I. H. REYNOLDS & F. E. NORTON.

APPARATUS FOR DRYING AIR.

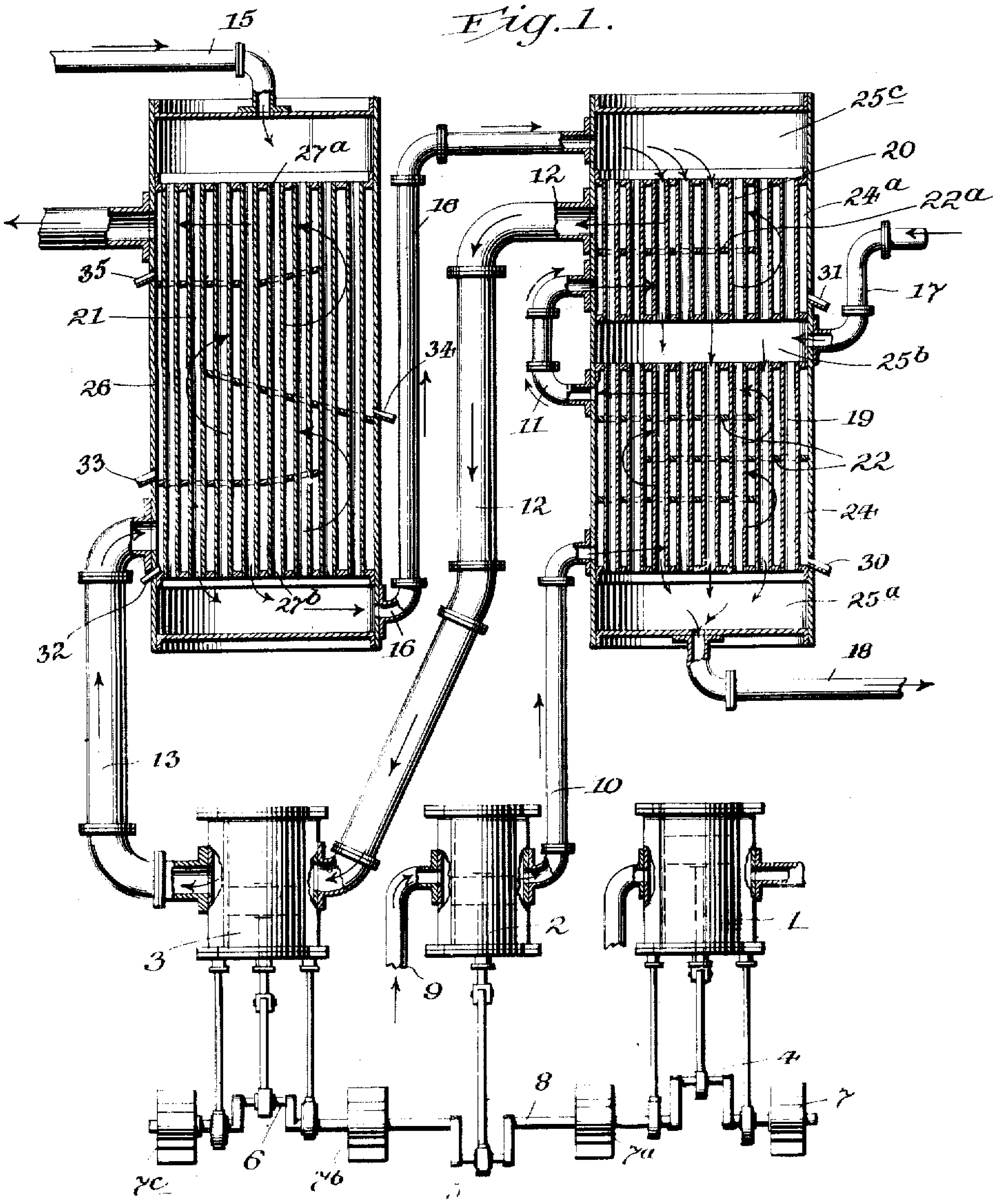
APPLICATION FILED JAN. 21, 1907.

946,069.

Patented Jan. 11, 1910.

2 SHEETS—SHEET 1.

Fig. 1.



Inventors.

Irving H. Reynolds and Fred E. Norton,

By Dodge and Sons, Attorneys.

Witnesses

C. H. Raeder

J. Stewart Rice

I. H. REYNOLDS & F. E. NORTON.

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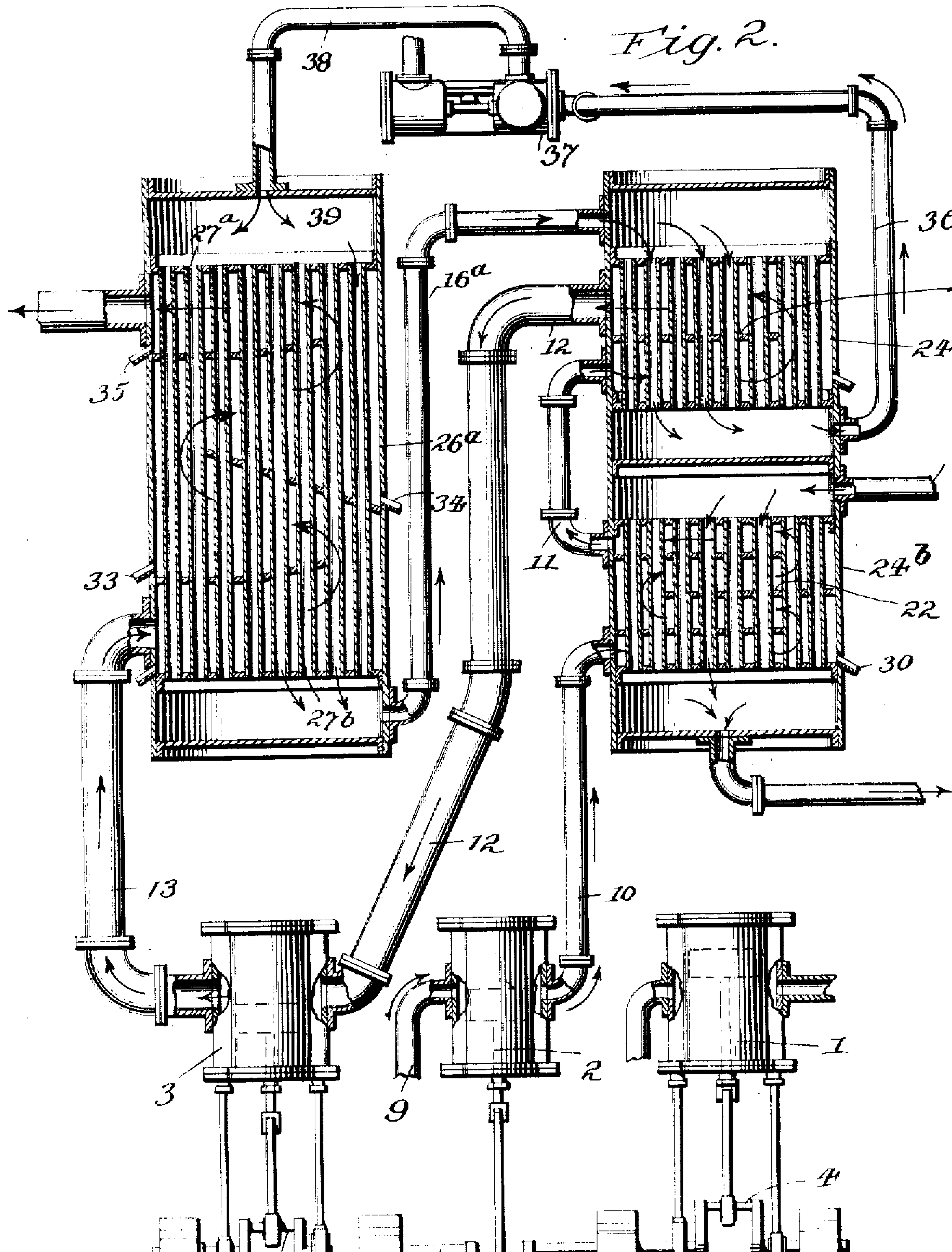
2 SHEETS—SHEET 2.

Fig. 2.



Inventors:

Irving H. Reynolds and Fred E. Norton,

Witnesses

C. H. Fowler

J. Stewart Rice.

By Dodge and Sons,

Attorneys.

UNITED STATES PATENT OFFICE.

IRVING H. REYNOLDS AND FRED E. NORTON, OF YOUNGSTOWN, OHIO.

APPARATUS FOR DRYING AIR.

946,069. Specification of Letters Patent. **Patented Jan. 11, 1910.**

Application filed January 21, 1907. Serial No. 353,358.

To all whom it may concern:

Be it known that we, Irving H. Reynolds and Fred E. Norton, citizens of the United States, residing at Youngstown, in the county of Mahoning and State of Ohio, have invented certain new and useful Improvements in Apparatus for Drying Air, of which the following is a specification.

Our invention relates to an improved apparatus for drying air, whereby the expansion of compressed air is utilized to a great extent.

The arrangement of the apparatus is such that the formation of snow and ice throughout the system is prevented.

The invention may be best understood upon reference to the annexed drawings, wherein:

Figure 1 is a diagrammatic view of one arrangement of the apparatus; and Fig. 2 a similar view showing a slightly modified form.

The main object of the invention is to utilize the expansion of compressed air for drying the air in a manner more effective than has, so far as we are aware, heretofore been practicable.

A further object of the invention is to provide means whereby the partial expansion of the compressed air as it passes from one portion of the apparatus to another may be utilized to assist the main motor in securing the initial compression of the air.

A still further object of the invention is to provide a system in which the formation of snow or ice is prevented and yet a low temperature employed so as to quickly and thoroughly remove the moisture from the compressed air as it passes through the system.

Another object of the invention is to provide a system in which the cooling medium for the air passes in a direction the reverse of that of the travel of the air through the system, thereby subjecting the air while in its most highly-compressed and moist condition to the cooling medium while said medium is at its lowest temperature, or at substantially such temperature.

The accompanying drawings disclose two forms of apparatus which fall within the scope of the present invention, but it is to be understood that the construction and arrangement of the parts may be modified so long as the essential features are retained.

Referring first to the apparatus shown in Fig. 1: 1 represents the motor cylinder of an air-compressing machine; 2 the compressor cylinder, and 3 the expanding cylinder. These cylinders are shown as all connected to a common crank-shaft 8, having three cranks 4, 5, 6, the shaft being supported or resting in suitable bearings 7, 7^a, 7^b, 7^c, as is usual in machines of this class. The air enters the compressor cylinder at 9 and after being compressed to a suitable degree is conveyed by a pipe 10 to a compound drier, comprising a lower drying chamber 24 and an upper drying chamber 24^a, the upper portion of the former being connected to the lower portion of the latter by a pipe 11. The air leaving the compressor through the pipe 10 passes around and about tubes 19 in the lower drying chamber 24, baffle-plates 22 therein causing it to pass back and forth from one side to the other of the drier before it enters the pipe 11. A baffle-plate 22^a, located in the upper drying chamber 24^a, causes the air to pass around the tubes 20 of said upper drying chamber before it enters pipe 12. The air is under constant compression during its passage through the driers 24 and 24^a.

The pipe 12 conveys the air to the cylinder 3, in which it is expanded to a suitable pressure or degree, and the work done by it is transmitted, through the piston mounted in the cylinder, to the crank 6 and shaft 8, and as a consequence to crank 5 and thence to cylinder 2, where the greater part of the force is usefully exerted to aid in compressing air entering at 9 and leaving through pipe 10. The air leaving the cylinder 3 will be considerably cooled, and passes by pipe 13 to the cooler 26 and around tubes 21 mounted therein, the baffle-plates 23 in said cooler 26 causing the air to take a circuitous route or passage therethrough. The air is in a constantly compressed state during its passage through the cooler 26 though the pressure is lower than in the driers 24 and 24^a.

In the form of cooler shown water supplied from any suitable source enters by pipe 15 and flows through the tubes 21 in a direction from 27^a to 27^b, while the air outside of the tubes circulates in the opposite direction, or from the lower to the upper portion of the cooler. As a consequence the temperature of the water leaving the cooler at the lower portion thereof by the pipe 16 may be reduced to within a few degrees of the temperature of the air at the lower portion of the cooler 26, and in practice this may be as near the freezing-point as is practicable to avoid freezing of the water.

The temperature of the water in the pipe 16 as it passes from the lower end of the cooler 26 to the upper portion of the drier 24^a, or the chamber 25^c in the upper part thereof, may be made to approximate as nearly as desired the temperature of the air in the lower portion of the cooler 26 by regulating the quantity of water passing into said cooler through the pipe 15, which regulation may be effected in any desired manner. As before noted, the water passes from the pipe 16 into the chamber 25^c. It then flows through the tubes 20 and into a space 25^b, thence through tubes 19 to a space 25^a, from which it is discharged by a pipe 18 to any convenient point of waste. Additional water may be introduced into the space 25^b through a pipe 17.

The purpose of the invention may be best illustrated by a concrete example. 30,000 cubic feet of atmospheric air per minute, saturated at 82° F. are required to be compressed to 15 lbs. gage-pressure and delivered with a moisture-content of less than one grain per cubic foot of original volume. At atmospheric pressure of 14.7 lbs. per square inch and 82° F. the air will contain 12.6 grains of moisture per cubic foot, or 30,000 cubic feet will contain 54 lbs. of moisture. In order to obtain the proper cooling effect by expansion in cylinder 3, the air should be compressed in cylinder 2 to 42 lbs. absolute pressure per square inch, or, say, 27 lbs. gage-pressure. The work of compression is 2280 H. P. and the air will leave the cylinder 2 at a temperature of 270° F. The cooling water entering by pipe 15 may be assumed to be at the same temperature as the air entering the cylinder 2, *i. e.* 82° F.

The air may be cooled in passing through the drier 24, so that it enters pipe 11 at 92° F. The cooling water passing through the pipe 16 may be reduced to 42°F. without danger of freezing, and consequently the air in pipe 12 may conveniently be reduced to 52° F. On expanding in cylinder 3 the pressure is reduced to 15 lbs. per square inch gage-pressure, and the temperature falls to 6° F. The air entering the cooler through pipe 13 may thus be reduced to 6° F. or 26° below freezing, and may be heated in passing around the tubes 21 to 72° F., at which temperature it is available for any use. In passing through the cooler 26 it, of course, absorbs the heat from the water flowing through the tubes therein, and thus reduces the temperature of the water, by the time the latter reaches the lower end of the cooler 26, to approximately 42° F.

The moisture-contents of the air at the various points will be as follows: Entering pipe 9, 12.6 grains per cubic foot free air; in pipe 11 6.2 grains; in pipe 12 1.4 grains; in pipe 13 the moisture will be reduced to one-fourth of one grain per cubic foot of free air. The air becomes heated in passing about tubes 21, but being dry no moisture is gained or lost. The work done in cylinder 3 is equal to 530 H. P., which taken from 2280 H. P. required for compression in cylinder 2, leaves but 1750 H. P. to be exerted by the motor cylinder 1. If the air had been directly compressed at atmospheric pressure and 82° F. to 15 lbs. gage-pressure, the horse-power would have been 1530 H. P., so that by the expenditure of 180 H. P. the air may be reduced to almost absolute dryness.

As above noted, one of the main advantages of the present invention resides in the fact that three sets of cooling surfaces, namely, the tubes or pipes 21, 20 and 19 (in the construction shown) are arranged in such manner that the air circulates around them in series in the order of 19, 20, 21, while the cooling water passes in the order of 21, 20, 19, with an additional cooling water supply between 19 and 20 if so desired. This arrangement of the apparatus results in the consumption of a minimum amount of power. The cooling surfaces may be small and the cost thereof low, since even in the extreme case noted above the surfaces need not be greater than those commonly utilized for air and gas coolers.

With the apparatus herein set forth nearly all of the moisture is removed from the air before it enters the expansion cylinder 3, thus enabling us to employ a temperature lower than has heretofore been possible on account of the difficulty experienced from the clogging of the exhaust ports and passages leading from the expansion cylinder. The apparatus also provides for the complete removal of the moisture in the form of water, without the possibility of the formation of ice or snow in any portion of the apparatus which, as will be readily appreciated, would clog the same.

It will be noted that the tubes 20 are maintained at a low temperature by the cool water flowing through them, but this never reaches the freezing-point. The tubes 21 in the cooler 26 would similarly be above freezing-point, and any snow tending to collect upon them would be melted and drawn away through suitable drains, such as 32, 33, 34 and 35. In a similar manner, the moisture would be removed from the tubes 19 and 20 by the drains 30 and 31.

Fig. 1 shows the arrangement of the compound drier 24, 24^a, but it is evident that the apparatus is subject to modification, and in Fig. 2 is shown a system in which separate driers 24^b and 24^c are employed, so far as the cooling medium which passes through the same is concerned. In said figure it will be noted that pipe 16^a which passes from the lower portion of the cooler 26^a discharges into the upper portion of the drier 24^c. The water passes from the lower portion of said drier into a pipe 36 which leads to a pump-chamber 37. Said chamber discharges through a pipe 38 into the upper portion 39 of the cooler 26^a. In this way the water is passed continuously through this portion of the system, while the initial drier 24^b is supplied through a separate pipe 40 from any suitable source. By this arrangement the water passing through the cooler 26^a and drier 24^c is used over and over again. The temperature at the lower portion of the cooler 26^a may be still further reduced if a strong solution of brine is used instead of pure water.

In the drawings one form of air-compressing mechanism is shown, but it is evident that any of the common forms of such machines may be employed, and the invention is, therefore, not to be limited to any particular type of apparatus. It is also evident that instead of using tubes to convey the cooling medium, the latter may be passed around the tubes and the air circulate through the same. In fact, the cooling chambers may be constructed in any suitable way known to the art, or in other words, the drawings are to be considered as merely diagrammatic and illustrative of the principles involved in the invention.

While throughout the specification the members 24 and 24^a have been referred to as "driers", and 26 as a "cooler", it is to be noted that the former, to wit, 24, 24^a act both as driers and coolers. The member 26, however, acts only as a cooler and will be thus referred to in the claims.

No claim is herein made to the method of drying air, as disclosed in this case, as said method forms the subject-matter of a divisional application filed by us under date of December 4, 1909, Serial No. 531,425.

Having thus described our invention, what we claim is:

1. In an apparatus for drying air, the combination of a compresser; an air-drier; means for conducting the highly compressed and heated air from the compressor into said drier, wherein, by reason of the action of the drier, the air is deprived of its moisture and lowered in temperature; a motor cylinder; means for conducting the dry and relatively cold air from the drier to the cylinder, wherein it exerts power by expansion and is further cooled; a cooler for the cooling medium of the air-drier; means for conducting the cold air which passes from the motor cylinder into said cooler; and means for conducting the cooling medium from the cooler to the drier.

2. In an apparatus for drying air, the combination of a drier for the air; a cooler for the cooling medium of the drier; means for conducting said medium from the cooler to the drier; a compressor discharging compressed and hot air into said drier, such air being deprived by said drier of its contained moisture and lowered in temperature; a motor cylinder receiving the dry and relatively cool air from said drier, such air exerting power in said cylinder by expansion and being thereby further cooled; and means for discharging the expanded and cold air from said cylinder into the cooler.

3. In an apparatus for drying air, the combination of a compressor; a drier into which said compressor discharges; a motor into which the compressed and dried air from the drier is discharged, said air as it expands actuating the motor; a cooler for chilling the cooling medium of the drier and into which the air from the motor is directly discharged while in its cold state; and means for conveying the cooling medium through the cooler and drier in a direction the reverse of that of the travel of the air.

4. In an apparatus for drying air, the combination of a drier for the air; a cooler for chilling the cooling medium of the drier; means for conducting said medium to the drier; an engine; a compressor; an air motor; a shaft common to the engine, compressor and motor; means for conducting the compressed and thereby highly heated air from the compressor to the drier, wherein it is deprived of its contained moisture and lowered in temperature; means for conducting the dried air from the cooler to the motor, wherein it is further cooled by reason of its expansion in operating the motor; and means for conducting the cold air to the cooler.

5. In an apparatus for drying air, the combination of driers and a cooler for lowering the temperature of the cooling medium of the driers, said driers and cooler being connected for the passage of air therethrough in one direction and the passage of a cooling medium in the opposite direction; a compressor for supplying compressed air to the first drier of the series; and a motor actuated by the expansive action of the air, said motor having its intake connected with one of the driers remote from the compressor, and its discharge connected directly with the air space of the cooler.

6. In an apparatus for drying air, the combination of an air-compressor; a cold condensing surface against which the compressed air is discharged and thereby deprived of its contained moisture; means for securing an expansion of the dried air as it passes from the condensing surface and thereby lowering its temperature; a cooler for the cooling fluid of the condensing sur-

face; means for conveying the cooling medium from the cooler to said surface; and means for passing the cold air from the air-expansion means to and through the cooler.

7. In an apparatus for drying air, the combination of a drier for the air; a cooler for the cooling medium of the drier; means for conducting the cooling medium from the cooler to the drier; an air-compressor, said compressor discharging into the drier, the air passing therethrough in a direction the reverse of the travel of the cooling medium therein and in its passage being deprived of its contained moisture and lowered in temperature; an expanding cylinder into which the dried and partially cooled air is discharged from the drier, whereby the air by reason of its expansion is further cooled; and means for discharging the cold air into the cooler, the air passing therethrough in a direction the reverse of the passage of the cooling medium, whereby the passage of the air and the cooling medium throughout the apparatus will be in opposite directions, the temperature and pressure of the air as it passes from the compressor to the drier being at their highest points, the temperature and pressure being reduced as the air passes through the apparatus so that the air in a relatively cold state is introduced into the cooler, while the temperature of the cooling medium is at its highest point as it is first introduced into the cooler and relatively low as it is passed into the drier.

8. In an apparatus for drying air, the combination of a drier for the air; a cooler for chilling the cooling medium of the drier; means for conveying said medium from the cooler to the drier; an air-compressor discharging into the drier, whereby the air is cooled and deprived of its moisture content; a motor into which the dried air is discharged from the drier, the air by reason of its expansion being further cooled; means for conveying such cooled air from the motor to the cooler and thereby effecting a chilling of the cooling medium; and means for passing water from an outside source into the drier.

9. In an apparatus for drying air, the combination of a drier for the air; means for passing water from an outside source through the initial portion of the drier and permitting the same to freely discharge; a cooler for chilling the cooling medium which cools the secondary portion of the drier; means for conveying the cooling medium from the cooler to the drier; a compressor discharging directly into the drier, the air in its passage through the drier being deprived of its moisture content and cooled; and a motor into which the dried and cooled air is discharged from the drier, said air in expanding actuating the motor and becoming further cooled, such cooled air being discharged from the motor into the cooler through which it passes, thereby chilling the cooling medium.

10. In an apparatus for drying air, the combination of a drier; a cooler for cooling the cooling medium of the drier; means for conducting said medium from the cooler to the drier; a compressor discharging compressed air into the drier, wherein it is deprived of its moisture content and lowered in temperature; means for conducting the dry air from the drier to the cooler; and means for further lowering the temperature of the air as it passes from the drier to the cooler.

11. In an apparatus for drying air, the combination of a compressor; a two-part drier into the initial portion of which said compressor discharges; a motor into which the compressed and dried air from the drier is discharged, said air as it expands actuating the motor; a cooler for chilling the cooling medium of the secondary portion of the drier and into which cooler the air from the motor is directly discharged while in its cold state; means for conveying said cooling medium through the cooler and the secondary portion of the drier in a direction the reverse of that of the travel of the air; and means for introducing water from an outside source to the initial portion of the drier to chill the same.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses.

IRVING H. REYNOLDS.
FRED E. NORTON.

Witnesses:
REGINALD P. DOYER,
HELEN M. HALLBERG.