EXPLOSION SUPPRESSION FOR INDUSTRIAL APPLICATIONS

by

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GENERAL BACKGROUND

● PROTECTED SYSTEMS

* Laminar and turbulent vapor/air mixtures (Propane typical).
* Dust explosions for ST 1 & 2 dusts ($K_{st} \leq 300$ bar m/s).
* Test data for volumes up to about 250 m³.
* Proprietary design methods developed by hardware manufacturers.

● TYPICAL CHARACTERISTICS

* Several types of agents used, including powders (Sodium bicarbonate, Mono-ammonium phosphate), water and pressurized liquids (Halon replacements). Water unsuccessful in suppressing gas explosions.

* Suppressant quantities of 5-30 liters per unit. Several units may be required for one installation.

* Suppression system activated by UV or pressure detector.

* Pressurizing agent, typically nitrogen, at 40-60 bar (600-900 psi).

* Activation time: 1-2 msec. Agent delivery time: 10-100 msec.
EXPLOSION SUPPRESSION RESEARCH AT FMRC

• GOAL

Develop an understanding of the mechanisms of explosion suppression and establish the effectiveness of new agents, or new delivery methods, in suppressing high-challenge explosions.

• COMPLETED WORK

* Carried out suppression tests in the 2.5-m³ pressure vessel for near-stoichiometric methane/air mixtures using mono-ammonium phosphate (MAP), sodium bicarbonate (SB), and water as suppression agents.

* The two powder agents (MAP and SB) were found to be successful at suppressing explosions in both quiescent and turbulent mixtures.

* No successful suppressions obtained with water.

• WORK IN PROGRESS

* Perform additional gas explosion suppression tests by experimenting with novel delivery methods to maximize the effectiveness of water as a suppression agent. Propellant-based gas generators seen as presenting a means to improve effectiveness of water.
EXPLOSION SUPPRESSION RESEARCH AT FMRC

- EXPERIMENTAL FINDINGS

* Inerting concentrations of the two powder agents from 20-liter sphere tests with a 10% methane/air mixture:

  Sodium bicarbonate (Ansul Plus 50C): 975 g/m³
  Mono-ammonium phosphate (Ansul Foray): 575 g/m³

* Suppression tests in the 2.5-m³ vessel performed for the following parameters:

  Amount of suppression agent: 3 Kg
  Pressure of driver gas (nitrogen): 50 barg
  Detection pressures: 1, 3, 5, 8 psig (0.07, 0.21, 0.34, 0.55 barg)
  Mixture conditions: Laminar \( u_i = 0.42-0.58 \text{ m/s} \)
                      Turbulent \( u_{i,eq} = 1.14-1.71 \text{ m/s} \)

* For the single concentration used (1,200 g of agent per m³ of protected volume), the two powder agents (SB and MAP) found to be always successful in suppressing the explosion and to have similar effectiveness.

* Failure by the water to achieve suppression in most runs. No appreciable improvement from the use of nozzle with smaller injection holes and addition of CO₂ to the nitrogen charge. Full unvented pressure developed by explosions where suppression failed.

* Location of the ignition source found to have a small effect on the performance of the suppression system. Surprisingly, mixtures ignited behind the injection nozzle are the easiest to suppress.

* Increased challenge to the suppression system due to presence of turbulence in the mixture, leading to higher suppressed pressures.
EXPERIMENTAL FACILITY

1. FMRC 2.5-M³ FACILITY

2. SUPPRESSION VESSEL/PIPING

3. INJECTION NOZZLES

NOTE: All Holes to be Drilled, Both Sides

Drilling Pattern for 1st Nozzle

Drilling Pattern for 3rd Nozzle
suprs0014 --> Explosion Suppression Test, 10.86% CH4/Air Mix, 3Kg MAP, PS#3, C.I.  -- # 0014

- PSIA
- PVESSEL2
- P_Agent

Time from the Beginning of the Test [SEC]

V -- x: 0.141  y: 725.1

20.2 PSIG
suppr0037 --> Explo. Suppr. Test, 9.99% CH4/Air Mix, Turb., 3Kg MAP, PS@3, Ctr Ig.  -- # 0037

PSIG
1000
100

P-Agent

PVESSEL2

37.2 psia

Time from the Beginning of the Test [SEC]

v: 0.1645

y: 27.53
supprs0029 --> Explo. Suppr. Test. 10.1% CH4/Air Mix, 31 H2O, 200psi CO2, PS03, C.I. --- # 0029

Time from the Beginning of the Test [SEC]

V —— x: 89.5m    y: 724.8

PSIG

900
100/

PSIA

120
20/

P_Agent

PVESSEL2

V —— x: 89.5m    y: 724.8
ENHANCEMENT OF WATER AS SUPPRESSION AGENT

- SUPPRESSION MECHANISMS

* Combination of direct interaction of the suppression agent with the flame front, and inerting of the unburnt mixture.

* Water droplets produced by the delivery system estimated to have a diameter in the range 100-150 μm.

* Droplets 10 times smaller (10-15 μm) are needed for water to be effective as an inerting medium.

* Pre-heating of the water charge may provide a means to enhance fragmentation of the stream and, therefore, extinction effectiveness.

- DISSOLVED GAS/STEAM FLASHING

* At pressures of 15-20 bar, water dissolves an equal volume of carbon dioxide. No improvement in extinction effectiveness found by the use of carbonated (200 psi of CO₂) over plain water.

* Equivalent amount of volume expansion can be obtained by steam flashing of about 0.7% of a water charge (corresponding to about 4°C of superheating).

* Water superheated to 200°C (392°F) would produce a flashed fraction of about 18% (Steam inverting of a 2.5-m³ volume achieved with 3 liters of "hot" water).
USE OF SOLID PROPELLANT GAS GENERATORS IN INDUSTRIAL EXPLOSION SUPPRESSION SYSTEMS

- POTENTIAL ADVANTAGES

* Storage of suppression agent at ambient pressure (and temperature) up to the time of system activation.

* Ability to preheat the agent during deployment (improved fragmentation, partial flashing of charge).

* Non-decaying pressure during agent delivery for faster deployment at fixed maximum design pressure.

- POTENTIAL DISADVANTAGES

* Higher cost than traditional systems based on pressurized driver gas.

* DOT classification of propellant (storage, maintenance, handling, etc.)

* Burden of proof of new technology.