

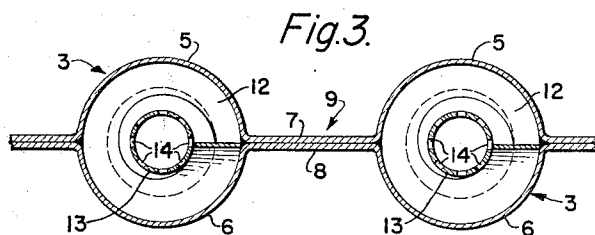
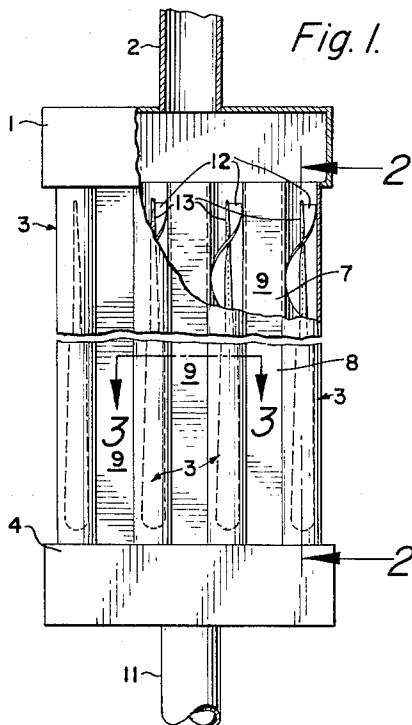
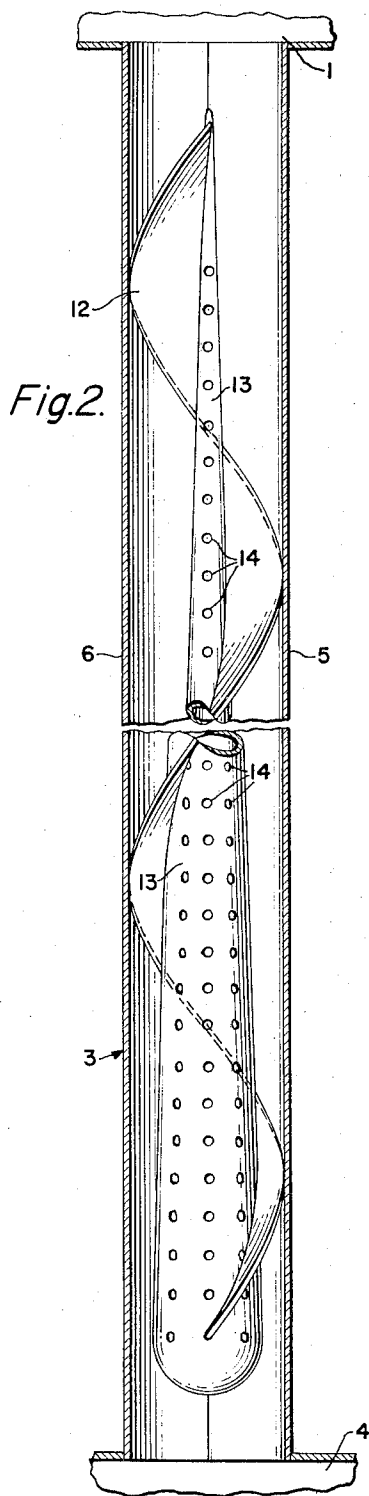
Feb. 1, 1966

L. R. WOODWORTH

3,232,341

CONDENSER

Filed Feb. 1, 1960



INVENTOR:
LEE R. WOODWORTH,
BY *Myron J. Seibold*
Attorney.

1

2

3,232,341

CONDENSER

Lee R. Woodworth, Calabasas, Calif., assignor to The Garrett Corporation, Los Angeles, Calif., a corporation of California

Filed Feb. 1, 1960, Ser. No. 6,033

7 Claims. (Cl. 165-111)

This invention relates to condensers for thermodynamic machines, such as fluid turbines, employing a working fluid which passes through a change of state in its operating cycle, specifically from a liquid to a gas in a boiler or other gasifying device and from a gas into a liquid in a condenser after performing work within the thermodynamic machine.

In the operation of condensers employing elongated tubes within which the change of state from a gas to a liquid is effected, plugging of the tube by the condensed liquid sometimes occurs with attendant erratic and unstable operation. While this may occur under all conditions of gravity and density of the working liquid, the effects of unstable operation are aggravated under conditions where the force of gravity is lessened or counteracted and where heavy liquids such as mercury constitute the working liquid.

In conventional condenser tubes the vapor entering the tube gradually condenses into liquid droplets which may collect into a globule sufficiently large to plug the tube. Pressure forces will then build up in the entrance portion of the tube and will force the globule to accelerate down the tube, trapping and compressing the vapor ahead of it. This compressed vapor will be forced into the outlet header for the tube and as the globule leaves the tube, the vapor will expand back from the header through the tube and will throw condensed liquid in the reverse direction toward the tube inlet. This erratic and unstable operation is undesirable and places serious design and operating restrictions on the condenser.

It is, accordingly, the object of this invention to provide a condenser for changing the state of a working liquid passing therethrough from vapor to liquid in which the liquid is prevented from plugging the condenser tube within which it is condensed.

Another object of the invention is to provide a condenser employing a tube within which a change of fluid state occurs, wherein a swirl is imparted to the entering vapor to move the condensing liquid to the outer radius of the swirl under the influence of the centrifugal field created thereby.

Another object of the invention is a condenser in accordance with the preceding objects in which the center of the tube is provided with a hollow, perforated core to equalize the pressure at opposite ends of any liquid plug which may occur in the annulus between the core and the inner surface of the tube.

Another object of the invention is a condenser in accordance with the immediately preceding object in which the center core of the tube is tapered from the outlet toward the inlet end of the tube in conical form to provide a varying annulus area along the length of the tube approximating the change in volume of the working fluid from the vapor at the inlet to the liquid at the outlet end of the tube.

Other objects and features of the invention will be readily apparent to those skilled in the art from the following specification and appended drawing, in which:

FIG. 1 is a schematic representation, partly in section and partly in elevation, of a condenser in accordance with the present invention.

FIG. 2 is an axial, vertical sectional view through a condenser tube taken on the line 2—2 of FIG. 1 with internal parts shown in elevation.

FIG. 3 is a traverse sectional view on the line 3—3 of FIG. 1.

The condenser, according to the present invention, comprises an inlet header 1 fed with vapor through the duct 2 and feeding into a plurality of spaced elongated condenser tubes 3 whose outlets are joined by an outlet header 4. The tubes 3 are formed by a pair of complementary, semi-cylindrical portions 5 and 6 integrally formed in plates 7 and 8, respectively, the portions of plates 7 and 8 between the tubes 3, such as at 9, spacing the tubes and forming, in effect, radiating fins which cooperate with the surfaces of the tubes 3 to increase heat transfer from the vapor and liquid within the tubes. From the outlet header 4 the working liquid may be fed through a duct 11 to a system boiler by a suitable liquid pump, in known fashion.

Within the tubes 3 are disposed spiral vanes 12 which extend from positions adjacent the inlet ends of the tubes to positions adjacent the outlets thereof and which impart a swirl to the vapor and liquid within the tubes 3 as they pass through the tubes from the inlet to the outlet ends thereof. The swirl vanes 12 are wrapped around hollow cores 13 disposed centrally of the tubes 3 and with the cores 13 provided with a multiplicity of perforations 14 extending through the walls thereof so as to communicate the hollow space within each core with the annulus between the outer surface of the core and the inner surface of the tube. In view of the large difference in volume between the vapor entering the tubes and the liquid leaving them, the cores 13 are tapered, as shown in the figures so that the difference in area between the annuli along the length of the tubes approximates the change in volume of the working fluid from its vapor to its liquid state.

As the working vapor enters tubes 3 from the inlet header 1, a swirl is imparted to the vapor by the vanes 12. As the vapor moves in spiral fashion along the tubes 3, condensation takes place due to cooling of the vapor and the higher density of the condensed liquid results in its moving to the outer radius of the swirl adjacent to the inner surface of the tube 3, under the centrifugal field created by the swirl. The center conical cores fill with vapor through the perforations 14.

If in any tube 3, the annulus between the center core 13 and the inner surface of the tube should plug up with a liquid globule, the perforated center core permits the pressure at opposite ends of the plug to be equalized through the perforations and the hollow center of the core so that unstable operation of the condenser is prevented. Any increase in pressure ahead of a liquid plug in the annulus would be immediately vented to the pressure behind the plug and the possibility of compressed vapor expanding back of the tube, with attendant throwing of condensed liquid, is removed.

The condenser tubes 3 are ordinarily made of very elongated form with their lengths many times their diameters, so as to secure a relatively large surface area contact for heat transfer from the vapor and liquid to the exterior of the tube. This heat may be radiated and conducted from the exterior surfaces of the tubes 3 and also from the plate or sheet portions 9 which serve to space the tubes 3 and also as radiating and conducting fins adding to the surfaces of the tubes 3. The complementary, semi-cylindrical portions 5 and 6 may be drawn, rolled or otherwise provided in the plates 7 and 8 and are then joined together by brazing, welding, riveting or other mechanical means to form the elongated tubes. The vanes 12 and the cores 13 may be supported within the tubes 3 in any desired manner, including brazing, welding, riveting or other mechanical means of support. As shown by the broken arrangement of FIGS. 1 and 2 the ratio of tube length to diameter is approxi-

3

mately 15, but this may be increased to as much as 50 or more where required to secure the desired surface contact to enable a complete change of state of the fluid from its vapor to its liquid form.

The condenser of this invention eliminates instability of operation within the condensing tubes caused by plugging thereof, permits the utilization of the condenser with a higher flow Reynolds number and provides more effective heat dissipation from the vapor and liquid within the tubes.

While a certain preferred embodiment of the invention has been specifically disclosed, it is understood that the invention is not limited thereto, as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation consistent with the prior art.

What is claimed is:

1. A condenser for transforming a working fluid from a vapor to a liquid state comprising a condenser tube having an inlet for the vapor and an outlet for the condensed liquid, said tube being of elongated form with its length many times its diameter, and a hollow core within said tube centrally thereof forming with said tube an annulus for the passage of fluid therethrough, said hollow core being closed at both the inlet and outlet ends of said condenser tube the walls of said core being perforated so as to equalize the pressure at opposite ends of any obstruction which may form in the annulus between the core and the inner surface of the tube, said core decreasing in diameter in the direction opposite to the direction of flow of the fluid through the tube by an amount inversely approximating the variation in volume of the fluid as it changes from a vapor to a liquid state in its passage through the tube.

2. A condenser for transforming a working fluid from a vapor to a liquid state comprising a condenser tube having an inlet for the vapor and an outlet for the condensed liquid, said tube being of elongated form with its length many times its diameter, and a hollow core within said tube centrally thereof forming with said tube an annulus for the passage of fluid therethrough, the walls of said core being perforated so as to equalize the pressure at opposite ends of any obstruction which may form in the annulus between the core and the inner surface of the tube, said hollow core being closed at both the inlet and outlet ends of said condenser tube, said core increasing in diameter in the direction of flow of the fluid through the tube by an amount inversely approximating the variation in volume of the fluid as it changes from a vapor to a liquid state in its passage through the tube, and a spiral vane within said tube between said core and the inner surface of said tube and extending from a position adjacent to the inlet of the tube to a position adjacent the outlet of the tube whereby to impart a swirl to the vapor and liquid passing through the tube to move the condensed liquid toward the inner surface of the tube under the centrifugal field created by the swirl.

3. A condenser for transforming a working fluid from a vapor to a liquid state comprising an inlet header for the vapor, an outlet header for the liquid, a plurality of condenser tubes interconnecting said inlet and outlet headers, said tubes being of elongated form with their length many times their diameter, a hollow perforated core within each of said tubes centrally thereof forming with each tube an annulus for the passage of fluid therethrough, spiral vanes within said tubes extending between said cores and the inner surfaces of said tubes from positions adjacent to the inlet header to positions adjacent to the outlet header whereby to impart a swirl to the vapor and liquid passing through said tubes between said cores and the internal surfaces of the tubes to move the condensed liquid toward the inner surfaces of the tubes under the centrifugal field created by the swirl, said cores serving to equalize the pressures at opposite

4

ends of any obstruction which may form in the annuli between the cores and the inner surfaces of the tubes, said hollow cores being closed at both the inlet and outlet ends of said condenser tubes, said cores increasing in diameter from the inlet toward the outlet ends of the tubes in approximately inverse relation to the change in volume of the fluid passing through the tubes.

4. A condenser for transforming a working fluid from a vapor to a liquid state comprising an inlet header for the vapor, an outlet header for the liquid, and a plurality of condenser tubes interconnecting said headers, said tubes being composed of complementary semi-cylindrical portions interconnected by flat sheet or plate portions spacing the tubes and serving to increase the normal heat radiating surfaces of the tubes, a hollow perforated core within each of said tubes centrally thereof forming with each tube an annulus for the passage of fluid therethrough, each of said hollow cores being closed at both the inlet and outlet ends of said condenser tubes, spiral vanes within said tubes extending between said cores and the inner surfaces of said tubes from positions adjacent to the inlet header to positions adjacent to the outlet header whereby to impart a swirl to the vapor and liquid passing through said tubes to move the condensed liquid toward the inner surfaces of the tubes under the centrifugal field created by the swirl, said cores serving to intercommunicate pressure conditions within the annuli between the cores and the inner surfaces of the tube at opposite ends of any obstruction which may form in the tubes.

5. A condenser for transforming a working fluid from a vapor to a liquid state comprising an inlet header for the vapor, an outlet header for the liquid, and a plurality of condenser tubes interconnecting said headers, said tubes being composed of complementary semi-cylindrical portions interconnected by flat sheet or plate portions spacing the tubes and serving to increase the normal heat radiating surfaces of the tubes, a hollow perforated core within each of said tubes centrally thereof forming with each tube an annulus for the passage of fluid therethrough, said hollow core being closed at both the inlet and outlet ends of said condenser tube spiral vanes within said tubes extending between said cores and the inner surfaces of said tubes from positions adjacent to the inlet header to positions adjacent to the outlet header whereby to impart a swirl to the vapor and liquid passing through said tubes to move the condensed liquid toward the inner surfaces of the tubes under the centrifugal field created by the swirl, said cores serving to intercommunicate pressure conditions within the annuli between the cores and the inner surfaces of the tubes at opposite ends of any obstruction which may form in the tubes, said cores being substantially conical in shape with their bases directed toward the outlet header and varying in diameter in approximately inverse relation to the variation in volume of the fluid passing through the tubes.

6. A condenser for transforming a working fluid from a vapor to a liquid state comprising an inlet header for the vapor, an outlet header for the liquid, a plurality of condenser tubes interconnecting said inlet and outlet headers, said tubes being of elongated form with their length many times their diameter, elongated perforated means forming a passage for fluid within each of said tubes wherein equalization of pressure at opposite ends of any obstruction which may form within said passage is thereby attained, said passage forming means being closed to fluid flow at both the inlet and outlet ends of said condenser tubes so that fluid flow at both the inlet and outlet ends of said condenser tubes is confined to the passage formed by said passage forming means, while fluid flow intermediate said inlet and outlet ends of said condenser tubes is not so confined to the passage formed by said passage forming means, spiral vanes within said tubes transversing said passages and extending to the inner surfaces of said tubes from positions adjacent to

to the inlet header to positions adjacent to the outlet header whereby to impart a swirl to the vapor and liquid passing through said tubes to move the condensed liquid toward the inner surface of the tube under the centrifugal field created by the swirl, said means forming a passage 5 increasing in diameter toward the outlet of each tube in approximately inverse relation to the change in volume of the fluid passing through the tubes.

7. A condenser for transforming a working fluid from a vapor to a liquid state comprising: 10
a condenser tube having an inlet for the vapor and an outlet for the condensed liquid, said tube being of elongated form with its length many times its diameter,
a hollow core within said tube centrally thereof forming with said tube an annulus for the passage of fluid therethrough, 15
said hollow core being closed at both the inlet and outlet ends of said condenser tube,
said hollow core being provided with perforations and providing a free interior passage substantially through-out so as to permit fluid to flow from said annulus through said perforations and through said hollow

core whereby pressure at opposite ends of any obstruction which may form in the annulus between the core and the inner surface of said tube may be equalized.

References Cited by the Examiner

UNITED STATES PATENTS

1,303,107	5/1919	Oderman	257—35
2,238,952	4/1941	Stacey	257—46
2,374,609	4/1945	McCollum	257—262.12
2,924,437	2/1960	Wilkins	257—262.12
2,934,322	4/1960	Hazard	257—256

FOREIGN PATENTS

144,413	6/1920	Great Britain.
348,358	5/1931	Great Britain.
748,562	5/1956	Great Britain.

20 ROBERT A. O'LEARY, *Primary Examiner.*

HORACE A. BERMAN, HERBERT L. MARTIN,
CHARLES SUKALO, *Examiners.*