# Suppression Effectiveness Studies of Inert Gases, Halons And Halon-Alternative Agents On Detonations


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**Abstract**

This work presents experimental results on the influence of inert gases, halons and halon alternative agents on propagation of detonation wave in square cross section channel. The velocity of detonation front was monitored using pressure transducers and microwave radar. It was found that detonation suppression is strongly influenced by the mixture stoichiometry and initial pressure, concentration of an agent and the structure and composition of an agent molecule


# Introduction

There are numerous examples of industrial accidents involving gaseous detonations that have resulted in severe destruction of capital equipment and loss of life. Conditions that lead to detonative combustion are more prevalent today in large modern installations with long pipe runs, large vessels, and high-velocity vapor lines than those in the smaller refineries in the past. Unfortunately, the majority of industrial installations is not designed to withstand detonations, this is simply too expensive and not recommended by risk analysis. So, the only way to prevent serious disasters and losses in human lives and property is to prevent detonation formation or quenching it during its propagation. In the practical situation of a pipe in which fuel-air mixture is created and ignited accidentally, leading to the formation of detonation wave, an upstream injection of a suitable inert gas may stop and damp out the detonation, preventing an accidental disaster. Some of the safety systems, especially in the oil field production and during the ship to shore off-loading, use similar technique to prevent an accidental explosions.

Moen et al. [1] studied the effect of chemical inhibitors and diluents on the detonability of fuel-air and fuel-oxygen mixtures. The influence of adding small amounts (1-3%) of $CF_3Br$, $CF_4$ and $CO_2$ to ethylene-air was determined by performing large-scale critical tube diameter tests. The results showed that the effect of $CF_3Br$ was not nearly as dramatic on detonations as it is on flames. Addition of 1.5% of $CF_4$ had no effect at all. For detonations, $CO_2$ was found to be a better inhibitor than $CF_3Br$. Ethylene-oxygen and hydrogen-oxygen detonation tests performed in laboratory scale showed that the addition of small amounts of $CF_3Br$ had a small sensitizing effect.

Gmurczyk and Grosshandler [2] studied the effect of halon-alternative agents on detonations in $C_2H_4$-air mixture. They found that the most effective are perfluorocarbons, then hydrofluorocarbons and hydrochlorofluorocarbons as the less effective. They have also found the dependence of suppressing effectiveness on mixture stoichiometry and agent concentration.

More fundamental knowledge on the suppression effectiveness of inert gases and fire fighting agents is required to improve the industrial safety measures.

# Experimental

The effectiveness of an inert gas or fire-fighting agent in suppressing detonation can be rated by the extent to which it decelerates the propagating wave and simultaneously attenuates the hazardous shock wave, which is always ahead of the flame in the decoupled quenched detonation. In this study the suppressant was injected into the combustible mixture prior the ignition.

The detonation tube shown in Fig.1 was used in the experiments. It consisted of a 1 m long booster and 8 m long square cross-section channel with internal dimensions 100×100 mm. The booster was filled with the oxy-acetylene stoichiometric mixture, which ignited, by a 1 J electric spark rapidly detonated initiating in turn detonation in the acceptor mixture in the main channel. The acceptor channel was filled with stoichiometric hydrogen-oxygen or hydrogen-air mixture at an initial pressure 0.01, 0.025 or 0.05 MPa. The suppressing gas was injected in the middle of the channel about 1 s prior the ignition by the Servojet solenoid valve. The pressure and time of injection varied the amount of suppressant.

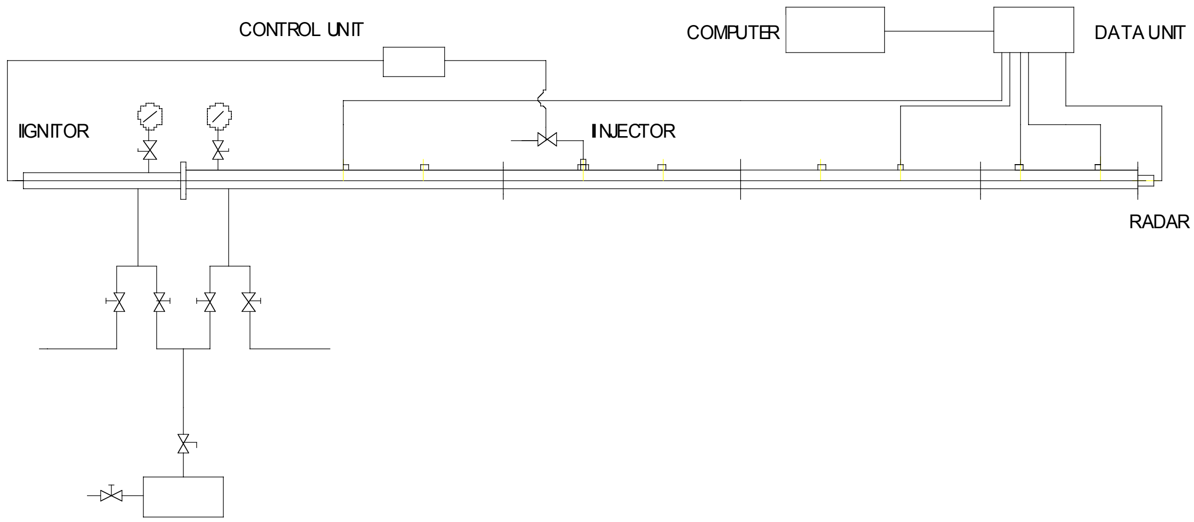


Figure 1. Schematic of experimental apparatus

A number of piezo-electric pressure transducers were fitted into the channel to monitor detonation and shock propagation. An X-band radar Doppler unit was also used for continuous monitoring of the detonation velocity. The Doppler unit was located at the end of the channel. The Doppler unit and the pressure transducers were used to observe the suppressing effect of injected gases on detonation wave. In few experiments smoked-foil measurements were used for qualitative observation of detonation attenuation. This was done by placing a thin steel plate along one of the walls of the channel.

Four inert agents: He, Ar, $N_2$ and $CO_2$, and nine fire inhibiting agents: $CF_3Br$ (Halon 1301), $CH_3Br$, $CH_3Cl$, $CF_4$, $C_2F_6$ (FC116), $C_3F_8$ (FC218), $C_4F_{10}$ (FC3110), $CH_2F_2$ (HCF32) and $C_2HF_5$ (HCF125) were used in the experiments.

The effectiveness of all suppressants under study was evaluated on the basis of performance parameters defined as the ratio of velocity and pressure reduction in comparison with baseline case of non-inhibited detonation. It was found that suppression process is strongly influenced by the mixture stoichiometry and initial pressure, concentration of an agent and the structure and composition of an agent molecule.

The presence of hydrogen in the agent molecule results in a significant increase in pressure ratio in comparison to the pure combustible mixture. The agent acts as an extra fuel, causing the mixture to be richer. The chlorine in the molecule further complicates the chemistry because it acts as an oxidizer. Bromine appears to inhibit flame effectively.

# References

[1] Moen I.O., Ward S.A., Thibault P.A., Lee J.H., Knystautas R., Dean T., Westbrook C.K.: The influence of diluents and inhibitors on detonations, Twentieth Symposium (Int.) on Combustion, pp.1717-1725, 1984

[2] Gmurczyk G.W., Grosshandler W.L.: Suppression effectiveness studies of halon-alternative agents in a detonation/deflagration tube, Halon Options Technical Working Conference Proceedings, pp.193-204, 1994

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