Jan. 8, 1952 M. B. SENNET 2,581,451

MIXING PUMP

Filed Sept. 14, 1949 4 Sheets-Sheet 1

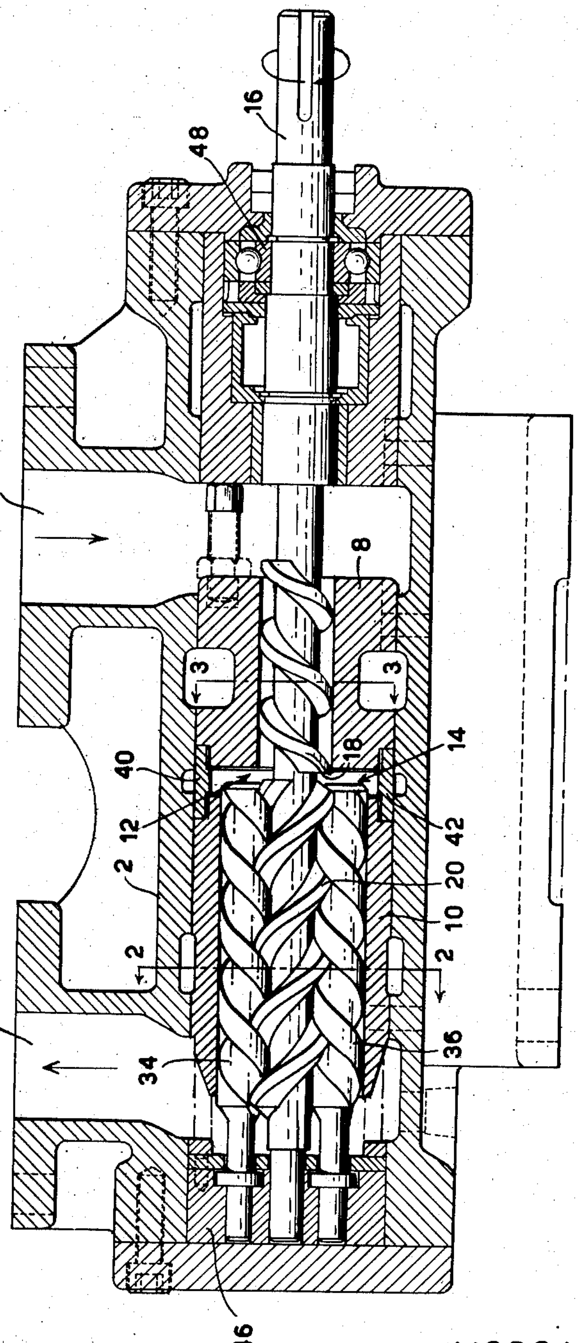

FIG. 1.

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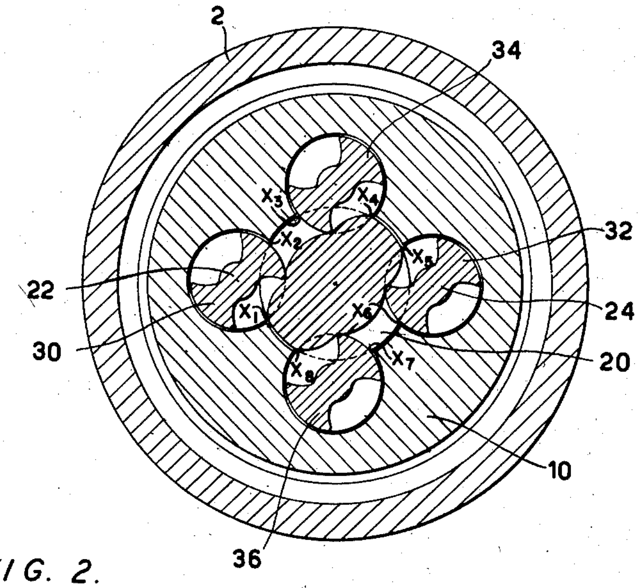

FIG. 2.

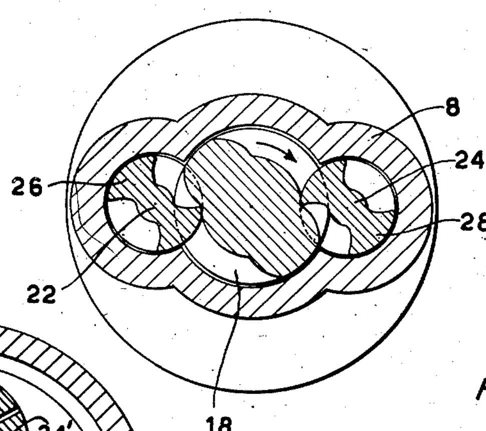

FIG. 3.

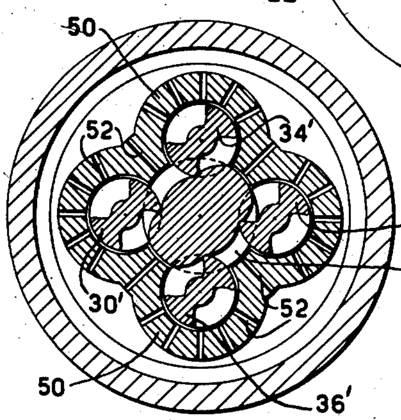

FIG. 8.

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4 Sheets-Sheet 3

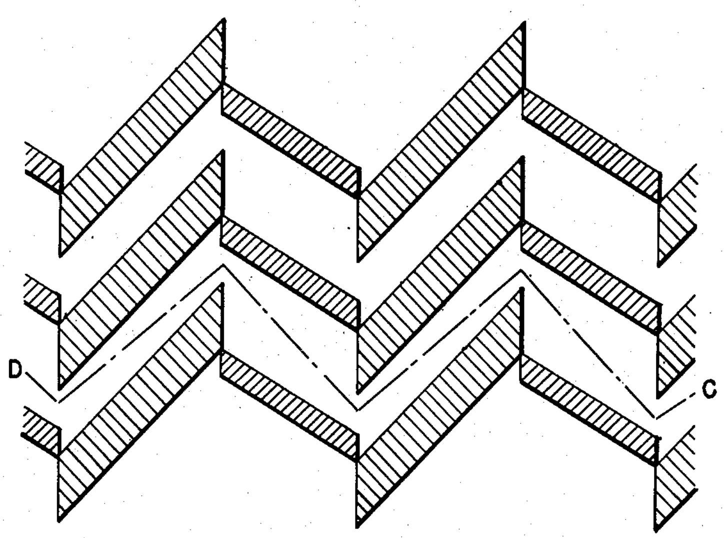

FIG. 4.

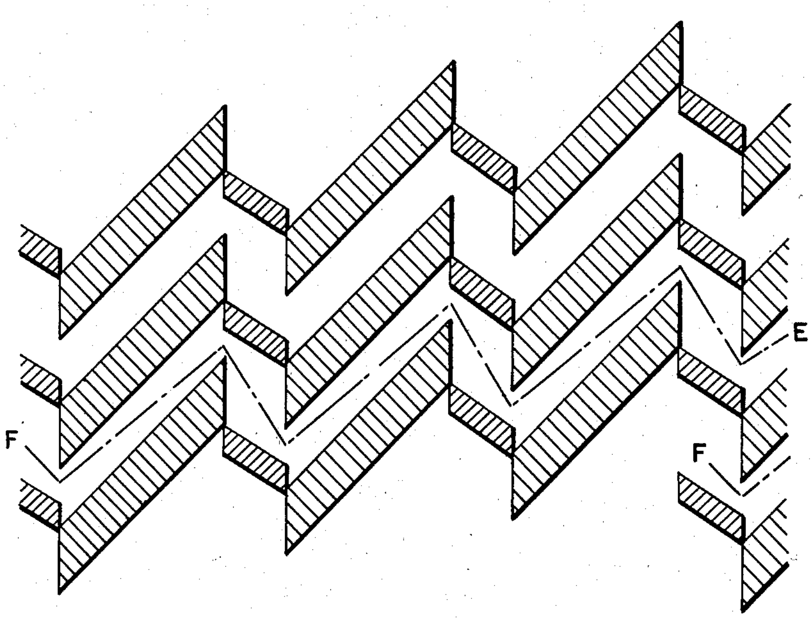

FIG. 5.

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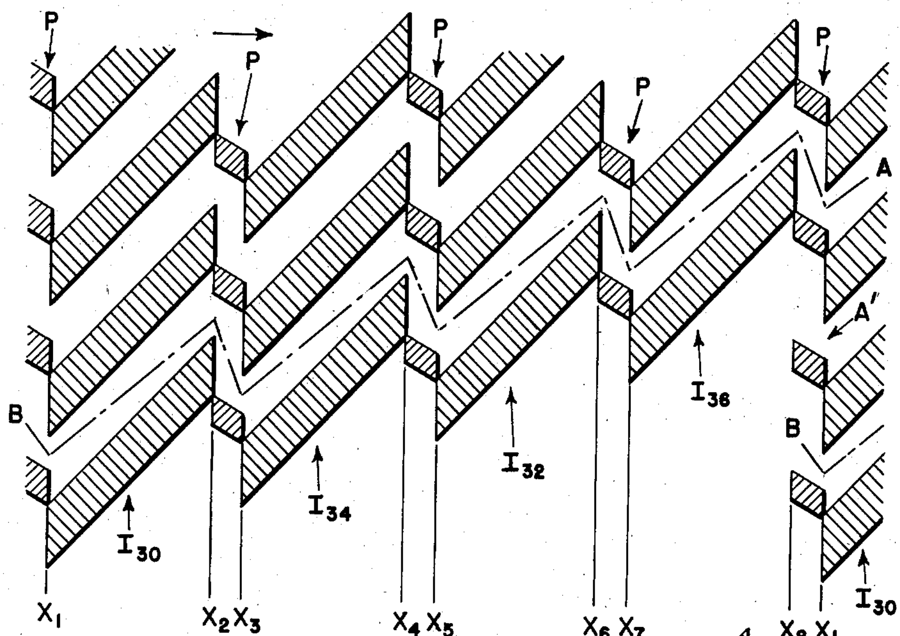

FIG. 6.

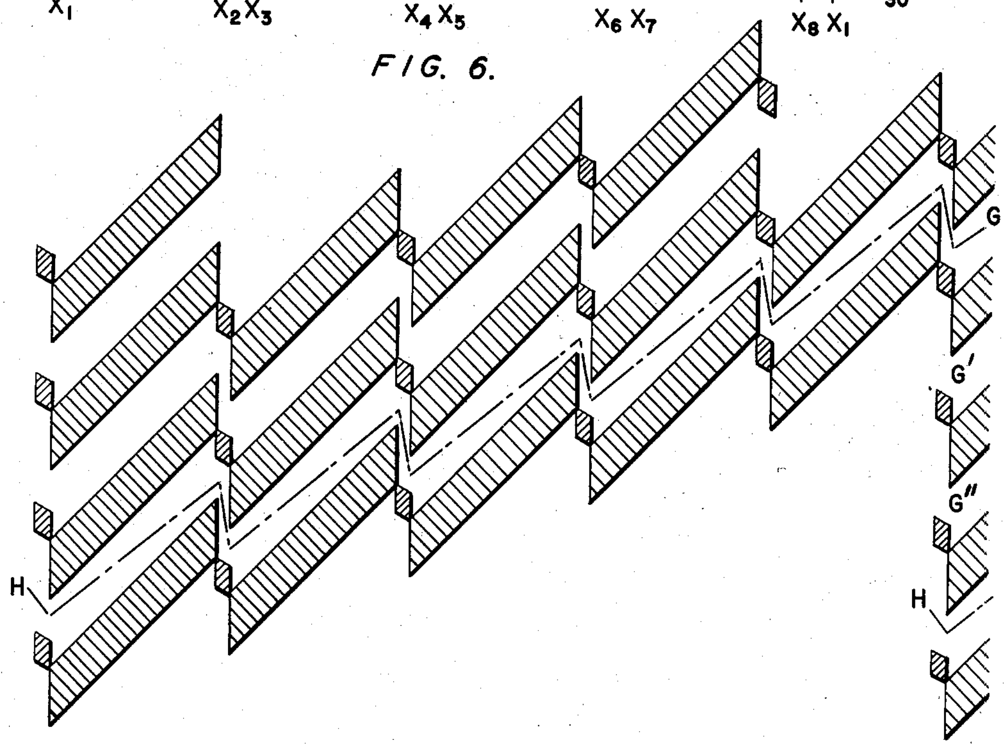

FIG. 7.

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UNITED STATES PATENT OFFICE

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MIXING PUMP

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Application September 14, 1949, Serial No. 115,671

13 Claims. (Cl. 259—6)

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This invention relates to a mixing pump particularly designed for the effective mixing or kneading of materials of a fluent or viscous type, the pump being of a multiple screw type.

The effective mixing of paints or other suspensions of solid, semisolid, or liquid materials in liquids to provide homogeneous products is generally a rather difficult and time consuming operation for which ordinary stirring or other agitation in batches will frequently not suffice to give the desired products. In accordance with the present invention the mixture of constituents is subjected to flow through tortuous paths provided between cooperating rotating screws involving kneading action which is extremely effective in producing homogeneity.

In the patent to Montelius 1,698,802, dated January 15, 1929, there is disclosed a type of screw pump which is positive in its displacement characteristics. Positive screw pumps of this type have gone into widespread use and are capable of operating at quite high speeds. A pump of this positive displacement type if fed with a solid-liquid mixture or with a mixture of liquids which are not mutually soluble in the proportions used will promote mixing to some extent due to the relative motions of the screw surfaces and housing surfaces with respect to the material trapped in the travelling chambers of the pump. However, since the portions of the material are carried through the pump effectively in the form of individual slugs of substantially fixed shape from the standpoint of their boundaries the mixing is not particularly effective and, in fact, much of the efficiency of these pumps is due to the fashion in which the liquid is advanced with a minimum rather than a maximum of turbulence imparted thereto.

In the Montelius patent referred to above there are discussed the requirements on the relationships between the numbers of threads on intermeshing screws required for the attainment of positive displacement. A violation of these requirements will result in an inherent non-positive characteristic of a screw pump provided with intermeshing screws even though the thread shapes are generated in accordance with the principles of the patent, and irrespective of the effective axial length of the pump which may be defined as the length which involves intermeshing of screws within intersecting bores in a housing, i. e., the length through which passages are defined bounded by thread and root surfaces and the walls of the bores.

If a non-positive screw pump is provided in

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accordance with departure from the principles established for positive screw pumps and such a non-positive pump is used for the pumping of a mixture with the object of providing homogeneity, more effective mixing is produced than would be produced by a positive screw pump of comparable length provided the pumping takes place against a substantial head. In contrast with a positive screw pump the pumping action of such a non-positive screw pump is dynamic in character, i. e., the material is progressed through the pump by virtue of a propelling action of the screws since no closed chambers are formed and if the pump is stopped the material will flow from the high pressure end of the pump through the low pressure end. Slippage of the material is accordingly an inherent characteristic of such a non-positive pump: i. e., the advance of the material pumped is always less than what might be considered the theoretical displacement of the pump involving no retrograde movement of the material relative to the screw threads. The fact that such slippage occurs accounts for the increase in effectiveness of mixing, inasmuch as the material, as it is progressed through the pump, has a greater amount of relative slippage with respect to the screws than would be the case in a comparable positive pump of the same effective screw length.

In accordance with the present invention the mixing effect is very greatly increased by combining a positive pump with a non-positive screw pump in such fashion as to drive the material undergoing admixture in a direction contrary to the direction in which the non-positive pump is attempting to effect pumping action. The positive pump which is used may be of any type to effect reverse flow through the non-positive screw pump but, as will hereafter appear, the invention lends itself to embodiment in a simple and highly effective mixer involving the combination of a positive pump and a non-positive pump both of screw type which may be in the same housing and may have common shafting to reduce to a minimum the problem of providing simplicity of drive, provision of proper bearings, small size, etc.

The invention, however, is not confined to a non-positive screw pump opposing a positive one. Similar effective results may be secured by opposition of a pair of non-positive pumps one of which has a more effective pumping action than the other so as to force the mixture in retrograde direction through the latter. As will appear hereafter various such combinations of pumps may be provided.

The broad object of the invention in providing an effective mixing device has been indicated above. The attainment of this object as well as the attainment of various other objects particularly relating to details of construction and operation will become apparent from the following description read in conjunction with the accompanying drawings, in which:

Figure 1 is an axial section through a mixer illustrating one preferred embodiment of the principles of the invention;

Figure 2 is a transverse section taken on the plane indicated at 2—2 in Figure 1;

Figure 3 is a transverse section taken on the plane indicated at 3—3 in Figure 1;

Figures 4, 5, 6 and 7 are diagrams which will clarify the nature of the flow paths of the types herein involved; and

Figure 8 is a section similar to Figure 2 but showing an entrance and/or exit arrangement for the non-positive mixing pump to promote mixing action.

Referring first to Figures 1, 2 and 3, the mixing pump comprises a casing **2** having an inlet opening **4** and an outlet opening **6**. The former may communicate with a source of roughly admixed material which is to be transformed into a homogeneous mixture, while the latter may communicate with a receiver. If more than one pass of the mixture through the apparatus is required to secure the necessary homogeneity the receiver and source may be merged into one receptacle through which the pump will produce recirculation to process a batch of material. As will be evident, various circuits external to the pump may be provided such as are common in connection with other mixers and these circuits form no special part of the present invention, which is concerned primarily with what occurs to the material from the entrance **4** and the exit **6**. Liners **8** and **10** contained within the casing **2** provide housings for a positive multiple screw pump indicated generally at **12** and a non-positive multiple screw pump illustrated generally at **14**. A shaft **16** has mounted thereon, or, as shown, cut thereon, a power screw **18** for the positive pump and a power screw **20** for a non-positive pump. As specifically indicated in the drawings each of these screws contain two threads with the threads of the respective screws of opposite hands. Meshing with the power screws are so-called idler screws formed on common spindles or shafts indicated at **22** and **24**. The idler screws meshing with the screw **18** of the positive pump are indicated at **26** and **28**. The idler screws meshing with the power screw **20** of the non-positive pump and formed on shafts **22** and **24** are indicated at **30** and **32**. In addition to the idler screws **30** and **32** there mesh with the screw **20** of the non-positive pump another pair of idler screws **34** and **36**. As will be evident, to provide meshing the idler screws **30**, **32**, **34** and **36** are of a hand opposite that of the idler screws **26** and **28**.

In the arrangement illustrated all of the idler screws are of two-thread type and except for their hand all of these idler screws are preferably identical. Both the power screws and idler screws are designed in accordance with the principles set forth in said Montelius patent so that, when assembly is provided, as indicated in Figure 3 in the case of the positive pump **12**, a conventional pump is provided such as is commonly used for high speed positive pumping. Desirably the screws are so proportioned as to minimize the production of mechanical wear between them in accordance with the disclosure of Montelius Patent 1,965,557, dated July 3, 1934. As will be evident, the pump **14** will be non-positive. This point will be discussed more fully hereafter.

The two sets of screws are separated within a region provided by a spacer cylinder **40**, the interior **42** of which provides a conduit for the passage of material from the positive pump to the non-positive pump. Bearings of suitable type are provided at **46** and **48** for mounting and taking the end thrusts of the various screws. The screws have additional mounting in the bores in their housings **8** and **10**, the former having two side bores for the reception of the positive pump idler screws and the latter having four side bores for the non-positive pump idler screws. The clearances of the screws with their mounting bores are quite small, being exaggerated in Figures 2 and 3.

As will be evident from consideration of the figures, a rotation of the shaft **16** in the direction of the arrow will cause the positive pump to operate to drive the pumped material from the right toward the left. The non-positive pump **14**, on the other hand, is so operated as to tend to drive the material from the left toward the right. However, being non-positive this last pump must yield to the action of the positive pump so that despite the effort which it exerts the material will flow therethrough from the right toward the left. From the standpoint of pressures produced it will be evident that this operation will give rise to a very high pressure in the space **42**. The overall pressure of the pump from inlet to outlet will depend upon the head which is pumped against and which, in most uses of the pump, would be relatively low. The shaft **16** and the idlers carried by the shafts **22** and **24** will have a net thrust toward the right but this is generally relatively low and simple thrust bearing arrangements will suffice to take care of this thrust. On the other hand, the thrusts on the screws **34** and **36** will be toward the left and quite large so that as indicated the bearing arrangement at **46** must be of a type sufficient to resist this left hand thrust of these screws.

As will be evident, the non-positive pump will produce an intense turbulence and shearing mixing action on the material passing therethrough since an extreme relative motion of the material with respect to the screws is provided due to the fact that the screws are operating to oppose the flow of material forced by the positive pump. The mixing action is greatly increased, furthermore, by the tortuous path of the material through the non-positive pump. To explain this, and in particular, the relative characteristics of different kinds of non-positive pumps reference may be made to Figures 4, 5, 6 and 7 which respectively indicate the characteristics of operation of a positive pump having two idlers, a non-positive pump having three idlers, a non-positive pump having four idlers, and a non-positive pump having five idlers, in each case there being a power screw having two threads and idlers each having two threads.

The various diagrams of Figures 4, 5, 6 and 7 may be best understood by considering that they represent, from a purely diagrammatic standpoint, sections of slightly more than a complete circuit about the power screw in each case. These diagrams may be best understood by considering the diagram of Figure 6 with reference to Figure 2, the diagram being a development of a section taken on an axial surface just inside the peripheries of the screws along a path from x_1 about the outer portion of idler **30** to x_2, thence to x_3 about the power screw **20**, thence about idler **34** to x_4 and similarly about the power screw and the other idlers to axial lines x_5, x_6, x_7 and x_8, and finally back to x_1. The segmental sections of the power screw are then indicated at P, while the segmental sections of the idler screws are indicated at the I's provided with subscripts corresponding to the various idlers provided. Figures 4, 5 and 7 are sections taken in similar fashion.

Continuing the reference to Figure 6, the form of pump having four idlers, assume rotation of the power screw in the direction of the arrow at the top of Figure 6. Under this assumption the inlet to the pump will be at the bottom of the figure and the outlet will be at the top of the figure. The liquid will be progressed upwardly by the dynamic action of the screw threads.

That the pump is non-positive will become evident by considering the path AB noting that starting at x_1 and returning to x_1 the point B is located in the second groove of the screws below A. It will accordingly be evident that a parallel path exists starting at A'. From the diagram it will be evident that irrespective of the lengths of the screws this path will be continuously open and will provide a tortuous leakage path from the outlet end of the set of screws to their inlet end. Furthermore, since the leakage path is duplicated there are, in effect, two parallel leakage paths preventing the pump from operating in a positive fashion. These paths, however, are so tortuous, as may be recognized particularly by reference to Figure 2, that the pump has a very effective dynamic action and, if of proper length, is capable of producing a quite substantial head.

Consideration may now be given to the question of proper length of the screws. By "length" is meant the effective length through which the screws are in mesh and are also properly surrounded by the housing to form a closed path.

By considering the contacts between the screws it will be found that, first assuming a symmetrical arrangement of the idlers about the power screw, a complete circuit of the power screw by the liquid to follow a leakage path will be required if the effective length of the pump, as above defined, is given by the following equation:

$$M=\frac{P}{N}\left\{N^2(n_{I-1})-N(n_{P-1})+n_P\right\}+W$$

in which, assuming a single power screw,

M is the minimum effective length of mesh and enclosure of the screws to insure that liquid passing from outlet to inlet must make at least a complete circuit of the power screw;

P is the pitch, equal to the lead of each screw divided by the number of its threads;

N is the number of idlers;

n_I is the number of threads on each idler;

n_P is the number of threads on the power screw; and

W is the axial width of the top of the power screw.

If the minimum effective length is less than this, it will happen that in some positions of the screws a path may be found from outlet to inlet which will make less than a complete circuit of the power screw. This possibility is undesirable giving not only an absence of full effectiveness of the screw arrangement in terms of producing maximum head for a given speed of operation, but will also give rise to pulsations by virtue of the less effective pumping action whenever the screws attain a configuration which gives the shorter path just mentioned.

As an application of the foregoing formula, the following tabulation indicates the values of M for pumps having a single power screw carrying two threads and two, three, four and five idlers, respectively, each carrying two threads:

N	M
2	$2P+W$
3	$\frac{8P}{3}+W$
4	$\frac{7P}{2}+W$
5	$\frac{22P}{5}+W$

The assumption of a minimum effective pump length for a symmetrical array of idler screws applies, however, to an asymmetrical array, since it will be found that, if an asymmetrical array is used, the minimum length would have to be greater than that given by the above formula to avoid a leakage path in certain positions of the screws which would provide less than a complete circuit of the power screw. Actually, symmetrical arrays are most desirable to avoid the existence of unbalanced lateral thrusts on the screws.

Attention may now be given to Figures 4, 5 and 7 which indicate the nature of the paths or chambers existing when two, three and five idlers, respectively, are used.

Figure 4 is provided only for completeness of the systematic disclosure. It represents a positive pump comprising a power screw of two threads meshing with two idlers of two threads each, this being the positive pump illustrated in Figure 1. If the path CD is noted, it will be seen that it starts and ends in the same groove position. Accordingly, it does not extend axially and this path represents a closed chamber making the pump positive. The expression given for M, however, still applies and in this case has a significance that the effective length of the pump should be as indicated in the foregoing tabulation to insure that the pump will actually be positive.

Referring to Figure 5, which shows a three idler arrangement it will be noted that the path EF, corresponding generally to the path AB of Figure 6, completes a circuit of the power screw in the next lower groove below the starting groove E. Since the value of M for this pump is less than for the four-idler pump, and only a single path is provided, it will be evident that for given screw dimension and for given speed of operation a greater head may be produced with the three-idler arrangement than with the four-idler arrangement with, however, a reduction in capacity.

The five-idler arrangement is illustrated in Figure 7, the free leakage path being indicated at GH. It will be noted that this path makes a circuit of the power screw dropping to the third groove below its beginning at the end of this circuit. This means that there will be three parallel paths running through the screws, the additional two paths, for example, passing through G' and G''. As pointed out in Montelius Patent 1,698,802 a positive pump is provided by a power screw having one thread meshing with a single idler screw having two threads. From this construction a non-positive pump may be derived merely by adding another idler of the two thread type. Numerous other non-positive pumps may be derived by departure from the conditions given in said Montelius Patent 1,698,802 for positive screw pumps.

It may be noted that the formula given above for M applies to such pumps in general provided with a single power screw, and from this there may be determined the minimum effective pump length for best utilization of any such screw arrangement.

It will also be evident that non-positive screw pumps may be derived from positive screw pumps merely be decreasing the circumferential extents of the threads of the power or idler screws so as to afford clearances which will prevent complete closures of pockets which would normally exist in positive pumps, though this modification is not recommended since it permits play between the screws and wear due to impact unless timing gears are added.

In all the cases referred to above effective mixing can be attained by causing flows to take place in directions opposite the flows through a non-positive pump.

It will also be evident that imposing reverse flow through a non-positive pump may be secured by causing two non-positive screw pumps to buck each other if one is of a type producing a dynamic propelling characteristic in excess of that of the other. As an example, a 3-idler pump of the type diagrammed in Figure 5 may be arranged to oppose the flow through a 4-idler pump of the type illustrated in Figure 6. In this case for the same or comparable lengths of the pump the 3-idler pump will overcome the 4-idler pump so as to enforce a reverse flow through the latter. At the same time a considerable degree of admixing action will occur in the 3-idler pump due to slippage therein. The arrangement may also be reversed so that a 4-idler pump overcomes a 3-idler pump by making the screws of the former sufficiently long.

Furthermore, two similar non-positive pumps of the same type, from the standpoint of numbers of screws and threads, may be arranged to oppose each other if they are of different lengths so that the longer of them will produce a head greater than the shorter.

Similar results may also be secured by the opposition of screw pumps of the same or different types having different pitches of their threads so that one of them may overcome the action of the other. As will be evident, a very great variety of screw pumps may be combined to attain mixing actions in accordance with the principles of the invention.

While the opposition of a pair of screw pumps is particularly desirable in carrying out the invention, it may be noted that it is the reverse flow through a non-positive pump which is particularly responsible for effective mixing; the pump which produces the reverse flow through the mixing pump has primarily only the function of producing that flow and, consequently, may be replaced by other positive pumps or by such non-positive pumps as may be capable of producing the reverse flow as described. When, as usual, viscous materials are being mixed it may be noted that the non-positive screw pumps which have been described actually are capable of producing very substantial heads and, consequently, the pump which enforces reverse flow must be capable of producing even greater heads. Another screw pump is particularly applicable for this purpose and, furthermore, the use of a pair of screw pumps results in the practical advantage of one or more common shafts incorporated in a single housing to provide a compact and free-running unit.

In the arrangement illustrated in Figure 1, entrance to the screws of the non-positive pump and exit therefrom takes place axially, i.e., the ends of the screws are completely open to entrance and exit chambers. An augmented mixing action may be produced in accordance with the arrangement illustrated in Figure 8 which applies to both the entrance and exit ends of the screws. In this modification, the ends of the screws may be confined and entrance of the mixture to the screws and exit from the screws may be provided through radially extending openings **52** in the ends of the housing **50** for the screws **20'**, **30'**, **32'**, **34'** and **36'** which correspond to the similarly numbered screws in Figures 1 and 2. It will be evident that the screw threads will cut across such openings and accordingly effect a chopping action on the entering or leaving mixture. If the pump is operating at high speed, this chopping action is particularly effective to produce a breaking up of any agglomerates of solid material or concentration of liquid droplets which may exist in the mixture. The screws should desirably be of such lengths exceeding the minimum effective lengths discussed above so that the openings **52** at the entrance and exit are spaced by more than this effective length.

What I claim and desire to protect by Letters Patent is:

1. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, a second multiple screw pump including a power screw and at least one idler screw, said power screws being coaxially mounted and rotating together and said idler screws being coaxially mounted and rotating together, said pumps having a common housing, and said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

2. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, a second positive multiple screw pump including a power screw and at least one idler screw, said power screws being coaxially mounted and rotating together and said idler screws being coaxially mounted and rotating together, said pumps having a common housing, and said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

3. In a mixing device, in combination, a non-positive multiple screw pump including a power screw having two threads and at least three idler screws, each having two threads, a second multiple screw pump including a power screw having two threads and at least two idler screws, each having two threads, said power screws being coaxially mounted and rotating together, and each of said idler screws of the second mentioned pump being coaxial with, and rotating with, a corresponding idler screw of the first mentioned pump, said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

4. In a mixing device, in combination, a non-positive multiple screw pump including a power screw having two threads and at least three idler screws, each having two threads, a second positive multiple screw pump including a power screw having two threads and two idler screws, each having two threads, said power screws being coaxially mounted and rotating together, and each of said idler screws of the second mentioned pump being coaxial with, and rotating with, a corresponding idler screw of the first mentioned pump, said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

5. In a mixing device, in combination, a non-positive multiple screw pump including a power screw having two threads and four idler screws, each having two threads, a second multiple screw pump including a power screw having two threads and at least two idler screws, each having two threads, said power screws being coaxially mounted and rotating together, and each of said idler screws of the second mentioned pump being coaxial with, and rotating with, a corresponding idler screw of the first mentioned pump, said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

6. In a mixing device, in combination, a non-positive multiple screw pump including a power screw having two threads and four idler screws, each having two threads, a second positive multiple screw pump including a power screw having two threads and two idler screws, each having two threads, said power screws being coaxially mounted and rotating together, and each of said idler screws of the second mentioned pump being coaxial with, and rotating with, a corresponding idler screw of the first mentioned pump, said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

7. In a mixing device, in combination, a non-positive multiple screw pump including a power screw having two threads and four idler screws, each having two threads, a second positive multiple screw pump including a power screw having two threads and two idler screws, each having two threads, said power screws being coaxially mounted and rotating together, and each of said idler screws of the second mentioned pump being coaxial with, and rotating with, a corresponding idler screw of the first mentioned pump, said two power screws being of opposite hands, said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

8. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, means for driving said pump, and a second pump for forcing a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

9. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, means for driving said pump, and a second positive pump for forcing a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

10. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, means for driving said pump, and a second positive multiple screw pump including a power screw and at least one idler screw for forcing a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

11. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, a second multiple screw pump including a power screw and at least one idler screw, said pumps having a common housing and a common drive shaft, and said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

12. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, a second positive multiple screw pump including a power screw and at least one idler screw, said pumps having a common housing and a common drive shaft, and said second pump being constructed and arranged to force a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

13. In a mixing device, in combination, a non-positive multiple screw pump including a power screw and at least one idler screw, means for driving said pump, and a second multiple screw pump including a power screw and at least one idler screw for forcing a fluent mixture through the first mentioned pump in a direction opposing the pumping action of the first mentioned pump.

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