EVALUATION OF SELECTED NFPA 2001 AGENTS FOR SUPPRESSING CLASS "C" ENERGIZED FIRES

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INTRODUCTION.

A review of total flooding fire extinguishing tests conducted on new clean agents by government agencies, universities and testing laboratories indicates that practically all of the tests have been conducted on Class " A and "B" fires. Limited guidance is available for conducting tests on Class "C" energized fires either in National Fire Protection Association (NFPA) Standard 2001 or testing laboratory standards. The Class "C' energized fire tests conducted by one testing laboratory employed a high energy electric arc as the ignition source. They acknowledged that this high energy level was a worst case heat scenario used to generate decomposition products and should not be considered as representative of low energy levels found in typical electronic systems.

In response to a number of electronics customers who had expressed a requirement to maintain power to essential electronic circuits in the event of a fire, Modular Protection Corporation decided to perform an in-house evaluation of selected NFPA 2001 agents for suppressing Class "C" energized fires.

OBJECTIVE:

The objective of the tests was to investigate the effectiveness of new clean agents to extinguish Class "C" energized fires of polymeric materials ignited by nickel-chromium resistance wire energized by a Direct Current (DC) power source. Specific tests were conducted to determine: (1) minimum agent concenuation required to extinguish Class "C" energized fires, (2) minimum agent concentration required for inerting to prevent reignition and reflash.

AGENT SELECTION CRITERIA:

The criteria considered for selecting the new clean agents to be tested were that they must (1) have zero Ozone Depletion Potential (ODP), (2) be approved as a total flooding agent for use in occupied areas by EPA/SNAP and NFPA 2001.

The agents selected for testing were: FC-3-1-10, HFC-227ea, HFC-23, and **IG-541.** Tests were completed on the halocarbon agents; however, tests on the inert gas, **IG-541,** are still in progress and are not included in this report. Halon 1301 was used as a baseline in the testing of the selected agents.

TEST FACILITY:

The test facility (Figure 1) consisted of a control room (3.7-m x 2.6-m x 2.7-m) and a test room (3.7-m x 2.6-m x 2.7-m). The control room contains the control equipment, agent delivery system, DC power system, and gas analyzer. The test room contains the test chamber, camera, agent piping, nozzle and ventilation system. The test chamber (Figure 2) consists of a 0.9-m x 0.9-m x **1.2-m** box mounted on four, 0.63-m steel legs. The side panels were constructed from 6-mm thick clear polycarbonate sheets reinforced by a frame constructed from angle iron. The top and bottom panels were constructed from 3-mm steel plate. Two clear polycarbonate ports (0.3-m x 0.3-m) were mounted on the front panel and one clear polycarbonate port (0.3-m x .0.3-m) was mounted on the rear panel. Inlets were provided for DC power, agent delivery, thermocouples and sampling probes. The ventilating system consisted of two 0.13-m exhaust duct with motorized exhaust fans and dampers and one 0.13-m intake duct with a manually operated damper. The internal volume of the test facility is 1.1-m^3. **A** volume of 0.03-m^3 was added for the volume of the intake and exhaust duct from the test chamber to the dampers.

DISCHARGE SYSTEM:

The discharge system (Figure 3) consisted of a simple piping network constructed from 3.6-m of 9.5-mm (od) seamless galvanized steel piping with associated fittings. The total length **of** the discharge system piping was 3.6-m. Two sizes of agent cylinders, 500-cc and 1000-cc, were **used** to meet the agent's liquid fill ranges. Each cylinder assembly was equipped with a 6-mm stainless steel, quarter turn ball valve with a locking handle, pressure gauge and relief valve to prevent over-pressurization. Various nozzles were tested to insure proper distribution of the agent in the test enclosure. The discharge system was not optimized for any specific agent but was designed to accommodate all of the agents tested.

INSTRUMENTATION

The temperature inside the test enclosure was measured **by** three thermocouples located at various heights within the enclosure. Each thermocouple was equipped with a digital readout to indicate *the* high/low temperature recorded during the tests. **A** three channel gas analyzer was used to measure agent concentrations at different heights within the enclosure. The gas analyzer was used to verify the calculated agent concentrations versus actual agent concentrations during control (cold discharge) tests. A video camera was used to record the results of each agent test. A gas sampling **port** was located near the bottom of the front panel for sampling decomposition **(HF)** products. Two DC fans were located at the base of the test enclosure to insure adequate air mixing within *the* test enclosure prior to sampling for hydrogen fluoride (HF).

TEST PROTOCOL:

All tests were conducted using Polymethylmethacrylate (PMMA) as the fuel source. This polymeric material is used in electronic equipment and its flammability characteristics can constitute a serious fire hazard.

The ignition source was a DC Power Unit energizing various gauges and lengths of nickel-chromium alloy (nichrome) resistance heating wire. Initial tests were conducted using 0.3-m (12-inches) of 20-gauge nichrome resistance wire wrapped around a PMMA block and energized by a DC power unit to 192 watts (Figure **4).** Test results indicated that much of the heat generated by the nichrome resistance wire was being dissipated within the test chamber and not being used to ignite the PMMA block. To more efficiently utilize the energy, tests were conducted at **48** Watts using 0.1-m (4-inches) of 24-gauge nichrome resistance wire in which the PMMA block was "sandwiched" around the resistance wire (Figure *5).*

TEST PROCEDURES:

The following procedures were used to conduct the tests:

- The test chamber was ventilated. The test chamber ventilation system was shut down and the chamber secured.

- Test name, number, date, fuel type and weight, agent type and agent concentration and ambient temperature were recorded prior to the start of the test.

- Nichrome resistance wire was either wrapped around the PMMA block to be tested (192 Watt tests) or sandwiched in the middle the PMMA block **(48** Watt tests). The PMMA block was placed on a V-shaped ceramic test block located inside the test chamber. The V-shaped ceramic test block was held in place by a V-shape steel template which was mounted on a 0.3-m x 0.2-m cinder block. DC power was applied to either the 20 gauge or 24 gauge nichrome resistance wire used to ignite the PMMA block. A metal framed glass baffle (0.24-m x 0.24-m x 0.2-m) was placed around the fuel sample to reduce the probability of flame extinguishment by turbulence during agent discharge.

- The amount of agent to be tested was calculated from the agent's total flooding tables listed in NFPA-12A or NFPA-2001 based on the test chamber volume and temperature. The agent was loaded into the test cylinder and weighed on a digital scales (minus the weight of the cylinder) taking care not to exceed the agent's maximum fill density. Two agents (FC-3-1-10 & HFC-227ea) were pressurized with nitrogen to 2.48 MPa (360 psi). HFC-23 was tested at its normal pressure of 4.72 MPa (686 psi).

- The doors in the test chamber were closed. The video camera was placed in position to view the fire test through the rear port and turned on.

- Sampling tubes were connected from the three air sample ports in the test chamber to the three channels in the gas analyzer. The gas analyzer was turned on and calibrated for the agent to be tested.

- The DC power system was turned on. The amount of energy required to heat the nickel-chromium resistance wire to its designated temperature was recorded. The time required for the fuel to ignite was recorded. If the fuel did not ignite within ten minutes the test was discontinued.

- In the event the fuel ignited, a 60 second prebum was allowed. The test agent was then discharged into the test chamber. The agent discharge time was recorded. A discharge time of ten seconds or less was considered to be acceptable.

- The time for fire extinguishment was recorded. If fire extinguishment did not occur within ten minutes (or when the fuel was consumed) the test was discontinued. The test was considered acceptable if fire extinguishment occurred within 30 seconds after agent discharge.

- In the event the flame was extinguished, the test was continued to determine the time required for reignition or reflash to occur. The time required for reignition or reflash to occur was recorded. If reignition or reflash did not occur within ten minutes the test was discontinued.

- The maximum and minimum temperatures in the test chamber were taken at three different heights in the test enclosure and recorded.

- Intake and exhaust vents were opened to ventilate the test chamber. The video camera was turned off. The test was completed and the data was analyzed.

- The tests were repeated using higher concentrations of agent until the inerting value was reached (or where reignition or reflash did not occur).

- The above tests were repeated at the two energy levels for each agent selected.

CALIBRATION AND CONTROL TESTS:

Calibration and control tests were conducted on Halon 1301 and the selected clean agents. These tests were conducted during cold discharge (without igniting the fuel). The purpose of the tests were to:

- Optimize agent discharge times. Various nozzles were tested to reduce agent discharge time. **A** three-port nozzle was selected for discharge tests conducted on FC-3-1-10, HFC-227ea and HFC-23.

- Verify actual versus calculated agent concentration values using the three-channel gas analyzer.

- Determine agent holding time in the test chamber. The gas analyzer strip charts indicated that the test chamber was very "tight" with less than **0.1%** loss in agent concentration after a 20 minute test period.

- The **fans** were tested to determine if proper agent mixing was occurring within the test chamber for decomposition product (HF) sampling.

AGENT TESTS:

From over 100 tests conducted on Halon 1301 (baseline) and the three agents (FC-3-1-10, HFC-227ea, and HFC-23) at energy levels of 48 Watts and 192 Watts, twenty (20) tests were selected to be representative of the overall test effort. The following criteria was established for the tests to be considered satisfactory: (1) Discharge time of 10 seconds or less, (2) Extinguishment in 30 seconds or less after agent discharge, (3) No reignition or reflash for ten minutes or less after extinguishment. The results of the tests are shown in Table 1.

DECOMPOSITION (HF) TESTS:

A limited number of tests were performed to measure products of thermal decomposition (HF). Tests were conducted at energy levels of 48 Watts and 192 Watts on three agents, FC-3-1-10, HFC-227ea and HFC-23 at inerting concentrations where reignition or reflash did not occur. No test samples were taken on Halon 1301. The decomposition test samples were analyzed using fluoride ion specific electrode. An insufficient number of test have been conducted to date to reach a definitive conclusion on levels of product decomposition. There is a need for further testing, which is in progress. Preliminary test results indicate that greater levels of HF were produced at higher energy levels.

TEST RESULTS:

The results of the tests indicated:

- All clean agents extinguished Class "C" energized fires.
- Reignition or reflash occurred with all clean agents at extinguishing concentration levels.
- Constantly energized fires required higher clean agent concentrations for extinguishing and inerting.
- Clean agent concentrations required for inerting were higher than clean agent concentrations required for extinguishing.

- Clean agent concentrations required to extinguish Class "C" energized fires compared favorably with Class "**B**" cup burner (heptane) extinguishing values.

- Decomposition products (HF) tended to be greater at higher energy levels.

CONCLUSIONS:

The following conclusions were reached:

- Clean agent extinguishing and inerting concentration values for Class "C" energized **fires** should be based on the energy levels to be protected. Higher energy circuits **require** higher agent concentration values for adequate fire protection.

- To prevent reflash or reignition of Class "C" energized fires, clean agent concentration values should be designed for the test inerting value plus a minimum 10% safety factor.

- The greater levels of HF generated using clean agent inerting concentrations to prevent reignition or reflash may make it necessary to limit the time that electronic circuits can be energized to prevent corrosion damage to sensitive electronic equipment.

ACTIONS PLANNED:

The following actions are planned:

- Complete inert gas tests. Preliminary results indicate that inert gas agents may be a viable alternative to the halocarbon agents when high levels of HF are a factor.

- Test other Polymeric materials. Some tests have been conducted on **ABS** and PVC.

- Tests higher energy level circuits up to 1,500 Watts. This is **a** typical energy level found in a **48** Volt DC power system at a cellular switching center.

- Conduct tests on other selected **NFPA** 2001 agents approved for occupied areas.

RECOMMENDATION

An acceptable Class "C" energized fire test protocol be developed for inclusion in appropriate test standards.

ACKNOWLEDGMENTS:

Acknowledge is made to the assistance received from Dan Moore, DuPont; **Paul** Rivers and Mark Driscoll, **3 M** Dave Pelton and Steve Hansen, Ansul, in providing clean agents for the tests **and** other valuable comments.

REFERENCES:

1. Moore, T. A., Dierdorf, D. *S.*, Skaggs, *S.* R., "Intermediate-Scale (645-ft^3) Fire Suppression Evaluation of NFPA 2001 Agents," Halon Alternatives Technical Working Conference, Albuquerque, **NM,** 10-13 May 1993.

2. Moore. T. A.. Dierdorf. D. **S..** Skaggs, **S.** R.. "Large-Scale Inertion Evaluation of NFPA 2001 Agents,;' 1993 CFC & Halon Alternatives Conference, Hilton Hotel, Washington, DC, 20-22 Oct. 1993.

3. Sheinson, R. *S.*, Eaton, H. G., Black, B. H., Brown, R., Burchell, H., Maranghildes, A., Mitchell, C., Salmon, G., Smith, W. D., "Halon 1301 Replacement Total Flooding Fire Testing, Intermediate Scale," Halon Alternatives Technical Working Conference, Albuquerque, **NM,** 3-5 May 1994.

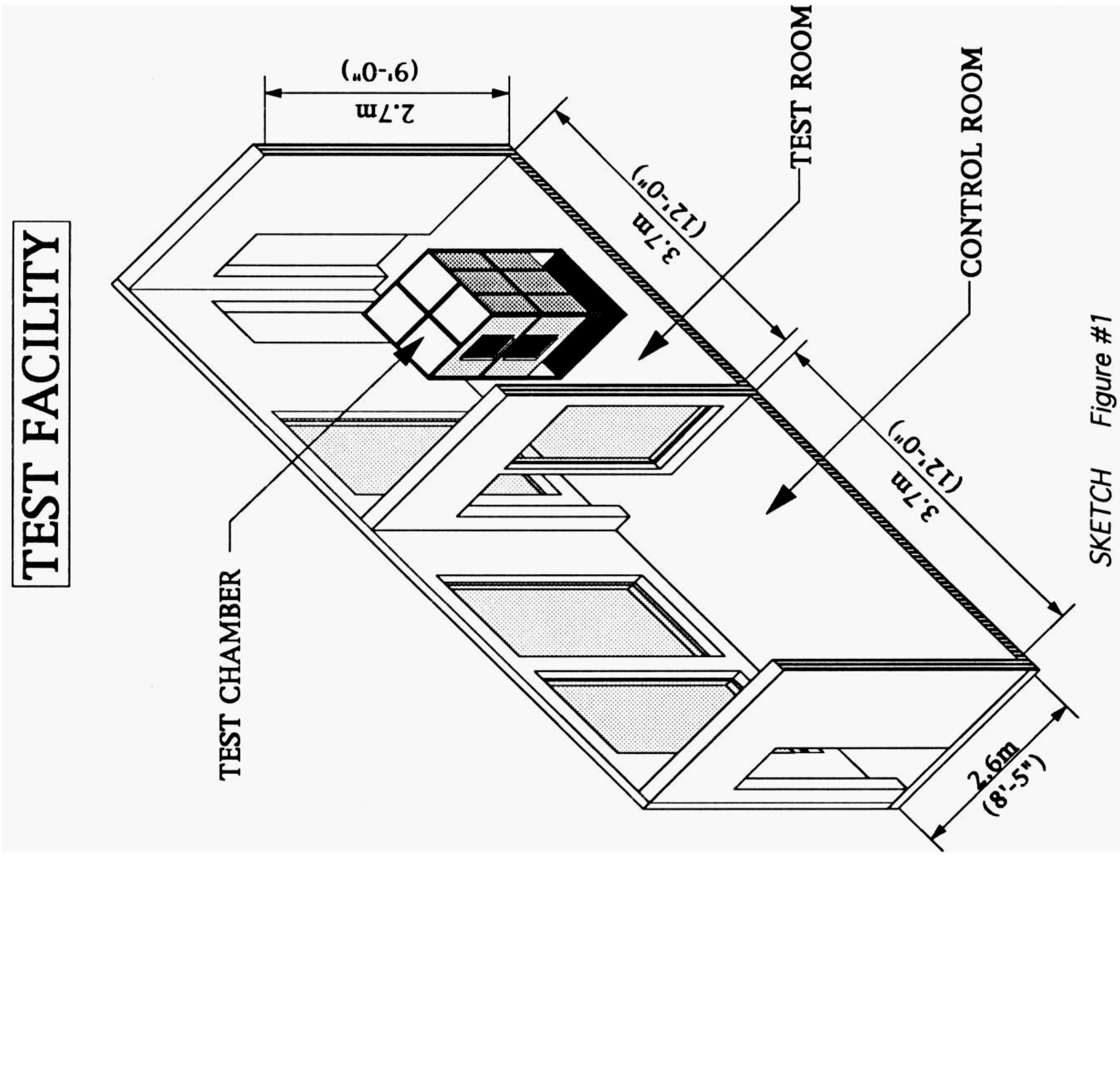
4. Shienson, R. **S.,** Maranghildes, A., Eaton, H. G., Barylski, D., Black, B., Brown, R., Burchell, **H.,** Byrne, P., Frilderichs, T., Clark., M., Peatross, M., Salmon, G., Smith. **W.,** Williams, F., "Large Sale (840 m3) HFC Total Flooding Fire Extinguishment Results," Halon Alternatives Technical Working Conference, Albuquerque, **NM,** 9-11 May 1995.

5. Hansen, R., Richards, R., Black, G., Moore, T., "USCG Full-scale Shipboard Testing of Gaseous Agents," 1994 CFC & Halon Alternatives Conference, Hilton Hotel, Washington, DC, 24-26 Oct. 1994.

6. Tewarson, A., Pion, R. F., "Flammability of Plastics-I. Burning Intensity," Factory Mutual Research Corporation, Norwood, MA, Technical Report No. 26,85-103, 1976.

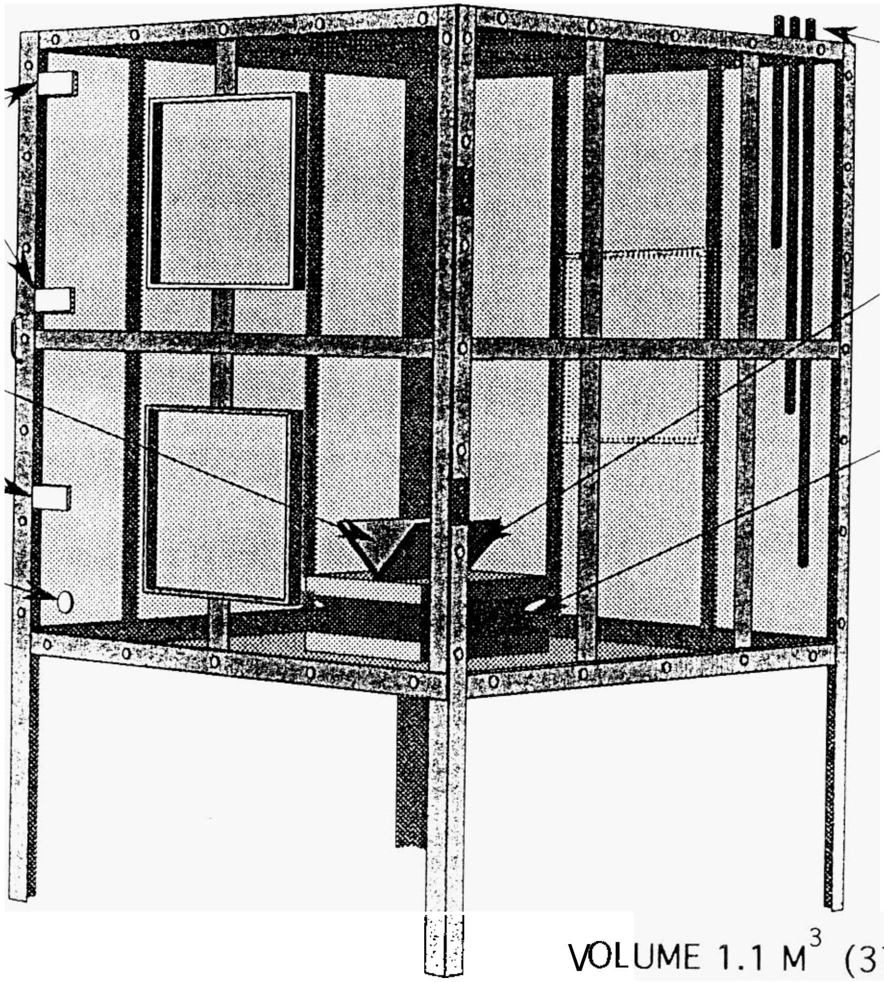
Table 1 - Agent Test Summary

Test Number	Agent	Test Energy Level (Watts)	Test Concentration (% by Volume)	Discharge Time (m:s)	Extinguishing Time (m:s)	Reflash or Reignition (m:s)
1	Halon 1301	48	3.0	0:05	0:11	No
2	FC-3-1-10	48	5.5	0:05	0:05	1:13
3	HFC-227ea	48	6.5	0:05	0:10	4:40
4	HFC-23	48	13.0	0:04	0:09	6.41
5	Halon 1301	48	3.0	0:05	0:10	No
6	FC-3-1-10	48	8.0	0:05	0:02	No
7	HFC-227ea	48	8.0	0:05	0:03	No
8	HFC-23	48	16.0	0:07	0:09	No
9	Halon1301	192	4.0	0:05	0:07	0:11
10	FC-3-1-10	192	6.5	0:05	0:01	0:07
11	HFC-227ea	192	8.0	0:05	0:06	2:29
12	HFC-23	192	14.0	0:05	0:20	5:14
13	Halon1301	192	5.5	0:05	0:03	No
14	FC-3-1-10	192	9.5	0:05	0:02	No
15	HFC-227ea	192	9.0	0:05	0:06	No
16	HFC-23	192	20.0	0:05	0:25	No



SKETCH Figure #1

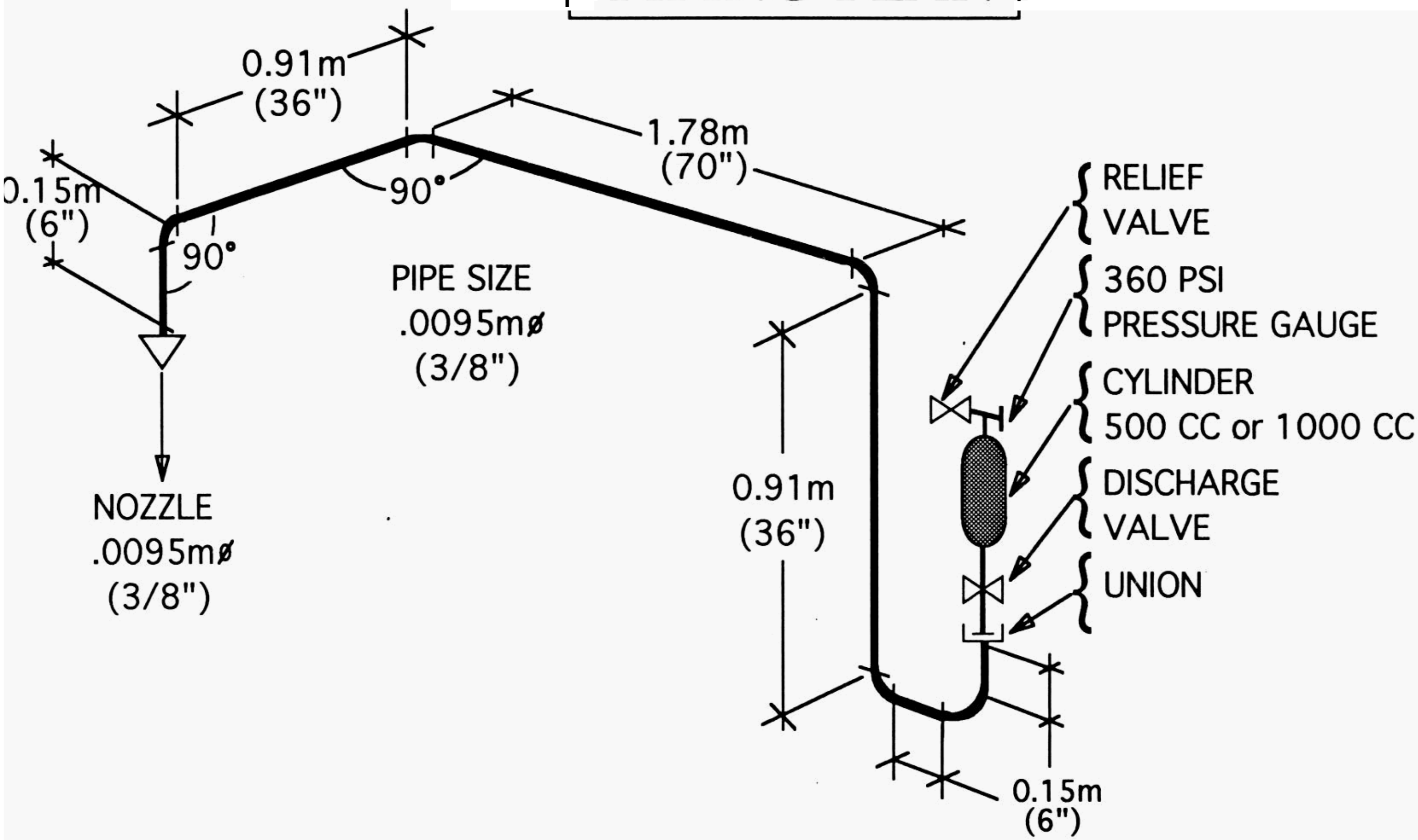
TEST CHAMBER



VOLUME 1.1 M^3 (37 CU.FT.)

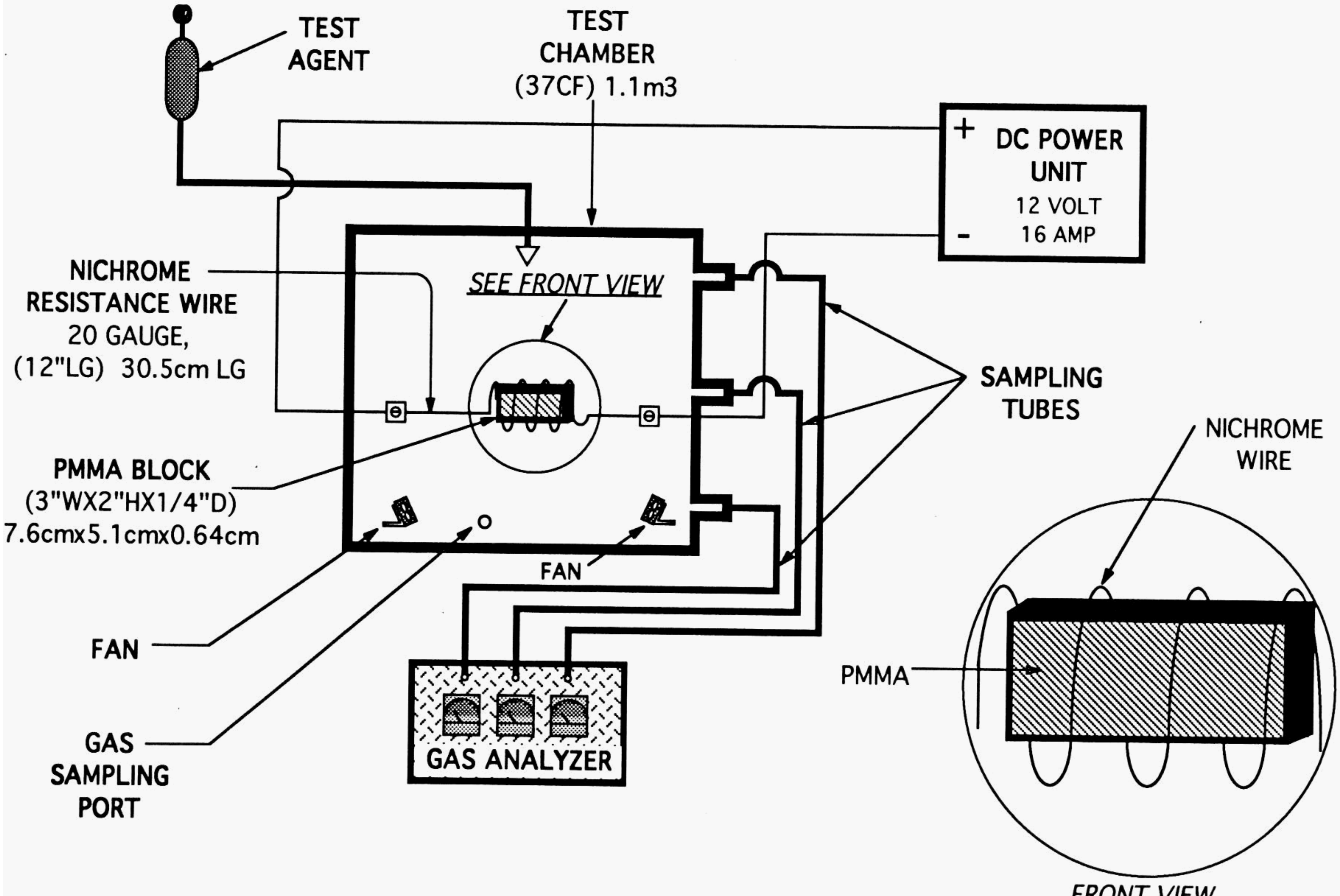
SKETCH Figure #2

PIPING PLAN



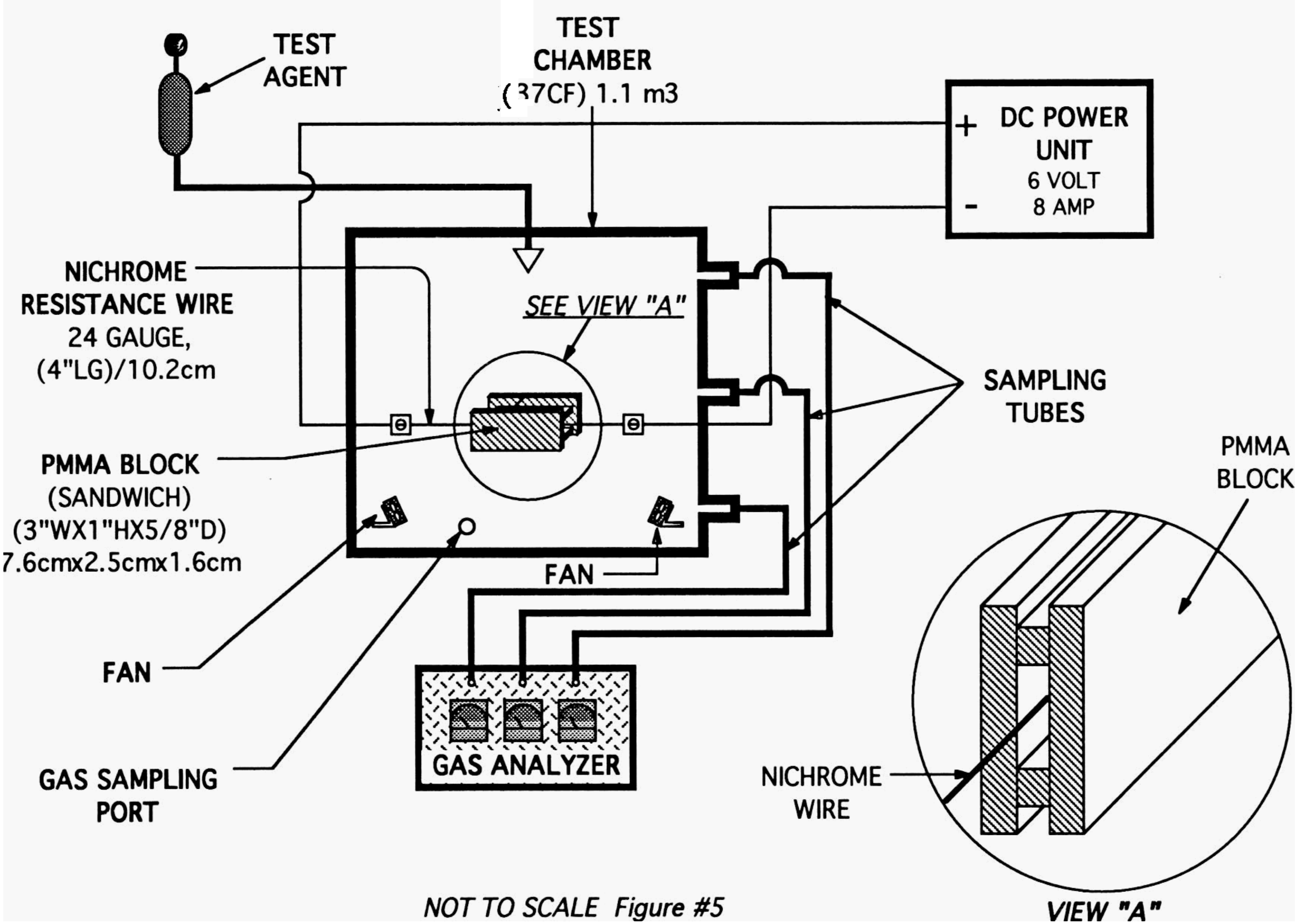
SKETCH Figure #3

TEST PROTOCOL - 192 WATTS



NOT TO SCALE *Figure #4*

TEST PROTOCOL - 48 WATTS



NOT TO SCALE *Figure #5*