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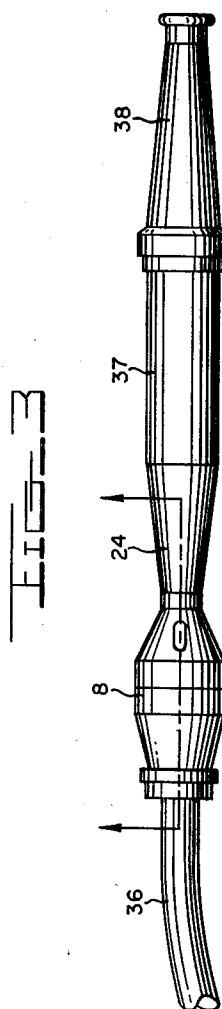
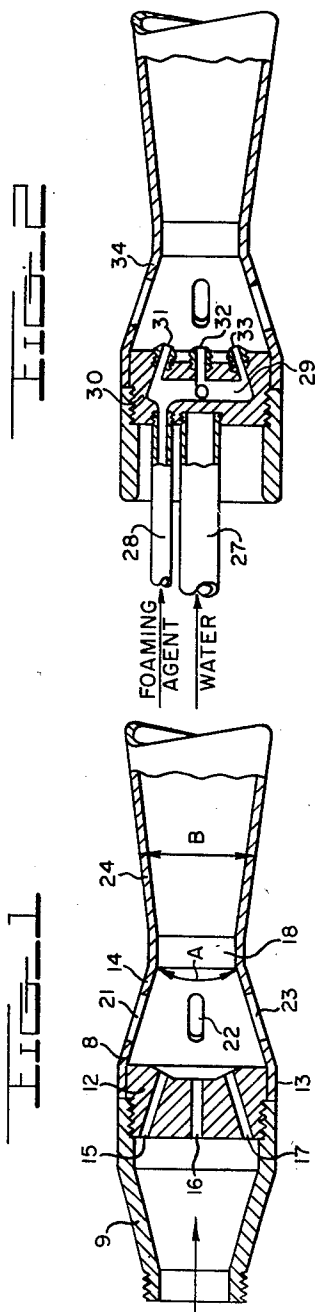
R. L. TUVE ET AL

2,556,239

FOAM FIRE FIGHTING METHOD

Filed April 1, 1947

2 Sheets-Sheet 1



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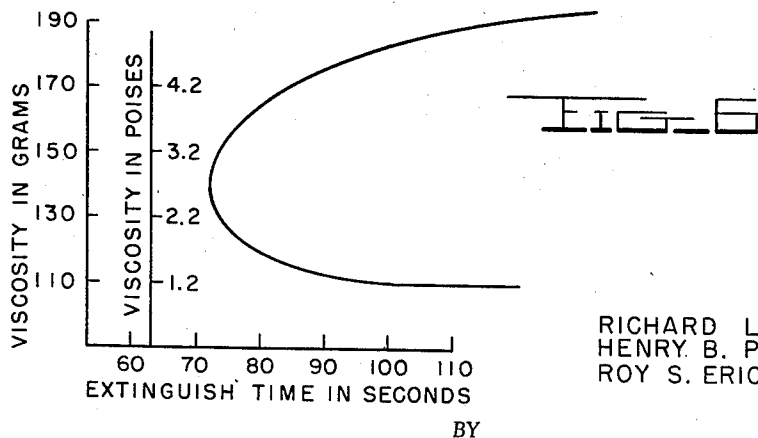
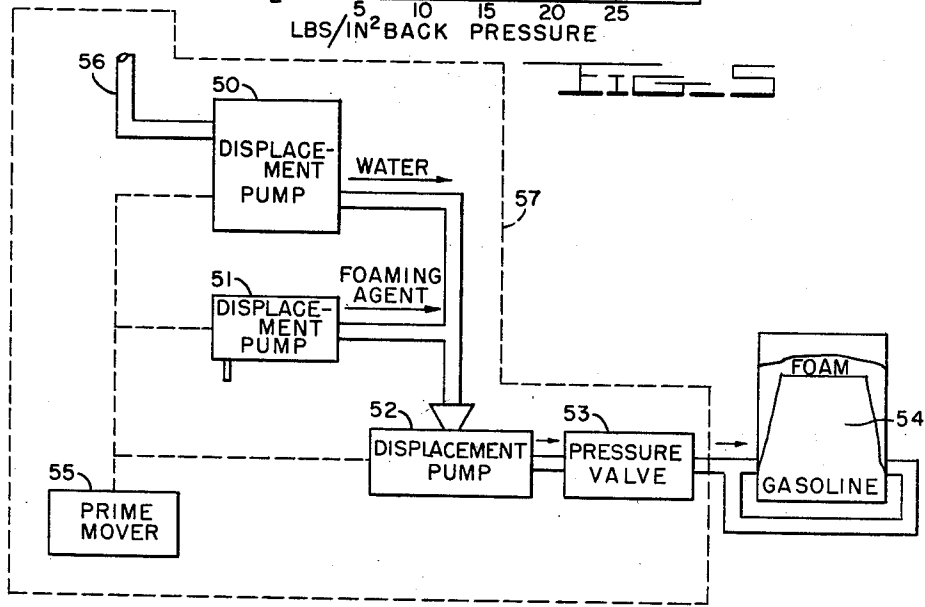
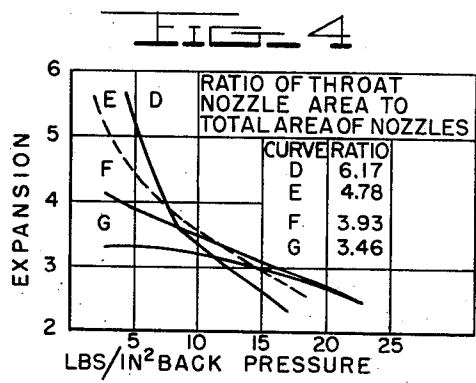
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FOAM FIRE FIGHTING METHOD

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This invention relates to the extinguishment of storage tank fires of volatile hydrocarbons such as gasoline, and is a continuation in part of our applications Serial Numbers 590,859 and 657,734, filed April 28, 1945 and March 28, 1946, respectively, both of which are now abandoned.

Basically, all fires supported by atmospheric oxygen and evolving flame and heat are vapor fires in which a material has been heated to a temperature such that it generates combustible vapors which mix with oxygen and are capable of being ignited to give flame. In the process of combustion, heat is evolved which produces additional vaporized material for combustion and the process thereby repeats itself until an equilibrium has been established. The intensity of the fire, or the equilibrium which is reached, is governed by the oxygen supply and the rate of supply of combustible vapor.

In order to halt the propagation of the fire, the material may be cooled below the temperature at which vapors are given off, or the atmosphere surrounding the combustible vapors may be diluted to such a low concentration of oxygen or combustible vapors that the combustion cannot be longer sustained.

Methods of extinguishing by cooling include the utilization of the latent heat of vaporization of carbon dioxide snow, methyl bromide liquid or water. The smothering, blanketing or starving of a fire are examples of the diluting method mentioned above. The fire extinguishing foam compositions as generated by our improved apparatus utilize both of the above principles.

The general present-day practice involving the use of mechanical foam for extinguishing fires has emphasized the qualities such foams need for forming blankets or layers of smothering and sealing emulsions of air and water to exclude oxygen from access to the combustible material, or, as in the case of gasoline or other volatile liquids, such foam layers prevent the escape of combustible vapors from the liquid.

One of the most important factors in the use of mechanical foam for extinguishing fires is the stability of the mechanically generated foam. The methods of application of the foam to the fire are quite numerous and depend to a large extent upon the type of material which is burning and its location. The stability of the generated foam is also dependent, sometimes to a large extent, upon the method of application, and a foam which may be comparatively stable if applied in one manner may be quite unstable when applied in another manner so that by the time it traverses

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the distance between its generator and the fire itself it has so broken down as to be ineffective to extinguish the fire.

Another important factor, particularly in the extinguishing of liquid fires, is the fact that the proportion of water in such water-air emulsions greatly affects the efficiency of the foams and frequently fires cannot be extinguished regardless of the total volume of foam used as a blanket in an attempt to smother the fire. If the water content of the foam is not relatively high, for example more than ten or fifteen per cent, extinguishment will not be effected efficiently.

A difficult problem is posed in the case of installations where mechanical foam is to be applied to a fire in an open top oil or gasoline tank. Since it is difficult to reach such a fire by means of foam thrown from hand held nozzles, due to the height of the tanks and the heat from the fire, permanent sub-surface injection installations are generally provided wherein the foam is delivered into the bottom of the tank against the pressure of the liquid in the tank, or into the bottom portion of a vertical pipe alongside the tank, the pipe generally delivering the foam at a level adjacent but below the liquid level therein. In either of these types of sub-surface injection the foam generator must be capable of generating a stable foam against the back-pressure of the liquid in the tank or pipe. The generated foam must be stable enough that it will not be broken down before it reaches the fire, because otherwise it will be substantially ineffective to extinguish it, and it is important that the generated foam have a high water content and that a substantial part of the kinetic energy of the generating water stream be retained so that the foam will reach the desired point.

It is therefore a primary object of our invention to provide an improved foam generating apparatus for producing a mechanical foam of relatively high water content and which is stable in spite of relatively high back pressures.

It is another primary object of our invention to provide a method of combatting hydrocarbon tank fires which features increased reliability, efficiency, safety of operating personnel over the methods now employed. No apparatus such as mixing chambers on the tank sides which are very vulnerable to explosions or collapsing roofs are required making our method more reliable. By applying the foam from the bottom it is not at any time exposed to the high temperatures and flames or the strong updraughts present above the burning surface which normally cause loss of

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a large percentage of foam applied by the present conventional methods. A small rate of foam application, such as .25 G. P. M./Ft.² is adequate to extinguish readily a fire by the methods of our invention. By use of this system it is not necessary to do any work at the base of the tank or for personnel to be even inside the dike area. The generating apparatus may be set up 1000 feet away from the fire.

It is a further object of our invention to provide an improvement of subsurface extinguishing which will permit operation under all conditions. Previously this method was applicable only to the heavy oils but the instant invention is workable with all inflammable liquids which are non-miscible with water. Furthermore with previously known employed equipment the method was limited as to height of the burning surface above the foam generator and also limited as to the distance from the burning tank.

It is another important object of our invention to provide an improved foam generating apparatus capable of delivering a stable, mechanically generated, air-water emulsion under a relatively high back pressure so that the emulsion can be injected through pipes or hose or a body of liquid to the point where it is needed with no loss in its quality or efficiency as an extinguishing agent.

Figure 1 is a transverse sectional view through a foam generating venturi illustrating our invention.

Figure 2 is a partial view similar to Figure 1 illustrating an alternate form of construction for injecting mixed water and foam stabilizing solution into the venturi.

Figure 3 is a general view of an apparatus indicating the arrangement of our venturi in connection with a water supply hose and a directing nozzle.

Figure 4 is a chart showing the effect of foam expansion with decreasing back pressure on foam generated by our improved apparatus compared with that generated by previously known apparatus.

Figure 5 is a general view showing a typical arrangement for extinguishing a hydrocarbon tank fire by the subsurface method of application of mechanical foam.

Figure 6 is a chart showing extinguishment time for foams of different viscosities.

Referring to Figure 1, our generator, designated generally by the reference number 8, comprises an inlet section 9 which may be connected to a hose or pipe for delivery of a mixture of water and foam stabilizing agent to the venturi wherein the liquid is mixed with air to form the mechanical foam. A fixture 12 which is threaded into the inlet section is rigidly attached as by welding or soldering to a cylindrical extension 13 on the large end of the converging approach section 14 of the venturi. The fixture 12 is provided with a series of fluid discharge nozzles, three of which are shown at 15, 16 and 17. Nozzles 15 and 17 are two nozzles of a concentric series of nozzles having an angle of convergence the intersection of which lies within the throat section 18 or within the approach section 14 substantially at its juncture with the throat section 18. Nozzle 16, being axial within the fixture 12 intersects the aforesaid angle or convergence at the same point. The fluid streams delivered by the said nozzles will also meet at the same point. We have found that the angle of convergence of the approach section 14 indicated by A in Figure 1

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should be substantially the same as the angle of convergence of the nozzles 15, 16 and 17. The optimum angle for the angle of convergence A has been found to be 20 degrees although it will be understood that a variation of this angle is possible, as long as the angle of convergence of the nozzles and of the approach section remain substantially equal. A series of equiangularly spaced air inlet ports 21, 22 and 23 are provided in the wall of the approach section 14 to admit the air which is mixed with the water-foam stabilizing mixture delivered by the nozzles 15, 16, and 17.

We have also determined that in order to provide a foam which will have the characteristics of stability, water content, and velocity as described above, there must be a definite relationship between the cross-sectional area of the throat section 18 and the total cross sectional area of all of the fluid nozzles within the fixture 12. As will be described subsequently, too high a ratio between these two areas will result in the production of a foam which includes too much air and too little water, being unsuitable to be fed beneath the surface of the fluid in oil or gasoline tanks. A foam of this unsuitable character will not flow readily and has a low velocity, and when it reaches the burning surface in an oil tank its low water content makes it so vulnerable to heat attack that its fire extinguishing ability is too low. When so used in a gasoline tank the small amount of foam reaching the surface is practically ineffective to put out the fire. In accordance with our invention, the cross sectional area of the throat section should be approximately from 2.25 to 4.0 times the total cross-sectional area of the nozzles in the fixture 12. Stated in another way, the radius of the throat section 18 should be approximately $1\frac{1}{2}$ to 2 times the radius of a circle having an area equal to the sum of the cross-sectional areas of the nozzles in the fixture 12.

Attached to the other end of the throat section 18 is an elongated diffusing section 24 having gradually diverging walls, the angle of divergence being indicated at B. We have determined that the angle B should be 7 degrees. Slight deviations of 1 or 2 degrees in the angle B are sufficient to upset the foam generating efficiency of the apparatus. In order to provide for full mixing and diffusion and proper expansion of the foam beyond the throat section and to cause the foam to retain as large a part as possible of the velocity of the water delivered to the generator, the length of the diverging diffusing section 24 should be from 20 to 30 times the diameter of the throat section 18. For example, in a generator having the proportions stated, with a diameter of 1.75 inches at the throat section, the diffusing section having a diverging angle of 7 degrees and a length of 35 inches, would have an outlet 6 inches in diameter.

The chart of Figure 4 shows the importance of maintaining within the stated limits the ratio of the cross-sectional area of the throat section 18 to the total of the cross-sectional areas of the nozzles in the fixture 12. Curves D and E show how the apparatus built in accordance with the Bedford Patent 2,375,009, wherein ratios of from 5:1 to 12:1 are used, cannot generate foam against as high a back pressure as our apparatus can.

By reducing the ratio of the cross-sectional area of the throat to the total area of all of the nozzles in the fixture 12 in accordance with our inven-

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tion, so that this ratio is from 2.25:1 to 4.0:1 instead of from 5:1 to 12:1 as taught by Bedford, a foam is produced having the characteristics shown by curves F and G of Figure 4, which contains more water, has less air, and smaller bubbles, so that it is very much less subject to breaking down when the back-pressure is reduced, as when the foam is rising in an oil or gasoline filled tank. The curves shown in Figure 4 were obtained by using the same foam stabilizer and water mixture in each test, and using throat sections of various diameters, the nozzles remaining the same in each case.

In the alternative form of the apparatus shown in Figure 2, the water and foam stabilizing agent are delivered through conduits 27 and 28 respectively to a mixing chamber 29 in the fixture 30. Nozzles 31, 32 and 33 deliver the mixture into the approach section 34 in the same manner as previously described in connection with Figure 1. Only a portion of the approach section 34 is shown, because it will be understood that the rest of the generator, including the approach section, throat section and diffusing section are similar to those of Figure 1. It is also to be understood that nozzles 31 and 33 are only two of an annular series of nozzles and that their angle of convergence is the same as that of the approach section 34, in the same manner as in Figure 1.

Referring to Figure 3, 6 represents the generator of our invention, and 36 represents the water and foam stabilizer feed line. At the discharge end of the diffusing section 24 is attached a cylindrical pipe section 37 to which may be attached a nozzle 38 if the apparatus is to be used to provide a high velocity, well defined stream of foam, or for the attachment of a hose or pipe which would replace the nozzle 38 if the apparatus is to be used to generate foam for use at a distant point. Since the foam in the pipe section is under pressure and has a pressure recovery in the order of 25% of the water pressure to the generator, various methods of distribution such as impinging spreaders or perforated disc distributors can be used at the discharge end of the apparatus.

We have found that with a foam generator built in accordance with our invention we are able to generate foam of uniform fine quality having an expansion of about 4:1 (3 volumes of air per volume of water) for delivery at the discharge end of the generator under a pressure at least one fourth of that of the water at the inlet end of the apparatus. For example, in an apparatus like that described, in which the throat diameter was 1.75 inches, the angle of divergence of the diffusing section 7 degrees, and the length of the diffusing section 35 inches with a diameter of 6 inches at its discharge end, water was delivered to the generator at the rate of 250 gallons per minute under a pressure of 100 lbs. per sq. inch. From the discharge end of the apparatus there was delivered 1000 gallons of foam per minute under a pressure of 30 pounds per sq. inch. The bubbles constituting the foam were uniformly 75 to 100 microns in diameter. Using a 2.75 inch nozzle on the discharge end of the apparatus, we are able to throw a well defined stream of foam to a distance of 75 feet.

Referring to Fig. 5, our alternate generator, designated generally by the reference number 57, consists of a rotary positive displacement pump 50 for the metering and pumping of the water needed for making the foam. A water

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supply line 56 leads from a hydrant or any available water supply. A second rotary positive displacement pump 51 is used for the metering and pumping of the foam stabilizing agent into the water stream. The foam supply is taken from a large tank provided for the purpose or is taken from the easily handled shipping drums or cans. The resulting 3 to 6% foam solution, depending on the stabilizer used, is then fed into a third rotary positive displacement pump 52 the inlet of which is also open to the atmosphere. The capacity of this third pump is purposely greater than the combined capacity of pumps 50 and 51, and air is drawn into the pump and mixed with the water and foaming agent. Further all three of these pumping units are driven from a single engine 55 through a gear drive so that the speed ratios are a fixed constant. This insures that the foam produced will always be of the same character and volume regardless of the pressures encountered at the generator outlet or of the water supply. To make the mixture of air, water and stabilizer into a homogenous, stable air-liquid emulsion, it is subjected to a minimum pressure and to accomplish this the mixture is passed through a pressure regulating valve 53 which maintains a pressure of 25 p. s. i. Wherever the discharge head at the pump is greater than 25 p. s. i. this valve has no action, and expansion takes place elsewhere.

After passing through the valve the foam is stable enough to be forced through long distances of pipe line without any breakdown of the foam or reduction of fire fighting ability. The pressure developed by the generator will also be sufficient to force the foam into a tank against the head exerted by the product in the tank 54. This pressure is limited only by the power available in the prime mover 55.

A cross section of the tank 54, shows the foam rising from the inlet line upward through the gasoline, due to its lower specific gravity, and thence spreading outward over the tank surface to extinguish the fire by effectively sealing off the oxygen from the hydrocarbon vapors.

In the manner of extinguishing hydrocarbon fires by the subsurface method several factors are quite critical especially in the case of the more volatile ones such as gasoline. Among these are the foam expansion (air-water ratio), foam viscosity or flowability, degree of stability, type of foam stabilizer, and the velocity of the foam as it enters into the oil and tank. Test results have shown that when the foam consists of 2 parts air and 1 part water its efficiency is at its highest. That is it will extinguish a given fire faster and with less water than any other content. However, for practical use, this ratio may be allowed to go as high as 3 parts air to 1 part water. Above this limit the extinguishing ability begins to be impaired and excessive amounts of materials will be necessary. Also the lower expansion will result in a lower foam volume application rate which will minimize the agitation where the foam breaks the oil surface.

A second critical factor for an efficient extinguishing process is the ability of the foam to flow freely and blanket the surface without having to build to greater depths. Generally speaking the viscosity of foam increases greatly with increasing expansion which is still another reason for using expansions of 3 to 4. However, even if one confines himself to an expansion of 3 there is still danger of obtaining a foam too viscous to extinguish the fire efficiently if the degree of

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dispersion of the air in the liquid is too high. On the other hand, if the degree of dispersion is not high enough the foam becomes unstable and loses water rapidly which prohibits forcing it through pipe lines, etc. Also, the water will fall rapidly from the foam on the surface thus lowering its resistance toward the heat and flame. Results of degree of this dispersion, conveniently represented as viscosity, is best shown by a graph as in Fig. 6. A suitable viscosity for the foam is within the range of 1.7 to 2.7 poises.

The viscosity values of Figure 6 were determined by a meter similar to one described in the German periodical Oel und Kohle, Nr 12, March 22, 1942, page 296. A ball $1\frac{1}{8}$ " diameter weighing 21 grams was drawn through a column of foam $2\frac{3}{8}$ " in diameter at a rate of 1 f. p. s. and the resistance of the ball observed in grams. To obtain the results in absolute units various oils of known viscosity were run and a calibration curve made from grams to poises.

Still another critical factor is the type of foam agent employed. The high expansion (16-20) foam agents consisting mainly of surface tension reducing agents such as the sulfonated alcohols are relatively useless in subsurface work. Better results are obtained by the use of the hydrolyzed protein base foaming agent since foams produced therewith are more resistant to destruction by flame attack and these are greatly improved further by the addition of ferrous salts as stabilizers. For use on gasoline this added stabilizer is almost a necessity. In the main these agents consist of a partially hydrolyzed protein containing large amounts of peptones, an intermediate product in the hydrolysis of proteins to amino acids, prepared in a manner similar to that described in British Patent 517,767.

The foam velocity as it enters the tank should not be higher than 5 to 6 ft./sec. as the foam will be diffused too greatly through the fuel becoming contaminated to an extent where it will not possess in full the desired extinguishing properties.

A foam inlet should be provided for every 4000 square feet of tank surface area especially in the case of volatile fuels. It is desirable to use a

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foam generator in which the rate of application can be readily controlled while keeping the expansion viscosity at the optimum, thus enabling its use in all sizes of tanks.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

10 What is claimed is:

1. A method of extinguishing light liquid hydrocarbon fires in tanks which comprises introducing into and beneath the surface of the light liquid hydrocarbon at a velocity of not more than 6 feet per second and at a volume rate of not less than about 0.25 gallon per minute per square foot of the light liquid hydrocarbon surface, a foam mechanically produced from air, water and a foam stabilizing agent capable of producing a foam resistant to destruction by flame attack, said foam having an air-water volume ratio of from about 3:1 to about 2:1 and a viscosity of from about 1.7 to about 3.7 poises.

2. A method as defined in claim 1, wherein the foam has been mechanically produced from air, water and a foam stabilizing agent comprising partially hydrolyzed protein.

3. A method as defined in claim 2, wherein the foam stabilizing agent comprises partially hydrolyzed protein and a polyvalent metal salt.

4. A method as defined in claim 1, wherein the light liquid hydrocarbon is gasoline and the foam has been mechanically produced from air, water and a foam stabilizing agent comprising partially hydrolyzed protein and a ferrous salt.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,115,887	Bartels	Nov. 3, 1914
2,324,605	Urquhart	July 20, 1943