Oct. 16, 1928.

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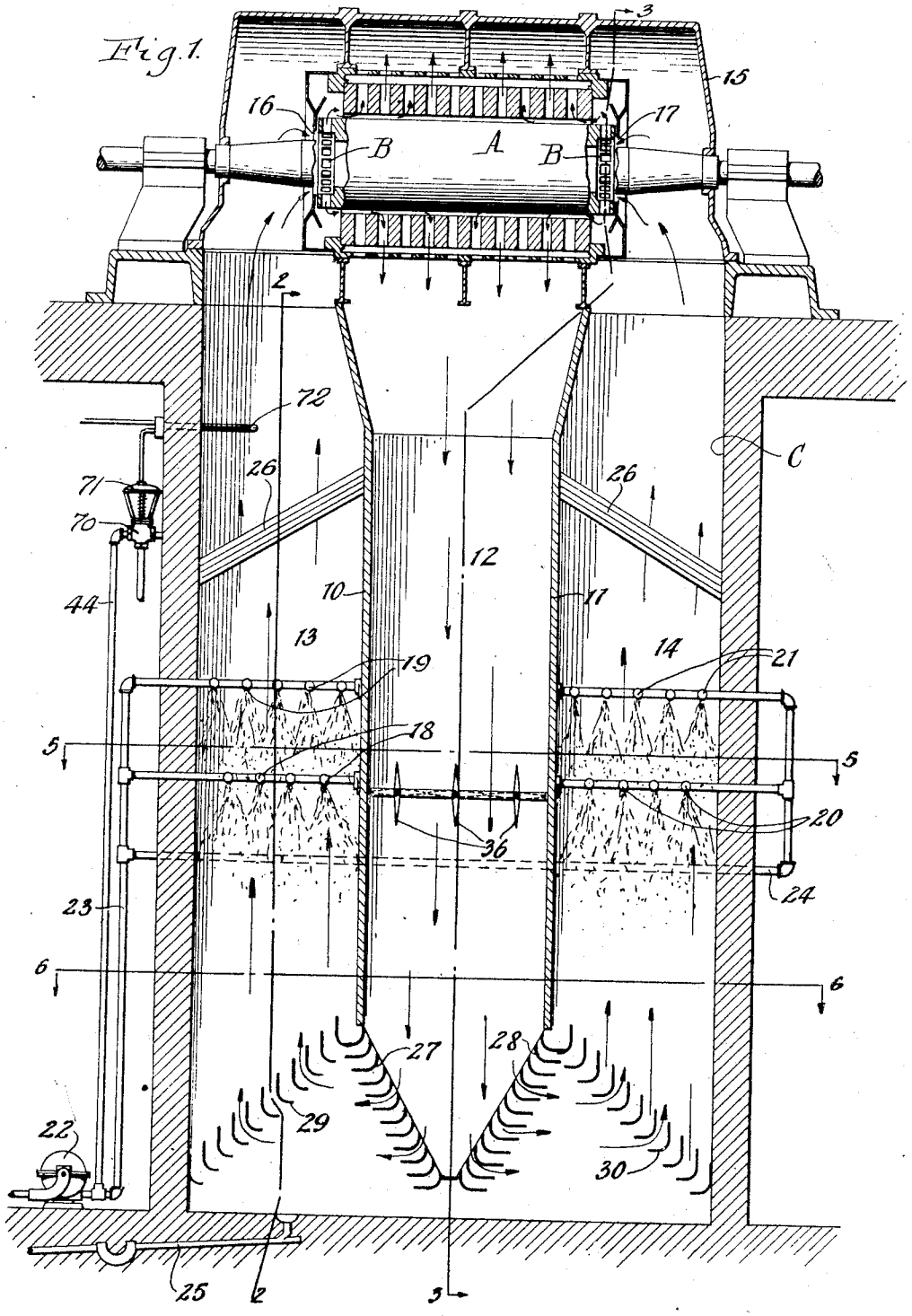
W. H. CARRIER

COOLING SYSTEM

Filed July 28, 1921

6 Sheets-Sheet 1

Fig. 1.



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Fig. 2

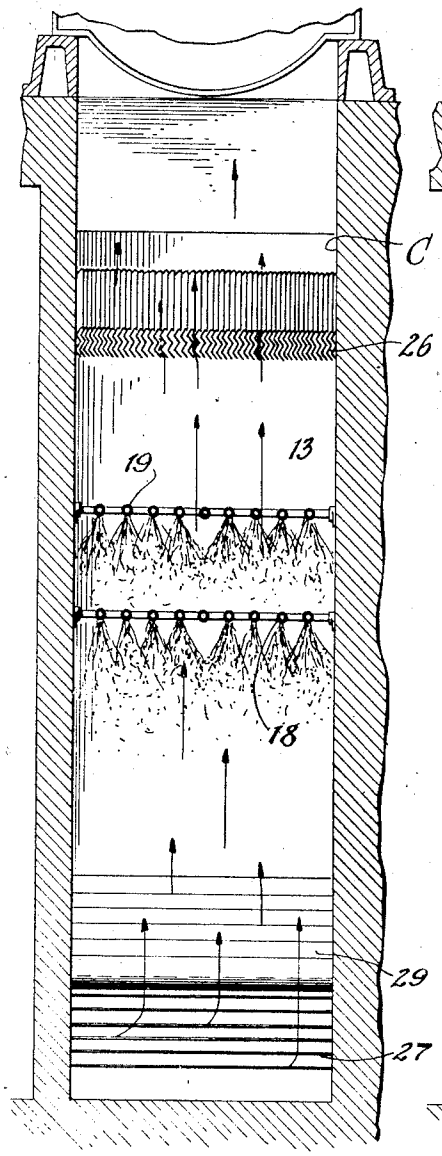
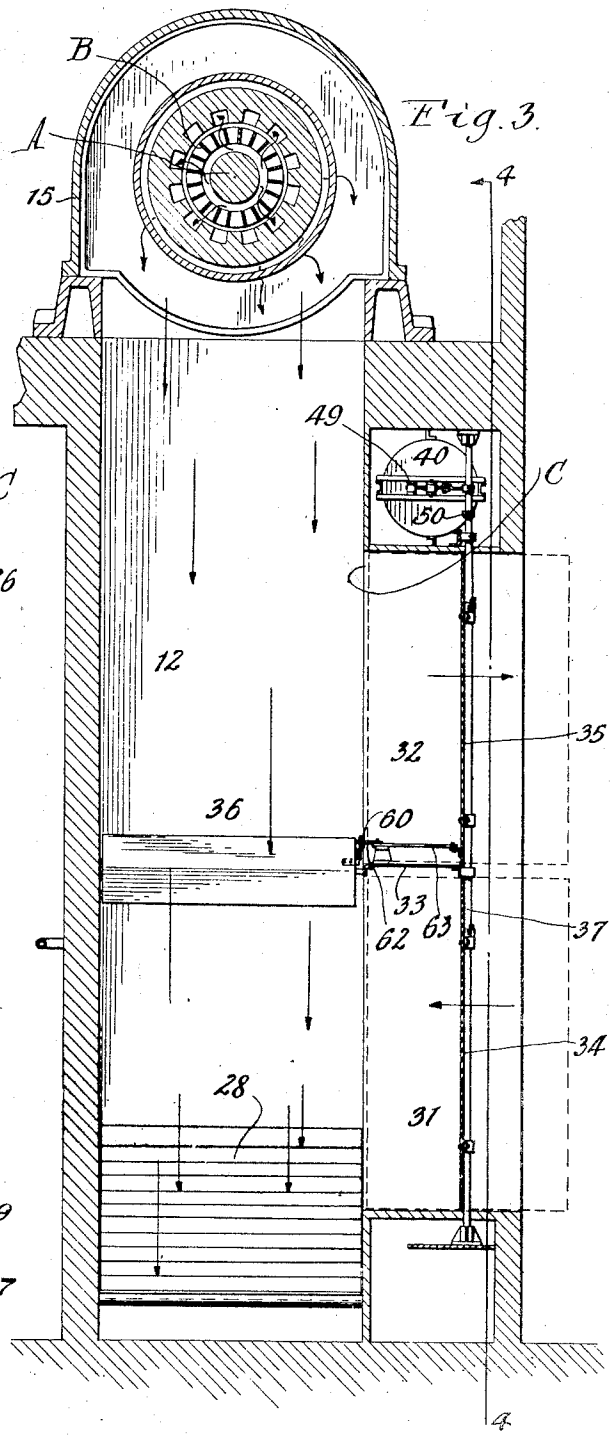


Fig. 3.



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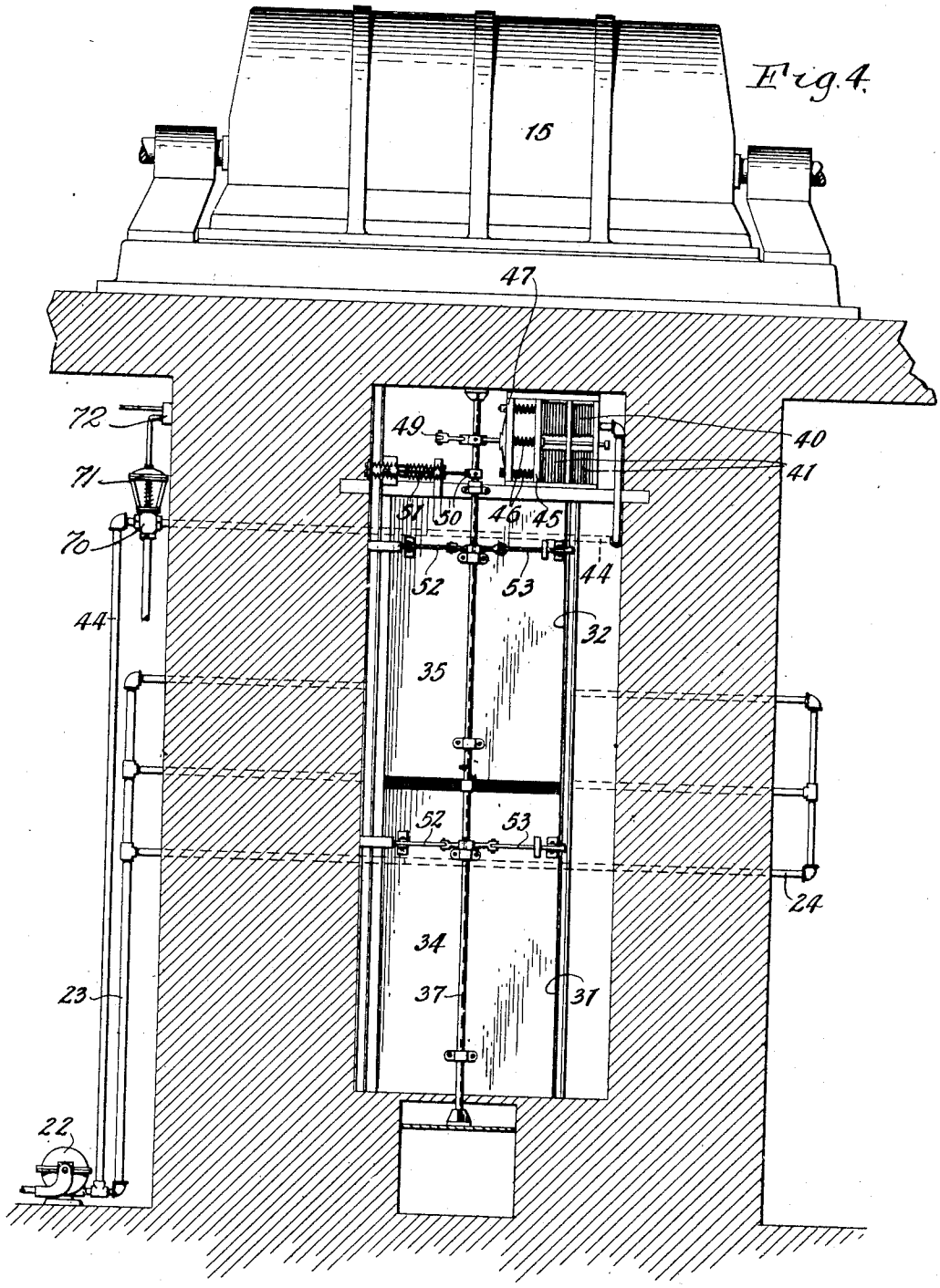
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Fig. 4.



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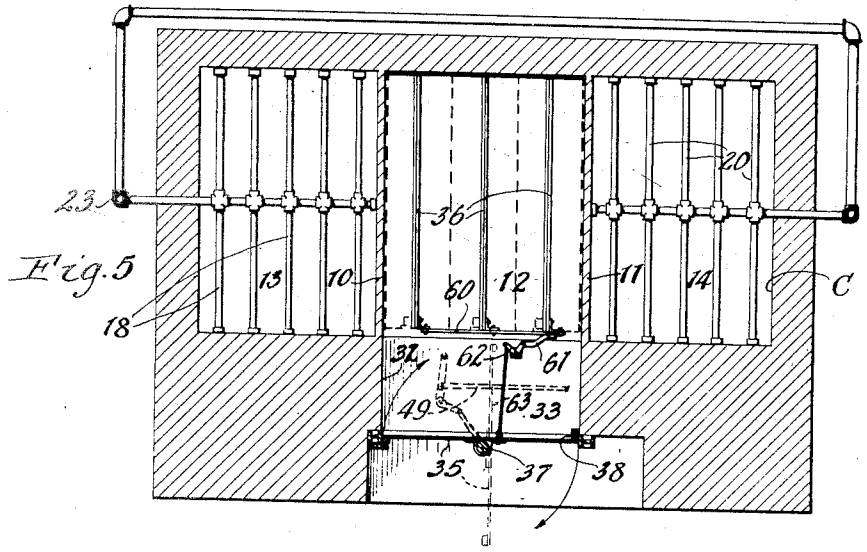


Fig. 5

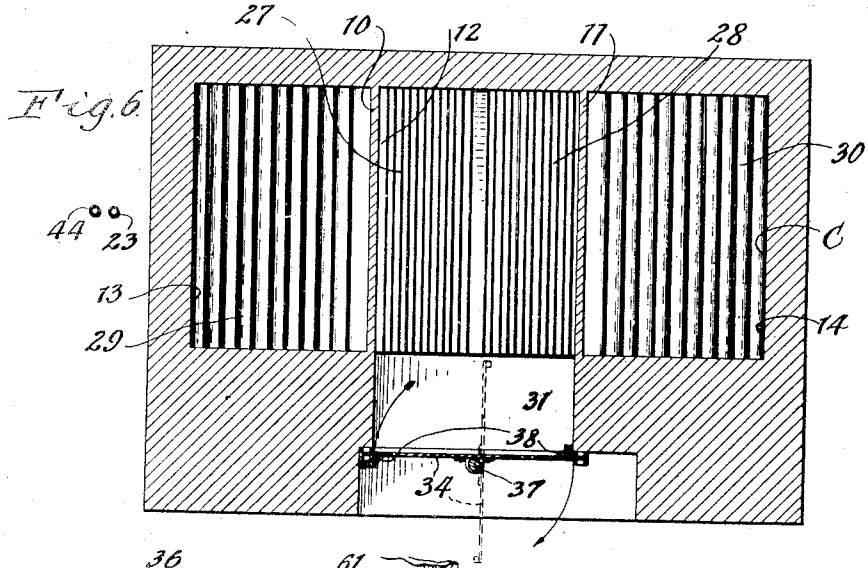


Fig. 6

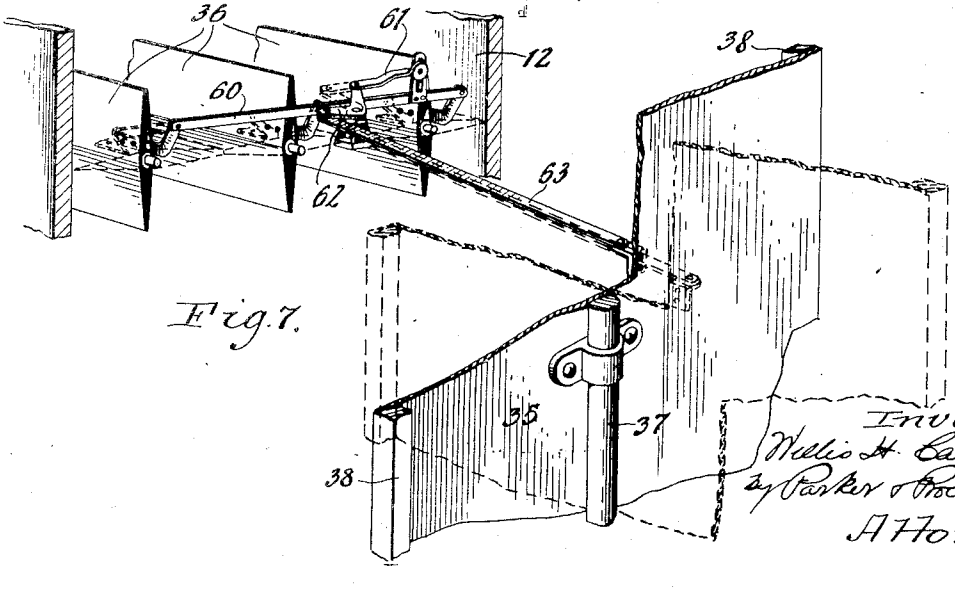


Fig. 7

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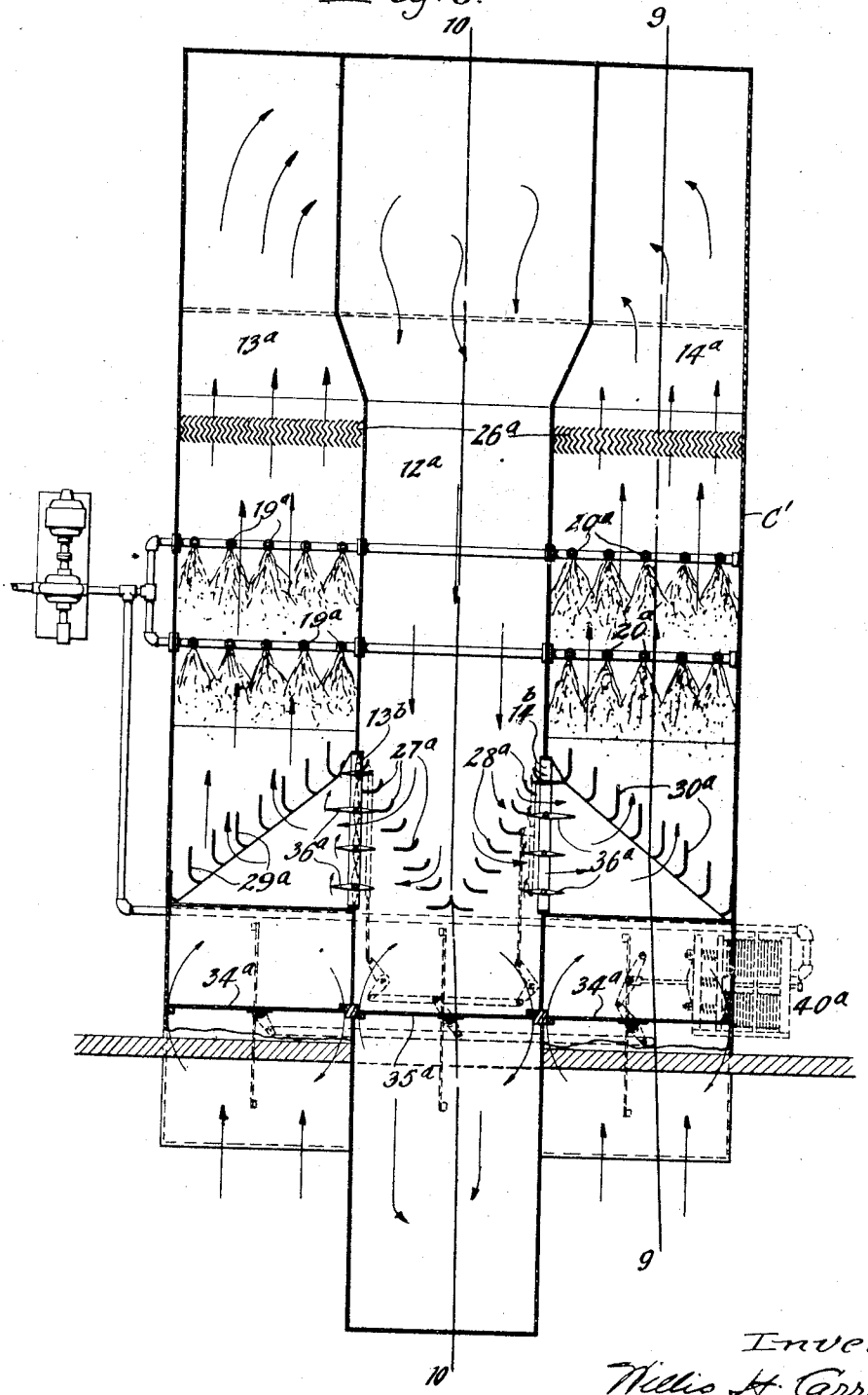
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Fig. 8.



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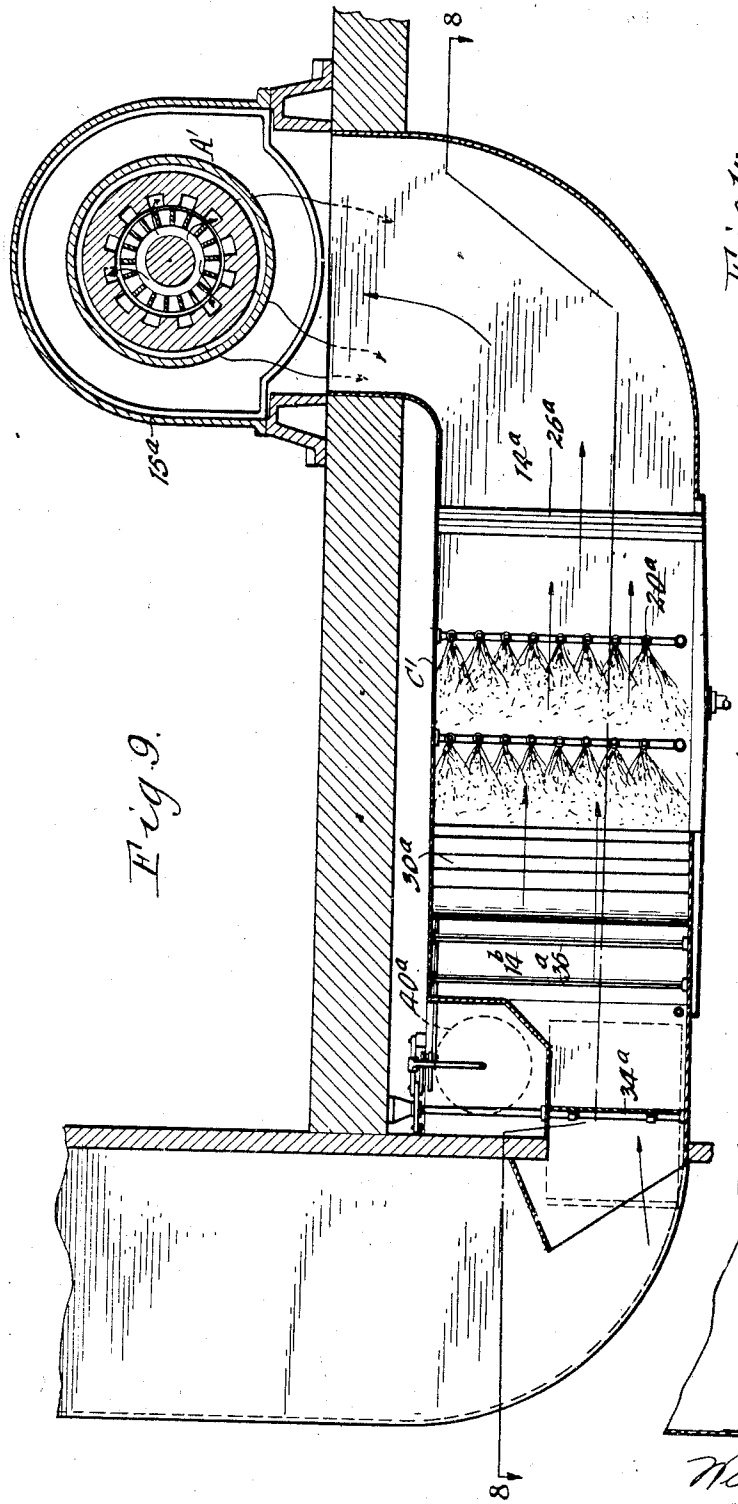


Fig. 9.

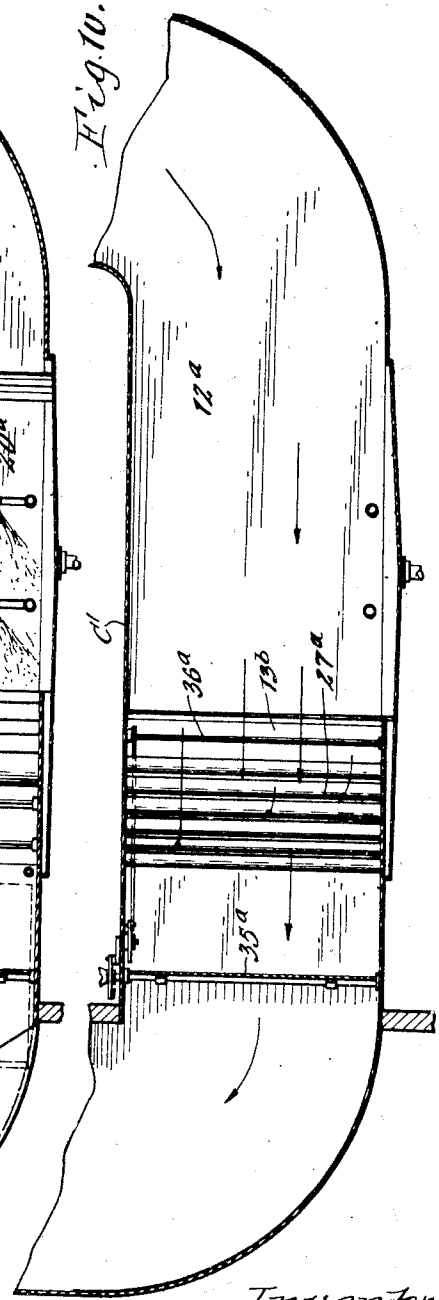


Fig. 10.

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COOLING SYSTEM.

Application filed July 28, 1921. Serial No. 488,116.

Electrical generators, when in operation develop a considerable amount of heat and it is necessary to make provision for cooling the generators to prevent them from overheating and being injured. For this purpose generators as ordinarily designed have fans built into them for producing a circulation of air through air spaces in the generator for cooling the same. Outside or fresh air has been used for generator cooling, but a serious objection to the use of outside air is that it is ordinarily more or less dirty and usually contains smoke or carbon in a very fine condition, which causes the clogging up of the air spaces in the generator and short circuiting the windings. Washers and filters of various kinds have been tried for cleaning the air but in spite of this there is a great deal of the fine carbon or smoke which cannot be removed from the air by any of the types of washers heretofore devised, and which will deposit and accumulate on the windings of the generator, due to the high velocities and the small size of the air spaces. With a view to avoiding the use of such dirty outside air, attempts have been made to recirculate the generator cooling air in a closed system, but in such closed recirculating systems in which the same air passes through the generator again and again, it is necessary to cool the air, and the air recirculating systems heretofore tried have been unsatisfactory from one cause or another, such as being prohibitively expensive, or not being efficient in producing the necessary cooling of the air.

In an air recirculating system it is also necessary to make provision for supplying outside air when the cooling system is not functioning properly, as for instance, in case the supply of water which is used for cooling the air should be reduced or fail from any cause, such as the bursting of a pipe or the stopping of the water pump. In such an event, it is essential to provide promptly the necessary cooling by admitting outside air. Without some such provision which will operate immediately and effectively, the generator would be burned out.

One of the objects of this invention is to provide an efficient, practical and economical cooling system for generators in which the air is recirculated and is cooled and washed by direct contact with a water spray. Another object is to provide such a system with inlets for admitting outside air, which inlets, in the normal operation of the system, are tightly closed to prevent the admission of any dirty air, but are automatically and immediately opened to admit the outside air for cooling the generator in the event of the failure or reduction in the pressure of the cooling water from any cause. Another object is to provide an automatically operating, three-way arrangement of dampers providing for recirculating the air whenever water pressure is available for the water cooling sprays and which, upon failure of the water pressure, will close the recirculating dampers and open admission and relief dampers to permit the supply and relief of outside air. Another object is the provision of a system for generator cooling in which the cooling air is recirculated and the heat is removed from the air by means of direct sprays of water discharged in opposition to the direction of air flow, the excess water being removed by means of eliminators. Another object is to cool the recirculating air by means of a plurality of sets of water sprays arranged to act on the air in series in such a way that one set of sprays has the effect of raising the moisture content of the air and the succeeding set or sets of sprays to condense the excess moisture out of the air and produce additional cooling. This spray system of cooling operates in two ways. First, the air is cooled by evaporation, the air becoming practically saturated, due to the evaporation, then the excess moisture is removed by the use of the succeeding set or sets of sprays having a water temperature below the wet bulb temperature of the entering air and also below the dew point of the air.

Other objects of the invention are to provide means for rectifying the flow of air and uniformly distributing the same throughout the area of the air conduits so as to insure uniform and efficient cooling and cleaning of the air; and also to provide means which will insure the ready and immediate opening of the outside air admission dampers, which are normally closed tightly, even though they may become frozen, which is liable to happen in cold weather.

In the accompanying drawings:

Fig. 1 is a sectional elevation of a generator cooling system or apparatus embodying the invention.

Figs. 2 and 3 are sectional elevations thereof on lines 2—2 and 3—3 respectively, Fig. 1.

Fig. 4 is a sectional elevation thereof on line 4—4, Fig. 3.

Figs. 5 and 6 are sectional plan views thereof on lines 5—5 and 6—6 respectively, Fig. 1.

Fig. 7 is a sectional perspective view of the deflecting and relief dampers and their connections.

Fig. 8 is a sectional plan view on line 8—8, Fig. 9 of a modification of the system shown in Figs. 1–7.

Figs. 9 and 10 are sectional elevations thereof on lines 9—9 and 10—10 respectively, Fig. 8.

Referring first to the system as shown in Figs. 1–7, A represents an electric generator which may be of any type or construction adapted to be cooled by air and which is provided at its opposite ends with the usual fans B, which in the operation of the generator cause the circulation of air through the air spaces or openings in the generator. As shown in these figures, the generator is supported over a vertical air shaft or chamber C, which is divided by transverse, upright partitions 10 and 11 into a central air return conduit 12 and two air supply conduits 13 and 14 disposed at opposite sides of the return conduit 12. The generator is enclosed by a casing 15 with which the upper end of the return conduit 12 communicates between the ends of the casing, and the upper ends of the supply conduits connect with the ends of the casing 15 and communicate through openings 16 and 17 with the fans B at the ends of the generator. The supply and return air conduits connect at their lower ends around the lower ends of the partitions 10 and 11. The generator fans B are thus adapted to draw the air from the supply conduits 13 and 14 and blow it through the generator into the return conduit 12, the air thus being recirculated and passing repeatedly through the generator.

18 and 19 represent spray nozzles arranged preferably in two sets one above the other in the supply conduit 13 and 20 and 21 represent spray nozzles preferably arranged similarly in two sets one above the other in the other supply conduit 14. Water is supplied under pressure to these spray nozzles, and the nozzles are constructed and arranged so as to discharge the water in a very fine spray or mist and preferably in a direction opposed to the direction of flow of the air through the conduits 13 and 14. Cool water can be supplied to the spray nozzles from any suitable source, such as the ordinary city water service system or by means of a pump drawing the water from a river, cooling pond or other source. In the system shown, a water supply pump 22 is provided, the discharge pipe 23 of which connects with headers for the nozzles 18 and 19 and connects by a branch pipe 24 with headers for the other sets of spray nozzles 20 and 21. The waste water from the spray nozzles escapes from the bottom of the air shaft C through a suitable drain or outlet 25.

In each of the air supply conduits 13 and 14, above the spray nozzles, is arranged an eliminator 26 for removing free moisture from the air after it passes the water sprays. Each of these eliminators preferably consists of a series of parallel, spaced zig-zag plates forming between them zig-zag passages through which the air passes so that the air in passing between the eliminator plates is caused to impinge against the successive inclined faces of the plates and deposit the free particles of water on the plates. The eliminator plates preferably extend across the conduits 13 and 14 at an inclination so that the water removed from the air by the contact of the air with the plates, is adapted to flow lengthwise along the surfaces of the plates and down the walls of the conduits into the bottom of the air shaft or chamber.

In order to change or rectify the direction of the air as it passes from the return conduit into the supply conduits, prevent the formation of eddies in the bottom of the air shaft or chamber, and insure an equal distribution of the air throughout the supply conduits so that all portions of the air will come into intimate contact with the water sprays, deflectors or partitions are provided in the lower portions of the conduits 12, 13 and 14. These deflectors preferably consist of spaced, curved or bent plates extending horizontally across the conduits and having upright upper portions and laterally extending lower portions. Preferably the deflector plates are arranged in four sets of series, two sets 27 and 28 extending in stepped order downwardly and towards each other from the lower ends of the partitions or walls 10 and 11, and the remaining two sets 29 and 30 extending downwardly and outwardly from the lower ends of said walls 10 and 11 to the lower corners of the shaft or chamber C. As the air flows downwardly through the return conduit 12, it passes between the deflectors of the two sets 27 and 28 and is thereby divided and deflected from a vertical to a horizontal direction toward the remaining sets of deflectors 29 and 30, and as the air passes between these deflectors its direction is again changed from a horizontal to a vertical direction upwardly into the supply conduits 13 and 14. The deflectors thus reverse the flow of the air from a descending to an ascending direction without the formation of eddies in the bottom of the shaft or chamber and at the same time, equally distribute the air throughout the horizontal cross section of the ascending conduits.

The air chamber C is provided at one side thereof, opposite the central return air conduit 12, with an outside or fresh air inlet opening 31 and an air relief or exit opening 32 arranged one above the other and separated by a horizontal partition 33. These openings 31 and 32 are controlled by air admission and exit dampers 34 and 35 respectively, and in the central or return air conduit 12 opposite the partition 33 are arranged deflecting dampers 36. In the normal operation of the system, when the air is being recirculated through the conduits 12, 13 and 14, the fresh air inlet and relief dampers 34 and 35 are closed and the deflecting dampers 36 are open. Under these conditions, therefore, no outside air is admitted to or discharged from the air circulating conduits, and the air for cooling the generator is all recirculated, passing upwardly through the supply conduits 13 and 14, through the generator and back through the return conduit 12 into the lower ends of the supply conduits 13 and 14. In the event however, of a failure of the supply or required pressure of cooling water from any cause, or the heating of the air above a predetermined temperature, the construction described enables the dampers 36 to be closed and the fresh air admission and relief dampers to be opened. Outside air for cooling the generator can then enter through the inlet opening 31 into the return conduit 12 below the deflecting dampers 36, flow around the lower ends of the partitions 10 and 11 and up through the supply conduits 13 and 14 to the generator, returning through the portion of the return conduit 12 above the dampers 36 and discharging through the relief opening 32.

It is desirable to have the outside air inlet and relief openings tightly closed to prevent the leakage of outside air into the system during its normal operation and to open them automatically and promptly when outside air is necessary, as above indicated. For this purpose the dampers 34, 35 and 36 are preferably arranged and operated automatically as follows:

The dampers 34 and 35 are mounted one above the other to turn horizontally by means of a central vertical operating shaft 37, and each of these dampers is provided at its edges with weather strips 38 of known construction or other means for producing tight closures of the admission and relief openings. The damper operating shaft 37 is actuated by a suitable motor 40 which is constructed and connected with the water supply for the spray nozzles so that in the normal operation of the system, the water pressure will retain the dampers 34 and 35 closed, and when the water pressure fails or is reduced the motor will act to open these dampers. The dampers 34 and 35 are operatively connected to the dampers 36 so that the latter dampers will be closed by the opening of the outside air dampers 34 and 35, and will be opened by the closing of said outside air dampers.

In the preferred construction shown in the drawings, the motor, see Figs. 3 and 4, consists of a group of sylphon diaphragms 41 which communicate with each other by suitable passages and are connected by a pipe 44 with the pump discharge or water supply pipe 23 for the spray nozzles. The several diaphragms 41 act upon and are adapted to move a movable head or member 45, the movement of which by the water pressure in the diaphragms is opposed by springs 46 arranged between the movable head 45 and a stationary abutment 47. The movable member 45 of the motor is connected by a rod and suitable lever mechanism 49 to the operating shaft 37 for the outside air admission and relief dampers. This shaft is also preferably provided with a rock arm 50 acted upon by a suitable spring mechanism 51 which cooperates with the motor springs 46 and tends to rock the damper operating shaft 37 in a direction to open the dampers 34 and 35, this actuation of the shaft by the springs being normally prevented by the water pressure in the motor diaphragms. Preferably the shaft 37 is not rigidly secured to the dampers 34 and 35, but is adapted to turn a limited extent relatively to the dampers and is connected to the dampers through the medium of levers 52 and 53 which, during the first portion of the rotation of the shaft 37, act forcibly to pry the dampers out of contact with the frames of the inlet and relief openings, and thereafter during the further rocking of the shaft 37, swing the dampers wide open. This arrangement insures the prompt and immediate opening of the dampers in case they should become frozen or stick to the frames. The construction of the damper actuating motor and operating connections between the same and the dampers for prying open the dampers, are not shown in full detail herein, since these parts are not claimed per se in this application, but form the subject matter of a separate application.

The deflecting damper 36 shown consists of three centrally pivoted plates which are connected to swing in unison by a rod 60 which is pivoted to arms fixed to the several damper plates. As shown, (see Figs. 5 and 7) the connecting rod 60 is connected by a link 61, bell crank 62 and link 63 to the air relief damper 35, the arrangement of these parts being such that when the damper 35 opens the dampers 36 will close, and when the damper 35 closes the dampers 36 will open. While the automatic damper-operating mechanism is preferably constructed as above described, a motor of any other suit-

able sort and any other suitable operative-connections between the motor and the dampers adapted to open the outside air admission and relief dampers upon a decrease or failure of pressure in the water supply for the spray nozzles, could be employed.

In the operation of the system, when the outside air admission and relief dampers 34 and 35 are closed and the generator is being cooled by recirculating air in the closed system formed by the conduits 12, 13 and 14 and generator casing 15, the air encounters the water sprays in the supply conduits by which it is cooled and dehumidified. The air then passes through the eliminators which remove the excess moisture from the sprays as well as any moisture that may be condensed from the air by the cooling effect of the water. By discharging the spray water downwardly, or in a direction opposed to the flow of the air, the efficiency of the system and the cooling effect on the air are very materially increased. The use of two or more sets of sprays through which the air passes in series, is also important to the commercial success of the system. The first set of sprays raises the moisture content of the air, and the second, or succeeding sets of sprays, condenses this excess moisture out of the air and provides additional cooling. The cooling of the air in this way by successive sprays operates in two ways. First the air is cooled by evaporation, the air becoming practically saturated, due to the evaporation. Then the excess moisture is removed by the succeeding sprays which have a water temperature below the wet bulb temperature of the entering air, and also below the dew point of the air. Less water is required with successive sets of sprays operating as described than would be necessary with only one set. A single set of sprays would require more nozzles, more water and more power for the pump to produce an equal cooling effect. The impurities are also washed out of the air by the sprays and eliminators and the recirculating air kept clean. As soon as the water pressure is removed by stopping the pump, or by the failure of the water supply from any cause, the dampers 36 will be closed and the dampers 34 and 35 opened by the operation of the motor spring mechanism as hereinbefore described. Outside air will then enter through the inlet opening 31, pass through the supply conduits and generator and be discharged through the return conduit and exit opening 32.

The system is also preferably provided with means for opening the outside air dampers in case the temperature of the recirculating air should exceed a predetermined maximum temperature while the water pressure is still on. As illustrated in the drawings, Fig. 1, this is accomplished by providing a water relief valve 70 in one of the water supply pipes, for instance the pipe 44. This valve is adapted to be opened to relieve the water pressure in the motor 40 and thus cause the opening of the outside air dampers in the manner before explained, by a valve actuating diaphragm or motor 71 under the control of a thermostat 72 which is affected by the temperature of the air entering the motor. The thermostat can cause the operation of the diaphragm and the opening of the relief valve 70 through the medium of water or air pressure, or any other usual instrumentalities.

Figs. 8, 9 and 10 illustrate a modified embodiment of the invention adapting the system for installations in which the air conduits and cooling means are arranged in a casing or chamber extending horizontally beneath the floor on which the generator is supported. A′ indicates the generator and C′ the casing which is divided into horizontal air supply conduits 13^a and 14^a and a return conduit 12^a. These conduits have upwardly directed inner ends connecting with the enclosing casing 15^a of the generator as in the construction first described. Near their opposite ends the conduits communicate with each other through openings, 13^b and 14^b in the partitions of the casing C′, which openings are adapted to be closed by deflecting dampers 36^a. 34^a indicates an outside air admission damper in the outer end of each supply conduit and 35^a indicates a relief damper in the outer end of the return air conduit. When the outside air dampers 34^a and 35^a are closed and the deflecting dampers 36^a open, as shown in Fig. 8, the air will recirculate in a closed system, and when the dampers 34^a and 35^a are opened and the dampers 36^a closed, outside air will be used and will enter through the supply conduits 13^a and 14^a and be discharged through the return conduit as in the first construction. Except for this difference in the arrangement of conduits and dampers, and the somewhat different position of the other parts necessitated thereby, this apparatus is substantially similar in organization and operation to that before described, and should be readily understood. Water spray nozzles 19^a and 20^a, eliminators 26^a and air deflectors or rectifiers 27^a, 28^a, 29^a and 30^a are provided in the conduits and function substantially like the corresponding parts in the first apparatus to cool and wash the air, remove free moisture therefrom, direct the flow of the air, and uniformly distribute it in the supply conduits. The outside air dampers 34^a and 35^a are opened and the other dampers 36^a are closed automatically as before in case of a failure of the spray water supply or reduction in its pressure. The dampers are connected to each other and to the damper actu-

ating motor 40ª by mechanism, shown by dotted lines in Fig. 8, which may be of any suitable construction adapted to produce the required reverse movements of the outside air and deflecting dampers.

I claim as my invention:

1. In combination with a device to be cooled, means for causing a circulation of air for cooling said device, air supply and return conduits connected with each other and with said device in a closed circuit through which the air recirculates, said air supply conduit being substantially vertical and connected through a bend with the air return conduit, means in one of said conduits for subjecting the circulating air to direct contact with a finely divided liquid, a liquid eliminator in the air supply conduit for receiving the air after it leaves said subjecting means and removing therefrom entrained unvaporized liquid, and partitions located in the connection between said conduits at the points of change of direction of travel of the air, for dividing the connection at those points into a plurality of sub-conduits for changing the direction of the air, as it passes from one conduit to the other, without the formation of eddies or an unequal distribution of the air throughout said other conduit, said eliminator being arranged at an inclination to the horizontal and obliquely to the direction of travel of the air along the air supply conduit.

2. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, of means for supplying water for cooling the air, and automatic mechanism controlled by the pressure of the cooling water and constructed and adapted to automatically open said air circuit for the admission of outside air when said water pressure is reduced a predetermined amount.

3. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, of means for supplying water for cooling the air, a damper-controlled opening for admitting outside air to said air circuit, and mechanism by which the pressure of said cooling water retains said damper closed and which permits the opening of said damper for the admission of outside air when said water pressure is reduced a predetermined amount.

4. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, of means for supplying water for cooling the air, a damper-controlled opening for admitting outside air to said air circuit, means actuated by the pressure of said cooling water for retaining said damper closed, and positively operating means for opening said damper when said water pressure is reduced a predetermined amount.

5. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, of means for supplying water for cooling the air, damper-controlled openings for the admission of outside air to and the relief of air from said air circuit, and mechanism actuated by the pressure of said cooling water for retaining said dampers closed, and opening the dampers when said water pressure is reduced a predetermined amount.

6. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, of means for supplying water for cooling the air, a system of dampers operable to cause the air to recirculate in said air circuit or to admit outside air to the circuit, and mechanism controlled by the pressure of the cooling water for operating said dampers.

7. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, of means for supplying water for cooling the air, a three-way arrangement of dampers operable to cause the air to recirculate in said air circuit or to admit outside air to and relieve air from said circuit, and mechanism controlled by the pressure of the cooling water for operating said dampers.

8. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, means for spraying water into the circulating air for cooling it, a system of dampers operable to cause the air to recirculate in said air circuit or to admit outside air to the circuit, and mechanism controlled by the pressure of the cooling water for operating said dampers.

9. The combination with a device to be cooled, means for causing a circulation of air for cooling the device, and air conduits connected with the device in a closed circuit through which the air is adapted to recirculate, of means for supplying water for cooling the air, automatic mechanism controlled by the pressure of the cooling water for

opening said air circuit for the admission of outside air when said water pressure is reduced a predetermined amount, a thermostat, and means controlled by said thermostat for reducing said water pressure when a predetermined maximum temperature is reached.

10. In combination with a device to be cooled, means for causing a circulation of air for cooling said device, air supply and return conduits connected with each other and with said device in a closed circuit through which the air may recirculate, a damper device disposed in the air return conduit and adjustable for shutting off air flow therethrough or for permitting such flow, said air return conduit also having openings leading thereto from the exterior upon opposite sides of said damper device, shutter means controlling said openings, air cooling means disposed in one of said conduits in the path of air flow through said conduits whereby the same air may be recirculated and conditioned during normal operation, or said damper device and shutter means operated to prevent such recirculation and cause a flow of exterior fresh air through said device to cool the same instead of the recirculated air.

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