March 28, 1950 C. A. GETZ 2,502,143

FIRE EXTINGUISHING METHOD

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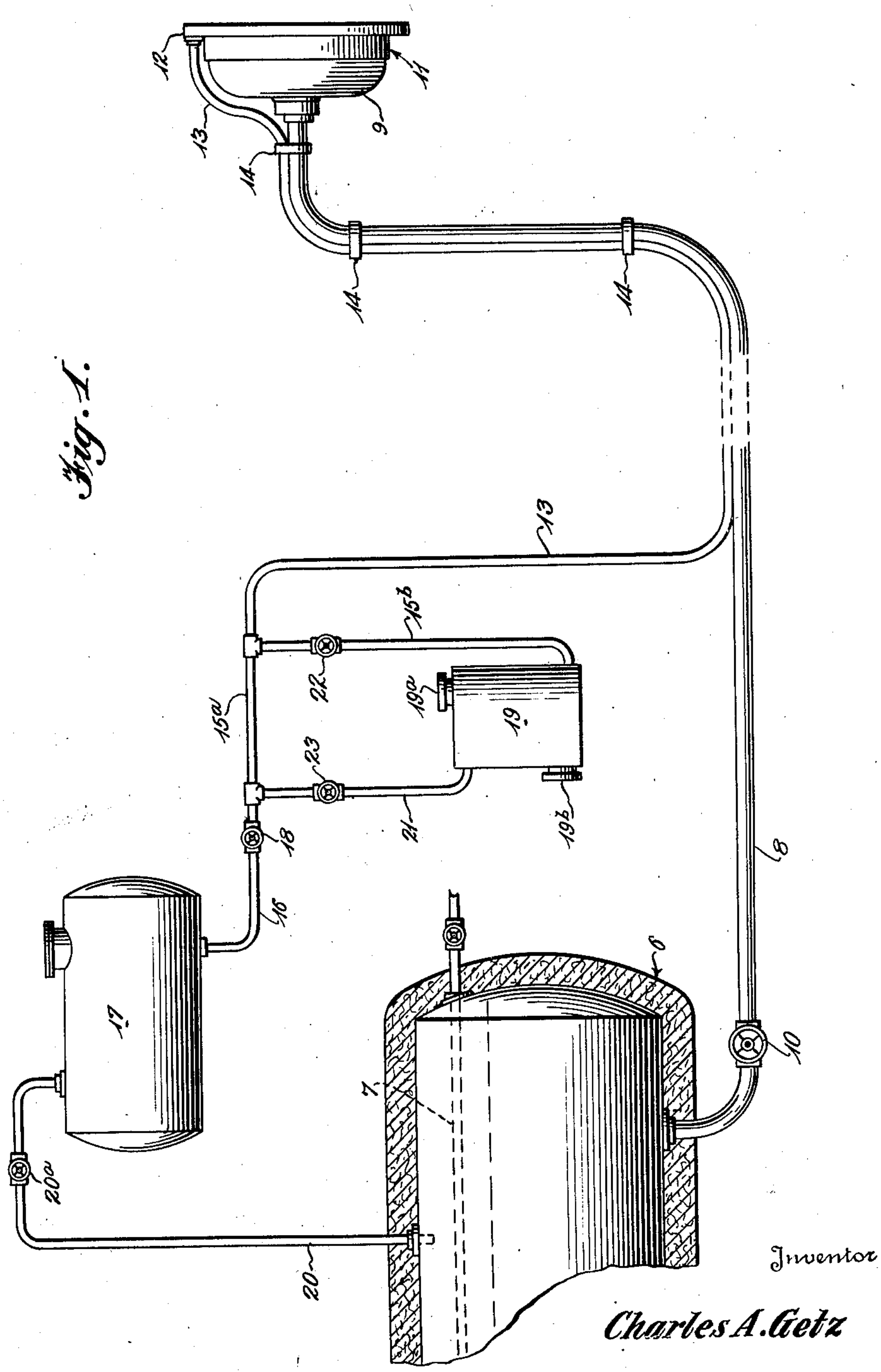
Fig. 1.



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FIRE EXTINGUISHING METHOD

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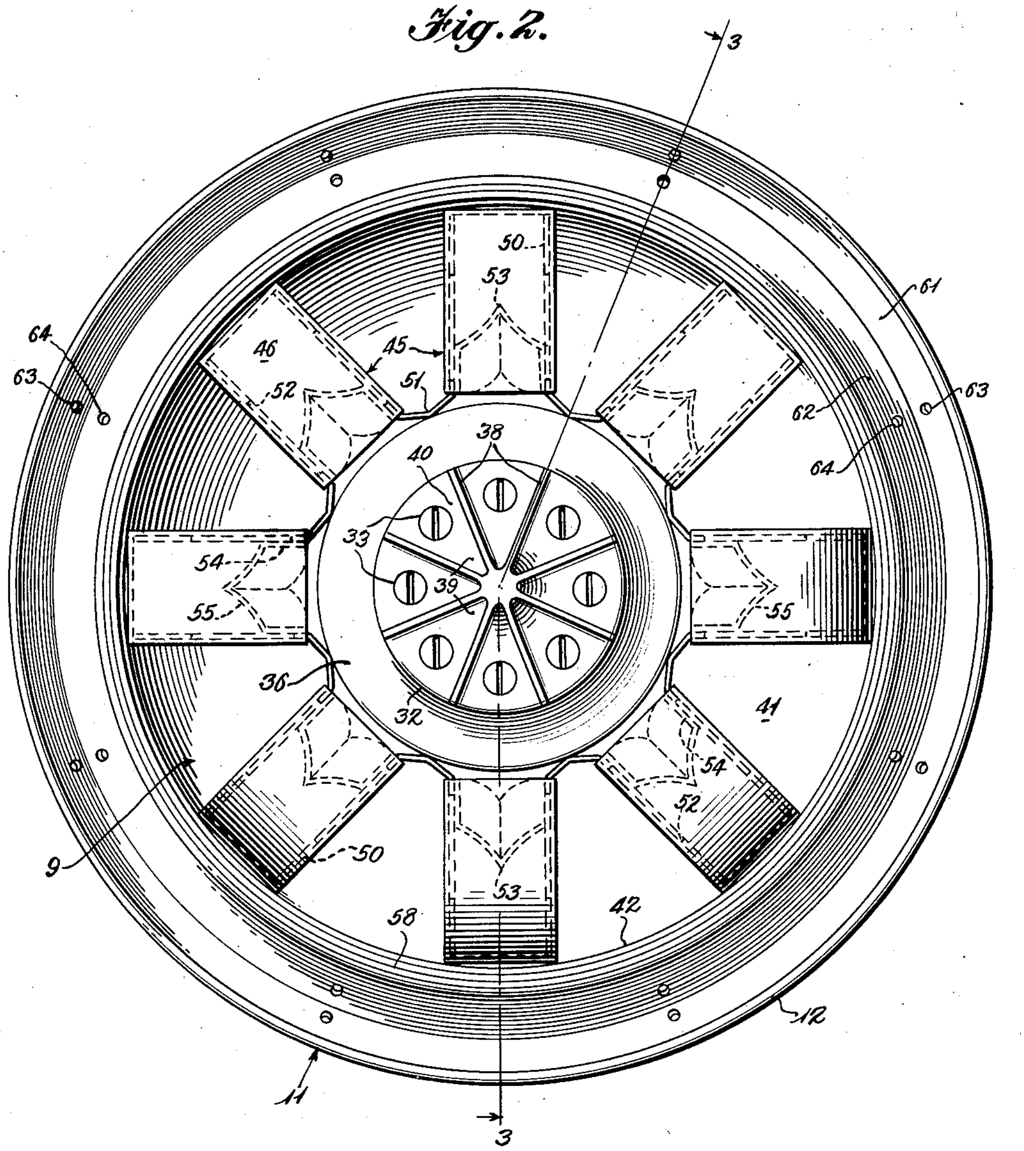
Fig. 2.



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FIRE EXTINGUISHING METHOD

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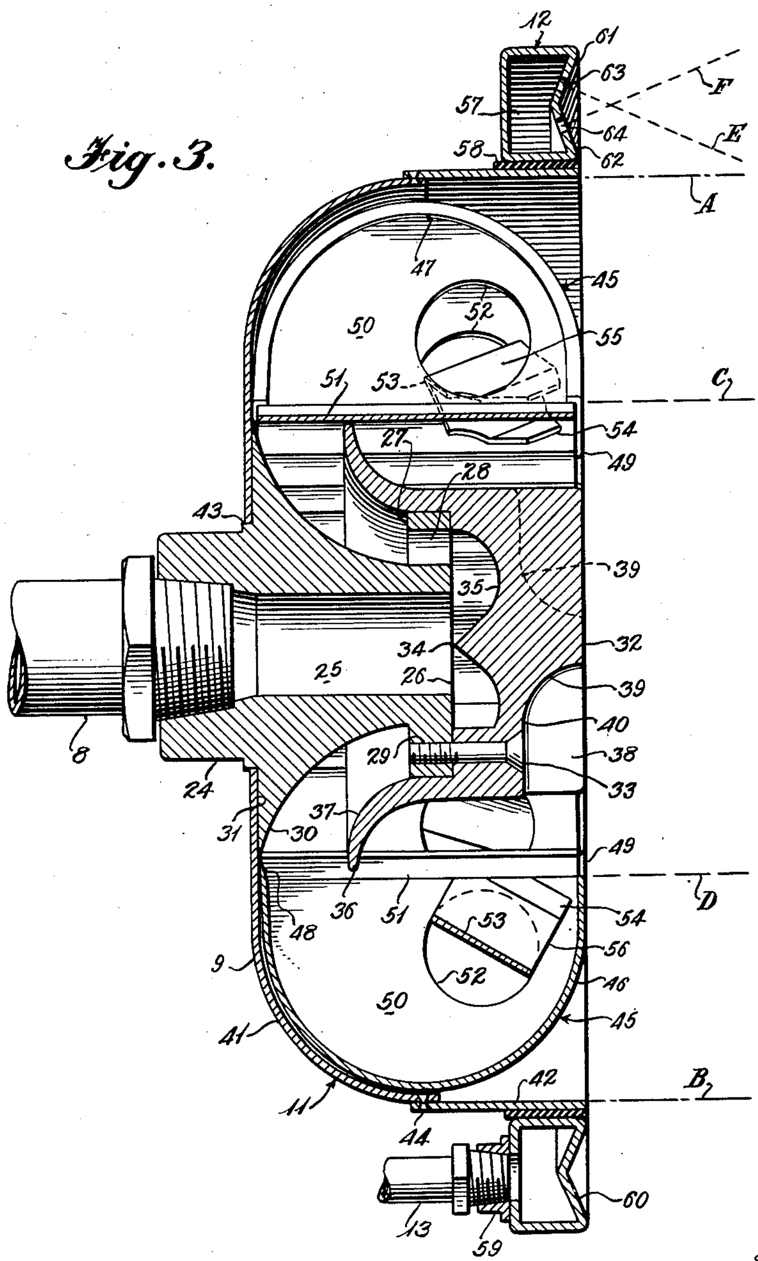
Fig. 3.



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FIRE EXTINGUISHING METHOD

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Fig. 5.

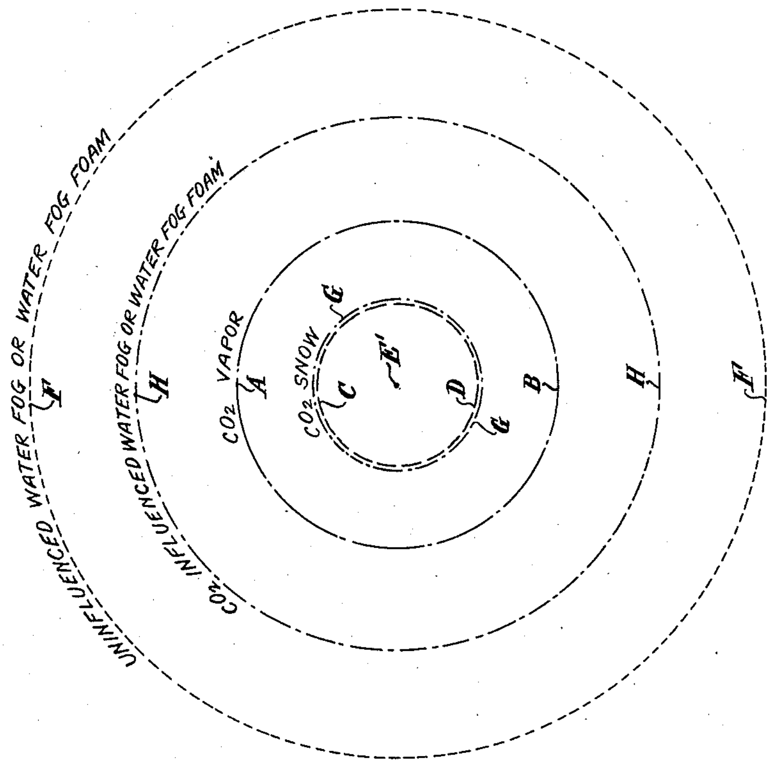
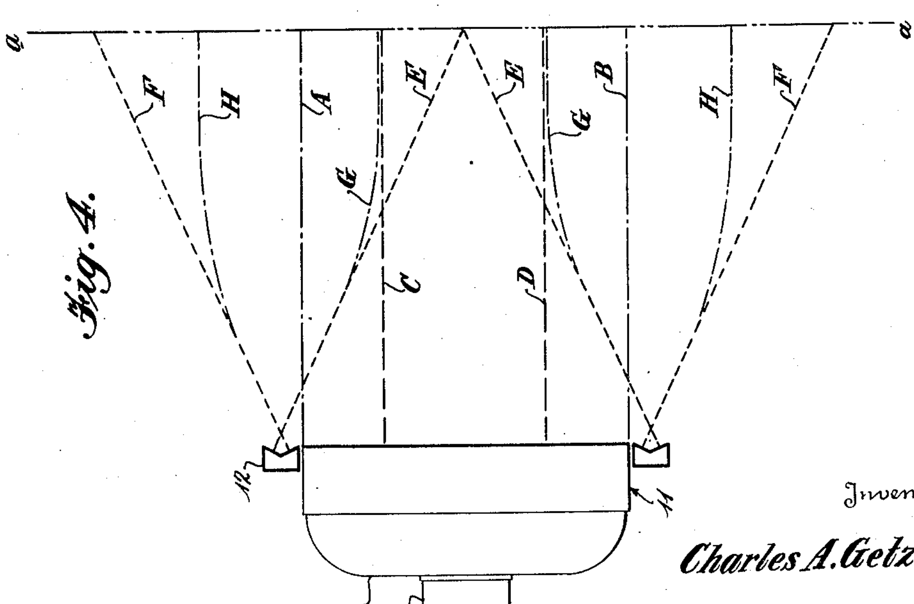


Fig. 4.



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FIRE EXTINGUISHING METHOD

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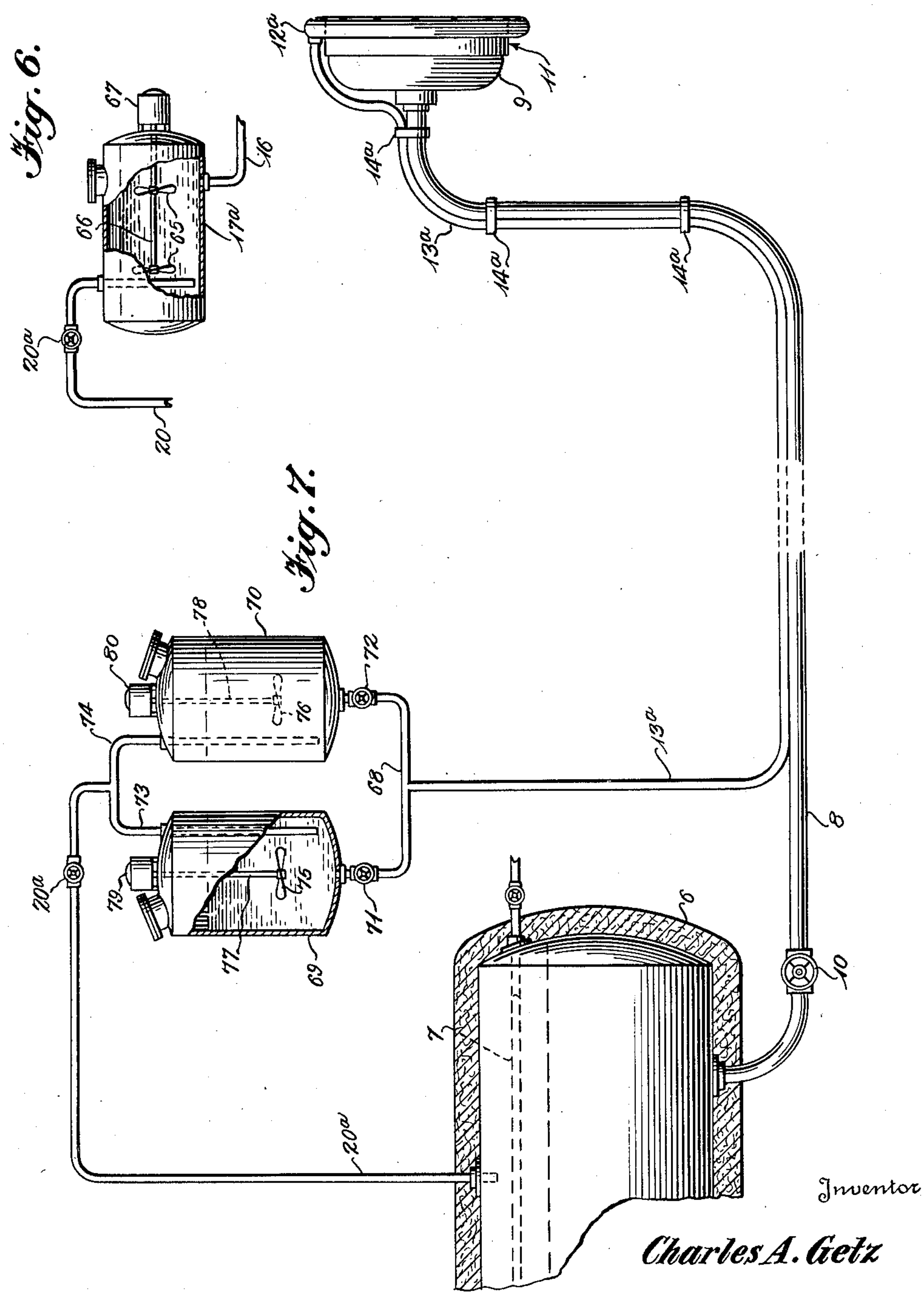

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FIRE EXTINGUISHING METHOD

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Fig. 8.

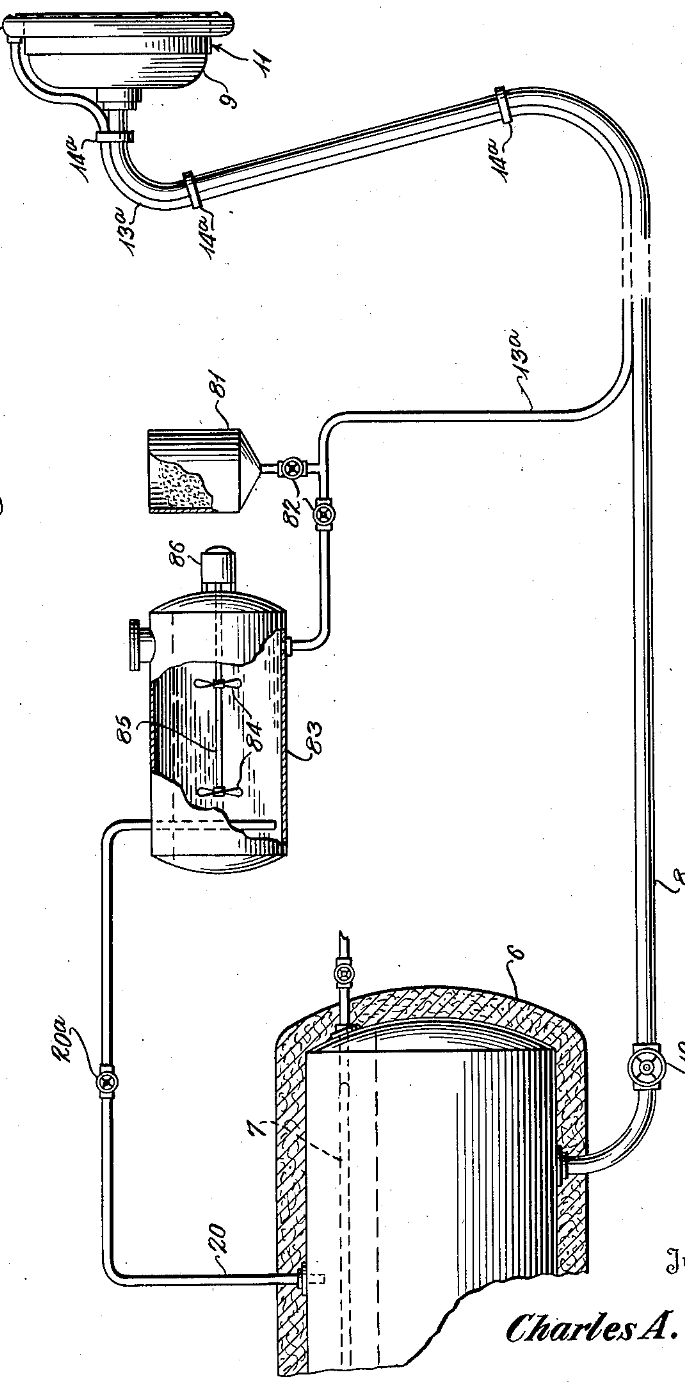

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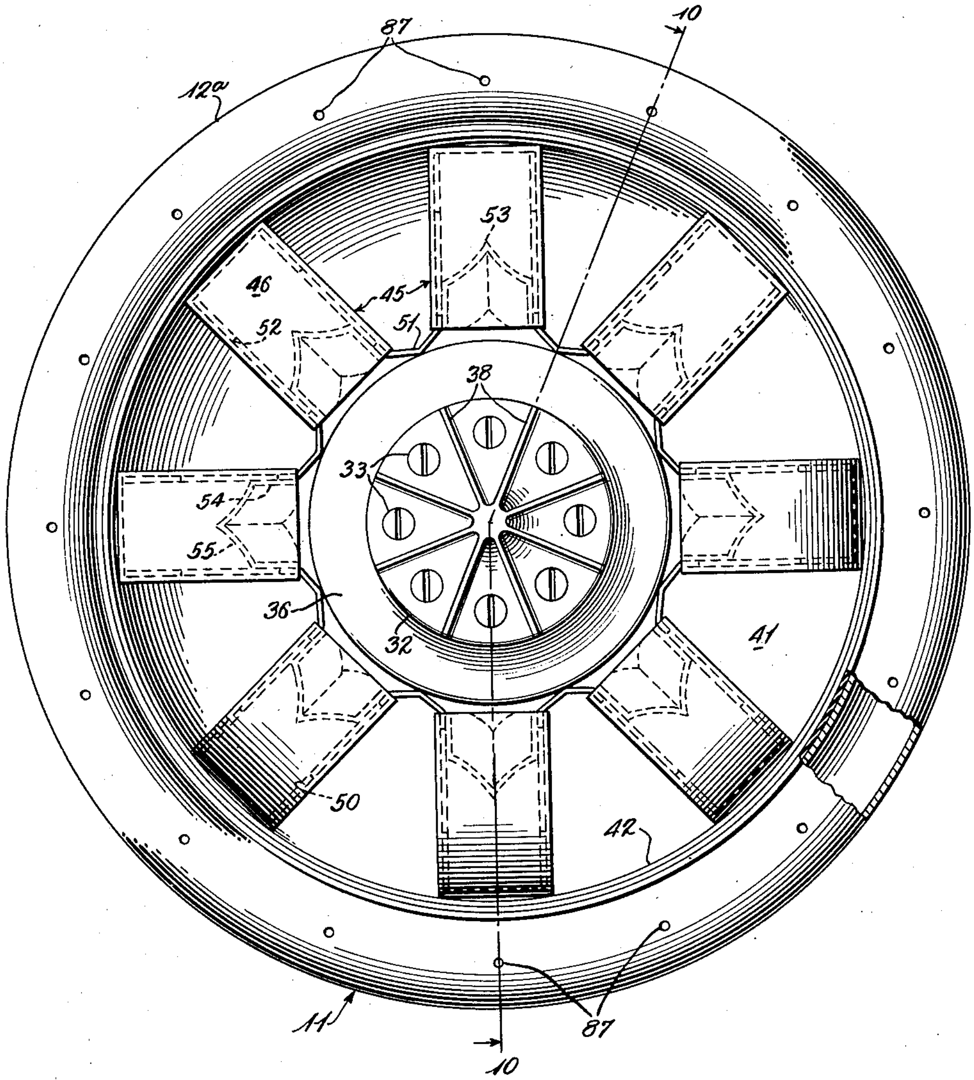
Fig. 9.



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March 28, 1950 C. A. GETZ **2,502,143**

FIRE EXTINGUISHING METHOD

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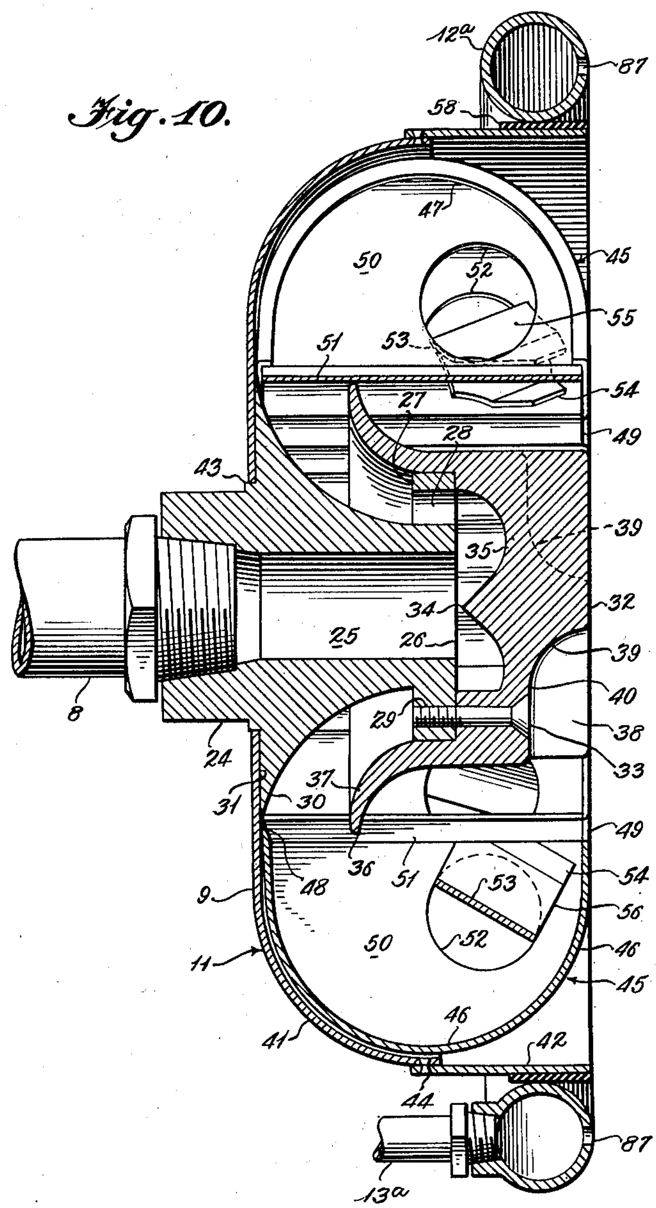
Fig. 10.



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FIRE EXTINGUISHING METHOD

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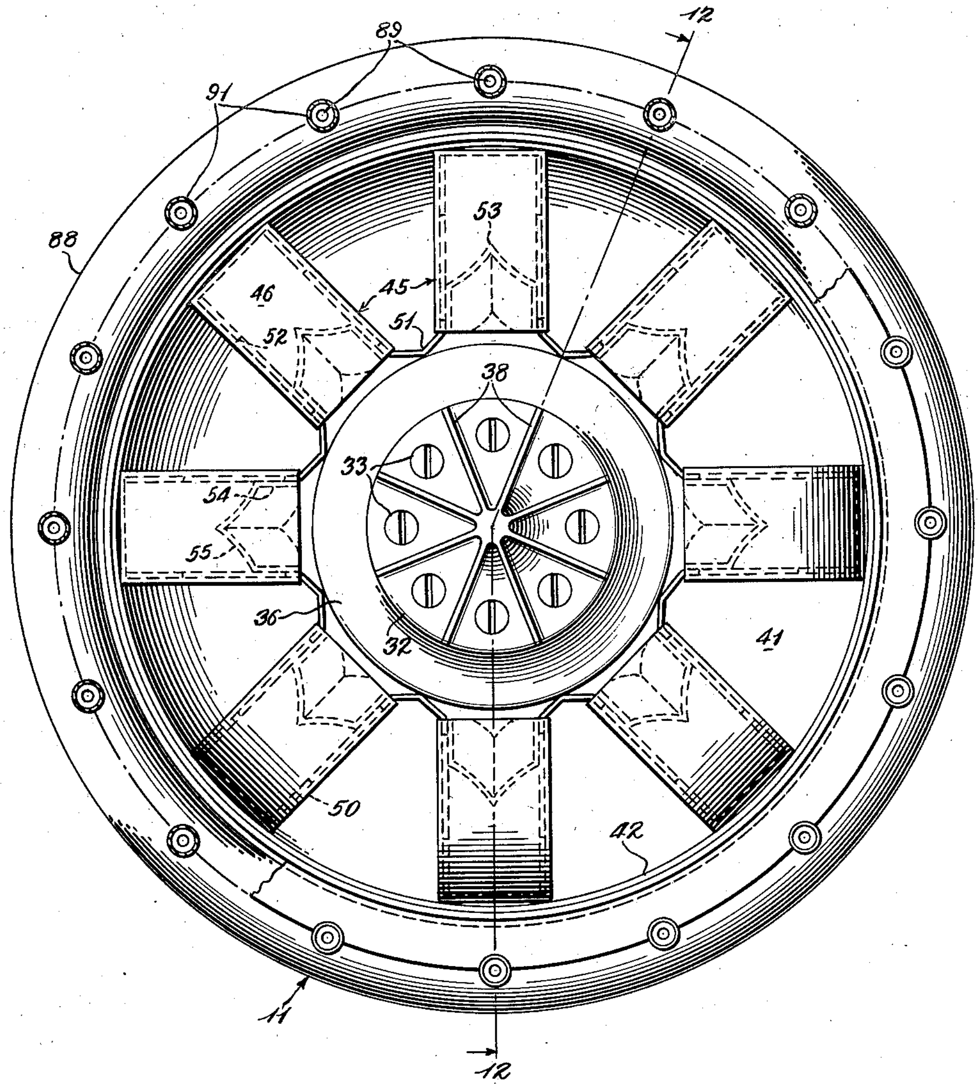
Fig. 11.



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FIRE EXTINGUISHING METHOD

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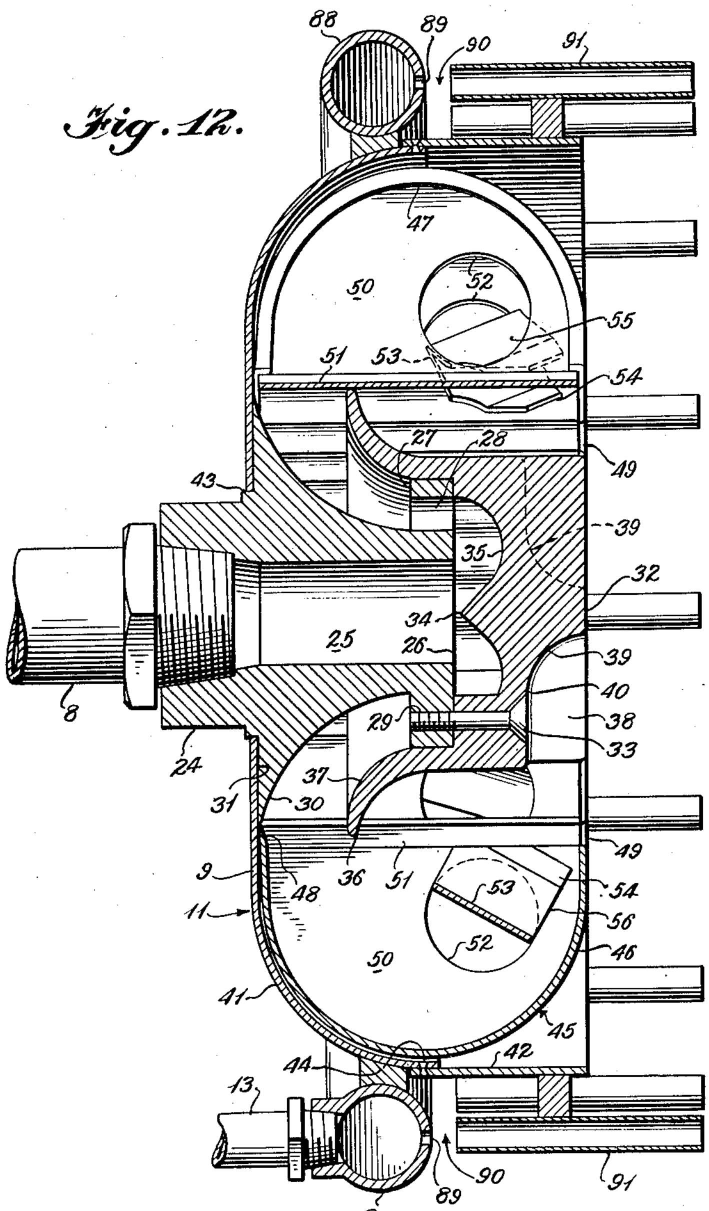
Fig. 12.



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Patented Mar. 28, 1950

2,502,143

UNITED STATES PATENT OFFICE

2,502,143

FIRE-EXTINGUISHING METHOD

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Application August 30, 1944, Serial No. 551,869

26 Claims. (Cl. 169—11)

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This invention relates to new and useful improvements in methods for extinguishing fires. This application is a continuation-in-part of my copending application Ser. No. 502,175, filed September 13, 1943, now abandoned.

Patent No. 2,352,399, issued to Leonard D. Myers on June 27, 1944, broadly covers the development of combining pre-formed water fog with carbon dioxide snow and vapor to provide an extinguishing medium discharge that possesses very marked improvements in carrying range and penetrating capacity, as well as ability to more quickly extinguish fires and cool the material being consumed, as well as associated heat absorbing masses, to a temperature below that at which the combustible materials will rekindle or reflash.

The specific apparatus that is disclosed in the above identified patent produces a combined discharge stream of carbon dioxide and water fog. The carbon dioxide of the discharge consists of snow and vapor components which are separated or segregated to provide a snow core and a vapor enclosing or encircling envelope. The water fog is completely formed or generated before it is combined with the carbon dioxide. The water fog generating device is so constructed and arranged that the angle of projection of the fog causes complete entrainment of all of the water droplets in the carbon dioxide. The combining of the carbon dioxide and water fog may be such that the water droplets are entrained by both the snow core and the vapor envelope, or so that all of the water droplets are entrained by the vapor envelope. Because of this complete entrainment of the water fog by the carbon dioxide, the amount of water fog that is delivered to the scene of the fire is limited to the entrainment capacity of the components of the carbon dioxide discharge to which the water droplets are delivered. That is to say, a greater volume of water fog can be delivered to the fire zone when the water droplets are entrained by both the snow and the vapor of the carbon dioxide discharge than when water droplets are only entrained by the vapor.

It has been determined that the combined carbon dioxide and water fog discharge of the aforesaid patent is only slightly more effective for extinguishing Class "A" fires—fires involving ordinary combustible materials, such as paper, wood, etc.—when water fog is entrained by both the snow and the vapor than when water fog is only entrained by the vapor, notwithstanding the fact that twice the volume of water fog may be

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delivered to the scene of the fire when both the snow and the vapor are employed as carriers. This peculiarity was assumed to be due to the fact that Class "A" fires are most effectively extinguished by a medium which both quenches and cools; that all of the water droplets that are entrained by the carbon dioxide snow are converted to water ice particles and for that reason afford very little immediate quenching action; and that substantially all of the quenching action of the entire discharge is accomplished by the water droplets that are entrained by the carbon dioxide vapor which converts only a portion of the droplets to water ice.

It was discovered that the high velocity of the carbon dioxide discharge produces sufficient suction or aspirating action to create an air current or flow adjacent the periphery of and in the same direction as the carbon dioxide stream and that this fluid moving force or reaction could be relied upon to carry to the fire zone water fog or water fog foam that is projected in a certain relation with respect to the periphery of the carbon dioxide stream. This discovery led to the development of the structural arrangement of the extinguisher discharge apparatus shown in the drawings of the present application, wherein the generated water fog or water fog foam is projected in such a manner that approximately one-half of it is actually entrained by the vapor envelope of the carbon dioxide discharge while the remainder is carried along to the fire zone by the aspirating action of the carbon dioxide stream.

Class "B" fires—fires involving flammable liquids, greases, etc.—are most effectively extinguished by a medium which cools and smothers. Carbon dioxide is an excellent extinguishing agent for this class of fires, including fluids of both high and low volatility, because of its high cooling capacity and its ability to form a smothering and fuel diluting blanket over the surface of the liquid. The single weakness of carbon dioxide for extinguishing fires of this class is that the carbon dioxide blanket dissipates rather rapidly and consequently fails to provide a relatively permanent protective blanket over the surface of the flammable liquid. The provision of such a permanent blanket is very important and highly desirable when the hazard involved includes spilled gasoline, or the like, because the relatively permanent blanket provides protection against reignition caused by accidentally created sparks, or the like.

Foam extinguishers are effective for Class "B" fires because of their extremely effective and permanent smothering characteristics. However, they are rather slow in their action, due to the necessity of gradually building up the blanket formation over the surface of the involved body of liquid. Their use is generally limited to the treatment of horizontal surfaces.

Water fog of the low-velocity variety depends primarily on cooling and diluting for its fire extinguishing action. Its range of application is limited because the water droplets are very small and necessarily have a low discharge velocity. Water fog is of distinct value in fighting fires involving the less volatile flammable fluids, such as fuel oil, but it has very definite limitations with reference to its use on the highly volatile liquids. For instance, burning gasoline flowing over a pavement can rarely be extinguished by water fog, although gasoline fires in open tanks, having a substantial amount of free-board, can some times be extinguished by directing the fog against the free-board if the latter is hot enough to convert the fog to steam.

Class "C" fires—fires involving electrical equipment—require a non-conducting extinguishing agent. Carbon dioxide undoubtedly is the best all-round extinguisher for this class of fires because of its non-damaging characteristics. However, electrical equipment that involves a substantial amount of insulation material that can smolder can only be extinguished with carbon dioxide by a prolonged application of the same.

Low-velocity water fog can be employed on electrical equipment fires because the fine droplets offer an enormous resistance to the flow of electricity and the quenching action of the water is very effective in extinguishing smoldering insulating material. However, complete extinguishment of electrical equipment fires by means of water in any form causes substantial property damage.

The use of foam on Class "C" fires is never recommended unless no other, more suitable extinguishing agent is available because of the high property damage that results and because foam is highly conductive of electricity.

From the above analysis of the different classes of fires and the effectiveness, or lack of effectiveness, of carbon dioxide, water fog, and foam as extinguishing agents therefor, it will be seen that no one of these agents is an "all purpose" extinguisher. It is because of that fact that city fire departments and the fire fighting organizations of large manufacturing plants, or the like, must be provided with different pieces of equipment for handling the different types of extinguishing agents that are required to combat all of the classes of fires such departments and organizations may be called upon to handle.

The primary object of the invention is the provision of methods of effecting quick and complete extinguishment of different classes of fires and of preventing reflashes by combined and/or separate applications of carbon dioxide and water fog foam, mechanical foam, chemical foam, or mechanical-chemical foam.

Another specific object of the invention is to provide methods of effecting the extinguishment of fires by means of a discharge stream consisting of a core of carbon dioxide snow, an encircling layer or envelope made up of a mixture of carbon dioxide vapor and pre-formed water fog foam, and an external layer or envelope of water fog foam.

A further object of the invention is to provide a method of effecting extinguishment by first attacking the fire with a combined discharge of carbon dioxide and pre-formed water fog foam to quickly dispose of the flame and partially cool down the burnt material and associated heat absorbing masses, and by finally applying to the surfaces of the burnt material and heat absorbing masses a cooling and smothering blanket formed of water fog foam to prevent reflash.

A still further object of the invention is to provide methods which are capable of effecting the extinguishment of different classes of fires as a result of the direct application of carbon dioxide and foam separately, or as a combination of carbon dioxide and foam.

Another object of the invention is to provide a method of effecting extinguishment by first attacking a fire with a combined discharge of carbon dioxide and foam; the foam being either of the water fog, mechanical, chemical, or mechanical-chemical type; to quickly dispose of the flame, cool down the burnt material and associated heat absorbing masses, and build up a thin smothering blanket of foam, and by finally completing the building up of a heavy smothering blanket of foam to prevent reflash.

Other objects and advantages of the invention will be apparent during the course of the following description.

In the accompanying drawings forming a part of this specification and in which like numerals are employed to designate like parts throughout the same,

Figure 1 is a diagrammatic view of the fire extinguishing apparatus embodying this invention,

Figure 2 is a front elevational view of the discharge apparatus for the fire extinguishing agents that are made available by the apparatus of Fig. 1,

Figure 3 is a sectional view taken on line 3—3 of Fig. 2,

Figure 4 is a diagrammatic view of the discharge apparatus of Figs. 2 and 3 and illustrates the projection angles, etc., of the carbon dioxide and the water fog or water fog foam discharges,

Figure 5 provides a diagram of the discharge pattern taken on line *a*—*a* of Fig. 4,

Figure 6 is an elevational view of a water carbonating tank which may be substituted for the water tank of Fig. 1,

Figure 7 is a similar view to Fig. 1 but illustrates apparatus for producing chemical foam for use with the carbon dioxide,

Figure 8 is a similar view to Figs. 1 and 7 but illustrates slightly different apparatus for producing chemical foam for use with the carbon dioxide,

Figure 9 is a front elevational view of the discharge apparatus for the fire extinguishing agents that are made available by the apparatus of Figs. 6, 7 and 8,

Figure 10 is a sectional view taken on line 10—10 of Fig. 9,

Figure 11 is a front elevational view of the discharge apparatus for the fire extinguishing agents that are made available by the apparatus of Figs. 1, 6, 7 and 8, and

Figure 12 is a sectional view taken on line 12—12 of Fig. 11.

In the drawings, wherein for the purpose of illustration are shown the preferred embodiments of this invention, and first particularly referring to Fig. 1, the reference character 6 designates in its entirety the insulated storage tank for liquid carbon dioxide. This liquid, preferably, is maintained at a desired subatmospheric temperature, and its corresponding low vapor pressure, by the cooling coil 7 which is included as a part of a mechanical refrigerating cycle. Although the liquid carbon dioxide used for carrying out this invention is more efficient and effective when it is at a preselected low temperature, and its corresponding low vapor pressure, it is to be understood that the invention contemplates the use of high pressure liquid carbon dioxide stored in a bank of pressure cylinders.

Liquid carbon dioxide is withdrawn from the insulated storage tank 6 through the pipe line 8 that extends to the carbon dioxide discharge portion 9 of the discharge apparatus or nozzle. A control valve 10 is illustrated as being provided in this carbon dioxide pipe line 8 adjacent the storage tank 6. This valve is employed for controlling the flow of liquid carbon dioxide from the tank to the nozzle portion 9. The valve 10 may be either manually or automatically operated, as desired. The pipe line 8 may be of a rigid character if the apparatus of Fig. 1 is employed as a fixed fire extinguishing system or if the entire apparatus is associated with mobile fire fighting apparatus of the type disclosed in the Eric Geertz patent, No. 2,352,379, issued June 27, 1944. This pipe line 8, also, may take the form of a flexible hose line if desired. If a flexible hose line is employed, a second control valve should be provided in close proximity to the carbon dioxide discharge portion 9 of the nozzle, in accordance with the disclosures of the patent to Hilding V. Williamson, for Fire extinguishing discharge apparatus, No. 2,354,631, issued July 25, 1944.

The discharge nozzle or apparatus, designated in its entirety by the reference character 11, also includes a water fog and water fog foam generating nozzle portion 12 which is associated with the periphery of the carbon dioxide discharge nozzle portion 9. A pipe line 13, which may either be rigid or flexible, depending upon the character of the carbon dioxide pipe line 8, is suitably attached at its outer end to the generating nozzle portion 12 and extends along a suitable part of the pipe line 8 to be attached thereto by clamps, bands, or the like 14. If the pipe line 8 takes the form of a flexible hose line and is provided with a valve adjacent the discharge nozzle 11, the pipe line 13, also, should be flexible and it should be provided with a flow control valve adjacent the discharge nozzle 11.

The water pipe line 13 is intended to be used as a premixing chamber for water and a foam stabilizing chemical and is connected to the branch lines 15*a* and 15*b* for that purpose. The branch line 15*a* is connected to the water supply pipe 16 that is in turn connected to the water storage tank 17. A suitable control valve 18 is located in the water supply pipe 16 and is employed for controlling and regulating the rate of flow of water. The branch line 15*b* is connected to the supply tank 19 for the foam stabilizing chemical.

Although the water can be wtihdrawn from the tank 17 and propelled to the generating nozzle portion or ring 12 by means of a suitable electric motor or gasoline engine driven pump, not shown, it is preferred insofar as this invention is concerned to expel the water from the storage tank by means of carbon dioxide vapor pressure obtained from the insulated carbon dioxide storage tank 6. This vapor pressure is obtained by the pipe line 20 that extends from the vapor space of the carbon dioxide storage tank 6 to the top of the water storage tank 17. A suitable flow controlling and pressure regulating valve 20*a* is provided in the pipe line 20. Although a vapor pressure of approximately 90 pounds per square inch can be employed for expelling the water from the tank 17, it has been determined that fogging of the water by the generating ring 12 is more efficient when pressures from 125 pounds to approximately 200 pounds, per square inch, are employed.

The foam stabilizing chemical supply tank 19 is provided with a removable cap 19*a* for closing an opening through which the chemical is introduced and a second cap 19*b* for closing an opening through which the tank may be drained and flushed out. A branch line 21 receives water from the supply pipe 16 and delivers it to the top of the chemical supply tank 19. This water enters the tank and forces the foam stabilizing chemical out of the tank through its bottom connection wtih the branch line 15*b*. A valve 22 is connected in the branch line 15*b* for regulating the rate at which the chemical is discharged from tank 19. In this way, the amount of chemical flowing through branch line 15*b* into the pipe line 13 as compared to the amount of water flowing through branch line 15*a* into the pipe line 13 can be regulated and controlled to obtain the desired proportions. Valve 23 is connected in branch line 21 to permit the chemical tank 19 to be completely cut off from pipe lines 13 and 16 for filling and cleaning purposes.

The foam stabilizing chemical placed in tank 19 can be any of the well known stabilizing agents, such as an aqueous solution of saponin, secondary extract of licorice, leguminous extract, extract of tanbark, or the like. When the apparatus is subjected to freezing temperatures, a suitable anti-freeze solution, such as calcium chloride, is added. This foam stabilizer can be mixed with water during the flow of the latter through the pipe line 13 and no foaming will occur until the mixture is discharged. If desired, the foam stabilizer can be premixed with the water in tank 17 and the chemical supply tank 19, with its piping, dispensed with.

Because of my desire to be able to generate either water fog or water fog foam at selected intervals by means of the generating nozzle ring 12, I can control delivery of the foaming chemical to the water flow pipe line 13 by means of valves 22 and 23.

The construction of the discharge apparatus or nozzle 12 is best disclosed in Figs. 2 and 3 and will be described in detail in connection with these figures.

The carbon dioxide discharge portion 9 of the complete nozzle is of the type disclosed and broadly claimed in the patent to Hilding V. Williamson, No. 2,357,039, issued August 29, 1944. The liquid carbon dioxide supply pipe line 8 is suitably threadedly connected to the stem or shank 24 of the carbon dioxide nozzle portion 9. This stem or shank 24 is provided with a bore 25 for delivering the liquid carbon dioxide to the interior of the body portion of the nozzle. The outer or forward end 26 of this bore communicates with the interior of a deflector element and cooperates with this element to form a flow path for the liquid carbon dioxide. The stem or shank 24 has formed on its outer end a radially extending flange 27 which is formed with a circular series of orifices 28 through which the liquid carbon dioxide is released to permit sudden expansion so that its pressure will drop below 75 pounds per square inch, absolute, which will cause a certain percentage of the liquid to flash to snow while the remainder of the liquid is vaporized. This annular flange 27 is further provided with a circular series of threaded openings 29, for a purpose to be explained at a later point. Exteriorly, the stem or shank 24 is provided with a rearwardly curved or flared surface 30 that terminates in a shoulder 31.

The deflector element referred to above is identified by the reference character 32 in Figs. 2 and 3. This deflector element is secured to the flange 27 by means of the series of screws 33 that are threaded into the holes 29 of the flange 27. The deflector is partially hollowed out so as to control the direction of flow of the liquid carbon dioxide to the discharge orifices 28. For this purpose, the interior of the deflector is provided with a conically shaped projection 34 that is axially aligned with the bore 25 of the shank or stem 24. The interior of the deflector element 32, radially outwardly of the spreading projection 34, is provided with the curved surfaces 35 that function to change the direction of flow of the liquid carbon dioxide so that it will be directed rearwardly through the discharge orifices 28. The inner or rear portion of the deflector element 32 is belled or curved outwardly at 36 to form an internal curved surface 37 that lies opposite to and cooperates with the curved exterior surface 30 of the stem or shank 24. Fig. 3 clearly shows that these two cooperating surfaces 30 and 37 diverge with respect to each other in any radial section to form an annular passageway that gradually increases in depth or thickness. This increase functions to permit further expansion of the released carbon dioxide so that the pressure of the same will drop still further and will provide for flashing of whatever liquid may remain as a part of the flowing material. The outer portion of the deflector element 32 is illustrated in Figs. 2 and 3 as being formed with radial ribs 38 which form the valleys 39 having curved inner surfaces 40 which will function to deflect forwardly or axially any of the discharged medium that comes in contact with the same.

The deflector element 32 and the cooperating portion of the stem or shank 24 are enclosed within a chambered body or casing which is formed by the inner portion 41 and the outer portion 42. The inner portion 41 of the body or casing is dish shaped and is centrally cut away at 43 to permit the inner portion of the stem or shank 24 to pass therethrough so that the shoulder 31 of the said stem or shank will act as a seat or an abutment for this inner portion 41 of the body or casing. Any suitable means may be provided for securing the body or casing portion 41 to the shoulder portion 31, such as by welding or by the use of suitable screws or bolts. The outer portion 42 of the body or casing is of cylindrical shape and has its inner edge portion overlapped or telescopically associated with the outer marginal edge portion of the inner body part 41 to provide a lapped joint 44. Welding, or the like, may be employed for rendering this joint permanent. Figs. 2 and 3 clearly show that the body or casing of the carbon dioxide discharge nozzle portion cooperates with the stem or shank 24 to provide a closed rear wall while leaving the front of the apparatus entirely open. The body or casing additionally cooperates with the stem or shank 24 and the deflector element 32 to form an annular

chamber for receiving the circular series of flow controlling and directing units 45.

These units 45 are equally spaced around and extend radially of the stem or shank 24 and the deflector element 32. Each one of these units includes a semi-circular or semi-cylindrical band 46 which is flanged at both of its longitudinal edges 47, see Fig. 3. The inner transverse edge 48 of each one of these bands 46 is suitably anchored either in close proximity to or in contact with the periphery of the flared portion or surface 30 of the stem or shank 24. The outer edge 49 of each one of these bands 46 terminates in the plane of the outer face of the body or casing portion 42 and the outer edges of the deflector element ribs 38.

The opposite sides of each one of these flow controlling and directing units 45 are formed by wall members 50 which lie inside of the edge flanges 47 and are suitably secured thereto. These Figs. 2 and 3 show the opposite side walls of each adjacent pair of units 45 as being formed by a single piece of sheet material with the center or intermediate portion of each one of these side wall forming pieces designated by the reference character 51. These center or intermediate portions 51 function to bridge the gaps or spaces left between the inner edges or sides of adjacent units 45.

Fig. 3 clearly discloses the side walls 50 of the several units 45 as having apertures 52 formed therein. These apertures are formed in the outer or front halves of the side walls 50; i. e., relatively close to the outer edges 49 of the bands 46. Each flow controlling and deflecting unit 45 has mounted within the same a plow-shaped deflecting and separating element 53. These elements are of V or wedge shape in section with securing flanges 54 formed on the sides thereof for securing, such as by welding, the elements 53 in their proper places within the units 45. Fig. 3 discloses these deflecting and separating elements 53 as being arranged with respect to the side wall openings or apertures 52 so that the lateral sloping surfaces 55 of each element will split or spread any material flowing through the interior of a unit 45 so that this material will be deflected through the cooperating side wall openings or apertures 52. These elements 53 are shown in Fig. 3 as being arranged so that their outer transverse edges 56 are spaced from the inner surfaces of the outer end portions of their associated bands 46. In other words, a space or gap is left between the inner surface of the hand 46 of each one of the units 45 and the outer edge 56 of its associated deflecting and separating element 53 through which the extinguishing medium may flow to the outer edge 49 of the band 46.

The mode of operation of the carbon dioxide discharge nozzle portion described above is explained in detail in the aforesaid Hilding C. Williamson patent and for that reason its mode of operation will be more generally set forth herein. Liquid carbon dioxide, at any desired pressure and temperature, will be delivered to the bore of the shank or stem 24 and will flow as a liquid to the discharge orifices 28. As the liquid carbon dioxide leaves these orifices, it expands suddenly and its pressure drops to such an extent that the liquid flashes and vaporizes. The carbon dioxide that enters the space formed between the outwardly flared surfaces 30 and 37, therefore, takes the form of a mixture of snow and vapor. Depending upon the temperature of the liquid carbon dioxide that is delivered to this discharge apparatus, a certain percentage of the same will flash into snow as a result of the self-cooling action that is produced. In other words, the entire discharge from the peripheral mouth, formed by the outer edges of the surfaces 30 and 37, will consist of a mixture of snow and vapor.

This snow and vapor mixture, as it leaves the aforesaid peripheral mouth, will be flowing in a truly radial direction. Some portions of the mixture will pass directly into the various flow controlling and directing units 45. The remainder of the mixture will be split and deflected laterally in opposite directions by the axially extending portion 51 of the side wall forming pieces 50. These deflected portions of the mixture, therefore, will be directed into the several units 45.

The outer curved bands 46 of the flow controlling and directing units 45 will deflect the flowing mixture from its straight line, radial path and convert the straight line flow of the same into a curvilinear flow or motion. As the carbon dioxide snow of the mixture is many times more dense than the carbon dioxide vapor, and as the velocity of both of these components is the same, the snow offers more resistance to the deflecting force exerted by the obstructing, curved bands 46 with the result that the snow will be moved to the outer side of each one of the curvilinear flow paths for the material. The snow, in seeking this outer portion of each flow path, will crowd or force the vapor inwardly away from the inner surfaces of the various bands 46. The difference in density of the snow, as compared to the vapor, therefore, effects a segregation of these two components. The snow is segregated at or close to the outer side of each one of the curvilinear paths while the vapor is segregated on the inner side of each path.

As the segregated snow and vapor reach the outer side of each one of the flow controlling and directing units 45, the snow passes through the gap or space left between the inner surface of its band 45 and the outer edge of its flow splitting and separating element 53. The inwardly positioned, segregated vapor, however, strikes the sloping surfaces 55 of the various elements 53 and is directed laterally through the side wall apertures 52 into the portions of the body or casing which lie between adjacent units 45. The segregated and separated snow passes radially outwardly beyond the edges 49 of the several bands 46 and is directed into the valleys 39 of the deflector element 32. The curved inner surfaces 40 of these valleys deflect the snow so that it will flow, or will be discharged, to the atmosphere in an axial direction with respect to the entire carbon dioxide discharging apparatus. This discharge of all of the separated snow from all of the units 45 causes the same to be assembled into a compact, dense core for the entire carbon dioxide discharge. The separated vapor will leave the spaces between the adjacent units 45 and will flow in an axial direction relative to the discharge apparatus. The vapor is in this way discharged outwardly of the dense snow core. Because the areas of discharge for the vapor are spaced distances equal to the width of the flow controlling and directing units 45, the vapor discharges will be separated from each other immediately adjacent the front face of the apparatus. However, the vapor discharges will blend together a short distance in advance of the apparatus and will form a surrounding or enclosing vapor envelope for the compact, dense snow which forms the core of the composite discharge.

From this description of the mode of operation of the discharge apparatus for the carbon dioxide, it will be appreciated that there is provided a discharge stream which is of substantially circular shape in transverse section. In Fig. 3 of the drawings, the dotted lines A and B are intended to represent the peripheral margin of this composite stream on the section of this figure. The dotted lines C and D are intended to illustrate the peripheral margin of the compact, dense snow core. Therefore, the inner and outer margins of the vapor envelope are represented by the dotted lines A—C and B—D.

The water fog and water fog foam generating portion 12 of the entire discharge nozzle or apparatus consists of the hollow water ring 57 that surrounds the outer edge portion of the body or casing part 42. Any suitable means may be employed for properly attaching this water ring to the body or casing and a band of any suitable heat insulating material of any proper thickness may be provided at 58 to insulate the water in the interior of the ring from the low temperature of the body or casing part 42. Water by itself or mixed with the foam stabilizing chemical is supplied to the interior of the ring by the pipe line 13 through the suitable connection 59. The ring 57 is provided with a front wall 60 that is formed with the two annular, angularly arranged portions 61 and 62. Each one of these front wall portions is provided with an annular series of apertures which may be of any size or diameter desired. The apertures for the front wall portion 61 are designated by the reference character 63 while the apertures for the wall portion 62 are designated by the reference character 64. Each one of the apertures 63 is arranged in the same radial plane as an aperture 64 so that the axes of the several apertures 63 are angularly arranged with respect to the axes of the apertures 64. These axes are designated by the reference characters E and F respectively. By inspecting Fig. 2, it will be seen that the associated pairs of apertures 63 and 64 are radially aligned with the carbon dioxide vapor discharging spaces that are located between adjacent carbon dioxide flow controlling and directing units 45.

As a solid stream of water or water mixed with a foam stabilizer will be discharged through each one of these apertures 63 and 64, the streams for each associated, radially aligned pair of apertures will impinge against each other with the result that the water or water and foam stabilizer mixture of both streams will be broken up into a fog or a fog foam which is formed of very fine water droplets or foam bubbles of uniform size. This water fog or water fog foam will fill to a substantially uniform density all portions of the space lying between the angularly arranged axes lines E and F outwardly of the point or zone of impingement of the two streams.

Let us now consider the diagrammatic disclosures of Figs. 4 and 5 in connection with the disclosure of Fig. 3. Figs. 4 and 5 have applied thereto the reference characters A and B which designate the outer limits of the carbon dioxide discharge stream, and, of course, the outer limits of the carbon dioxide vapor envelope. The reference characters C and D are applied to Figs. 4 and 5 to designate the outer limits of the carbon dioxide snow core and the inner limits of the carbon dioxide vapor envelope. The reference characters E and F, also, have been applied to the disclosures of Figs. 4 and 5 to designate the angles of projection that are normally provided by the associated fog generating apertures **63** and **64**. Fig. 5 discloses the dotted lines of Figs. 3 and 4 translated into circles to illustrate the type of pattern provided by the discharges of carbon dioxide and water fog or water fog foam at the transverse plane that is represented by the line *a—a* of Fig. 4.

If we consider that the carbon dioxide is being discharged all by itself, the margins of the carbon dioxide stream will be represented by the circle A—B of Fig. 5. The circle C—D of this figure represents the outer margin of the snow core and the inner margin of the vapor envelope. If we now consider that the generating nozzle portion **12** is discharging all by itself; i. e., without any carbon dioxide discharge taking place, the outer ring F of Fig. 5 designates the outer projection margin of the water fog or water fog foam pattern on plane *a—a*. The center dot E' of Fig. 5 indicates where the inner projected margins of the water fog or water fog foam discharges intersect. These inner margins are represented by the dotted lines E of Fig. 4.

Let us now consider that we have a composite discharge of carbon dioxide and water fog or water fog foam. It has been determined that the high velocity of discharge of the carbon dioxide vapor, which occurs between the lines or circles A—C and B—D, deflects and entrains the portion of the water fog or water fog foam discharge that overlaps or coincides with the carbon dioxide discharge with the result that the water fog or water fog foam does not penetrate the carbon dioxide stream beyond the inner margin C—D of the carbon dioxide vapor. The deflected line G, therefore, is employed to designate the new inner margin of the water fog or water fog foam.

In the introductory portion of this specification, it has been stated that the aspirating action of the carbon dioxide discharge stream will function to carry with the stream, in a zone surrounding and encircling the carbon dioxide stream, the fine droplets of the water fog or the fine bubbles of the water fog foam that are properly associated with the periphery of the carbon dioxide stream. This aspirating action produced by the carbon dioxide stream, therefore, causes the outer margin F—F of the water fog or water fog foam discharge to be drawn in to parallelism with the outer margin A—B of the carbon dioxide stream. This deflection of the outer margin of the water fog or water fog foam discharge is represented by the lines H. These lines are curved in Fig. 4 axially of the composite discharge and take the form of a circle in Fig. 5. The water fog or water fog foam lying between the circles H—H and A—B of the pattern disclosure of Fig. 5 will be carried along the scene or zone of the fire by the aspirating action of the carbon dioxide stream. Of course, this inward deflection of the water fog or water fog foam discharge is accompanied by entrainment of some of the fog or fog foam by the carbon dioxide vapor portion of the composite discharge. Such peripheral entrainment by the carbon dioxide discharge stream is a normal, inherent function and it will be noted that if water fog or water fog foam were not being generated, the carbon dioxide stream would entrain air at its periphery.

It is believed that persons familiar with the art of producing and using foams for extinguishing fires will fully understand what is meant by the term "water fog foam" as applied to the type of foam that is produced by the apparatus so far described. Nevertheless the following explanation will be given so that no misunderstanding will be possible.

There are two well recognized types of fire extinguishing foams; i. e., mechanical air foam and chemical foam. Mechanical air foam is produced by discharging under pressure a mixture of water and a foam stabilizing agent in such a manner that air, or some other gas, will be mixed therewith and the air will be entrapped in the stable bubbles of the resultant foam. Chemical foam is produced by the reaction of two chemicals, stored either in dry or solution form, water and a stabilizing agent. The reaction produces a mass of carbon dioxide bubbles which are toughened, or rendered long-lasting by the stabilizing agent.

Heretofore, mechanical air foam has been discharged as a solid stream of air foam bubbles ready for application onto fire because the water, the stabilizing agent and the air, or other gas, are mixed and the foam produced upstream of the zone of discharge, or the discharge orifice. The "water fog foam" referred to above is of the mechanical air foam type but is produced in an unconventional manner. A mixture of water and a stabilizing agent is brought to a zone of discharge and released under pressure to the atmosphere as two, or more, impinging streams. The impingement breaks up the mixture into a fog and air is entrained or entrapped in each water particle to produce the water fog foam.

Tank **17** of the apparatus disclosed in Fig. 1 has been described as containing water which is expelled by means of carbon dioxide vapor which is delivered thereto by the pipe line **20**. If the carbon dioxide vapor is delivered to this tank **17** at the time the water is to be discharged through the pipe **16**, the carbon dioxide vapor merely functions as the expelling or propelling medium for the water. If the carbon dioxide vapor is delivered to the water tank **17** a considerable time in advance of the discharge of the water from this tank so that the water will be maintained under carbon dioxide vapor pressure for a substantial length of time, the water will be carbonated. If the apparatus of Fig. 1 is mounted on a vehicle that is moved some distance from a fire station to the scene of a fire and the carbon dioxide vapor is delivered to the water tank **17** prior to making the "run" to the fire, the agitation produced by the travel of the vehicle will assist in bringing about carbonation of the water in tank **17**.

It has been determined that by employing carbonated water, either with a suitable stabilizing agent mixed therewith in the tank **17** or with a stabilizing agent added thereto so as to become mixed therewith while flowing through the pipe line **13**, a new type of foam is produced. This new foam can best be described as a chemical-mechanical air foam because the bubbles of the foam have entrapped therein both carbon dioxide vapor and air. That is to say, the carbon dioxide vapor comes out of solution when the carbonated water and foam stabilizer mixture is formed and this released carbon dioxide vapor with the air that is entrained at the time of impingement are entrapped in the water particles of the fog.

Figure 6 discloses a water tank structure 17a which may be substituted for the water tank 17 of the apparatus disclosed in Fig. 1 when it is desired to use carbonated water under all conditions of operation of this apparatus. This tank 17a is supplied with carbon dioxide vapor from the carbon dioxide storage tank 6 through the pipe line 20 and the control valve 20a. In this arrangement, however, the pipe line 20 extends inwardly of the tank 17a to a point adjacent its bottom so that the carbon dioxide vapor will be required to bubble up through the water stored in this tank. The bubbling of the carbon dioxide vapor through the water will assist in effecting carbonation of the latter. Additional means to effect complete carbonation of the water by agitating the same is provided and takes the form of the stirring or agitating blades 65 which are mounted on the shaft 66 that extends through one end wall of the tank 17a for being driven by the electric motor, or other prime mover, 67.

It will be appreciated that this tank 17a can be employed in the apparatus of Fig. 1, in place of the illustrated tank 17, either when the apparatus of Fig. 1 is employed with the foam stabilizing chemical supply tank 19 operating as a result of having valves 22 and 23 open or when the foam stabilizer is premixed with the water in the tank 17a and the chemical supply tank 19 is rendered inoperative by closing valves 22 and 23.

Fig. 7 illustrates apparatus that is designed for generating chemical foam that is to be discharged with or independently of the carbon dioxide discharge. This apparatus includes the insulated storage tank 6 for liquid carbon dioxide which, preferably, is maintained at a desired subatmospheric temperature, and its corresponding low vapor pressure, by the cooling coil 7 that is included as a part of a mechanical refrigerating cycle.

Liquid carbon dioxide is withdrawn from the tank 6 through the pipe line 8 that extends to the carbon dioxide discharge portion 9 of the discharge apparatus or nozzle that is designated in its entirely by the reference character 11. A control valve 10 is provided in the pipe line 8 adjacent the tank 6. This valve operates in the same manner as the valve bearing the same reference character in the apparatus of Fig. 1.

The discharge nozzle or apparatus 11, also, includes the chemical fog discharge ring 12a which encircles the carbon dioxide discharge nozzle portion 9. A pipe line 13a, which may be either rigid or flexible depending upon the character of the carbon dioxide pipe line 8, is suitably attached at its outer end to the fog discharge ring 12a and extends along a suitable portion of the pipe line 8 to be attached thereto by clamps, bands, or the like, 14a. If the pipe lines 8 and 13a are flexible for manual manipulation, suitable control valves, not shown, should be interposed in both of these pipe lines adjacent the discharge nozzle assembly 11.

The pipe line 13a extends to and communicates with the manifold pipe 68 which has its two branches connected to the bottoms of the chemical solution tanks 69 and 70 respectively. Control valves 71 and 72 are provided in the branches of the manifold pipe 68 for controlling and proportioning the delivery of the chemical solutions from the tanks 69 and 70 to the pipe line 13a.

Chemical tank 69 provides a suitable source of supply of bicarbonate of soda and a foam stabilizing agent dissolved in water. Tank 70 provides a suitable source of supply of aluminum sulphate dissolved in water. The reaction of these two chemicals is well known in the art. The proper mixture of these two chemicals, with the stabilizing agent, will be conducted to the foam discharge ring 12a by the pipe line 13a. The manner in which this foam discharge ring 12a functions to deliver a plurality of solid streams of the carbon dioxide bubble type of foam will be explained at a later point.

The two chemical solutions stored in the tanks 69 and 70 are expelled by carbon dioxide vapor which is delivered by the pipe line 20 from the carbon dioxide storage tank 6. This pipe line 20 is provided with the same flow controlling and pressure regulating valve 20a referred to in connection with the disclosure of Fig. 1. The delivery end of this pipe line 20 is formed into two branch lines 73 and 74 which are illustrated as extending into the tanks 69 and 70 to points located near the bottoms thereof. When these branch lines 73 and 74 are arranged in the manner illustrated, the carbon dioxide vapor discharged into the tanks 69 and 70 will be caused to bubble up through the chemical solution stored in these tanks. The agitation of the solutions resulting from this upward movement of the carbon dioxide vapor will help to carbonate the water of the two solutions. To further aid in carbonating this water, stirring blades 75 and 76 are located in the tanks 69 and 70 respectively and are mounted on shafts 77 and 78 which extend through the tops of the tanks to be driven by electric motors, or other prime movers, 79 and 80 respectively.

This use of carbonated water in preparing the chemical solutions stored in the tanks 69 and 70 has been found to produce a chemical foam which is richer in carbon dioxide gas; i. e., liberates more of such gas, than chemical foam that is produced from solutions prepared with uncarbonated water.

Fig. 8 discloses fire extinguishing apparatus which differs from the disclosure of Fig. 7 only by the means for producing the chemical foam. The apparatus of Fig. 8 operates with a stored supply of dry foam producing chemical, or chemicals, as distinguished from a supply of two foam producing solutions. For that reason, the same reference characters will be applied to the corresponding structural elements of Fig. 8 and these elements will not be specifically referred to.

In this apparatus of Fig. 8, the foam delivery pipe line 13a has connected thereto a suitable storage hopper 81 which functions to deliver at the desired rate the dry powder chemical or chemicals for producing the foam. The hopper type of foam generating apparatus is well known in the art and for that reason no attempt has been made to illustrate in detail the aspirating mechanism, etc., by means of which the dry powder is delivered to and is mixed with the flowing stream of water. Conventional hopper type foam generators are of two different styles. One style uses a single foam producing powdered dry chemical which contains all of the necessary ingredients to initiate the chemical reaction for producing the desired foam. The other style uses two separate powdered dry chemicals which produce solutions at the generator, these solutions subsequently being brought together, usually at the discharge outlet, so as to mix at that point to produce foam.

The illustration provided by Fig. 8 is of the single powder hopper type. It is to be understood, however, that a two-powder type of hopper may be substituted without changing the principle or function of the apparatus as a whole.

The dry powder chemical or chemicals used in this type of foam generating system are well known in the art and need not be specifically identified.

Suitable controls **82** are merely diagrammatically illustrated and function in a conventional manner to determine the rate of feed of the foam producing powder or powders to the water stream flowing through the pipe line **13***a*.

The water required to produce the foaming solution, when mixed with the powder, or powders, supplied by hopper **81**, is stored in the water tank **83**. The water in this tank is expelled by carbon dioxide vapor pressure and the vapor pipe line **20**, with its control valve **20***a*, is illustrated for this purpose. Fig. 8, however, illustrates the pipe line **20** as extending to a point adjacent the bottom of tank **83** so that the liberated vapor will bubble up through the water to assist in carbonating the same. Agitation of this water to increase the degree and rate of carbonation is obtained by the stirring blades **84** mounted on the drive shaft **85** which extends outwardly of the tank **83** to be driven by the electric motor, or other prime mover, **86**.

The combined carbon dioxide and foam discharge nozzle or apparatus disclosed in Figs. 9 and 10 is primarily intended for use in connection with the apparatus illustrated in Figs. 7 and 8. This discharge apparatus of Figs. 9 and 10, however, can be incorporated in or used with the apparatus of Fig. 1 when the water for the foam is carbonated in accordance with the disclosure of Fig. 6.

The carbon dioxide discharge portion of the nozzle assembly shown in Figs. 9 and 10 is the same as the carbon dioxide nozzle portion **9** disclosed and described in detail in connection with Figs. 2 and 3. For that reason, the same reference characters will be applied to identical structural elements and no further description of this carbon dioxide discharge nozzle portion will be given at this time.

The foam discharging ring **12***a* is supplied with the desired foam producing solution by the pipe line **13***a*. This ring **12***a* is of hollow construction and merely includes a desired number of openings or orifices **87** through which solid streams of the chemical foam are discharged. These streams are arranged in parallelism with the axis of the carbon dioxide discharge nozzle portion **9** in the showing provided by Figs. 9 and 10. It will be understood, however, that the foam streams may be discharged at any desired angle with respect to the axis of the carbon dioxide discharge.

The discharge apparatus of Figs. 11 and 12 can be used to effect independent discharges, or a combined discharge, of carbon dioxide and mechanical air foam when substituted for the discharge apparatus of the system illustrated in Fig. 1.

Because the carbon dioxide discharge nozzle portion of the apparatus shown in Figs. 11 and 12 is the same as the nozzle portion **9** of Figs. 2 and 3, the same reference characters will be applied to like structural elements and the specific description of these elements will not be repeated.

The water and foam stabilizer mixture provided by the system of Fig. 1 will be delivered to the discharge ring **88** by means of the pipe line **13**. This mixture is discharged under the desired pressure through the series of openings or apertures **89**. These discharged streams flow through the air gap **90** and are delivered to the foam discharge tubes **91**. While passing through the air gaps **90**, air is entrained and mixes with the water and foam stabilizer in the tubes **91** so that solid streams of mechanical air foam will be discharged from the outer ends of the tubes **91**. This broad idea of entraining air in a mixture of water and a stabilizing agent to produce mechanical air foam is well known in the art and for that reason a more detailed description will not be provided.

The disclosure of Figs. 11 and 12 illustrates the mixture discharge openings or apertures **89** and the foam generating and delivering tubes **91** as being arranged with respect to the axis of the carbon dioxide discharge nozzle portion **9** so that the solid foam streams will be discharged in parallelism with the carbon dioxide discharge. It will be understood, however, that the apertures **89** and tubes **91** may be so arranged that the solid foam streams will be discharged at any desired angles with respect to the carbon dioxide stream.

Let us now consider the methods of extinguishing the various classes of fires that can be performed by the apparatus embodying this invention.

Class "A" fires—Extinguished by cooling and quenching

One of the best methods of extinguishing this class of fires has been determined to consist of first attacking the fire with a combined discharge of carbon dioxide and water fog to "knock down" or extinguish the flame and partially cool the burning material and associated masses of heat absorbing materials or objects, and then follow up with a discharge of the water fog all by itself. By so directing the initial discharge of carbon dioxide and water fog that the carbon dioxide portion of the composite stream will strike the heart or combustion zone of the fire, the encircling discharge of free water fog will start cooling down the associated heat absorbing masses because of its wetting action. If the fire zone is so large that its combustion zone will take up the entire discharge of the carbon dioxide and water fog, the heat of the fire will convert the free water fog to steam and this conversion will help to cool the burning material. After the flame has been destroyed and the discharge of carbon dioxide has ben stopped, the water fog discharge will cover a considerably larger area, although its range has been reduced substantially because it cannot rely on the high velocity carbon dioxide discharge as a carrier. The water fog discharge will be employed to thoroughly wet down the surfaces of the burnt material and the associated heat absorbing masses with the result that all glowing embers will be extinguished.

Of course, the initial attack on the fire may be performed with only a carbon dioxide discharge and the water fog discharge not be employed until the final stages of the extinguishment, or until after the flame has disappeared. This method, however, is not as desirable because the combined carbon dioxide and water fog discharge possesses a higher total heat absorbing value than does the carbon dioxide when discharged by itself. Consequently, more carbon dioxide must be employed in carrying out this second method and, of course, carbon dioxide is more expensive than water.

Because all of the above referred to foams are composed largely of water which has a pronounced coolng and wetting effect that is very effective in the extinguishment of glowing embers, any one of the described foam discharges may be substituted for the water fog discharges in effecting extinguishment of Class "A." It will be obvious, however, that the foam producing chemicals will be wasted unless the hazard is of such a size or character that the building up of a foam blanket to prevent reflash or rekindling is deemed necessary.

Class "B" fires—Requiring cooling and smothering

It has been determined that the best method of extinguishing this class of fires is by initially attacking the same with a combined discharge of carbon dioxide and foam. This composite discharge is continued until the flame has disappeared and the associated heat absorbing masses have been cooled to a temperature below that at which the combustible vapors rising from the surface of the flammable liquid will reignite. On extended fires which are larger than the area covered by the discharge stream when the discharge apparatus is held stationary, it is necessary to begin the attack on one side and sweep the discharge slowly over the surface of the burning material so as to sweep the fire from one side to the other. During this action the combined discharge stream of carbon dioxide and foam is manipulated so as to form and maintain a continuous curtain between the fire and the flammable material which is no longer burning. A composite discharge will quickly extinguish the flame in the area which it covers and will also leave behind on the surface of the flammable fluid a thin film of foam containing particles of carbon dioxide snow. This surface film will prevent any sudden reflash which would ordinarily occur if the operator allows the discharge stream to waver for an instant so that a complete curtain is not maintained between the fire and the material that is not burning. Therefore, with this type of composite discharge the operator will have no difficulty in extinguishing relatively large fires which might otherwise be impossible to control. After the final portion has been extinguished, the foam is discharged by itself for the purpose of increasing the thickness of the foam blanket. If any of the flammable fluid has spilled over and remains on the surface of the surrounding ground, or the like, the final foam discharge is employed for blanketing down this free fluid. The foam blanket that is thus formed on the surface of the flammable fluid that still remains in its original confining tank, pool, or the like, and on the surface of the flammable fluid that is lying on the surrounding territory, prevents reignition by accidentally created sparks, or the like. This blanketing of all of the free flammable fluid is a very important method step in handling airplane crash fires because such fires are almost always accompanied by spilling of a substantial quantity of high octane aviation gasoline. This free gasoline is very readily reignited because all that is required is for a spark to be struck or created by a wrecking tool or the heel of a person engaged in rescue or salvage work.

Class "C" fires—Requiring cooling and frequently quenching

Fires involving electrical equipment can oftentimes be completely extinguished by the use of carbon dioxide all by itself. However, if a substantial amount of combustible insulating material is involved, glowing or smoldering portions of this material can best be quickly extinguished by quenching. Therefore, this class of fires can best be handled by first attacking the fire with a discharge of carbon dioxide by itself and this discharge is continued until the flame has been destroyed and the associated masses of metal that constitute the framework, casing, or the like, of the electrical equipment is thoroughly cooled. The glowing embers of smoldering insulating material can then be quickly extinguished by a very short discharge of water fog. This method of extinguishment results in the saving of a substantial amount of carbon dioxide and the final wetting down step can be accomplished with such a small volume of water that it effects very little if any permanent damage to the equipment.

It is to be understood that I do not desire to be limited to the exact sequence of method steps described above nor to the specific form of the apparatus that has been disclosed as the method steps and apparatus that have been shown and described are to be taken as preferred examples only, and that various changes in the method steps and in the shape, size, and arrangement of structural parts may be resorted to without departing from the spirit of the invention or the scope of the subjoined claims.

Having thus described the invention, I claim:

1. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating foam, projecting the foam in an associated relation with respect to the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

2. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating foam by the impingement of streams of a mixture of water and a foam stabilizing material, so associating the generated foam with the carbon dioxide stream that the carbon dioxide and foam will be simultaneously applied, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

3. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating foam, projecting the foam in such a relation to the carbon dioxide stream that a portion of the foam will be entrained by the carbon dioxide stream for delivery to the point of application while the remainder of the foam will be carried to the point of application as an encircling envelope by the

aspirating action of the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

4. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating foam at one or more points in close proximity to the periphery of the formed carbon dioxide stream, projecting the foam in such an associated relation with respect to the carbon dioxide stream that the carbon dioxide and foam will be simultaneously applied to the same general area of the fire, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

5. A method of extinguishing a fire, comprising effecting sudden release of liquid carbon dioxide to lower its pressure sufficiently to form a mixture of snow and vapor, effecting separation of the snow and vapor from each other, forming the separated snow and vapor into a composite discharge stream, separately generating foam, so projecting the foam that it will be carried to the point of application by the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

6. A method of extinguishing a fire, comprising effecting sudden release of liquid carbon dioxide to lower its pressure sufficiently to form a mixture of snow and vapor, effecting separation of the snow and vapor from each other, forming the separated snow and vapor into a composite stream in which the vapor surrounds the snow, separately generating foam, so projecting the foam that it will carry to the point of application of the carbon dioxide in closely associated relation with the surrounding vapor portion of the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

7. A method of extinguishing a fire, comprising the steps of first attacking the fire with a combined discharge of carbon dioxide and foam to quickly extinguish the flame, partially cool down the combustible material and associated heat absorbing masses, and form a thin cooling and smothering foam blanket on said material and masses; and then continuing the discharge of the foam by itself to increase the depth of the foam blanket until it is sufficient to prevent reflash.

8. A method of extinguishing a fire, comprising the steps of first attacking the fire with a combined discharge of carbon dioxide and mechanical air foam to quickly extinguish the flame, partially cool down the combustible material and associated heat absorbing masses, and form a thin cooling and smothering foam blanket on said material and masses; and then continuing the discharge of the foam by itself to increase the depth of the foam blanket until it is sufficient to prevent reflash.

9. A method of extinguishing a fire, comprising the steps of first attacking the fire with a combined discharge of carbon dioxide and chemical foam to quickly extinguish the flame, partially cool down the combustible material and associated heat absorbing masses, and form a thin cooling and smothering foam blanket on said material and masses; and then continuing the discharge of the foam by itself to increase the depth of the foam blanket until it is sufficient to prevent reflash.

10. A method of extinguishing a fire, comprising the steps of first attacking the fire with a discharge of carbon dioxide to quickly extinguish the flame and partially cool down the combustible material and the associated heat absorbing masses, and while the combustible material and associated heat absorbing masses are still partially cooled applying to their surfaces a cooling and smothering blanket of foam to prevent reignition or reflash.

11. In the method for extinguishing a fire involving flammable liquid confined in a tank, or the like, and spilled over a surrounding area, the improvement which comprises first attacking the fire with a combined discharge of carbon dioxide and foam to quickly extinguish the flame, to lower the temperature of the liquid and the associated tank and other adjacent heat absorbing masses to a value below the reignition temperature of the liquid vapors, and to leave a foam deposit on the surfaces of the confined and spilled liquid; and then delivering to the surfaces of the confined and spilled liquid additional foam to build up a foam deposit on said surfaces that will prevent reflash.

12. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating water fog foam, so associating the generated water fog foam with the carbon dioxide stream that the water fog foam will be carried to the point of application by the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and water fog foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

13. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating water fog foam, projecting the water fog foam in such a relation to the carbon dioxide stream that a portion of the water fog foam will be entrained by the carbon dioxide stream for delivery to the point of application while the remainder of the water fog foam will be carried to the point of application as an encircling envelope by the aspirating action of the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and water fog foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

14. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating

chemical foam, projecting the chemical foam in such a relation to the carbon dioxide stream that the carbon dioxide and chemical foam will be simultaneously applied to the same general area of the fire, and attacking the fire with the combined discharge of carbon dioxide and chemical foam to extinguish the flame and form a cooling and smothering blanket on the involved area.

15. A method of extinguishing a fire, comprising conducting liquid carbon dioxide to a region of release, permitting sudden expansion of the liquid to produce snow and vapor, projecting the snow and vapor into the atmosphere in the form of a stream, separately generating water fog foam at a plurality of points in close proximity to the formed stream of carbon dioxide, so projecting the water fog foam at all of said points that it will be carried to the point of application by the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and water fog foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

16. A method of extinguishing a fire, comprising effecting sudden release of liquid carbon dioxide to lower its pressure sufficiently to form a mixture of snow and vapor, effecting separation of the snow and vapor from each other, forming the separated snow and vapor into a composite discharge stream, separately generating water fog foam, so projecting the water fog foam that it will be carried to the point of application by the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and water fog foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

17. A method of extinguishing a fire, comprising effecting sudden release of liquid carbon dioxide to lower its pressure sufficiently to form a mixture of snow and vapor, effecting separation of the snow and vapor from each other, forming the separated snow and vapor into a composite discharge stream in which the vapor surrounds the snow, separately generating water fog foam, so projecting the water fog foam that a portion of it will be entrained by the said surrounding vapor portion of the carbon dioxide stream for delivery to the point of application while the remainder of the water fog foam will be carried to the point of application by the aspirating action of the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and water fog foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

18. A method of extinguishing a fire, comprising effecting sudden release of liquid carbon dioxide to lower its pressure sufficiently to form a mixture of snow and vapor, effecting separation of the snow and vapor from each other, forming the separated snow and vapor into a composite discharge stream in which the vapor surrounds the snow, separately generating chemical foam, and attacking the fire with a combined discharge of the carbon dioxide and chemical foam to extinguish the flame and cool the combustible material and associated heat absorbing masses.

19. A method of extinguishing a fire, comprising the steps of first attacking the fire with a combined discharge of carbon dioxide and water fog foam to quickly extinguish the flame and partially cool down the combustible material and the associated heat absorbing masses, and then applying to the surfaces of the combustible material and the heat absorbing masses a cooling and smothering blanket of water fog foam to prevent reflash.

20. A method of extinguishing a fire, comprising the steps of first attacking the fire with a discharge of carbon dioxide to quickly extinguish the flame and partially cool down the combustible material and the associated heat absorbing masses, and while the combustible material and associated heat absorbing masses are still partially cooled applying to their surfaces a cooling and smothering blanket of chemical foam to prevent reignition.

21. A method of extinguishing a fire, comprising the steps of first attacking the fire with a discharge of carbon dioxide to quickly extinguish the flame and partially cool down the combustible material and the associated heat absorbing masses, and while the combustible material and associated heat absorbing masses are still partially cooled applying to their surfaces a cooling and smothering blanket of water fog foam to prevent reignition.

22. A method of extinguishing a fire, comprising the steps of first attacking the fire with a discharge of carbon dioxide to quickly extinguish the flame and partially cool down the combustible material and the associated heat absorbing masses, and while the combustible material and associated heat absorbing masses are still partially cooled applying to their surfaces a cooling and quenching discharge of mechanical air foam to extinguish glowing embers, or the like.

23. In the method for extinguishing a fire involving flammable liquid confined in a tank, or the like, and spilled over a surrounding area, the improvement which comprises first attacking the fire with a combined discharge of carbon dioxide and water fog foam to quickly extinguish the flame, to lower the temperature of the liquid and the associated tank and other adjacent heat absorbing masses to a value below the reignition temperature of the liquid vapors, and to leave a foam deposit on the surfaces of the confined and spilled liquid; and then delivering to the surfaces of the confined and spilled liquid additional water fog foam to build up the foam deposit on said surfaces.

24. A method of extinguishing a fire, comprising the steps of first attacking the fire with a discharge stream consisting of a core of carbon dioxide snow, a core enclosing layer formed of a mixture of carbon dioxide vapor and foam, and an external envelope of foam to quickly extinguish the flame and cool down the combustible material and associated heat absorbing masses; and then continuing the discharge of foam by itself to build up a heavy foam deposit on the surface of the combustible material.

25. A method of extinguishing a fire, comprising producing and discharging to the atmosphere a stream of carbon dioxide snow and vapor, separately generating foam, projecting the foam in such a manner that it will be carried to the point of application by the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cool-

ing and smothering foam blanket on the involved material.

26. A method of extinguishing a fire, comprising producing carbon dioxide snow and vapor, discharging the carbon dioxide snow and vapor in a composite stream with the snow forming the dense core of the stream and with the vapor forming the exterior portion of the stream, separately generating foam, projecting the foam in such a manner that a portion of it will be entrained by the vapor of the carbon dioxide stream while the remainder of the foam will be carried to the point of application by the aspirating action of the carbon dioxide stream, and attacking the fire with a combined discharge of the carbon dioxide and foam to extinguish the flame and form a cooling and smothering foam blanket on the involved material.

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