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REGENERATIVE TUBE-BUNDLE HEAT EXCHANGER HAVING
SCREW-LIKE FLATTENED TUBES HELICALLY
WOUND IN SPACED-APART RELATIONSHIP
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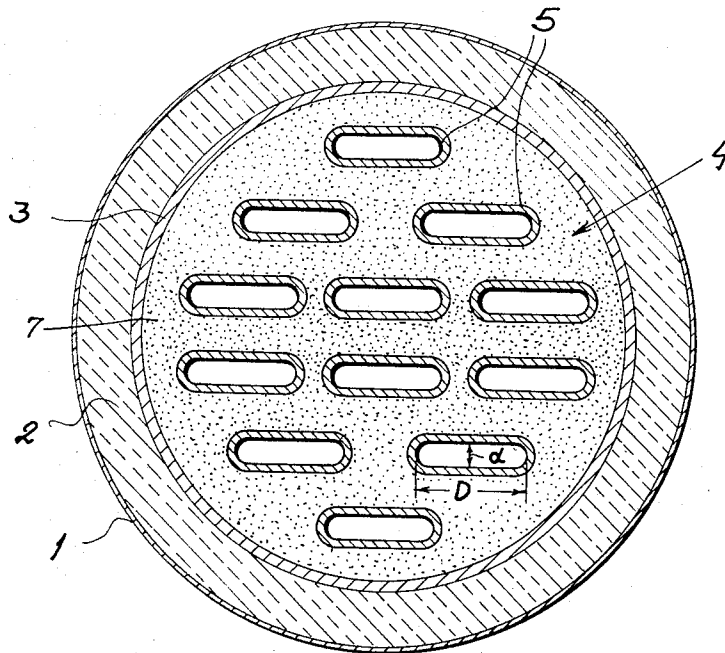


Fig. 1

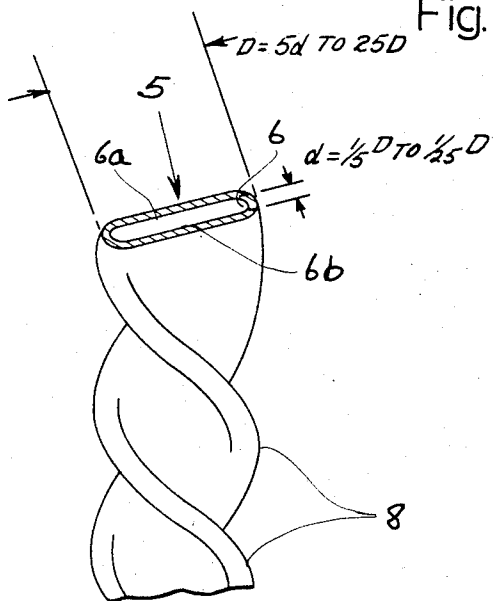


Fig. 2

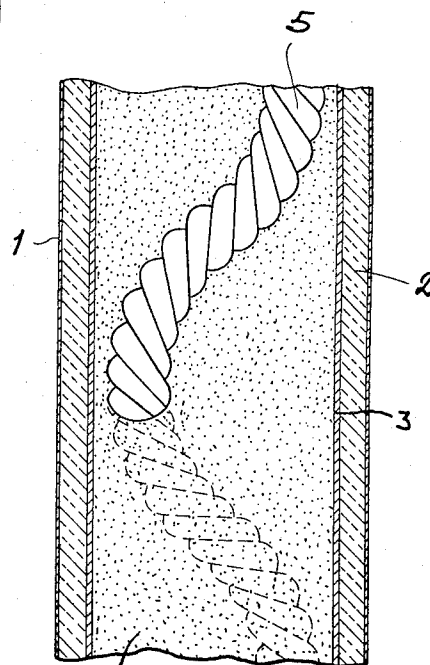


Fig. 3

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1

2

3,401,682

REGENERATIVE TUBE-BUNDLE HEAT EXCHANGER HAVING SCREW-LIKE FLATTENED TUBES HELICALLY WOUND IN SPACED-APART RELATIONSHIP

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2 Claims. (Cl. 126—400)

ABSTRACT OF THE DISCLOSURE

A regenerative tube-bundle heat exchanger having a plurality of spaced-apart helicoidally wound tubes of flattened cross-section with a ratio of the major internal diameter to the minor internal diameter of 5:1 to 25:1 and twisted in a screw-like configuration; and a heat-storage mass packed around the tubes and filling the spaces between them.

My present invention relates to tube-bundle heat exchangers and, more particularly, to indirect heat-exchange systems having large heat-transfer surface areas and high fluid throughput.

While heat exchangers of the tube-bundle type have been used for many years in order to obtain high throughputs and large effective heat-transfer areas, considerable research has gone into the development of more efficient units of this general type. It is, for example, known to provide regenerative heat exchangers, especially for cryogenic operations (e.g. air rectification by the so-called Linde process), with tube bundles through which a relatively cool fluid and a relatively warm fluid are passed in succession to effect a transfer of sensible heat between them. For this purpose the tube bundle can be surrounded by a heat-storage mass to which the heat from a relatively warm fluid is imparted as it passes through the tube bundle and from which the heat is abstracted by the relatively cold fluid in its turn. Such heat exchangers may be constructed as direct-transfer heat exchangers in which one fluid passes through the bundle while another fluid flows through a chamber surrounding the bundle or a further tube-bundle so that heat exchange is effected directly through the tube walls. The present invention is directed primarily to heat exchangers of the regenerative type in which the tube bundle constitutes, or is surrounded by and is in heat-exchanging relationship with a heat-storage mass; it has, however, been found to be applicable to other types of heat exchangers as well.

For the most part, tube-bundle regenerative heat exchangers, especially those in use for cryogenic purposes, have tube bundles formed by closely spaced tubes of circular cross-section. A disadvantage of this system is that the tubes themselves, for a given pressure drop through the tube bundle and heat-exchange efficiency, occupy a relatively large volume. In order for the unit to contain the corresponding volume of the heat-storage mass, the entire system must be of relatively large dimension and may be unsuitable for use in places where compact devices are necessary. On the other hand, the unit must concede heat-exchange efficiency if its dimensions are to be reduced.

It is, therefore, the principal object of the present invention to provide an improved tube-bundle heat exchanger, especially for use in cryogenic or low-temperature installations, which can be of relatively small overall dimension without sacrifice of heat-exchange capacity or

has a relatively high efficiency in terms of its overall volume.

A further object of this invention is to provide a highly efficient regenerative heat exchanger of low manufacturing and operational cost.

These objects and others which will become more apparent hereinafter are attainable in accordance with the present invention with a regenerative-type heat exchanger whose tube bundle is surrounded by a heat-storage mass and whose individual tubes are flattened so as to have a general elongated cross-section of limited width. According to a further feature of this invention, the flattened tubes (which may have a generally rectangular or elliptical cross section preferably with parallel sides) can be twisted into a screw-like configuration with the twisted tubes being further coiled generally helically along the length of the heat exchanger about a common axis so as to have a corkscrew construction.

I have found, moreover, that the flattening of the individual tubes of the tube bundle gives rise to a surprising increase of the heat-transfer efficiency and corresponding reduction in the pressure differential across the tube bundle by comparison with circular-tube bundles for a given volume of the bundle and a substantial decrease in this volume for a given flow resistance and heat-transfer efficiency. Consequently, regenerative heat exchangers according to the present invention can have a substantially reduced volume by comparison with heat exchangers having circular-section tubes and thus need a correspondingly reduced quantity of insulation with lower construction costs; when the present improvement is used to reduce the flow resistance of tube bundle for a given heat-exchanger volume, significantly less energy is necessary to displace the fluid and operation costs are correspondingly reduced.

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description reference being made to the accompanying drawing in which:

FIG. 1 is a cross-sectional view taken along a plane perpendicular to the axis of heat exchanger according to the present invention;

FIG. 2 is an elevational view, drawn to an enlarged scale, of the individual tube of this heat exchanger; and

FIG. 3 is a fragmentary elevational view of the heat exchanger of FIG. 1 showing the corkscrew configuration of the turns of the tubes.

In FIGS. 1 and 3 I show a regenerative heat exchanger for use in low-temperature installations (e.g. air rectification, low-temperature separation of liquified gases, cryogenic purification), which comprises an outer shell 1 of cylindrical configuration. This shell may be formed at its extremities with the usual manifold-type heads, covers or bonnets, as described and illustrated, for example, at pages 11-2 ff. of Perry's Chemical Engineers Handbook, fourth edition, McGraw-Hill, New York, 1963. The shell 1 surrounds a layer 2 of thermal insulation which, in turn, isolates an inner pressure-retaining vessel 3 whose compartment 4 is filled with a heat-storage mass 7. The heat-storage mass can be a cermet or a metal, preferably of high thermal conductivity; for low-temperature technology aluminum particles in tightly packed relationship can serve as the heat-storage mass. The vessel 3 further contains at least one tube bundle consisting of the tubes 5 which extend longitudinally through the heat exchanger between its heads. The tubes are required in regenerative heat-exchange systems in which it is important to prevent condensate and precipitate from one of the fluids undergoing treatment from contaminating the thermal-storage mass 7 packed around the tubes.

The tubes 5 are spaced from one another in a staggered arrangement so that they lie at the vertices of polygons

3

when considered in a cross section perpendicular to the axis of the heat exchanger. Thus the tube bundle can also be termed a tube "nest." It will be understood that the present invention applies equally to heat exchangers having two or more tube bundles in spaced relationship or in interleaved construction.

As can be especially seen from FIGS. 1 and 2, each of the tubes 5 is flattened to have a flow cross section 6 which is relatively narrow and elongated with a pair of parallel sides 6a, 6b, terminating in rounded ends. The flattened tubes 5 are, moreover, twisted into turns 8 of a screw-like configuration. The tube is advantageously made by compressing and twisting commercially available circular-section copper, stainless-steel, Monel, or aluminum tubing. The flow cross section 6 has a major inner diameter D and a minor inner diameter d which is constant over most of the length of the narrow flow cross section. I have observed that best results are obtained when the tube is flattened so that the ratio $D:d$ ranges from 5:1 to 25:1.

By way of example, it can be pointed out that a regenerated heat exchanger of the type illustrated in FIGS. 1 and 2 can have 374 tubes of a length of 16 m., a major inner diameter $D=30.4$ mm. and a minor inner diameter $d=2.6$ mm.; the tubes of this regenerator occupy 1.34 m^3 . A similar regenerator with the same pressure drop in the tubes and heat-transfer efficiency can be constructed from 702 tubes with an individual tube length of 8 m., and inner diameters $D=31.7$ mm. and $d=1.3$ mm. In this latter regenerator, the tubes occupy a volume of 1.04 m^3 .

By contrast, when using tubes of circular cross section to obtain a heat exchanger with the same heat-transfer efficiency and pressure drop, it is necessary to use 90 tubes with a length of 76 m. and a diameter of 23 mm. These tubes occupy a volume of 3.45 m^3 , thereby necessitating that the overall dimensions of the heat exchanger be from 2-3 times those obtainable in accordance with the present invention. A corresponding increase in the quantity of thermal insulation makes the disparity in outer dimension even greater.

As is illustrated in FIG. 3, the tubes 5 can be wound in corkscrew configuration generally helically about the axis of the tube bundle and the heat exchanger.

It will be understood that the tube arrangement of the

4

present invention is applicable as well to crossflow counter-current heat exchangers; in this case the flattened tubes can be coiled into spiral-tube bundles without nonuniform constriction of the tubes as has characterized circular-section tubes similarly employed.

The invention described and illustrated is believed to admit of many modifications within the ability of persons skilled in the art, all such modifications being considered within the spirit and scope of the appended claims.

I claim:

1. In a regenerative-type tube-bundle heat exchanger for indirect heat exchange between a relatively warm fluid and a relatively cool fluid having a plurality of spaced-apart tubes for conducting a fluid therethrough, the improvement wherein each of said tubes is of flattened cross section and is twisted in a screw-like configuration with at least some of said tubes of flattened cross section wound helically about a common axis to form a tube bundle; said improvement further comprising a heat-storage mass packed around said tubes individually and filling the spaces between them, the flow cross section of said tubes having a pair of parallel longitudinal sides, and a major inner diameter and a minor inner diameter in a ratio ranging from 5:1 to 25:1.

2. The improvement defined in claim 1 wherein said flow cross section of said tubes is generally rectangular with rounded ends, each of said tubes being twisted along its length into a multiplicity of screw-like turns and being helically wound about an axis of the tube bundle, said heat exchanger further comprising a pressurizable vessel enclosing said mass and said tube bundle, and a layer of thermal insulation surrounding said vessel.

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