

## **FIRE SUPPRESSION**

### **BACKGROUND**

**[0001]** Fire occurs for many reasons including unattended cooking, failure of an electronic device, improperly stored combustible materials and etc. Fire suppression systems such as sprinklers, consisting of water supply, are commonly installed in buildings to at least control or suppress fire at its incipient stage before it develops further and results in damages to the properties or before the arrival of fire brigades. The sprinkler system, consisting of water supply, however, can only be used to extinguish or minimize certain types of fire. Additionally, the typical sprinkler system requires the installation of a fire pump and this leads to exorbitant cost.

**[0002]** In view of the foregoing, there is a need to provide improved and cost effective fire suppression and extinguishing system.

### **SUMMARY**

**[0003]** A fire suppressant system is disclosed in one embodiment. The fire suppressant system includes a first sub-system having a first suppressant and a second sub-system having a second suppressant. The fire suppressant system further includes a control unit and a dispensing unit. The control unit controls the discharge of the first suppressant to a fire in a first suppressing phase to reduce at least a first element of the fire and the discharge of the second suppressant to the fire in a second suppressing phase to reduce a second element of the fire.

**[0004]** In another embodiment, a method of suppressing fire is disclosed. The method includes supplying a first suppressant to the fire in a first suppressing phase to reduce at least a first element of fire. The method further includes supplying a second suppressant to the fire in a second suppressing phase to reduce a second element of fire.

**[0005]** These and other objects, along with advantages and feature of the present invention herein disclosed, will become apparent through reference to the following description and the

accompanying drawings. Furthermore, it is to be understood that the features of the various embodiments described herein are not mutually exclusive and can exist in various combinations and permutations.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** In the drawings, like reference characters generally refer to the same parts throughout the different views. Also, the drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments of the present invention will now be described hereinafter, by way of example only with reference to the accompanying drawings, in which:

**[0007]** Fig. 1 shows a combustion triangle;

**[0008]** Fig. 2 shows an embodiment of a fire suppression system;

**[0009]** Fig. 3a shows a schematic diagram of an embodiment of a controller for a fire suppression system;

**[0010]** Fig. 3b shows an actual implementation of an embodiment of a controller for a fire suppression system;

**[0011]** Fig. 4 shows an embodiment of a dispensing unit;

**[0012]** Fig. 5 shows flux-time curves;

**[0013]** Fig. 6 illustrates suppressant flow of angled and non-angled dispensing units; and

**[0014]** Fig. 7 shows an alternative embodiment of a fire suppression system.

#### DETAILED DESCRIPTION

**[0015]** Embodiments generally relate to fire suppression system. The fire suppression system in accordance with the embodiments can be applied in various types of buildings, for e.g., offices, residential apartments, warehouse, or even to transportation vehicles such as aircraft or ships. The fire suppression system can be either a permanently installed or a portable system.

**[0016]** Fig. 1 shows a combustion triangle 100. The combustion triangle is a simple model, from the perspective of firefighting, for understanding the ingredients of fires. The combustion triangle illustrates the rule that in order to ignite and burn, a fire requires three elements. The three elements are heat, fuel, and an oxidizing agent, usually oxygen. Each element corresponds to a side of the triangle. A fire naturally occurs when the elements are combined in the right mixture. Preventing or extinguishing a fire can be achieved by removing any one of the elements. Embodiments suppress fire by depriving a fire of at least two elements which enables fire to burn.

**[0017]** Fig. 2 shows a fire suppression system 200 in accordance with one embodiment. The fire suppression system, in one embodiment, comprises first and second sub-systems 220 and 240, a control unit 260 and at least one discharge unit (270a or 270b). As shown, two discharge units 270a-b are provided. Providing other number of discharge units, including 1, is also useful. The number of discharge units may depend on the application, such as size of the area to suppress. Output ports of the supply units are coupled to inlets of the control unit while the outlet of the control unit is coupled to discharge units. In one embodiment, tubing and tubing couplers can be used to couple the different components of the system. The tubing, for example, comprises copper tubes or pipes. The couplers can be permanent or non-permanent couplers. Other types of tubing, such as stainless steel or copper pipes, or couplers are also useful. The diameter of the tubes can be about  $\frac{1}{4}$  or  $\frac{1}{2}$  inch. Providing tubes of other sizes are also be useful and may depend on design applications or requirements.

**[0018]** The first sub-system supplies a first fire suppressant to the system. The first suppressant, for example, is stored in a first storage container 222. The first suppressant suppresses at least a first element of fire. In one embodiment, the first suppressant suppresses or removes the oxygen element of fire. The first suppressant may also be used to suppress a second element of fire. For example, the first suppressant also suppresses the heat of the fire by cooling

the fire. Preferably, the first suppressant comprises carbon dioxide (CO<sub>2</sub>) gas. The CO<sub>2</sub> suffocates the fire and also cools the heated contents. The use of CO<sub>2</sub> advantageously avoids leaving a mess after being discharged.

**[0019]** In alternative embodiments, other types of first fire suppressants which suppresses at least the oxygen element of fire or other elements of fire may be used. The first suppressant may be in a gaseous or non-gaseous form such as powder or liquid. For example, the first suppressants may include NO<sub>2</sub> gas, water, FM200, dry powder and etc.

**[0020]** The second sub-system 240 supplies a second fire suppressant to the system. The second suppressant suppresses another or second element of fire. In one embodiment, the second suppressant suppresses, for example, the heat element of fire. Various types of suppressants which suppress the heat element can be used. In one embodiment, the second suppressant comprises water or H<sub>2</sub>O. The water, for example, can be discharged at ambient temperature. Other types of fire suppressants, whether in liquid or non-liquid form, which suppresses the heat element of fire or other types of suppressants that extinguish other elements of fire can also be used as the second fire suppressant. To supply water to the system, the second sub-system may be coupled to a water source 242 which supplies water to the house or building. Providing the second sub-system with a container storing the second suppressant is also useful.

**[0021]** The control unit controls the first and second sub-systems. For example, the control unit controls the actuation of the first and second sub-systems to dispense the first and second suppressants when the system is actuated or activated. In one embodiment, the control unit discharges the suppressants sequentially in first and second discharge phases. The control unit, in one embodiment, discharges the first suppressant in a first discharge phase and the second suppressant in a second discharge phase. The control unit can control the discharge phases mechanically, electronically or a combination thereof.

**[0022]** In one embodiment, the control unit discharges CO<sub>2</sub> in the first phase. Discharging other types of fire suppressants may also be useful. The first phase should be sufficient to reduce or eliminate at least the first element of fire. For example, a sufficient amount of first suppressants should be discharged for a sufficient duration to reduce or eliminate at least the first element of fire. The discharge rate may affect the discharge duration. For example, higher discharge rates may enable shorter discharge durations and vice-versa.

**[0023]** In one embodiment, the first phase discharges CO<sub>2</sub>. The amount of CO<sub>2</sub> that is discharge, for example, can range from about 20 – 300 g. Other amounts of discharge are also useful. For example, about 20 – 249 g, 20-100 g, 20-80g or 24-30 g may also be useful. For example, CO<sub>2</sub> can extinguish a small stove fire within 5 seconds. However, the discharge of CO<sub>2</sub> should continue for a longer period of time, such as at least one minute. Other amounts and duration may also be useful and may depend on the application as well as other considerations, among which may include the type of suppressants used and/or discharge rate. In one embodiment the amount and duration should be selected to effectively suppress at least the first element of fire which facilitates compactness of the system. For example, lower amounts suppressants used while still effectively suppress at least the first element of fire results in smaller or more compact systems.

**[0024]** In one embodiment, the system is actuated by a mechanical actuator. The mechanical actuator may be incorporated into the discharge unit. For example, the mechanical actuator maybe a heat-sensitive glass bulb. The actuator holds the discharge unit in a non-discharge or closed position. When the temperature reaches or exceeds an activation temperature, the actuator breaks due to thermal expansion. Breakage of the actuator activates or opens the discharge unit, causing suppressants to be discharged. The activation temperature, for example, may be about 93 °C. Other activation temperatures are also useful, depending on the application.

**[0025]** In alternative embodiments, the actuator may be an electrical or electro-mechanical actuator. For example, the actuator electrically or electro-mechanically senses temperature and activates the system when the temperature exceeds the activation temperature. Various types of actuators, such as heat sensors or solenoid valves can be used.

**[0026]** The actuator is provided for respective discharge units, enabling them to be activated independently. Other configurations of actuators are also useful. For example, an actuator can be associated with a plurality of discharge units to cover a larger area.

**[0027]** Fig. 3a shows a schematic diagram of an embodiment of a control unit 260. Fig. 3b shows an actual implementation of a control unit 260. Referring to Figs. 3a-b, the control unit comprises first and second flow paths 361a-b. The first flow path flows from first inlet 362 to the outlet 366; the second flow path flows from the second inlet 364 to the outlet. Output port of the first supply is coupled to the first inlet while output of the second supply is coupled to the second inlet. The control unit controls the flow of the first suppressant from the first supply to the discharge units via the first flow path. As for the second suppressant, it flows from the second supply to the discharge unit through the second flow path.

**[0028]** In one embodiment, the first flow path comprises a flow regulator 330 and a first supply valve 350 coupled in series between the first inlet and outlet. As shown, an input 331 of the flow regulator is coupled to the first inlet and an output 332 of the flow regulator is coupled to an input 351 of the first supply valve. An output 352 of the supply valve is coupled to the outlet of the control unit. Other configurations of components, including additional or different components, in the first flow path are also useful.

**[0029]** The flow regulator, for example, comprises a pressure regulator to regulate the pressure of the first supply. For example, the regulator controls the discharge rate or pressure of the first suppressant, such as CO<sub>2</sub>, flowing through the control unit and to the discharge unit. The regulator should be appropriately rated for the first suppressant. For example, non-freezing

types of regulators should be used for discharging CO<sub>2</sub>. In one embodiment, CO<sub>2</sub> is discharged at a pressure of about 7 bars. Discharging suppressants at other pressures may also be useful.

**[0030]** The first supply valve, in one embodiment, may optionally include a pressure gauge to indicate the pressure of the first suppressant. The supply valve serves as an on/off valve, controlling whether the second suppressant flows therethrough. The pressure gauge function may be integrated with, for example, the CO<sub>2</sub> cylinder.

**[0031]** Various types of supply valves can be used. For example, the supply valve can be controlled mechanically, electrically or electro-mechanically. In one embodiment, the supply valve comprises a mechanically controlled supply valve. For example, the supply valve allows flow of suppressant through the input to the output when the pressure at the input is greater than the pressure at the output.

**[0032]** As for the second flow path, in one embodiment, it comprises a second supply valve 370. The second valve serves as an on/off valve to control the flow of the second suppressant, such as water, from the second supply through the control unit and to the discharge unit. Various types of supply valves can also be used. For example, a one or unidirectional valve can be used. The supply valve can be controlled mechanically, electrically or electro-mechanically. In one embodiment, the supply valve comprises a mechanically controlled supply valve. For example, the supply valve allows flow of suppressant through the input 371 to the output 372 when the pressure at the input is greater than the pressure at the output.

**[0033]** As shown, the first and second flow paths merge after the respective components of the paths. For example, the flow paths meet after the output of the respective supply valves. Other arrangements of paths and components are also useful. For example, the first and second sub-systems can have separate flow paths with separate discharge nozzles. Furthermore, the various components of the control unit can easily be incorporated into a compact control unit casing or box 368 having the size of, for example, a palm.

**[0034]** Fig. 4 shows an embodiment of a discharge unit 270. The discharge unit comprises a flow controller 480 and a discharge nozzle 485. The discharge nozzle, in one embodiment, allows for the first or second suppressant to be discharged at an angle to suppress the fire. In one embodiment, the discharge nozzle enables the first suppressant such as CO<sub>2</sub> to be discharged at an angle range of about 50 – 60°. Discharging the first suppressant at other angles may also be useful.

**[0035]** Fig. 5 shows first and second flux-time curves (flux curves) 592a-b of CO<sub>2</sub> suppressant. The flux curves may also be applicable to other types of suppressants. Flux, for example, corresponds to the amount of gas that flows through a unit area per unit time. The first curve 592a corresponds to gas flux of a discharge unit which dispenses the suppressant, for example, perpendicular or substantially perpendicular to surface on which the fire burns. The second curve 592b, in accordance with one embodiment, corresponds to gas flux of a discharge unit which dispenses the suppressant at an angle of about 50 – 60 ° to the surface on which the fire burns.

**[0036]** The first curve indicates that the flux reaches its peak C2 within a very short time and decreases quickly to a critical value C0 at time T1. At or below the critical value, the suppressant is essentially ineffective in reducing or suppressing fire. As for the second curve, flux reaches its peak value quickly, like the first curve. However, the peak value is at C1, which is much lower than that of the first flux curve which is at C2. The second curve remains at its peak for a much longer duration and dissipates to the critical value C0 at time T2, much later than T1. This indicates that dispensing the suppressant at an angle is more effective and efficient at suppressing fire. For example, the discharge of CO<sub>2</sub> gas at a desired angle such as 50 – 60 ° can envelop the fire effectively. A direct or near vertical discharge may not be desirable for stove fires. For example, it can potentially spill or splash the overheated contents of a stove fire, such as oil.

**[0037]** Fig. 6 is an attempt to illustrate a theory, without being bound to it, as to why dispensing the suppressant at an angle may be more efficient. When gas is not dispensed at an angle, it requires higher velocity to penetrate the flame of the fire. This is because hot air from the flame flows away from the flame, countering the energy and flow of the suppressant. This requires higher flow rates which results in a larger amount of suppressant being dispensed.

**[0038]** In contrast, when the suppressant is dispensed at an angle, it is not countered by the hot air flow of the flame. Instead, the suppressant flows around to envelope the flame. This reduces the supply of the entrained oxygen from the surrounding air. In addition, the suppressant can be drawn into the center of the fire surface due to buoyancy effect with presence of the temperature, pressure and velocity gradients along the centerline of the “plume”. The first supply can mix well with the flame and reduces the flame temperature. At the same time, there is a continuous shielding effect from the first supply flow enveloping the “plume”, thus reducing the supply of oxygen to the fire. Thus, oxygen can hardly be supplied to the fire from the air above the “plume”. Once the flame is enveloped by the first supply, the fire can be extinguished in a more effective manner.

**[0039]** In one embodiment, to operate the system, it is initialized. Initialization comprises precharged the system with the first suppressant. In one embodiment, the first suppressant is precharged at about 7 bars. Precharging the system with the first suppressant at other pressures is also useful. Generally, the water from the water supply is at a pressure of about 2 bars. Since the pressure at the output of the second supply valve is greater than at its input, the valve is switched off. This prevents the water flowing beyond the second supply valve.

**[0040]** After initialization, the system is actuated when fire is detected. This causes the first suppressant to be discharged. The first supply unit should contain sufficient amount of first suppressant, such as CO<sub>2</sub> to reduce or eliminate at least the first element of fire. For example, the fire can be distinguished within about 5 seconds and the discharge of the first suppressant

such as CO<sub>2</sub> can last up to about at least 1 minute. In one embodiment, the amount of the first suppressant being discharged can range from 20 – 300 g. Other amounts of discharge are also useful. For example, about 20 – 249 g, 20-100 g, 20-80g or 24-30 g may also be useful. As the amount of CO<sub>2</sub> in the supply container is reduced to a threshold amount, the pressure in the flow path reduces. As the pressure is reduced below the pressure of the second suppressant or water, the first supply valve is switched off while the second supply valve is switched on. This results in water flowing pass the flow paths and being discharged by the discharge unit. The second suppressant reduces and eliminates the heat element of fire. The second suppressant is discharged until the fire is completely extinguished.

**[0041]** Fig. 7 shows an alternative embodiment of a fire suppression system 700. The system comprises a suppression sub-system 704. The sub-system, for example, is similar to the system 200 described in Fig. 2. The suppression sub-system includes an actuator 718 which activates the sub-system to dispense the suppressants. When the fire is completed extinguished, the second subsystem may be switched off. Switching of the second sub-system can be achieved using various techniques. For example, the second sub-system may be switched off manually, using a timer or temperature sensors.

**[0042]** In one embodiment, a fire detector 794 is provided. The fire detector is coupled to the actuator. Various types of fire detectors can be employed. For example, the fire detector comprises one or more heat sensors. When the fire detector detects a fire, it sends a signal to the actuator to activate the sub-system to dispense the suppressants. The actuator, for example, can be coupled to the dispensing unit of the sub-system. In other embodiments, the actuator may be provided at other parts of the sub-system. The actuator, for example, can comprise an electrical or electro-mechanical actuator. Other types of actuators are also useful.

**[0043]** In another embodiment, the fire detector is coupled to a fuel source switch 798. The fuel source switch, for example in a kitchen extinguisher application, can be a gas supply switch

which controls gas flow to a stove. Other types of fuel sources may also be useful. The fire detector, when a fire is detected, sends a signal to the actuator to switch off the fuel supply switch. By turning off the fuel supply switch, a third element of fire is reduced or eliminated. In other embodiments, the fire detector can be coupled to the actuator and fuel supply switch.

**[0044]** In some embodiment, the various components in the control unit may be electrical or electro-mechanical components. For example, the supply valves in the flow paths can be electrically or electromechanically controlled to switch on and off depending on various factors, such as time limit, temperature and/or pressure or amount of suppressants left. Sensors and timers may be employed to facilitate controlling the valves. In one embodiment, temperature and pressure sensors may be provided. The pressure sensor senses the pressure in the first supply container to indicate amount of suppressants remaining while the temperature sensor senses the temperature of the fire. When the temperature of the fire is below a first threshold temperature or that the pressure reaches below a threshold pressure, the first supply valve is switched off and the second supply valve is switched on. This terminates the flow of the first suppressant to allow the second suppressant to be dispensed. When the fire reaches below a second threshold temperature which indicates that the fire is extinguished, the second supply valve can be turned off. Alternatively, a timer may be employed to determine the period of phase 1 and/or phase 2. In other embodiments, other configurations of sensors and valves may be employed.

**[0045]** The system, as described, has been found to be very effective in suppressing fires, particularly oil fires which generally occurs in kitchen. Additionally, the overall system is compact. For example, the various components of the control unit can be fit into a casing of about the size of a palm. Due to the compactness of the system, it can easily and inexpensively be installed in residences. For example, discharge units can be located above the stove while the remaining components can be located nearby. Furthermore, the system can easily be scaled as

needed for commercial applications. For example, numerous systems can be employed in parallel or a single system with greater amount of suppressants being supplied.

**[0046]** In other embodiments, the first and second sub-systems can be decoupled. For example, the first sub-system can be an independent unit, such as a fire extinguisher containing the first suppressant. When a fire starts, a user can activate the fire extinguisher followed by, for example, manually activating the second sub-system disposed over the area of the fire. Alternatively, both first and second sub-systems can be independent units or containers which manually sequentially activated.

**[0047]** In alternative embodiments, the system can be used in other applications. For example, the system can be used for applications other than oil fires. Although the system has been described as dispensing suppressants in first and second phases, additional phases can be added. For example, the system additional phases may be employed to repeatedly dispense first and second suppressants, dispense additional types of suppressants or a combination thereof. Additional flow paths in the control box and supply containers may be provided.

**[0048]** The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The foregoing embodiments, therefore, are to be considered in all respects illustrative rather than limiting the invention described herein. Scope of the invention is thus indicated by the appended claims, rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are intended to be embraced therein.

**[0049]** What is claimed is:

## CLAIMS

1. A fire suppressant system comprising:  
a first sub-system which comprises a first suppressant and a second sub-system which comprises a second suppressant;  
a control unit; and  
a dispensing unit,  
wherein the control unit controls the discharge of the first suppressant to a fire in a first suppressing phase to reduce at least a first element of the fire and the discharge of the second suppressant to the fire in a second suppressing phase to reduce a second element of the fire.
2. The fire suppressant system of claim 1 wherein the first suppressant comprises CO<sub>2</sub> and the second suppressant comprises water.
3. The fire suppressant system of claim 1 wherein the first element of the fire is oxygen and the second element of fire is heat.
4. The fire suppressant system of claim 1 wherein the first sub-system is detachable from the fire suppressant system.
5. The fire suppressant system of claim 1 wherein the dispensing unit comprises a dispensing nozzle.
6. The fire suppressant system of claim 5 wherein the dispensing nozzle that dispenses the first or second suppressant at an angle range of about 50 - 60°.

7. The fire suppressant system of claim 1 wherein the control unit discharges the first and second suppressants sequentially in the first and second suppressing phases.
8. The fire suppressant system of claim 1 wherein the control unit comprises first and second flow paths.
9. The fire suppressant system of claim 8 wherein the first flow path is coupled to the first sub-system and the second flow path is coupled to the second sub-system.
10. The fire suppressant system of claim 9 wherein the first flow path comprises a flow regulator.
11. The fire suppressant system of claim 1 wherein the first suppressant is discharged at a pressure of about 7 bars and the second suppressant is discharged at a pressure of about 2 bars.
12. A method of suppressing fire comprising:  
supplying a first suppressant to the fire in a first suppressing phase to reduce at least a first element of fire; and  
supplying a second suppressant to the fire in a second suppressing phase to reduce a second element of fire.
13. The method of claim 12 wherein the first element of fire is oxygen and the second element of fire is heat.
14. The method of claim 12 wherein the first suppressant comprises the CO<sub>2</sub> and the second suppressant comprises water.

15. The method of claim 14 wherein the first suppressant is supplied at a pressure of about 7 bars and the second suppressant is supplied at a pressure of about 2 bars.
16. The method of claim 12 further comprises controlling discharge of the first and second suppressants sequentially.
17. The method of claim 16 wherein the discharge of the first and second suppressants sequentially is controlled by a control unit.
18. The method of claim 12 wherein the first and second suppressants are discharged to the fire through a dispensing unit.
19. The method of claim 18 wherein the dispensing unit comprises a dispensing nozzle.
20. The method of claim 19 wherein the dispensing nozzle dispenses the first or second suppressant at an angle range of about 50 - 60°.