

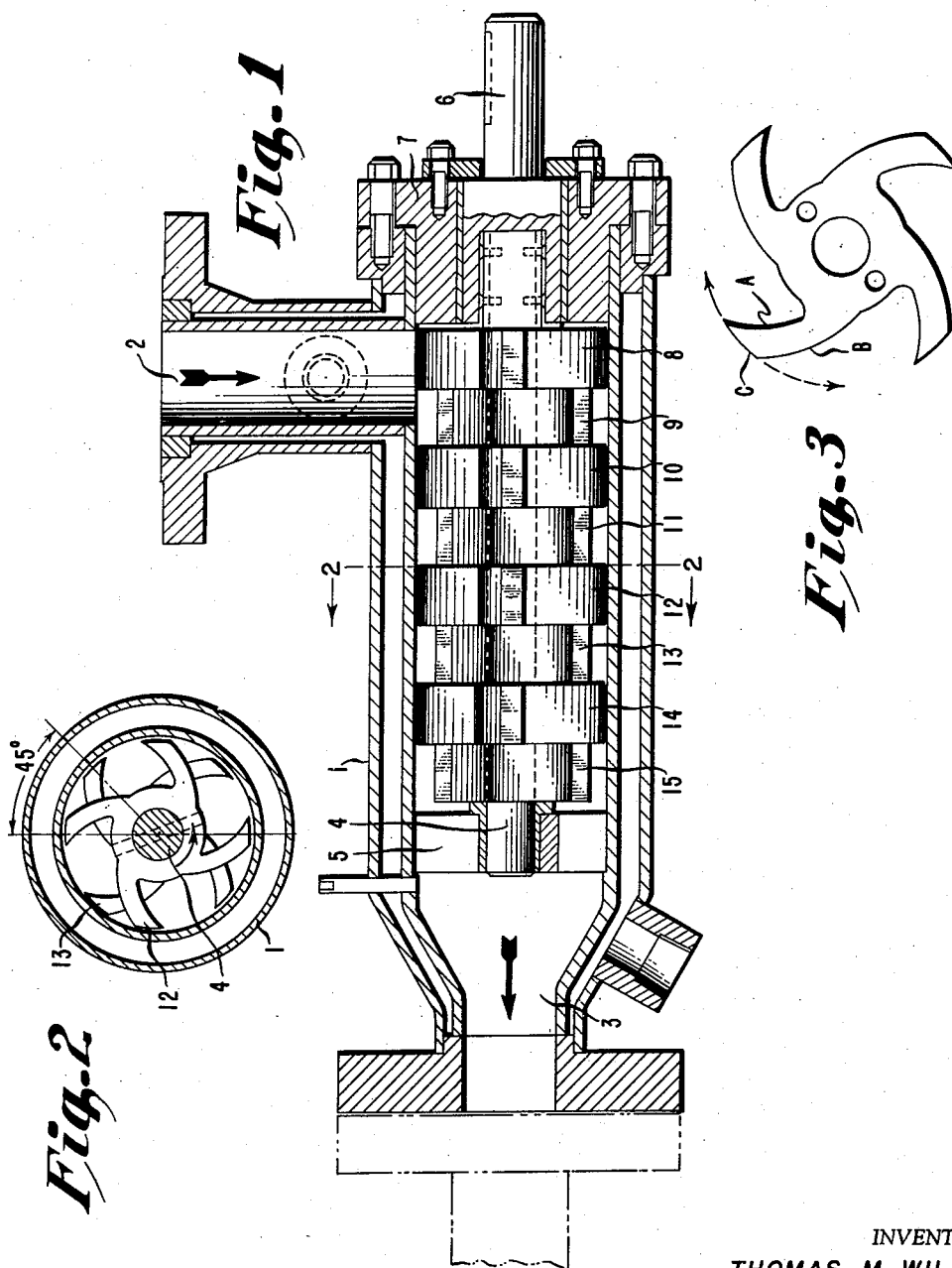
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T. M. WILLS

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VISCOUS LIQUID MIXING APPARATUS

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INVENTOR

THOMAS M. WILLS

BY

A. Rabich Snyder

ATTORNEY

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VISCIOUS LIQUID MIXING APPARATUS

Thomas Mason Wills, Wilmington, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

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2 Claims. (Cl. 259—9)

This invention relates to fluid mixing apparatus and, more particularly, to apparatus for mixing or homogenizing a stream of viscous liquids.

An object of this invention is to provide improved means for rapidly and thoroughly mixing or homogenizing a continuous stream of viscous liquids. A further object is to provide improved apparatus for rapidly and thoroughly blending or homogenizing viscous molten polymeric materials flowing in a continuous stream originating from at least two sources of molten polymer. A still further object is to provide apparatus effective to efficiently homogenize viscous liquids, e. g., molten polymers of different viscosities, as they travel at relatively high rates through pipe lines. The foregoing and additional objects will more clearly appear from the description which follows.

These objects are realized by the present invention which, simply stated, comprises, in combination, an elongated cylindrical vessel having liquid inlet means in one end thereof and liquid outlet means in the opposite end thereof, a driven shaft in said vessel extending longitudinally thereof and coaxially therewith and a multiplicity of flat-faced rotors in face-to-face contact with one another and fixed to said shaft to rotate therewith, each of said rotors having four identical protuberances forming turbine-like, flat-faced vanes, each of said vanes on alternate rotors having a substantially concave leading edge and a tip surface conforming to the inside surface of the cylindrical vessel and closely spaced from said surface, each of the vanes on the remaining rotors having a substantially convex leading edge and a curved tip surface having a curve conforming to the inside curved surface of the cylindrical vessel and closely spaced from said surface, said rotors and their corresponding vanes having a thickness about 0.3 of the inside diameter of the vessel, and the vanes of alternate rotors being out of phase, i. e., displaced, by about 45° from the vanes of the adjacent rotors.

Referring now to the accompanying drawings wherein:

Fig. 1 is a side view, partly in section, of mixing apparatus comprising the features of the present invention,

Fig. 2 is a cross-sectional view on the line 2—2 of Fig. 1, and

Fig. 3 is a front elevation of the preferred form of rotor.

An elongated cylindrical vessel 1, preferably jacketed to permit thermal control of the viscous liquids flowing therethrough, is provided at one end with a liquid inlet opening 2 which, in the preferred embodiment of the invention, is so disposed that the liquid enters the mixer substantially at right angles to the longitudinal axis of the vessel, and is provided at the other end with a liquid outlet 3 which, preferably, is in line with the longitudinal axis of the vessel 1. A rotary shaft 4 whose axis is concentric with the longitudinal axis of the mixing vessel, extends for substantially the entire length of the vessel, and is journaled at one end in spider bearing 5 adjacent

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to outlet opening 3 and at its opposite end is supported in and suitably keyed to a hollowed drive shaft 6 which is, in turn, carried in bearing 7 fitted in the end wall of vessel 1 adjacent the inlet 2. The drive shaft 6 is driven by any convenient means (not shown).

A multiplicity of rotors 8, 9, 10, 11, 12, 13, 14 and 15, each consisting of a flat plate of metal which has been machined and/or cast to form a disc-like structure having a hole in the middle and four identical protuberances which are in the form of turbine-like curved vanes, are keyed to a drive shaft for rotation therewith, each rotor being mounted in close contact with adjacent rotors so that there is substantially no space between adjacent faces of the rotors. The rotors are so mounted that the vanes of alternate rotors, e. g., rotors 8, 10, 12 and 14 curve oppositely to the vanes of the rotors therebetween, i. e., rotors 9, 11, 13 and 15. The rotor structure is preferably integral, that is, machined from an initially flat metal plate. However, the structure may be composed of a multiplicity of parts wherein individual vanes are attached, by bolts, for example, onto a ring which would be keyed to the drive shaft.

The rotor illustrated in Fig. 3 is a typical and preferred construction within the scope of this invention; each vane of the rotor comprises a concave edge A, a convex edge B, and a curved tip edge C, curved to fit the contour of the inner wall of the vessel 1. If this rotor were rotated in the direction of the solid arrow, the leading edge of the rotor vane would be illustrated by edge A, this being substantially concave in contour. The trailing edge, therefore, would be edge B. In the assembly shown in Fig. 1, the rotors adjacent to the rotor just described would have reversed edges, i. e., concave edge B is the leading edge of the vane and the trailing edge is A.

An angular separation or displacement of about 45° between vanes of adjacent rotors, as shown in Fig. 2, was found to be critical for the mixing apparatus of the present invention. Another factor critical to this invention pertains to the relationship between the thickness of the rotors and the inside diameter of the cylindrical vessel. It is critical that the thickness of each rotor (the rotor vane is the same as the thickness of all other parts of the rotor), be about 0.3 of the inside diameter of the cylindrical vessel. These critical limitations of angular separation and thickness of the rotors have been found to influence mixing efficiency of the apparatus, and optimum efficiency under substantially all circumstances is obtained when these specifications are incorporated into the apparatus design.

It is also requisite that there be close clearance between the tip surface of each vane and the inside surface of the cylindrical vessel. Preferably, the clearance between the tip surface of each rotor and the inside surface of the cylindrical vessel is in the neighborhood of 0.01–0.06", but it could be less or could be as much as 0.25".

Mixing in the present apparatus is believed to be caused by fluid shearing. Each vane of the rotors forms a vortex; and the centers of the vortices formed by vanes having leading edges designated by A are in a different position relative to the centers of the vortices formed by vanes having leading edges designated by B. Since these vortex centers do not coincide, the relative motions of fluids influenced by vanes of alternate rotors do not coincide; and fluid shearing occurs.

The mixing efficiencies of the apparatus of the present invention were determined by employing a photometric method wherein a dyed viscous corn syrup was continuously mixed with a viscous colorless corn syrup, and photographs of the blend were taken at a point immediately downstream of the mixing apparatus. The ap-

paratus was tested by operating it under various conditions, such as varying rates of rotor rotation, varying linear flow of viscous material through the apparatus, varying degrees of angular separation between vanes of adjacent rotors, etc. The negatives of photographs taken of the blended liquids immediately downstream of the mixing apparatus were scanned on a microphotometer to measure the density variations in the negatives caused by the variations in the color of the dyed mixture of viscous liquids.

In order to set up a density standard, an arbitrary linear relationship was assumed using completely mixed samples and substantially unmixed samples. The completely mixed samples had a chart variation of 1.0 centimeter (deflection of the microphotometer recording needle) or less and were designated as 100% mixed, and the unmixed samples had a variation of approximately 8 centimeters and were designated as 0% mixed. Mixtures of a dyed viscous liquid and a colorless viscous liquid intermediate between the two extremes were assigned values expressed in terms of percent mixing efficiency between 0 and 100%.

An apparatus, such as is shown in Fig. 1, was employed using 8 rotors and an agitated length of 12". The inside diameter of the cylindrical vessel was 5" and each of the rotors was 1½" in thickness. This apparatus was employed to blend 1 part of a red dye with 30 parts of viscous corn syrup (having a viscosity of 2,000-3,000 poise). To test the apparatus, the rate of syrup flow was varied from 500 lbs./hr. to 1500 lbs./hr., and the rate of rotation of the rotors was varied from 60 revolutions/minute to 120 revolutions/minute. At a syrup flow of 500 lbs./hr., a mixing efficiency of 100% was obtained at 60, 90 and 120 revolutions/minute respectively. At a syrup flow of 1,000 lbs./hr., mixing efficiencies of 100% were obtained at 60, 90 and 120 revolutions/minute. At a syrup flow of 1500 lbs./hr., a mixing efficiency of 74% was obtained with a rate of rotation of 60 revolutions/minute, while 90 and 120 revolutions/minute gave mixing efficiencies equal to 100%.

Actually, it appeared to be more difficult to blend small amounts of coloring agents with larger amounts of syrup than it was to blend, for example, equivalent portions of dyed syrup and colorless syrup in mixing apparatus within the scope of this invention. Therefore, the above-described tests were rather severe and indicated a rather accurate picture of the efficiency of the mixing apparatus.

Since the present apparatus is designed to effect homogenization of viscous liquids as they travel at relatively high rates through pipe lines, the essential advantage of the present apparatus is its capacity to effect highly efficient agitation, and, consequently, homogenization of such viscous liquids in relatively short lengths of piping. By realizing the tortuous path through which the liquids must travel in traversing the present apparatus, it is readily evident as to the reason for its high efficiency. A further advantage of the apparatus is that it is relatively easy and economical to construct and assemble.

I claim:

1. Apparatus for homogenizing a stream of viscous liquid comprising an elongated cylindrical vessel having a liquid inlet opening at one end and a liquid outlet opening at the opposite end, a driven shaft extending centrally of said vessel and for substantially the length thereof, a plurality of flat-faced rotors mounted face-to-face on, and driven by said shaft, each of said rotors mounted in contact with adjacent rotors and having four identical equally spaced flat-faced curved vanes lying in a plane perpendicular to the axis of said shaft, each vane having a curved leading edge and terminating in a curved tip edge corresponding in curvature to the curvature of the inside curved wall of the vessel and closely spaced from said wall, the vanes of each rotor having leading edges oppositely curved to the leading edges of the vanes of the rotors in contact therewith, said rotors and their vanes having a thickness about 0.3 of the inside diameter of the vessel, and the vanes of alternate rotors being displaced about 45° from the vanes of the rotor therebetween.

2. Apparatus according to claim 1 wherein the inlet opening is located on the side of said vessel whereby viscous liquids enter said vessel substantially at right angles to the axis of said driven shaft.

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