FEATURES OF COMBUSTION AND FIRE-EXTINGUISHING OF METALS AND METAL HYDRIDES WITH POWDER FIRE-EXTINGUISHING COMPOUNDS

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Introduction

Production connected with the abstraction of metal from ore, with the procession of metals, their alloys, metal hydrides and organometallic compounds are characterized by elevated fire and explosion-fire hazard. When choosing the safe conditions of control of technological processes where the indicated substances and materials are handled it is necessary to take into account the features of their ignition, combustion and fire-extinguishing.

Results and Discussion

The combustion of the metals, their alloys, metal-containing substances including organometallic compounds are divided into 3 classes according to GOST 27331-87:

- D1Class covers the combustion of light metals (aluminium, magnesium and their alloys, calcium, titanium), conditionally "heavy" metals (zirconium, niobium, uranium and others);
- D2 Class covers the combustion of alkali metals (lithium, natrium, potassium and others);
- D3 Class covers the combustion of organometallic compounds: organoaluminium, organolithium, organozinc compounds, hydrides of aluminium, lithium and others.

The above mentioned metals and their hydrides each are solid substances in ordinary state except the organometallic compounds (OMC) which are liquids.

The following features of the metals directly govern their fire-and-explosion hazard and combustion:

- propensity to spontaneous combustion under standard conditions (i.e. pyrophorus ability);
- the ability to explode in the state of suspension in air;
- reaction of the burning metals with water, some gas fire-extinguishing compounds: halons (chlorofluorohydrocarbons), nitrogen (e.g. magnesium) and others.

Alkali metals, metal chips, metal powders with non-oxidized active surface, metal hydrides, OMCs (D2 and D3 fire Classes) are able to self-ignite.

Light metals in the form of the products of their processing: powders of various dispersity, metal chips are the most fire-and-explosion hazardous, their combustion refers to D1 Class. It is actually impossible to ignite the metals in the form of the products of various configuration (sheets, profiles and so on) if heat dissipation conditions prevail over those of heat gain.

Metal hydrides occupy an intermediate position between the metals and the organic compounds. It is explained by the fact that their decomposition is accompanied by the release of hydrogen what can be considered as an analogy to the process of combustible gases release during the pyrolysis of organic materials which burn out in the gaseous phase [1].

Meanwhile the metal hydrides differ substantially by their physical- and- chemical parameters, by the mechanism of combustion and ignition. Thus the hydrides of titanium, niobium, tantalum and so on are intrinsically the solutions of hydrogen in the metal and have a variable formula with the metallic bond type. They burn basically in the smoldering regime, flaming combustion of hydrogen is not actually observed.

Simultaneously lithium – aluminium hydride (LAH), hydrides of aluminium (HA) and lithium (HL) are pronounced individual compounds with ionic bond (HL has partially covalent bond) characterized by the regimes of flaming and heterogeneous combustion [2].

HA and hydrides of alkali metals reveal pyrophorus properties, intensely react with the moisture of the air, at the weak heating they intensely generate hydrogen and due to this fact in the state of air suspension they form hybrid explosion hazardous mixtures with air.

At elevated temperatures and during the combustion the reaction between nitrogen and the most active hydrides e.g. HA is possible. A minor dilution of nitrogen by air can cause a very "harsh" explosion of HA air suspension, that is why nitrogen as a protective medium can not be used for all metal hydrides. Sometimes argon has to be used for this purpose.

Thus the character of metals combustion and that of the metal-containing substances excludes the use of water, water-based fire-extinguishing foams and some gas fire-extinguishing compositions since they react with the burning metals what leads to the growth of combustion.

In Russia and in modern world practice the fire-extinguishing powder compounds of special purpose are used to extinguish Class D1, D2 and D3 fires (FEPCSP). The following factors are taken into account when developing the formula of such compounds:

- the basic substance determining this composition (from 80 to 95% vol.) shall not contain oxygen atom in the molecule (not to support the combustion) and shall not react with metal;
- FEPCSP shall have certain fractional composition (in the range of 50-75 micron);
- FEPCSP shall not become caked during the storage what is achieved by the introduction of the anti-caking waterproofing additives. They also shall possess a number of other operation properties in accordance with the generally accepted technical requirements.

At present FEPCSP based on hydrides of alkali metals are the most widely used to fight Class D1, D2 and D3 fires (KCl – in Russia, NaCl - in Europe, USA). A number of liquid compositions (e.g. based on boric acid esters) are known as the extinguishing agents for metal fires but they didn't become widely adopted in the practice of fire-extinguishing. The creation of the complete protective covering of the fire seat which prevents oxygen access to the combustion zone with the help of FEPCSP is the main principle to achieve the positive result when extinguishing the metal-containing substances fires (Class D1, D2 and D3 fires). Such covering should be tight enough, have a necessary thickness of the powder layer along the whole fire seat surface what is achieved at the certain specific powder discharge (kg/m^2).

The extinguishing of metals and the metal-containing substances fires has a number of features typical to each group of substances of Class D1, D2 and D3 fires:

- for the extinguishing of Class D1 metal fires the FEPCSP should conform the criteria described above, and e.g. potassium chloride with the density of 1g/cm^3 constitutes the base of the powder;

- for the extinguishing of Class D3 metal hydrides fires the FEPCSP are used with properties similar to those of FEPCSP used for the Class D1 fires;

- for the extinguishing of fires of the organometallic compounds which are liquids under normal conditions the FEPCSP shall have density close to the density of these substances (~ 0,7 -0,8 g/cm^3) which is achieved by the introduction of the non-combustible additive with low density (pearlite, vermiculite) in the powder compositions. This also promotes the adsorption of OMC and improves the reliability of fire-extinguishment.

During the extinguishment of natrium [3] a so-called "capillary" or wick effect of combustion takes place owing to the oxide formations which grow through the powder layer and along which the liquid natrium penetrates and burns in the form of a wick. Special additives are usually used to avoid this effect.

The extinguishing of metals and the metal-containing substances fires by FEPCSP radically differs from that of e. g hydrocarbon highly flammable liquids , combustible liquids (Class A, B, C fires) by powders of common use. In case of extinguishing of Class D (D1,D2, D3) fires the basic task relating to the discharge of FEPCSP is to create a layer of powder covering with preferably uniform thickness on the surface of the fire seat. It is achieved with the help of so-called damping devices adjusted at the discharge facility (at the outlet of the supply nozzle) of fire extinguishers, powder appliances. The use of the nozzle - damping device at the discharge of FEPCSP is necessary when powder metals fires and metal hydrides fires are treated simultaneously the formation of air suspension of fire-extinguishing powder is prevented. For the extinguishing of Class A, B, C fires a pistol-type spraying nozzle is used and a powder cloud is formed over the fire seat which facilitates the effective extinguishment.

FEPCSP can be used for the extinguishment of radioactive metals fires. The amount of the radioactive aerosols release is substantially decreased when e.g. fire-extinguishing composition based on potassium chloride is used.

However the use of powder fire extinguishment has its drawbacks:

- fire – extinguishing powder composition in contrast to water does not have a cooling effect. A reliable extinguishment can be achieved at the cooling of metals to the point below the autoignition temperature. As a rule the temperature of the burning metals is much higher than the autoignition temperature so the process of extinguishment of metals fires and those of metal hydrides is rather prolonged;
- actually all chemical powder fire appliances have limited technical potential and can not

provide a reliable extinguishment of fires in the rooms with the volume exceeding 300 – 600m^3. The maximal height of FEPC discharge depending on the type of the chemical powder fire appliance and the pressure in the container is 10-25m while the maximal distance at horizontal powder discharge is 40-60m what is insufficient to provide the delivery of the powder to the fire origin in a number of cases.

Conclusions

1. In spite of the drawbacks of chemical powder fire-extinguishing described above the powder compositions of special purpose are the most universal, reliable and effective fire-extinguishing agents for extinguishing of metals and metal-containing materials fires.
2. Argon is recommended for extinguishing and prevention of fires of metals and metal hydrides fires in technological machinery.

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