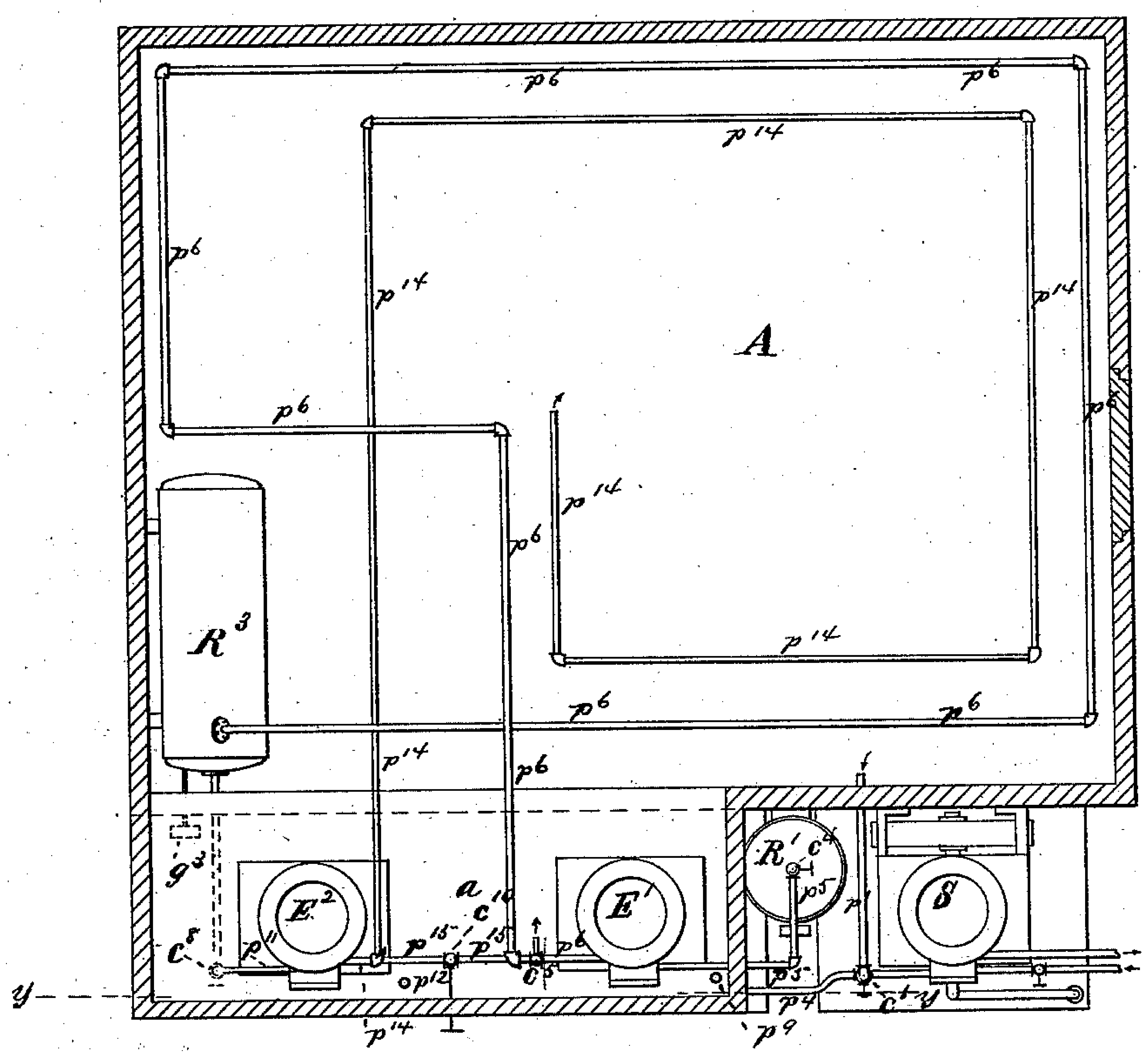
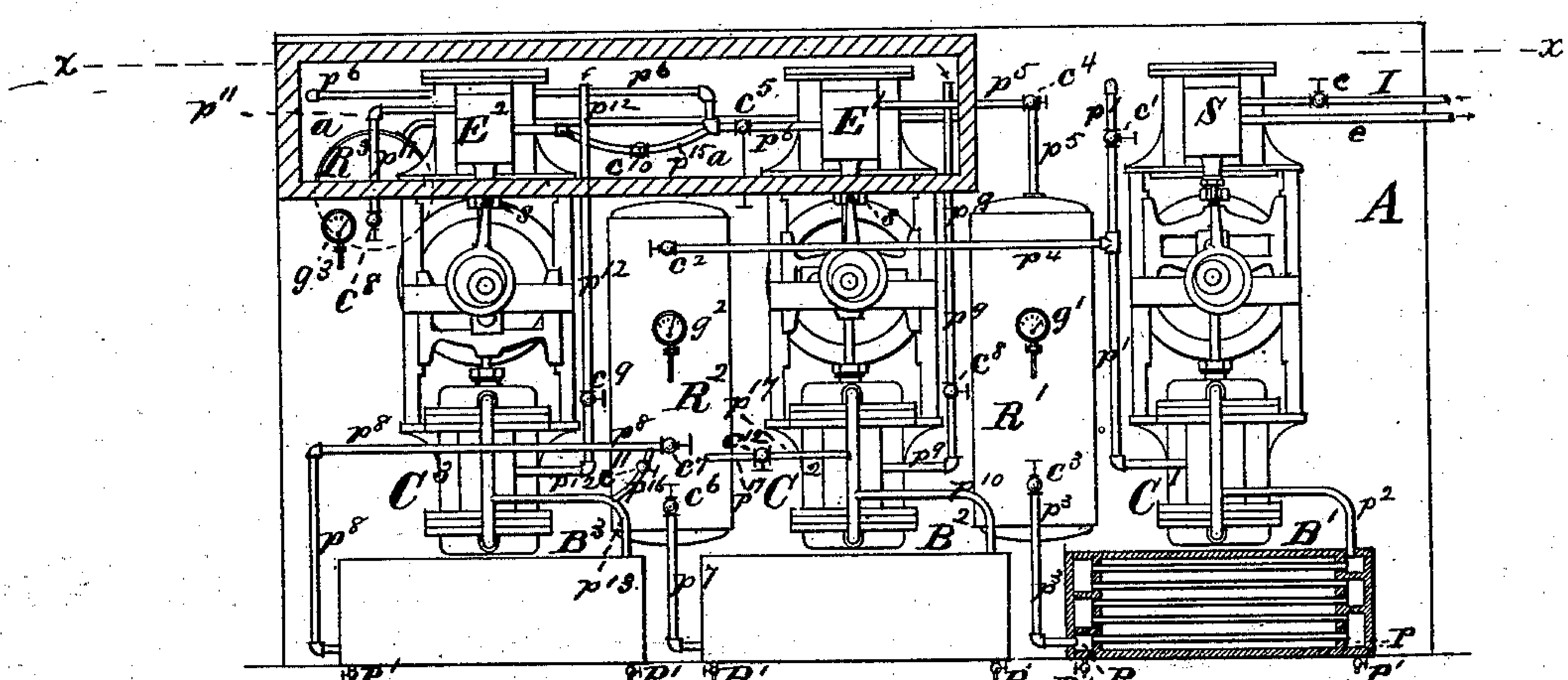


FIG. 2.



WITNESSES:

Chas. M. Higgins.

John E. Gavin

INVENTOR:

Leicester Allen.

N. PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

LEICESTER ALLEN, OF BROOKLYN, NEW YORK.

PROCESS AND APPARATUS FOR COOLING AIR.

SPECIFICATION forming part of Letters Patent No. 231,886, dated September 7, 1880.

Application filed June 9, 1879.

To all whom it may concern:

Be it known that I, LEICESTER ALLEN, of the city of Brooklyn, county of Kings, and State of New York, have invented certain Improvements in Processes and Apparatus for Cooling and Drying Air, applicable to all purposes which require cool or both cool and dry air, but more particularly to the preservation in large refrigerators of animal and vegetable substances or products; and I do hereby declare that the following is a full, clear, and exact description of the same, reference being had to the accompanying drawings, forming part of this specification, in which—

Figure 1 is a sectional plan view of a refrigerating store-room with my apparatus thereunto attached, and Fig. 2 is a sectional front elevation of the same, the section in Fig. 1 being made on the line *x x* in Fig. 2, and the section in Fig. 2 being made on the line *y y* in Fig. 1.

My invention relates to that class of cooling or refrigerating apparatus in which cold is produced by first compressing air, cooling it while so compressed, or during the process of compression, or both during and after compression, and, lastly, expanding the same in the performance of work in an engine-cylinder or other appliance, whereby the said expansion may be made to perform work.

The objects sought in the improved construction and organization of my apparatus are means for obtaining large expansion and much work from the compressed air and a correspondingly large effect in cooling either with or without great intensity of cold; means whereby the heat at low temperatures in the refrigerating-inclosure may be made to perform work in its transfer from the interior of such inclosure to the exterior of the same; means whereby a very high degree of compression may be obtained without making the steam-cylinder or other prime motor do more than a comparatively small amount of the work of such compression, while at the same time it works independently, having no direct or positive connection with the air-expanding engine or engines or apparatus; means whereby all the cold produced by expansion may be utilized in the refrigerating inclosure or room to be cooled, or body of air to be cooled; means for carrying out a hereinafter-to-be-described process of drying the air while cooling the same, if necessary to be dried, and means for preventing the formation of fog or visible vapor in the refrigerating-inclosure through the sudden contact and commingling of very cold air with warm and moist air at the point where the final exhaust of expanded air enters such inclosure.

My invention consists in the construction and arrangement of apparatus for carrying out the various parts of my improved process of cooling and drying air, and utilizing the heat of the contents of the refrigerating-inclosure, and in the parts of said process, which may be readily understood after a description of the apparatus.

In the drawings, A represents the refrigerating-inclosure; S, a steam-engine; C′, C^2, and C^3, air-compressors; E′ and E^2, air-expanding engines; R′, R^2, and R^3, reservoirs for compressed air; c' c^2 c^3, &c., sundry cocks or valves for regulating the flow of air, as hereinafter explained, and p' p^2 p^3, &c., pipes through which the air flows. B′, B^2, and B^3 represent coolers for compressed air. P represents recesses, pockets, or traps for the collection of condensed water, and P′ cocks or valves in such traps for the removal of such condensed water. The steam-induction pipe is shown at I, and the steam-exhaust pipe at *e*. The steam throttle-valve is indicated at *c*.

The refrigerator or inclosure A may have any approved form and construction calculated to obstruct the transmission of heat through its walls.

The steam-cylinder should be constructed to perform (either by following with steam through its full stroke, or by expanding the steam from a given point of cut-off, or by a variable cut-off-valve gear,) any desired amount of air compression in the cylinder C′, the said steam-cylinder and compressor-cylinder forming a compressing air-pump; but for the steam-cylinder any other motor may be substituted as circumstances may dictate.

The air-expanding engines E′ and E^2 and their attachments may be slide-valve engines, the valve of each being adjusted to cut off at such point of the stroke as will (the air being delivered to each of their valve-chests at a uniform pressure) expand the air in each engine down to a constant and predetermined pressure. The engine E′ is connected with and operates the compressor C², forming with said compressor a compressing air-pump driven by compressed air. The engine E² is connected with the air-compressor C³, forming with said compressor a compressing air-pump driven by compressed air.

The engines E′ and E² are placed within the refrigerating-inclosure preferably in a recess, *a*, at the top and one side of said inclosure, such position bringing them into the upper and warmer stratum of air in the inclosure or refrigerator A, this position being chosen to better carry out a purpose hereinafter explained. On the contrary the steam-engine S and air-compressors C′ C² C³ are all placed outside of the inclosure, as shown in the drawings.

The piston and valve-rods of the engines E′ and E² are preferably made to pass through stuffing-boxes *s* in the lower wall of the recess *a* in the refrigerator A, and they may be made, by tightening, to work with sufficient friction to keep their temperature elevated a little above the point of congelation of moisture, which will condense upon them during their reciprocation through air exterior to the inclosure A.

The air-compressors C′, C², and C³ may be of any approved design. I prefer for some purposes to make the connection between the engines and compressors direct, and effect the action and reaction of the cranks of the fly-wheels and piston-rods upon each other by slotted cross-heads, as shown in the drawings; but this is not absolutely essential. In fact there will be a greater loss of power in this method of connection by friction than in some other construction; but the compactness of this arrangement renders it desirable where space is limited, as between decks of vessels, &c.

The steam-engine S being set at work, the compressor C′ takes air, in starting the apparatus, from the interior of the refrigerator or inclosure A through the primary induction air-pipe *p*′, delivers its charge of air after compression into the cooler B′ through the pipe *p*², whence, after cooling, it passes into the reservoir R′ through the pipe *p*³, compressing the air in said reservoir to a predetermined primary pressure. To effect this result the cock *c*′ in the primary induction air-pipe *p*′ is opened, the cock *c*² in the pipe *p*⁴ is closed, the cock *c*³ in the pipe *p*³ is opened, and the cock *c*⁴ in the induction-pipe *p*⁵ of the engine E′ is closed. As soon as the predetermined pressure in the reservoir R′ is reached, which is indicated by a gage, *g*′, thereunto attached, the cock *c*⁴ in pipe *p*⁵ is opened, the cock *c*⁵ in the pipe *p*⁶ (which is a two-way cock that, turned into one position, permits free exhaust into the inclosure A, and in another compels the passage of air through the entire length of the pipe *p*⁶) is turned to permit direct exhaust from the engine E′ into the refrigerating-inclosure A, the cock *c*⁶ in the pipe *p*⁷, Fig. 2, is opened, the cock *c*⁷ in the pipe *p*⁸ is closed, and the cock *c*⁸ in the secondary induction air-pipe *p*⁹ is opened. The engine E′ now operates, taking compressed air from the reservoir R′ through the pipe *p*⁵, expanding it to a predetermined volume, and exhausting through the two-way cock *c*⁵ into the refrigerating-inclosure A, the prescribed pressure in the reservoir R′ being maintained by the compressor C′. At the same time the compressor C² takes air from the inclosure A through the secondary air-induction pipe *p*⁹, compresses it, and delivers it, through the pipe *p*¹⁰, cooler B², and pipe *p*⁷, into the reservoir R², in which the pressure is allowed to accumulate to a predetermined degree, indicated by a gage, *g*², attached to said reservoir.

When the last-named pressure has been reached in the reservoir R², I proceed to accumulate pressure in the reservoir R³, as follows: The two-way cock *c*⁵ in the pipe *p*⁶ is turned to stop the direct exhaust of the engine E′ into the refrigerating-inclosure A and direct the expanded air from said engine through the entire length of the pipe *p*⁶ into the reservoir R³. At the same time the cock *c*′ in the primary air-induction pipe *p*′ is closed to prevent the compressor C′ from taking its air any longer directly from the refrigerating-chamber, and the cock *c*² is opened. The compressor C′ then takes its air from the reservoir R² through pipe *p*⁴ at the pressure prescribed for said reservoir, imparts to said air another increment of pressure equal to what it first imparted, and passes it by the route hereinbefore explained into the reservoir R′, ultimately accumulating in said reservoir a pneumatic pressure equal to the sum of the pressures prescribed as the limit of work for the compressors C′ and C², respectively.

While the pressure is thus accumulating in the reservoir R′ the engine E′ is kept at work, taking air from the reservoir R′ ultimately at the final pressure prescribed for said reservoir; but the air now expands no more in said engine than at first, while the engine takes air at a much higher pressure than when first started; consequently said engine exhausts its air still in a compressed state through the pipe *p*⁶, and finally accumulates in the reservoir R³ a pressure corresponding to the difference of pressures at which said engine takes and discharges its air.

The accumulation of pressure in the reservoir R³ enables the compressed-air engine E² to be set at work. This is done by simply opening the cock or throttle-valve *c*⁸ in the pipe *p*¹¹. The engine E² applies its work to the compression of air in the compressor C³. This compressor takes air for compression from the refrigerating-chamber A through a third induction-pipe, *p*¹², provided with a cock, *c*⁹. The compressed air from said compressor passes through a pipe, *p*¹³, into and through a cooler, B³, and thence through the pipe *p*⁸ to and into the reservoir R², the cock *c*⁷, previously closed, being opened when the compressor C³ commences its work. The relative pressures in the several reservoirs having been thus established are maintained by a proper velocity imparted to the piston of each engine, the required velocity being independently controlled in the several engines by adjustment of their respective throttle cocks or valves c, c^4, and c^8. The engine E^2 exhausts into the chamber A through the exhaust-pipe p^{14}.

I extend the pipes p^6 and p^{14} a greater or less distance through the air-space of the inclosure or refrigerator A, to carry out purposes hereinafter named, and I preferably place the reservoir R^3 within the said inclosure to assist in carrying out one of those purposes.

Having minutely described the circulation of the air through the apparatus organized as described, I will add that I do not confine myself to the number of engines and compressors indicated and described, nor to the precise manner of connecting the air-spaces in the different parts of the apparatus by pipes, nor to the exact arrangement of cocks or valves shown and described. Any manner of organizing the apparatus may be employed with three engines and compressors operating as shown and described, which, when the pressures have properly accumulated in the reservoirs, shall act as follows: One compressor, C′, in the series must be operated by steam or other prime motor to add an increment of pressure to cooled air already compressed by another or others of the series of compressors employed, in order to maintain a higher pressure of cooled air in one of the reservoirs than is maintained in others of the series. One engine must operate to take air from the reservoir in which such maximum pressure is maintained, expand it partly, and exhaust through a pipe or passage leading through the air-space of the refrigerating-chamber, which pipe will then perform the triple function of an exhaust-pipe, an induction-pipe, and a heater, as hereinafter more fully set forth. The partly-expanded air which passes through this pipe must expand in still another engine, and both the last-named compressed-air engines must expend their work in compressing air to supply the first-named compressor. Neither do I confine myself to a series of three engines and three compressors, as it is obvious that more than one compressor may be supplied with compressed air from a compressor or compressors which compress to a less degree, and that the compressor or compressors so supplied will respectively deliver air at a pressure equal to the sum of the pressures they are respectively constructed to effect and the pressures at which they take their air. In this way, with a single steam-engine working with a moderate pressure of steam and compressing air to a moderate degree, I am able to extend the system indefinitely and accumulate air in a reservoir at a pressure far exceeding the pressure the steam-engine alone could generate. Consequently I can obtain a far greater degree of expansion and cooling than I could effect by any single engine running independently.

To illustrate further this extension of the principle, I will, in general terms, describe a series of five engines, each driving a compressor, and one of the engines being driven by steam to compress to five atmospheres more than the pressure of the air inducted to it, each compressed-air engine expanding its air to five atmospheres less pressure than that of the air which is inducted to it, and each of the remaining compressors compressing its air to a pressure of five atmospheres more than that at which the air enters such compressors. In this case after the pressures have been obtained in the intermediate reservoirs by starting the engines and compressors successively, as hereinbefore described, the first compressor (which is driven by steam) of the series takes air already compressed to fifteen atmospheres from the reservoir of the second compressor and compresses the air five atmospheres more. The second compressor of the series takes air already compressed to ten atmospheres from the reservoir of the third compressor and compresses the air to fifteen atmospheres. The third compressor takes air already compressed to five atmospheres from the reservoir of the fourth compressor and compresses it five atmospheres more. The fourth compressor takes air direct from the refrigerator and compresses it to five atmospheres. The fifth compressor takes air also direct from the refrigerator and compresses it to five atmospheres, delivering its compressed air into the same reservoir as the fourth. At every compression the air passes through a cooler before entering a reservoir. The second engine takes air at twenty atmospheres from the reservoir of the first compressor (operated by the steam-engine) and expands the air down to fifteen atmospheres. The third engine takes air at fifteen atmospheres from the reservoir of the second compressor and expands the air down to ten atmospheres. The fourth engine takes air at ten atmospheres from the reservoir of the third compressor and expands the air down to five atmospheres. The fifth engine takes air at five atmospheres from the reservoir of the fourth compressor and completes the expansion, exhausting into the refrigerating-inclosure. After each expansion, except the last, the air, which is cooled to a low temperature by the performance of work during expansion, is heated more or less by passing it through a heater, (shown as a pipe, p^6, and reservoir R^3 in the refrigerating-inclosure,) by which it acquires greater expansive force, and also extracts heat of low intensity from said chamber. By placing the compressed-air engines in the refrigerating-inclosure I also increase the heating-surface acted upon by the low heat of the refrigerating-inclosure, and insure that all the cooling effect of the expansion shall be actually utilized or expended in said refrigerating-inclosure.

Having thus described the apparatus, I will now more fully point out the modes of procedure which I follow in cooling and drying air, which constitute parts of my invention.

I first accumulate different and graduated pressures in reservoirs, air-spaces, or pipes of an air-cooling apparatus by inducting to each of a series of three or more compressors cooled air already compressed to a lesser degree by another of said series until I reach in one of said reservoirs, air-spaces, or pipes a maximum pressure from which to begin a series of fractional expansions. I then expand the air in a series of air-expanding engines without recompressing it again until the original pressure is reached. The compressions are not only graduated but consecutive from the lowest to the highest in the series, and not alternated with intermediate expansions between the minimum and maximum pressures. The expansions are also graduated and consecutive, and not alternated with compressions between the maximum and minimum pressures. To increase the quantity of work performed by the air-expanding engines I also heat the air which exhausts from one or more of the air-engines, in which the air expands partly by passing such air, which, by its partial expansion, is cooled below the temperature of the refrigerating-inclosure, through a heater (pipe passage or reservoir) placed in said inclosure; and the chief end and purpose of my system of fractional expansions is to chill the air low enough, before its further expansion, that it may take up and utilize, as expansive force in further expansion, some heat from said inclosure. In this way, by expanding, say, four times from thirty-six atmospheres in equal decrements of nine atmospheres, the air may be passed, at much lower temperature than the apartment to be cooled, twice through heaters in such apartment, and thereby acquire a notable accession of expansive force through absorption of heat abstracted from the room, each centigrade degree of heat so absorbed increasing the expansive force by one two-hundred-and-seventy-third of what the same air would have at zero centigrade.

By this procedure I am able to obtain a very high degree of compression and expansion and consequent cooling without reducing the temperature in any of the air-engines lower than is due to the expansion in that engine alone. I am also able to obtain this high compression without compressing in any one of the compressors to a degree beyond the limit at which its engine can actuate it freely and easily and without the employment of very heavy fly-wheels, and can make all the moving parts of the apparatus of medium strength and weight. I also avoid the wear caused by friction under very great pressures and escape the inconveniences of freezing in the compressed-air engines which are met in the employment of very low temperatures consequent upon very great expansion in a single engine. Moreover, the low heat in the inclosure to be cooled is made available as a working force in the compressed-air engines when it is transferred to the compressed air previous to instead of after expansion, as is the case when the exhaust-air from a compressed-air engine is directly commingled with the air in the refrigerating-inclosure, as has heretofore been done. In this way also I obtain a very large amount of compression and expansion with consumption of a comparately very small amount of power by the steam-engine, as the volume of air to be compressed by the steam-engine is greatly reduced by previous compressions and coolings, while the increment of pressure per square inch of cylinder-area remains a constant quantity.

Another feature of my improvements in processes for cooling and drying air is the heating of the exhaust-air from the engine which exhausts its air fully expanded by heat transferred to said exhaust in the interior of the refrigerating-inclosure before permitting said exhaust to commingle with the warmer air of said inclosure. This I accomplish by the extension of the exhaust-pipe p^{14} in the drawings a considerable distance through the warmer air of the refrigerator A. The exhaust-air passing through this pipe approaches very nearly the temperature of the air exterior to said pipe, which thus forms a heater for said air; but I do not confine myself to this form of heater, as other forms may, of course, be substituted. By this means I avoid the generation of fog or visible vapor which results from the direct mixing of very cold air with warm moist air.

I dry the air in the refrigerator A to any desired extent by repeated abstraction of the air from the refrigerator, isolating it from moisture other than that contained in the air itself, compressing it, cooling it, whereby the moisture is precipitated, trapping out the precipitated moisture, and returning it, finally, to the refrigerator, where, having less moisture than is normal to its temperature and pressure, it acts as a drying agent upon the other air in the refrigerator, which, in the storage of fresh meat and many other articles, is constantly recharged with moisture during the early stages of the process of cooling.

I do not claim as my invention any form of cooler or trap, but have shown a convenient form in the drawings, the coolers being adapted to cool air by the circulation of water over surfaces of pipes through which the air passes, said pipes being inclosed in boxes through which water is caused to circulate.

At the lower part and the ends of each box are pockets or traps P, in which pet-cocks P^2 are inserted for drawing off the water which collects there.

By using the same air over and over and taking out the water, as described, I am able to dry substances in the inclosure A very rapidly at any temperature above the freezing-point of water, and can thus efficiently desiccate substances which drying by heat would injure. The heating of the air by compression converts its contained water into steam of high temperature. The cooling of the air while under pressure condenses the steam to water, in which state it falls to the bottom of the cooling apparatus. Then, in passing back to the inclosure A after expansion, the air has less than its normal moisture at the temperature and pressure at which it enters said inclosure, and therefore attracts and absorbs any free moisture or water-vapor with which it comes in contact. Moreover, in thus reducing the moisture in the compressed air while partially compressed, and before adding other increments of compression by successive compressors, I reduce the amount of power necessary to perform the successive compressions as the steam produced by compression when the water is allowed to remain in the air is a resistant force to be overcome in further compressions which it is desirable to remove. Lastly, the drying of the air by thus trapping out the water, and the prevention of fog formation by an exhaust-heater, produces the very best condition of air in the inclosure A for the rapid radiation of heat from the substances to be cooled in said inclosure, as it is well settled that the presence of aqueous vapor is one of the greatest obstructions to rapid radiation.

It will be seen that the apparatus, working as described, is analogous to a magneto-electric machine designed to produce a large quantity of electricity at low tension, instead of producing a smaller quantity having a higher tension. I obtain a large quantity of heating and cooling without an extremely low temperature anywhere in the apparatus; but by simple additions to the apparatus and a slight change of procedure, which I will now describe, I can reverse these conditions and obtain a lesser amount of cooling with a far greater intensity of cold.

The additions to the apparatus as heretofore described by which I am able to effect the said change in procedure and results are the by-passes p^{15}, p^{16}, and p^{17}. The by-pass p^{15} extends from a point in the pipe p^6 near where said pipe is connected with the exhaust-port of the engine E′ to another point in the same pipe near where it enters the engine E^2. Said by-pass is a short pipe provided with a cock, c^{10}.

The by-pass p^{16} connects the pipe p^{12}, leading from the compressor C^3 to the cooler B^3, with the pipe p^8, leading from said cooler to the reservoir R^2. This by-pass is also a short pipe provided with a cock, c^{11}.

The by-pass p^{17} connects the discharge-port of the compressor C^2 with the reservoir R^2. This is also a short pipe provided with a cock, c^{12}.

By opening the cock c^{11} in the by-pass p^{16}, I pass the air from the compressor C^3 directly to the reservoir R^2, thus supplying said reservoir with uncooled compressed air, the air in such case not circulating through the cooler B^3. Similarly, by opening the cock c^{12} in the by-pass p^{17}, I supply to the same reservoir uncooled compressed air from the compressor C^2. This heated and compressed air then receives another increment of heat by compression in the compressor C′, and thereby becomes heated to so high a temperature that water in the cooler B′, even if at a temperature of 100° Fahrenheit, would still act as a very efficient cooling agent. In expanding this air in the engines E′ and E^2, I open the cock in the by-pass p^{15}. Then the air in its passage no longer circulates through the heater p^6 R^3, and the full fall of temperature due to its total expansion in both engines is reached in the engine E^2, from which said air will issue intensely cold.

Although I have described my improved apparatus as taking air directly from and again delivering the air to the inclosure A, which inclosure is described as a refrigerating storeroom, it is obvious that such inclosure with walls constructed for the free transmission of heat and of any suitable form or dimensions may be used only for air, and be itself inclosed in a store-room for containing substances to be cooled. I therefore mean by the term "refrigerating-inclosure" to designate any inclosed air-space whatever to which air is supplied after expanding and performing work in the manner herein described, whether such air-space contains the substance other than air to be cooled, or whether the air-inclosure is itself to be cooled for the purpose of transmitting cold to or abstracting heat from any substance placed exterior to it through radiation or surface contact.

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

1. In cooling air for refrigerating purposes, where air is compressed, cooled artificially, and then expanded to perform work, the mode of obtaining artificially-compressed air having a lower temperature than that of the compartment or substances to be cooled, which consists in first obtaining a high degree of compression in moderately-cooled air by successive and consecutive compressions in separate compressors without intermediate expansions and with intermediate cooling, and then expanding the air so compressed by successive and consecutive expansions without intermediate compressions, whereby, after the first of the series of expansions, the still compressed air is brought to a temperature at which it may abstract heat from said compartment or substances to be cooled before further expansion, substantially as described.

2. In cooling air for refrigerating purposes, where air is compressed, cooled, and then expanded to perform work, the mode of adding to the expansive force of the compressed air and obtaining therefrom a maximum amount of work and refrigerating effect, which consists in heating the air after compression and cooling, and, after partial expansion in the performance of work, abstracting the heat for this

purpose from the refrigerating compartment or the substances to be cooled, and subsequently expanding the air further in the performance of work, substantially as described.

3. In a process of dynamic cooling in which a series of successive and consecutive compressions of air taken from a refrigerating-compartment is performed in a series of independent compressors delivering air one to another, to compress it from atmospheric pressure to a maximum pressure before any expansion of such compressed air is permitted, and in which the air is cooled between the several stages of compression so obtained, and in which the so-compressed air is expanded down to atmospheric pressure and then exhausted again into said refrigerating-compartment, the method of removing vapor resistance to compression, which consists in trapping out the water precipitated from the cooled and compressed air after the first stage of compression and before attaining the maximum pressure, substantially as and for the purpose specified.

4. The combination of a refrigerating-inclosure, an air-compressor, a cooler for cooling compressed air, a primary compressed-air engine driven by air discharged from the compressor for partly expanding said air, a supplementary air-engine driven by air exhausted from the primary engine for further expanding the air, and a heater placed in and extracting heat from said inclosure for heating the partly expanded and cooled air during its passage to said supplementary air-engine, substantially as and for the purposes set forth.

5. The combination, with a refrigerating-inclosure, of an air-compressor placed outside of said inclosure, a cooler for cooling the compressed air discharged from said compressor, and a compressed-air engine placed within said inclosure, driven by compressed air delivered from said compressor and applying its work outside of said inclosure, substantially as and for the purpose specified.

6. The combination, with a series of air compressors and coolers for compressed air, of one or more by-passes, whereby air compressed by one or more of the compressors may be passed without cooling into the cooler or coolers of another or other compressors in the series, substantially as and for the purposes specified.

7. The combination, with a series of compressed-air engines delivering air into a refrigerating-inclosure and heater, abstracting heat from said inclosure for heating said air on its way from one of said engines to another, of a by-pass through which said air may be delivered at will from one engine to another without being heated in its passage, whereby a very low temperature may be acquired in the expanded air, substantially as described.

8. An air-cooling apparatus consisting of a refrigerating-inclosure, a series of air-compressors supplied with air from said inclosure, air-coolers, a series of compressed-air engines delivering air into said inclosure and driving all the compressors but one, heater for abstracting heat from the inclosure and imparting heat to the air on its way from one engine to another, pipes for conveying the air, and cocks or valves for directing the flow of air through the different parts of the apparatus, all combined substantially as and for the purposes set forth.

9. In an apparatus for dynamic cooling wherein air is compressed, cooled, expanded to perform work, and exhausted into a refrigerating-compartment, a heater for heating the final exhaust of the expanded air previous to its intermingling with the air of such refrigerating-compartment, said heater being placed within the refrigerating-compartment and operating substantially as specified, whereby the production of fog by the sudden commingling of cold air with warm moist air is prevented, as herein described.

10. The combination of two air-expanding engines, one of which is driven by air partly expanded and exhausted from the other, and an intermediate reservoir for the reception and storage of the partly-expanded air previous to its induction to the engine in which it is to be further expanded, substantially as herein described, and for the purposes set forth.

LEICESTER ALLEN.

Witnesses:
CHAS. M. HIGGINS,
JOHN E. GAVIN.