AN INTRODUCTION TO CLEAN AGENTS HEPTAFLUOROPROPANE

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ABSTRACT

Heptafluoropropane, one of the clean agents in substituting Halon for use in gas protection systems will be introduced in this paper. Current standard requirement is briefly reviewed. Minimum design concentration measured by the cup burner test on propanol, petrol and kerosene will be reported.

Keywords: heptafluoropropane, halon, cup burner test

1. INTRODUCTION

The total flooding gas protection system with Halon 1301 (CF_3Br) is demonstrated to be effective in suppressing fire, saving numerous human lives and billions of dollars of property. However, the agent has a potential to damage the upper stratospheric ozone. Production of Halon 1301 was been halted, or going to be stopped in many countries, as agreed in the Montreal Protocol. One of the clean agents substituting Halon 1301 is, HFC-227ea (CF_3CHFCF_3, 1,1,1,2,3,3,3-Heptafluoropropane), with tradename Fire Master 200 (FM-200®). Total flooding gas protection systems based on heptafluoropropane is for practical use.

Fire is the physical manifestation of a series of high heat-releasing chemical reactions between fuel and oxygen. To sustain the burning process, sufficient heat generated must be fedback to the fuel surface to get sufficient fuel vapors for combustion. Also the amount of oxidizer should be sufficient. The extinguishment of fires has traditionally been attributed to three actions: removal of heat, the physical separation of the fuel and the oxidizer, or the removal of the oxidizer. Thermal feedback would be reduced if heat is absorbed by external agents. Introducing sufficient amount of agent into the fire gases would reduce the flame temperature so that the flame cannot be sustained [1].

For heptafluoropropane, the contribution of physical mechanisms to the extinguishment of fires predominates over the chemical mechanism. It suppresses fires primarily by extracting heat from the flame reaction zone, reducing the flame temperature below that which is necessary to maintain sufficiently high reaction rates by a combination of heat of vaporization, heat capacity, and the energy absorbed by the decomposition of the agent. Oxygen depletion plays an important role in reducing flame temperature. The energy absorbed in decomposing the agent by breaking fluorine bond is quite important, particularly with respect to decomposition production formation [2].

The chemical contribution to flame extinguishment which arises from the thermal decomposition of small amounts of heptafluoropropane in the flame and form fluorinated fragments such as CF_3 and CF_2. These will then consume the key combustion chain-propagating species H and O, but to a lesser extent on OH radicals. The rates of chain-branching combustion reaction will decrease, the chemical flame is inhibited and the flame propagation is halted [3].

In the extinguishment process, small amounts of heptafluoropropane would be decomposed thermally to form the halogen acid (HF). HF is the primary decomposition product affecting human safety and damaging equipment. Exposure to high HF concentrations would lead to health problems; and corrosion of delicated electronic equipment. Numerous studies have indicated that the amount of HF produced from the extinguishment of Class B fires with heptafluoropropane ranges from 2 to 6 times more than the total decomposition products (HF and HBr) formed from extinguishment of the same fire with Halon 1301. Rapid detection and discharge allow for the control and reduction of thermal decomposition products generated from extinguishment of fires with heptafluoropropane [4].

2. EXTINGUISHING CONCENTRATION AND DESIGN CONCENTRATION

The amount of clean agent required W (in kg) to achieve the design concentration C (in %) in a room of space of net volume V (in m^3) can be calculated [2] by:

$$W = \left(\frac{V}{S}\right) x \left(\frac{C}{(100 - C)}\right) \qquad (1)$$

where S is the specific volume of the superheated agent vapour (in m^3kg^{-1}) which can be found from design tables of product catalog.

The extinguishing concentration of the agent C_{ext} (in % v/v) in air for flammable liquids can be determined by the cup burner test method. An on-line gas analyser is calibrated for the concentration range of the extinguishant-air mixtures being measured. The remaining oxygen concentration in the chimney $[O_2]$ (in % v/v) can be measured with a continuous oxygen analyser. The extinguishing concentration will then be calculated [5] as follows:

$$C_{ext} = 100\left(1 - \frac{[O_2]}{[O_2]_{SA}}\right) \qquad (2)$$

where $[O_2]_{SA}$ is the oxygen concentration in supply air (in % v/v).

The extinguishing or inerting concentrations shall be used in determining the agent design concentration for a particular fuel. The minimum design concentration for a Class B fuel hazard is equal to the extinguishing concentration as calculated from equation (2) times a safety factor of 1.3 [6].

3. THE CUP BURNER TEST

The cup burner test was designed to determine extinguishing concentrations for Class B fire, it served as the basis for establishing the design concentration for clean agent fire extinguishing systems. The cup burner test provides a difficult extinguishing challenge due to the elimination of turbulent air flow past the flame and the high stability of the cup burner flame resulting from flame anchoring effects. A generalized description of a cup burner test procedures may be found in Annex B of the BS ISO 14520-1:2000 Standard on Gaseous Fire-Extinguishing Systems [5].

The principle of the test is that the diffusion flames of fuels burning in a round reservoir (burner as the cup), centrally positioned in a coaxially flowing air stream, and is extinguished by addition of a gaseous extinguishant (heptafluoropropane) to the air. The components included in the whole set-up are a glass cup, a glass chimney, a diffuser, a mixer, the delivery system, the air supply, the liquid fuel supply and also the extinguishant supply (heptafluoropropane). Design of the cup burner test rig follows the ISO Standards [5].

Diameters of chimney and cup are 60 mm and 20 mm respectively. The chimney and the cup are made of glass which can stand high temperature. The diffuser is made by a debris screen with many holes of diameter 2 mm. Some glass beads are placed inside the diffuser. It is located at the bottom of the chimney for mixing well the extinguishing agent before flowing up towards the fire source in the cup. The design concentrations of the clean agent against different kind of fuels are studied. In this paper, three liquid fuels: propanol, petrol and kerosene were tested. They are filled in the fuel cylinder besides the chimney. The fuel levels in the fuel cylinder and in the cup are equilibrium balanced due to gravity. For the fuel level in the cup will be fluctuated during burning, the levelling jack is used for adjustment in order to maintain equilibrium fuel level and also a constant flow of fuel. The mixer is also used to premix the air and the agent before entering the diffuser. The amount of heptafluoropropane is pre-calculated by using equation (1).

4. RESULTS

For Class B fire, the minimum design concentration required is 8%. The enclosure temperature is measured to be 23.8^{o}C and RH of 78%. The specific vapour volume can be found out from the table given in the ISO Standards. Referring to the dimensions of the chimney, the net enclosure volume can also be calculated. According to equation (1) in determining total agent quantity, the weight of heptafluoropropane is 1.8 g.

The flames for the three fuels, i.e. propanol, petrol and kerosene are observed to be different in the cup:

- Petrol is the most flammable liquid which produces massive black smoke and also with soot. It produces high concentration (3-6%) of carbon dioxide and over 1000 ppm of carbon monoxide during the incomplete combustion occurred in the extinguishment process. Petrol fire can be extinguished by hepta-fluoropropane within 10 s.

- Kerosene is commonly used as a liquid fuel in domestic buildings. It burns with a steady flame and produces some black smoke. It produces around 2 to 4% of carbon dioxide and around 300 to 600 ppm of carbon monoxide during the incomplete combustion occurred in the extinguishment process. Kerosene fire can be extinguished by heptafluoropropane within 10 s.

- Propanol burns with a little bit of black smoke. It produces normally below 2% of carbon dioxide during the incomplete combustion occurred in the extinguishment process.

Propanol fire can be extinguished by heptafluoropropane in about 10 s.

5. DISCUSSIONS

Heptafluoropropane extinguishing concentration against the air flow is shown in Fig. 1. For the propanol, the extinguishing concentration in small cup is 6.3%. For the flame behaviour of fuel, petrol fire and kerosene fire give a more stabilized flame. Both are more flammable fuels which give out a higher and larger fire size along with the air flow. The heat is easily and directly removed out of the chimney. In contrast, the propanol fire is quite fluctuated in burning.

6. CONCLUSIONS

The design concentration is adjusted to a suitable value for different situations such that the amount of heptafluoropropane can be estimated. Obviously, it is suggested that the concentration of the agent can be reduced as much as possible. It saves not only the space provided to agent storage (fewer cylinders required) but also the cost of installation. Especially, the lower design concentration of the extinguishant minimizes the potential health effect against human beings. Also, concerning the environmental aspects, Halon 1301 must be replaced by another suitable gas suppression system. Using heptafluoropropane for Halon replacement depends on the client. In summary, the heptafluoropropane gas suppression system actually is worth to adopt in replacing the existing Halon system because of the feasibility usage of heptafluoropropane extinguishing agent.

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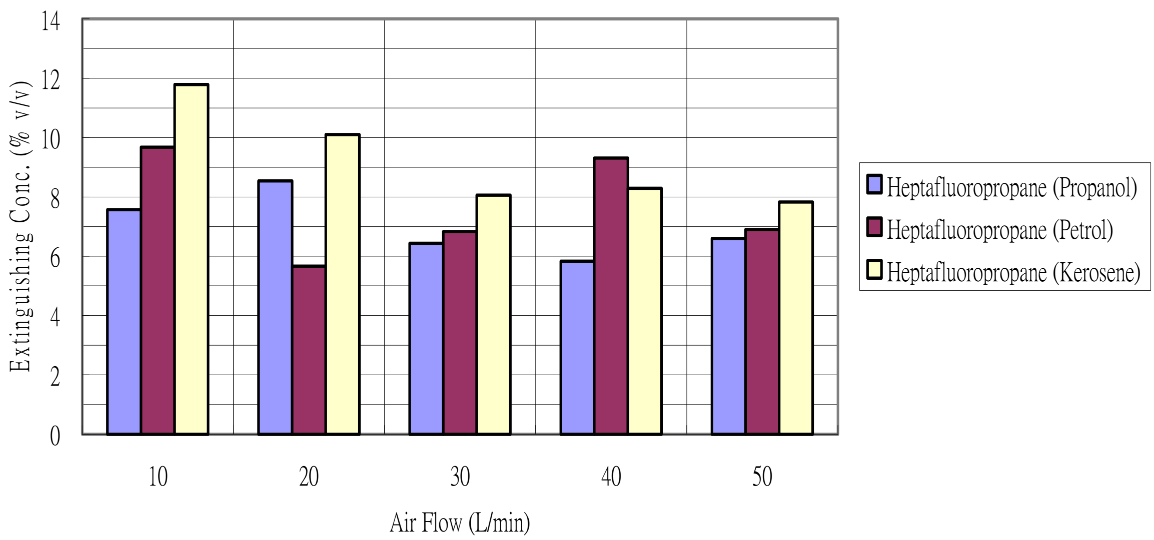

Fig. 1: Extinguishing concentration of heptafluoropropane against different fuels with small cup and large chimney (agent flow rate = 15 L/min)

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