Feb. 15, 1966 H. V. WILLIAMSON 3,234,962

FOAM PUMP SYSTEM

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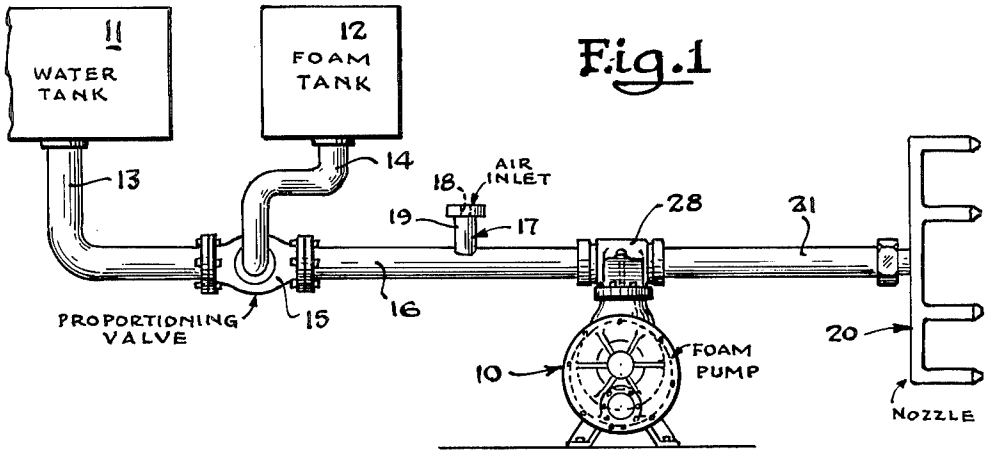


Fig.1

Fig.2

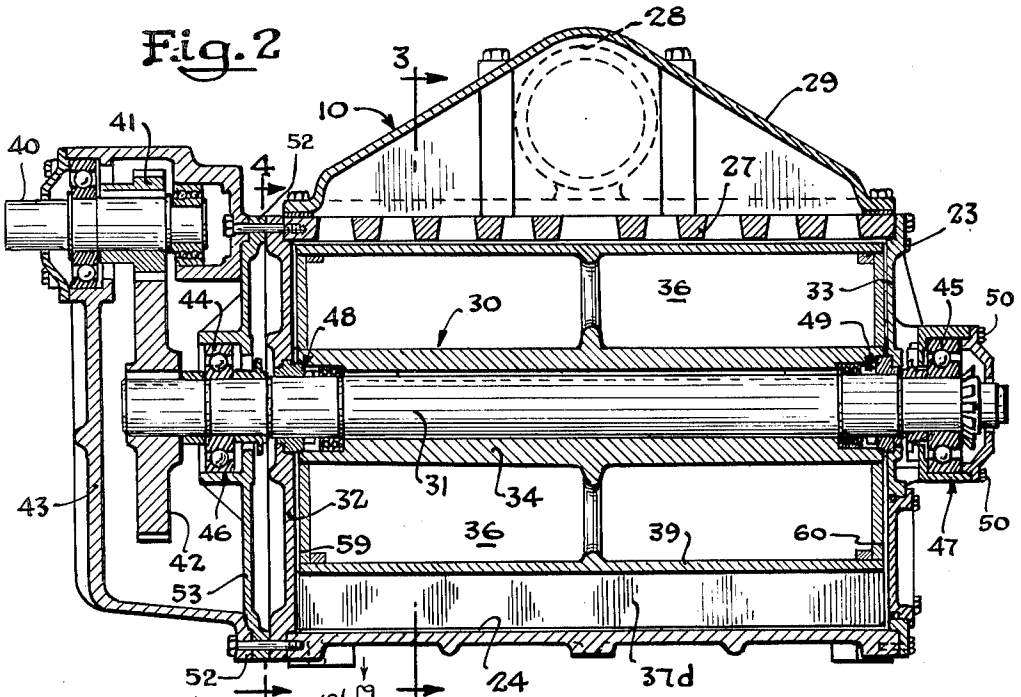


Fig.7

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Fig. 3

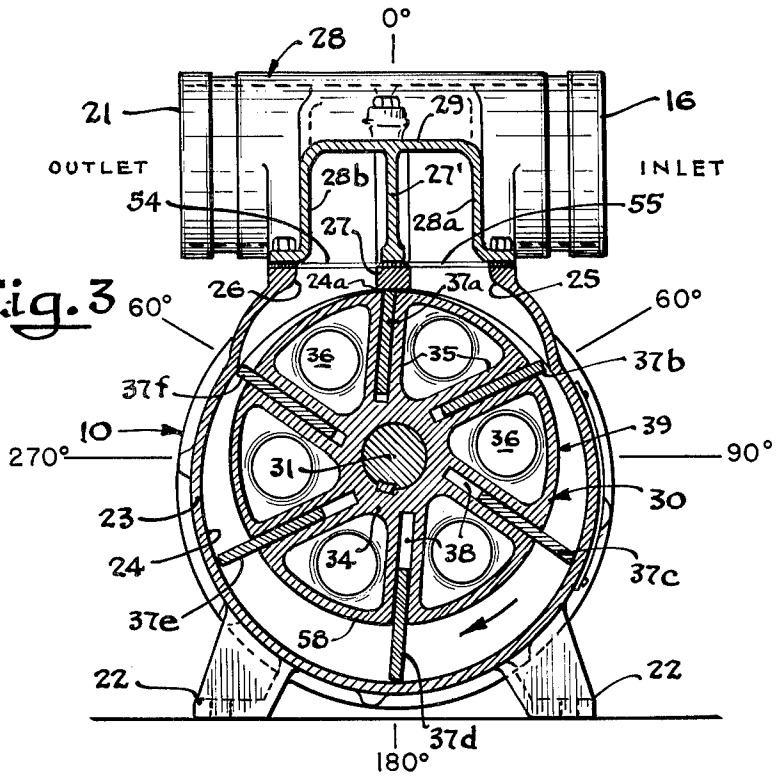
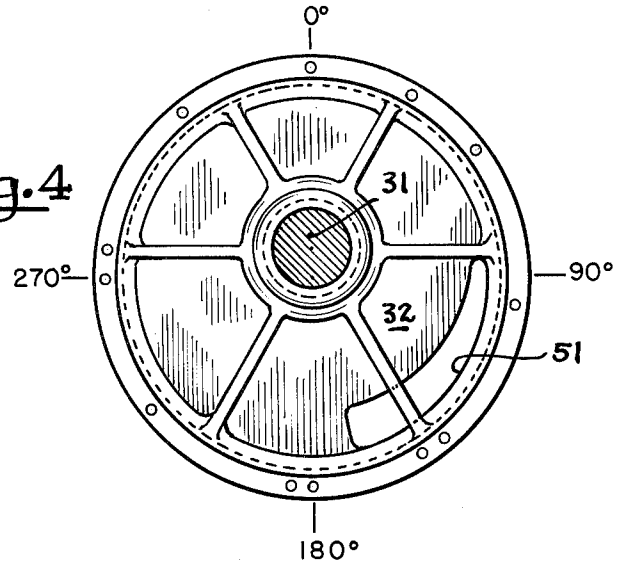


Fig. 4



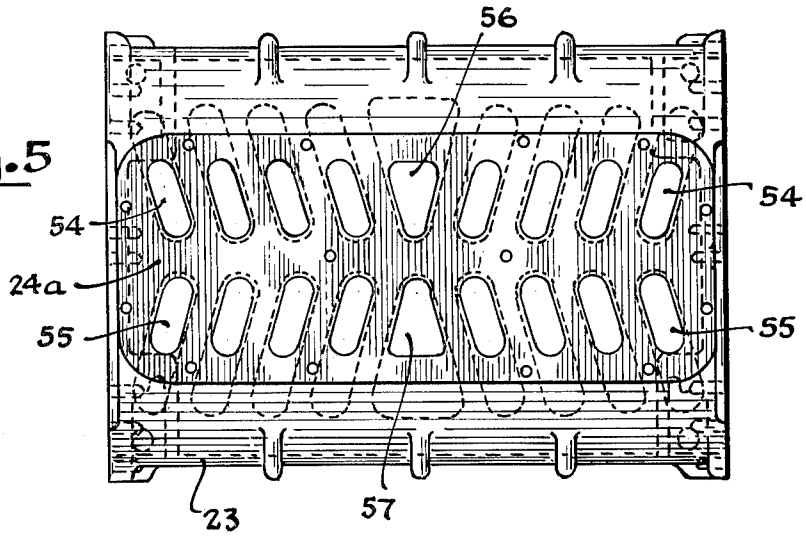
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Fig.5



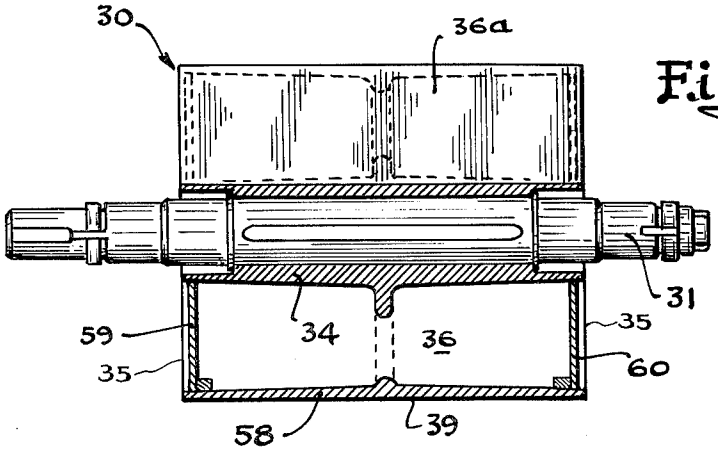


Fig.6

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FOAM PUMP SYSTEM

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Filed Aug. 27, 1962, Ser. No. 219,540
9 Claims. (Cl. 137—565)

This invention relates to a foam producing system for fire fighting purposes. More particularly, this invention is concerned with an improved vane type pump and a control means therefor for producing foam with large quantities of water for fighting fires.

The vane type pump as a foam producing mechanism is well known. It employs an eccentric rotor mounted in a housing into which water, air and a foam stabilizer are introduced. A homogenous mixture of these materials is formed between the rotating vanes which mix and also compress the previously mentioned ingredients. While under compression the homogenous mixture is moved to the outlet of the pump and thereby released under pressure into an adjoining pipe line wherein foam is formed by turbulence of the mixture in its passage to the discharge nozzles. The vane type pump works in a dual capacity as both a mixing and a pumping mechanism. Pumps of this type however, have many drawbacks in their operation. For example, in the pump described in U.S. 2,827,858 issued to Hesson, the operation of the pump has no influence on the rate of water flow into the pump. The rate instead is entirely dependent upon the pressure in the feed line. This severely limits the flexibility of installation, particularly on truck mounted units since this particular pump has to be mounted at a low level below the water supply tank to effect a gravitational flow of water to the pump. The rate of water flow to the pump will vary considerably between the full tank and empty tank operation since the flow rate is determined by the height of water in the tank.

Other shortcomings of vane type pumps presently used are their low theoretical compressing efficiency. This is necessitated by the fact that they must be capable of operating without damage even though they may be completely flooded with water. Such designs make it impossible to efficiently compress the air portion before discharging the volume trapped between the blades to the discharge outlet of the pump. When the leading blade reaches the discharge opening in the ordinary vane type pump, the pressure on the trailing blade is still near atmospheric pressure. Pressure from the discharge side thereupon flows back into the pump to create full pressure on the trailing blade when it is in the fully extended position. This increases the stress on the blade and also increases the power required to operate the pump. If the discharge port is moved so as to permit precompression, there will be danger of blade breakage if the volume between the two blades were completely filled with non-compressible liquid such as water.

Other undesirable features of vane type pumps and particularly those in the pump described in the previously referred to patent, included excessive air leakage into the intake portion of the pump due to open end rotor construction having hollow compartments to reduce weight and cost in manufacturing; single speed operation; and relatively complicated design due to the nature of the air inlet requirements.

It is therefore, an object of the present invention to provide an improved vane type pump system which will operate at a maximum efficiency.

It is another object of this invention to provide a vane type pump capable of drawing in its own water supply so that it can be mounted at any location on a truck without regard to the level of the water supply tank.

It is still another object of the present invention to provide a vane type pump system wherein the water flow to the pump is limited so that the liquid portion will not completely fill the volume trapped between the vanes, thus making it possible to precompress the air portion before discharge without danger of breaking the vanes.

Another object is to provide means for controlling the water flow so as to regulate the expansion ratio and also permit operation at different speeds and capacities.

Further objects of this invention are to provide a simplified design to reduce the cost of manufacture; to provide maximum capacity for a given size unit; and also a body housing for a vane type pump which is symmetrical so that the pump is capable of reverse rotation by merely reversing the direction of the rotor.

The foregoing objects and other objects of the present invention will be readily appreciated by reference to the following detailed description when considered in conjunction with the accompanying drawings showing an embodiment of the invention wherein:

FIGURE 1 is a diagrammatic view of the present foam pump system, showing the present foam pump operatively connected to a source of water and foam stabilizer at one side and leading to a bank of nozzles at the other side.

FIGURE 2 is a view in vertical section of the novel foam pump shown in FIGURE 1.

FIGURE 3 is a sectional view taken along line 3—3 of FIGURE 2 but showing the pump in a reversed position from that of FIGURE 1.

FIGURE 4 is an end view taken along line 4—4 of FIGURE 2.

FIGURE 5 is a top plan view of the pump housing with the manifold removed showing the inlet and discharge openings.

FIGURE 6 is a view in vertical section of the rotor assembly shown in FIGURE 3 with the vanes removed and illustrating the hollow compartments in the rotor.

FIGURE 7 is a schematic view showing the pump positioned above the liquid supply sources.

Briefly stated, the foam pump system of this invention is comprised of an improved foam pump and a control means therefor. The pump has a chambered housing which accommodates a vaned rotor positioned in an eccentric manner. An inlet and outlet pipe are connected to a unitary manifold leading to an inlet and an outlet passage which communicate with the interior of the housing. The passages are divided by a relatively small wall portion in the housing. As the rotor turns, liquid with foam stabilizer is drawn under vacuum from a suitable source. A regulated amount of air is admitted into the liquid to control the volume of liquid entering the inlet passage. The air is compressed with the liquid containing the stabilizer and released into the outlet passage. The rotor is positioned in the housing so that the vanes reach their maximum extension from the rotor when they are diametrically opposite the dividing portion of the adjacent passages. Additional air is admitted into the housing through an end plate into the increasing spaces

between adjacent rotor blades. The pump is designed so that the leading vane does not reach the outlet passage until substantial compression of the foam solution is effected and the trailing vane is partially retracted. A sealed hollow drum is employed to carry the vanes eccentrically around the pump housing.

Proceeding to a detailed description of the present invention, a foam pump **10** is shown in FIGURE 1 connected in a fluid tight manner to a water tank **11** and a foam tank **12** by means of pipes or conduits **13** and **14**, respectively, which lead to a valving device **15** for proportioning the desired amount of foam stabilizer and water to the intake side of pump **10** through pipe **16**. An air intake means **17** is disposed in pipe or conduit **16** having an orifice **18** of a predetermined size at the end of a relatively short stand pipe **19**. While any proportioning device creating a slight vacuum is suitable for operating in conjunction with pump **10**, that described in applicant's copending application Serial No. 163,841, filed January 2, 1962, is preferred. The output side of pump **10** is connected to a bank of nozzles **20** through pipe **21**.

Referring specifically to FIGURES 2 and 3 of the drawing it will be seen that pump **10** comprises a generally cylindrical, chambered housing **23** with a smooth annular inner surface **24**. It is supported by four legs **22** which are suitably secured to an appropriate surface. Disposed at the top of housing **23** and contiguous therewith are adjacent inlet and outlet passages **25** and **26**, respectively. A common wall **27** separates passages **25** and **26** and a partition **27'** divides manifold **28** into inlet and outlet portions **28***a* and **28***b* for communication with inlet and outlet pipes **16** and **21**, respectively. Manifold **28** is enclosed by a hood **29** as best seen in FIGURE 2. Eccentrically mounted in housing **23** is a rotor **30** keyed to a shaft **31** supported in end plates **32** and **33** mounted on housing **23**. Rotor **30** comprises a cylindrical drum **39** with a hub portion **34** and six equally spaced spokes **35** with hollow compartments **36** between the spokes. Six vanes **37***a–f* are carried by the six spokes **35** in slots **38** for reciprocal movement in and out of the rotor when it is rotated. Through centrifugal force exerted on vanes **37***a–f* their outer edges are maintained in slidable engagement with inner surface **24**. As shown specifically in FIGURE 3, rotor **30** is positioned in housing **23** so that vanes **37***a–f* reach their maximum extension when they are diametrically opposite common wall **27** of inlet and outlet passages **25** and **26**, respectively, as depicted by vane **37***d*.

Rotor **30** is driven by the rotation of shaft **40** having a pinion **41** keyed thereto which meshes with gear **42** secured on shaft **31**. Gear casing **43** encloses pinion **41** and gear **42**, as well as portions of shafts **31** and **40**. Two antifriction bearing units **44** and **45** are housed in hub portions **46** and **47**, respectively. Hub portion **46** is disposed in gear casing **43** while hub portion **47** is secured to end plate **33** by means of cap screws **50**. To prevent liquid from leaking around shaft **31** two sealing units **48** and **49** are provided on shaft **31** for contact with the associated surfaces of end plates **32** and **33**, respectively.

Referring specifically to FIGURE 4, a curved or substantially horned-shaped opening **51** is provided in end plate **32** so that air will be admitted between the vanes when they are in a portion of their maximum intake cycle. This is accomplished by having end plate **32** positioned on housing **23** as it appears in FIGURE 4, in circular alignment. As best shown in FIGURE 2, air enters the space between gear case plate **53** and end plate **32** through open spaces between the bolting bosses **52**. More will be said of the position of opening **51**, in the operation of the pump to follow.

In FIGURE 5 it will be seen that inlet and outlet passages **25** and **26**, respectively, communicate with the interior of housing **23** by means of slots **55** and **54**, respectively, which extend circumferentially through housing **23**. With the exception of the two central triangular slots

56 and **57**, the remaining slots are arranged in an opposing chevron-like pattern. This provides an angular engagement by vanes **37***a–f* with a consequent distribution of wear. Intermediary portion **24***a* divides inlet and outlet slots **55** and **54**, respectively, and has a relatively small arcuate distance with respect to the total inner surface **24**. This design allows a vane **37***a* to move from the outlet passage to the inlet passage without prolonged contact with surface **24***a*.

FIGURE 6 illustrates the hollow compartments **36** and **36***a* in hollow, metal drum **39** defined by hub **34** and the periphery **58** as well as adjacent spokes **35**. Sealing plates **59** and **60** close the ends of compartments **36** and **36***a*. It will be apparent that a substantially hollow metal rotor is lighter and consequently will not add appreciably to the weight of a fire fighting truck on which it is mounted. This is important to the unit as a whole since the pump must of necessity be made of heavy metal. Plates **59** and **60** serve to prevent air from entering the compartments during the compression cycle of the pump and later leaking out during the intake cycle to diminish the needed vacuum. The efficiency of the pump is thereby increased through the use of these plates and weight is kept to a minimum.

Operation

The advantages of novel pump **10** and its control means which comprises the novel foam pump system can best be understood with respect to its operation. It will be seen that when vane **37***a* is positioned, by means of rotor **30**, adjacent common wall **27** and between outlet slots **54** and inlet slots **55** that its outer edge is contiguous with the periphery of rotor **30**. This is best shown in FIGURE 3. As the rotor is driven in the direction of the arrow, and about an axis in parallel relationship to the axis of inner surface **24**, a vane as shown at **37***b* will begin to emerge from rotor **30** and simultaneously move across slots **55**. When a leading vane passes beyond inlet slots **55** a vacuum is created behind the vane since the volume between the leading vane and the adjacent following vane is constantly increasing. With pump **10** operatively connected to the proportioning valve **15**, this vacuum will be transmitted to valve **15** to cause it to open and thereby pull a proportioned solution of foam and water through pipe **16** and into inlet passage **25**. The volume between two adjacent vanes will continue to increase till they are equidistantly straddling a point 180° from common wall **27**. At this point the leading vane will have already begun to retract and the trailing vane will have almost reached its maximum extension. This in effect is the intake cycle of the pump. It will be noted that large volumes of air are introduced into the increasing spaces through opening **51** in end wall **32**, which terminates just short of the 180° mark. After a pair of vanes moves beyond the position of straddling the 180° point the leading vane will through its contact with inner surface **24** continue to retract into rotor **30** as shown by vane **37***e* thereby causing a decrease in the volume of the spaces and a consequent compression of the air and foam stabilizer. The compression cycle is thereby begun. This compression continues until a leading vane reaches the nearest oncoming portion of the outlet passage **26** whereupon the compressed solution will be ejected out through slots **54**.

By having both the intake and outlet adjacently disposed and with common wall **27** having a relatively small arcuate distance full advantage can be taken of the 360° rotation of the vanes. The amount of compression is of course determined by the number of vanes employed and the extent of the curvature of the inlet and outlet passages. In the present pump the arcuate distance of the inlet and outlet passages are approximately equal and extend approximately 60° from common wall **27**. Pump **10** can, under appropriate circumstances, thus be run in a clockwise or counter clockwise direction with no loss in

efficiency. With vanes 37*a–f* being angled in the normal direction of rotation it is preferred that rotor be turned end for end. However, it is not essential that the vanes be so angled, and if they are disposed at a strict tangent, a mere reversal of direction of rotor 30 is all that is required.

Adding to the efficiency of the present pump is the factor that precompression of the air and water mixture is effected prior to discharge. It can be demonstrated that it takes less energy to compress a given volume of air or other compressible gas than it does to pump a similar volume of water or other noncompressible fluid. A higher efficiency can only be obtained by precompressing the air portion before discharging to pump outlet 26. Without precompression vanes 37*a–f* are exposed to a maximum pressure when they are fully extended, thus requiring more torque for rotation. With precompression, the vane is not exposed to full discharge pressure until it has been partially retracted, thus the total torque for rotation is somewhat reduced. This is accomplished in the present design by having a vane partially retracted by the time the leading vane passes over the nearest oncoming portion of outlet passage 26.

An additional and important feature for maximum efficient operation of pump 10 are the control means for introducing water into inlet 25. As stated earlier proportioning valve 15 serves to create a vacuum or a pressure drop in inlet line 16 and preferably at about 3 to 4 p.s.i. By admitting air through intake means 17 in controllable amounts by means of orifice 18, the rate of water flow into the pump can be increased or decreased. The rate of water flow is related to the vacuum that can be created by the vanes during the intake cycle. If air is admitted by intake means 17, the vacuum thus created will be less and the rate of water flow will be lower. The proportioning unit is an essential part of this arrangement because it maintains the desired vacuum at the pump inlet even though the head of water in the supply tank may be somewhat above the pump inlet. Without the proportioning valve 15 the pressure at the pump inlet may be greater than atmospheric and therefore water would flow out of opening 18 rather than air flowing in to reduce the vacuum for the previously stated purpose. Opening 18 would consequently have no influence on the rate of water flow into the pump. The pressure drop of 3 to 4 p.s.i. created by the proportioning unit 15 is equal to a head of water of about six or eight feet. The same effect could thereby be accomplished if the pump were mounted six or eight feet above the water supply and the porportioning valve omitted. Any such means for creating a vacuum in inlet line 16 is what is required.

The present foam system operates with a high degree of efficiency when pipe lines 16 and 21 have a 5 inch diameter. This allows for pump 10 to operate effectively even up to a rate of 600 g.p.m. A ½" diameter for orifice 18 provides for a controlled rate of about 300 g.p.m. when the vacuum on the intake side of the pump is at 4–5 p.s.i.

It will be recognized that air inlet means 17 has a fixed orifice 18 for introducing air into inlet line 16 for controlling water flow. If desired, any other restriction such as a suitable valve could be employed instead to provide a variable orifice to effect immediate changes in the flow rate or to adjust for operational variances.

The foam pump 10 in the present system has been advantageously described for use with a control means which includes means to effect a pressure drop upstream of the pump in conjunction with air inlet 17. This control means can likewise be employed on any suitable positive displacement pump which is designed to pump liquids and to create a vacuum at its intake portion during the normal operation. For example, the flow rate through a gear or piston type pump can be regulated by the present control means without the need of varying the speed of the pump.

In the previous description of the pump control means, air has been introduced into the water through inlet 17. If desired, other gaseous fluids can be employed in place of air, or supplementary thereto, such as carbon dioxide, nitrogen, hydrogen, etc. Other obvious modifications of the present invention pertain to the introduction of air or gas into the water. If desired, the means to effect the pressure drop in the water can be eliminated and the rate of water flow through pump 10 can be controlled by introducting a gaseous material through inlet 17 at a pressure greater than that of the water in line 16.

Through the use of the previously described control means for pump 10 when employed with air inlet 51 the expansion ratio of foam produced can be regulated for various speeds and capacities of the pump. This is an important factor since the emergency at hand will dictate to the fire fighter the type to be used. For example, where foam is to be employed in spraying an airport runway for an emergency landing, a dry foam is desired having a high expansion ratio with a low water content since it will last much longer than a foam having the opposite characteristics. A wet foam with a high water content and a low ratio of expansion is employed to fight fires close at hand such as the ordinary gasoline fire. By controlling the amount of water entering pump 10 these desired foams can be effected irrespective of the speeds and capacities of a pump.

FIGURE 7 is a schematic view in which the reference characters correspond to those employed in FIGURE 1 with the addition of a prime symbol. A pump 10′ is shown to be disposed at a higher elevation than liquid supply sources contained in tanks 11′ and 12′. Pipes or conduits 13′ and 14′ lead from the respective tanks 11′ and 12′ to a proportioning valve 15′. A pipe or conduit 16′ connects the proportioning valve 15′ and an inlet passage of the pump 10′, and a pipe or conduit 21′ leads from an outlet passage of the pump 10′ to nozzles like those illustrated in FIGURE 1. A gaseous fluid such as atmospheric air is capable of being admitted into the pipe 16′ through a pipe 19′ having a valve 18′ which provides a variable orifice to effect immediate changes in the flow rate and adjustment for operational variances.

It will thus be apparent that through the present invention there is provided an improved foam pumping system which affords maximum efficiency for a vane type pump. The highest degree of compression is effected yet at the same time breakage of rotor vanes is virtually eliminated. Further, there is provided a vane type pump which is easy to manufacture because of the simple design; lighter in weight than previously known pumps of this type; and also capable of being operated with the same degree of maximum efficiency in a reverse manner. Additionally, it will be seen that the present invention affords a unique manner of controlling the flow rate through a positive displacement type pump which also assures that the proper amount of water and air are present in the pump for desired expansion ratios of foam. The flow rate of a pump can also be regulated without changing its speed and the pump can be located relative to a water supply tank without regard to the height of the supply tank or the level of the water therein.

One embodiment has been described in the specification for the practice of this invention. It will be understood that various modifications within the scope of the invention are possible and it is intended that such modifications and variations be included within the invention as described herein and defined by the appended claims wherein there is claimed:

1. A foam pump system comprising a pump including a housing, said housing defining an inner chamber having an annular inner surface with adjacent inlet and outlet passages opening into said chamber, said passages spaced apart by a dividing solid portion in said inner surface covering a relatively small arcuate distance, a liquid supply source in communication with said inlet

passage, means to create a pressure drop between said liquid supply source and said inner chamber of said housing, restricting means to admit a controlled amount of gaseous fluid between said liquid supply source and said inner chamber for controlling the amount of liquid drawn into said pump, said pump including a rotor mounted in said housing for rotation about an axis in parallel relationship with the axis of said inner surface and presenting an eccentric surface with respect to said inner surface, a plurality of vanes carried for rotation with said rotor and reciprocating movement relative to said rotor to maintain the outer edges of the vanes in sliding engagement with said inner surface, means for admitting air freely into said inner chamber to fill the expanding spaces between adjacent vanes, said rotor positioned in said housing so that two of said adjacent vanes form a space of maximum volume when they straddle a point 180° opposite said dividing portion of said inlet and outlet passages, said vanes positioned in said rotor to substantially decrease the space defined by adjacent vanes, said rotor and said inner surface of said housing before the leading vane reaches said outlet passage.

2. A foam pump system comprising a pump having a housing, said housing defining an inner chamber having an annular inner surface with adjacent inlet and outlet passages opening into said chamber, said passages spaced apart by a dividing solid portion in said inner surface covering a relatively small arcuate distance, at least one liquid supply source, a liquid supply line interconnecting said supply source and said inlet passage, a proportioning device designed to create a relatively small pressure drop between said liquid supply source and said inlet passage, restricting means to admit controlled amount of gaseous fluid into said liquid supply line for controlling the amount of liquid drawn into said pump, said pump including a rotor mounted in said housing for rotation about an axis in parallel relationship with the axis of said inner surface and presenting an eccentric surface with respect to said inner surface, a plurality of vanes carried for rotation with said rotor and reciprocating movement relative to said rotor to maintain the outer edges of the vanes in sliding engagement with said inner surface, means for admitting air freely into said inner chamber to fill the expanding spaces between adjacent vanes, said rotor positioned in said housing so that two of said adjacent vanes form a space of maximum volume when they straddle a point 180° opposite said dividing portion of said inlet and outlet passages, said vanes positioned in said rotor to substantially decrease the space defined by adjacent vanes, said rotor and said inner surface of said housing before the leading vane reaches said outlet passage.

3. A foam pump system as defined in claim 2 wherein said restricting means includes an air inlet comprising a relatively short stand pipe in communication with said liquid supply line between said proportioning device and said pump.

4. In a foam pump system: a pump including a housing defining a chamber, said housing having an inlet passage and an outlet passage in communication with said chamber, conduit means for conducting a liquid mixture of water and foam stabilizer to said inlet passage of said pump, said pump having means disposed in said chamber for creating a vacuum to draw the fluid mixture from said conduit means, through said inlet passage and into said chamber and for discharging the liquid mixture from said chamber through said outlet passage under pressure, means for enabling a gaseous fluid to be freely admitted into said chamber between said inlet and outlet passages, and restricting means to admit a controlled amount of a gaseous fluid into said conduit means for controlling the amount of liquid mixture drawn into said pump.

5. In a foam pump system: a pump including a housing defining a chamber, said housing having an inlet passage and an outlet passage in communication with said chamber, conduit means for conducting a liquid mixture of water and foam stabilizer to said inlet passage of said pump, said pump having means in said chamber for drawing the fluid mixture from said conduit means, through said inlet passage and into said chamber by vacuum and for discharging the liquid mixture from said chamber through said outlet passage under pressure, means for enabling a gaseous fluid to be freely admitted into said chamber between said inlet and outlet passages, and restricting means to admit a controlled amount of a gaseous fluid into said conduit means for controlling the amount of liquid mixture drawn into said pump, said restricting means including a valve.

6. In a foam pump system: a pump including a housing defining a chamber, said housing having an inlet passage and an outlet passage in communication with said chamber, an eccentrically mounted rotor in said chamber, a plurality of vanes carried by said rotor, and means for enabling the admission of a gaseous fluid into said chamber between said inlet and outlet passages, means for proportioning two liquids, conduit means leading from two liquid supply sources to said proportioning means and from said proportioning means to said inlet passage of said pump, and restricting means to admit a controlled amount of a gaseous fluid into said conduit means for controlling the amount of proportioned liquids drawn into said pump.

7. In a foam pump system: a pump including a housing defining a chamber, said housing having an inlet passage and an outlet passage in communication with said chamber, an eccentrically mounted rotor in said chamber, a plurality of vanes carried by said rotor, and means for enabling the free admission of a gaseous fluid into said chamber between the inlet and outlet passages, means for proportioning two liquids, a tank adapted to contain an aqueous liquid, a tank adapted to contain foam stabilizer, conduit means in communication with liquids in said tanks below the level of said pump and connected to said proportioning means, conduit means connecting said proportioning means to said inlet passage of said pump, and restricting means, to admit a controlled amount of gaseous fluid into said conduit means for controlling the amount of proportioned liquids drawn into said pump.

8. A method of making foam in a foam making system having a water supply source, a source of foam stabilizer, a pump designed to create a vacuum at its intake portion and a device for proportioning the water and the foam stabilizer to the pump, the proportioning device effecting a pressure drop on the water which passes therethrough, said method comprising the steps of: proportioning water and liquid foam stabilizer while effecting a pressure drop on the resulting proportioned water and foam stabilizer mixture entering the pump and simultaneously controlling the quantity of proportioned liquid mixture drawn into the pump by admitting a restricted amount of gaseous fluid into the liquid mixture between the proportioning device and the pump, and admitting air freely directly into the proportioned liquid mixture in the pump.

9. A foam pump system comprising a pump including a housing, said housing defining an inner chamber having an annular inner surface with adjacent inlet and outlet passages opening into said chamber, said passages spaced apart by a dividing solid portion in said inner surface covering a relatively small arcuate distance, a liquid supply source in communication with said inlet passage, means to create a pressure drop between said liquid supply source and said inner chamber of said housing, restricting means to admit a controlled amount of gaseous fluid between said liquid supply source and said inner chamber for controlling the amount of liquid drawn into said pump, said pump including a rotor mounted in said housing for rotation about an axis in

parallel relationship with the axis of said inner surface and presenting an eccentric surface with respect to said inner surface, a plurality of vanes carried for rotation with said rotor and reciprocating movement relative to said rotor to maintain the outer edges of the vanes in sliding engagement with said inner surface, means for admitting air freely into said inner chamber to fill the expanding space between adjacent vanes, said rotor positioned in said housing so that two of said adjacent vanes form a space of maximum volume when they straddle a point 180° opposite said dividing portion of said inlet and outlet passages, said vanes positioned in said rotor to substantially decrease the space defined by adjacent vanes, said rotor and said inner surface of said housing before the leading vane reaches said outlet passage, wherein said pressure drop is created by positioning said pump above said liquid supply source.

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