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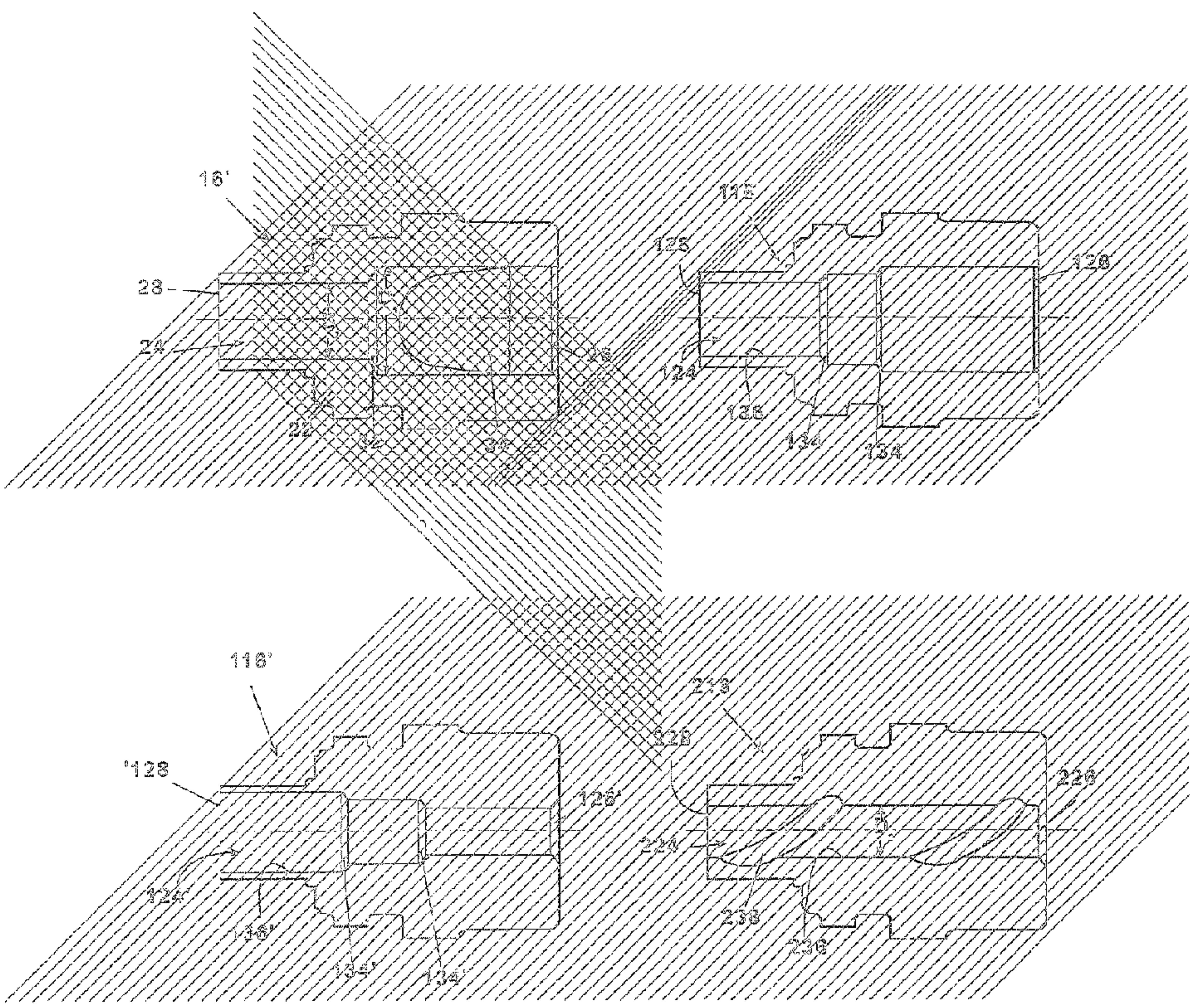
(54) Title: DEVICE FOR INDUCING TURBULENCE IN REFRIGERANT SYSTEMS



(57) Abrégé/Abstract:

A refrigerant expansion device outlet port includes a generally annular body defining a flow path between an inlet and an outlet, with a mixing device interposed between the inlet and outlet to promote turbulent mixing of refrigerant as it passes through the port. In one embodiment, the mixing device is a screen inserted between the inlet and the outlet, preferably adjacent the outlet. In a second embodiment, the mixing device is provided as a set of concentric axially spaced annular shoulders formed on an inner circumference of the flow path between the inlet and outlet. In a third embodiment, the flow path includes a series of rifling grooves on an inner circumferential surface of the flow path for inducing turbulent flow. In a fourth embodiment, the flow path is formed from radially offset or mismatching inlet and outlet flow paths.

ABSTRACT

A refrigerant expansion device outlet port includes a generally annular body defining a flow path between an inlet and an outlet, with a mixing device interposed between the inlet and outlet to promote turbulent mixing of refrigerant as it passes through the port.

In one embodiment, the mixing device is a screen inserted between the inlet and the outlet, preferably adjacent the outlet. In a second embodiment, the mixing device is provided as a set of concentric axially spaced annular shoulders formed on an inner circumference of the flow path between the inlet and outlet. In a third embodiment, the flow path includes a series of rifling grooves on an inner circumferential surface of the flow path for inducing turbulent flow. In a fourth embodiment, the flow path is formed from radially offset or mismatching inlet and outlet flow paths.

DEVICE FOR INDUCING TURBULENCE IN REFRIGERANT SYSTEMS

FIELD OF THE INVENTION

The present invention relates to thermal expansion valves for refrigerant systems and more particularly to thermal expansion valves that induce turbulent mixing of two-phase refrigerant to provide a homogenous refrigerant mixture at an outlet of the valve.

BACKGROUND OF THE INVENTION

Expansion devices are used in refrigerant systems to improve efficiency by allowing adiabatic (i.e. no heat is added or lost) expansion of refrigerant before the refrigerant flows into a plurality of evaporator tubes. In one type of system, expansion of compressed liquid refrigerant occurs as the refrigerant flows through a simple expansion orifice. In more complex systems, a thermal expansion valve is interposed in the refrigerant system between a condenser and the evaporator tubes. A compressor upstream of the condenser compresses the refrigerant, so that the refrigerant is predominately a high-pressure liquid as it enters an inlet port of the expansion device. As refrigerant flows through the expansion device, refrigerant pressure is significantly reduced to allow the refrigerant to expand. Expansion of the refrigerant through the expansion device causes a portion of the refrigerant to undergo a phase change, resulting in some of the refrigerant bursting into the vapor phase (i.e. "flashing") as it passes through the valve. Since expansion through an expansion device is adiabatic, when a portion of the refrigerant flashes to vapor, the remaining liquid refrigerant is subcooled. Thus, at an expansion device outlet port, the refrigerant comprises a mixture of both subcooled liquid (i.e. cooled below the refrigerant vaporization temperature) and vapor at the refrigerant vaporization temperature.

Refrigerant from the expansion device outlet port then passes to a flow divider, where the refrigerant flow is divided among a plurality of evaporator tubes. As is well known, the refrigerant boils upon entering the evaporator tubes, thereby absorbing heat from the ambient environment located outside of the tubes during the intentional liquid to vapor phase transition. As is also well known, an air to liquid heat transfer is far more efficient than an air to air heat transfer. Therefore, any refrigerant vapor entering the evaporator coils from the flow divider adversely impacts efficiency of the refrigerant system. Thus, to maximize efficiency, only subcooled refrigerant liquid should flow from the expansion device outlet port to a flow divider. On the other hand, refrigerant flow from the expansion device outlet port should not be subcooled to such an extent that some liquid refrigerant remains unevaporated after passing through the evaporator. Refrigerant efficiency is maximized only when all refrigerant has evaporated by the end of all evaporator coils and becomes superheated equally in each coil. Therefore, one function of any expansion device is to ensure that liquid refrigerant does not enter the compressor and cause hydraulic damage to it as the compressor attempts to compress a liquid refrigerant.

It is nearly impossible to achieve ideal flow of perfectly subcooled refrigerant through the expansion device without providing a relatively long steadying flow region between the expansion device and the flow divider. However, in modern high-efficiency refrigerant systems, the expansion device and flow divider are closely interconnected to minimize space requirements, such that the expansion device outlet port feeds directly into the flow divider inlet. Unfortunately, in this compromise configuration, refrigerant flowing from the expansion device outlet port into the flow divider is two-phase, including both liquid and vapor. Moreover, the refrigerant flow tends to separate into discrete liquid and vapor flow portions such that discrete liquid and vapor flows are passed from the expansion device directly to the flow divider. As the discrete liquid and vapor flows enter the flow divider, the flows remain separated, potentially causing some evaporator coils to receive predominantly subcooled liquid refrigerant while adjacent coils receive predominantly vapor refrigerant. Additionally, some evaporator coils may receive more refrigerant than other adjacent coils. In those evaporator coils that receive predominantly subcooled liquid refrigerant, a danger exists that not all refrigerant will evaporate before reaching the compressor. However, in those evaporator coils that receive predominantly vapor refrigerant, ambient heat transfer is less efficient and evaporator coils are loaded unequally, greatly affecting efficiency of the refrigerant system.

Therefore, a need exists for an expansion device design that maximizes the efficiency of modern refrigerant systems while preventing conditions that may harm components within the system.

SUMMARY OF THE INVENTION

The present invention resolves the above noted problems by maximizing the efficiency of refrigerant systems using expansion devices such as expansion orifices and thermal expansion valves for expansion of refrigerant. In particular, an expansion device outlet port is disclosed that includes a generally annular body defining a flow path between an inlet and an outlet, where the outlet provides refrigerant directly to a flow divider. Preferably, the flow path defines a generally cylindrical passage from the inlet to the outlet. A mixing device is interposed between the inlet and outlet to promote turbulent mixing of two-phase refrigerant as it passes through the expansion device outlet port.

In one embodiment, the mixing device is a screen inserted between the inlet and the outlet, preferably adjacent the outlet. Preferably, the screen extends radially to cover an entire cross-sectional area of the flow path adjacent the outlet. In a second embodiment, the mixing device is provided as a set of concentric axially spaced annular shoulders formed on an inner circumference of the flow path between the inlet and outlet. The concentric shoulders may be of increasing or decreasing diameter, or a combination of the two, and have the effect of preventing laminar flow and inducing turbulent flow within the orifice. In a third embodiment, the orifice flow path includes a series of rifling grooves on an inner circumferential surface of the flow path for inducing turbulent flow. In a fourth embodiment, the flow path is formed from radially offset or mismatching inlet and outlet flow paths. In this embodiment, at least one shoulder is formed between the inlet and outlet to enhance mixing of refrigerant within the orifice.

The expansion device outlet port of the present invention therefore induces turbulent mixing of two-phase refrigerant in a relatively short distance between the port inlet and outlet. Due to the induced turbulence, the refrigerant flowing from the outlet into the flow divider becomes a generally homogenous two-phase mixture. The generally homogenous mixture is then equally divided among a plurality of evaporator coils within the flow divider, ensuring that no evaporator coil receives significantly more vapor than liquid refrigerant, and that no refrigerant liquid enters the compressor after traveling through the evaporator tubes. In this way, efficiency of the refrigerant system is maximized though provision of a relatively inexpensive and easily manufactured outlet port. Increased efficiency also increases the cooling capacity of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and inventive aspects of the present invention will become more apparent upon reading the following detailed description, claims, and drawings, of which the following is a brief description:

FIG. 1 is a diagrammatic view of a refrigerant system.

FIG. 2 is a cross-sectional view of an expansion device outlet port including a first embodiment of the present invention having a turbulence-inducing screen adjacent an outlet of the port.

FIG. 3 is a cross-sectional view of an expansion device outlet port including a second embodiment of the present invention having concentric axially spaced annular shoulders of increasing diameter within the port.

FIG 4 is a second cross-sectional view of an expansion device outlet port including the second embodiment of the present invention having concentric axially spaced annular shoulders of decreasing diameter within the port.

FIG. 5 is a cross-sectional view of an expansion device outlet port including a third embodiment of the present invention having rifling grooves on an inner circumference of the refrigerant flow path within the port.

FIG. 6 is a cross-sectional view of an expansion device outlet port including a fourth embodiment of the present invention having a radially offset flow path within the port.

FIG. 7 is a cross-sectional view of another type of expansion device outlet port including the turbulence-inducing screen of the first embodiment of the invention.

FIG. 8 is a more detailed view of the expansion device outlet port of FIG. 8.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

As seen in FIG. 1, refrigerant systems 10 generally include at least a compressor 12, a condenser 14, an expansion device 13 including an outlet port 16, a flow divider 18 and a plurality of evaporator coils or tubes 20. Expansion device 13 may be a simple expansion orifice interposed between condenser 14 and flow divider 18, or it may be a thermal expansion valve in a more complex system. Compressor 12 compresses refrigerant (not shown) to a high temperature, high-pressure liquid state. As the refrigerant flows from compressor 12 through condenser 14, the high-pressure liquid refrigerant is forced to give up heat to the environment (indicated by arrows 15), ensuring that all refrigerant is cooled to a liquid state. The refrigerant then flows through the expansion device 13, which allows adiabatic expansion of the refrigerant from a high-pressure to the relatively lower operating pressure of evaporator coils 20. In addition to reducing refrigerant pressure, refrigerant flow may be metered by the expansion device 13 in any conventional manner such as a needle stem or a small diameter orifice or tube that limits the amount of refrigerant exiting the expansion device outlet port 16 and entering the flow divider. Flow divider 18 then separates the lower pressure refrigerant between the plurality of coils 20. Once within the coils 20, the refrigerant absorbs heat (indicated by arrows 21) from the surrounding environment, thereby changing from predominantly liquid to vapor. After absorbing heat, the refrigerant flows back to compressor 12 and on to the condenser, where the absorbed heat is removed.

When the refrigerant passes through expansion device 13, a portion of the refrigerant "flashes" to vapor due to the rapid pressure drop. As noted in the Background Of The Invention, conventional orifice designs allow vapor and liquid refrigerant to separate, increasing the likelihood that some evaporator coils 20 receive more vapor refrigerant than others, thereby decreasing efficiency of the refrigerant system. Moreover, current high-efficiency designs only allow a relatively short flow path within the outlet port 16, on the order of zero to two inches, between the expansion device 13 and the flow divider 18, such that phase-separated refrigerant is passed to flow divider 18.

The present invention provides a homogenous refrigerant mixture to flow divider 18 by inducing refrigerant mixing within the expansion device outlet port 16. A first embodiment of an expansion device outlet port 16' according to the present invention is shown in FIG. 2, which shows one outlet port design of a thermal expansion valve. Outlet port 16' includes a generally annular body 22 that defines a flow path 24 having a generally circular cross-section between an inlet 26 and an outlet 28. When installed, refrigerant flows from the condenser through any type of expansion device and into inlet 26. After passing through port 16', the refrigerant exits through outlet 28 to the flow divider. In other words, inlet 26 of outlet port 16' receives expanded refrigerant from an outlet side (not shown) of any type of expansion device 13.

As refrigerant exits expansion device 13 and enters outlet port 16', a portion of the refrigerant expanded within expansion device 13 flashes to vapor and separates from the liquid refrigerant. To prevent phase-separated refrigerant from flowing into a flow divider, a mixing screen 34 is inserted at a point adjacent outlet 28 to cover a predetermined radial area of flow path 24. By altering the radial area covered by mixing screen 34, and by altering the positioning of the screen, the valve may be "tuned" to provide a particular vapor/liquid refrigerant mixture to the flow divider. Additionally, the mesh size of screen 34 may be altered to maximize mixing of two-phase refrigerant while minimizing the pressure drop as the refrigerant passes through the screen. Preferably, though, mixing screen 34 covers the entire radial flow area of flow path 24. In the embodiment shown in FIG. 2, outlet port 16' further enhances continued mixing of refrigerant downstream of an expansion device by concentrically shrinking flow path 24 slightly from a diameter D_1 to a smaller diameter D_2. Additionally, the smaller diameter D_2 acts to seat screen 34 in place within port 16'. However, an decreased diameter D_2 within outlet port 16' upstream of screen 34 is not required for proper operation of the invention.

As the separated vapor/liquid refrigerant flows through mixing screen 34, the refrigerant flow becomes turbulent, inducing mixing of the two-phase refrigerant into a generally homogenous vapor/liquid mixture as the refrigerant exits outlet 28 and enters the flow divider. In this way, generally mixed-phase refrigerant is provided to each of the evaporator coils.

In a second embodiment, show in FIGS. 3 and 4, turbulent mixing is accomplished within expansion device outlet ports 116, 116' by providing a plurality of concentric axially spaced annular shoulders 134 on an inner circumference 136 of the flow path 124 between inlet 126 and outlet 128. In FIG. 3, a plurality of concentric shoulders 134 gradually decrease the diameter of flow path 124 between inlet 126 and outlet 128 in small, but controlled increments. The decreasing diameter arrangement is used in outlet ports 116 having relatively low velocity flow at inlet 126. As refrigerant flows from inlet 126 to outlet 128, the refrigerant velocity is increased, thereby promoting turbulent mixing in the area of shoulders 134. While three diameter increases are shown, more such diameter increases may be desired. Moreover, depending on the environment, the change in diameter may be either constant or varied. FIG. 4 shows concentric shoulders 134' of increasing radius, which is used in outlet ports having relatively high velocity flow at inlet 126'. Because the incremental diameter increases are relatively small, the refrigerant flow velocity is maintained at a turbulent flow velocity, preventing separation of the refrigerant into liquid and vapor flow portions. Finally, ports 116, 116' may include both increasing and decreasing diameter changes, if desired, to maximize mixing of the two-phase refrigerant.

A third embodiment of expansion device outlet port 216 is shown in FIG. 5. In the third embodiment, flow path 224 has a generally constant inner diameter D_3 from inlet 226 to outlet 228. To induce turbulent flow of refrigerant through flow path 224, the inner surface 236 of the flow path includes at least one helical rifled groove 238. Groove 238 forces the refrigerant to spiral as it flows through the body 222, enhancing turbulence and mixing of the two-phase refrigerant within the outlet port prior to entering the flow divider.

In a fourth embodiment, shown in FIG. 6, expansion device outlet port 316 includes a flow path 324 having a generally constant diameter D_4 at both inlet 326 and outlet 328. However, inlet flow path 324A and outlet flow path 324B are slightly radially offset at a point 338 in between the inlet and the outlet. Inlet flow path 324A is axially centered about axis A-A while outlet flow path 324B is axially centered about axis B-B. At the point of offset, a shoulder 334 causes mixing of the refrigerant, thereby enhancing mixing and homogeneity of the two-phase refrigerant.

The embodiment shown in FIGS. 7 and 8 demonstrates that the present invention may be utilized in any refrigerant system having a short flow path between an expansion device 413 and a flow divider 418. The expansion device 413, in this case a plug 470 having a relatively small diameter orifice 472 axially therethrough, is located a short distance X upstream of flow divider 418. In current high-efficiency designs, the distance X may be anywhere between zero to two inches, and is generally less than 1.5 inches. According to the present invention, a mixing device 434 is provided within an expansion device outlet port 416. The mixing device 434 is shown in

FIGS. 7 and 8 as being a screen, but may be any device that allows separated two-phase refrigerant to mix turbulently to provide a generally homogenous two-phase mixture to flow divider 418. As shown in FIG. 8, it is known to provide a debris screen 430 upstream of expansion device 413 to prevent debris from blocking the expansion device. It does not promote refrigerant mixing. However, debris screen 430 is located upstream of any refrigerant expansion, and is designed to filter debris out of predominantly liquid refrigerant. In contrast, locating a second screen within a relatively short distance X between expansion device 413 and flow divider 418 enhances turbulent mixing of refrigerant, and enhances the efficiency of the refrigerant system.

All of the inventive embodiments enhance turbulent flow between an inlet and an outlet on a TXV body to increase mixing of two-phase refrigerant into a homogenous mixture. When a homogenous mixture is provided to flow divider 18, each evaporator coil 20 receives a well-mixed two-phase refrigerant, thereby increasing the efficiency of each coil and of the system as a whole. Moreover, each inventive embodiment is relatively inexpensive and simple to manufacture, and provides a relatively simple way to increase efficiency or capacity of a refrigerant system.

Preferred embodiments of the present invention have been disclosed. A person of ordinary skill in the art would realize, however, that certain modifications would come within the teachings of this invention. Therefore, the following claims should be studied to determine the true scope and content of the invention.

CLAIMS

What is claimed is:

1. An expansion device outlet port for use in a refrigerating system having refrigerant being expanded within an expansion device before being divided within a flow divider among multiple evaporator coils, comprising:

a generally annular body defining a flow path from an inlet to an outlet wherein said inlet receives refrigerant from the expansion device, said flow path including a passage from said inlet to said outlet; and

a mixing device between said inlet and said outlet to promote mixing of two-phase refrigerant between the expansion device and the flow divider.

2. The expansion device outlet port of claim 1, wherein said mixing device is a screen inserted within said passage.

3. The expansion device outlet port of claim 2, wherein said screen includes a mesh sized to maximize mixing of the refrigerant while minimizing the pressure drop across the screen.

4. The expansion device outlet port of claim 2, wherein said screen radially extends and covers an entire cross-sectional area of said passage.

5. The expansion device outlet port of claim 1, wherein said mixing device is formed as a plurality of concentric, axially spaced annular shoulders formed on an inner circumference of said passage.

6. The expansion device outlet port of claim 5, wherein consecutive shoulders increase in diameter along said flow path between said inlet and said outlet.

7. The expansion device outlet port of claim 5, wherein consecutive shoulders decrease in diameter along said flow path between said inlet and said outlet.

8. The expansion device outlet port of claim 1, wherein said mixing device includes at least one rifling groove on an inner circumferential surface of said passage.

9. The expansion device outlet port of claim 1, wherein said flow path further includes an inlet flow path and an outlet flow path, a center axis of said inlet flow path radially offset with respect to a center axis of said outlet flow path.

10. The expansion device outlet port of claim 9, wherein said inlet flow path and said outlet flow path have substantially the same radial cross-sectional area.

11. A refrigerant system, comprising:

a compressor fluidly connected to a condenser, said condenser further connected to a refrigerant expansion device;

a flow divider connected to an outlet port of said refrigerant expansion device for dividing refrigerant flow between a plurality of evaporator coils, said outlet port further comprising

a generally annular body defining a flow path from an inlet to an outlet, said flow path including a passage from said inlet to said outlet and

a mixing device between said inlet and said outlet to promote mixing of two-phase refrigerant between said expansion device and said flow divider.

12. The refrigerant system of claim 11, wherein said mixing device is a mixing screen inserted within said passage.

13. The refrigerant system of claim 12, further comprising a debris screen interposed between said condenser and said expansion device to filter debris from generally liquid refrigerant.

14. The refrigerant system of claim 12, wherein said mixing screen radially extends and covers an entire cross-sectional area of said passage.

15. The refrigerant system of claim 11, wherein said mixing device is formed as a plurality of concentric, axially spaced annular shoulders formed on an inner circumference of said passage.

16. The refrigerant system of claim 15, wherein consecutive shoulders increase in diameter along said flow path between said inlet and said outlet.

17. The refrigerant system of claim 15, wherein consecutive shoulders decrease in diameter along said flow path between said inlet and said outlet.

18. The refrigerant system of claim 11, wherein said mixing device includes at least one rifling groove on an inner circumferential surface of said passage.

19. The refrigerant system of claim 11, wherein said flow path further includes an inlet flow path and an outlet flow path, a center axis of said inlet flow path radially offset with respect to a center axis of said outlet flow path.

20. The refrigerant system of claim 19, wherein said inlet flow path and said outlet flow path have substantially the same radial cross-sectional area.

21. The refrigerant system of claim 20, wherein a distance between said expansion device and said flow divider is less than two inches.

22. The refrigerant system of claim 20, wherein said inlet is immediately adjacent said expansion device and said outlet is immediately adjacent said flow divider.

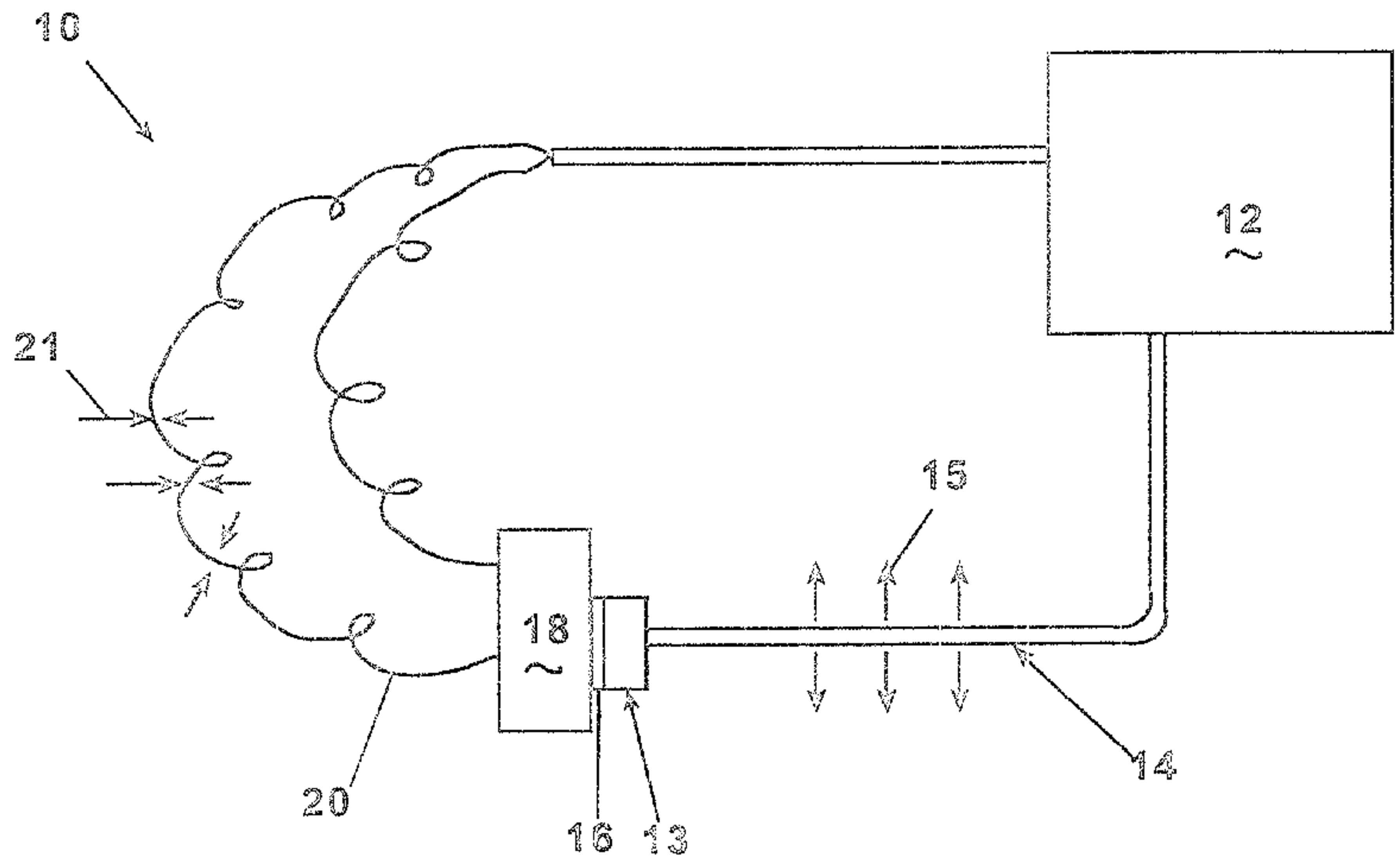


Fig. 1

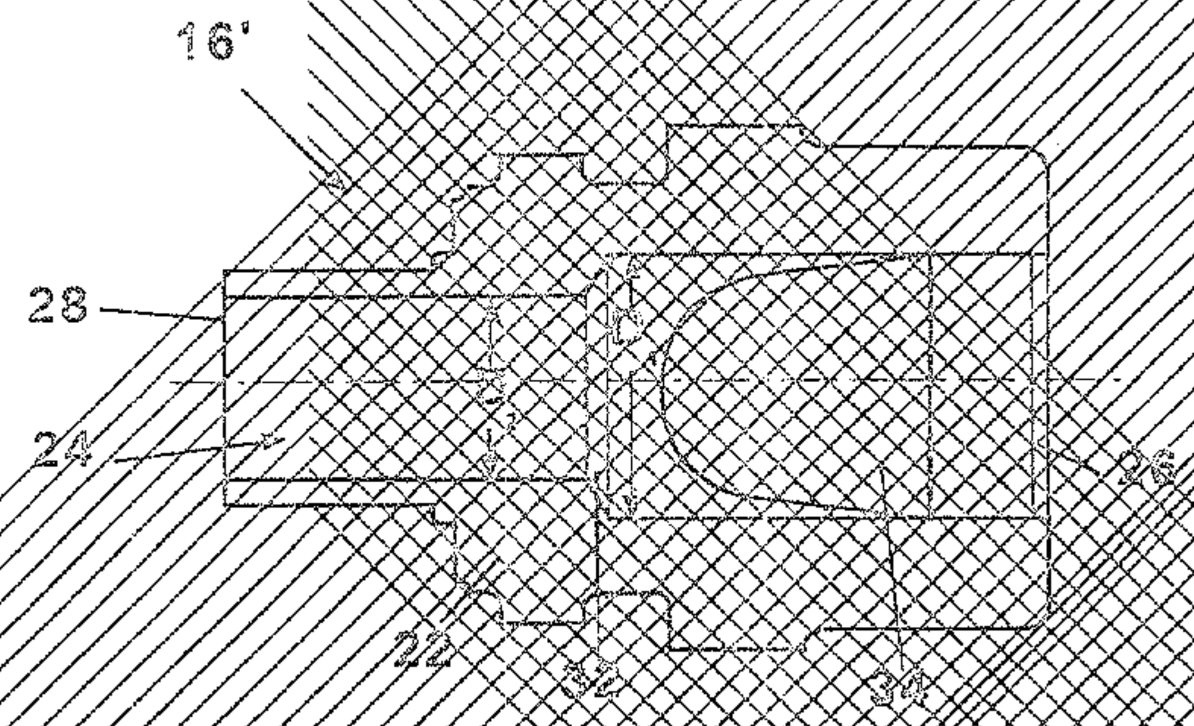


Fig. 2

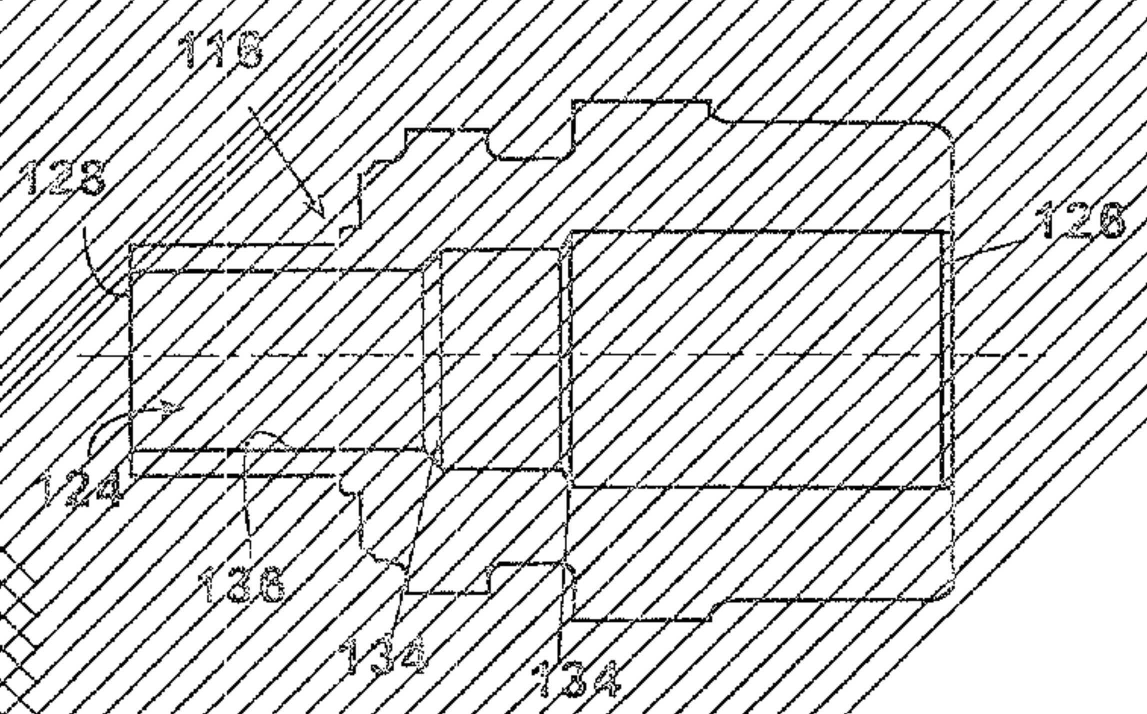


Fig. 3

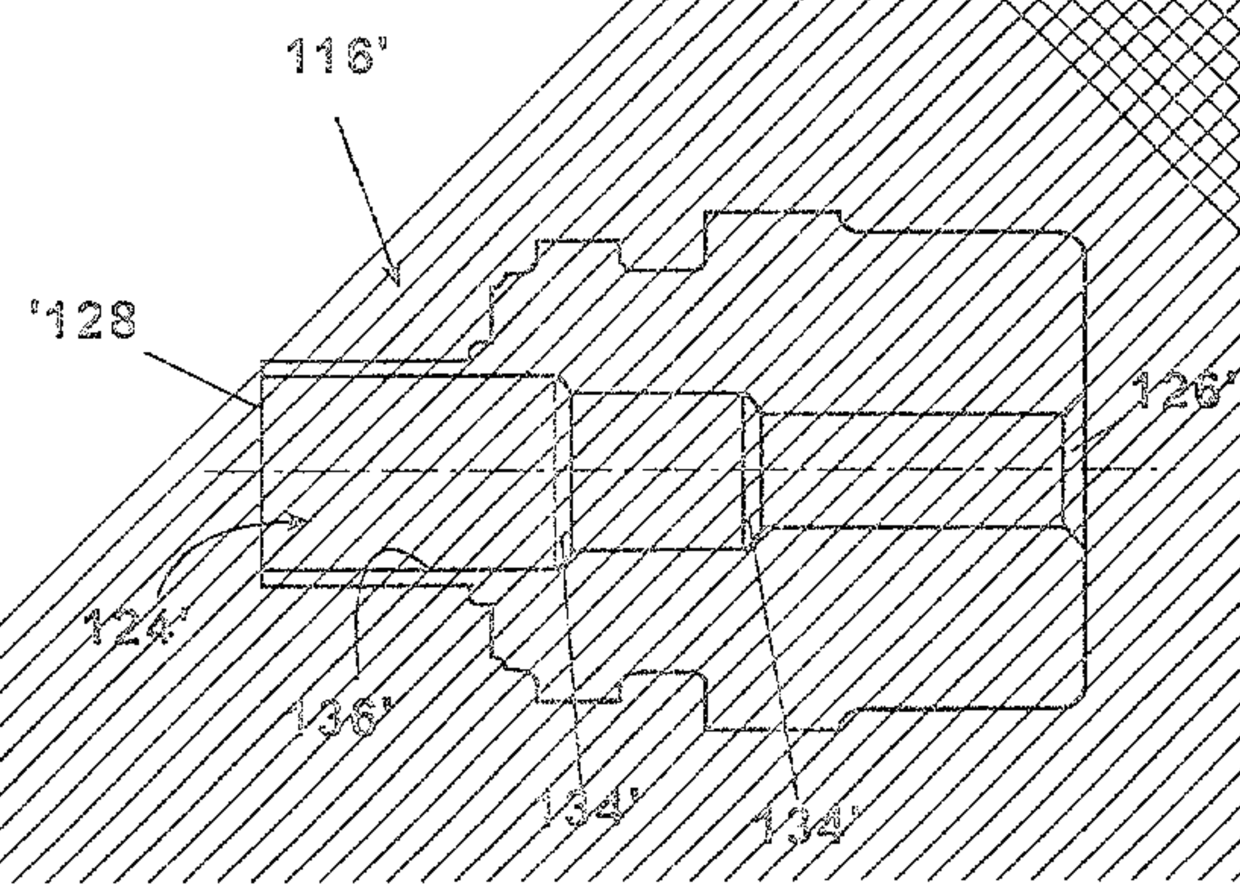


Fig. 4

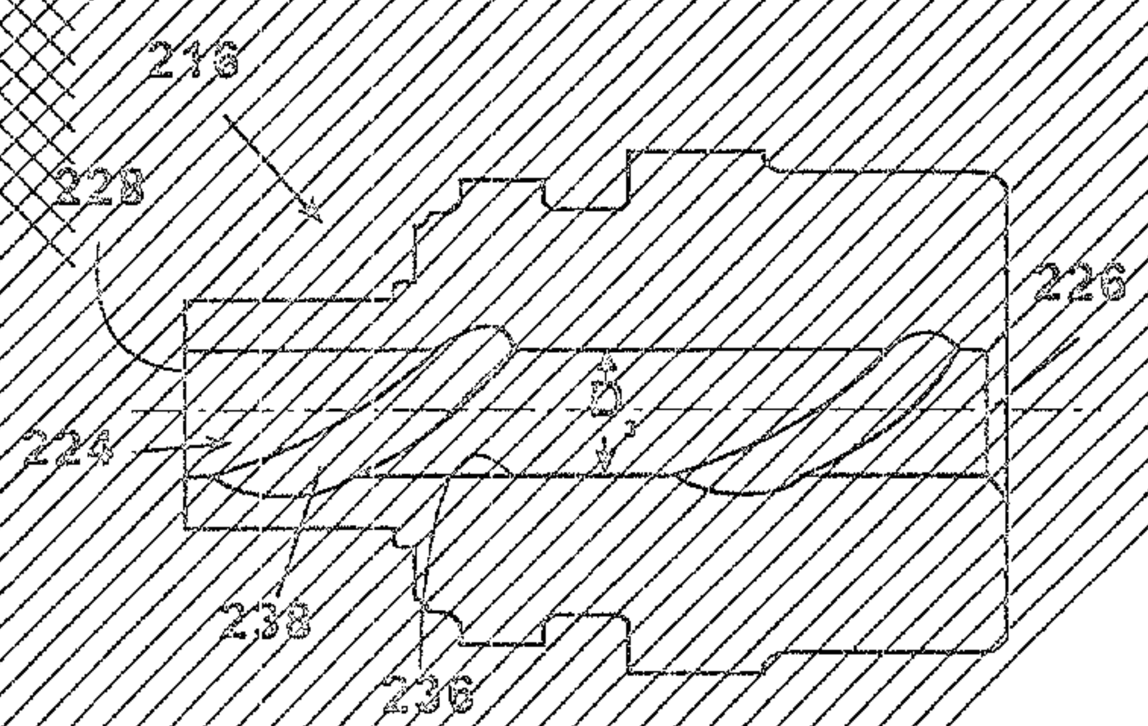


Fig. 5

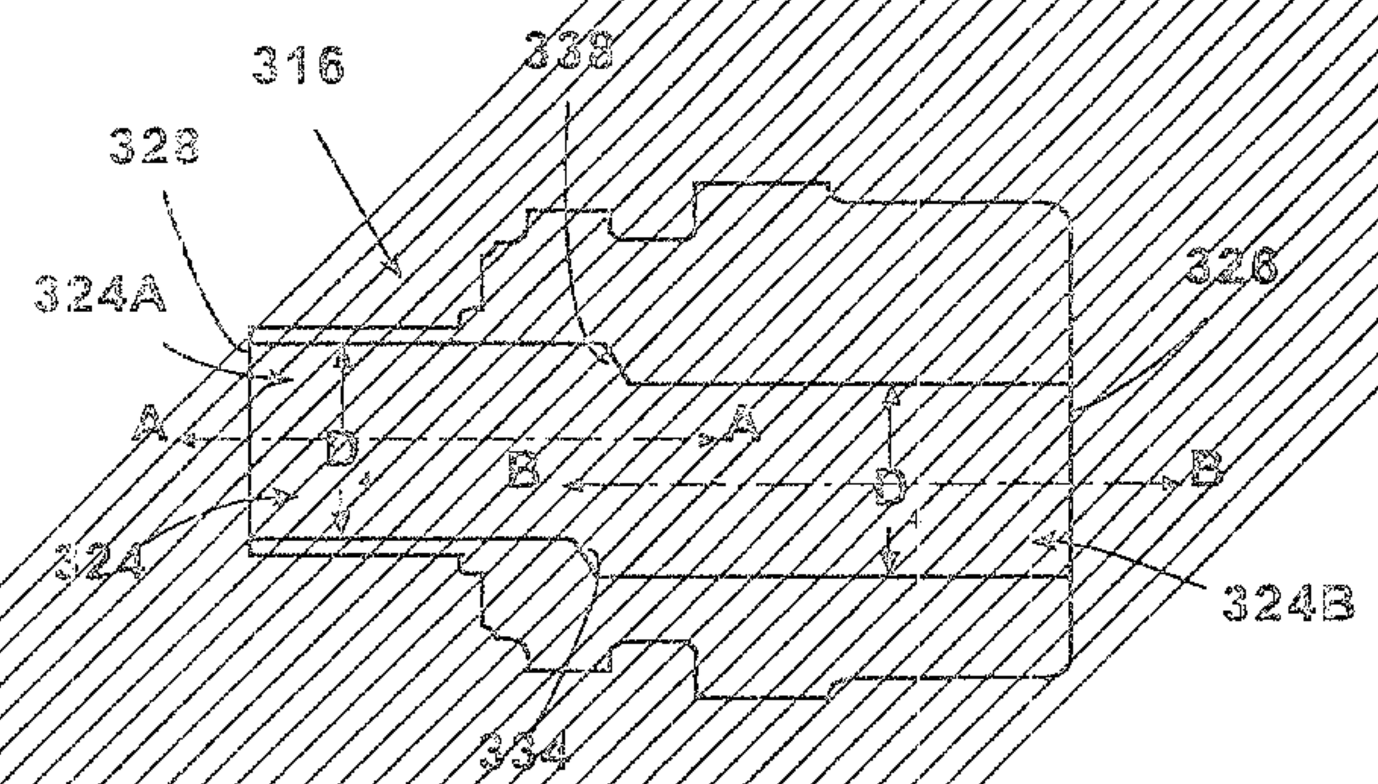


Fig. 6

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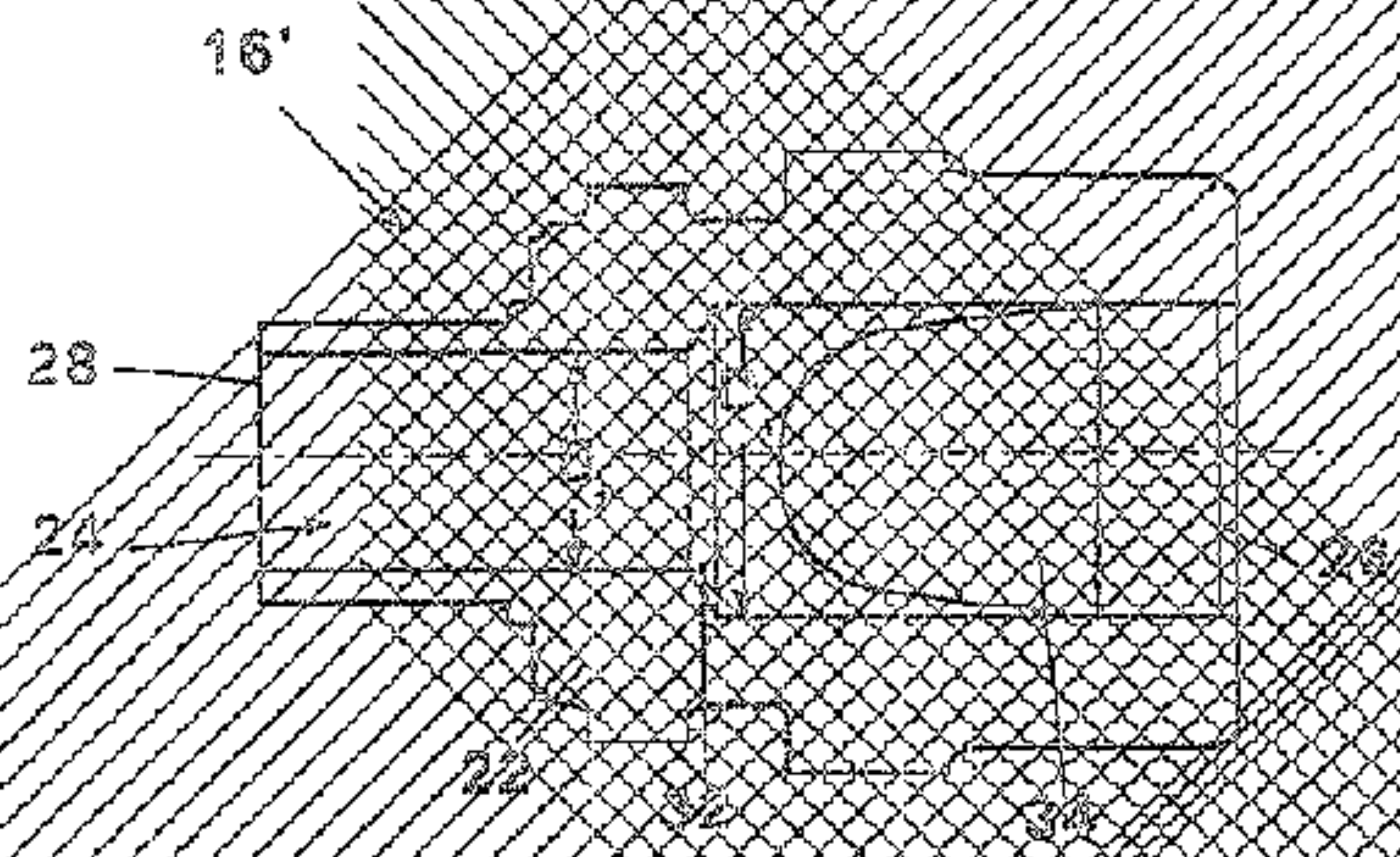
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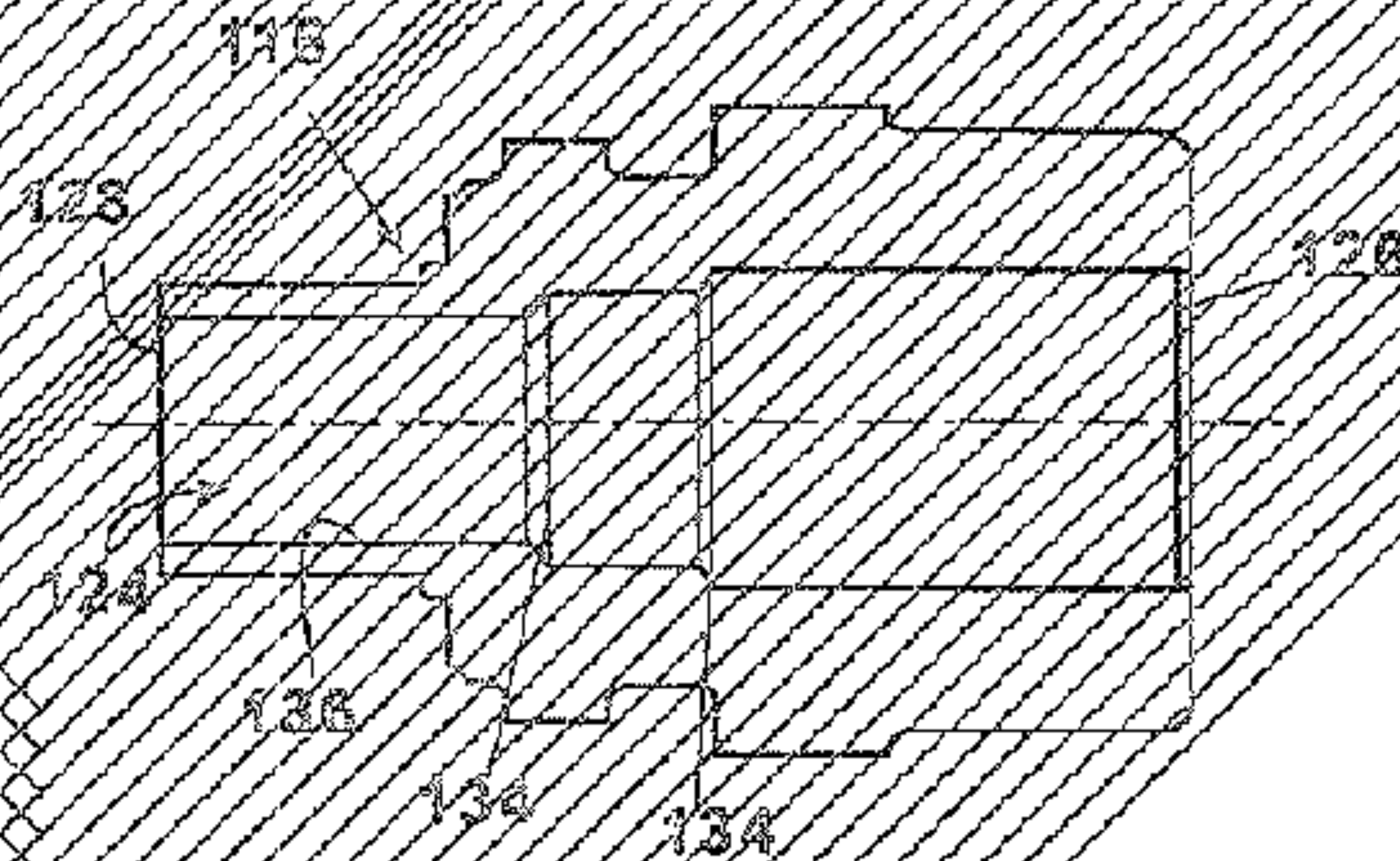
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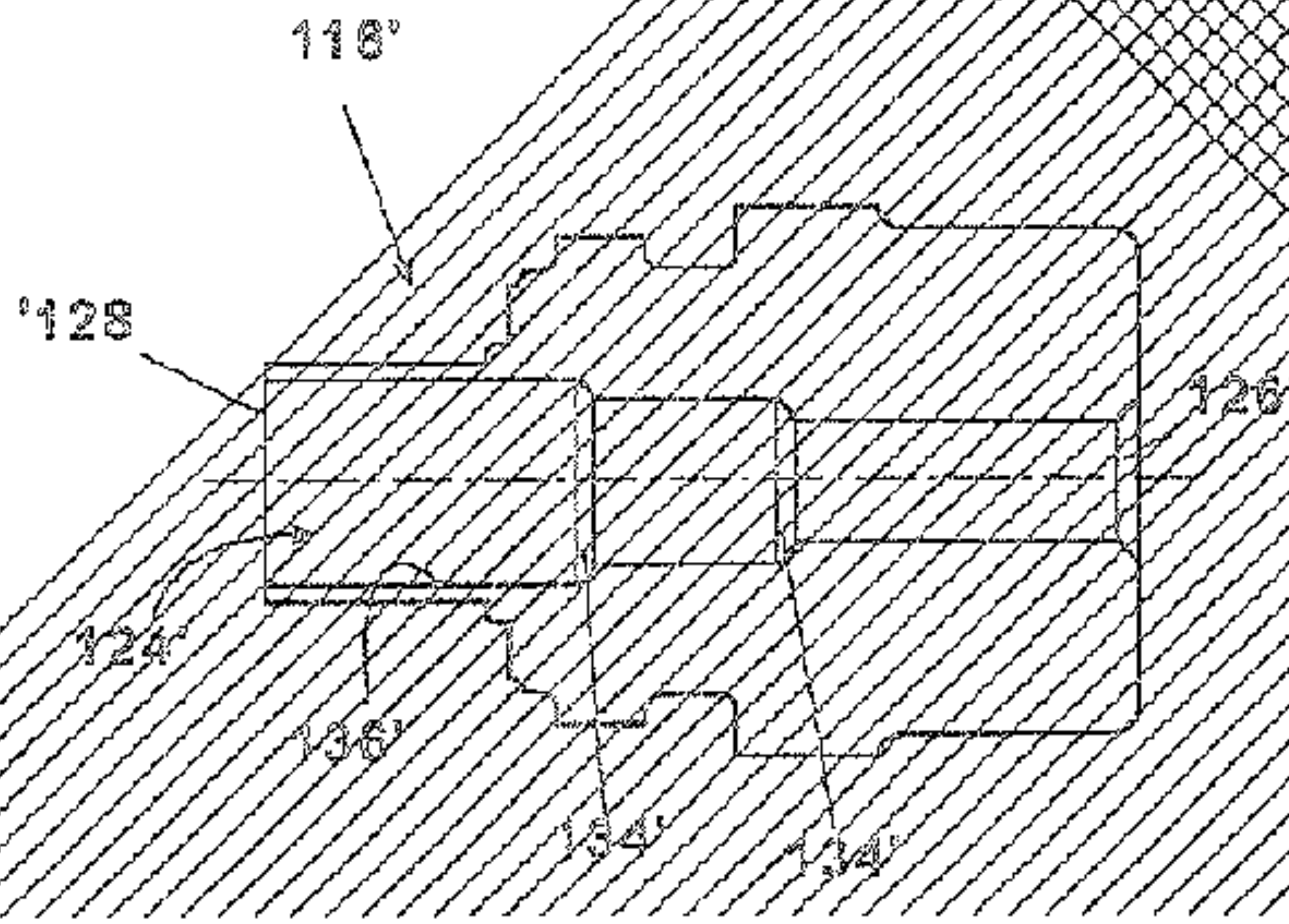
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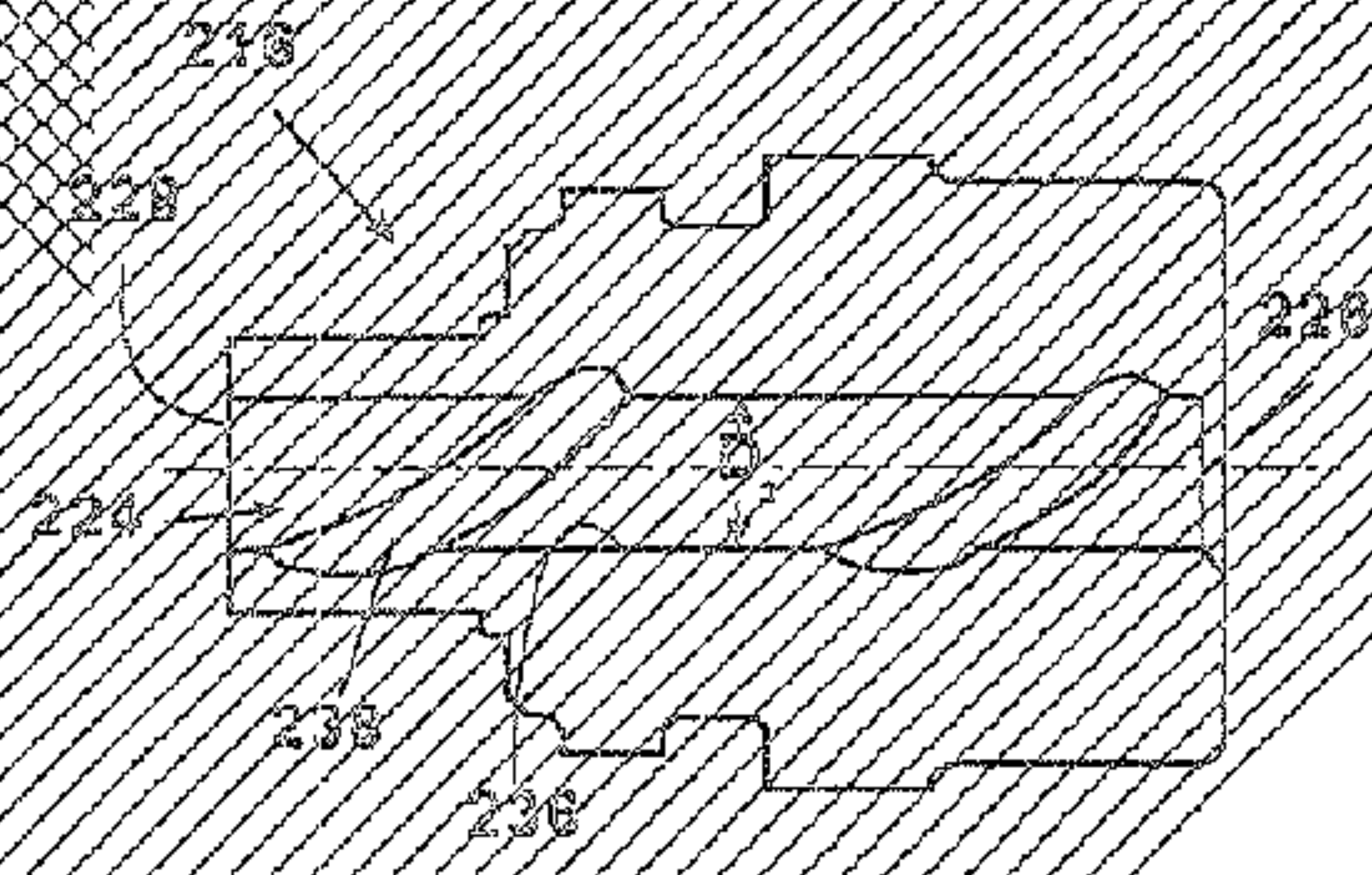
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