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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 m^3.

  * 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-m^3 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/m^3
Mono-ammonium phosphate (Ansul Foray):	575 g/m^3

* Suppression tests in the 2.5-m^3 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_l = 0.42-0.58 m/s)
	Turbulent ($u_{t,eq}$ = 1.14-1.71 m/s)

* For the single concentration used (1,200 g of agent per m^3 of protected volume), the two powder agents (SB and MAP) found to be always successful in suppressing the explosion and to have similar effectiveness.

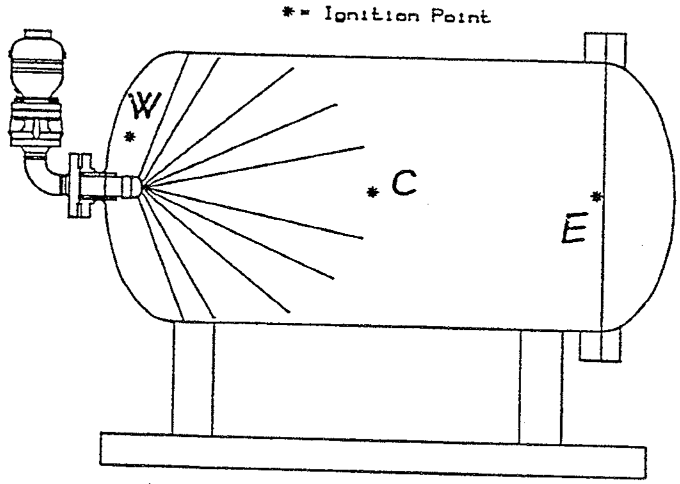
* Failure by the water to achieve suppression in most runs. No appreciable improvement from the use of nozzle with smaller injection holes and addition of CO_2 to the nitrogen charge. Full unvented pressure developed by explosions where suppression failed.

* 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.

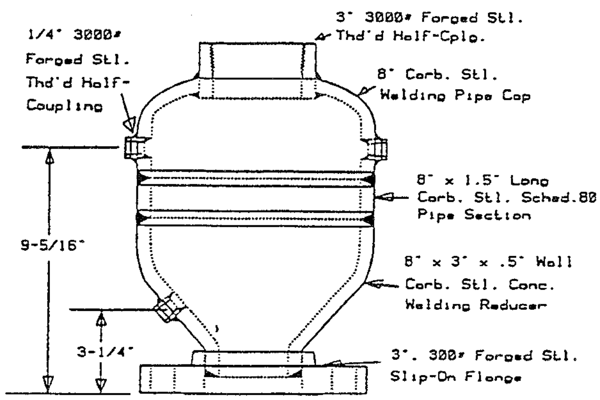
* Increased challenge to the suppression system due to presence of turbulence in the mixture, leading to higher suppressed pressures.

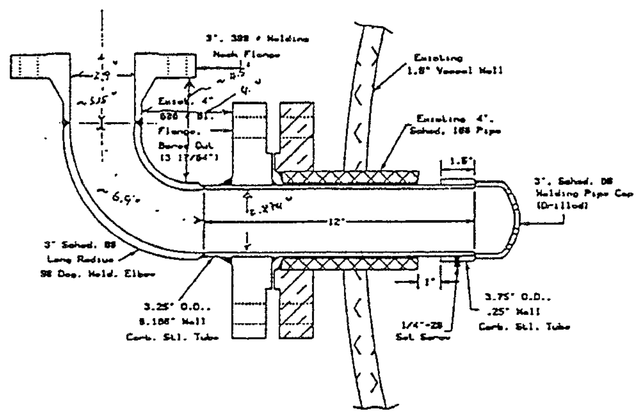
EXPERIMENTAL FACILITY

1. FMRC 2.5-M³ FACILITY

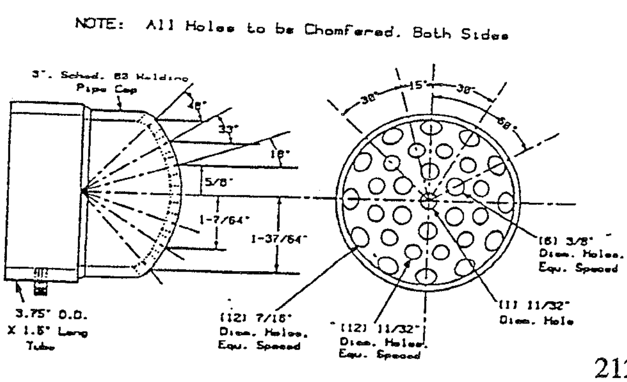


2. SUPPRESSION VESSEL/PIPING

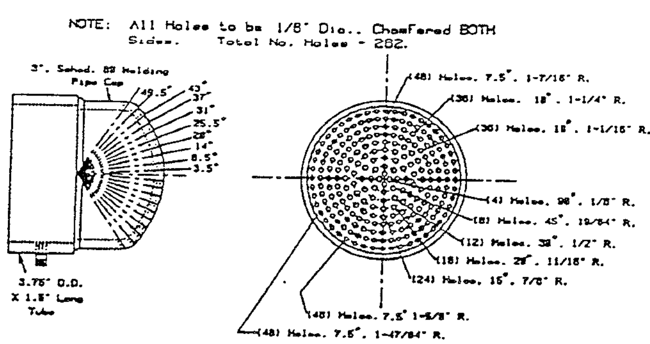




3. INJECTION NOZZLES

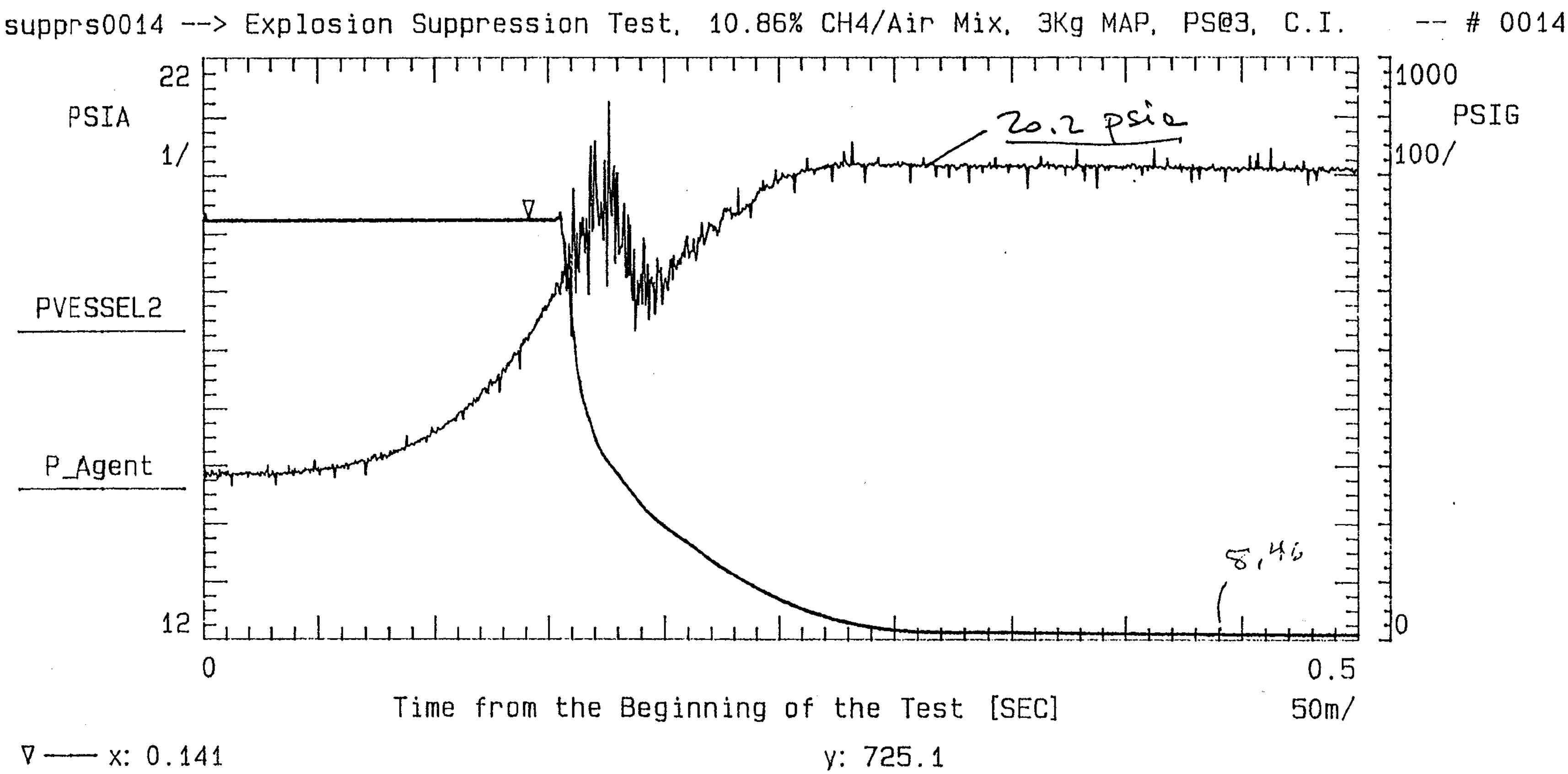


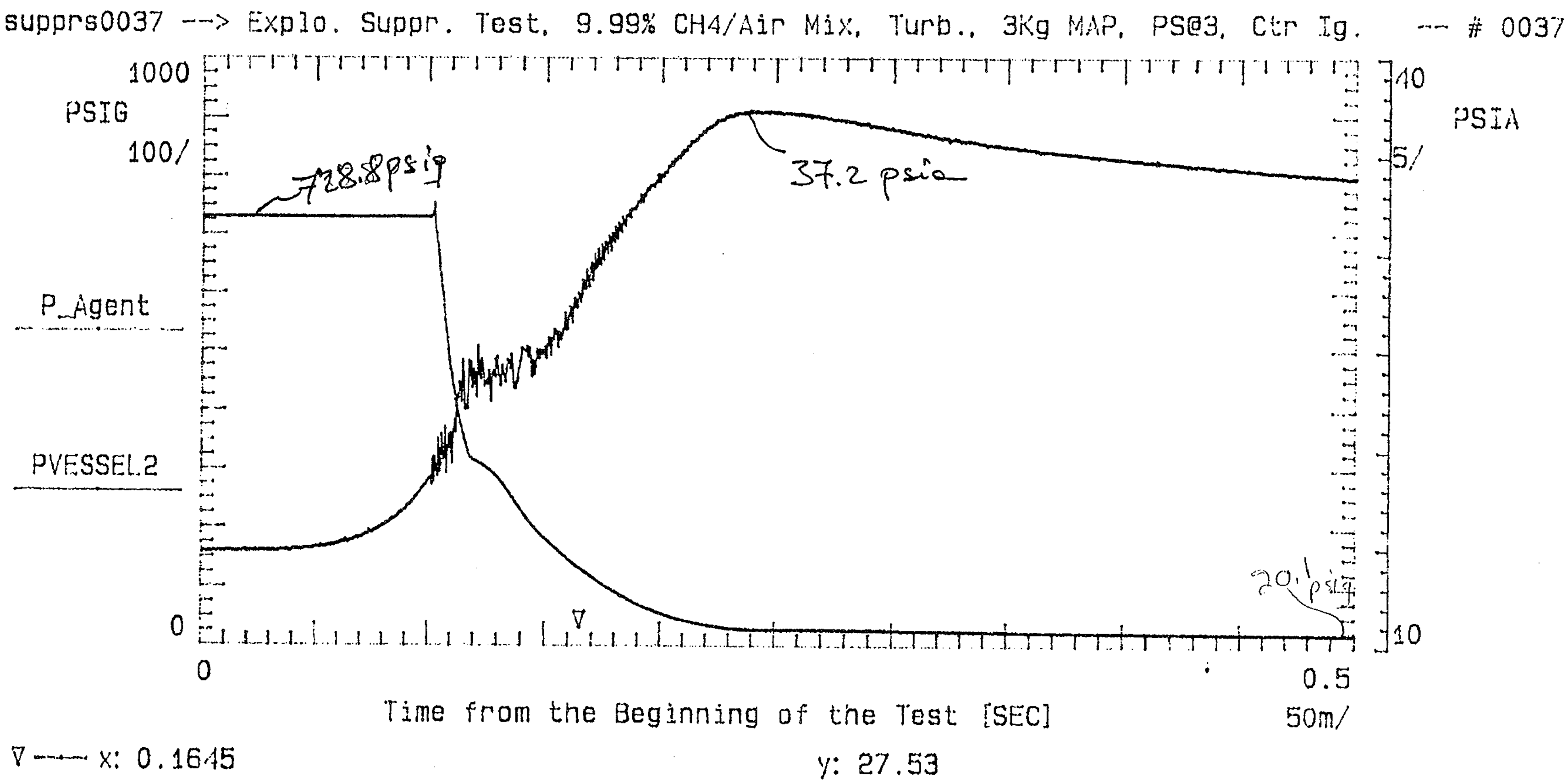
Drilling Pattern for 1st Nozzle



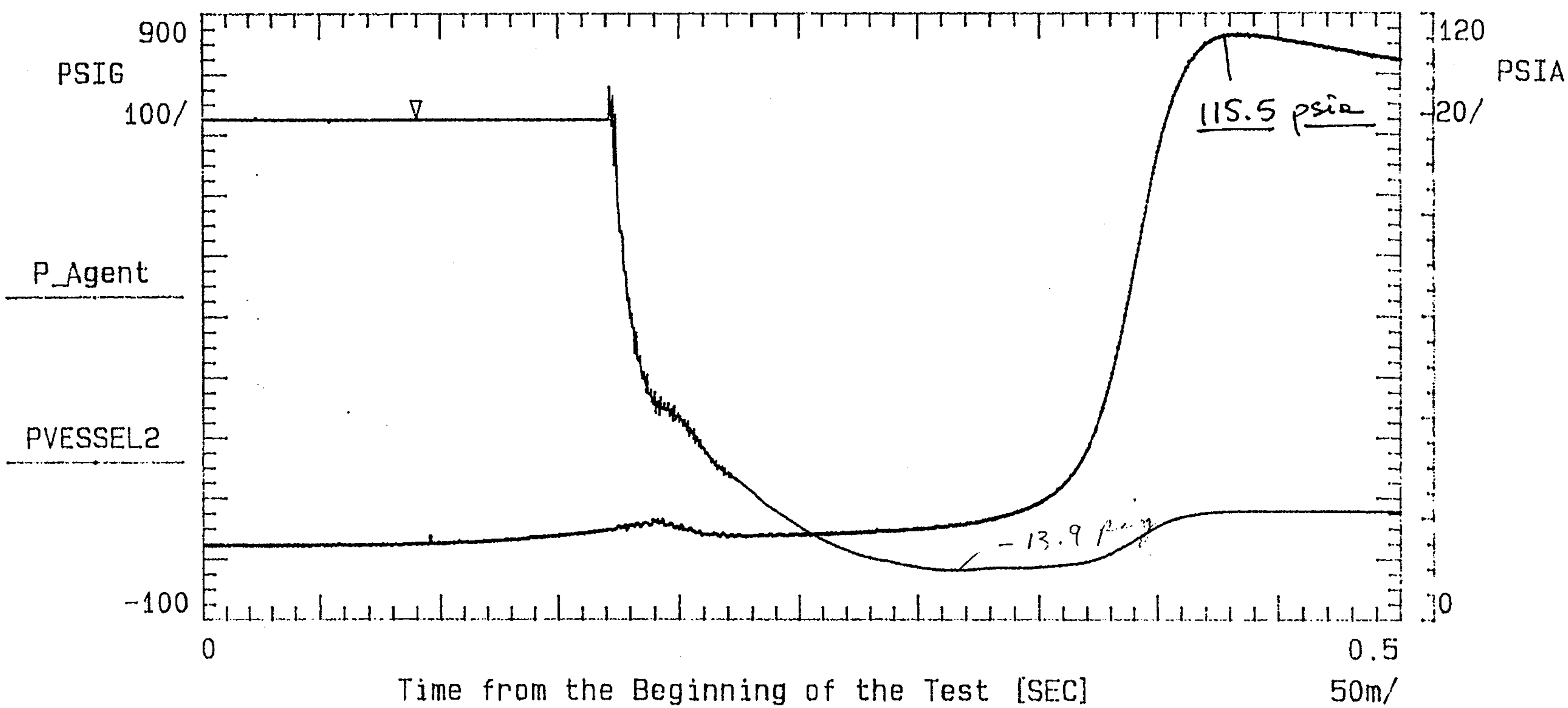
Drilling Pattern for 3rd Nozzle

213


supprs0014 --> Explosion Suppression Test, 10.86% CH4/Air Mix, 3Kg MAP, PS@3, C.I. -- # 0014
22
PSIA
1/
PVESSEL2
P_Agent
12
1000
PSIG
100/
0
20.2 psia
8.46
0
0.5
Time from the Beginning of the Test [SEC]
50m/
∇ —— x: 0.141
y: 725.1


supprs0037 --> Explo. Suppr. Test, 9.99% CH4/Air Mix, Turb., 3Kg MAP, PS@3, Ctr Ig. -- # 0037
1000
PSIG
100/
728.8psig
37.2 psia
P_Agent
PVESSEL2
20.1 psig
0
PSIA
40
5/
10
0
0.5
Time from the Beginning of the Test [SEC]
50m/
∇ x: 0.1645
y: 27.53

supprs0029 --> Explo. Suppr. Test, 10.1% CH_4/Air Mix, 31 H_2O, 200psi CO_2, PS@3, C.I. --- # 0029



∇ —— 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 CO_2) 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 inerting of a 2.5-m^3 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.