# United States Patent [19]

**Abbott et al.**

[11] **3,788,392**

[45] **Jan. 29, 1974**


[54] **REVOLVING LINEAR TUBE HEAT EXCHANGER**


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[73] Assignee: **FMC Corporation,** San Jose, Calif.



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[21] Appl. No.: **159,912**

[52] **U.S. Cl.** ..... **165/92,** 99/348, 165/135, 159/28, 259/109

[51] **Int. Cl.** ..... **F28d 11/04**

[58] **Field of Search** ..... 165/86, 92, 135; 99/348; 259/103, 109; 159/28



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[57] **ABSTRACT**

A linear tube through which heating fluid flows is mounted to revolve within an elongated tank containing a liquid to be heated. The tube extends longitudinally within the tank and moves transversely in an orbital path with the trailing portion of the tube formed to reduce the tendency for a film of liquid being heated to burn thereon. The tube can be formed in such a manner by either streamlining the transverse surface configuration thereof so that the tube will move through the liquid within the tank with a more nearly unbroken flow thereabout or by insulating the trailing portion of the tube to reduce heat transfer by conduction from the heating fluid within the tube. The tube is supported in a manner so as to remove heating fluid condensate and cause liquid being heated to flow longitudinally within the tank. An arrangement of a multiplicity of tubes for movement through the liquid being heated without elimination of flow thereabout is also provided.


**8 Claims, 10 Drawing Figures**

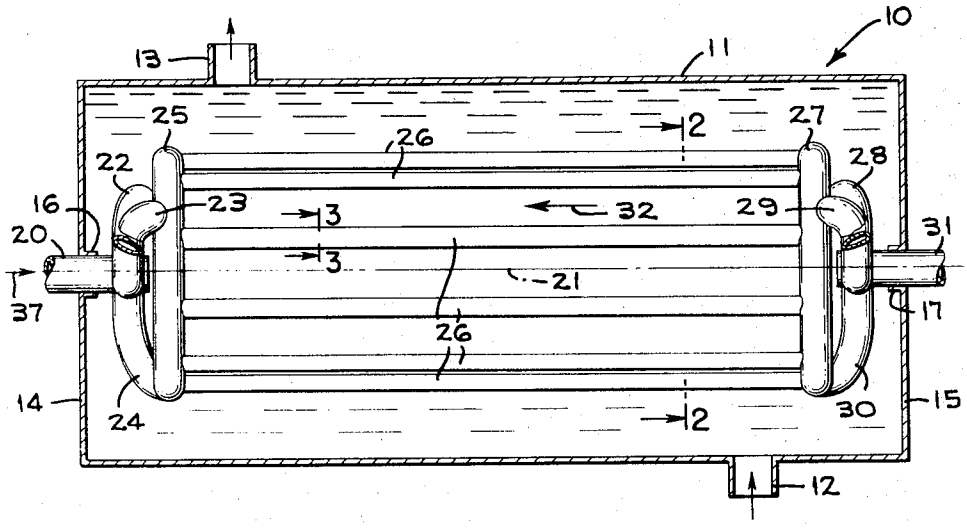


FIG_1

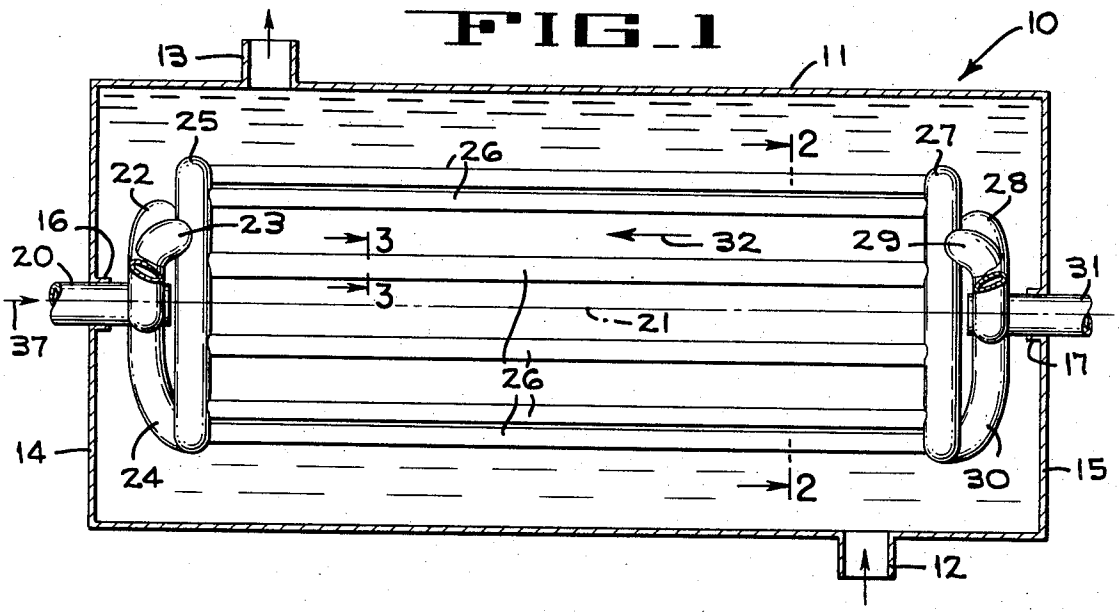



FIG_2

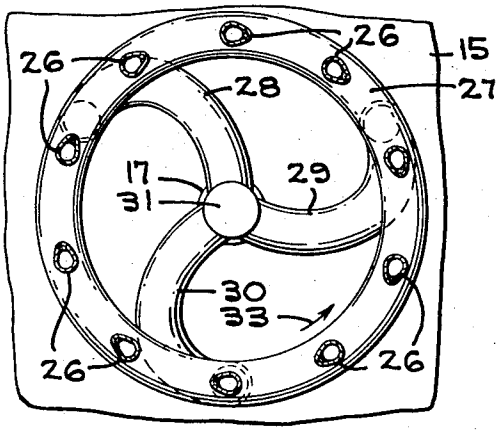



FIG_3

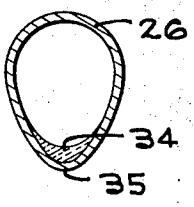



FIG_8

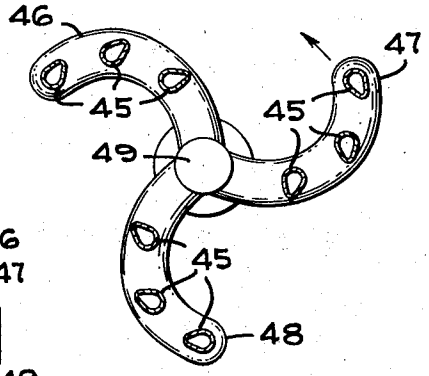
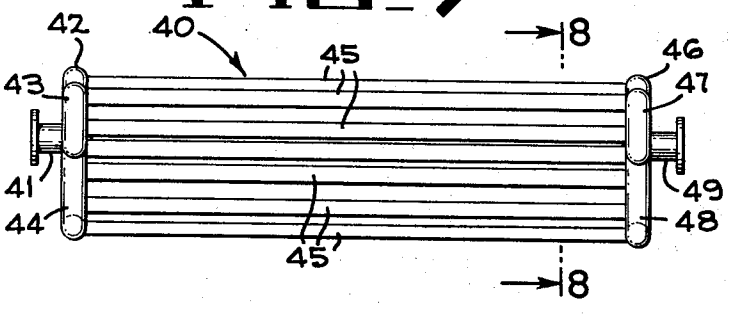


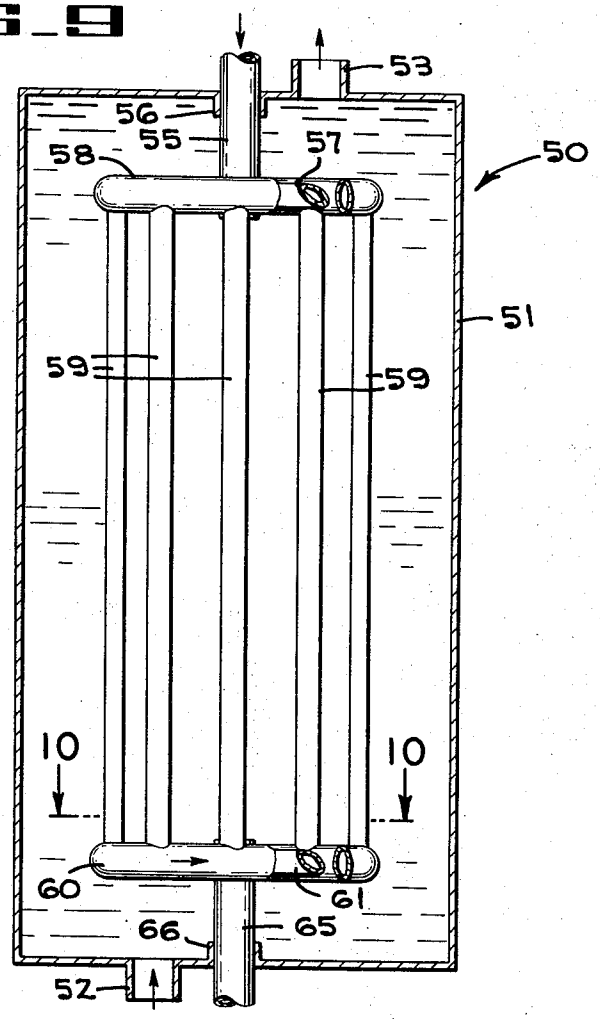

FIG_7




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FIG_9



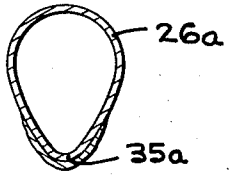




FIG_4

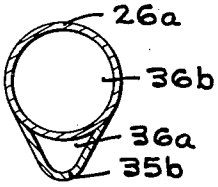



FIG_5

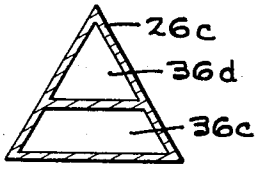
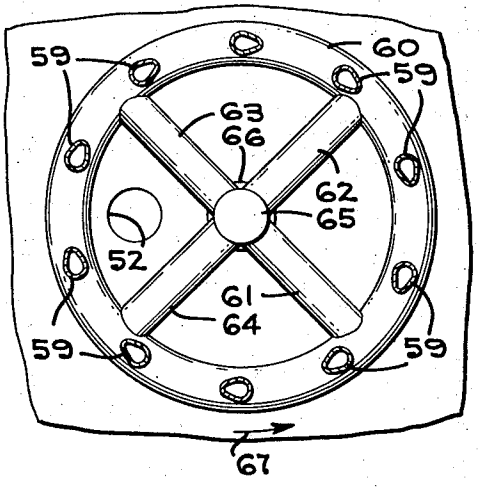



FIG_6

FIG_10



# REVOLVING LINEAR TUBE HEAT EXCHANGER

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a heat exchange device having movably supported surface means exposed for contact with material to be heated, and more particularly, wherein said movable surface means is part of a hollow rotating device through which heating fluid flows. Such a heat exchange device can be used as a concentrating evaporator by the food industry to make high density food products such as tomato paste, strawberry preserves, etc.

2. Description of the Prior Art

Rotary steam coil devices have been used in evaporators for heating food products. Normally, such rotary coils are formed with tubing having a circular cross-section and helical shape about the axis of rotation of the coil. Steam is passed through the tubing as the coil is rotated within the product to be heated.

It has been found that as such coils rotate, a cavity develops within the product on the trailing side of the tubing due to the velocity of the tubing moving through the product and the viscosity of the product. A thin film of product adheres to the hot trailing edge of the tubing adjacent the cavity and there is a tendency for this film to burn and give a detrimental flavor to the finished product.

In the U.S. Pat. application Ser. No. 861,831, filed Sept. 29, 1969, now Pat. No. 3,623,548 issued Nov. 30, 1971, and having a common co-inventor with the present application, the above problem was disclosed, and it was therein suggested that the trailing portion of the heat exchanger coil tubing could be made less heat conductive than the rest of the coil by adding insulating material to the trailing portion or by forming an air chamber within the tubing adjacent the trailing edge. It was also suggested that the circular cross-section of the tubing be modified to a more streamlined shape to reduce the size of cavity that develops on the trailing portion thereof. It has, however, been found to be difficult to fabricate a tubular coil of helical shape with the trailing portions thereof during rotation being modified to include insulation and/or a streamlined configuration.

## SUMMARY OF THE INVENTION

At least one linear tube through which heating fluid flows is mounted to revolve in an orbital path about a generally parallel longitudinal axis within an elongated tank which receives liquid to be heated. The trailing portion of the tube, with reference to its orbital path motion is formed to reduce the tendency for a film of liquid from burning on the exterior surface thereof. Since the tube is straight, the trailing portion thereof can be readily fabricated to provide a streamlined transverse surface configuration and to provide for insulation therealong. Tubular connections mounting the tube for rotation are preferably curved in in a spiral path opposite to the rotation of the tube where necessary to expel condensate collecting therein, and they can be angled for propelling liquid longitudinally within the tank along the linear tube.



## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a longitudinal section of a heat exchanger embodying the present invention.

FIG. **2** is an enlarged transverse section taken on the line **2—2** of FIG. **1.**

FIG. **3** is an enlarged transverse section taken on the line **3—3** of FIG. **1** and showing a tube through which heating fluid flows with insulation on the inner trailing portion thereof and with a streamlined transverse surface configuration.

FIG. **4** is a transverse section of a modified form of tube.

FIG. **5** is a transverse section of a second modified form of tube.

FIG. **6** is a transverse section of a third modified form of tube.

FIG. **7** is a side elevation of a rotary heating element illustrating a modified form of the invention.

FIG. **8** is an enlarged transverse section taken on the line **8—8** of FIG. **7.**

FIG. **9** is a longitudinal section of a second modified form of heat exchanger.

FIG. **10** is an enlarged transverse section taken on the line **10—10** of FIG. **9.**

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Looking first at FIG. **1,** a heat exchanger **10** has a tank **11** with an inlet **12** through which liquid to be heated enters and an outlet **13** from which heated liquid is discharged. The tank is preferably of a hollow cylindrical shape enclosed by a left end plate **14** and a right end plate **15.** A sleeve bearing **16** defines a shaft opening through the left end plate and a similar sleeve bearing **17** defines a shaft opening through the right end plate.

A hollow shaft **20** is journalled within sleeve bearing **16** in left end plate **14** for rotation about an axis **21** and tubular spokes **22, 23** and **24** projecting outward from the shaft are coupled with a ring-shaped conduit **25.** A series of tubes **26** extend from conduit **25** parallel with axis **21** to a second ring-shaped conduit **27.** Tubular spokes **28, 29** and **30** connect conduit **27** with a hollow shaft **31** journalled in sleeve bearing **17.** It will be further noted, from FIG. **1,** that each tubular spoke has an oblong transverse shape and is inclined to propel liquid within tank **11** in the direction of an arrow **32** upon normal rotation of the shafts.

With reference to FIG. **2,** shaft **31** rotates counterclockwise in the direction of arrow **33** and each tube **26** has a streamlined transverse surface configuration whereby liquid can flow thereabout with a substantially unbroken flow. This configuration tends to prevent a void from forming in the liquid behind a moving tube. Each tubular spoke is curved along a spiral path extending from conduit **27** rearwardly opposite to the direction of rotation for connecting in substantially radial alignment with shaft **31.** This curvature of the spokes enables condensate from heating fluid which collects in the bottom of conduit **27** to be fed through the tubular spokes to shaft **31** and thereby pass out of the heat exchanger structure.

FIG. **3** shows the interior of a tube **26** and it will be noted that an insulating or low heat conduction material **34** has been filled into the trailing portion **35** of the tube. Teflon, lead, or solder can be used as the insulat-

ing material inside the tube or as an alternative illustrated in FIG. 4, the exterior trailing portion 35*a* of a modified tube 26*a* could be coated with an insulating and non-sticking material such as Teflon. Another alternative illustrated in FIG. 5 would provide an air cell 36*a* between the trailing portion 35*b* of a second modified tube 26*b* and a heating fluid conduit 36*b* therein. Thus, the exterior trailing portion of the tube can be insulated from heating fluid within the tube and this reduces the tendency for a film of liquid to burn thereon. A further alternative illustrated in FIG. 6 provides a third modified form of tube 26*c* of a generally triangular transverse surface configuration and having an air cell 36*c* along the trailing base portion thereof for insulating that portion from heat within a heating fluid conduit 36*d*. While the transverse surface configuration is not streamlined and a void would develop in liquid behind the tube, insulation provided by the air cell is sufficient to prevent burning of a film of liquid on the trailing portion of the tube.

In operation, heating fluid such as steam is fed through shaft 20 in the direction of an arrow 37 and from that shaft, the heating fluid flows through tubular spokes 22, 23 and 24, conduit 25, tubes 26, conduit 27, tubular spokes 28, 29 and 30, and shaft 31 to discharge from the heat exchanger structure. Liquid to be heated enters tank 11 through inlet 12 and flows toward outlet 13 due to pressure differential and the current developed in the direction of arrow 32 by the tubular spokes. Rotation of shafts 20 and 31 causes tubes 26 to revolve in an orbital path about axis 21 and heat is transferred from the tubes to the liquid within the tank. The tendency for a film of liquid on the trailing edge of tubes 26 to burn is inhibited by the streamlined shape of the tubes and insulation thereon.

The alignment of tubes 26 generally parallel to the axis of revolution 21 provides that the trailing edge of each tube will follow a straight line. This simplifies fabrication of the tubes with streamlined and insulated trailing portions.

A modified form of the invention is illustrated in FIGS. 7 and 8. A rotary heating element 40, shown in FIG. 7, has a hollow shaft 41 from which tubular spokes 42, 43 and 44 project and tubes 45 extend therefrom parallel with the axis of rotation of the shaft to tubular spokes 46, 47 and 48 (FIG. 8) which project from a tubular shaft 49 aligned with the tubular shaft 41. It will be noted in FIG. 8 that tubes 45 are mounted for communication with the tubular spokes at different radial distances from shaft 49. This tends to stagger tubes 45 within the enclosed heat exchanger tank and thereby eliminate the possibility of a void forming along a circular path within the liquid being heated because of insufficient spacing between tubes.

A second modified form of the invention is illustrated in FIGS. 9 and 10 wherein a heat exchanger 50 has a tank 51 with an inlet 52 and an outlet 53. Liquid to be heated is pumped upward through the inlet and flows vertically through the tank to the outlet.

A hollow rotatable shaft 55 is journalled in a sleeve bearing 56 mounted in the top of tank 51. Four tubular spokes 57 (only one spoke being shown) project outward from shaft 55 to a ring shaped conduit 58 and tubes 59 depend therefrom to a ring shaped conduit 60 coupled by tubular spokes 61, 62, 63 and 64 to a hollow rotatable shaft 65. This latter shaft is journalled in a sleeve bearing 66 mounted in the bottom of the tank.

The tubular structure revolves in the direction of an arrow 67 (FIG. 10), and tubular spokes 57, 61, 62, 63, and 64 have an oblong shape inclined rearwardly and upwardly with reference to the direction of motion thereof in order to assist in forcing liquid upward through tank 11. Heating fluid flows downward through the tubular structure so that no problem develops in the event of condensation therein.

Although the best modes contemplated for carrying out the present invention have been herein shown and described, it will be apparent that modification and variation may be made without departing from what is regarded to be the subject matter of the invention.

What is claimed is:

1. A heat exchanger comprising an elongated tank for receiving a liquid to be heated therein; a pair of hollow rotatable shafts journalled at opposite ends of the tank for rotation about a common longitudinal axis; a first tubular connection projecting from a portion of one of said shafts located within the tank in a direction outward from the common longitudinal axis; a second tubular connection projecting from a portion of the other shaft located within the tank in a direction outward from the common longitudinal axis; and at least one linear tube extending between the first and second tubular connections spaced from and generally parallel with the common longitudinal axis about which said tube revolves in an orbital path upon rotation of said shafts; said hollow rotatable shafts, tubular connections, and tube forming a conduit through which heating fluid flows; said tube having a transverse configuration of generally triangular shape with the apex of the triangle aligned as the leading edge of the tube with reference to motion in said orbital path and said tube being divided longitudinally to form a heating fluid conduit adjacent the leading edge thereof and an air cell adjacent the trailing base portion of the triangle to insulate that portion of the tube from the heating fluid conduit and thereby reduce the tendency for liquid in the tank to burn on the exterior surface of the tube.

2. A heat exchanger as described in claim 1 wherein said first and second tubular connections each have a ring-shaped conduit concentric with one of said hollow rotatable shafts and a plurality of tubular spokes connecting the ring-shaped conduit with the hollow rotatable shafts, said tubular spokes following a spiral curved path from the ring-shaped conduit to the hollow rotatable shaft in a direction opposite to the direction of rotation of the ring-shaped conduit whereby condensate from heating fluid collecting at the bottom of the ring-shaped conduit can be fed to the hollow rotatable shaft for discharge.

3. A heat exchanger as described in claim 1 wherein said first and second tubular connections each have portions angled to the direction of rotation thereof for propelling liquid within the tank longitudinally thereof.

4. A heat exchanger as described in claim 2 wherein said tubular spokes are angled to the direction of rotation thereof for propelling liquid longitudinally within the tank.

5. A heat exchanger as described in claim 1 including a multiplicity of tubes extending between said first and second tubular connections at staggered radial spacing from the common longitudinal axis of rotation to maintain unbroken flow of liquid about the tubes.

6. A heat exchanger as described in claim 3 wherein the common longitudinal axis of the rotatable shafts is

a vertical line and liquid to be heated flows upward within the tank while heating fluid flows downward through the rotatable shafts, tube and tubular connections.

**7.** A heat exchanger comprising an elongated tank for receiving a liquid to be heated; a hollow rotatable shaft journalled at one end of said tank for rotation about a longitudinal axis; a tubular connecting portion in communication with and projecting from a portion of the shaft located within the tank in a direction outward from said longitudinal axis; and at least one linear tube communicating with said connecting portion and extending within the tank parallel to but spaced from said longitudinal axis, said tube being arranged to rotate in an orbital path about said longitudinal axis upon rotation of said shaft; said shaft, connecting portion, and tube forming a conduit through which heating fluid may be passed to heat the liquid in said tank; said tube having a wedge-shaped transverse section with the point of the wedge aligned as the leading edge of the tube, with reference to motion in said orbital path, and said tube being divided longitudinally to form a heating fluid conduit adjacent the leading edge thereof and an air cell adjacent the trailing portion of the tube to insulate that portion from the heating fluid conduit and thereby reduce the tendency for liquid in the tank to burn on the exterior surface of the tube.

**8.** A heat exchanger as set forth in claim **7** including a plurality of spaced linear tubes communicating with said connecting portion and extending within the tank parallel to but spaced from said longitudinal axis.

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