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Sprinkling Powder Fire Extinguishing Compounds into Fire Containers and Enhancing Effective Fire Extinguishing

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Currently, there are 7.5-8 million fires every year in 193 countries, resulting in 85-90 thousand fatalities. Additionally, the material damage totals billions of dollars. Statistics show that both the number of fires and the amount of material damage they cause are rising. The fire also has a significant negative effect on the environment's ecology. The prevention and suppression of fires, enhancing the effectiveness of emergency rescue operations, updating fire-technical and rescue equipment, and inventing new fire-fighting equipment are all areas where scientists throughout the world are conducting scientific and research work.

Only by the technical means of moving powders in high-speed containers can excellent functional qualities of highly distributed powder compounds be attained. The explosive method of releasing fire-extinguishing powders from the inside of their containers is one way to release powdered fire-extinguishing compounds (PFEC) from containers. It represents a qualitatively new direction in fire extinguishing system development. This technique guarantees the efficient development of a gas-powder flow that effectively extinguishes fire from a single powder mass that is placed in a container and has high kinetic energy and density.

In this sense, this method's implementation is accomplished by building a container with a multi-section interior space (Fig. 1). A powder compound is placed inside the internal space, which is separated into portions. To pressurize the inside cavity of the container and expel the powder compound from the container, an actuator along the center of the cavity, such as a powder, is needed.

Separate amounts of the powder compound are placed in the container's structure section by section, allowing for the most efficient use of the fire-extinguishing compound that has been added to the interior space. This allows for the ability to control the direction in which the gas-powder cloud will spread after being forced out of the container body. One actuator -1 is positioned in each segment along the central axis 8 to generate excess pressure and rapidly squeeze the fire-extinguishing powder through the open parts of the container body (Fig. 2).

The following release method describes the interaction between the explosion wave and fire extinguishing powders at the time of release, as well as their acceleration and spraying by the explosion's byproducts. When the incendiary device is charged, the internal cavity of the container experiences a sudden rise in pressure that leads to erosion along the loose portions of the outer shell of the container body and the formation of violent gas, both of which result in the appearance of a compression wave of explosive products. The wave transmits the majority of its energy to the mass of powder after burning through it. Accelerated release of the powder compound, explosive product leakage through powder layers, powder movement and heating, partial separation, and powder particle spraying all take place. An internal rarefaction wave is fired by a portion of the wave energy that has returned from the powder-air environment compartment on the inner surface of the casing shell. This rarefaction wave causes the powder structure to become more compact and pliable, making it suitable for ejection. Because a significant portion of the compression wave is simultaneously converted into the kinetic energy of the powder ejection, the powder mass's inertia is overcome, it expands, the container case's shell cracks, and a directed spray of the powder occurs through the cracks in the case, this effect only happens once. A two-phase gas-powder explosion is the result of this.

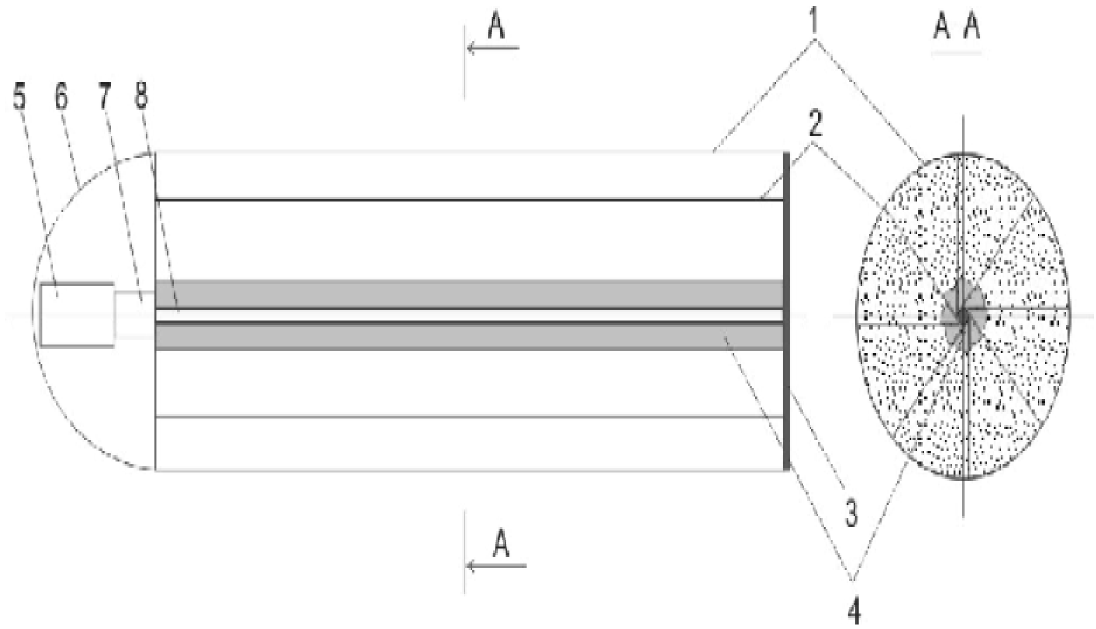

Figure 1. Container model with powder fire extinguishing compound:
1-corps; 2-section separator; 3-the short rear side of the container; 4-exciting device; 5-the mechanism for driving the drive device; 6-chapter; 7-5 engine fire extinguisher; 8- the central axis of the body

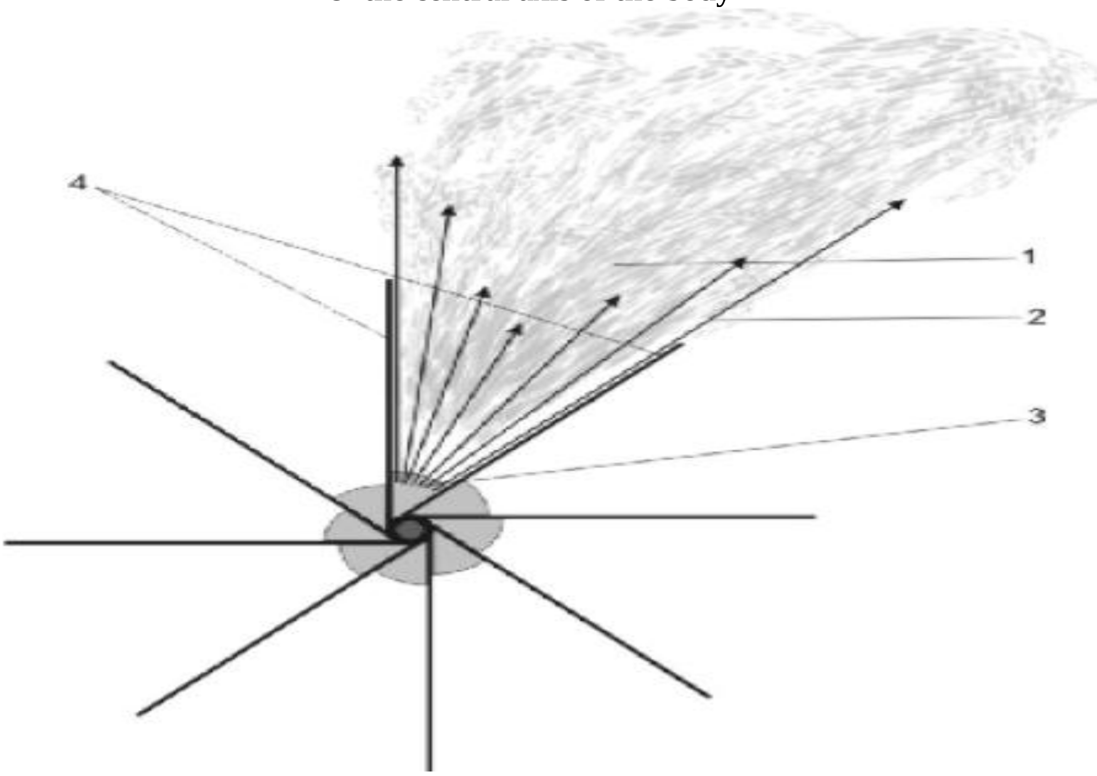

Figure 2. Multi-section directional discharge of a powder fire extinguishing compound from a container under the influence of excess pressure:
1-discharge of fire-extinguishing powder; 2 - directional sectional discharge vector; 3 - charging device; 4 - section separator

Gas-powder flow and powder explosion wave as it exits the container body; the ejection of explosion products forms a sprayed inhomogeneous mixture of explosion products and powder, with the solid dispersion phase predominating. Under pressure, the powder-gas mixture explodes as a result of explosive products. An expanding gas-powder flow is produced after a portion of the explosion products encircle the gas-dispersed powder combination after the explosion and increase their front impact. The phlegmatization of the combustion process in the firebox is achieved in this instance in addition to the fire-extinguishing impact of powder compounds.:

1. separation of the flame front from the combustible load;
2. separation of the flame front into separate sections that do not maintain combustion;
3. mixing the combustion zone with inert explosion products.

The flow splits into two after it reaches the fire's surface; the majority of the flow then returns from the burning area, forming a lower cloud that shields combustible material from the heat flow of the burning zone, separates it, and subsequently stops burning from spreading throughout the entire coverage area. The condensed zone where solids burn is destroyed when a second, smaller piece of the flow moves at high speed and enters the burning surface's interior. The formula below can be used to represent how the concentration of the powder fire extinguisher ingredient placed in the container during diffusion combustion changes after the powder is ejected from the container since the fire primarily involves diffusion combustion.

$$C_{PV} = \frac{\beta \cdot {d_{PS}^{SR}}^2 \cdot \rho_{PS}}{12 \cdot \varepsilon}, \tag{1}$$

here ε - diffusion coefficient of powder particles in the gas environment of the combustion preparation zone, m^2 c^{-1}; d_{PS}^{SR} - average diameter of a particle of a powder compound, m; β - the minimum value of the heterogeneous recombination (redistribution) constant at which flame extinction is observed, c^{-1}; ρ_{PS} - density of a powder fire-extinguishing compound particle, kg m^3. The volume of the combustion zone is where the heterogeneous response of atomic (free atom) oxygen redistribution occurs in this instance, making it possible to determine the necessary amount of powder based on the size of the flame. In line with DST "Fire engineering. Burning classification "The descriptive size of the flame of the fire area of categories A and B is $l = F^{\frac{1}{2}}$ in reference to 27331-87. can be estimated by (where F is the fire area), but since 1^3 =1, the combustion volume is calculated from the following expression

$$V_{ZG} = F_{ZG}^{\frac{3}{2}}, \tag{2}$$

here F_{ZG} – area of the combustion zone, m^2.

Because of $C_{PV} = \frac{m_B}{V_{Z\Gamma}}$ кг·м$^{-3}$, formula (10) takes the following form

$$\frac{m_{PS}^{R}}{V_{Z\Gamma}} = \frac{\beta \cdot {d_{PS}^{SR}}^2 \cdot \rho_{PS}}{12 \cdot \varepsilon} \tag{3}$$

After the transformation, we get the following formula

$$m_{PS}^{R} = \frac{\beta \cdot {d_{PS}^{SR}}^2 \cdot V_{Z\Gamma} \cdot \rho_{PS}}{12 \cdot \varepsilon}, \tag{4}$$

here m_{PS}^{R} – V_{ZG} the calculated mass of a powder fire extinguishing compound capable of stopping a fire in a volume of flame. Putting (11) into (13), we get the minimum mass of the powder compound capable of stopping combustion in the calculation area

$$m_{PS}^{R} = \frac{\beta \cdot d_{PS}^{SR^2} \cdot F_{ZG}^{\frac{3}{2}} \cdot \rho_{PS}}{12 \cdot \varepsilon}, \qquad (5)$$

here ε - diffusion coefficient of powder particles in the gas environment of the combustion preparation zone, m ^{2} c^{-1}; d_{PS}^{SR} - average diameter of a particle of a powder compound, m; β - the minimum value of the heterogeneous recombination (redistribution) constant at which flame extinction is observed, c^{-1}; ρ_{PS} - density of a powder fire-extinguishing compound particle, kg m^3; F – fire pit area, m^2. The issue of putting out fires in facilities for the processing, storing, and transportation of flammable liquids (TFL) and highly flammable liquids (HFL), particularly for the fleet of oil and oil product reservoirs, remains relevant during the development of large-scale (large) aerosol-powder fire extinguishing devices. Using powder fire extinguishers is one method for putting out TFL and HFL fires.

Foreign nations manufacture a wide range of powder fire extinguishers, including fire extinguishers, modular devices, stationary devices made of distribution pipes, permanent and mobile devices made of levers, a series of levers, and various levers.

In reality, it can be difficult to reach the burning zone with a substantial quantity of fire extinguishing agent from a great height, distance, or region during flames in huge items. The task can be accomplished more effectively by developing stationary or mobile large-sized (giant) aerosol-powder systems. When using aerosol generators to increase and compress the amount of powder, the experience of developing and carefully studying powder fire extinguishers with volumes of 2, 3, 5, 6 and 10 liters and powder fire extinguishing modules with volumes of 50 and 100 liters demonstrated their high fire extinguishing ability.

The development of a big aerosol-powder fire extinguisher with a 600 kg fire-extinguishing charge has resulted in technical proposals. The fire-extinguishing aerosol generator must make sure that the aerosol's temperature to increase the amount of powder and its compression is not higher than 300°C and that the aerosol-powder mixture is widely consumed between 9 and 40 kg/s and delivered at a time between 5 and 65 s to a distance of at least 25 m. With the proper tools, a network of distribution pipes and (or) a carriage handle, the device can be produced in both a stationary form and a mobile version. The device is serviced when fire extinguishing powders are being used, thus it doesn't need to be inspected on a regular basis.

As a result of careful study of the technical proposal and analysis of the tactical-technical and operational parameters of the created aerosol-powder fire extinguishers, stationary and mobile effective large-sized (large) aerosol-powder fire extinguishers with a charge (bullet) of fire extinguishing powder exceeding 600 kg for different climatic conditions the possibility of creating devices was determined. Knowing the container, its technical performance parameters, and the physico-chemical properties of the powder fire extinguishing compound in use, the optimal and minimum required mass of the fire extinguishing compound placed in the container for extinguishing is determined. It is necessary to create conditions where the entire mass of the powder compound inside the container is maximally distributed in the volume of the combustion zone and actively contributes to the localization and suppression of the fire in order to use powder fire-extinguishing compounds in containers and continue researching their fire-extinguishing effectiveness.

The powder fire extinguishing ingredient was transferred and released from the container using efficient ways for this. The process of ejecting powder fire-extinguishing compounds from the interior of the container under the influence of excess pressure is a qualitatively new, promising area of practical application of scientific research to the challenges of developing effective techniques and technical means of extinguishing fires. The provision of the necessary excess pressure in the interior cavity of the container to release the powder fire-extinguishing compound as well as the occurrence of its spraying in the combustion zone in virtually full volume are the examined methods' key advantages. The release duration is 10 seconds, and it takes no more than 5 seconds to build up the pressure required inside the container body to release the fire-extinguishing powder.

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