The present invention relates to an air-cooled turbo-refrigerator which totally dispenses with cooling water for the condenser of the type normally used in ordinary turborefrigerators by permitting the condenser to be air-cooled by means of a fan, whereby the necessity for space for a cooling tower for cooling water can be eliminated.

Usually conventional turborefrigerators are installed in basements of buildings, and are equipped with water-cooled condensers. Water for cooling the condensers are, generally, pumped up to cooling towers built atop the buildings, where the water is atomized and ejected to heat-exchange with air, and the heat of condensation is thus discharged in air and the water is cooled. The cooled water is returned to the condenser for another cycle of refrigeration.

Such conventional refrigerators have several disadvantages. First, large spaces are required for installation of the equipment, because a large cooling tower is needed in addition to the main unit of the refrigeration system. Second, auxiliary parts such as pumps and piping systems are necessary, bringing the total installation cost still higher. Last but not least, but equally important, the cooling water must be constantly replenished while the refrigerator is in operation, and this requires great expenses and steady attention, since water is partially lost by continuous evaporation in an ordinary cooling tower, and is also lost by spattering on the stream of air caused by the fan.

It is one object of the present invention, therefore, to provide an air-cooled turborefrigerator, which entirely dispenses with cooling water for the condenser.

It is another object of the present invention to provide a compact turborefrigerator consisting of an evaporator for cooling fluid, a compressor, a driving means such as motor, an air-cooled condenser, a fan which sucks air in through the condenser for the purpose of cooling the condenser, a separator plate for guiding air for cooling, and a housing for the main body of the refrigeration, all assembled to a single unit.

It is still another object of the present invention to provide a turborefrigerator of the above structure which is readily accessible from both sides of the main body for inspection of the inside of the refrigeration.

It is yet another object of the present invention to provide a turborefrigerator of the above structure, which can be improved in performance by facilitating return of the liquid refrigerant from the condenser to the evaporator.

It is a further object of the present invention to provide a turborefrigerator wherein the smooth flow of the refrigerant is ensured by a pressure difference produced between the header on the gas side of the condenser and the header on the side of the liquid refrigerant.

It is a further object of the present invention to provide an air-cooled turborefrigerator, wherein the flow resistance of gas in the cooling pipe of the condenser is reduced, in order to attain an increased cooling effect without any increase in the compressor load.

With these and other objects in view which will become apparent from the following detailed description, the present invention will be clearly understood in connection with the accompanying drawings, in which:

FIGURE 1 is an end view of a turborefrigerator, which constitutes one embodiment of the present invention, particularly in section for showing the internal structure thereof.

FIG. 2 is a front elevational view, partly in section, as seen in the direction of the line 2—2 of FIG. 1, the separator plate being removed.

FIG. 3 is a view similar to that of FIG. 1, disclosing another embodiment of the present invention.

FIG. 4 is a front elevational view, partly in section, as seen in the direction of the line 4—4 of FIG. 3.

FIG. 5 is a view similar to that of FIG. 1, disclosing a third embodiment of the present invention.

Reverting now to the drawings, and in particular to FIG. 1, the turborefrigerator according to the present invention comprises a housing 1, in which a plurality of different members or elements are accommodated. The housing 1 is divided by a separator plate 2 into two compartments for enhancing the ventilating effect of the fan, to be described later. Inside one of the compartments, an evaporator 3 is located, which communicates through a suction pipe 4 for evaporated refrigerant to a turbocompressor 5. The latter is driven by a motor 6, which may be either of the direct coupling type or equipped with a gear box for acceleration. Gasous refrigerant, compressed by the compressor 5, is fed through a discharge pipe 7 into a header 8 for distribution of compressed refrigerant, which header is located in the other of the compartments. The header 8 communicates with an air-cooled condenser 9, in which many lengths of refrigerant pipe 10 extend downwardly, thereby providing a plurality of fins 11 provided on the pipe 10 for promoting heat exchange. The refrigerant pipe 10 terminates in a reservoir 12 for condensed refrigerant, from which liquified refrigerant is returned through a return pipe 13 to the first of the compartments. The return pipe 13 extends along a channel base 14 on the bottom of the machine, back to the evaporator 3 through a reducing valve or expansion valve 15.

As can be determined from the drawings, the condenser 9 designed according to the present invention is flat shaped, like a radiator used for cooling an automobile engine, and constitutes one side of the refrigeration unit. On top of the refrigeration, a fan, for example a propeller fan 16, is mounted. When the fan 16 is driven by a motor 17, air is sucked into an opening of the housing 1, passing the fins of the condenser 9, and then discharged through the opening above the fan 16. By the flow of air, the refrigerant in the cooling pipe 10 of the condenser 9 is cooled to its liquid state, and is fed back through the return pipe 13 to the evaporator 3.

Reverting now to FIG. 2, the cooled liquid enters and leaves the evaporator 3 through a cooled water (liquid) header 18, in the direction indicated by arrows. The liquid refrigerant fed back through the return pipe 13 extracts heat from the water to be refrigerated, which water is fed in through the header 18, as the refrigerant is evaporated in the evaporator 3. Then the refrigerant is drawn into the compressor 5, where gasified refrigerant is again compressed and fed back to the condenser 9, and thus the above described cycle is repeated. Cooled water, leaving the cooling water header 18, is delivered to a desired place or places for use, and the warm liquid is fed back to the inlet of the header 18.

The turborefrigerator of the present invention hereinabove described dispenses entirely with cooling water for the condenser 9, and hence needs no space for a cooling tower which has hitherto been a requisite for conventional refrigerating machines, to a great practical advantage.
Furthermore, it is capable of being installed at the top of a building, since it is of light-weight and since its compressor, which is of the centrifugal type provides little vibration. Where necessary, the compressor and evaporator 3 can be readily inspected by simply removing the front panel (at the right in FIG. 1) of the housing 1. It is, therefore, possible to install the apparatus with the side of the large opening W in close proximity to a building wall.

In the apparatus as described above, liquefied refrigerant drops by its own gravity, while the condenser 9 is in operation, and hence the lower end of the cooling pipe 10 may be clogged to prevent effective heat transmission. This possibility is precluded in an improved embodiment of the present invention, wherein the upper portion of the reservoir 12 for liquefied refrigerant communicates with a portion having lower pressure, for example the intermediate step of the compressor 5 or the evaporator 3, through a thin connecting pipe 21 and a throttle valve 22 disposed intermediate the ends of the pipe 21. The valve 22 is adjusted such as to keep the pressure of the liquid slightly higher than that of the header 8, so that a pressure difference is maintained between the two elements, whereby refrigerant gas is permitted to pass readily through the cooling pipe 10 and proper functioning of the condenser is ensured.

Now, reference will be made to FIGS. 3 and 4, wherein another embodiment of the present invention is disclosed. This refrigerator has the advantage that it is accessible from both sides for inspection of the inside, which is a very important feature in actual operation of the machine. Further, this embodiment advantageously enables liquefied refrigerant to be fed back simply without the use of such additional means as the thin connecting pipe 21 and the throttle valve 22 disclosed in FIG. 1.

In this embodiment, the individual constituent elements are practically the same as in the embodiment described above in connection with FIGS. 1 and 2, but arranged in a different manner.

To be precise, the space inside a housing 31 is divided by a separator plate 32 inclined on both sides like a gable roof into two chambers, that is, upper and lower compartments, the upper compartment being provided with air suction openings 49 on both side walls opposite to each other. An evaporator 33 is disposed above a compressor 35 and refrigerant gas is led to the compressor 35 through a suction pipe 34. In the same manner as described in connection with the first embodiment, compressed gas is urged into a discharge pipe 37 from the compressor 35 driven by a motor 36. The upright discharge pipe 37 extends upwardly, and communicates with a compressed gas inlet 38. Compressed gas is fed through the inlet 38 into an air-cooled condenser 39, and is cooled to its liquid state by the stream of air sucked in from the opening 49 on both sides of the housing 31 by means of a fan 46 driven by a motor 47 on the top of the housing 31. Then, the liquefied refrigerant is collected in a reservoir 43, and is fed back readily into the evaporator 33 through a return pipe 43 extending vertically downwards and through a reducing valve 45. This type of refrigerator performs similarly to the one described in the first embodiment before, except that it dispenses with such means as the throttle valve 22 thereby to stop the flow of the refrigerant gas.

Another modification which attains a further improved cooling effect is disclosed in FIGS. 5 and 6. Before describing in detail the structure of the third embodiment, it should be noted that, because turborefrigerators generally use a conventional low-pressure refrigerant, the unit volume of refrigerant gas required is much greater than that of a high-pressure refrigerant for the same refrigeration capacity and hence the passage of refrigerant gas must be accordingly larger with respect to the required heat transfer area of the condenser. The modification described hereunder has been designed to meet the above requirements.

The refrigerator comprises a housing 51 and a base plate 51a on which an evaporator 53 is placed horizontally, and a turbocompressor 55 is disposed thereon, so that it is driven by a motor 56 mounted on the evaporator 53 through a mounting block. The refrigerant which has been gasified upon extraction of heat from a material to be cooled, such as water disposed within the evaporator 53, is fed into the compressor 55 through a suction pipe 54. The material to be cooled enters and leaves the evaporator or cooler 53 through headers 68. The refrigerant which has been compressed by the compressor 55 is discharged in a discharge pipe 57, and then is fed into air-cooled condensers 59 through a multiplicity of branch pipes 77a. Each condenser 59 consists of horizontally extending refrigerant gas headers 68, a large number of refrigerant cooling pipes 60 extending vertically, a plurality of flanged air passages 61, and condensed refrigerant headers 62.

In this embodiment, there are provided four sets of condensers 59; two sets disposed one upon the one side of the housing 51, and the other two sets on the other side of the housing 51. The advantage accruable from this arrangement will be described later.

Atmospheric air is drawn into the machine in the directions indicated by arrows by means of a fan 65 provided on the top of the housing 51, and is discharged from the upper opening after having passed through the condensers 59 extracting heat therefrom. The fan 66 is driven by a motor 67. Liquid refrigerant received in the condenser refrigerant headers 62 is fed back to the evaporator 53 through respective ducts 63 and expansion valves 65, thus completing the refrigeration cycle.

This preferred embodiment is characterized, as mentioned above, by division of the refrigerant header 62 and condenser 59 into a large number of sub-units. It will be apparent that the number of cooling pipes 60 to be branched from the headers 58 can be determined consequentially, when only the longitudinal dimension of the machine is decided. Now, assuming that there are provided two sets of condensers 59, one on each side having a refrigerant cooling pipe of a length twice as long as one unit condenser 59 shown in the drawings, the refrigerant must pass through the cooling pipe at a doubled speed.

At this time, if the refrigerant gas occupies a large space, the flow resistance will be increased correspondingly, which has to be overcome by increasing the discharge pressure of the compressor 55, to a substantial disadvantage. Another difficulty is encountered if the cooling pipes are too long, because liquefied refrigerant may clog the ducts as it is fed down, thereby bringing an undesirable decrease in the necessary heat transfer area.

On the other hand, according to the present invention, condensers and refrigerant headers are provided in multistage arrangements, and hence the cooling pipes for passing the refrigerant are shortened to minimum lengths, whereby the resistance which large-volume gas encounters as it is fed into the cooling pipes is reduced. Thus, the desired cooling effect can be attained without requiring any increase in the compressor load.

While the present invention has been described hereinafter in connection with some specific embodiments thereof by example only, it is appreciated that various modifications of the present invention may be apparent to those skilled in the art, and it is intended that the present invention be defined only by the appended claims:

Claim:
1. An air-cooled turbo-refrigerator comprising a housing having at least one air-intake opening, a fan as air-drawing air through said opening into said housing, at least one condenser disposed in said opening and to be cooled by flow of air from said opening to said fan,
an evaporator operatively connected with said condenser for receiving refrigerant therefrom, to perform heat exchange between said refrigerant and fluid to be cooled,

a compressor operatively connected to said evaporator for compressing and directing refrigerant gas from said evaporator toward said condenser,

a drive means for operation of said compressor,

a separator plate disposed in said housing and separating said condenser,

said condenser having a flat shaped configuration comprising a header connected to the discharge side of said compressor,

a refrigerant pipe disposed downwardly from said header and having a plurality of fins attached thereto,

a reservoir disposed at the lower end of said refrigerant pipe and collecting the refrigerant from said pipe, said reservoir being adapted at the lower end of said refrigerant pipe to receive said refrigerant by gravity,

said reservoir being connected to said evaporator, means providing differential pressure between said reservoir and said evaporator,

said means providing differential pressure between said reservoir and said evaporator comprising a pipe means connecting a portion of said reservoir with a portion of said evaporator at a lower pressure, and

a throttle valve being disposed in said pipe means intermediate the ends thereof.

2. The air-cooled refrigerator, as set forth in claim 1, which includes

a plurality of condensers disposed along opposite walls of said housing.

3. The air-cooled refrigerator, as set forth in claim 2, wherein

said evaporator is disposed below said compressor, conduits connecting said evaporator with said condensers,
a main discharge pipe,
a plurality of branch conduits, and

said compressor is connected through said main discharge pipe and said plurality of branch conduits to said condensers.