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Scott et al.

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[54] **APPARATUS AND METHOD FOR GENERATING FOAM FROM PRESSURIZED LIQUID**

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[21] Appl. No.: **458,260**

[22] Filed: **Jun. 2, 1995**

Related U.S. Application Data

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[51] **Int. Cl.**[6] **B01F 15/02**; B01F 13/02

[52] **U.S. Cl.** **366/163.2**; 169/44; 366/101

[58] **Field of Search** 366/163.1, 163.2, 366/101, 106, 107; 169/44, 15; 137/889, 890, 599.1

[56] **References Cited**

U.S. PATENT DOCUMENTS

615,213	11/1898	Deming .	
644,237	12/1900	Deming .	
862,867	8/1907	Eggleston .	
2,513,417	2/1946	Lindsay	261/116
3,234,962	2/1966	Williamson	137/565
3,701,482	10/1972	Sachnik	239/590.3
3,856,270	12/1974	Hemker	259/4
4,123,800	10/1978	Mazzei	366/163.2
4,147,478	4/1979	Vork	417/458
4,361,407	11/1982	Pellegrini	366/340
4,478,516	10/1984	Kessler	366/87
4,645,009	2/1987	Hawelka et al.	169/15
4,688,643	8/1987	Carter et al.	169/33
4,781,467	11/1988	Williams	366/163.1
4,805,700	2/1989	Hoover	169/15
4,830,790	5/1989	Stevenson	261/18.1
4,964,733	10/1990	Fredriksson et al.	366/336
4,993,495	2/1991	Burchert	169/14
5,082,633	1/1992	Stuper	422/133
5,137,094	8/1992	Broussard	169/15
5,171,090	12/1992	Wiemers	366/163.2
5,388,905	2/1995	Ake	366/163.2

FOREIGN PATENT DOCUMENTS

1266073 of 0000 Canada .

OTHER PUBLICATIONS

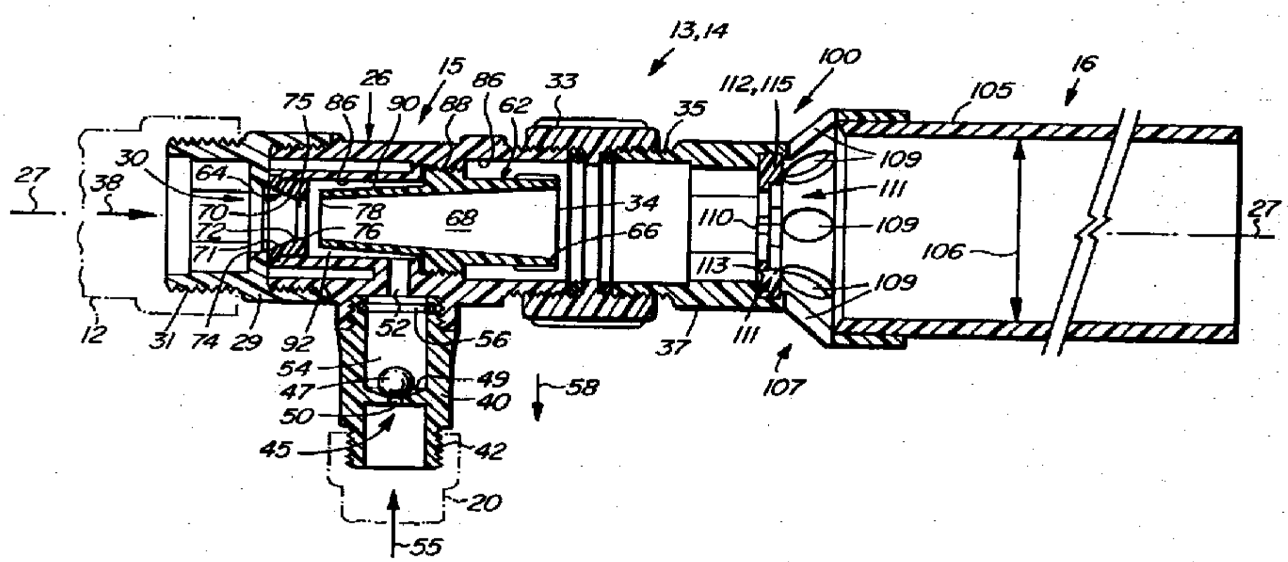
Maverick Foam Vest System Brochure Date of publication unknown.

Primary Examiner—Robert W. Jenkins
Attorney, Agent, or Firm—Bull, Housser & Tupper

[57] **ABSTRACT**

A foam generating apparatus can be attached to a water bearing hose and comprises an eductor nozzle to receive water and foam concentrate, and a foam generating nozzle to discharge a foam/water mixture therethrough. A foam concentrate conduit delivers concentrate to a manifold extending peripherally around a suction port of the eductor nozzle, and foam concentrate is drawn into the eductor nozzle to mix with water and to be discharged as a foam/ water mixture to the foam generating nozzle. The nozzle has an agitator jet orifice for agitating the mixture, and an air entrainment opening to admit air into the agitated mixture. The agitator jet orifice has inlet and outlet jet openings interconnected in series, the outlet jet opening being larger than the inlet jet opening to provide a diverging passage with at least one step between the inlet and outlet jet openings to agitate the flow. The step has an abrupt step edge to enhance agitation and is relatively long when compared with cross-sectional area of the inlet jet opening. The inlet jet and outlet jet openings are non-circular, and preferably elongated slits to provide a long length of step.

19 Claims, 3 Drawing Sheets



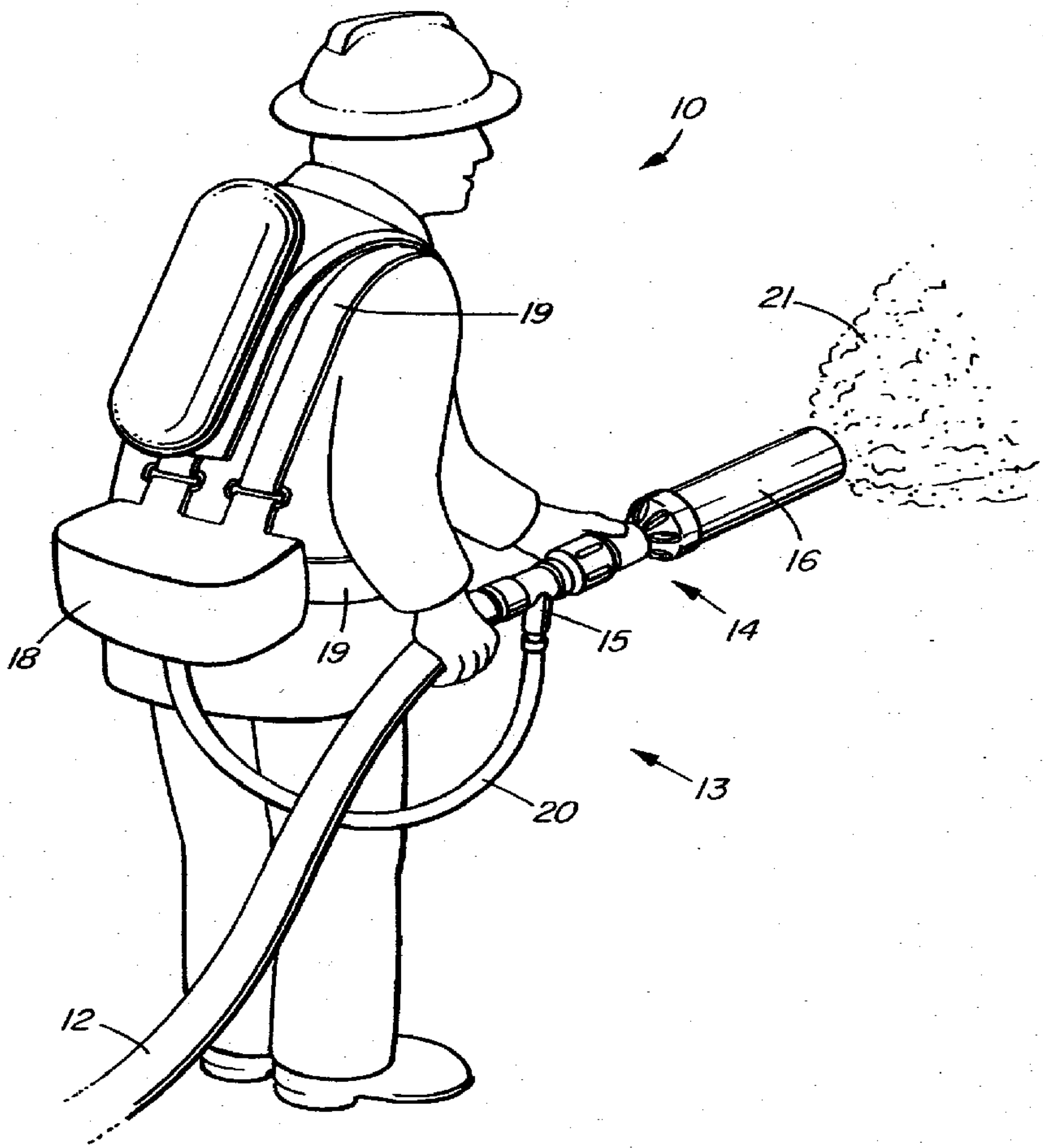


FIG. 1

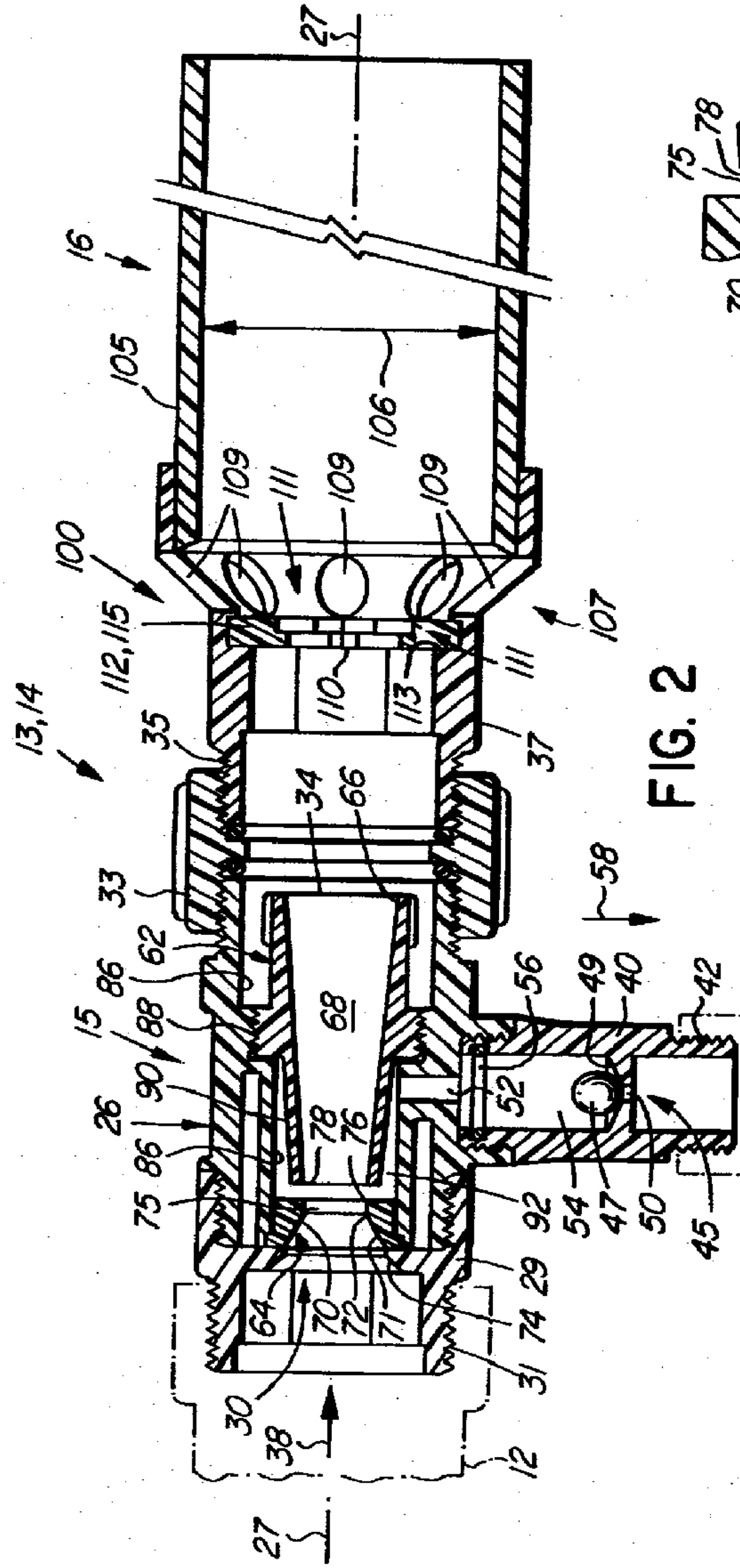

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FIG. 2

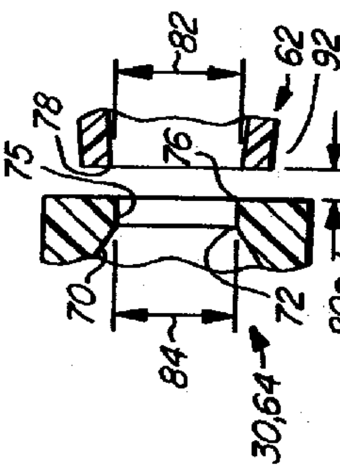
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FIG. 2A

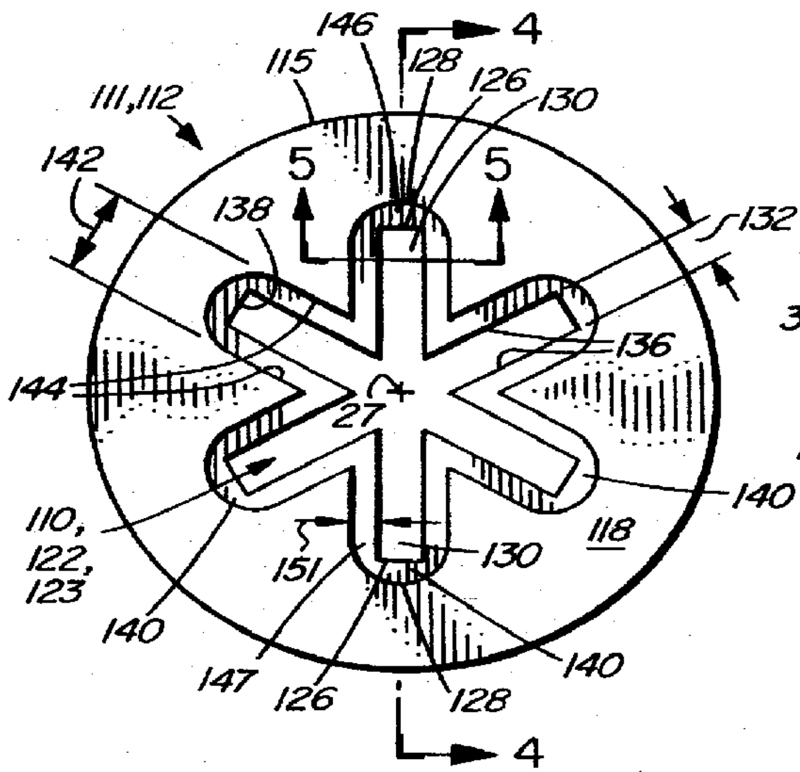

FIG. 3

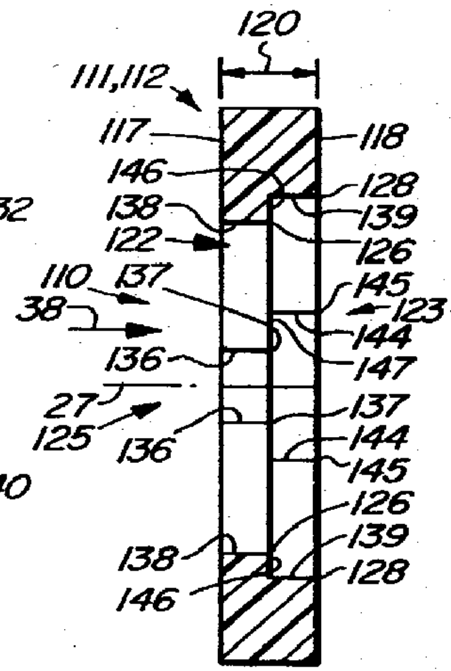

FIG. 4

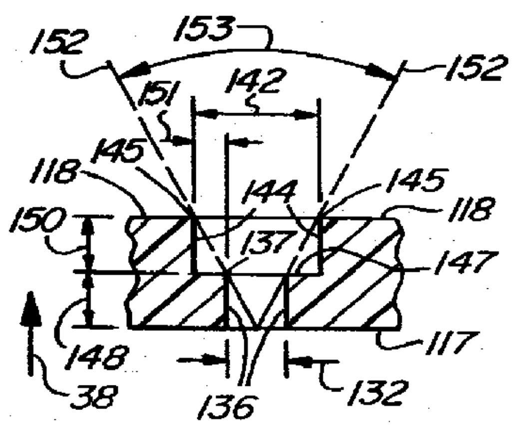

FIG. 5

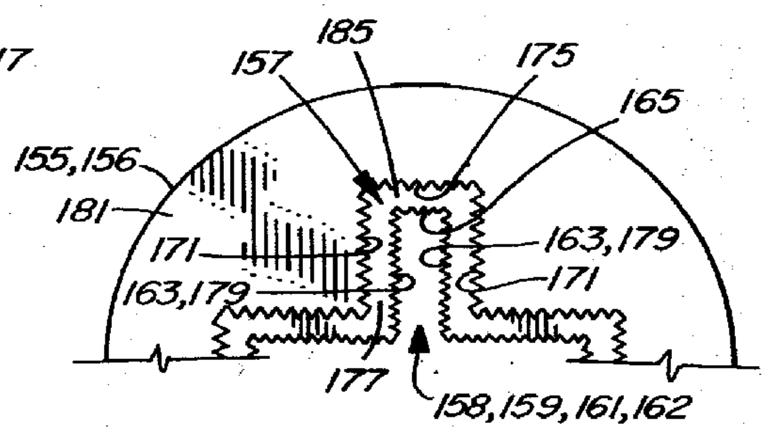

FIG. 6

APPARATUS AND METHOD FOR GENERATING FOAM FROM PRESSURIZED LIQUID

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a divisional application of application Ser. No. 08/055,882, filed 4 May 1993 and entitled FOAM GENERATING APPARATUS FOR ATTACHMENT TO HOSE DELIVERING PRESSURIZED LIQUID, now U.S. Pat. No. 5,445,226.

BACKGROUND OF THE INVENTION

The invention relates to an apparatus which can be attached to a pressurized water bearing hose to generate foam, in particular to an apparatus for attachment to a fire fighting hose to generate fire fighting foam from a supply of pressurized water as used in fire fighting.

While water is used for many fire fighting applications, when the water is mixed with a small amount of foam concentrate or foaming agent and passed through a suitable foaming nozzle, a large volume of foam can be generated. For many common fire fighting applications e.g. Class A fires involving wood, paper etc., foam is considerably more effective than water by itself. Also for special fire fighting situations e.g. Class B fires involving liquid fuels, combustible solvents etc., water by itself cannot be used, and thus foam, dry powder or gaseous extinguishers must be used. Foam is usually necessary for large Class B fires, as the other methods are too costly or not practical.

Foam can be applied on a fire from two sources, namely from a pressurized canister source, or by adding foam concentrate to a stream of water under pressure. The first source of foam applying equipment is limited for use on small fires only, due to its small capacity which is usually limited to the size of canister that can be easily handled by one person. The second source of foam applying equipment is commonly mounted on a fire truck to facilitate transport to a site. The second source of foam applying equipment is described herein and comprises a foam concentrate metering and mixing device for adding to pressurized water from a hydrant or to another pressurized water source. The mixture of pressurized water and foam concentrate must be passed through a suitable nozzle to generate foam, the nozzle also providing a means of mixing air with the water and foam mixture so as to generate a suitable continuous supply of foam. Where water is not pressurized, a water pressurizing device such as a pump is used to raise water pressure, often concurrently with adding a metered amount of foam concentrate to the water stream. The foam concentrate can be introduced to the water stream at the truck itself, in which case the foam concentrate is simultaneously mixed and fed along the hose, and is then discharged at the source of fire. If the foam concentrate is fed along a sufficient length of hose, there is usually no difficulty in mixing the concentrate with the water, so that when the foam water mixture passes through the foaming attachment on the nozzle, a good supply of foam is generated.

One disadvantage with introducing the foam to the hose pipe at the truck is that the hose pipe is then somewhat limited to delivering only foam, and cannot be quickly easily changed to delivering water, at least not by the person directing the hose. Relatively complex machines that resemble the first type of foam generating devices are shown in U.S. Pat. Nos. 4,645,009 (Hawelka et al.) and 3,234,962 (Williamson). Such machines can be relatively costly and this detracts from their use.

Alternatively, the foam concentrate can be fed in a separate concentrate hose extending along the main water hose to an eductor nozzle located at a position in the hose, suitably some distance from the discharge nozzle to permit adequate mixing of the foam concentrate with the water prior to discharge. This method has a disadvantage of having two parallel lengths of hoses for at least a short length of the water hose, with a separate control on the foam concentrate hose to control supply of the foam concentrate. A simple means of metering foam concentrate into a water stream is shown in U. S. Pat. No. 4,993,495 (Burchert) in which water passes through a venturi means and generates suction to draw foam concentrate into the water flow. With this alternative device, there must be sufficient length of hose downstream from the venturi means to provide adequate mixing of the concentrate and foam before the mixtures passes through a nozzle to generate foam. A nozzle to generate foam from a water and foam concentrate mixture is shown in Canadian Patent 1,266,073 (Stevenson). Such a nozzle requires to be supplied with a mixture of water and foam and thus requires at least a foam concentrate metering and mixing structure upstream of the nozzle which structure is usually provided at the fire tank or in the length of the water hose.

An apparatus which combines metering and mixing of foam concentrate essentially integral with a foaming nozzle is shown in U.S. Pat. No. 2,513,417 (Lindsay). This patent shows an eductor nozzle structure for drawing foam concentrate into a stream of water prior to ejecting the resulting mixture through a foaming nozzle which draws in air to generate foam. This is a relatively complex mixing nozzle with an annular gap located downstream of a converging section for drawing foam concentrate into the water, followed by a constant cross-section portion with a conical spreader which separates the stream of mixture in an air entrainment chamber. A further teardrop-shaped baffle is required to control velocity of the fluid to achieve a more uniform foam quality.

SUMMARY OF THE INVENTION

The invention reduces the difficulties and disadvantages of the prior art by providing a relatively simple foaming apparatus which can be easily attached to an end of a water bearing hose. The apparatus permits an accurately metered supply of foam concentrate to be added to water flowing through the hose, and immediately thereafter to be generated into foam within a length of discharge nozzle which is sufficiently short to be easily handled by a single operator. In this way, an operator can easily manoeuvre the foam generating nozzle, e.g. as a fire fighting nozzle, when in confined spaces, and has easy access to initiate or stop the supply of concentrate. If the foaming apparatus is not required, it can be easily removed from the hose. Preferably, the supply of foam concentrate for this apparatus can be carried in a container which can be carried on the back of the person holding the nozzle, preferably adjacent the hips so that the person's back is free of obstruction to permit the person to carry a breathing apparatus if required. In addition, the invention is light-weight, easy to adjust for different capacities and has a relatively low production cost and thus contrasts with some of the prior art apparatus which are costly investments.

One example of a foaming apparatus according to the invention disclosed herein is for attachment to a water bearing hose and comprises an eductor nozzle, delivery manifold means and a foam concentrate conduit. While a specific structure is shown for the eductor nozzle, other eductor nozzles can be substituted to admit foam concentrate into a flow of pressurized water to produce a foam/water mixture. In addition, foam can be admitted into a flow of pressurized water in a conventional fire fighting apparatus, and agitation of the mixture can take place downstream therefrom at an air entrainment nozzle provided with an agitator apparatus according to the invention.

The agitator apparatus according to the invention generates foam from a flow of pressurized water and foam concentrate, and has an agitator body which comprises an agitator jet orifice and a first step means. The agitator jet orifice comprises an inlet jet opening and an outlet jet opening disposed in series, and the first step means is located between the inlet and outlet jet openings. The outlet jet opening is larger than the inlet jet opening and communicates with the inlet jet opening to define a diverging passage extending through the agitator body. Flow through the agitator jet orifice passes across the first step means to agitate the flow to enhance mixing and generation of foam. Preferably, the step means has an abrupt edge to enhance agitation, and the jet orifice is non-circular to provide a relatively long step edge when compared with the cross-sectional area of the inlet jet opening. Preferably, the inlet jet opening is an elongated inlet slit having a width defined by space between oppositely facing inlet slit side walls. Similarly, the outlet let opening is an elongated outlet slit having a width defined by space between outlet slit side walls. The width of the outlet let opening is greater than the width of the inlet jet opening. The inlet and outlet jet openings are aligned about a jet axis to define at least one step located between at least one inlet slit side wall and one outlet slit side wall adjacent one side of the slit.

A method of generating foam from a flow of pressurized water and foam concentrate comprises passing the flow through a relatively small inlet jet opening and across at least one first step edge into a relatively large outlet jet opening communicating therewith to provide a diverging passage, the step edge augmenting agitation of the flow to produce a foamed mixture. Preferably, the method further comprises passing the flow across the step edge which is relatively long when compared with cross-sectional area of the inlet jet opening. Also, the method further comprises passing the flow through the relatively small inlet jet opening defined by at least one pair of laterally spaced apart parallel inlet slit side walls, passing the flow through the relatively large outlet jet opening defined by a pair of parallel outlet slit side walls, and as the flow passes from the inlet jet opening to the outlet jet opening, passing the flow across the step edge which causes portions of the flow to move laterally outwardly across the step edge to agitate the flow.

A detailed disclosure following, related to drawings, describes a preferred apparatus and method according to the invention which are capable of expression in structure and method other than those particularly described and illustrated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a fire fighter using a foam fire-fighting apparatus according to the invention;

FIG. 2 is a simplified, fragmented, longitudinal section through a portion of the apparatus of FIG. 1;

FIG. 2A is a fragmented enlarged detail of a portion of FIG. 2;

FIG. 3 is a rear elevation of a downstream side of a foaming orifice of the invention;

FIG. 4 is a simplified section on line 4—4 of FIG. 3;

FIG. 5 is a simplified fragmented section on line 5—5 of FIG. 3;

FIG. 6 is a rear elevation of a downstream side of an alternative foaming orifice.

DETAILED DESCRIPTION

FIG. 1

A fire fighter **10** is shown carrying a conventional water bearing fire hose **12** and a fire fighting foaming apparatus **13** according to the invention. The apparatus **13** includes a foaming apparatus **14** according to the invention fitted to an end of the hose **12**, the foaming apparatus comprising a mixing body **15** and a foam generating nozzle **16** fitted to the mixing body. The fire fighting apparatus **13** also includes a foam concentrate container **18** for carrying foam concentrate liquid, the container having shoulder and waist straps **19** for passing around the torso of the fire fighter to secure the container adjacent the fire fighter's back. A foam concentrate hose **20** extends from the container **18** to the apparatus **14** to supply foam concentrate thereto which is mixed with water from the hose **12** and ejected from the nozzle **16** as foamed water **21**, or fire fighting foam.

As illustrated, the container **18** is mounted in a low position on the torso, generally adjacent the hips, to provide room on the fire fighter's back to carry breathing apparatus or other accessories commonly used by fire fighters. Clearly, if the fire fighter is not required to carry other equipment on the upper portion of the back, an alternative and larger concentrate container could be worn higher on the back, more as a conventional backpack, which would permit carrying more foam concentrate if required. In any event, the container straps are connected thereto to permit the container to be carried on the fire fighter's back. Also, preferably the container is made from a liquid impermeable fabric, which is resistant to chemical action of the foam concentrate, to facilitate carrying on a person's back. As the fabric is relatively flexible, the container can collapse as foam concentrate is withdrawn therefrom, thus eliminating the need for a breather opening. Alternatively, the container could be rigid with a suitable breather or vent to permit removal of foam concentrate from the container.

FIGS. 2 and 2A

The mixing body **15** is generally T-shaped and has a main tubular portion **26** disposed along a longitudinal axis **27**. An inlet connector sleeve **29** is threaded adjacent an inlet end portion of the tubular portion **26** and has a male threaded portion **31** to cooperate with a complementary threaded connector on the end of the hose **12**, shown in broken outline. An outlet connector sleeve **33** is similarly threaded on complementary male threads at an outlet end of the tubular portion **26**, and has a female threaded portion which receives a male threaded portion **35** of a nozzle inlet portion **37** of the foam generating nozzle **16**. The sleeves **29** and **33** cooperate with a water inlet port **30** and a mixture outlet port **34** respectively, the ports **30** and **34** being at opposite ends of the mixing body **15**. The connector sleeves **29** and **33**, the main tubular portion the foam generating nozzle **16** and related structure are all axially aligned along the axis **27**. Thus, it can be seen that portions of the mixing body adjacent the water inlet port **30** and the mixture outlet port

34 have releasable connecting means to releasably connect hollow members thereto, e.g. inlet and outlet sleeves and equivalent members, to discharge therethrough in direction of an arrow **38**.

The body **15** has a foam concentrate conduit **40** extending generally transversely from the axis **27** at **90** degrees thereto, although the angle is not critical. The conduit **40** has an inner portion threadedly secured to the main tubular portion **26**, and a male threaded outer portion **42** which releasably connects to a complementary threaded sleeve connector at an outer end of the concentrate hose **20**, shown in broken outline. The conduit **40** has a concentrate valve **45** comprising a valve ball **47** which is received on a truncated conical valve seat **49** to close a valve orifice **50** at an apex of the seat. The main tubular portion **26** of the body **15** has a foam concentrate inlet port **52** extending into a valve chamber **54** located between the valve seat **49** and the inlet port **52**. The port **52** receives foam concentrate from the orifice **50** and the hose **20** as will be described. The ball **47** is free to move within the chamber **54**, and is displaced from the seat **49** when foam concentrate flows inwardly through the orifice **50** in direction of an arrow **55** to pass into the port **52**. The ball **47** is prevented from blocking the port **52** by a wire spacer means **56** which holds the ball clear of the port **52**, so as to prevent blockage of the port **52**. However, when fluid in the portion **26** exerts a pressure outwardly in direction of an arrow **58**, the ball **47** is forced against the seat **49** and prevents fluid flow outwardly therethrough. Thus it can be seen that the foam concentrate conduit **40** communicates with the concentrate inlet port **52**, and the concentrate valve **45** is a one-way check valve to control flow in the concentrate conduit. The valve **45** permits foam concentrate to pass into the body **15**, and prevents water from passing outwardly from the body through the valve orifice **50**, which effectively also blocks the foam concentrate inlet port **52** against outwards flow of water as will be described.

The foaming apparatus **14** further includes an eductor nozzle disposed within the body and extending between the inlet and outlet ports **30** and **34**, which ports receive water from the hose and discharge a water/foam mixture therethrough respectively, as will be described. The eductor nozzle has an eductor inlet portion **64** adjacent and axially aligned with the water inlet port **30**, and an eductor outlet portion **62** communicating with the eductor inlet portion **64**. along the axis **27** and located to discharge through the outlet port **34**. The eductor inlet portion **64** has a relatively short, downstream-converging inlet side wall **70** having upstream and downstream side wall portions **71** and **72** respectively defining relatively large and relatively small openings. The eductor outlet portion **62** has a relatively long, downstream-diverging side wall providing an essentially unobstructed diverging or expanding passage **68**, with a downstream rim **66** defining an outlet of the eductor outlet portion which has a net cross-sectional area greater than cross sectional area of an upstream opening of the outlet portion **62**, defined by an upstream rim **78**. The inlet portion **64** is a relatively short ring retained in place by the sleeve **29**, and can be removed if needed, and has a size which is matched to the eductor outlet portion **62** as will be described. The upstream side wall portion **71** merges smoothly with a similarly angled side wall of an inwardly extending rim **74** of the inlet connector sleeve **29**. The downstream side wall portion **72** has a short cylindrical section **75** terminating at a downstream rim **76**, which defines net area of the inlet port **30**.

As best seen in FIG. **2A**, the eductor outlet portion **62** has the upstream rim **78** spaced axially downstream from the downstream rim **76** of the inlet portion **64** by an axial manifold spacing **80**. Thus, the eductor nozzle is characterized by a converging passage in the inlet portion **64** spaced upstream by the manifold spacing **80** from a diverging passage in the outlet portion **62**. The manifold spacing **80** provides an eductor suction port which is disposed between the eductor inlet portion and the eductor outlet portion, and when water flows through the eductor nozzle, low pressure or suction is generated adjacent the spacing **80** to induct foam concentrate into the portion **62** as will be described. The upstream rim **78** of the eductor outlet portion **62** has an internal diameter **82**, and the downstream rim **76** of the eductor inlet portion **64** has an internal diameter **84**. The diameter **84** is smaller than the diameter **82** and is disposed concentrically therewith. For a discharge nozzle **16** having a nominal delivery capacity of 70 U.S. gallons per minute (318 litres per minute), the internal diameter **82** of the outlet portion upstream rim **78** is 0.500 inches (127 mms.), and the internal diameter **84** of the eductor inlet portion downstream rim **76** is 0.450 inches (124 mms.). This provides a difference in diameters of 0.050 inches (2.6 mms.), which results in a radial difference of 0.025 inches (1.3 mms.). This radial difference is relatively critical and also defines radial thickness of the annular spacing **80** between the downstream rim **76** and the upstream rim **78**. The foam concentrate is usually mixed at a concentration ratio of about 1:100 of concentrate:water. This ratio is determined by various factors, but particularly by size of the valve orifice **50** which can be about 0.0781 inches (1.984 mm) in diameter and the above radial difference above between the eductor inlet and outlet portion, i.e. 0.025 inches (1.3 mm). The spacing or suction port **80** has an axial width of about 0.150 inches (7.8 mms) although this is not critical.

The mixing body **15** is hollow, and has a continuously extending, non-perforated, inner side wall **86** having a generally central annular portion provided with a female screw thread **88**. The eductor outlet portion **62** has an outer side wall **90** spaced from an upstream portion of the inner side wall **86** of the body to define an annular manifold chamber **92** extending around a portion of the eductor nozzle. A central portion of the outer side wall **90** of the portion **62** has a male screw thread which can engage the female screw thread **88** of the mixing body, so as to permit insertion and removal of the eductor outlet portion **62** as required. The annular manifold chamber **92** communicates with the foam concentrate inlet port **52** and the manifold spacing **80**, and thus comprises a portion of a delivery manifold means for communicating the foam concentrate inlet port with the eductor suction port. While the concentrate port **52** is located on one side only of the eductor nozzle, because the manifold chamber **92** extends peripherally completely around the eductor suction port or manifold spacing **80**, foam concentrate can pass completely around and surround the upstream rim **78** and thus is drawn into the eductor outlet portion from all positions therearound. Thus, the manifold chamber **92** serves as the manifold means to provide a generally uniform distribution of foam concentrate into the eductor suction port and thus into the nozzle itself to discharge therethrough as will be described.

Engaging means **94** are provided adjacent the downstream rim **66** to permit rotation of the eductor nozzle for insertion and removal as required. Thus, it can be seen that the male screw thread and the complementary female thread **88** serve as releasable connecting means to releasably connect the eductor outlet portion **62** to the body **5** so that the eductor outlet portion is removable from the body as required. It is added that the removable inlet and outlet portions **64** and **62** are for manufacturing convenience only, and it is not anticipated that the eductor inlet and outlet portions will be changed by users in the field. To suit customer requirements, matched eductor portions nozzles having different sized passages can be shop installed within the body **15** for determining flow rating of the apparatus **14** as will be described.

The foam generating nozzle **16** serves as an air entrainment nozzle and, in some instances, resembles portions of prior art air entrainment foaming nozzles. For example, the nozzle **16** has a nozzle body **100** with the nozzle inlet portion **37** having the male threaded portion **35** releasably connected to sleeve **33** which in turn is connected to the mixing body **15** adjacent the outlet port **34** thereof for receiving the mixture. The nozzle has a nozzle outlet portion **105** to discharge the foamed water as will be described, the portion **105** having an internal diameter **106**. The nozzle body also has an intermediate portion **107** disposed between the nozzle inlet and outlet portions **37** and **105**, which serves as a transition between the relatively small inlet portion **37**, and the relatively larger outlet portion **105**. Thus, the intermediate portion has a truncated conical side wall to provide the transition,the side wall having a plurality of air entrainment openings **109** disposed thereabout to entrain air into the mixture passing through the nozzle.

The nozzle **16** also includes an agitator means **111** for agitating the mixture to produce the foamed water, the agitator means being in accordance with a portion of the present invention and having an agitator jet orifice **110** located generally adjacent the air entrainment openings in the intermediate portion **107**. As will be described, the agitator means has a disk-like agitator body **112** which has a circular periphery **115** and is located against a complementary annular shoulder **113** extending around the nozzle inlet portion **37**, and is located immediately upstream of the air entrainment openings **109**.

FIGS. 3, 4 and 5

As best seen in FIG. **4**, the body **112** of the agitator means **111** has a front or upstream face **117** and a rear or downstream face **118**, and axial distance between the faces defines thickness **120** of the agitator means. The faces **117** and **118** have an inlet jet opening **122** and an outlet jet opening **123** respectively, which are disposed symmetrically about the longitudinal axis **27** passing through the centre of the agitator jet orifice **110**, the axis **27** also serving as a jet axis. The body **112** is integral, ie is in one piece for manufacturing convenience and maintaining registration, and the terms upstream, downstream, inlet, and outlet refer to general direction of flow through the agitator jet orifice in direction of the arrow **38**. The outlet jet opening is larger than the inlet jet opening and communicates with the inlet jet opening to define a single diverging passage **125** of the orifice **110** having a pair of generally similar, oppositely facing, first steps **126** which have sharp edges and are located on opposite sides of the orifice as best seen in FIG. **4**. In addition, portions of the rear face **118** adjacent the outlet jet opening provide a pair of generally similar, oppositely facing, second steps **128** which are spaced further apart than the first steps **126**, thus further defining portions of the diverging passage **125** through the orifice **110**.

As best seen in FIG. **3**, the inlet jet opening **122** has a plurality of generally similar elongated inlet slits **130** extending radially outwardly from the jet or nozzle axis **27** and disposed to define a symmetrical six-pointed star-shaped pattern. The inlet slits each have a width **132** defined by space between oppositely facing inlet slit side walls **136**, two only being designated in FIG. **3** and shown in FIG. **5**. Preferably, the inlet slit side walls **136** are parallel to each other and disposed symmetrically on opposite sides of a radius, not shown, extending from the axis **27**, and have outer ends interconnected by a straight slit end wall **138**. Also, the outlet jet opening **123** has a plurality of generally similar elongated outlet slits **140** extending radially outwardly from the jet or nozzle axis **27**, the outlet slits having a width **142** defined by a space between oppositely facing outlet slit side walls **144**, two only being designated in FIG. **3** and shown in FIG. **5**. The side walls **144** of each slit are interconnected at outer ends by a curved outlet slit end wall **139**. While the inlet slit end walls **138** are straight and the outlet slit end walls **139** are smoothly curved, this is not critical, and is for manufacturing convenience and only slightly changes geometry of the steps. One of the prime purposes of the jet orifice **110** is to provide a relatively long length of sharp or abrupt step edges for a given overall cross-sectional area of the orifice **110**. As can be seen in FIG. **3**, the length of step edges provided by the sets of slit end walls of the orifice **110** is considerably less than the length of step edges provided by the slit side walls, but all step edges contribute to the overall purpose of agitating the mixture as it passes through the jet orifice.

Referring to FIG. **4**, portions of the slit end walls **138** and **139** are generally parallel to the axis **27**. A transverse portion **146** extends between the inlet slit end wall **138** and the outlet slit end wall **139** so as to provide a "tread" portion of the first step **126**, the tread portion being disposed normally to the axis **27**. As best seen in FIG. **5**, the inlet slit side walls **136** and the outlet slit side walls **144** are generally parallel to each other and parallel to the axis **27**. Also a transverse portion **147** extends between adjacent inlet slit side walls **136** and outlet slit side walls **144** to define the first step **137** and is also a "tread" portion disposed normally to the axis **27**. The outlet slit side walls **144** intersect the downstream face **118** to define relatively sharp edges of second steps **145**. The transverse portions **146** and **147** are generally coplanar and extend around the periphery of the orifice, and are also in a plane parallel to the upstream and downstream faces **117** and **118**, and disposed at a mid-point between the plane. Consequently, the inlet slit side walls **136** and the outlet slit side walls **144** have respective axial depths and **150** which are equal to each other and equal to one-half of the width **120**, and equal to undesignated axial depths of the slit end walls. The transverse portion **147** has a width **151** which is of a similar order of magnitude as the axial depths **148** and **150** although this is not critical and can vary with different orifice sizes. The transverse portion **146** adjacent the end walls of the slits has a variable width due to the curved outlet slit end wall **139** and has a maximum width equal to the width **151**, but this is generally unimportant.

Referring to FIG. **5**, the width **142** of the outlet slit is preferably about twice the width **132** of the inlet slit, which provides a theoretical angle of divergence of flow through the orifice **110** as follows. A pair of inclined broken lines **152** interconnect edges of the first and second steps **137** and **145** on opposite sides of a pair of slits, and an angle **153** is subtended by the lines **152** as shown. The angle **153** is dependent on relative sizes of the dimensions **148**, **150** and **151** and can vary between about 45 and 90 degrees. Selection of the angle is also dependent to some extent on the diameter **106** of the nozzle outlet portion **105**. Thus, the single diverging stepped passage **125** through the agitator jet orifice is in fact a plurality of interconnected diverging elongated passages arranged as a six-pointed star, each passage extending downstream and outwardly from the orifice into the nozzle body as will be described.

The axial and transverse portions of all the steps intersect at a right angle of 90 degrees to define an edge of the respective step. Clearly, all the slit side walls and slit end walls are generally parallel to the jet axis, whereas the transverse portions, both on the side walls and end walls, are generally normal to the jet axis. The edges of the steps should be relatively sharp, although the actual angle between adjacent side walls and transverse portions is less critical, but should be within a range of between about 70 degrees and 90 degrees. It can be seen that the relatively short step edges of the first step **126** (defined by intersection of the inlet slit end walls **138** and the transverse portions **146**), and the relatively long step edges of the first step **137** (defined by intersection of the inlet slit side walls **136** and the transverse portion **147**) together define a first step means located between the inlet and outlet jet openings. Similarly, the step edges of the second steps **128** and **145** defined by intersections of the outlet slit end walls **139** and the agitator body **112** together define second step means.

Clearly, referring to FIG. **4**, a pair of lines, not shown but equivalent to the lines **152** of FIG. **5**, which would interconnect the first and second steps **126** and **128** respectively adjacent the end walls of the slits would be at an angle greater than the angle **153** of FIG. **5**, but this also is not critical.

Dimensional and Operating Parameters

Certain aspects of the invention have critical dimensions, and the dimensions are dependent upon operating parameters of water flowing through the nozzle, e.g. primarily volume flow.

The following description refers to a specific example which has been tested and found to produce a foam that is of at least equivalent quality to other commercial foam generating attachments and has been used to extinguish fires of Class A and Class B standards, as specified by the U.S. Underwriters Laboratories. For a nozzle **16** having a discharge flow of 70 U.S. gallons per minute (318 litres per minute) the diameter **82** of the eductor upstream rim is as described previously, namely 0,500 inches (127 mms) and receives water from an downstream rim **76** having a diameter **84**, namely 0.450 inches (114 mms). The inlet connector sleeve **29** has a bore of 1,450 inches (368 mms) to receive a standard coupling of a nominal 1.5 inches hose pipe. Such a hose pipe is normally operated pressures of between about 60 and 120 PSI (413 and 827 kPa).

The agitator jet orifice **110** has a net cross-sectional area determined by dimensions of the eductor nozzle, and is based on minimum size of the orifice opening, i.e. size of the inlet jet opening **122** which has a total cross-sectional area of 0.306 sq. inches (197 sq. mms.), which is the sum of six (6) radial inlet slits. Each diametrical pair of inlet slits has an overall diametrical length measured between the end walls of about 0.850 inches (215 mms) and an inlet slit width of about 0,125 inches (3.17 mms). The outlet jet opening **123** has a total area of 0.759 sq. inches (489 sq. mms) and each diametrical pair of outlet slits has an overall diametrical length measured between the curved end walls of about 1.192 inches (30.2 mms) and an outlet slit width of about 0,250 inches (6.3 mms). The transverse portion **147** of the first step **137** of the side walls has a width of 0.063 inches (1.6 mms) and the axial depths **148** and **150** of the side walls are both 0.125 inches (3.17 mms).

The foam generating nozzle **16** has an internal diameter **106** of 2.050 inches (52.07 mms) and an axial length of about 20 inches (50.8 mms) following conventional practice. Also, following conventional practice, the total area of air entrainment openings **109** equals approximately one-half of the cross-sectional area of the discharge nozzle outlet portion **105**. Thus, for a discharge nozzle having a cross-sectional area of 3.300 sq. in. (21.29 sq. mms), the total area of air entrainment openings equals 1.570 sq. in. (1012.9 sq. mms). Thus, for eight openings as shown, each opening has a diameter of 0.500 inches (12.7 mms).

Optimum performance for foam generation and water flow is determined by the cross-sectional area of the agitator jet orifice **110**, and maximum volume flow rate through the eductor nozzle **62**. For the above jet orifice area of 0.306 sq. inches (197 sq. mms), the maximum volume flow through the eductor nozzle is 60 U.S. gallons per minute (270 litres per minute) which generates a suction at the spacing **80** of about 26 inches (630 mm) of mercury. If the flow rate through the eductor nozzle is increased beyond the maximum, the eductor nozzle will "choke". Consequently, even though the nozzle **16** is rated at 70 U.S. gallons per minute, it is preferable to operate the eductor at less than that, e.g. about 60 U.S. gallons per minute, to avoid choking of the nozzle. When the nozzle chokes, pressure in the eductor nozzle will be excessive and will cause water to "back-up" into the valve chamber **54**, thus forcing the ball **47** against the seat and closing the concentrate valve **45** thus preventing water from passing into the concentrate container and diluting the concentrate. Clearly, closing the valve **45** cuts off supply of concentrate and prevents further generation of foam which is immediately visible to the operator, who could then make adjustments to reduce inlet flow and pressure to re-establish foam generation. Steadily reducing the flow rate from the maximum rate of flow of the nozzle, reduces "throw" of the nozzle to a condition where there is insufficient suction at the spacing **80** to draw foam concentrate into the stream. If there is insufficient suction, a smaller eductor nozzle and corresponding inlet nozzle ring **69** should be substituted, thus reducing rating of the nozzle.

Operation

The mixing body **15** and associated inlet connector sleeve **29** and outlet connector sleeve **33** can be used at different locations on a standard fire hose, e.g. at the beginning of the hose generally adjacent the water source, at a mid-point on the hose, or at an outer end of the hose adjacent the nozzle as illustrated in FIG. **2**. In general, most of the advantages of the invention are obtained by locating the mixing body **15** and sleeves in combination with the foam generator nozzle **16** at the outer end of the hose and the following description assumes this is the location. Clearly, if the mixing body **15** and sleeves **29** and **33** are located at any other position other than the outer end of the hose, the foam generating nozzle **16**, complete with the agitator means **111**, is connected to the outer end of the hose, and generates foam in a normal manner. The hose can be used in the normal manner to deliver water, and can be quickly adapted to deliver foam as follows. The male threaded portion **31** of the inlet connector sleeve **29** is threaded into a complementary female coupling, not shown, on the end of the hose **12**. Usually, the foam fire fighting apparatus **13** is supplied completely assembled with all the components as shown in FIG. **2**. A fire fighter merely has to ensure that the foam concentrate container **18** has sufficient foam concentrate, and to connect the concentrate hose **20** to the foam concentrate conduit **40** using a threaded coupling to engage the male threaded portion **42**. Water is supplied at sufficient delivery pressure and flow rate as determined by the size of the eductor nozzle and agitator orifice, passes into the water inlet port **30**, and is discharged as a generally parallel sided column of water or jet past the downstream rim **76** and into the eductor inlet portion **64**. The moving column of water passes across the manifold spacing **80** at a pressure sufficient to generate suction in the annular chamber **92** which serves as a portion of the delivery manifold means.

As described with reference to FIG. 2A, there is a relatively small difference in size between the upstream rim internal diameter **82** of the eductor outlet portion **62**, and the downstream rim internal diameter **84** of the eductor inlet portion **64**. The difference in diameters and the suction generated by the column of water passing the spacing **80** entrains a thin layer or film of foam concentrate around the outside of the column of water entering the eductor outlet portion **62**. This thin layer of foam concentrate encloses the column of water and is drawn along the side wall of the diverging passage **68** and starts to be mixed immediately in the column of water. A quick start of mixing is essential for effective operation of the invention as there is very little mixing length between the manifold spacing **80** and the agitator means **111**. Consequently, it is essential that thorough mixing is initiated in this short section, which contrasts with the prior art devices known to the inventor. It is anticipated that severe agitation of the foam concentrate and the water occurs as the column of water leaves the eductor outlet portion **62** into an expanded chamber portion adjacent the outlet port **34**, prior to passing through the jet orifice **110** of the agitator means **111**. The jet orifices has a cross sectional area which is much smaller than other openings through which water passes, and thus causes a temporary constriction and severe turbulence in flow passing through the agitator jet orifice **110**.

The effectiveness of the foaming method of the present invention is attributed to the severe turbulence being generated in the water/foam concentrate mixture as it passes through the agitator means, in particular, as it passes over the edges of the first steps **126** and **137** provided between the inlet and outlet jet openings **122** and **123**, and then the second steps **128** and **145** against the downstream face **118**. It is assumed that a phenomenon associated with fluid dynamics, termed the "Coanda effect", augments agitation as the column of the water/foam concentrate mixture commences to "expand" upon entering the diverging passage **125** and passing through the inlet slit opening where it is drawn first around the first step **126** and **137**, and then into the outlet slit where the mixture passes around the second steps **128** and **145**, immediately prior to being exposed to air passing through the air entrainment openings **109**.

It can be seen from FIG. **3** that the six radially aligned pairs of inlet and outlet slits provide a considerable length of sharp edges for a relatively small cross-sectional area of orifice. Thus, it is anticipated that a large portion of the relatively small cross-sectional area of mixture passing through the agitator means is subjected to passing sequentially over the two sharp edges of steps, which thoroughly agitates the mixture in a very short length. Immediately after the agitation, large volumes of air are supplied to assist in generating foam, which can then expand into the relatively large nozzle outlet portion **105**. The highly agitated foam is discharged from the nozzle outlet portion over "throw" distances of approximately 90 feet (27.5 metres) for a delivery pressure of 70 PSI (490 kPa) and a flow rate of 70 U.S. gallons per minute (265 litres per minute).

Thus, in summary, it can be seen that the foam generation method of the invention is characterized by admitting foam concentrate into a flow of water to form a foam/water mixture and passing the mixture through a relatively small jet opening and across at least one first step edge into a relatively large jet opening to agitate the mixture, followed by entraining air into the agitated mixture to generate the fire fighting foam. Preferably, the mixture is passed across a plurality of step edges between the inlet and outlet jet openings to provide a long length of edges around a relatively small opening. Also after passing the mixture over the first step edges, the mixture is preferably passed over second step edges prior to entraining air therein. Because a circular opening has a minimum circumference for a given cross-sectional area of opening, to provide a step edge which is relatively long compared with the cross-sectional area of the inlet opening, the inlet and outlet jet openings are non-circular. As a minimum, the inlet jet opening could be an elongated inlet slit, and the outlet jet opening could be an elongated outlet slit, with the inlet and outlet jet openings being aligned to define at least one step located between at least one inlet side wall and one outlet side wall adjacent one side of the slit. As in all the arrangements described, the inlet slit side walls and the outlet slit side walls are generally flat and disposed parallel to the jet axis aligned with the flow direction to provide an aligned pair of parallel-sided laterally elongated passages or slits separated by a laterally elongated step edge. It can be seen that, as the flow passes from the inlet jet opening to the outlet jet opening, the flow passes over or across the first step edge which causes portions of the flow to move laterally outwardly across the step edge to agitate the flow. After passing the flow across the first step edge, the flow is passed through the outlet jet opening and across a second step edge spaced laterally outwardly from the fist step edge to enhance generation of foam. Air is entrained into the flow during or after passing the flow across the step edges. Also, preferably the foam concentrate is admitted into the mixture by enclosing a moving column of water with a thin film of foam concentrate to form the mixture.

Thus, it can be seen that the agitator means comprises an inlet jet opening and an outlet jet opening, the outlet jet opening being larger than the inlet jet opening and communicating with the inlet jet opening to provide at least one aligned pair of openings in communication with each other to define a diverging passage. The step means is located between the inlet and outlet jet openings, and flow through the agitator jet opening passes across the step means to agitate the flow to enhance foaming.

Alternatives

The eductor nozzle of the present invention is shown with axially aligned convergent and divergent passages in the inlet and outlet portions **64** and **62** respectively. Adjacent and oppositely facing rims of the inlet and outlet portions are spaced axially apart by a manifold spacing or eductor suction port **80** which is located at the minimum cross-section of the two passages. The nozzle portions could have alternative non-tapered passages in the inlet and outlet portions, that is the inlet and outlet portions could have cylindrical passages, but in this alternative the passage of the inlet portion would be slightly smaller than the passage in the outlet portion to provide space for a thin film of concentrate to form around the column of water, as previously described. Also, sizes of nozzles will vary depending on the particular requirements, one example having been shown for a fire fighting foam generating nozzle having a nominal flow of 70 U.S. gallons per minute, for use with an eductor nozzle having a flow of 60 U.S. gallons per minute.

Smaller size nozzles can be used, for example, for a nozzle having a nominal discharge flow of 30 U.S. gallons per minute (113 litres per minute), the eductor upstream rim internal diameter **82** would be 0.305 inches (7.7 mm) and the inlet portion downstream rim **76** would have a diameter **84** of 0.255 inches (6.5 mm). The agitator jet orifice **110** would have a total cross-sectional area of 0.11 sq. inches (70.9 sq. mm). For this size of nozzle, the six radial inlet slits of FIG. **3** are reduced to four radial inlet slits which are disposed at ninety degrees to each other, i.e. from a six-pointed star to a four-pointed star. In the alternative agitator orifice, each diametrical pair of inlet slits has an overall diametrical length measured between the end walls of about 0.500 inches (1.27 mm), and have an inlet slit width of 0.125 inches (3.2 mm). The outlet jet opening **123** has a total cross-sectional area of 0.222 sq. inches (143 sq. mm). Each diametrical pair of outlet slits has a diametrical length measured between the curved end walls of about 0.625 inches (15.87 mm) with an outlet slit width of 0.25 inches (6.3 mm). The transverse portion **147** of the first step **137** of the side walls has a width of 0.062 inches (1.57 mm). The alternative foam generating nozzle **16** for 30 U.S. gallons per minute has an internal diameter **106** of 1.500 inches (38.1 mm) and an axial length of about 14.5 inches (368.3 mm). This discharge nozzle has a cross-sectional area of 1.767 sq. inches (1140 sq mm) and the 8 air entrainment openings would each have a diameter of 0.375 inches (9.5 mm). For the above jet orifice area of 0.110 sq inches (70.9 sq mm), the maximum volume flow through the eductor nozzle is 20 U.S. gallons per minute (76 litres per minute).

Clearly, other sizes and shapes of jet orifices and appropriate eductor nozzle diameters and discharge nozzles diameters can be devised by simple experiment. For manufacturing convenience, it has been found appropriate to provide a complementary recess adjacent the shoulder **113** in the nozzle inlet portion **37** to receive the agitator body **112** having the appropriately sized agitator orifice, with the body **112** having a constant thickness, irrespective of size of the orifice opening. Consequently, as the orifice opening becomes smaller to match smaller flow rates through the nozzle, the angle **153** of FIG. **4** becomes correspondingly smaller.

The two examples of dimensions described above relate to fire fighting nozzles for attachment to a conventional fire fighting hose pipe of a nominal 1.5 inches (38 mms) bore. Advantages of the invention can also be obtained for use with much smaller sized hose pipes, for example domestic garden hoses having nominal bores of about 0.5 inches (12.7 mms). A nozzle of the present invention for use with such pipes would be rated at approximately 3 U.S. gallons per minute (11.3 litres per minute) and would require a correspondingly much smaller eductor nozzle and agitator jet orifice. For manufacturing convenience, due to the relatively small size of the components, the eductor inlet and outlet portions could have cylindrical passages, that is non-tapered passages, and the agitator jet orifice would preferably have no more than four radial inlet slits to form a four-pointed star. The agitator jet orifice **110** would have a total cross-sectional area of 0.175 sq inches (11.29 sq mms). Each diametrical pair of inlet slits would have an overall diametrical length measured between the end walls of about 0.200 inches (15.08 mms), with an inlet slit width of 0.050 inches (1.27 mms). The outlet jet opening would have a total cross-sectional area of 0.050 square inches (32.26 square mms). Each diametrical pair of outlet slits would have a diametrical length measured between the curved end walls of about 0.300 inches (7.62 mms) with an outlet slit width of 0.100 inches (2.54 mms). The transverse portion **147** of the first step **137** of the side walls would have a width of

0.050 inches (1.27 mms), and the axial depth **148** and **150** of the side walls would be about 0.100 inches (2.54 mms). Residential garden hoses can operate at water pressures of between about 30 and 60 PSI (207 and 414 kPa), and clearly could have applications for spraying foaming garden or household chemicals as well as fire-fighting foam.

As stated previously, it is believed that the effectiveness of the foam generation aspect of the present invention is dependent upon providing a relatively long length of step edges for a given cross-sectional area of agitator orifice opening. While the agitator means of FIGS. **3**, **4** and **5** is shown having six radial pairs of inlet and outlet slits extending from the axis, clearly shape of the orifice can be changed depending on the size or diameter of the body of the agitator means. Alternatively, in addition, the edges of the steps can be provided with a "saw-tooth" profile so as to increase considerably overall length of step edge for a given size of inlet and outlet slits. This is shown in FIG. **6**.

FIG. 6

An alternative agitator means **155** has a disk-like agitator body **156** and an agitator jet orifice **157** having four pairs of inlet and outlet jet openings **158** and **159** respectively. One complete pair of an elongated inlet slit **161** and aligned elongated outlet slit **162** is shown, with undesignated portions of similar pairs of slits being shown on one side only of a diameter of the body. While the number of pairs of inlet and outlet jet openings could be varied, and could be six as shown in the agitator means or eight or more, depending on the size, the major difference between the two agitator means **111** and **155** relates to the shape of the slit side walls as follows.

The elongated inlet slit **161** of the inlet jet opening **158** has a pair of oppositely facing inlet slit side wall **163** which are provided with a plurality of small serrations resembling saw teeth. An inlet slit end wall **165** disposed perpendicularly to the inlet slit side walls **163** is similarly provided with serrations. Similarly, the outlet slit **162** of the outlet jet opening **159** has a generally parallel pair of elongated outlet slit side walls **171** which are also provided with a plurality of fine serrations as shown. Similarly, the outlet slit **162** has an outlet slit end wall **175** disposed perpendicularly to the slit side walls **171** and is similarly provided with serrations. The serrations are disposed generally parallel to the axis **27**, and extend the full depth of the respective slit side walls. A flat transverse portion **177** extends between the inlet slit side walls and outlet slit side walls and normally to the jet axis, not shown, to provide the inlet slit side walls with a first step edge **179**. Clearly, the step edge will be similarly serrated, which will increase considerably the effective length of the step edge compared with a straight step edge. It is anticipated that the effective length of the step edge is probably doubled or tripled by the serrations, depending on the pitch and depth of the serrations. Similarly, a rear or downstream face **181** of the alternative agitator means **155** intersects the outlet slit side walls **171** to provide second steps **183**, which are similarly serrated with a corresponding increase in length over a straight side wall. A corresponding transverse portion **185** extending between the slit end walls **165** and **175**, and the face **181** also provide first and second serrated step edges adjacent ends of the slits. It can be seen that at least one side wall of the alternative has a plurality of serrations or teeth extending therealong to increase overall length of the step edge associated with the said side wall to enhance agitation of water flowing through the alternative agitator means. The transverse portions **177** and **185** are coplanar and disposed mid-way between front and rear faces of the agitator body **156**.

Other means of increasing effective length of the step means can be devised, e.g. third and if necessary fourth steps can be provided expanding downstream in a manner similar to the first and second steps as shown, which would in general require a greater thickness of agitator means. In any event, the last step of the agitator should be positioned closely adjacent and upstream of the air entrainment openings, so as to obtain maximum benefit of aeration occurring immediately after the agitator orifice.

The agitator means is shown in use with a eductor nozzle and an air entrainment nozzle, particularly to generate fire fighting foam. Existing equipment is available which admits an accurate ratio of foam concentrate into a pressurized flow of water, which then passes along a hose pipe to a foaming nozzle having a jet orifice, and air entrainment openings. Clearly, the agitator body using the jet orifice of the present invention could be substituted for the jet orifice in existing fire fighting nozzles to provide the advantages of the present invention without requiring use of the specific eductor and other structure as described herein.

The description above describes use of the invention to generate fire fighting foam. Other uses are envisaged wherein a foam concentrate for other applications, e.g. herbicide or insecticide spray in foam form, are envisaged. This would likely require lower rates of flow and delivery pressures, which could be accommodated by scaling down the invention, whilst still obtaining benefits of foam generation-in a relatively short space of mixing body and nozzle combination as described.

We claim:

1. An agitator apparatus for generating foam from a flow of pressurized water and foam concentrate, the agitator apparatus having an agitator body comprising:

(a) an agitator jet orifice comprising an inlet jet opening in an upstream face of the body and an outlet jet opening in a downstream face of the body, the openings being disposed in series, the outlet jet opening being larger than the inlet jet opening and communicating with the inlet jet opening to define a diverging passage extending through the agitator body; and

(b) a first step means having a relatively abrupt step edge located between the inlet and outlet jet openings, so that flow through the agitator jet orifice passes across the first step means to agitate the flow to enhance mixing and generation of foam.

2. An apparatus as claimed in claim **1**, in which:

(a) the step edge is relatively long when compared with cross-sectional area of the inlet jet opening.

3. An apparatus as claimed in claim **1**, in which:

(a) the inlet jet opening is an elongated inlet slit having a width defined by space between oppositely facing inlet slit side walls,

(b) the outlet jet opening is an elongated outlet slit having a width defined by space between outlet slit side walls, the width of the outlet jet opening being greater than the width of the inlet jet opening, and

(c) the inlet and outlet jet openings are aligned about a jet axis to define at least one step located between at least one inlet slit side wall and one outlet slit side wall adjacent one side of the slit, the step having an abrupt step edge to enhance agitation.

4. An apparatus as claimed in claim **3**, in which:

(a) the agitator body has upstream and downstream faces, and axial distance between the faces defines thickness of the body,

(b) the outlet slit side walls intersect the downstream face of the agitator body to provide second steps having an abrupt edge to enhance agitation.

5. An apparatus as claimed in claim **3**, in which:

(a) at least one side wall of the inlet slit side wall or outlet slit side wall has a plurality of teeth extending therealong to increase overall length of the step edge associated with said side wall to enhance mixing and generation of foam.

6. An apparatus as claimed in claim **1**, in which:

(a) the inlet and outlet jet openings are non-circular, and

(b) the first step means has a step edge which is relatively long when compared with cross-sectional area of the inlet jet opening.

7. An apparatus as claimed in claim **6**, in which:

(a) the inlet slit side walls and the outlet slit side walls are generally flat and disposed parallel to a jet axis aligned with flow direction to provide an aligned pair of parallel sided laterally elongated passages separated by a laterally elongated step edge.

8. An apparatus as claimed in claim **1** in which:

(a) the agitator jet orifice comprises a plurality of interconnected elongated passages extending downstream and outwardly away from each other to define a multi-pointed star.

9. An apparatus as claimed in claim **1** in which:

(a) the jet openings are aligned about a jet axis passing through the orifice;

(b) the inlet jet opening has at least one elongated inlet slit extending outwardly from the jet axis, the inlet slit having a width defined by space between oppositely facing inlet slit side walls;

(c) the outlet opening has at least one elongated outlet slit extending outwardly from the jet axis and being aligned with the inlet jet opening to define a pair of aligned slits, the outlet slit having a width defined by space between outlet slit side walls, the width of the outlet slit of the pair of aligned inlet and outlet slits being greater than the width of the inlet slit of the pair; and

(d) the aligned inlet and outlet openings of the said pair have at least one step located between an inlet slit side wall and an outlet slit side wall adjacent one side of the slit.

10. An apparatus as defined in claim **9**, in which:

(a) the width of the outlet slit is approximately twice the width of the inlet slit.

11. An apparatus as claimed in claim **1** in which:

(a) the step has an axial portion and a transverse portion meeting at an angle to define an edge of the step, the angle between approximately 70 and 90 degrees.

12. An apparatus as claimed in claim **11**, in which:

(a) the agitator body has upstream and downstream faces, and axial distance between the faces defines thickness of the agitator body,

(b) the transverse portion of the step is disposed approximately midway between the upstream and downstream faces of the body, so that the inlet slit side wall, which defines the axial portion of the step, has an axial depth generally equal to axial depth of the outlet slit side wall, and

(c) the transverse portion of the step has a width which is of a similar order of magnitude as the axial depth of the inlet and outlet slit side walls.

13. An apparatus as claimed in claim **11**, in which:

(a) the axial portion is generally parallel to a jet axis passing through the orifice,

(b) the transverse portion is generally normal to the jet axis; and

(c) the step has a step edge defined by a generally perpendicular intersection between said axial and said transverse portions of the step.

14. An apparatus as claimed in claim **1**, further comprising:

(a) an air entrainment nozzle having a nozzle body with a nozzle inlet portion to receive the flow of water and foam concentrate, a nozzle outlet portion to discharge foamed water, and an intermediate portion disposed between the nozzle inlet and nozzle outlet portions, the intermediate portion having at least one air entrainment opening to entrain air into the flow passing through the nozzle to enhance foam generation, and

(b) the agitator body is located within the intermediate portion of the nozzle body and upstream of the air entrainment opening.

15. A method of generating foam from a flow of pressurized water and a foam concentrate, the method comprising:

(a) passing the flow through a relatively small inlet jet opening in an upstream face of an agitator body, and across at least one first step edge into a relatively large outlet jet opening in a downstream face of the agitator body, the inlet and outlet jet openings communicating with each other to provide a diverging passage, the step edge being relatively abrupt to augment agitation of the flow.

16. A method as claimed in claim **15** further comprising:

(a) passing the flow across the step edge which is relatively long when compared with cross-sectional area of the inlet jet opening.

17. A method as claimed in claim **15**, further comprising:

(a) passing the flow through the relatively small inlet jet opening defined by at least one pair of laterally spaced apart parallel inlet slit side walls,

(b) passing the mixture through the relatively larger outlet opening defined by a pair of parallel outlet slit side walls, and

(c) as the flow passes from the inlet jet opening to the outlet jet opening, passing the flow over the step edge which causes portions of the flow to move laterally outwardly across the step edge to agitate the flow.

18. A method as claimed in claim **15**, further characterized by:

(a) after passing the flow across the first step edge, passing the flow through the outlet jet opening and across a second step edge spaced laterally outwardly from the first step edge to enhance generation of foam.

19. A method as claimed in claim **15**, further characterized by:

(a) entraining air into the flow during or after passing the flow across the step edges to generate the foam.

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