United States Patent

Zygiel

[15] **3,693,711**

[45] **Sept. 26, 1972**

[54] **MONOLITHIC CAST BODY HEAT EXCHANGER**

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[22] Filed: **March 8, 1971**

[21] Appl. No.: **121,750**

Related U.S. Application Data

[60] Continuation-in-part of Ser. No. 871,112, Oct. 2, 1969, abandoned, Division of Ser. No. 645,436, June 12, 1967, Pat. No. 3,498,371.

[52] **U.S. Cl.**.....**165/164,** 165/180

[51] **Int. Cl.**.....**F28d 7/00**

[58] **Field of Search**.....165/163, 164

[56] **References Cited**

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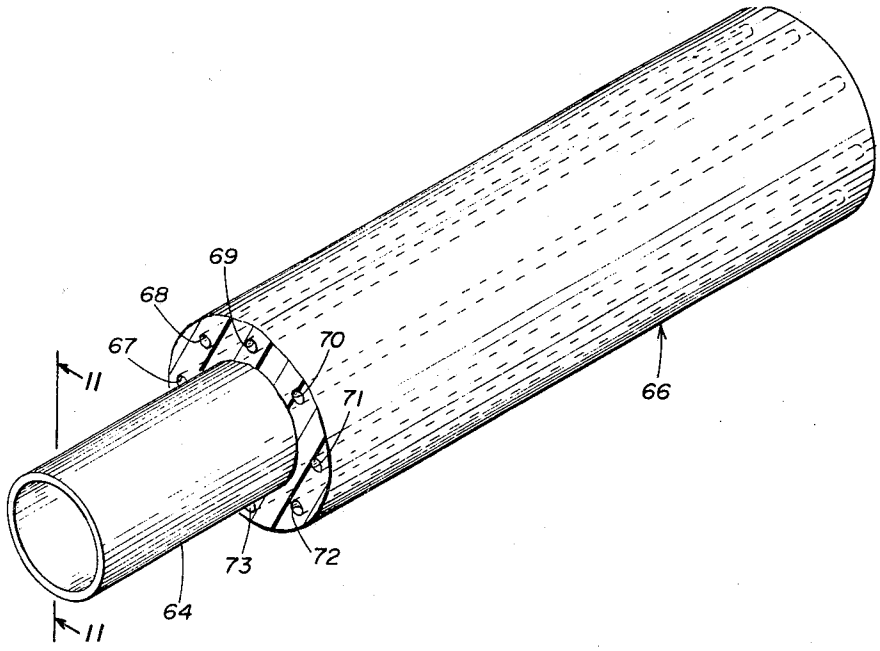
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[57] **ABSTRACT**

Heat transferring apparatus cast from a resinous metallic composition and having a plurality of passages formed therein. The resinous metallic composition includes a base material, such as an epoxy resin, mixed with a solidifying hardener and metallic particles to enhance the heat transferring abilities of the solidified resin. Individual heat exchanger passages are formed by pressurizing flexible tubing arranged in the desired configuration during the solidifying process of the resinous metallic composition.

7 Claims, 12 Drawing Figures



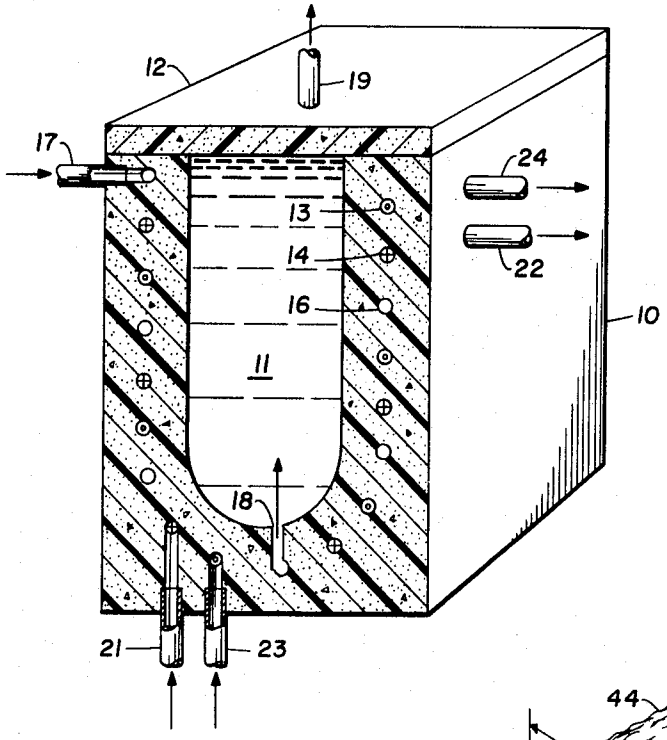


FIG. 1

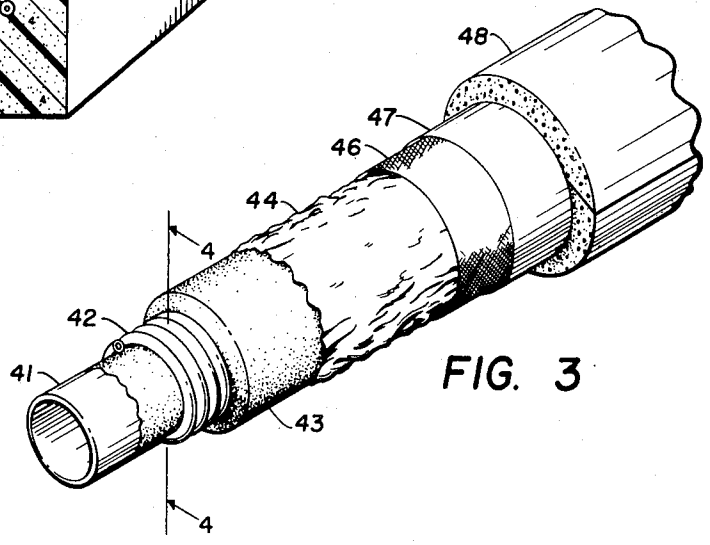


FIG. 3

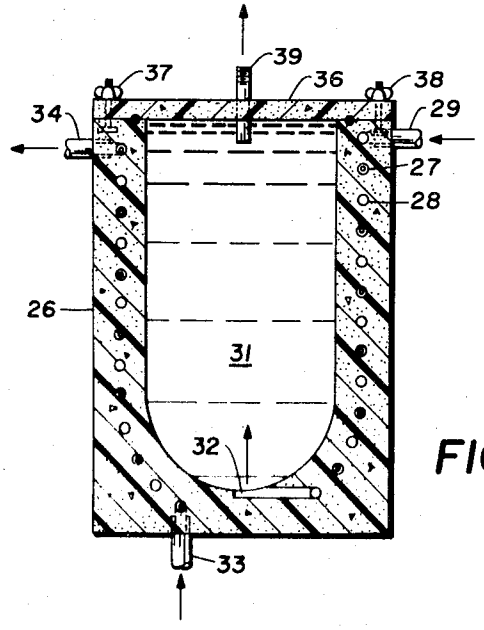


FIG. 2

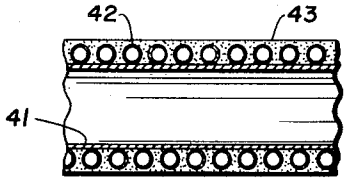


FIG. 4

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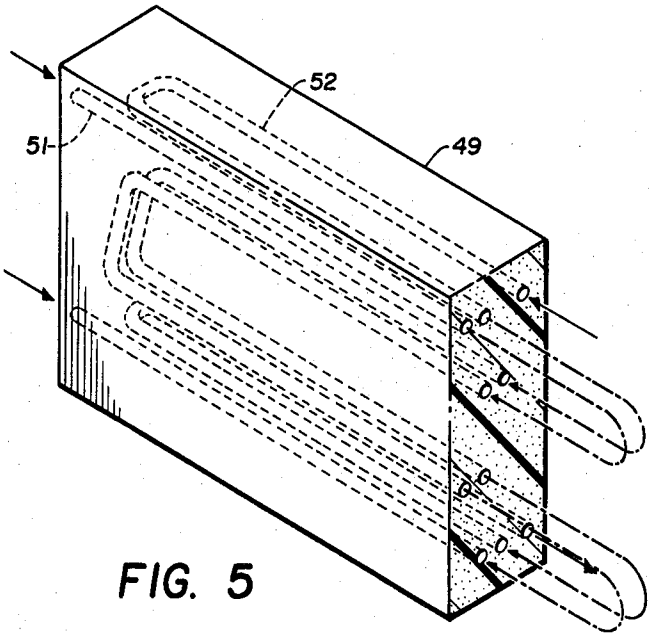


FIG. 5

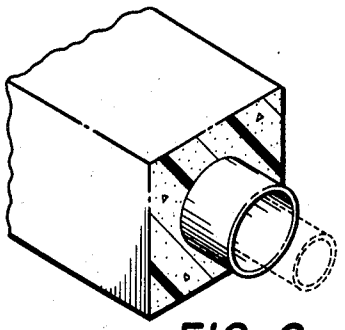


FIG. 6

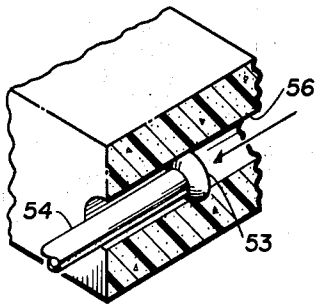
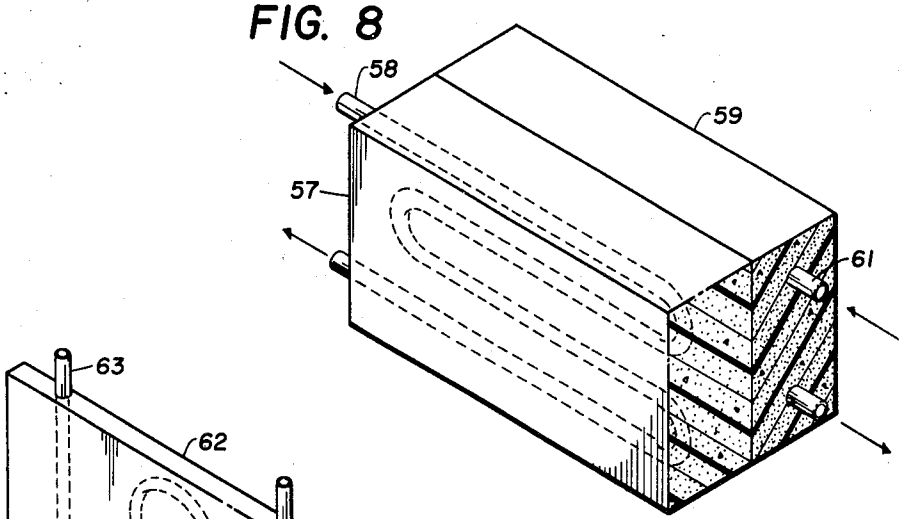


FIG. 7

FIG. 8



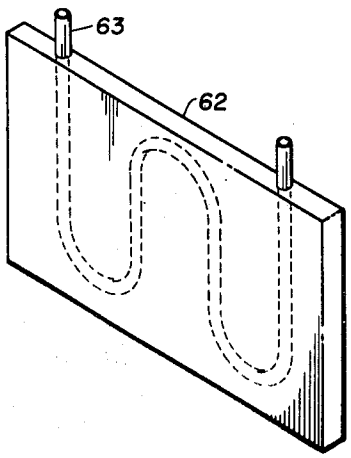


FIG. 9

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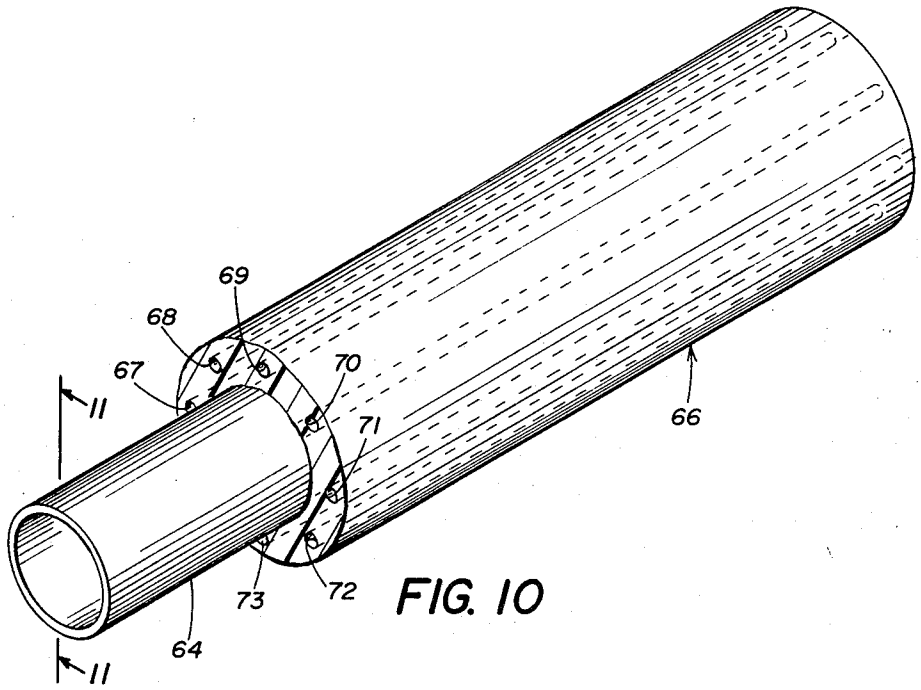


FIG. 10

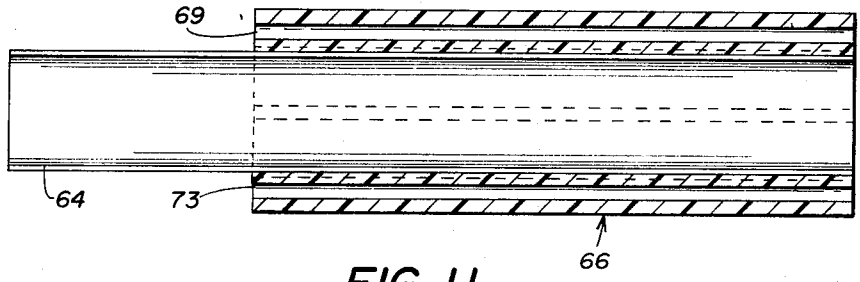


FIG. 11

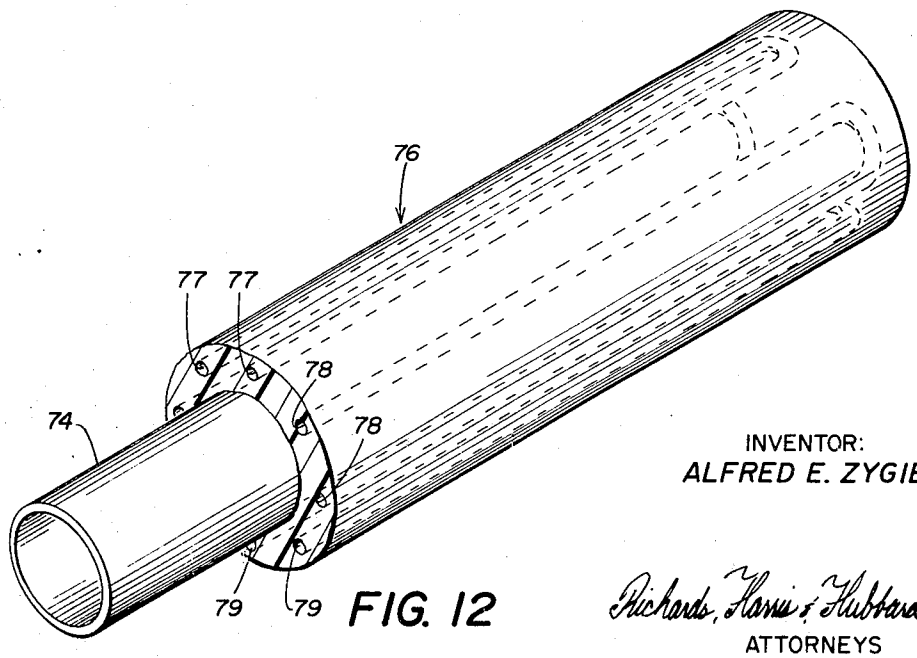


FIG. 12

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MONOLITHIC CAST BODY HEAT EXCHANGER

BACKGROUND OF THE INVENTION

This is a continuation-in-part of application Ser. No. 871,112, filed Oct. 2, 1969, now abandoned which is a division of application Ser. No. 645,436, filed June 12, 1967, now U.S. Pat. No. 3,498,371.

Heat exchangers in general use today consist of complicated arrangements of metallic tubes soldered together into a continuous path. The manufacture of such complicated piping arrangements is difficult and leaks at faulty solder connections are common. Further, the solder connections loosen from the continuous vibrational environment in which many heat exchangers are used.

In some heat exchangers, the metallic tubes are surrounded by metal fins in an attempt to make the most efficient use of available heat conducting surfaces. These metallic fins are themselves difficult to manufacture and are not too efficient. In other heat exchanger applications, the metallic tubes are wrapped in contact with the outer surface of a container, the contents of which are to be heated or cooled. Even using the most flexible metallic tubing, the area of contact between the tubing and the container is relatively small resulting in an inefficient heat exchanging device.

In accordance with this invention, the passages of a heat exchanger are formed into a resinous metallic composition. Where one fluid is used to cool or heat another, multiple passages are easily formed. The resinous metallic composition provides a good thermal conducting path from one passage to another thereby resulting in an efficient heat exchanger.

In addition to providing an efficient multiple passage heat exchanger, a heat exchanger in accordance with this invention is relatively simple to manufacture. The passages are formed in the resinous metallic composition as it solidifies thereby eliminating the need for an extensive soldering operation. Since there are no connections in the heat exchanger tubes, the problem of leakage due to vibration is not present.

The resinous metallic composition used in the heat exchangers of this invention consists of a base material mixed with a hardener to form a complex, amorphous mixture, having no definite melting point and showing no tendency to crystallize. During the mixing stage, metallic particles are mixed with and suspended in the base and hardener mixture. As the mass solidifies the metallic particles are frozen in position scattered throughout the heat exchanger body. The metallic particles are of a material having good thermal conductivity, and when frozen in the resinous mass, provide a heat exchanger body that itself has good thermal conductivity.

SUMMARY OF THE INVENTION

A heat exchanger including the novel features described in the claims and having a body of a solidified resinous material composition with one or more passages formed therein. The resinous metallic composition is a mixture of a resinous base material, a hardener for mixing with said base material to form a complex, amorphous mixture, having no definite melting point and showing no tendency to crystallize, and metallic particles mixed with and suspended in said base and hardener mixture.

A more complete understanding of the invention and its advantages will be apparent from the specification and claims and from the accompanying drawings illustrative of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an oblique view in section of a reservoir heat exchanger having three independent fluid passages;

FIG. **2** is a sectional view of a reservoir type heat exchanger having two independent fluid passages;

FIG. **3** is an oblique view of a tube type heat exchanger having a cooling coil surrounding a main conduit;

FIG. **4** is a cross section of the heat exchanger of FIG. **3** taken along the line **4—4**;

FIG. **5** is a two passage heat exchanger having parallel tubes molded into the body;

FIG. **6** shows a method of forming the passages in the heat exchanger of FIG. **5** using flexible tubing;

FIG. **7** is an illustration of one method of removing the flexible tubing used in forming the passages of the heat exchanger of FIG. **5**;

FIG. **8** shows a two passage heat exchanger where one passage is formed in a block containing one type of metal particles and the other passage is formed in a block containing another type of metal particles;

FIG. **9** shows a single tube heat exchanger for use in heating or cooling large volumes such as in a bath;

FIG. **10** is an oblique view of a tube-type heat exchanger of the type shown in FIG. **3** wherein fluid passages extend along an axis parallel to the main tube;

FIG. **11** is a cross-sectional view of the tube-type heat exchanger of FIG. **10**; and

FIG. **12** is an oblique view of a tube-type heat exchanger wherein the fluid passages outline a path within said body for a fluid to circulate independent of fluid in the main tube.

Referring to FIG. **1**, there is shown a reservoir type heat exchanger having a housing **10** of a resinous metallic composition. A reservoir **11** is formed into the housing **10** and capped by means of a plate **12**, also of a resinous metallic composition. Formed into the walls of the housing **10** are three independent passages **13**, **14** and **16**. The passage **16** (identified by the open circles) has an inlet **17** and an outlet **18** opening into the reservoir **11**. Fluid enters the inlet **17** and circulates through the walls of the housing **10** in the passage **16** and into the reservoir **11** through outlet **18**. The fluid is withdrawn from the reservoir **11** by means of a pipe **19** in the cap **12**. A second fluid, such as a cooling fluid, enters the housing **10** though a pipe **21**, circulates through the passage **14** (identified by the circled cross), and leaves the housing at a pipe **22**. A third fluid, possibly a heating fluid, enters the housing **10** by means of a pipe **23**, circulates through the passage **13** (identified by concentric circles), and leaves the housing through a pipe **24**.

A heat exchanger of the type shown in FIG. **1** finds many uses, for example, water entering the pipe **17** is cooled as it circulates through the passage **16** by means of a cooling fluid being circulated through the passage **14**. Water cooled as it circulates through the passage **16** is maintained in its chilled condition upon being stored in the reservoir **11**. It is also possible for the

water entering the pipe 17 to be heated as it circulates through the passage 16 by means of a heated fluid circulating through the passage 13. Again, the heated water is maintained in its heated condition in the reservoir 11. It should be apparent that a fluid circulating in the passage 14 can be used to chill two different fluids circulating in the passages 13 and 16, respectively.

In the prior art heat exchangers of the type shown in FIG. 1, each of the three passages are formed independently by a complex and time consuming manufacturing process, such as soldering together preformed copper tubing. However, in accordance with the present invention, the passages 13, 14 and 16 and the reservoir 11 are simultaneously formed when casting the housing 10. The housing 10 is formed from a composition of a resinous base material and metallic particles mixed with and suspended in the resinous base material and frozen into place throughout the housing 10 as the base material solidifies. The metallic particles have good thermal conducting properties and can be either in the form of powder, chips or spheres. Some of the better materials for use as metallic particles to be mixed with the resinous base material are aluminum, copper, brass, stainless steel, and iron. The particular type of metallic particles used in any given heat exchanger depends on its application. For example, if corrosive fluids are to be circulated through any of the passages 13, 14 or 16 of the heat exchanger of FIG. 1, stainless steel particles are preferred. The amount of metallic particles mixed with the resinous base material also depends on the use of a particular heat exchanger. However, it has been found that the use of metallic particles in excess of about 80 percent by weight of the total mix results in an unsatisfactory housing 10. A composition with metallic particles in excess of about 80 percent is structurally weak due to the small amount of resinous material available to bind the metal particles together. On the lower end, a composition having less than about 15 percent by weight of metallic particles results in a heat exchanger with poor thermal conducting properties.

The resinous base material is also selected after considering the application of a particular heat exchanger. Some of the more common resinous materials are the epoxy resins, the polyester resins, silicone resins, melamine resins, furane resins, resorcinol resins, and the phenolic resins. Generally, the epoxy resins used today are linear polymers made by condensing epichlorhydrin with polyhydroxide compounds. These resins are stable for long periods and are cross-linked by the action of a curling agent through their epoxy or hydroxyl groups and result in a thermosetting product. Many curling agents are available, some of the most common are amines, or amine derivatives, dicarboxylic acid anhydrides, other resins, (e.g., phenolic, polymide, polysulfide) and catalysts. Cured epoxy resins have excellent resistance to organic solvents and inorganic materials and adhere to many materials including metals, such as those listed above. Because there is no volatile loss during the curing process, a cured epoxy resin product is dimensionally stable.

The polyester resins also exhibit dimensionally stable characteristics. Many of the commercially available polyester resins comprise an unsaturated polymer the chemical chain of which has been built up by a polyesterfication process, for example, a glycol is heated with a dibasic acid thereby producing a linear polyester. The polyester resins are also made from a poly-unsaturated ester monomer partially polymerized to produce a polymer containing residues of unsaturation. Almost any of the common compatible unsaturated organic compounds which polymerize alone, or copolymerize with other reactive materials, may be used in the production of unsaturated polyesters. A few of the more common monomers are methyl methacrylate, vinyl acetate, vinyl phenol, and ethylacrylate. A catalyst is added to the resin to initiate polymerization shortly before use. An accelerator is also sometimes added to the catalyzed resin to enable the polymerization reaction to proceed at a lower temperature and a greater rate. A few of the more common catalysts used with polyester resins are peroxides, hydroperoxides, and reducing agents.

The silicone resins are thermosetting and exhibit considerable resistance to high temperatures when cured. Silicone resins are available as solutions in toluene or other aromatic solvents; they are semi-organic compounds with chemical chains of alternative silicon and oxygen atoms and are inert materials due to the lack of affinity of the polysiloxane molecule for other materials. A silicone resin has the property of being curable without the use of a catalyst. The melamine resins, the furane resins and the resorcinol resins are useful in some specific applications; they are all recently developed resins and their properties are not fully understood. A typical phenolic resin is the result of a phenyl-formaldehyde reaction that is a combination of a condensation and polymerization. There are many other resins available that are too numerous to mention each having properties useful in specific heat exchanger applications.

The mixing of the metallic particles with the resinous base material is a straight forward process. It is important that a full and adequate mixing of the resin, catalyst and accelerator, and metallic particles take place. For satisfactory results, it would appear that some mechanical mixing means is necessary, if an adequate mixing is to be achieved. If the resin includes a solvent, adequate precautions are necessary in the use of such materials.

Referring to FIG. 2, there is shown another reservoir type heat exchanger including a housing 26 of a solidified resinous metallic composition. The resinous metallic composition can be any one of the above-described resins mixed with one or more of the listed metals. Whereas in FIG. 1 the housing 10 included three separate passages, the housing 26 of FIG. 2 includes a passage 27 and a passage 28. A liquid circulating through the passage 28 enters by means of a pipe 29 and is discharged into a reservoir 31 through an opening 32. A heat exchanger of this type is particularly well suited for use as a water cooler. As such, the passage 27 has a refrigerant circulating therein which enters by means of a pipe 33 and exits by means of a pipe 34. The reservoir 31 is capped with a plate 36 bolted to the housing 26 by means of wing nuts 37 and 38. Liquid is discharged from the reservoir 31 by means of a pipe 39 extending through the plate 36. If it is necessary to prevent the liquid in the passage 28 and the reservoir 31 from coming in contact with the resinous metallic

composition of the housing 26, a nylon or teflon liquid can be blown through the passage 28 and into the chamber 31 to form a protective coating.

Referring to FIG. 3, there is shown a straight pipe heat exchanger wherein the cooled or heated liquid flows through a stainless steel pipe 41. Formed around the pipe 41 is a helical shaped cooling coil 42, the individual turns of which are in contact with the pipe 41 and spaced apart, as shown in FIG. 4. A resinous metallic filler material 43 is pressure molded around the coil 42 such as shown in FIG. 3. An aluminum foil 44 and a fiberglas cloth 46 are wrapped around the filler 43 preferably before the resinous metallic composition solidifies. A vapor barrier 47 is placed around the fiberglas 46 and a high density insulation 48 covers the vapor barrier 47.

Prior to this invention, pipe type heat exchangers were wrapped with a layer of insulation around the coil 42 with the result that only a small area of the individual turns were in actual thermal contact with the pipe 41. In accordance with this invention, the resinous metallic composition surrounding the coil 42 effectively places the entire surface of a turn in contact with the pipe 41. The good thermal conductivity of the metallic particles transfers the thermal energy in the coil 42 to the pipe 41 and the thermal insulation, including the foil 44, the fiberglas cloth 46, the vapor barrier 47, and the high density insulation 48 add to the efficiency.

Referring to FIG. 5, there is shown a simple two passage heat exchanger including a body 49 having two independent passages 51 and 52. The body 49 is formed by pouring a resinous metallic composition into a mold of the desired shape. After the composition has solidified the mold is removed and the heat exchanger is completely formed. The passages 51 and 52 are formed during the molding process by means of pressurized flexible tubing.

A flexible tubing, such as a nylon tubing, is arranged in the desired shape and distribution of the passages in the mold into which the body 49 is to be formed. For a two passage heat exchanger, two flexible tubes are arranged in the desired shape and distribution, such as shown in FIG. 5, independent of each other. The resinous metallic composition is prepared by using any of the previously mentioned resins and one or more of the listed metals and poured into the mold containing the flexible tubing. After the resinous metallic composition has been poured into the mold and before it solidifies, tubing used to form the passages 51 and 52 is pressurized thereby causing it to expand to a diameter larger than normal, such as shown in FIG. 6, to the desired diameter of the finished passages. The tubes are maintained in a pressurized condition until the resinous metallic composition has completely solidified. After solidification, the tubing is depressurized and allowed to return to its normal diameter which is somewhat smaller than the now formed passages 51 and 52. Next the flexible tubing is removed from the body 49 leaving a heat exchanger with the desired number of fluid passages each independent of the other and completely free of troublesome solder connections.

Referring to FIG. 7, there is shown one method of removing the flexible tubing from the finished passages. An expanding flexible cup 53 is affixed to the end of the tubing 54 and allowed to expand to the diameter of the passage 56. The passage 56 is pressurized on the side of the disk opposite the tube 54 and the tubing is forceably ejected from the passage.

It should be apparent that a heat exchanger of the type shown in FIG. 5 is simple to manufacture and will be substantially leak proof since the passages 51 and 52 are molded into the body 49 when it is formed. Although only two independent passages have been shown in FIG. 5, it should be understood that any number of such passages can be molded into the body during its formation.

Referring to FIG. 8, there is shown a heat exchanger wherein a first body 57 containing a passage 58 is cemented to a second body 59 containing a passage 61. A heat exchanger of the type shown in FIG. 8 has application to installations where one of the circulating fluids is highly corrosive, such as salt water in marine applications. The body 57, for example, is molded from a resinous metallic composition containing stainless steel particles for resistance to corrosion, and the body 59 is formed from a resinous metallic composition containing aluminum particles for good thermal conductivity. The body 57 is molded separate from the body 59 by the process described with reference to FIG. 5 after which they are cemented together with a material having good thermal conductivity. The resulting overall mass having a good thermal conductive path between the passages 58 and 61.

Referring to FIG. 9, there is shown an embodiment of the invention used for cooling large bodies of liquid. A body 62 is formed from a resinous metallic composition and includes a single passage 63. In operation, the body 62 is lowered into a liquid with a refrigerant circulating through the passage 63. One particular application for the device shown in FIG. 9 is the manufacture of ice.

Referring to FIG. 10, there is shown another form of straight pipe heat exchanger wherein the cooled or heated liquid flows through a pipe 64. The pipe 64 is encased by a body 66 of a resinous metallic material such as was described previously with reference to FIGS. 1 and 2. Formed within the body 66 are independent passages 67 through 73 extending in the general direction of the longitudinal axis of the pipe 64. Thus, as best illustrated in FIG. 11, the passages 67 through 73 are in a parallel relationship with the pipe 64. An aluminum foil, such as foil 44, FIG. 3, and a fiber glass cloth, such as cloth 46, FIG. 3, may be wrapped around the body 66 to provide protection therefor or to retain within the heat exchanger the heat energy of fluids in either the pipe 64 or the passages 67 through 73. A vapor barrier, such as barrier 47 of FIG. 3, may be placed around the fiber glass cloth and a high density insulation, such as insulation 48, may cover the vapor barrier. Again, these additional features may be necessary for certain applications.

The body 66 may be formed by pouring the resinous metallic composition into a mold of a desired shape, and, after hardening, assembled around the pipe 64. In the alternative, the body 66 may be formed around the pipe 64. The passages 67 through 73 are formed during the molding process by means of the pressurized flexible tube technique described previously. The flexible tube is arranged parallel to the longitudinal axis of the pipe 64 in the mold into which the body 66 is to be

formed. In the case of the embodiment of FIG. **10**, the passages are straight with terminations at each end of the body **66**. The resinous metallic composition is prepared by using any of the previously mentioned resins and one or more of the listed metals. It is then poured into the mold containing the flexible tubing. After the composition has been poured into the mold, but before it solidifies, the tubing to form the passages **67** through **73** is pressurized causing it to expand to a diameter larger than normal. The tubes are maintained in this pressurized state until the composition solidifies and then removed, as explained. The tubing may be removed by the process described with reference to FIG. **7**.

Referring to FIG. **12**, there is shown a modification of the tube-type heat exchanger of FIG. **10** wherein a main tube **74** is encased with a body **76** of a resinous metallic composition. Within the body **76** there are formed passages **77** through **79** having a closed loop at one end thereof. The path of each of the passages **77** through **79** is such that a fluid circulating therein will travel within the body **76** a distance at least as great as the longitudinal dimension of the body. It should be understood, that the ends of the passages **77** through **79** removed for illustrating the embodiment of FIG. **12**, may also be formed such that one continuous passage is formed within the body **76** with one inlet and one outlet thereto. Such a configuration is generally illustrated by the passage **58** of FIG. **8**.

It should be apparent that where reference was made to either a refrigerant or a heated liquid, they can be readily substituted for each other. Heat exchangers made from a resinous metallic composition have been used up to 300° F. without adverse effects. They have been cycled from a temperature of −15° F. to a temperature of +50° F. in approximately three minutes, and have remained dimensionally stable. Also by the proper selection of a resinous base material, it is possible for a heat exchanger in accordance with this invention to be used with cryogenic fluids. Also, it should be understood that wherever the term "fluid" has been used, it is intended to include gases and liquids.

While several embodiments of the invention, together with modifications thereof, have been described herein and shown in the accompanying drawings, it will be evident that various further modifications are possible without departing from the scope of the invention.

What is claimed is:

1. A heat exchanger comprising:
a main conduit,
a monolithic cast body substantially coextensive with said main conduit, said body of a solidified resinous metallic composition wherein the metallic particles comprise not more than 80 percent and not less than 15 percent by weight of the composition enclosing said main conduit, and
a passage formed wholly within said composition and defined during the formation of said body by the solidification of the resinous metallic composition, said passage outlining a path that allows a fluid circulating therein to travel independent of the fluid in said main conduit.

2. A heat exchanger as set forth in claim **1** wherein said passage is formed to extend in a direction substantially parallel to the longitudinal axis of said main conduit.

3. A heat exchanger as set forth in claim **1** wherein said resinous metallic composition is a mixture of a resinous base material, a hardener for mixing with said base material to form a complex, amorphous mixture, having no definite melting point and showing no tendency to crystallize, and metallic particles mixed with and suspended in said base and hardener mixture.

4. A heat exchanger as set forth in claim **1** wherein the metallic particles of said resinous metallic composition are selected from the group consisting of aluminum, copper, brass, stainless steel and iron.

5. A heat exchanger as set forth in claim **1** wherein said main conduit is stainless steel and said helical coil is copper tubing.

6. A heat exchanger comprising:
a main conduit,
a monolithic cast body substantially coextensive with said main conduit, said body of a solidified resinous metallic composition wherein metallic particles comprise not more than 80 percent and not less than 15 percent by weight of the composition enclosing said main conduit, and
a plurality of independent passages formed within said composition and defined during the formation of said body by the solidification of the resinous metallic composition, each passage outlining a path within said body for a fluid to circulate independent of fluids in other passages.

7. A heat exchanger as set forth in claim **6** wherein each of the plurality of independent passages extends in a direction generally parallel to the main conduit.

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