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METHOD AND APPARATUS FOR PREVENTING MIXING AT THE
INTERFACE OF TWO FLUID PRODUCTS IN A PIPELINE

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2 Sheets-Sheet 1

FIG. 1

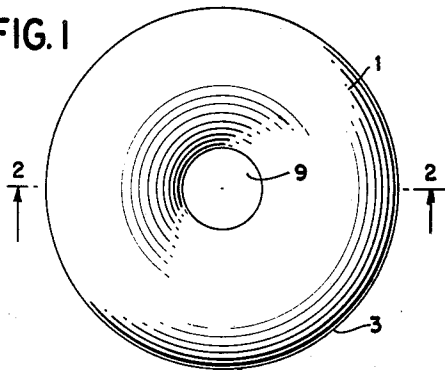


FIG. 2

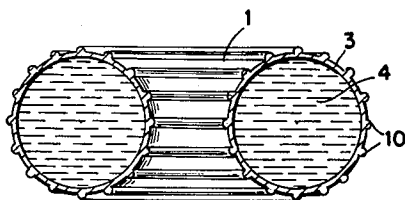
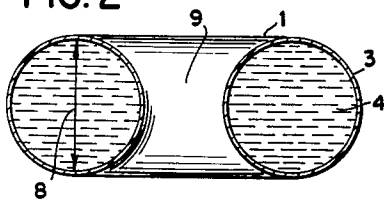


FIG. 2a

FIG. 3

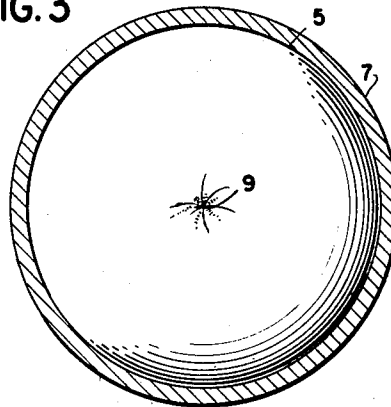
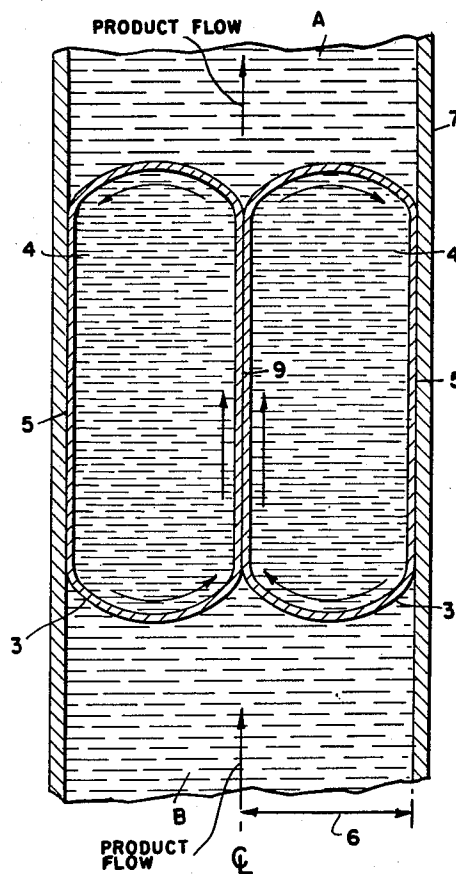


FIG. 4



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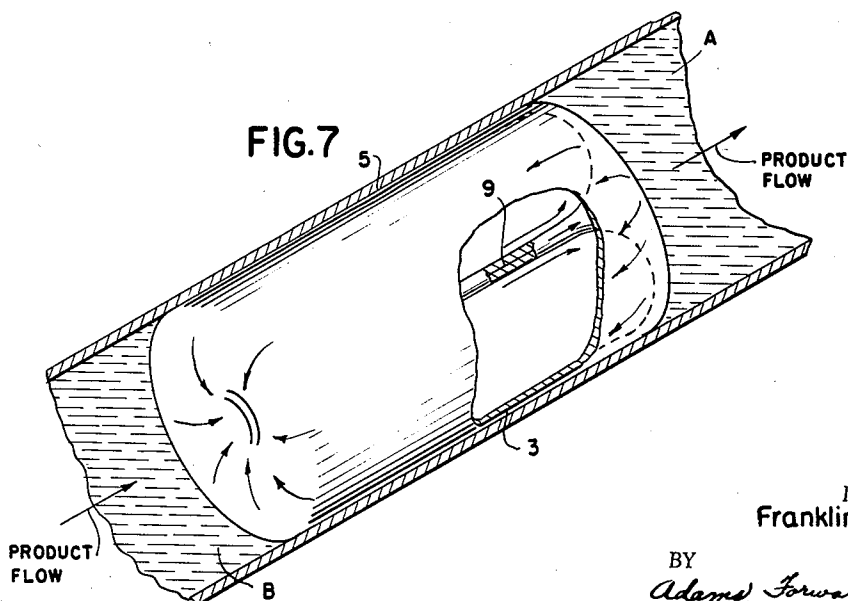
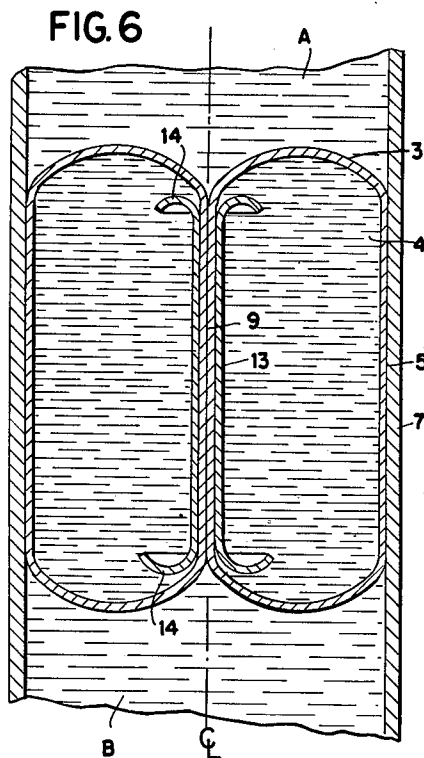
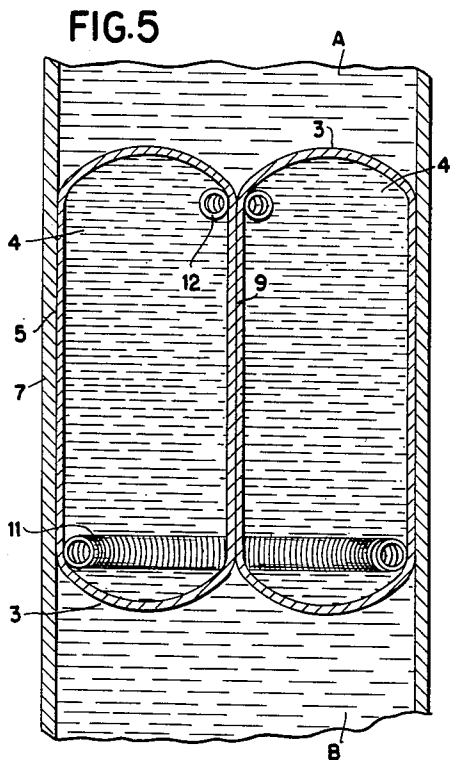
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2,941,537**METHOD AND APPARATUS FOR PREVENTING MIXING AT THE INTERFACE OF TWO FLUID PRODUCTS IN A PIPELINE**

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8 Claims. (Cl. 137—1)

This invention relates to pipeline transportation of fluids and to an improved means for separating different fluid cargoes being pumped through a pipeline system.

A large pipeline system handling refined petroleum products will frequently contain ten products or more following one after another through the pipeline. The degree of intermixing between the products or pipeline cargoes varies widely depending on operating conditions and the mechanical characteristics of each pipeline. One problem which is particularly troublesome results from shutting down the pipeline while the interface between the cargoes is on a long downhill slope. If, under these conditions, a product of heavy gravity (fuel oil) is on the uphill side of a light product (gasoline), the heavy product runs down hill and simultaneously the lighter product is dispersed upwardly. Hundreds of barrels of intermixed products can result. Intermixing also occurs at the interface while pumping. Further, turbulence at the interface can be caused by irregularities in the pipeline, e.g., pits and weld metal projections at joints, and such turbulence produces intermixing. Other factors contributing to intermixing include the mixing action of pumping consecutively through sections of pipeline having different diameters. Again, intermixing results when products are pumped through filters, hay tanks and other relatively larger diameter portions of a products pipeline.

Pipeline plugs for the separation of different moving fluid cargoes have been used heretofore, but they all have certain disadvantages which are compounded by the fact that most existing pipelines are pitted to some degree, contain pipe of varying diameters and are not smoothly welded. These disadvantages stem largely from the fact that, with the plugs known to the art, a sliding friction is created between the internal walls of the pipeline and the moving plug. On the one hand, this friction causes the plugs to wear and, ultimately, to leak and to cause intermixing between consecutive cargoes. On the other hand, the frictional forces cause a pressure build-up behind the plug which, if the seal it forms with the pipe is not adequate, forces leakage of the following cargo into the preceding cargo. Thus, whether these plugs are fitted tightly or loosely into the pipe, the sliding friction between the two eventually causes undesirable intermixing of the several cargoes at their interface.

It is, therefore, an object of the present invention to provide a means for keeping separate at their interface two or more fluid cargoes being transported sequentially in a pipeline.

It is a further object of the present invention to provide a traveling pipeline plug which affords a tighter, more complete seal at the interface of cargoes moving in a pipeline than has heretofore been available.

It is also an object of the present invention to provide a traveling pipeline plug which affords such a seal without substantial sliding friction between the plug and the pipeline into which it is inserted.

Another object of this invention is to provide a traveling pipeline plug which can expand or contract to ac-

commodate irregularities in old pipelines, for example, pipelines having pits or weld metal projections at pipeline joints, without either excessive wear and tear or adverse effect upon the interfaced seal.

Further, it is an object of this invention to provide a traveling pipeline plug which can pass without loss of its sealing effectiveness through flattened pipe having an elliptical cross-section and which can effectively seal the joints in sections of spiral welded pipelines.

These and other objects of the present invention are essentially obtained by employing a doughnut-shaped plug formed by a pliable, relatively thin skin which is filled with a fluid such as water or gasoline. The plug is inserted between pipeline cargoes with its central axis aligned axially with the pipeline and the plug is sized such that its periphery is compressed into a cylindrical form in sealing contact with the inner wall of the pipeline and such that its center opening is closed and thereby self-sealing. Subsequently, pumping of the pipeline cargoes causes the plug to move axially along the pipeline turning upon itself, rolling its peripheral surface along the inner wall of the pipeline.

For a more complete understanding of the practical application of the features and principles of the present invention, reference is made to the appended drawings in which:

Figure I is an end view of a traveling pipeline plug constructed in accordance with the invention;

Figure II is a vertical section of the traveling pipeline plug; in Figure I taken substantially along line 2—2;

Figure II(a) is a vertical section of a modified, traveling plug constructed in accordance with the invention;

Figure III is an end view of a traveling pipeline plug constructed in accordance with the invention and inserted into a portion of pipeline;

Figure IV is a longitudinal section of the traveling pipeline plug in Figure III taken substantially along the centerline of the portion of pipeline;

Figure V is a longitudinal section of a modified, traveling pipeline plug constructed in accordance with the invention and inserted into a portion of pipeline taken substantially along the centerline of the portion of pipeline;

Figure VI is a longitudinal section of a second, modified, traveling pipeline plug constructed in accordance with the invention and inserted into a portion of pipeline taken substantially along the centerline of the portion of pipeline; and,

Figure VII is an isometric view of the traveling pipeline plug in Figure III.

As shown in Figure I to VII, the pipeline plug of the present invention consists of a doughnut-shaped article 1 which is placed between two moving fluid cargoes A and B in pipeline 7. This doughnut shaped plug has a thin, continuous, pliable skin 3 and, preferably, is constructed by joining together the ends of a piece of thin-skinned, cylindrical rubber tubing. The skin can also be fabric and nonresilient, but, in any event, should be resistant to the type of cargo transported in the pipeline. The doughnut shaped plug 1 is filled with a fluid 4 which is, preferably, of low compressibility, such as water or any one of a number of liquid petroleum products, so that the plug can be used at pipeline pressure.

As shown in Figures III and IV, the exact dimensions of the doughnut shaped pipeline plug of the present invention are determined by the length of the largest inner radius 6 of any portion of pipeline 7 through which the plug 1 is to pass. The diameter 8 of the tubing from which doughnut shaped plug 1 is made must be sufficient to afford a complete closure of hole 9 of doughnut shaped plug 1 when the latter is inserted into pipeline 7, i.e., at least equal the length of the inner radius 6 of pipeline 7. In other words, then, the minimum transverse dimension

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of the doughnut shaped plug, taken on a line perpendicular to its central axis, must be at least equal to the maximum inner diameter of pipeline 7 through which it must pass. Moreover, the diameter 8 of such tubing must, in order to maintain the central axis of the inserted doughnut shaped plug 1 in a line coinciding with the center line of the pipeline 7, exceed the length of inner radius 6 by a length which affords the inserted doughnut shaped plug 1 a thickness or length along such center line of at least twice the length of inner radius 6 or, in other words, which is at least as long as the inner diameter of pipeline 7. This is shown in Figure IV. Also shown is the cylindrical sealing surface 5 formed between pipeline 7 and a doughnut shaped plug 1 having dimensions according to the foregoing requirements.

As shown in Figures II, V, and VI, the traveling pipeline plug can be modified in various ways. Thus, the doughnut-shaped article 1 containing fluid 4 of Figure I can have fillets 10, i.e., ridges, incorporated into its skin 3, as in Figure II(a), which lie in planes perpendicular to the central axis of the doughnut shaped plug and which provide annular rings of upraised skin material about such axis. The reasons for these ridges will be better understood after the discussion below of the operation of the present invention and of the manner of employing the traveling pipeline plug.

Again, the doughnut-shaped article, containing fluid 4 of Figure I can be modified by the incorporation of one or more annular rings of coiled spring wire in the inner surface of the skin 3 of the doughnut shaped plug, as in Figure V. These rings lie in planes perpendicular to the central axis of the doughnut shaped plug. Ring 11 is a hoop of coiled expansion spring wire which serves to maintain the sealing surface 5 between the inner wall of the pipeline 7 and the outer wall of the doughnut shaped plug 1. Ring 12 is a hoop of coiled contraction spring wire which serves to maintain the seal, i.e., closure, of hole 9 of doughnut shaped plug 1 along its central axis.

Or, the doughnut-shaped article 1 containing fluid 4 of Figure I is modified by the inclusion within the doughnut shaped plug of an inflexible, hollow alignment core or guide 13, as in Figure VI. As shown, the alignment core has, preferably, outwardly flared ends 14 to protect the thin skin 3 of doughnut shaped plug 1. Alignment core 13 should have a length exceeding the inner diameter of any portion of pipeline 7 through which the doughnut shaped plug containing it is to pass and, preferably, its weight should be substantially the same as that of the fluid contents of the doughnut shaped plug. Such an alignment core is particularly useful in those instances where there are bends in the pipeline which can cause the surface of the doughnut shaped plug in contact with the pipeline on the outer radius of the bend to travel farther than the surface in contact with the inner radius of the bend and, thereby, cause the doughnut shaped plug to assume a position such that its central axis is perpendicular to the center line of the pipeline.

When transporting different petroleum products through a pipeline system in an operation in accordance with the present invention, preceding product A, shown in Figure IV, is pumped into pipeline 7 and doughnut shaped plug 1, filled with fluid 4, is inserted in pipeline 7 behind product A by any suitable means, for example, through a by-pass line, in such a way as to have its central axis coincide with the center line of the pipeline. Following product B is then pumped into pipeline 7 behind doughnut shaped plug 1.

As already noted, the dimensions of doughnut shaped plug 1 are such that, upon its compression within pipeline 7 and its distortion, hole 9 of doughnut shaped plug 1 is closed, thereby preventing leakage and intermixing of following product B with preceding product A through such hole. At the same time, the doughnut shaped plug is so constructed as to afford a cylindrical sealing surface 5 between its outer wall and the inner wall of pipeline 7,

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thereby preventing leakage and intermixing of following product B with preceding product A around the circumference of the plug. This seal, as well as the hole closure, is maintained by the presence of a fluid 4 of low compressibility inside the doughnut shaped plug.

As the pumping of the products proceeds, doughnut shaped plug 1 moves along its central axis in the direction of product flow because of the pressure exerted against it through product B by the pumps and, in so doing, maintains the separation between preceding product A and following product B. At the same time, however, the doughnut shaped plug is subjected to another motion. This motion involves the rolling of the pliable thin skin 3 of doughnut shaped plug 1 upon itself in the manner of a tractor tread. Thus, the pressure exerted upon doughnut shaped plug 1 by following product B is, in part, resisted by pipeline 7 along the cylindrical sealing surface 5 and the resulting frictional force causes that portion of skin 3 forming the sealing surface 5 to intermittently remain stationary. The effect is to cause the entire flexible skin 3 to move in the manner suggested by the small arrows in Figures IV and VII. In other words, doughnut shaped plug 1 turns "inside out" and that portion of flexible skin 3 which is, at one instant, substantially at the center line of pipeline 7 proceeds, in succeeding intervals, forward in the direction of product flow, then outwardly toward the inner wall of the pipeline, where it remains stationary while the plug moves forward, after which portion 3 moves inwardly toward the center line of the pipeline and then begins the cycle again.

As will be readily seen, it is the ability of the doughnut shaped plug to turn itself inside out which substantially eliminates any sliding friction between the doughnut shaped plug and the pipeline wall. There remains only a rolling friction which imposes considerably less wear and tear on plug 1 and which exerts very little back pressure, both of which are normally factors in leakage and intermixing between different pipeline cargoes. On the other hand, nothing is lost insofar as sealing ability is concerned, since the plug presents a constant cylindrical sealing surface to the inner wall of the pipeline.

It will also be seen that, depending whether the fabric of pliable skin 3 is resilient or non-resilient, the distinctive "inside-out" motion of the doughnut shaped plug will be accompanied by tendencies of the fabric either to expand and contract or to fold and unfold or a combination of all of these. It is with these factors in mind that the modifications shown in Figures II, II(a), V and VI are included in the basic doughnut shaped plug structure. By filleting, i.e., ridging, skin 3, its propensity for folding and unfolding can be controlled and ordered to achieve the greatest efficiency. Similarly, annular rings 11 and 12 of coiled spring reinforcing wire are suited to counteracting any contraction of the skin which would either adversely affect the perfection of sealing surface 5 or of the closure of hole 9. An alignment core 13, in addition to maintaining the alignment between the central axis of doughnut shaped plug 1 and the center line of pipeline 7, serves to smooth the rolling motion of skin 3 as it passes along center portion of the doughnut shaped plug. In any event, however, the energy losses due to the subsidiary movement of the skin are minor.

I claim:

1. In a pipeline between two fluid products, a pipeline plug forming a cylindrical sealing surface along its peripheral surface and the inner wall of said pipeline, between said products and closing upon itself to form a self-sealing closure along the center line of said pipeline, said plug being doughnut-shaped and having a continuous, pliable, thin skin, said doughnut shaped plug being filled with a fluid and having its central axis positioned along said center line of said pipeline.

2. The pipeline plug of claim 1 in which said cylindrical sealing surface has a length measured along the cen-

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ter line of said pipeline which exceeds the inner diameter of said pipeline.

3. The pipeline plug of claim 1 within which at least one annular ring of coiled spring reinforcing wire is incorporated in said skin in a plane perpendicular to said central axis.

4. The pipeline plug of claim 1 within which an inflexible alignment tube is disposed along the said central axis, said tube having a length which exceeds the inner diameter of said pipeline.

5. In the transportation of fluid products through a pipeline, the method of preventing intermixing at the interface of two products which comprises conducting the first product into the pipeline, inserting into the pipeline a pipeline plug forming a cylindrical sealing surface along the inner wall of said pipeline between said products and closing upon itself to form a self-sealing closure along the center line of said pipeline, said plug being doughnut-shaped and having a continuous, pliable, thin skin, said doughnut shaped plug being filled with a fluid and having its central axis positioned along said center line of said pipeline, conducting the second product into the pipeline, and pumping said products, whereby said

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doughnut shaped plug is transported along said central axis through said pipeline between said products turning upon itself and rolling said peripheral surface along said inner wall of said pipeline.

6. The method of claim 5 in which said cylindrical sealing surface has a length measured along the center line of said pipeline which exceeds the inner diameter of said pipeline.

7. The method of claim 5 in said pipeline plug of which at least one annular ring of coiled spring reinforcing wire is incorporated in said skin in a plane perpendicular to said central axis.

8. The method of claim 5 in said pipeline plug of which an inflexible alignment tube is disposed along the said central axis, said tube having a length which exceeds the inner diameter of said pipeline.

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