HALON 1301 AND GASEOUS DETONATIONS

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ABSTRACT

Halon 1301 has been used as a fire extinguisher for many years. However, its role on gaseous detonations has been less considered although detonations induce important damages for people and properties when such events occur.

It has been established that the influence of flame inhibitors is also visible on gaseous detonations. The action of those compounds on detonation velocity is quite small, but their presence in the original mixture modify to a large extent the structure of the detonation waves and play an important role on their behavior at the Limits, allowing to stop the propagation of those phenomena.

The actual action of the inhibitor is depending on the nature of the fuel (hydrogen, carbon monoxide, methane, acetylene, ...) as well as the chemical composition of the additive.

The value of some fluorocarbon compounds and halon 1301 will be compared and discussed.
INHIBITION PARAMETER $\phi$ FOR PREMIXED LAMINAR FLAMES

Velocity

\[ V_0 = \frac{D_T}{S_f} \]

$D_T$ : Total flow

$S_f$ : Flame Surface

\[ \phi = \frac{V_0 - V_i}{V_0} \cdot \frac{[O_2]}{[I_n]} \]

with $V_0$ burning velocity of the uninhibited flame

$V_i$ burning velocity of the inhibited flame

$[O_2], [I_n]$ concentration of oxygen and inhibitor in fresh gases mixture.

Inhibitor efficiency

$CF_3Br > CFCl_3 > CF_2Cl_2 > CF_3Cl > CF_3H > CF_4$
1. Shock Wave  
2. Ignition Zone  
3. Reaction Zone  
4. Expansion Wave

One-dimensional steady detonation  
Z.N.D. Model  
Pressure- Temperature- and Density profiles  
behind the leading shock  
V.N. von Neuman spike  
C.J. Chapman-Jouguet plane
Multidimensional detonation
1. Interaction of triple shock configurations
A: Triple point; T: Reflected shock; M: Mach stem shock; S: Slipstream line; I: Incident shock

2. Triple point trajectories in a detonation wave
$\tau_1$, $\tau_2$: detonation wave at two time intervals
ABCD detonation cell
L: cell length and S: cell width
I, M and T: incident, Mach and reflected shocks
Broken line is the reaction (hex release) zone.
- Experimental Conditions

Cross-section of Detonation Tube : 3.2 cm x 9.2 cm.

Detonation initiated by a shock through a diaphragm

Detonation Tube length : 11 m.

Variable Mixture Composition.

- Measured quantities

\[ D = \text{Detonation velocity (m/s)} \]

\[ L = \text{Cell length (cm)} \]

- Deduced Parameters

\[ t_{\text{car}} = \frac{L}{D} \quad \text{and} \quad t_{\text{car}} = \text{cst.} \ t_{\text{ind}} \]

\[ t_{\text{car}} : \text{characteristic time}; \ t_{\text{ind}} : \text{induction time} \]
Experimental soot records
for a 44.3 CO/2.3 H₂/23.3 O₂/30.0 Ar mixture
at initial pressure 150 Torr

<table>
<thead>
<tr>
<th>PHOTO</th>
<th>% CF₃Br</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>0.47</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>0.93</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>1.40</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>1.87</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2.33</td>
<td>shock</td>
</tr>
</tbody>
</table>
Detonation Cell Length vs. Pressure

- no inhibitor; A CF₃Cl
  - □ CF₂Cl₂; ♦ CFC₁₃; ○ CF₃Br
Characteristic Time vs. Pressure
at variable CF₃Br percentage

- no CF₃Br; 0 0.47; A 0.93
- O 1.40; □ 1.87; V 2.33
Detonation Velocity vs. Pressure
at variable CF$_3$Br percentage

- no CF$_3$Br; ◊ 0.47; A 0.93;
- O 1.40; □ 1.87; V 2.33
CF₃Br-Inhibition in Acetylen-Oxygen Detonations

a. Detonation velocity (D) vs. CF₃Br percentage w.r.t. Fuel
b. Cell length (L) vs. CF₃Br percentage w.r.t. Fuel

Curves at variable initial pressure P₀
**Induction time**

Induction time is the time required to reach a critical concentration in radical intermediates. It is related to the chemical kinetics of chain branched mechanism for oxidation.

a. with chain branching reaction:

\[
\begin{align*}
\dot{H} + O_2 & \rightarrow \dot{OH} + \dot{O} \\
[\text{ Radical}], r & \approx \text{cst} \cdot e^{k_1[O_2]t_{\text{ind}}}
\end{align*}
\]

or

\[
k_1[O_2]t_{\text{ind}} \approx \text{cst}
\]

b. with chain terminating processes:

\[
\begin{align*}
\dot{H} + CF_3Br & \rightarrow \dot{CF}_3 + HBr \\
H + HBr & \rightarrow Br + H_2
\end{align*}
\]

\[
\{k_1[O_2] - k_2[CF_3Br]\}t_{\text{ind}} = \text{cst}
\]

**CONCLUSIONS**

The inhibitors increase $t_{\text{ind}}$, $t_{\text{car}}$, L delaying the reaction zone from the leading shock(s). They interfere thus with the sustainance mechanism of a detonation wave. Halon 1301 is the most efficient of the fluorocarbons.