

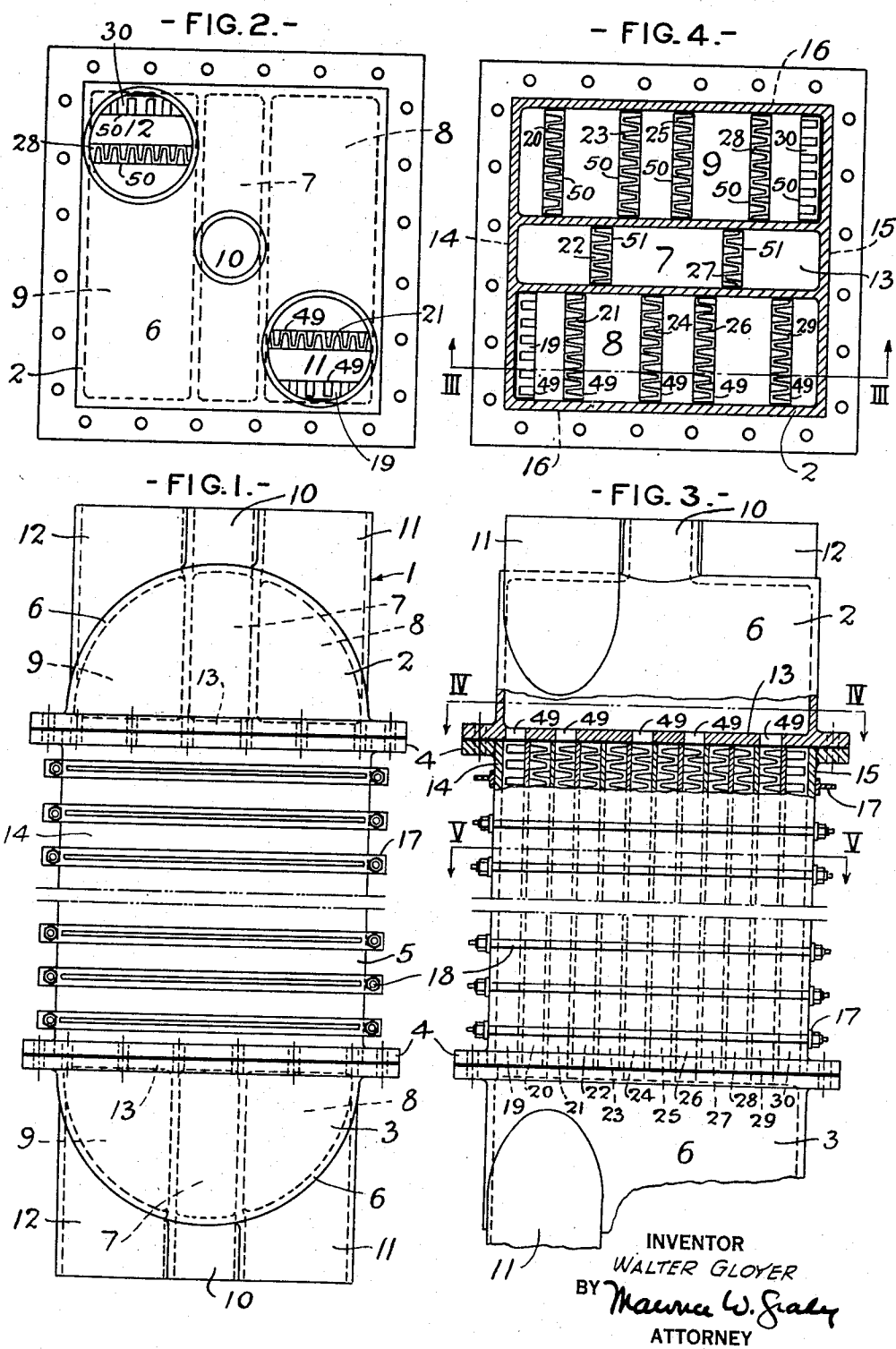
Dec. 22, 1953

W. GLOYER
HEAT EXCHANGER

2,663,170

Original Filed May 10, 1945

4 Sheets-Sheet 1



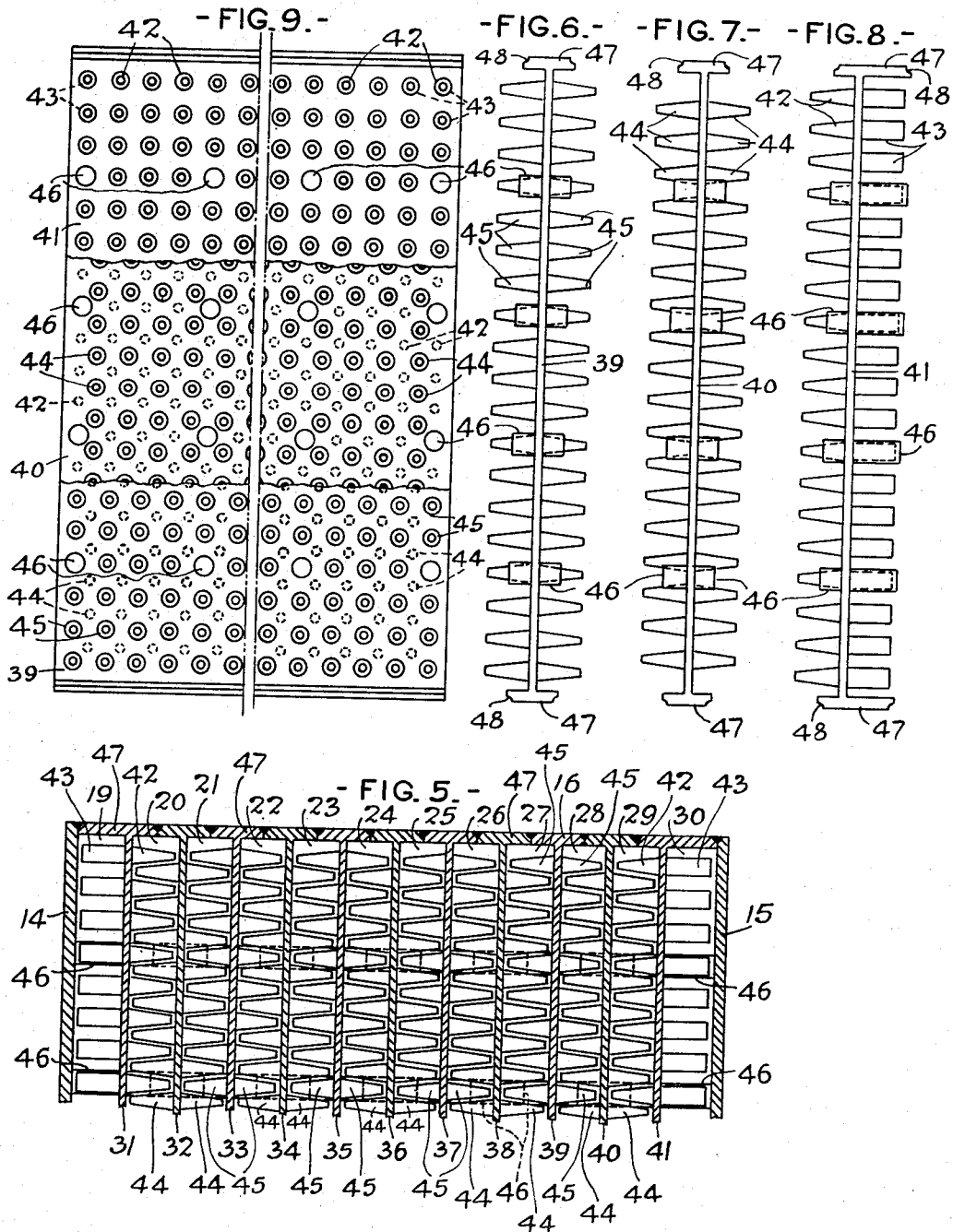
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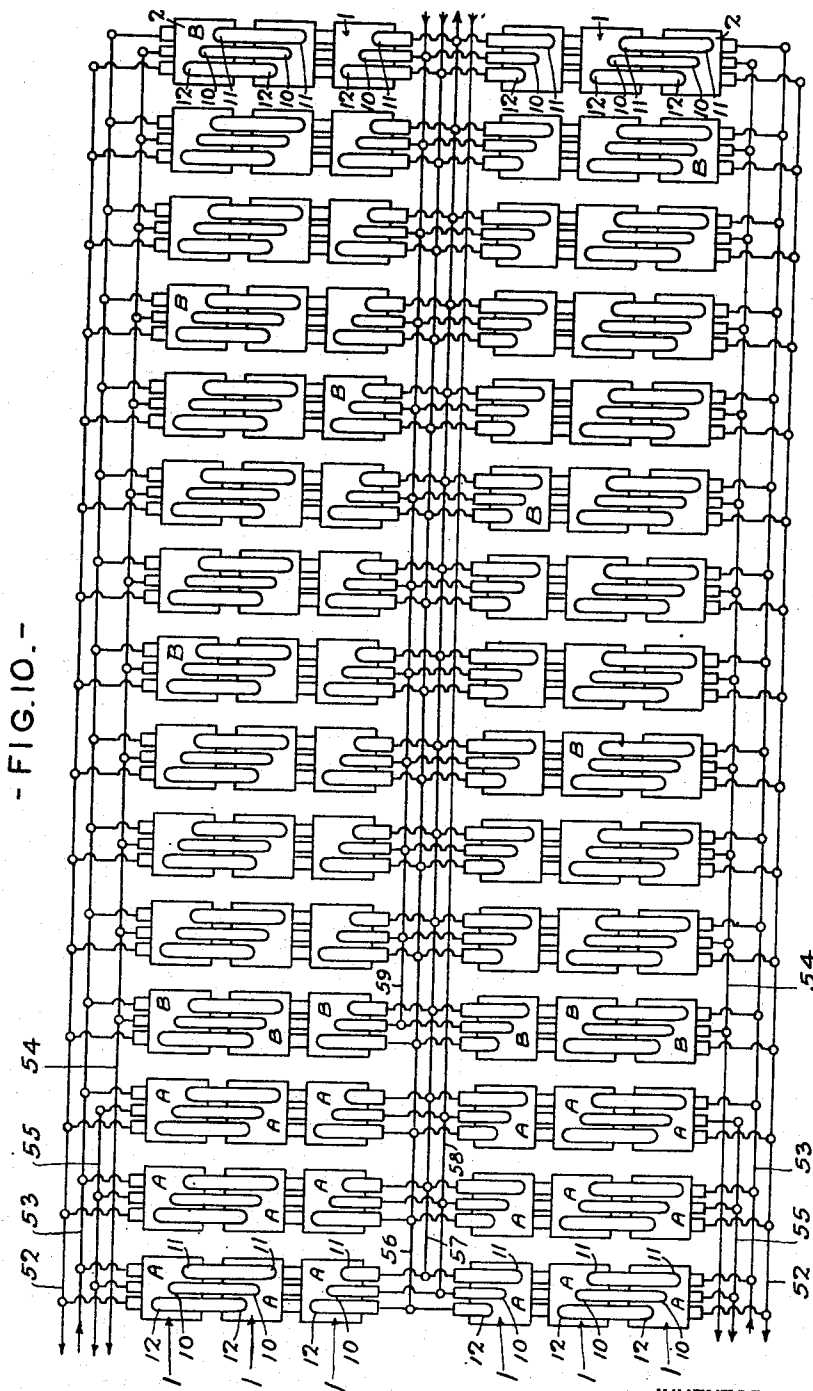
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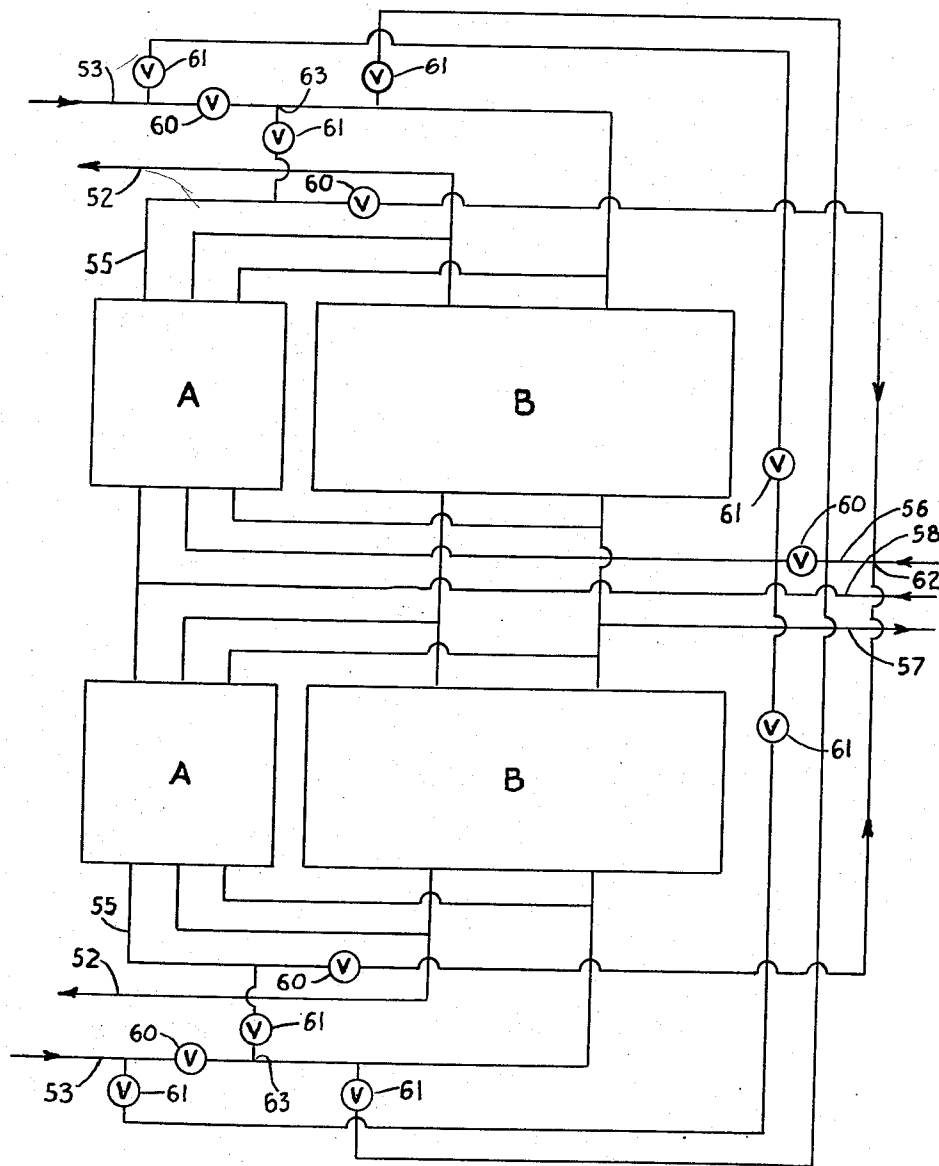


FIG. II.

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HEAT EXCHANGER

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4 Claims. (Cl. 62—175.5)

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This invention relates to a method of heat exchange.

This application is a divisional application, the parent application, now Patent Number 2,529,013, having been filed on May 10, 1945 by applicant as the sole inventor.

The principal object of this invention is to provide an improved method of heat exchange. More particularly, it is the object of the invention to cool air by passing confined streams of atmospheric air individually along individual passing confined streams of cold nitrogen, no two of the air streams being adjacent to each other and no two of the nitrogen streams being adjacent to each other. The air and nitrogen streams are thereafter transferred or transposed so that the air streams flow through the confines previously containing the nitrogen and the nitrogen streams flow through the confines previously containing the air streams so that defrosting is achieved while the transferred air is cooled. Another object is to cool air by passing confined streams of air along confined streams of nitrogen and confined streams of oxygen, the latter two streams being arranged to function in a novel and effective manner. Other and further objects of this invention will appear from the following description, the accompanying drawings and the appended claims.

Referring to the drawings forming a part of this application, Figure 1 is a foreshortened front elevation of a heat exchanger constructed in accordance with this invention; Fig. 2 is a plan view of the heat exchanger; Fig. 3 is a foreshortened side view of the heat exchanger, taken from the right side of Fig. 1, partly in side elevation and partly in section on the line III—III of Fig. 4, parts being broken away; Fig. 4 is a section on the line IV—IV of Fig. 3; Fig. 5 is an enlarged sectional view on the line V—V of Fig. 3 of a portion of the exchanger; Fig. 6 is an enlarged plan view of one plate of the exchanger; Fig. 7 is an enlarged plan view of another plate of the exchanger, adapted to be disposed adjacent the plate of Fig. 6; Fig. 8 is an enlarged plan view of an outer plate of the exchanger, adapted to be disposed adjacent the plate of Fig. 7; and Fig. 9 is a foreshortened view looking at the three plates of Figs. 6-8 from the left side thereof, parts being broken away to show the lower third of the plate of Fig. 6, the middle third of the plate of Fig. 7 and the upper third of the plate of Fig. 8; Fig. 10 is a diagrammatic plan view of the apparatus on a reduced scale showing an assemblage of heat exchangers and

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pipes connecting the heat exchangers, and Fig. 11 is a schematic layout illustrating reversal of some of the streams for the defrosting operation.

The heat exchange apparatus shown in Fig. 10 includes ninety heat exchangers 1. These exchangers are identical and only one will be described.

The heat exchanger 1 is of the plate-type having pin fins. It includes a top header 2 and a bottom header 3, the headers being similar and being bolted respectively to top and bottom flanges 4 of a shell 5.

Each header includes a semi-cylindrical dome 6 partitioned into a central chamber 7 and side chambers 8 and 9 on opposite sides thereof. Chamber 7 is provided with a small cylindrical nozzle 10 and chambers 8 and 9 are provided respectively with large cylindrical nozzles 11 and 12. The chambers are closed at their inner ends by a wall 13 in which are ports later to be described for communicating with the shell.

The shell 5 is rectangular in cross section and includes two walls 14 and 15 each formed of a long solid plate of metal. Wall 14 will be considered the shell front wall for the purpose of clarity in the following description. The side walls 16 of the shell are built-up welded constructions as will presently appear, these walls 16 being welded to the walls 14 and 15. The shell is very long (high) relative to its cross-sectional dimensions and is braced externally by rows of spaced T-irons 17 extending across the walls 14 and 15, and secured together by tie bolts 18 extending across the walls 16.

The shell is partitioned into twelve longitudinal compartments or chambers 19-30 inclusive by eleven longitudinal plates 31-41 inclusive provided with pin fins. The chambers are numbered in order from the front of the shell rearward and the plates are similarly numbered in order, plate 31 being adjacent chamber 19 (Fig. 5). Plates 31 and 41 are similar but oppositely disposed. Plates 31 and 41 each have rows of conical pin fins 42, arranged in square pitch, integral with its inner side, and cylindrical pin fins 43 in line with the fins 42 on its outer side. The pin fins are spaced and they extend substantially the full depth of the chamber in which they are disposed, the depth being the distance, for example, between adjacent plates.

Plates 32, 34, 36, 38 and 40 are similar. Each has conical pin fins 44 extending in alignment from its opposite sides. These fins are similar to fins 42. Plates 32 and 40 are disposed so that their fins 44 on the outer sides fit in the spaces

between the adjacent fins 42. Plates 33, 35, 37 and 39 are similar. Each has conical pin fins 45 extending in alignment from its opposite sides. These fins are similar to fins 44 and are disposed in the spaces between these fins 44. The clearance in the inner chambers between the pin fins is very small, but is shown enlarged somewhat in the drawings for clarity. The clearance between the cylindrical pin fins 43 is also shown enlarged in the drawings for clarity. The fins greatly reduce the net free flow area of the chambers.

Each plate also has extending from its opposite sides, rows of cylindrical bosses 46. The bosses extending outwardly from the plates 31 and 41 abut the walls 14 and 15 respectively and the other bosses extend half the depth of the adjacent chambers and abut each other, thus forming segmental bracing rods extending between walls 14 and 15 for bracing the plates against bending due to pressure differentials.

Each plate has integral therewith at its longitudinal edges, flanges 47. These flanges, when welded together, form the side walls 16, as is clearly shown in Fig. 5. The shapes of the flanges in cross section are best shown in Figs. 7 and 8. The flanges of all the inner plates are similar to the flange of Fig. 7, extending equal distances on opposite sides of the plate and having welding shoulders 48 formed in the outer longitudinal edges. The flanges of the outer plates are similar except that on the outer sides of these plates they extend beyond the cylindrical fins in order to abut the walls 14 and 15, which are also provided with welding shoulders 48. Mating shoulders 48 form outwardly opening U-grooves for welding.

Nozzle 11 communicates, through chamber 8, with chambers 19, 21, 24, 26 and 29, wall 13 being provided with ports 49 opening into these chambers at the right side (Fig. 1) thereof. Nozzle 12 communicates, through chamber 9, with chambers 20, 23, 25, 28 and 30, wall 13 being provided with ports 50 opening into these chambers at the left side (Fig. 1) thereof. Nozzle 10 communicates, through chamber 7, with chambers 22 and 27, wall 13 being provided with ports 51 opening into these chambers at the center thereof. While ports 49 and 50 open into their respective chambers only at one end thereof, the fluid entering the chambers through these ports will disperse through the spaces between the pin fins and entirely fill these chambers. The same is true of the center ports 51, the dispersion here being in opposite directions on each side of the ports 51.

Referring to Fig. 10, wherein an apparatus is shown including ninety heat exchangers in plan of the above described type, it will be seen that these exchangers are arranged in two groups of forty-five exchangers each. Each group is divided into two sets, one set including the nine exchangers A at the left in Fig. 10, and the other set including the remaining 36 exchangers B. The group at the bottom of Fig. 10 will be referred to as the front group and the other group as the rear group.

These exchangers are connected by piping as follows:

A set of four pipes 52, 53, 54 and 55 extends along both the front and back of the apparatus at the bottoms of the exchangers thereof. Pipes 52 are connected to the adjacent bottom nozzles 12. Pipes 53 are connected to the adjacent bottom nozzles 11. Pipes 54 are connected to the adjacent bottom nozzles 10 of exchangers B. Pipes

55, which are shorter than the other pipes, are connected to the adjacent bottom nozzles 10 of exchangers A.

A set of four pipes 56, 57, 58 and 59, serving both groups, extends along the apparatus between the two groups thereof at the top of the exchangers. Pipe 56 is connected to the adjacent top nozzles 12. Pipe 57 is connected to the adjacent top nozzles 11. Pipe 58 is connected to the adjacent top nozzles 10 of exchangers A. Pipe 59 is connected to the adjacent top nozzles 10 of the exchangers B.

The above described connections between the nozzles and their respective pipes are through branch pipes as shown diagrammatically.

The apparatus is laid out in a rectangle in longitudinal rows of fifteen exchangers each and transverse rows of six exchangers each. Thus each group includes fifteen transverse rows of three exchangers. The three exchangers of each transverse row are connected in series, the top nozzles of the outer fifteen exchangers being connected to corresponding top nozzles of the adjacent exchangers, these last exchangers having their bottom nozzles connected to corresponding bottom nozzles of the inner adjacent exchangers. The transverse rows of three exchangers of each group are connected in parallel with the adjacent pipes 52 and 53, and with pipes 56 and 57, the rows of exchangers B thereof are connected in parallel with the adjacent pipe 54 and with pipe 59, and the rows of exchangers A thereof are connected in parallel with the adjacent pipe 55 and with pipe 58. It will be obvious that the apparatus could include a greater or lesser number of exchangers, if desired, and the sets A and B could be rearranged to have a different number of exchangers each.

The present invention proposes a method of cooling hot air. The operation of the aforedescribed heat exchanger and apparatus will be now set forth, by way of example, in connection with carrying out the above method.

Pipes 52 and 56 may be for air or nitrogen. As will later more fully appear, they are employed at times for each fluid in carrying out the present method. Assuming that, to start with, they are for nitrogen, then pipes 53 and 57 will be employed for air. The directions of flows are indicated in Fig. 10 by arrows. As an example, air from the atmosphere is compressed to 85 pounds per square inch pressure at 100 degrees Fahrenheit, and is conveyed to the exchangers of the apparatus by the two pipes 53, flowing into the bottom nozzles 11 connected thereto and flowing in series through each transverse row of three exchangers, entering the pipe 57 from the top nozzles 11 connected thereto.

According to the present invention, this hot air is cooled to -250 degrees Fahrenheit by cold nitrogen (-266 degrees Fahrenheit) and oxygen (-288 degrees Fahrenheit), both at 10 pounds per square inch pressure. The main stream of nitrogen is delivered to pipe 56 and conducted thereby to each of the nozzles 12 connected thereto for series flow through each transverse row of three exchangers, entering the pipes 52 from the bottom nozzles 12 connected thereto. The oxygen is delivered to pipe 59 and conducted thereby to each of the nozzles 10 connected thereto for series flow through each corresponding transverse row of three exchangers B, entering the pipes 54 from the bottom nozzles 10 of the exchangers B connected thereto. A fourth stream is delivered to pipe 58 and conducted

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thereby to each of the nozzles 10 connected there-
to for series flow through each corresponding
transverse row of three exchangers A, entering
the short pipes 55 from the bottom nozzles 10 of
the exchangers A connected thereto. This fourth
stream is so-called unbalanced nitrogen, and its
function will later be more fully described.

The nitrogen and oxygen, in cooling the hot
air as thus described, are raised to an outlet
temperature of 90 degrees Fahrenheit. They are
in counterflow with the hot air.

Atmospheric air contains a certain amount of
water vapor and carbon dioxide, which are con-
densed and solidified in the exchanger apparatus
as the air is cooled. For a continuous operation
of the process, the air flow chambers of the ex-
changer have therefore to be defrosted and
cleared from time to time. This is done by
switching air and the main nitrogen streams
from one to the other of their respective flow
chambers at a definite switching cycle. The cold
main stream nitrogen, while being heated to nine-
ty degrees Fahrenheit as aforesaid in the cham-
bers previously containing air, will vaporize the
solidified carbon dioxide and water present in
the chambers through which it is flowing and
will carry them out of the exchangers.

For a successful defrosting operation, the main
stream of nitrogen has to be of approximately
the same temperature as the air on the hot side.
For this purpose an 8 degree Fahrenheit approach
for the main nitrogen stream on the cold end of
the exchanger apparatus is desired. As men-
tioned before, the main nitrogen stream has a
temperature of -266 degrees Fahrenheit when
approaching the exchanger apparatus. This
temperature has to be brought up to -258 de-
grees Fahrenheit to satisfy the above mentioned
limitation, and this is done by quenching into
the entering main stream of nitrogen, before its
heat exchange with air, the aforementioned
fourth so-called unbalanced nitrogen stream af-
ter this fourth stream has been in heat exchange
with air. This fourth stream is relatively small
and is heated from -266 degrees Fahrenheit to
90 degrees Fahrenheit as aforesaid, and thereaf-
ter quenched into the main nitrogen stream in
any suitable manner to bring the main nitrogen
stream inlet temperature up to -258 degrees
Fahrenheit. The main nitrogen stream then
enters the exchangers suitable for defrosting at
-258 degrees Fahrenheit and is heated to 90
degrees Fahrenheit at leaving the exchangers.
Thus the fourth stream takes the place of oxygen
in the exchangers A and is in heat exchange re-
lation with the air and further preheats the main
nitrogen stream during defrosting. Of course
both of the chambers in communication with the
nozzles 11 and with the nozzles 12 have to be
alternately defrosted due to the switching of
the air.

The schematic layout for the defrosting opera-
tion is illustrated in Fig. 11. For convenience,
the exchangers A and B as shown in Fig. 10 are
shown as blocks in Fig. 11. The various piping
and valves in addition to Fig. 10, necessary for
defrosting are shown schematically. Lines 52
and 53 and lines 56-58 are shown as they ap-
pear in the overall layout of Fig. 10.

The various valves 60 are always either all
open or all closed. Similarly the valves 61 are
either all open or all closed at the same time
being opposite to valves 60. For the description
given concerning Fig. 10 valves 60 are all open
and valves 61 are all closed. Hot air enters lines

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53, passes through the exchangers and emerges
cold through line 57. Cold nitrogen enters line
56 and emerges hot through lines 52. The un-
balanced cold nitrogen stream enters line 58 and
emerges from lines 55. By following line 55 on
Fig. 11, with the valves in the position stated, the
unbalanced nitrogen stream from both sets of
exchangers A is returned to the main nitrogen
stream for quenching at junction 52 after it has
passed in heat exchange relation and before the
main nitrogen stream passes in heat exchange
relation as stated supra. Thus the apparatus
operates in one direction.

When it is necessary to defrost, the air and
nitrogen streams must be reversed. That is,
the hot air must now enter line 56 where the
cold nitrogen had previously entered and the cold
nitrogen must enter line 53 where the hot air had
previously entered. In addition, the unbalanced
nitrogen stream must be quenched, after it has
passed in heat exchange relation, into line 53 into
the main nitrogen stream before it passes in heat
exchange relation. This is done at junction 53.
All that is necessary to accomplish these condi-
tions is to reverse the positions of all valves. In
other words all valves 60 are now closed and all
valves 61 are opened. By following the lines on
Fig. 11 it can be seen that the flow is as required
for defrosting. The positions of valves 60 and
61 are periodically changed as the apparatus re-
quires defrosting.

The above mentioned defrosting switching op-
eration of the air and main nitrogen streams
necessitates identical chamber arrangement for
air and main nitrogen streams. Size and ar-
rangement are dictated by the allowable pres-
sure drop on the low pressure nitrogen side. This
identical chamber arrangement is best shown
in Fig. 5. When nitrogen is admitted through
pipe 56, it flows through chambers 20, 23, 25, 28
and 30, but when the switch is made so that ni-
trogen is admitted through pipe 57, then it flows
through chambers 19, 21, 24, 26 and 29. This
effects an alternating of flow of nitrogen and
air but maintains the same relation. That is,
before the switch, the twelve chambers 19-30 have
the fluids arranged in a definite order and after
the switch, the same order is found but in the
opposite direction, that is, from chamber 30 to 19.
The cold oxygen is always in heat exchange re-
lation with a stream of air.

This invention is adapted to be employed in
the production of pure oxygen from atmospheric
air, which is compressed and then cooled in the
apparatus of the present invention. On account
of the low temperature of the oxygen when pro-
duced, it may be utilized in the apparatus as a
supply of an air cooling medium, thereby effect-
ing an economy. In the present method of cool-
ing air by nitrogen, oxygen, for the reasons above
stated, is preferably also employed, but may not
be availed of in all instances. When the pro-
duced pure oxygen is employed, it will be evident
that no contamination thereof is allowable. The
oxygen stream is therefore not switched between
any chambers. The cross sections of the cham-
bers for the oxygen streams and for the fourth
streams are dictated by the allowable pressure
drop in the two streams.

Inasmuch as the process involves temperatures
of some minus 250 degrees Fahrenheit, a special
material, such as copper or aluminum is resorted
to in constructing the heat exchanger apparatus.
To obtain a unit of low cost and weight, an
aluminum alloy has been found preferable as the

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most suitable material. This material is castable and weldable, and thus has two desirable features for a simple design.

While there has been hereinbefore described an approved embodiment of this invention, it will be understood that many and various changes and modifications in form, arrangement of parts and details of construction thereof may be made without departing from the spirit of the invention and that all such changes and modifications as fall within the scope of the appended claims are contemplated as a part of this invention.

The invention claimed and desired to be secured by Letters Patent is:

1. A method of cooling air which consists in passing streams of said air each along a passing stream of relatively cold nitrogen, passing a minor number of said air streams each along another passing stream of relatively cold nitrogen, and passing at least some of the remainder of said air streams each along a passing stream of relatively cold oxygen, and quenching said first mentioned passing streams of nitrogen prior to their said passing by said other streams of nitrogen subsequent to said passing of said other streams of nitrogen.

2. A method of cooling air which consists in passing confined streams of atmospheric air each along a passing confined stream of relatively cold nitrogen, no two of said air streams being adjacent and no two of said nitrogen streams being adjacent, passing a minor number of said air streams each along another passing confined stream of relatively cold nitrogen, and passing at least some of the remainder of said air streams each along a passing confined stream of relatively cold oxygen, quenching said first mentioned passing streams of nitrogen prior to their said passing by said other streams of nitrogen subsequent to said passing of said other streams of nitrogen, and prior to said quenching transferring said air and said first mentioned nitrogen streams so that said air streams flow through the confines previously containing said first mentioned nitrogen streams and said first mentioned nitrogen streams flow through the confines previously containing said air streams for defrosting said last mentioned confines by said first mentioned nitrogen streams of frost formed during cooling of said air therein.

3. A method of cooling air by relatively cold nitrogen and relatively cold oxygen which consists in passing confined streams of said air along confined streams of said cold nitrogen and confined streams of said cold oxygen thereby heating said streams of cold nitrogen and cold oxygen, passing other confined streams of said air along other confined streams of said cold nitrogen thereby heating said other streams of

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cold nitrogen, quenching some of said heated other streams of cold nitrogen into said first mentioned streams of cold nitrogen before said heating thereof for initially partially heating said first mentioned cold nitrogen streams before they are brought into heat exchange relation with said air streams, the consequent cooling of said air streams frosting the means confining said air streams, and thereafter defrosting said air confining means by alternating said air streams with said first mentioned and said nitrogen streams, said first mentioned and said nitrogen streams then being passed through said air confining means.

4. A method of cooling air at substantially 85 pounds per square inch pressure from substantially 100 degrees Fahrenheit to substantially -250 degrees Fahrenheit by cold nitrogen at substantially 10 pounds per square inch pressure and -266 degrees Fahrenheit and cold oxygen at substantially 10 pounds per square inch pressure and -288 degrees Fahrenheit which consists in passing confined streams of said air along confined streams of said cold nitrogen and confined streams of said cold oxygen thereby heating said streams of cold nitrogen and cold oxygen, passing other confined streams of said hot air along other confined streams of said cold nitrogen at said substantially 10 pounds per square inch pressure and said -266 degrees Fahrenheit, thereby heating said other streams of cold nitrogen to substantially 90 degrees Fahrenheit, quenching said heated other streams of cold nitrogen into said first mentioned streams of cold nitrogen before said heating thereof for initially partially heating to substantially -258 degrees Fahrenheit said first mentioned cold nitrogen streams before they are brought into heat exchange relation with said air streams, the consequent cooling of said air streams dropping their temperature to said substantially -250 degrees Fahrenheit, said cooling of said air streams frosting the means confining said air streams, and thereafter defrosting said air confining means by alternating said air streams with said nitrogen streams, said nitrogen streams then being passed through said air confining means.

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