A shell-and-plate heat exchanger and use of a shell-and-plate heat exchanger

Disclosed is a shell-and-plate heat exchanger (1) for cooling and condensing a circulating refrigerant. The heat exchanger (1) comprises a desuperheater (2) for lowering the temperature of the gaseous refrigerant to a temperature above the condensation temperature of the refrigerant, wherein the desuperheater (2) is formed by a stack of corrugated desuperheater heat transfer plates (3). The desuperheater (2) is connected to a condenser (4) for condensing a main part of the refrigerant, wherein the condenser (4) is formed by a stack of corrugated condenser heat transfer plates (5). The condenser (4) is connected to a subcooler (6) for further lowering the temperature of the condensed refrigerant, wherein the subcooler (6) is formed by a stack of corrugated subcooler heat transfer plates (7), and wherein the stack of corrugated desuperheater heat transfer plates (3), the stack of corrugated condenser heat transfer plates (5) and the stack of corrugated subcooler heat transfer plates (7) are arranged inside the same common continuous shell (8).
Description

Field of the Invention

The present invention relates to a shell-and-plate heat exchanger for cooling and condensing a circulating refrigerant. The invention further relates to use of a shell-and-plate heat exchanger.

Background of the Invention

Shell-and-plate (or plate-and-shell) heat exchangers consist of a series of corrugated plates peripherally welded to each other in pairs (so-called cassettes) which in turn is welded to each other along the entrance holes and exit holes to form a complete plate pack. The welded plate pack is inserted and either welded or bolted within a tubular shell, typically formed from steel and typically without peripheral gaskets. The shell-and-plate heat exchanger is a versatile design which combines the strength of a shell-and-tube exchanger with the thermal efficiency of a plate exchanger in that the shell-and-plate heat exchanger combines the pressure and temperature capabilities of a typically cylindrical shell with the excellent heat transfer performance of a plate heat exchanger. The round or oblong shell and plates ensure an even distribution of mechanical loads, without the stress concentrations that occur in the corners of rectangular plates. Thus, the shell-and-plate heat exchanger combines the benefits of a traditional shell and tube type heat exchanger but with the high efficiency provided for in a plate type exchanger.

From WO 97/45689 it is therefore known to use a plate and shell heat exchanger for evaporating the refrigerant in a refrigerator circuit and another plate and shell heat exchanger for condensing the refrigerant in the refrigerator circuit. But this heat exchanger design is complex and difficult to install.

It is therefore an object of the present invention to provide for a more simple and cost-efficient heat exchanger design.

The invention

The invention relates to a shell-and-plate heat exchanger for cooling and condensing a circulating refrigerant. The heat exchanger comprises a desuperheater for lowering the temperature of the gaseous refrigerant to a temperature above the condensation temperature of the refrigerant, wherein the desuperheater is formed by a stack of corrugated desuperheater heat transfer plates. The desuperheater is connected to a condenser for condensing the refrigerant, wherein the condenser is formed by a stack of corrugated condenser heat transfer plates. The condenser is connected to a subcooler for further lowering the temperature of the condensed refrigerant, wherein the subcooler is formed by a stack of corrugated subcooler heat transfer plates, and wherein the stack of corrugated desuperheater heat transfer plates, the stack of corrugated condenser heat transfer plates and the stack of corrugated subcooler heat transfer plates are arranged inside the same common continuous shell.

Pressure vessels like desuperheaters, condensers and subcoolers have to be pressure tested and approved by an independent authority before commercial use. This is both complex and expensive. Thus, by arranging the desuperheater, the condenser and the subcooler inside the same common continuous shell all three functions can be obtained by means of only one test and approval.

Furthermore, by arranging the desuperheater, the condenser and the subcooler inside the same common continuous shell, complicated finishing arrangements and piping between the three can be avoided hereby reducing cost and simplifying installation. And the overall shell-and-plate heat exchanger arrangement is more compact hereby simplifying installation and increasing usability.

In an aspect of the invention, said condenser and said subcooler is connected through a liquid refrigerant container arranged bellow said stack of condenser heat transfer plates and/or said stack of subcooler heat transfer plates, in that said condensed refrigerant is collected in said liquid refrigerant container from which said liquid refrigerant continues into said subcooler through a subcooler inlet conduit. The efficiency of the subcooler is severely reduced if the refrigerant is gaseous when entering the subcooler. And since the efficiency of e.g. a refrigeration cycle is also severely reduced if the shell-and-plate heat exchanger delivers gaseous refrigerant it is advantageous to ensure that only liquid refrigerant is continued into the subcooler by using gravity to collect the liquid refrigerant in a liquid refrigerant container arranged beneath the condenser and/or the subcooler.

In an aspect of the invention, a conduit inlet opening of said subcooler inlet conduit is arranged at the bottom of said liquid refrigerant container.

Arranging the inlet opening of the subcooler inlet conduit at the bottom of the liquid refrigerant container is advantageous in that it increases the capacity of the refrigerant container, in that the subcooler inlet conduit hereby is capable of almost completely emptying the liquid refrigerant container.

In an aspect of the invention, said liquid refrigerant container is arranged outside said shell.

Arranging the liquid refrigerant container outside the heat exchanger shell is advantageous in that it enables a simpler heat exchanger design.

In an aspect of the invention, said shell encircles said desuperheater, said condenser and said subcooler.

Making the shell encircle the desuperheater, the condenser and the subcooler is advantageous in that this design ensures a strong an durable shell capable of withstanding high internal pressure.
In an aspect of the invention, said shell-and-plate heat exchanger comprises a refrigerant conduit through which said refrigerant is moved from said desuperheater to said condenser and wherein said refrigerant conduit is arranged inside said shell.

Arranging the refrigerant conduit inside the shell is advantageous in that complicated piping hereby can be avoided, thus reducing cost and simplifying installation.

In an aspect of the invention, said shell-and-plate heat exchanger comprises a coolant conduit extending continuously through said desuperheater, said condenser and said subcooler inside said common continuous shell.

Arranging the coolant conduit to extend continuously through the desuperheater, the condenser and the subcooler inside the shell is advantageous in that external piping is avoided, thus reducing cost and simplifying installation.

In an aspect of the invention, said desuperheater and said condenser are separated by a first separation plate arranged inside said common continuous shell and wherein said first separation plate comprises a refrigerant conduit and a coolant passage opening.

Arranging a separation plate between the desuperheater and the condenser is advantageous in that the plate will ensure that refrigerant is guided correctly from the desuperheater and into the condenser, while at the same time ensuring that condensed liquid cannot pass from the condenser and into the desuperheater. Hereby is the efficiency of both functions increased.

In an aspect of the invention, said condenser and said subcooler are separated by a second separation plate arranged inside said common continuous shell and wherein said second separation plate comprises only a coolant passage opening.

Arranging a separation plate between the condenser and the subcooler is advantageous in that the plate will prevent that refrigerant is passed directly from the condenser and into the subcooler, hereby enabling that liquid and gaseous refrigerant can be separated to subsequently open the shell e.g. in case of maintenance or repair work.

In an aspect of the invention, said continuous shell is formed by two or more connected shell parts.

Forming the shell by two or more connected shell parts is advantageous in that it hereby is possible to subsequently open the shell e.g. in case of maintenance or repair work.

In an aspect of the invention, said heat exchanger comprises endplates welded to both ends of said shell.

Welding the endplates ensures that the pressure vessel is both strong and tight.

Forming the shell cylindrical is advantageous in that this shape ensure an even distribution of the pressure load on the shell.

In an aspect of the invention, said desuperheater heat transfer plates, said condenser heat transfer plates and said subcooler heat transfer plates are substantially identical.

Forming all the heat transfer plates inside the shell-and-plate heat exchanger substantially identical is advantageous in that it reduces production costs and simplifies assembly.

In an aspect of the invention, said common continuous shell is a pressure vessel designed and/or approved to withstand a pressure between 0.7 and 15 MPa, preferably between 1.5 and 10 and most preferably between 2.5 and 7.5 MPa.

If the pressure, the shell is designed to withstand, is too low, the risk of leakage or even explosion is too big. However, if the pressure, the shell is designed to withstand, is too high the shell becomes too heavy and expensive. Thus, the present pressure ranges presents an advantageous relationship between safety and cost.

The invention also relates to use of a shell-and-plate heat exchanger according to any of the previously disclosed shell-and-plate heat exchangers for cooling and condensing a refrigerant in a refrigeration cycle.

Using a shell-and-plate heat exchanger according to the present invention for cooling and condensing a refrigerant in a refrigeration cycle is advantageous in that it ensures a less expensive and safer refrigeration cycle.

Figures

The invention will be explained further herein below with reference to the figures in which:

Fig. 1 shows an embodiment of the coolant flow through a cross section of a shell-and-plate heat exchanger, as seen from the side,

Fig. 2 shows an embodiment of the refrigerant flow through a cross section of a shell-and-plate heat exchanger, as seen from the side,

Fig. 3 shows a cross section through a dividable shell-and-plate heat exchanger, as seen from the
Fig. 4 shows an embodiment of a heat transfer plate for a shell-and-plate heat exchanger, as seen from the front.

Detailed description

Figure 1 shows an embodiment of the coolant flow through a cross section of a shell-and-plate heat exchanger 1, as seen from the side.

In this embodiment the coolant inlet 22 is arranged in one endplate 21 and the coolant outlet 23 is arranged in the opposite endplate 21, while the refrigerant inlet 24 and/or refrigerant outlet 25 and/or some or all the inlets 22, 24 and/or all the outlets 23, 25 could be arranged in the endplates 22.

In this embodiment the heat exchanger 1 comprises a desuperheater 2, a condenser 4 and a subcooler 6 arranged inside the same common continuous shell 8 encircling all three heat exchanger functions.

Each of the desuperheater 2, the condenser 4 and the subcooler 6 are formed by a number of heat transfer plates 3, 5, 7 welded together as discussed in relation with fig. 4.

The arrows on figure 1 illustrate an embodiment of a coolant flow through the coolant conduit 14 of the heat exchanger 1.

In this embodiment the entire coolant conduit 14 is arranged inside said shell 8 but in another embodiment at least parts of the coolant conduit 14 could be arranged outside the shell 8 e.g. to pass a separation plate 15, 18 or other.

First the coolant enters the heat exchanger 1 at the coolant inlet 22 and flows through the subcooler 6. A second separation plate 18 blocks the access to the condenser 4 and thus forces the coolant to run transversely towards the upper coolant passage opening 17 in the second separation plate 18 from which it enters the condenser 4. In the condenser 4, condenser coolant blocking means 30 forces the coolant to run transversely towards the bottom of the condenser 4 and then longitudinal until a first separation plate 15 forces the coolant upwards towards the upper coolant passage opening 17 in the first separation plate 15. From the coolant passage opening 17 the coolant is forced down through the desuperheater 2 and finally out through the coolant outlet 23.

Thus, in this embodiment the coolant performs one pass in the subcooler 6 and the desuperheater 2 and two passes in the condenser 4 but in another embodiment one or more of the desuperheater 2, condenser 4 and subcooler 6 could be arranged to comprise means for allowing fewer or particularly more passes.

The differences between the refrigerant and the coolant, flowing through the heat exchanger 1, are that the refrigerant is always circulating in a closed circuit, wherein it changes phase from one state of matter to another (between gas and liquid form) at least twice during circulation, while the coolants main purpose is to remove heat from the refrigerant.

In this embodiment the coolant is water e.g. circulating through an external air cooled heat exchanger or transporting the absorbed heat to a particular place where it can be utilised.

However, in another embodiment the coolant could be brine or another form of natural or artificial coolant suitable for flowing through a combined desuperheater 2, condenser 4 and subcooler 6.

In this embodiment the desuperheater heat transfer plates 3, the condenser heat transfer plates 5 and the subcooler heat transfer plates 7 are substantially identical to reduce production cost and simplifying assembly but in another embodiment the plates 3, 5, 7 could be designed for their specific use, for their specific location in the heat exchanger 1, for specific temperatures or other making the design of the plates 3, 5, 7 in the heat exchanger vary.

Likewise, in this embodiment all the plates 3, 5, 7, the shell 8 and the endplates 21 are all made from stainless steel because of this materials strength and durability but in another embodiment all or some of the heat exchanger parts could be made from another material such as titanium, aluminium, a composite material or other.

Fig. 2 shows an embodiment of the refrigerant flow through a cross section of a shell-and-plate heat exchanger 1, as seen from the side.

The arrows on figure 2 illustrate an embodiment of a refrigerant flow through the combined desuperheater 2, condenser 4 and subcooler 6.

In this embodiment the hot gaseous refrigerant enters the heat exchanger 1 through the refrigerant inlet 24 from which it is directed up through the desuperheater 2 to dissipate some of its heat to the coolant flowing through the inside of the plate pack in the desuperheater 2. A refrigerant conduit 13 along the upper periphery of the first separation plate 15 ensures that the desuperheated gaseous refrigerant is directed into the condenser there the refrigerant condenses while passing down through the relatively cold heat transfer plates 5 in the condenser 4. The liquid refrigerant is then guided out of the shell 8 through the liquid refrigerant outlet 16 and collected in a liquid refrigerant container 9 arranged outside the shell 8.

In another embodiment the liquid refrigerant could instead or also be collected inside the shell 8 before being lead to the subcooler 6.
A subcooler inlet conduit 10 extends down into the liquid refrigerant container 9 so that an conduit inlet opening 11 of the subcooler inlet conduit 10 is arranged at the bottom 12 of the liquid refrigerant container 9 to ensure that only liquid is guided into the subcooler 6.

In the subcooler 6 the liquid refrigerant is further cooled before it exits the heat exchanger 1 through the refrigerant outlet 25 arranged at the top of the shell 8.

This embodiment the refrigerant only makes one pass through each of the desuperheater 2, the condenser 4 and the subcooler 6 but in another embodiment one or more of the desuperheater 2, condenser 4 and subcooler 6 could be arranged to comprise means for allowing more than one pass.

In this embodiment the refrigerant is ammonia but in another embodiment the refrigerant could be carbon dioxide, Butane, a HFC, water vapour or another fluid suitable for acting as a refrigerant in a shell-and-plate heat exchanger 1.

In this embodiment the shell-and-plate heat exchanger 1 according to the present invention is used for cooling and condensing a refrigerant in a refrigeration cycle. I.e. after the cold liquid refrigerant leaves the shell-and-plate heat exchanger 1 it is typically directed to an expansion valve, which will reduce the pressure making at least some of the refrigerant evaporate and thus making its temperature drop drastically. At this stage the cold refrigerant is then used for cooling purposes by which the entire refrigerant evaporates. The gaseous refrigerant is then directed through a compressor compressing the refrigerant, which in turn raises its temperature drastically. The hot gaseous refrigerant is then lead to the desuperheater 2, where the refrigerant's temperature is lowered to just above the condensation temperature before it enters the condenser 4 where the gaseous refrigerant is condensed into a liquid refrigerant. Finally, the liquid refrigerant is cooled further in the subcooler 6 before the cycle is repeated.

In the embodiment disclosed in figures 1-3 the different functions in the heat exchanger 1 i.e. the desuperheater 2, condenser 4 and subcooler 6 are separated by means of a first separation plate 15 and a second separation plate 18. However, in another embodiment of the invention functions could be separated by means of dedicated gaskets (not shown) arranged to guide the refrigerant flow between the two neighbouring functions. If gaskets are used instead of separation plates 15, 18, the desuperheater 2, condenser 4 and subcooler 6 could be formed as one big plate pack with coolant blocking means strategically arranged in one of the inlet cassette opening 26 and outlet cassette opening 27 where the gasket(s) is arranged - inlet cassette opening 26 or outlet cassette opening 27 are shown and discussed in relation with fig. 4.

Fig. 3 shows a cross section through a dividable shell-and-plate heat exchanger 1, as seen from the side.

In the embodiments disclosed in figs. 1 and 2 the shell 8 is formed as a single monolithic cylindrical tube to increase the strength of the shell 8 and reduce the risk of unwanted stress concentrations in the shell 8. In another embodiment the shell 8 could also be formed by a number of shell parts welded together or as disclosed in fig. 3 by means of several shell parts 19, 20 bolted together to ensure that the shell 8 subsequently can be opened e.g. in case of maintenance and/or repair.

The fully welded desuperheater heat transfer plate pack, condenser heat transfer plate pack and subcooler heat transfer plate pack allows quick and easy removal and refitting in the shell 8, thus ensuring that process downtime is kept to a minimum.

In this embodiment the first separation plate 15 is arranged to extend out between the two shell parts 19, 20 in the joint. It is hereby possible to securely arrange the first separation plate 15 in a fixed position.

Fig. 4 shows an embodiment of a heat transfer plate 3, 5, 7 for a shell-and-plate heat exchanger 1, as seen from the front.

In this embodiment the plate 3, 5, 7 is welded back to back to another plate 3, 5, 7 to form a so-called cassette. The plates 3, 5, 7 are welded along the outer periphery so that water entering the cassette at the inlet cassette opening 26 will only be able to exit the cassette through the outlet cassette opening 27. A number of these cassettes are then welded together around the inlet cassette openings 26 and the outlet cassette openings 27 to form a desuperheater heat transfer plate pack, a condenser heat transfer plate pack or a subcooler heat transfer plate pack. The coolant flow is then established inside the cassettes and the refrigerant flow is established across the outside of (i.e. between) the cassettes.

In this embodiment the plate 3, 5, 7 is primarily circular to fit into a circular shell 8 but in another embodiment the plates 3, 5, 7 could be formed differently to fit into a shell 8 of a different shape - such as oval or prolonged.

In this embodiment the plate 3, 5, 7 is provided with an embossed pattern of channels 29 so that when a cassette is formed the coolant can flow through these channels 29 from the inlet cassette opening 26 to the outlet cassette opening 27. The embossed pattern also increases the surface area of the plate 3, 5, 7 thus increasing its heat transferring ability.

In this embodiment the plate 3, 5, 7 is provided with a peripheral cutting 28 both at the top and at the bottom of the plate 3, 5, 7 to allow the refrigerant to pass this plate along both the upper and the lower periphery while at the same time ensuring that the refrigerant does not pass along the sides of the plate 3, 5, 7 and ensuring that the plate 3, 5, 7 is firmly centred inside the shell 8.

In this embodiment the plates 3, 5, 7 - and thus the cassettes, and the plate packs - fits firmly inside the shell 8 to ensure correct refrigerant flow through and around the cassettes 3, 5, 7 but in another embodiment the plates 3, 5, 7, cassettes and/or plate packs could comprise gaskets or other form of sealing means ensuring correct flow through the shell 8.
To ensure that the coolant do not mix with the refrigerant, the respective plate packs are also welded to the respective separation plates 15, 18 around the coolant passage openings 17, inlet cassette openings 26 and outlet cassette openings 27.

In the foregoing, the invention is described in relation to specific embodiments of shell-and-plate heat exchangers 1, desuperheaters 2, condensers 4, subcoolers 6 and other as shown in the drawings, but it is readily understood by a person skilled in the art that the invention can be varied in numerous ways within the scope of the appended claims.

List

1. Shell-and-plate heat exchanger
2. Desuperheater
3. Desuperheater heat transfer plates
4. Condenser
5. Condenser heat transfer plates
6. Subcooler
7. Subcooler heat transfer plates
8. Shell
9. Liquid refrigerant container
10. Subcooler inlet conduit
11. Conduit inlet opening
12. Bottom of liquid refrigerant container
13. Refrigerant conduit
14. Coolant conduit
15. First separation plate
16. Liquid refrigerant outlet
17. Coolant passage opening
18. Second separation plate
19. First shell part
20. Second shell part
21. Endplates
22. Coolant inlet
23. Coolant outlet
24. Refrigerant inlet
25. Refrigerant outlet
26. Inlet cassette opening
27. Outlet cassette opening
28. Peripheral cutting
29. Channel
30. Condenser coolant blocking means

Claims

1. A shell-and-plate heat exchanger (1) for cooling and condensing a circulating refrigerant, said heat exchanger (1) comprising a desuperheater (2) for lowering the temperature of the gaseous refrigerant to a temperature above the condensation temperature of said refrigerant, wherein said desuperheater (2) is formed by a stack of corrugated desuperheater heat transfer plates (3), said desuperheater (2) being connected to a condenser (4) for condensing said refrigerant, wherein said condenser (4) is formed by a stack of corrugated condenser heat transfer plates (5), said condenser (4) being connected to a subcooler (6) for further lowering the temperature of said condensed refrigerant, wherein said subcooler (6) is formed by a stack of corrugated subcooler heat transfer plates (7), and wherein said stack of corrugated desuperheater heat transfer plates (3), said stack of corrugated condenser heat transfer plates (5) and said stack of corrugated subcooler heat transfer plates (7) are arranged inside the same common continuous shell (8).

2. A shell-and-plate heat exchanger (1) according to claim 1, wherein said condenser (4) and said subcooler (6) is connected through a liquid refrigerant container (9) arranged bellow said stack of condenser heat transfer plates (5) and/or said stack of subcooler heat transfer plates (7), in that said condensed refrigerant is collected in said liquid refrigerant container (9) from which said liquid refrigerant continues into said subcooler (6) through a subcooler inlet conduit (10).

3. A shell-and-plate heat exchanger (1) according to claim 2, wherein a conduit inlet opening (11) of said subcooler inlet conduit (10) is arranged at the bottom (12) of said liquid refrigerant container (9).

4. A shell-and-plate heat exchanger (1) according to claim 2 or 3, wherein said liquid refrigerant container (9) is arranged outside said shell (8).

5. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said shell (8) encircles said desuperheater (2), said condenser (4) and said subcooler (6).

6. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said shell-and-plate heat exchanger (1) comprises a refrigerant conduit (13) through which said refrigerant is moved from said desuperheater (2) to said condenser (4) and wherein said refrigerant conduit (13) is arranged inside said shell (8).

7. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said shell-and-plate heat exchanger (1) comprises a coolant conduit (14) extending continuously through said desuperheater (2), said condenser (4) and said subcooler (6) inside said common continuous shell (8).

8. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said...
desuperheater (2) and said condenser (4) are separated by a first separation plate (15) arranged inside said common continuous shell (8) and wherein said first separation plate (15) comprises a refrigerant conduit (13) and a coolant passage opening (17).

9. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said condenser (4) and said subcooler (6) are separated by a second separation plate (18) arranged inside said common continuous shell (8) and wherein said second separation plate (18) comprises only a coolant passage opening (17).

10. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said continuous shell (8) is formed as a monolithic tube.

11. A shell-and-plate heat exchanger (1) according to one or more of claims 1-9, wherein said continuous shell (8) is formed by two or more connected shell parts (19, 20).

12. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said heat exchanger (1) comprises endplates (21) welded to both ends of said shell (8).

13. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said desuperheater heat transfer plates (3), said condenser heat transfer plates (5) and said subcooler heat transfer plates (7) are substantially identical.

14. A shell-and-plate heat exchanger (1) according to one or more of the preceding claims, wherein said common continuous shell (8) is a pressure vessel designed and/or approved to withstand a pressure between 0.7 and 15 MPa, preferably between 1.5 and 10 and most preferred between 2.5 and 7.5 MPa.

15. Use of a shell-and-plate heat exchanger (1) according to any of the preceding claims for cooling and condensing a refrigerant in a refrigeration cycle.
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<th>Citation of document with indication, where appropriate, of relevant passages</th>
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**CATEGORY OF CITED DOCUMENTS**

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For more details about this annex: see Official Journal of the European Patent Office, No. 12/82
REFERENCES CITED IN THE DESCRIPTION

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