EFFECTS OF RICH OXYGEN AND HIGH GAS DENSITY ON FLAMMABILITY OF SOME MATERIALS UNDER HYPERBARIC DIVING CONDITION

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INTRODUCTION

Fire in hyperbaric diving chamber is one of the main danger to divers. If oxygen content was kept less than 8 % within the chamber, a fire would not happen. In general, oxygen partial pressure (Po_2) to maintain human life is higher than 0.16 bar. During saturation diving, Po_2 in living chamber can be permitted up to 0.5 bar. When divers leave their living chamber to make excursion dives by bell or to do some tasks in welding habitat, they breathe pressurized *air* or *mixed* gases containing oxygen of 0.5-1.0 bar. In these cases, the oxygen content of 8% is exceeded in shallow water. It is therefore of practical importance to obtaining the knowledge about flammability, ignition temperature and burning behaviour, of some materials used in diving chamber. This paper deals with the effects of rich oxygen, high pressure and gas density upon flammabilities of three different materials.

METHODS

A hyperbaric fire test facility was used for the experiments, consisting of a special hyperbaric vessel with a movable test frame, 5 thermal sensors and a computer that records and processes test results. The ignition temperature and the buming behaviour of the three materials were measured in hyperbaric *air*, nitrox (N_2-O_2) and trimix (He-N_2-O_2, N:5%) conditions. General properties of the test materials are given in Table 1. In the experiments constant heating sources of 600 and 800°C were employed to ignite paper and textile respectively. The oxygen concentration of experimental gas *mixtures* was varied between 4 to 16%.

Table 1 General properties of the test materials

Test material	Colour	Special weight [g/m²]	Notice
Blotting paper	White.	150	normal quality
Special art paper	white	100	wood-free
Aramid cloth material *	milk-white	270	100% Aramid,

* Aramid cloth material is a fire-resistant fabric from DU PONT Company

The test materials were previously cut into smpes of 80 x 35 mm. The sample stripe was fastened to a test rack at an angle of 45° with the bulkhead. The rack was then fixed on the movable test frame. And vertical distance between the sample stripe and the heating source was about 3 mm. The vessel was evacuated to 60 mbar before the compression with mixed gas. During a measuring, a mark was made on recording data while the sample smpe begins to produce a strong smoulder or a flame. Each measurement was repeated two or three times under same hyperbaric condition. Detailed data of the experiments are given in Table 2. The test results of the burning behaviour have been classified according to a code of the burning extent. The burning code is referred to *CODE 1* "complete burning", *CODE 2* "incomplete burning", *CODE 3* "slight burning" and *CODE 4* "no burning".

RESULTS

In air condition the ignition temperatures of the three materials were decreased with the pressure (gas density) raising. But under nitrox and trimix conditions containing the same oxygen concentration, the decreases of the ignition temperature were accompanied by the rise in the pressure in lower gas density condition, whereas the increases of the temperature were caused by the pressure continuous raising in higher density condition. Two factors of gas density and oxygen partial pressure act on the ignition temperature under the hyperbaric diving condition.

Table 2 Detailed data of the experiments

Test material	Blotting paper	Special art paper	Aramid cloth material
Number of experiments	58	130	74
Sort of gas	air	air and nitrox	air and trimix
Temp. of heating source, T [°C]	600	600	800
Oxygen concentration, O_2 [%]	20.95	20.95 - 3.99	20.95 - 8
Oxygen partial pressure, Po_2[bar]	0.207 - 1.475	1.886 - 0.079	0.105 - 4.963
Total absolute pressure, P [bar]	0.99 - 7.04	0.96 - 15.03	0.98 - 31.15
Gas density, ρ [g/l]	1.193 - 8.481	1.157 - 17.747	0.402 - 12.497

By statistical analysis, multiple regressive equations were derived as follows:

$$T_1 = 16.131\rho - 110.263\,Po_2 + 215.660 \qquad T_3 = 5.444\rho \times 10^3 - 3.144\,Po_2 \times 10^4 + 689.181$$

$$T_2 = 48.377\rho - 182.079\,Po_2 + 787.405 \qquad T_4 = 226.121\rho - 1.321\,Po_2 \times 10^3 + 372.595$$

where T_1 to T_4 represent the ignition temperature of special art paper, Aramid cloth material in trimix, Aramid cloth material in air and blotting paper, respectively, °C.

In hyperbaric *air* conditions the burning behaviour of the three materials revealed complete burning (Code 1). However the variations in the burning behaviour of special art paper and Aramid cloth material were accelerated in the mixed gas condition containing the same oxygen concentration but declined in the condition containing the same oxygen pressure with the environmental pressure raising. It is observed that there are two elements, oxygen concentration and environmental pressure, to have an effect on the burning behaviour. On the basis of the test results, two multiple regressive equations were respectively worked out as follows:

$$D_1 = 5.571 - 0.069\,P - 0.220\,O_2 \qquad D_2 = 6.634 - 0.053\,P - 0.200\,O_2$$

where D_1 and D_2 respectively represent the burning behaviour of special art paper and Aramid cloth material, burning code.

In accordance with F-test, it is recognized that the regressive equations possess a statistical significance for the variance of the dependent variable (*Eq.*T_1: $p < 0.0001$; *Eq.*T_2: $p < 0.0001$; *Eq.*T_3: $p < 0.0007$; *Eq.*T_4: $p < 0.04$; *Eq.*D_1: $p < 0.0001$; *Eq.*D_2: $p < 0.0001$). The burning code is defined in a number of categories, calculated value is referred to an integer. To be safe, borderline value is referred to the code with smaller integer than the borderline value.

CONCLUSIONS

1 In the same isobaric oxygen conditions, oxygen partial pressure plays an important role in the ignition temperature of the materials in lower pressure condition, but it is replaced by gas density with the pressure continuous raising.
2 The variations in burning behaviour of the materials are accelerated in mixed gas conditions containing the same oxygen concentration but declined in the conditions containing the same oxygen pressure during the environmental pressure increasing.
3 Under hyperbaric diving condition, rise in density of inert gas hinders oxygen molecule from contacting and colliding with the sample stripe effectively and enhances heat transfer between the stripe and the surrounding gas, which results in the decline of oxidative reaction or flammability of the materials.

REFERENCES

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