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(54) **EDUCTOR MIXER SYSTEM**

EDUKTOR-MISCHERSYSTEM

SYSTEME DE MELANGEUR-EJECTEUR

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- **PATENT ABSTRACTS OF JAPAN vol. 003, no. 027 (C-039), 7 March 1979 (1979-03-07) & JP 54 004869 A (BABCOCK HITACHI KK), 13 January 1979 (1979-01-13)**

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Description

Technical Field

[0001] This invention relates to an eductor-mixer system particularly adapted for the preparation of dispersions, solutions and slurries. More particularly, the eductor-mixer system of this invention is an improvement over the eductor-mixer system disclosed in my prior United States Patent Nos. 4,186,772 (on which the two-part form of independent claim 1 is based) and 3,777,775.

Background Art

[0002] An eductor-mixer system is designed to continuously mix a solute such as paint pigments, fire retardants, liquids and gels, (e.g., a powder, particulate, or other pressure transportable or fluidizable material, a liquid or a gas) and a solvent or working fluid (e.g., a liquid or in some instances a gas) to form a dispersion, slurry, or solution.

[0003] The solute inlet of an eductor-mixer system is conventionally connected to the discharge outlet of a fluidized container so that a vacuum generated within the eductor-mixer by the flow of solvent (working fluid) through an internal nozzle cooperates with the fluidized discharge of the powder from the container to positively draw the fluidized solute into the eductor-mixer. Existing state-of-the-art eductor-mixer systems typically include a conical, converging stream of working fluid, as most solutes used with these systems require a relatively large diameter solute tube and conveying line (more than 1.0 - 1.5 inches) to be transported vacuum pneumatically without clumping or clogging. With such large diameter delivery tubes, a conical nozzle is required to deflect the working fluid stream into a discharge tube small enough in diameter to meet the cross-sectional area criterion for vacuum generation and mixing. Although some solute materials may be vacuum transported in smaller diameter tubes, these smaller diameter solute tubes suffer from accretion of the solute material at the discharge outlet due to small amounts of the working fluid splashing back into the solute tube from turbulence formed at the conical deflector in the discharge tube.

[0004] Additionally, traditional eductor-mixer systems are thought to be somewhat burdened by the introduction of an radial component of translational energy into the conical converging jet of working fluid, and hence are not as efficient as theoretically possible in generating the vacuum to positively draw the solute thereinto. Reference may be made to United States Patent Nos. 1,806,287, 2,100,185, 2,310,265, 2,695,265, 2,772,372, 3,166,020, 3,186,769, and to Canadian Patent No. 790,113, each of which discloses various eductor-mixer systems and air conveying apparatus in the same general field as the present invention.

[0005] Reference is also made to US patent No. 5.023,021 which discloses a cartridge Venturi having an aspirator tube received with the discharge end thereof in a Venturi throat of a cartridge body. Fluid from the aspirator tube is discharged into the Venturi throat upstream of the divergent outlet section thereof. In one embodiment, an end piece is fixed to the cartridge body to form a radial diffuser. In another US patent No. 5,842,600 there is disclosed a mixing Venturi in which an outlet projection of a delivery pressure conduit is received in a nozzle throat upstream of a nozzle outlet.

[0006] In many known prior art eductor-mixer systems, the powder supply, even if it is in a fluidized container, is required to be located above the level of the eductor-mixer system because the latter is dependent upon gravity feed of the powder. In the systems shown in the United States Patent Nos. 4.186.772 and 3.777.775. the eductor-mixers are not dependent upon gravity feed because the vacuum within the eductor-mixer is sufficient to positively draw the powder from the container into the eductor-mixer systems, and thus these systems are not dependent upon the relative location of the powder container and the eductor-mixer system.

[0007] The eductor-mixer system of the present invention is a significant improvement of the aforementioned eductor-mixer systems and is capable of conveying a greater amount of material and generating a higher vacuum pressure due to an improved nozzle design. Furthermore, it overcomes problems associated with splashback and clogging of narrow diameter solute tubes commonly associated with the use of conical working fluid jets.

Summary of the Invention

[0008] Among the several features of this invention may be noted the provision of an eductor-mixer system particularly well suited for either continuous or batch preparation of dispersions, solutions, or slurries from a fine granular, particulate, or powdered solute, or other pressure transportable or fluidizable material and a working fluid or solvent:

[0009] The provision of such an eductor-mixer system which is also capable of mixing gas or vapor solutes with liquid or gaseous working fluids; the provision of such an eductor-mixer system which thoroughly mixes the solute and working fluid;

[0010] The provision of such an eductor-mixer system which is self-flushing and which effectively prevents back flow of the working fluid into the solute inlet;

[0011] The provision of such an eductor-mixer system which minimizes working fluid flow losses therethrough and which is highly efficient in transferring momentum from the working fluid to the solute and to the resulting dispersion;

[0012] The provision of such an eductor-mixer system which minimizes the introduction of a radial component of translational energy to the working fluid stream, maximizing the kinetic energy available to produce a vacuum capable of drawing the solute through the solute tube;

[0013] The provision of such an eductor-mixer system which eliminates the need for convergence of the working fluid stream, directing substantially all of the working fluid kinetic energy in a longitudinal manner;

[0014] The provision of such an eductor-mixer system which is optimized for use with smaller diameter solute delivery tubes;

[0015] The provision of such an eductor-mixer system which substantially eliminates splash-back of the working fluid into the solute delivery tube due to turbulence;

[0016] The provision of such an eductor-mixer system in which relatively high vacuum levels may be efficiently generated therewithin so as to positively draw fluidizable material into the eductor-mixer system and so that the relative location of the eductor-mixer system and the fluidizable material supply is much less critical;

[0017] The provision of such an eductor-mixer system which reduces undesired turbulence adjacent the location of the fluidizable material supply;

[0018] The provision of such an eductor-mixer system in which the radial location of the eductor nozzle is dependent upon the outer diameter of the solute tube, and the cross sectional area of the nozzle is proportional to the cross sectional area of the discharge tube;

[0019] The provision of such an eductor-mixer system in which certain parts subject to flow erosion may be readily and inexpensively replaced and may be adjusted relative to one another to compensate for wear so as to lengthen the service life while maintaining the desired flow characteristics through the eductor-mixer;

[0020] The provision of such an eductor-mixer system in which certain parts thereof may be readily changed so as to vary the flow rate through the eductor-mixer system within a predetermined range; and

[0021] The provision of such an eductor-mixer system which is of relatively simple and rugged construction, which is reliable in operation, which may be retrofitted to existing eductor-mixer systems, and which requires no special training or skill for use.

[0022] In general, an eductor-mixer system of this invention, as defined in independent claim 1, comprises an eductor body having a working fluid passage extending therethrough for flow of a pressurized working fluid from one end of the working fluid passage, constituting an inlet end, to the other end of the working fluid passage, constituting a discharge end, the working fluid passage being generally of uniform circular cross-section throughout its length. The body has an opening therein opposite the discharge end of the working fluid passage with the opening being coaxial with the discharge end and being of substantially smaller diameter than the diameter of the working fluid passage. A insert comprising a ring separate from the body, having inside and outside faces, and a central opening therethrough from its inside to its outside face, is removably mounted in place at the discharge end of the working fluid passage coaxial with the discharge end The central opening in the ring being of substantially smaller diameter than the diameter of the working fluid passage. A cylindrical tube of substantially smaller diameter than the diameter of the working fluid passage extends from outside the body through the opening in the body opposite the discharge end of the working fluid passage and extends forward in the working fluid passage from the inner end of the opening in the body into the central opening in the ring. The tube is open at its end in the central opening in the ring, the open end of the tube constituting a discharge end. The tube is axially adjustable in, and removable from, the opening, and is adapted for connection of its end outside the body to a source of fluent material to be educted and mixed with the working fluid for the flow of the material through the tube and out of the discharge end of the tube. The discharge end of the tube is substantially coplanar with the outside face of the ring. The inner periphery of the ring bounding the central opening in the ring is formed in-part as a entrance extending from the inside face towards the outside face of the ring and convergent in downstream direction from the inside to the outside face of the ring, and in part as a cylindrical nozzle surface extending from the narrowest portion of the entrance to the outside face of the ring. The narrowest portion of the entrance of the ring surrounds and is spaced from the cylindrical exterior surface of the tube a distance which is small relative to the diameter of the outer end of the entrance, the cylindrical nozzle surface thereby providing an annular orifice between the exterior cylindrical surface of the tube and the cylindrical nozzle surface of the ring for delivery of the pressurized working fluid from the passage through the orifice. The pressurized working fluid is delivered in the form of an annular jet. The gap between the exterior cylindrical surface of the tube and the cylindrical nozzle surface of the ring is relatively small and the length of the annular cylindrical orifice is relatively short for rapid acceleration of the working fluid flowing through the orifice to a relatively high linear velocity with low flow losses. Means separate from the ring providing a discharge passage downstream from the ring at the discharge end of the working fluid passage in the body in which the material issuing from the discharge end of the tube and the working fluid cylindrically jetted through the orifice may mix, is removably secured to the body at the discharge end of the working fluid passage in the body. The discharge passage extends outwardly from the ring and has an external diameter at its end at the outside face of the ring larger than the diameter of the cylindrical nozzle surface of the ring, the internal surface of the means lying outward of, and parallel to, the projection of the jet throughout its length.

[0023] The foregoing and other features, and advantages of the invention as well as presently preferred embodiments thereof will become more apparent from the reading of the following description in connection with the accompanying drawings.

Brief Description of Drawings

[0024]

Figure 1 is an exploded perspective view of an eductor-mixer of this invention;
Figure 2A is a longitudinal cross-sectional view of a prior art eductor-mixer;
Figure 2B is a longitudinal cross-sectional view of the eductor-mixer of the present invention;
Figure 3 is an enlarged cross-sectional view of a portion of the eductor-mixer illustrating certain details of the eductor nozzle;
Figure 4 is an enlarged cross-sectional view of a portion of the eductor-mixer illustrating enlarged solute tube wall thickness;
Figure 5 is a chart comparing the vacuum pumping capacity of an eductor-mixer system of the present invention with that of the prior art, illustrating the improved efficiency of the present invention.

[0025] Corresponding reference numerals indicate corresponding parts throughout the several figures of the drawings.

Best Mode for Carrying Out the Invention

[0026] The following detailed description illustrates the invention by way of example and not by way of limitation. The description will clearly enable one skilled in the art to make and use the invention, describes several embodiments, adaptations, variations, alternatives, and uses of the invention, including what we presently believe is the best mode of carrying out the invention.

[0027] Referring now to the drawings, a preferred embodiment of the eductor-mixer of the present invention, indicated in its entirety at 1, is shown to comprise an eductor body or housing 3, having a curved passage therethrough for a working fluid or solvent from an inlet 5 at one end of the passage (also referred to as a first inlet). The housing is adapted to be connected to a source of pressurized working fluid or solvent (e.g., to a liquid line or a pump) and to convey the working fluid or solvent to the other end of the passage, constituting a discharge end, and a second inlet 7 adapted to be connected to a supply of pressure transportable or fluidizable material (also referred to herein as a solute or fluent material). The passage is generally of uniform circular cross-section throughout its length. However, passages having non-uniform cross sectional areas and of different shapes such as "T" forms, may be adapted for use with the disclosed eductor-mixer system, and correspondingly are considered within the scope of the invention. As mentioned above, the solvent inlet may be connected to the discharge side of a liquid pump or to another source of pressurized working fluid. Inlet 7 may be connected via an appropriate hose to the discharge opening of a fluidized container.

[0028] Fluidized containers are used in transporting and storing "semi-bulk" quantities (e.g., more than a bag full and less than a truck or railroad car full) of powdered, fine granular, particulate, or other fluent or fluidizable material, such as powdered fire retardant materials, paint pigments, cement, oil well drilling muds, barite, diatomaceous earth, talc, lime, etc. It is often necessary to mix the powdered solute with a solvent upon unloading of the solute to form a dispersion, slurry or solution. While the eductor-mixer system of this invention described and claimed hereinafter will be referred to primarily in conjunction with fluidized containers for mixing powdered solutes with liquid solvents, it will be understood that the eductor mixer system of this invention need not be used in conjunction with a fluidized container, and it may be used to mix all types of solutes and solvents. It will be particularly understood that the eductor-mixer system of this invention may be used to mix both liquid and gaseous solvents and solutes.

[0029] The eductor-mixer system of the present invention is an improvement over the eductor-mixer system shown in United States Patent Nos. 4,186,772 and 3,777,775, illustrated in Figure 2A. Referring now to Figures 1 and 2B, the body or housing 3 of the eductor-mixer system of this invention is preferably cast or fabricated of a suitable metal, such as stainless steel, and has the passage or plenum chamber 9 formed therewithin in communication with solvent inlet 5. A sleeve 11 extends from the housing coaxial with the discharge end of the passage. It will be understood, however, that sleeve 11 could extend internally into housing 3. While housing 3 is shown to be generally in the shape of a 90° pipe elbow, it will be understood that the housing may assume other shapes and still be in the scope of the invention. Solute inlet 7 is shown to comprise a cylindrical tube 13 of somewhat smaller diameter than the bore of sleeve 11. Tube 13 is insertable into the sleeve so as to extend through plenum chamber or passage 9 with the pressurized working fluid or solvent filling the plenum chamber or passage and surrounding the solute inlet tube. A receiving member, generally indicated at 15, is removably secured to housing 3. The interior of this receiving member constitutes a passage means 17 in which the solute is dispersed in the solvent and in which the solute and solvent are mixed. An insert 19 is disposed within housing 3 at the discharge end of the passage or chamber 9 between chamber 9 and passage means 17. This insert is shown to be a flat ring having a central or nozzle opening 21 therein which receives the inner or discharge end of solute tube 13. The nozzle opening 21 is somewhat larger than the outer diameter of the discharge end of the solute tube and the latter is substantially centered within the opening 21 thereby to define an annular nozzle opening or orifice N concentric with the solute tube through which working fluid under pressure in plenum chamber or passage 9 is discharged at high velocity into the receiving member 15. The solvent is discharged as an annular jet J, and it generates a vacuum within the passage means.

The vacuum is in communication with the discharge end of solute tube 13 and thus positively draws or sucks the solute into the passage means 17.

[0030] As best shown in Fig. 3, solute tube 13 is of substantially smaller diameter than passage 9 and has uniform outer diameter OD and inner diameter D1 adjacent the discharge end, thereby having a cylindrical exterior surface 23. Insert 19 has an inner cylindrical nozzle surface 25 concentric to the cylindrical exterior surface 23, which defines a central opening or nozzle 21. The insert 19, at its inside face (toward the left in Figs. 2B and 3), has a conical entrance 26 converging toward the cylindrical nozzle surface 25. The latter extends from the narrowest portion of the conical entrance 26 to the outside face (toward the right in Figs. 2B and 3) of the ring. The diameter of opening 21 and the length of cylindrical nozzle surface 25 in the direction of flow through the nozzle depend on the desired flow conditions through the nozzle. It will be appreciated that the flow rate through the nozzle is similarly a function of the pressure within plenum chamber or passage 9 and passage means 17 and the cross sectional flow area of nozzle N. The latter is the cross-sectional area of the gap G (see Fig. 3) between cylindrical exterior surface 23 of the solute tube and the cylindrical nozzle surface 25. The vacuum generated by the jet discharged from the nozzle into the passage means is dependent upon the velocity of the jet.

[0031] The eductor-mixer 1 of this invention is particularly well suited to efficiently accelerate the working fluid from plenum chamber or passage 9 into the passage means 17 in several important ways. First, the cross-sectional area of the plenum chamber or passage is quite large in relation to the cross-sectional area of nozzle N. This allows working fluid to flow through the passage at a speed much slower than it flows through the nozzle so that there is little or no energy lost by the flow of the working fluid through the passage. The length L of the nozzle in the direction of the flow therethrough is relatively quite short. This permits the solvent to be almost instantaneously accelerated to its discharge velocity in a short distance, thus minimizing the flow losses while flowing through, and discharging from, the nozzle at high linear velocity. At one extreme, nozzle surface 25 may be a sharp knife edge having an extremely short effective length L (e.g., a few thousandths of an inch) in the direction of flow through the nozzle. In other instances, the nozzle surface may preferably have longer length L approximately equal in length to the width of gap G for purposes that will later be described. It will be understood that as the nozzle length L increases, shear (and related energy loss) in the nozzle is increased. Shear, of course, is also greater with narrower nozzle gaps.

[0032] Second, it has also been found that the ratio of the nozzle length L to the gap thickness G (i.e., L/G) preferably should range between about 0.001 for a knife edge surface 23 and up to about 10 for a cylindrical nozzle surface 25 which is parallel to the exterior cylindrical surface 23 on tube 13. As shown in Figs. 2B and 3, receiving member 15 comprises a constant-diameter discharge conduit 16 abutting the outside surface of the nozzle member 19, defining passage means 17. The diameter D3 of the inner end or bore of the discharge conduit 16 is slightly larger than the outer diameter D2 of nozzle opening 21.

[0033] A third way in which the eductor-mixer system of this invention minimizes energy loses is to equalize the areas into which the jet of fluid passing through nozzle N can expand. To provide approximately equal areas of expansion, the cross sectional area of the discharge conduit 16, as seen in Fig. 3, which is inside the jet at the surface of the annular nozzle N, having the diameter OD of the solute tube 13, must approximate the cross sectional area of the discharge conduit 16 which is external to the jet at the surface of the annular nozzle N. This second cross sectional area is defined as the annular area between the inner diameter D3 of the discharge conduit and the outer diameter of the annular nozzle N, defined by D2 at the outer surface of the nozzle N. When these two cross sectional areas are of nearly equal size, the jet of fluid passing through nozzle N can expand in a uniform manner in all directions while minimizing energy losses due to wall friction or mutual interference.

[0034] The eductor-mixer system of this invention minimizes energy losses is that the internal surface of discharge conduit 16 adjacent nozzle N lies outward of and parallel to the projected path of the cylindrical jet J (as indicated by the dotted lines in FIG. 3) as the jet is discharged from the nozzle. This insures that frictional wall losses along the passage means walls are minimized as the jet flows at high speeds into the passage means. Further, the diameter of the discharge conduit at any point there along is larger than the diameter of the projected path of the jet so as to insure that the walls of the discharge conduit are clear of the jet. In accordance with this invention, the cross-sectional area of the discharge conduit 16 downstream from passage means 17 is about 3 to 10 times the cross-sectional area of gap G larger for higher discharge velocities and on the low side for lower discharge velocities.

[0035] Finally, by discharging the solvent in a concentric cylindrical jet J, as opposed to a converging conical jet as described in the referenced patents, the radial component of the jet's energy is substantially eliminated, and the translational kinetic energy available to produce the vacuum is correspondingly increased. Eliminating the converging jet further results in substantially eliminating backsplash of the solvent towards the discharge end of the solute tube 13, preventing accretion of the solute and clogging of the tube. Displacement of the jet away from the opening in the discharge end of the solute tube 13 may be further accomplished by a uniform increase in the wall thickness of the solute tube as shown in Fig. 4, adjacent the discharge end, and a corresponding radial enlargement of the cylindrical nozzle surface 25 outward to maintain the cross sectional area of gap G within the desired range. One skilled in the art will recognize that the resulting structure will have an annular nozzle of a larger diameter, a gap G of narrower width, and no corresponding change in cross sectional area of the gap.

[0036] These improvements result in a dramatic increase in the efficiency of the eductor-mixer system over the systems described in the referenced patents, as can be seen from reference to Fig. 5, which compares the vacuum pumping capacity of the eductor-mixer system disclosed in United States Pat. No. 4,186,772 with that of the present invention. In Fig. 5, at a predetermined working fluid pressure, both the volume of gas drawn through the solute tube and the flow rate of the liquid exiting the discharge conduit were measured to produce a ratio representative of the vacuum pumping capacity. For example, with a working fluid pressure of 40 psig measured at the first inlet, the prior eductor-mixer system yields a vacuum pumping capacity ratio of 0.23 scf/usg, whereas the present invention at the same fluid pressure yields a vacuum pumping capacity ratio of 0.34 scf/usg, a 48% improvement in efficiency.

[0037] As described above, the vacuum generated by the educator-mixer system 1 of this invention is more efficient than the prior art eductor-mixer system shown in the above United States Patent Nos. 4,186,772 and 3,777,775 in positively drawing more air and consequently even more solute into the eductor-mixer system. Thus, the eductor-mixer system of this invention is able to induct a greater quantity of powered solute or to be located at a greater distance from the powdered solute in the solute fluidized container than had been heretofore possible. Accordingly, the location of the eductor-mixer system and the solute supply even less critical that had heretofore been the case with the prior art systems.

[0038] It will be understood that the surfaces 23 and 25 on the solute tube and insert, respectively, may be hardened (e.g., carburized or nitrided) to provide a hard wear-resistant surface for resisting flow wear abrasion by the solvent and solute flowing therethrough at high speeds. It will also be understood that, alternatively, these surfaces may be hardened by making them of a special material which resists flow wear abrasion.

[0039] As heretofore described, solute tube 13 extends into housing 3 through sleeve 11 with the sleeve having an inside diameter slightly greater than the outside diameter of the solute tube. The latter has one or more circumferential grooves 28 for receiving an O-ring seal 29 which in turn seals the solute tube relative to the bore of the sleeve when the former is axially inserted into the latter. This seal permits the solute tube to be moved axially in and out of the sleeve while remaining sealed relative thereto. As is best shown in Fig. 2B, the sleeve 11 is substantially coaxial with nozzle opening 21 in insert 19 and with mixing tube 15. Preferably, solute tube 13 is inserted into housing 3 via sleeve 11 and through plenum 9 so that the discharge end of the tube is generally coplanar with the downstream end of nozzle surface 25 and is coaxial with nozzle opening 21 so that the gap G is of uniform thickness around the tube and so that the solvent in the plenum surrounds the solute tube. A plurality (e.g., three) of threaded fasteners 31 is threadably carried by sleeve 11 for engagement with the outer surface of solute tube 13. With all of the fasteners 31 engaging the outer surface of tube 13, the tube is firmly secured in place relative to the sleeve at any desired axial position within the sleeve. By adjusting the various fasteners 31 in and out, the end of the tube may be readily adjusted relative to nozzle surface 25, and secured in position when the tube is properly centered within the nozzle opening with gap G being of substantially uniform thickness around the outlet end of the solute tube. It will also be noted that in the event the cylindrical exterior surface 23 of the solute tube becomes worn so as to affect the flow geometry through the eductor-mixer, fasteners 31 may be loosened and solute tube 13 may be readily removed thereby to enable resurfacing of cylindrical exterior surface 23 on the tube, or the solute tube may be moved farther into the housing thereby to accommodate the wear of the solute tube and/or the wear of nozzle surface 25. With fasteners 31 located in sleeve 11 clear of the insert 19 and plenum 9, solvent flows through the plenum and the nozzle opening without encountering any resistance from the fasteners. It will also be noted that in its preferred embodiment, the nozzle opening or orifice through the eductor-mixer of the present invention is a continuous annular gap around the solute tube with no supports, flow dividers or other restrictions in the nozzle which would block or otherwise impede the flow of fluid therethrough. In this manner, the concentric solvent jet is a continuous annular jet as it is discharged from the nozzle. It will be understood, however, that flow dividers could be placed between the outer surface of the solute tube and the inner surface of the nozzle for supporting or centering the outer end of the solute tube in the nozzle opening. If this is done, the solvent jet discharged from the nozzle will not necessarily be a continuous annular jet, but rather would be a series of separate cylindrical jets within the passage means. These separate jets are considered to be within the scope of the present invention.

[0040] As heretofore mentioned, insert 19 is a ring-like member and, as best shown in Fig. 3, has a shoulder 41 in its front face toward chamber 9 and an outwardly projecting flange 43. Shoulder 41 has a diameter substantially the same as the circular inner bore of housing 3 and thus the step is readily received within the open end of the housing so as to center the nozzle opening relative to the longitudinal center line of sleeve 11 and solute tube 13 inserted therein. Housing 3 and receiving tube 15 each have respective flanges 45 and 47 adapted to be sealingly secured together in face-to-face relation. With the receiving tube flange 47 in sealing engagement with nozzle flange 43, insert 19 is held captive in a desired position relative to the housing and the receiving member. A circumferential groove 49 is provided on the outer face of flange 47 for receiving an O-ring 51 which seals the receiving member to the housing. Flanges 45 and 47 each have sloped outer faces and are adapted to be drawn together by a sealing hoop clamp 53, such as is commercially available from the Aeroquip Company of Los Angeles, California. Upon tightening clamp 53 on flanges 45 and 47, these flanges are drawn into face-to-face sealing engagement with the O-ring 51. It will be understood, however, that means other than clamp 53 may be used for releasably and sealably securing the mixing tube 15 to housing 3. It will thus be appreciated that eductor 1 of this invention may readily be converted from one flow rate capacity to another merely by exchanging one insert 19 for another having different nozzle opening dimensions and exchanging receiving member 15 to maintain a desired ratio between the gap cross sectional area and the passage means cross sectional area.

[0041] In accordance with this invention, the length L' of the conduit 16 is preferably about 5 to 50 times longer than its diameter D3, and even more preferably, is about 15 to 30 times longer than its diameter so as to enhance the mixing (i.e., dispersion) of the solute and the working fluid within the conduit. Expressed in another manner, the ratio L'/D3 preferably should range between about 5 and 50 and even more preferably between about 15 and 30. It will be understood, however, that this ratio could be varied considerably and even be outside the above-stated preferred ranges and still be within the scope of this invention. This ratio depends upon many factors, such as the physical characteristics of the solute and solvent being mixed, the flow rates and pressures, and temperatures of the solute and solvent, and many other factors. Thus, this ratio could vary considerably and satisfactory mixing of the solute and solvent could still be attained within the eductor-mixer system of this invention. The above-stated preferred ranges indicate ranges which for many materials have been readily and satisfactorily mixed by the apparatus of this invention.

Claims

1. An eductor-mixer system consisting of an eductor body (3) with a passage (9) extending therethrough for the flow of a pressurized working fluid from one end (5) of the passage (9), constituting an inlet end (5), to the other end of the passage (9), constituting a discharge end;

an annular insert (19) within said passage (9) and adjacent the discharge end;
a solute tube (13) of smaller diameter than the diameter of said passage (9), said solute tube (13) extending from outside said eductor body (3) into said eductor body (3) with the inner end of said solute tube (13) being substantially coaxial with respect to said annular insert (19) and with the inner end of said solute tube (13) terminating substantially coplanar with the downstream face of said insert (19); and
a discharge tube (15) connected to said body (3) downstream from said insert (19);
said solute tube (13) and said insert (19) defining an annular nozzle (N), said pressurized fluid, upon flowing through said annular nozzle (N) undergoing a substantial increase in velocity so as to generate an area of low pressure within said discharge tube (15) downstream from said annular nozzle (N), said solute tube (13) being adapted for the conveying of a flowable material which can be a granular, powdered, or other particulate solid, or a liquid or a gas, therethrough for mixing with said pressurized working fluid downstream from said nozzle (N);
an inner surface (25) of said insert (19) defining an outer surface of said annular nozzle (N), and an outer surface (23) of said solute tube (13) defining an inner surface of said annular nozzle (N),

characterized in that said outer surface (23) of said solute tube (13) has a uniform cylindrical surface (23) defining with said inner surface (25) of said insert (19) a uniform cylindrical nozzle discharge opening coaxial with said solute tube (13) so as to maximize the longitudinal velocity component of the working fluid as it emerges from said annular nozzle (N) into the discharge tube (15).

2. The eductor-mixer system as set forth in claim 1, **characterized by** further comprising a first cross-sectional area defined by a diameter (OD) of said outer cylindrical surface (23) of said solute tube (13), a second cross-sectional area of an annular region bound by said inner diameter (D3) of said discharge tube (15) and a diameter of said outer surface of said annular nozzle (N) at the discharge opening (21), said first cross-sectional area being approximately equal to said second cross-sectional area.

3. The eductor-mixer system as set forth in claim 1, **characterized in that** the length of said annular nozzle (N) is about 0.10 - 2.0 times the distance between the outer cylindrical surface of said solute tube (13) and the inner surface (25) of said insert (19) in the region defining said discharge opening (21) of said annular nozzle (N).

4. The eductor-mixer system as set forth in claim 1, **characterized in that** said discharge tube (15) has an inner cross sectional area 2-10 times the cross sectional area of said annular nozzle opening (21).

5. The eductor-mixer system as set forth in claim 1, **characterized in that** the length of said discharge tube (15) is about 10-40 times the inner diameter (D3) of said discharge tube (15).

6. The eductor-mixer system as set forth in claim 1,

characterized in that said annular nozzle (N) is configured such that the velocity of said working fluid emerging from said annular nozzle (N) ranges between about 30 feet/second and 300 feet/second.

7. The eductor-mixer system as set forth in claim 1, **characterized by** said inner surface (25) at the discharge opening (21) of the insert (19) being a cylindrical nozzle surface (25) surrounding said cylindrical outer surface (23) of said solute tube (13) and being spaced therefrom a distance which is small relative to the diameter of the cylindrical nozzle surface (25),
and an area defining said annular nozzle (N) between the cylindrical exterior surface (23) of the solute tube (13) and the cylindrical nozzle surface (25) of the insert (19) being relatively small and the length of said nozzle (N) being relatively short for rapid acceleration of the working fluid flowing through the nozzle (N) to a relatively high linear velocity.

8. The eductor-mixer system as set forth in claim 1, **characterized in that** said discharge tube (15) has a uniform internal diameter (D3) at a first end abutting the outside face of said insert (19) larger than the outer diameter of the discharge opening (21) of said annular nozzle (N), the internal surface of said discharge tube (15) lying outward of and wholly clear of a working fluid jet projected from the downstream face of the insert (19) throughout the length of said jet.

9. The eductor-mixer system as set forth in claim 1, **characterized in that** said insert (19) comprises a ring including a peripheral flange (43) engaging the end of said body (3) at the discharge end of said passage (9);
said discharge tube (15) comprises a discharge conduit having a length of uniform diameter, said discharge conduit abutting and retaining said ring in the discharge end of said passage (9); and
means (53) removably securing said discharge conduit to said body (3).

10. The eductor-mixer system as set forth in claim 1, **characterized in that** the cross sectional area of a discharge passage (17) of said discharge tube (15) is proportional to the cross sectional area of said annular nozzle (N), and the radial location of said annular nozzle (N) is dependent upon the outer diameter of the cylindrical exterior surface (23) of said solute tube (13).

11. The eductor-mixer system as set forth in claim 1, **characterized in that** the inner surface (25) of the insert (19) at the nozzle discharge opening (21) is in the form of a sharp knife edge having an extremely short axial length of e.g. a few thousands of an inch, or in the form of a cylindrical surface of a longer length, preferably approximately equal to the radial width of the nozzle discharge opening (21).

Patentansprüche

1. Eduktor-Mischersystem mit einem Eduktorkörper (3), der einen durch den Körper hindurchführenden Kanal (9) aufweist zur Strömung eines unter Druck stehenden Arbeitsfluids von einem Kanalende (5), das ein Einlassende (5) des Kanals (9) bildet, zu dem anderen Kanalende, das ein Auslassende des Kanals (9) bildet;

   einem ringförmigen Einsatzstück (19) in dem Kanal (9) angrenzend an das Auslassende;
   einem Rohrstück für Gelöstes (13) mit kleinerem Durchmesser als der Durchmesser des Kanals (9), wobei das Rohrstück für Gelöstes (13) sich von ausserhalb des Eduktorkörpers (3) in den Eduktorkörper (3) hineinerstreckt und ein inneres Ende des Rohrstückes für Gelöstes (13) im Wesentlichen koaxial mit Bezug auf das ringförmige Einsatzstück (19) ist und das innere Ende des Rohrstückes für Gelöstes (13) im Wesentlichen koplanar mit der stromabwärtigen Fläche des Einsatzstückes (19) ist; und
   einem Auslassrohr (15), das an dem Körper (3) stromabwärts des Einsatzstückes (19) befestigt ist;

   wobei das Rohrstück für Gelöstes (13) und das Einsatzstück (19) eine Ringdüse (N) begrenzen, und das Druckfluid beim Durchströmen der Ringdüse (N) eine wesentliche Geschwindigkeitszunahme erfährt, um einen Niedrigdruckbereich in dem Auslassrohr (15) stromabwärts der Ringdüse (N) zu bilden, wobei das Rohrstück für Gelöstes (13) zum Transport eines fliessfähigen Materials dient, das ein körniger, pulveriger oder anderer partikelartiger Feststoff, oder eine Flüssigkeit oder ein Gas sein kann, zum Vermischen mit dem unter Druck stehenden Arbeitsfluid stromabwärts der Düse (N);
   wobei eine Innenfläche (25) des Einsatzstückes (19) eine Aussenfläche der Ringdüse (N) bildet, und eine Aussenfläche (23) des Rohrstückes für Gelöstes (13) eine Innenfläche der Ringdüse (N) bildet,
   dadurch gekennzeichnet, dass die Aussenfläche (23) des Rohrstückes für Gelöstes (13) eine einheitliche zylindrische Fläche (23) aufweist, die mit der Innenfläche (25) des Einsatzstückes (19) eine einheitliche zylindrische Düsenauslassöffnung bildet koaxial mit dem Rohrstück für Gelöstes (13), um die longitudinale Geschwindigkeitskomponente des Arbeitsfluids beim Austritt aus der Ringdüse (N) in das Auslassrohr (15) zu maximieren.

2. Eduktor-Mischersystem nach Anspruch 1, **gekennzeichnet** desweiteren durch eine erste Querschnittsfläche, die durch einen Durchmesser (OD) der äusseren zylindrischen Fläche (23) des Rohrstückes für Gelöstes (13) begrenzt ist, und eine zweite Querschnittsfläche eines Ringbereiches, der durch den Innendurchmesser (D3) des Auslassrohres (15) und einen Durchmesser der Aussenfläche der Ringdüse (N) an der Auslassöffnung (21) begrenzt ist, und wobei die erste Querschnittsfläche etwa gleich der zweiten Querschnittsfläche ist.

3. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Länge der Ringdüse (N) etwa das 0,10-2,0-fache des Abstandes zwischen der äusseren zylindrische Fläche des Rohrstückes für Gelöstes (13) und der Innenfläche (25) des Einsatzstückes (19) in dem Bereich, der die Auslassöffnung (21) der Ringdüse (N) begrenzt, beträgt.

4. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** das Auslassrohr (15) eine innere Querschnittsfläche aufweist, die dem 2-10-fachen der Querschnittsfläche der ringförmigen Düsenöffnung (21) entspricht.

5. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Länge des Auslassrohres (15) etwa das 10-40-fache des inneren Durchmessers (D3) des Auslassrohres (15) beträgt.

6. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Ringdüse (N) so gestaltet ist damit die Geschwindigkeit des aus der Ringdüse (N) austretenden Arbeitsfluids zwischen etwa 30 Fuss/Sekunde und 300 Fuss/Sekunde liegt.

7. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Innenfläche (25) an der Auslassöffnung (21) des Einsatzstückes (19) eine zylindrische Düsenfläche (25) ist, die die zylindrische Aussenfläche (23) des Rohrstückes für Gelöstes (13) umgibt, und von dieser um ein Mass beabstandet ist, das klein ist im Vergleich zu dem Durchmesser der zylindrischen Düsenfläche (25),
und ein Bereich, der die Ringdüse (N) zwischen der zylindrischen Aussenfläche (23) des Rohrstückes für Gelöstes (13) und der zylindrischen Düsenfläche (25) des Einsatzstückes (19) bildet, ziemlich klein ist und die Länge der Düse (N) verhältnismässig kurz ist zur schnellen Beschleunigung des durch die Düse (N) strömenden Arbeitsfluids auf eine verhältnismässig hohe Lineargeschwindigkeit.

8. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** das Auslassrohr (15) einen gleichförmigen Innendurchmesser (D3) an einem ersten an der Aussenfläche des Einsatzstückes (19) anliegenden Ende aufweist, der grösser ist als der Aussendurchmesser der Auslassöffnung (21) der Ringdüse (N), wobei die Innenfläche des Auslassrohres (15) ausserhalb eines Arbeitsfluidstrahles liegt, welcher auf der stromabwärts liegenden Fläche des Einsatzstückes (19) austritt, und völlig frei von diesem Strahl entlang seiner gesamten Länge ist.

9. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** das Einsatzstück (19) einen Ring aufweist mit einem Umfangsflansch (43), der an dem Ende des Körpers (3) am Auslassende des Kanals (9) anliegt;
wobei das Auslassrohr (15) eine Auslassleitung aufweist mit einer Länge gleichförmigen Durchmessers, wobei die Auslassleitung am Ring anliegt und diesen in dem Auslassende des Kanals (9) zurückhält; und Mittel (53) zum lösbaren Befestigen der Auslassleitung an dem Körper (3).

10. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Querschnittsfläche eines Auslasskanals (17) des Auslassrohres (15) proportional ist zu der Querschnittsfläche der Ringdüse (N), und die radiale Lage der Ringdüse (N) abhängig ist vom Aussendurchmesser der zylindrischen Aussenfläche (23) des Rohrstückes für Gelöstes (13).

11. Eduktor-Mischersystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Innenfläche (25) des Einsatzstückes (19) an der Düsenauslassöffnung (21) die Form einer scharfen Schneidkante aufweist mit einer äusserst kurzen axialen Länge, von z.B. einigen Tausendstel Zoll, oder die Form einer zylindrischen Fläche hat mit grösserer Länge, vorzugsweise etwa entsprechend der radialen Weite der Düsenauslassöffnung (21).

Revendications

1. Système de mélangeur-éjecteur consistant en un corps d'éjecteur (3) avec un passage (9) s'étendant par le corps, pour le courant d'un fluide de travail pressurisé d'une extrémité (5) du passage (9), constituant une extrémité d'entrée (5), vers l'autre extrémité du passage (9), constituant une extrémité de décharge ;

   une pièce d'insertion annulaire (19) située dans ledit passage (9) à proximité de l'extrémité de décharge ;
   un tube de soluté (13) à plus petit diamètre que le diamètre dudit passage (9), ce tube de soluté (13) s'étendant de l'extérieur du corps d'éjecteur (3) dans le corps d'éjecteur (3), l'extrémité interne du tube de soluté (13) étant généralement

coaxiale par rapport à la pièce d'insertion annulaire (19) et cette extrémité interne du tube de soluté (13) étant située généralement dans le même plan que la face avale de la pièce d'insertion (19) ; et

un tube de décharge (15) connecté au corps (3) à l'aval de la pièce d'insertion (19) ;

le tube de soluté (13) et la pièce d'insertion (19) définissant une buse annulaire (N), le fluide pressurisé, en s'écoulant par cette buse annulaire (N) subissant une augmentation de vitesse substantielle en vue de former une zone de faible pression dans le tube de décharge (15) à l'aval de la buse annulaire (N), le tube de soluté (13) étant adapté en vue de transporter une matière à fluidiser qui peut être une matière granulaire, en poudre ou une autre matière particulaire solide, ou un liquide ou un gaz, par ce tube (13) en vue d'être mélangée avec le fluide de travail pressurisé à l'aval de la buse (N) ;

une surface interne (25) de ladite pièce d'insertion (19) définissant une surface externe de la buse annulaire (N), et une surface externe (23) du tube de soluté (13) définissant une surface interne de la buse annulaire (N) ;

caractérisé en ce que ladite surface externe (23) du tube de soluté (13) a une surface cylindrique uniforme (23) définissant avec ladite surface interne (25) de ladite pièce d'insertion (19) une ouverture de décharge cylindrique uniforme de ladite buse, coaxiale avec le tube de soluté (13) en vue de maximaliser la componente de vitesse longitudinale du fluide de travail lorsqu'il émerge de la buse annulaire (N) et entre dans le tube de décharge (15).

2. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce qu'**il comporte une première superficie en coupe transversale définie par un diamètre (OD) de la surface externe cylindrique (23) du tube de soluté (13), une seconde superficie en coupe transversale d'une région annulaire délimitée par ledit diamètre interne (D3) du tube de décharge (15) et un diamètre de ladite surface externe de la buse annulaire (N) à l'ouverture de décharge (21), cette première superficie en coupe transversale étant approximativement égale à la seconde superficie en coupe transversale.

3. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce** la longueur de la buse annuaire (N) est environ 0,10 - 2,0 fois la distance entre la surface externe cylindrique du tube de soluté (13) et la surface interne (25) de la pièce d'insertion (19) dans la région définissant l'ouverture de décharge (21) de la buse annulaire (N).

4. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** ledit tube de décharge (15) a une superficie interne en coupe transversale qui est 2-10 fois supérieure à la superficie en coupe transversale de l'ouverture (21) de la buse annulaire.

5. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** la longueur du tube de décharge (15) est environ 10-40 fois plus grande que le diamètre interne (D3) du tube de décharge (15).

6. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** la buse annulaire (N) est configurée de sorte que la vitesse du fluide de travail émergeant de la buse annulaire (N) soit située entre environ 30 pieds/seconde et 300 pieds/seconde.

7. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** la surface interne (25) de l'ouverture de décharge (21) de la pièce d'insertion (19) est une surface de buse cylindrique (25) entourant ladite surface cylindrique externe (23) du tube de soluté (13) et espacée de celle-ci d'une distance qui est faible par rapport au diamètre de la surface de buse cylindrique (23),

et une aire délimitant la buse annulaire (N) entre la surface cylindrique externe (23) du tube de soluté (13) et la surface de buse cylindrique (25) de la pièce d'insertion (19) est relativement faible et la longueur de la buse (N) est relativement courte pour accélération rapide du fluide de travail s'écoulant par la buse (N) à une vitesse linéaire relativement élevée.

8. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** ledit tube de décharge (15) a, en une première extrémité contactant la surface externe de la pièce d'insertion (19), un diamètre interne uniforme (D3) plus grand que le diamètre externe de l'ouverture de décharge (21) de la buse annulaire (N), la surface interne du tube de décharge (15) étant située à l'extérieur d'un jet de fluide de travail émergeant de la surface avale de la pièce d'insertion (19), cette surface interne du tube de décharge étant totalement écartée de ce jet le long sa longueur complète.

9. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** ladite pièce d'insertion (19) comporte un anneau ayant un bord périphérique (43) engageant l'extrémité dudit corps (3) à l'extrémité de décharge dudit passage (9) ;

ledit tube de décharge (15) comportant un conduit de décharge ayant une longueur à diamètre uniforme, le conduit de décharge contactant et retenant ledit anneau dans l'extrémité de décharge dudit passage (9) ; et

des moyens (53) pour attacher le conduit de décharge de façon amovible audit corps (3).

10. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** la superficie en coupe transversale d'un passage de décharge (17) dudit tube de décharge (15) est proportionnelle à la superficie en coupe transversale de la buse annulaire (N), et la position radiale de la buse annulaire (N) dépend du diamètre externe de la surface cylindrique externe (23) du tube de soluté (13).

11. Système de mélangeur-éjecteur selon la revendication 1, **caractérisé en ce que** la surface interne (25) de la pièce d'insertion (19) à l'ouverture de décharge (21) de la buse a la forme d'un tranchant pointu ayant une très courte longueur axiale de, par exemple, quelques millièmes d'un pouce, ou la forme d'une surface cylindrique d'une plus grande longueur, de préférence approximativement égale à la largeur radiale de l'ouverture de décharge (21) de la buse.

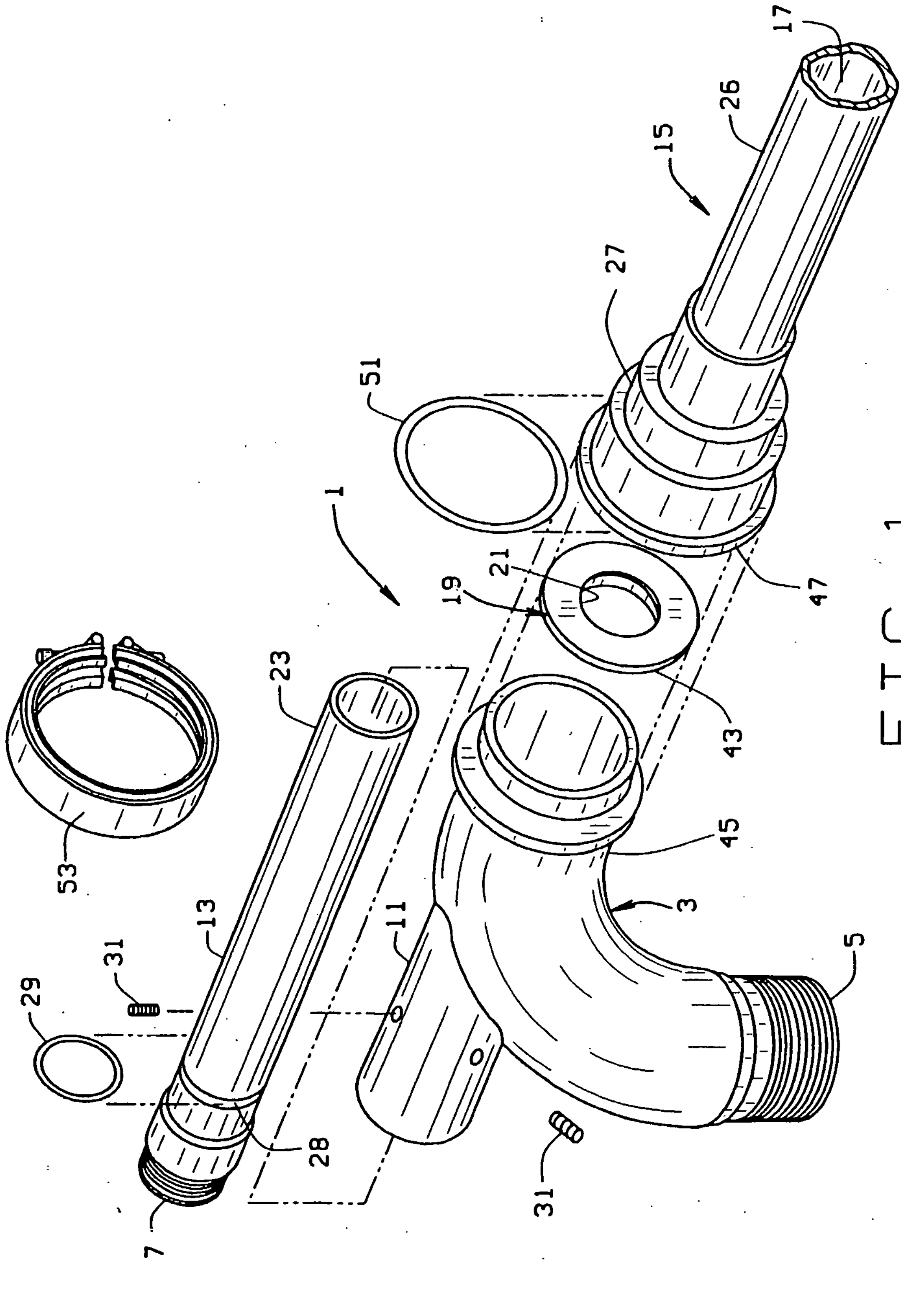


FIG. 1

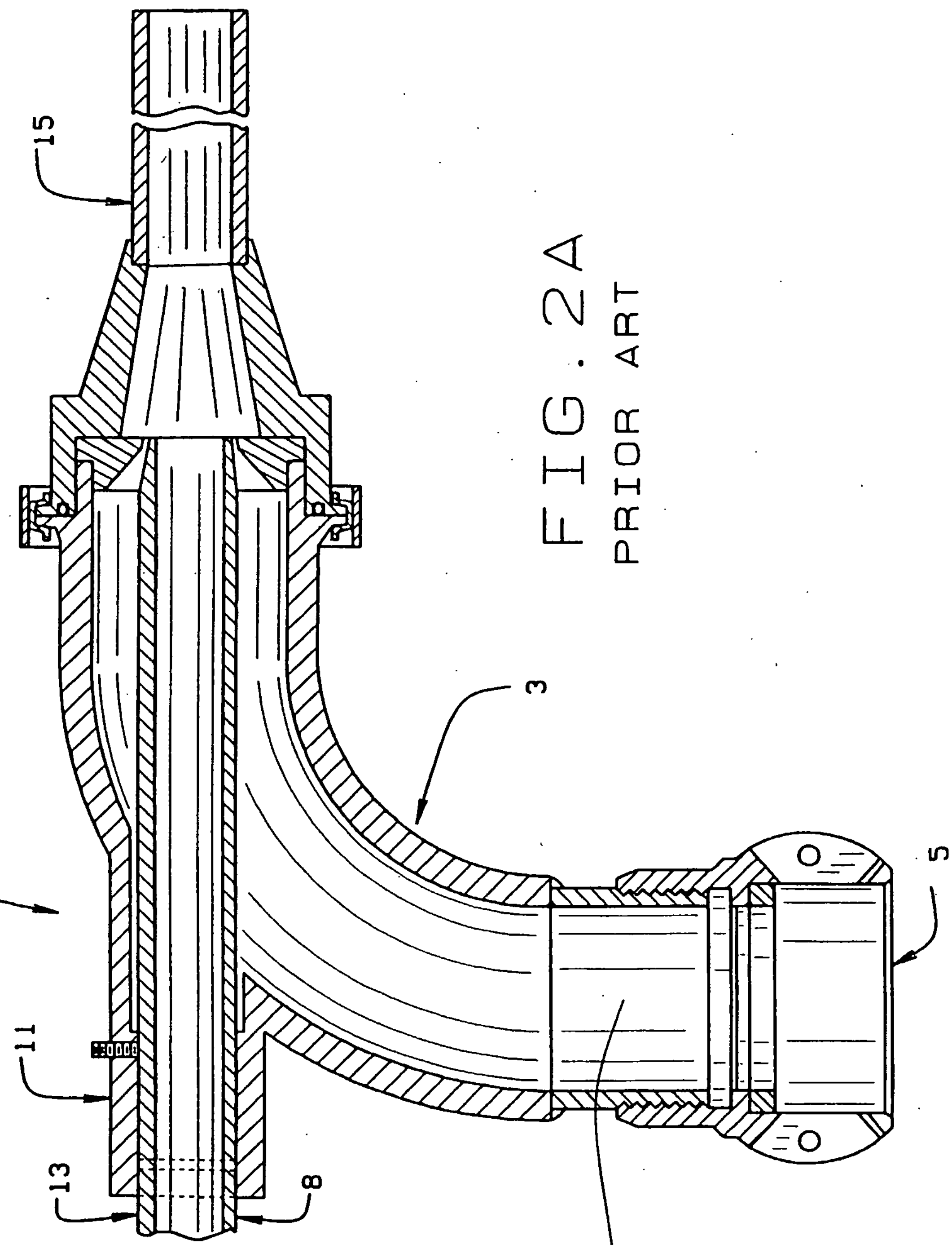


FIG. 2A
PRIOR ART

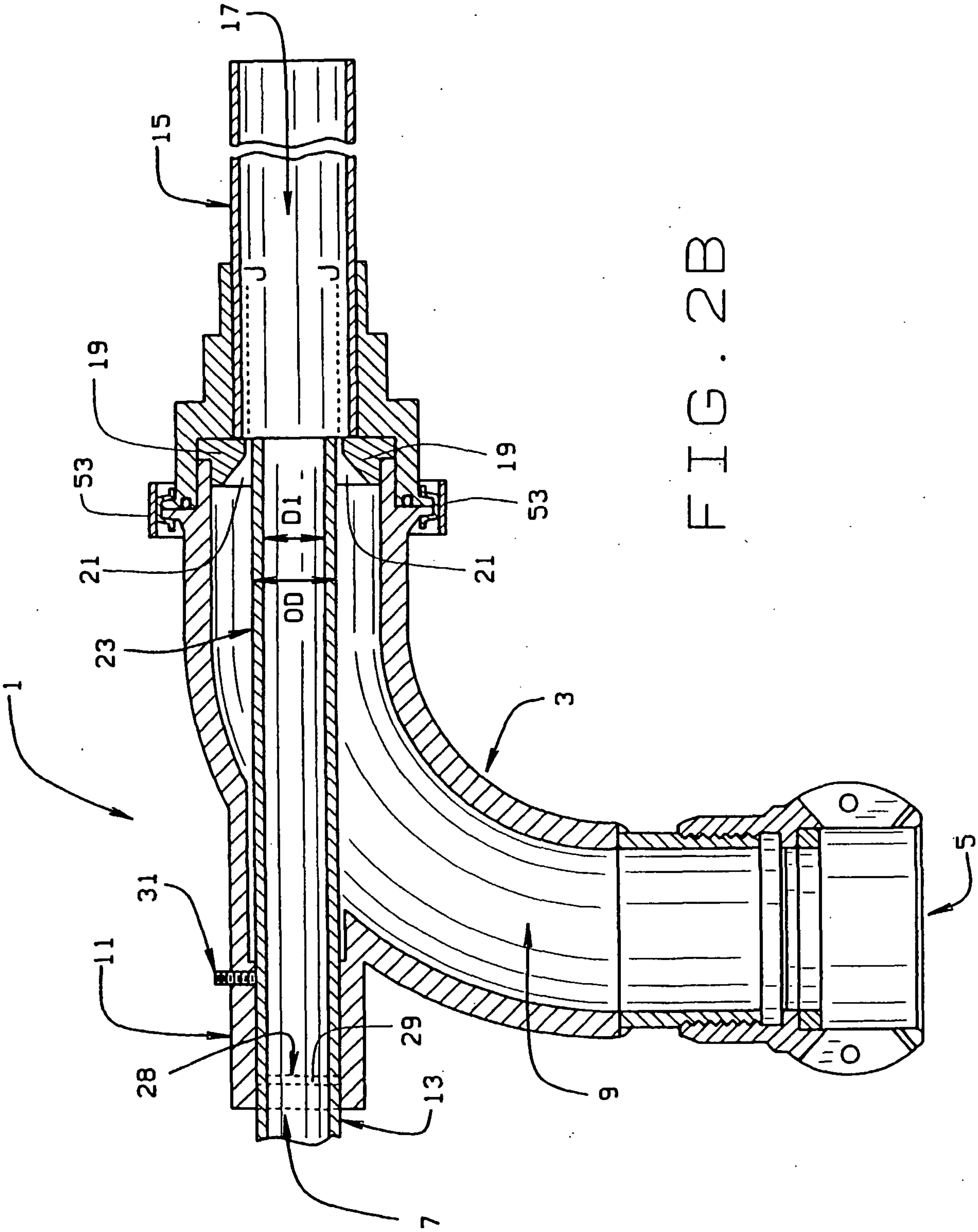
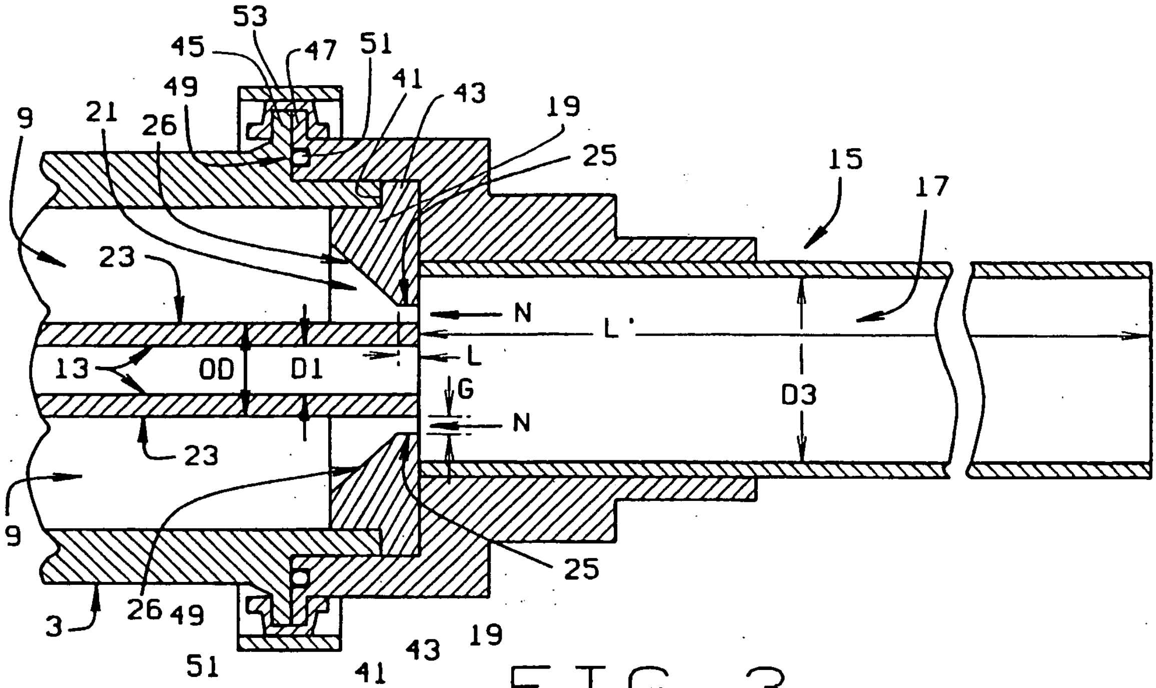


FIG. 2B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17
23
N
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OD
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G
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N
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19
51
41
43

FIG. 3

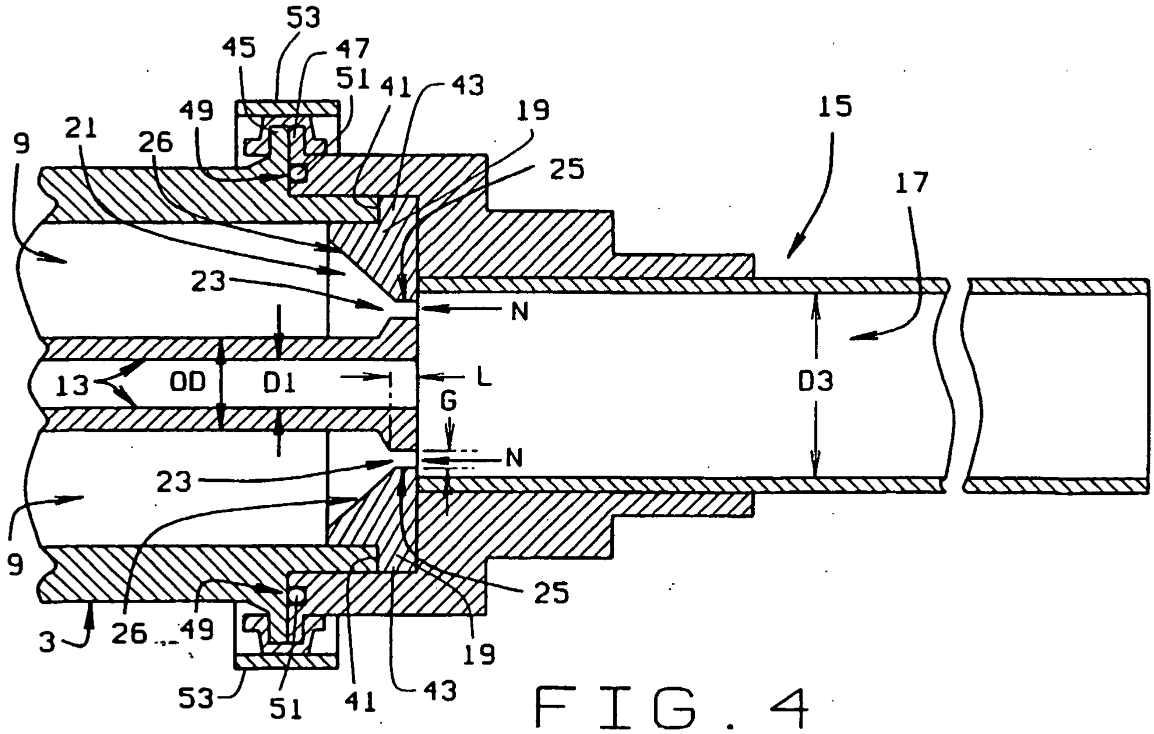
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FIG. 4

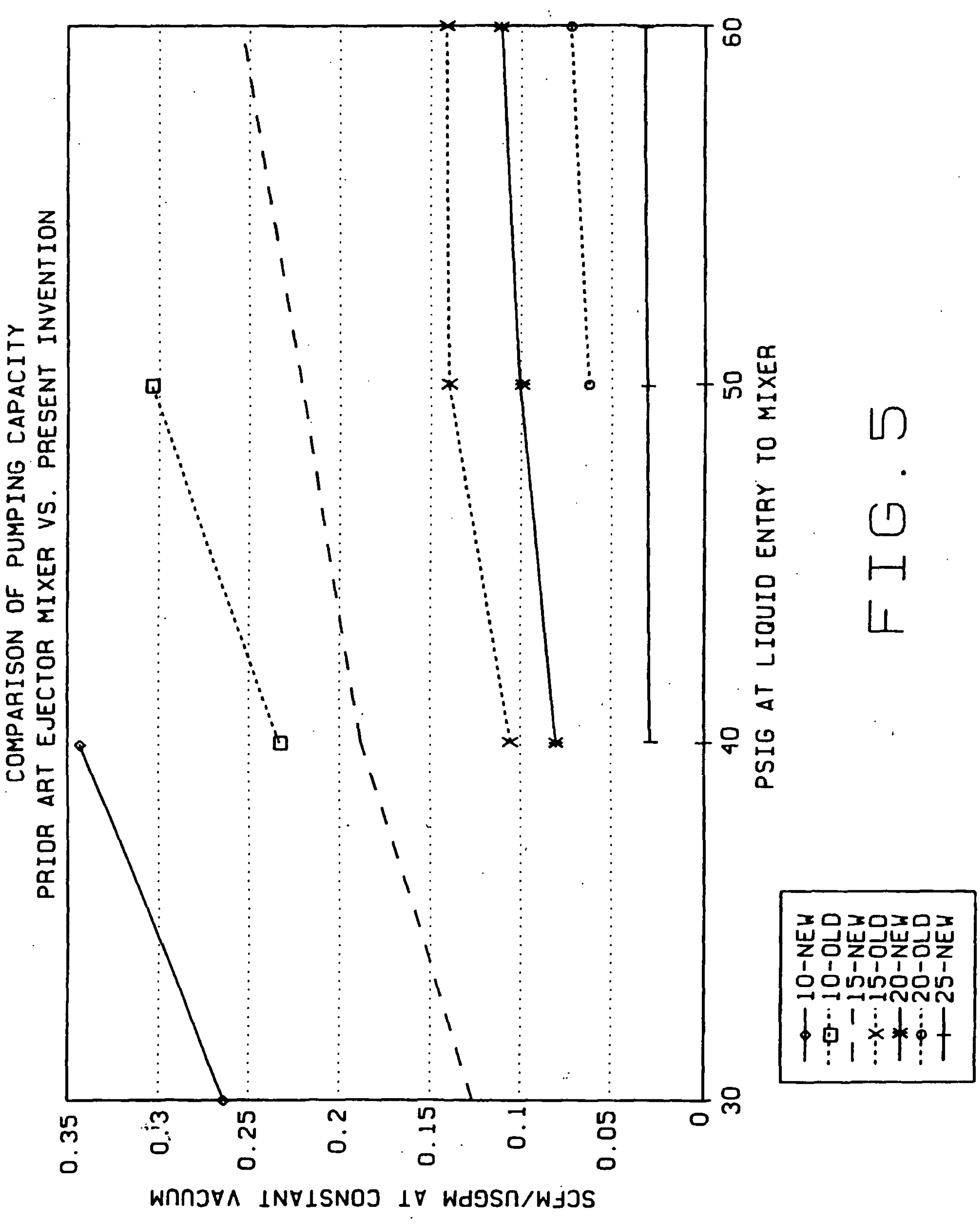
COMPARISON OF PUMPING CAPACITY
PRIOR ART EJECTOR MIXER VS. PRESENT INVENTION
SCFM/USGPM AT CONSTANT VACUUM
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
30
40
50
60
PSIG AT LIQUID ENTRY TO MIXER
10-NEW
10-OLD
15-NEW
15-OLD
20-NEW
20-OLD
25-NEW

FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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