PYROGEN™

# PYROGEN

## Pyrotechnically Generated
## Fire Extinguishing Aerosol System

## Local Applications

# SUBSTATION ELECTRICAL PANEL CUBICLES FIRE TESTS

## INTEGRAL ENERGY SEVEN HILLS SERVICE CENTRE

**04-2-1998**



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## 1. PURPOSE OF TESTS

This series of tests were to demonstrate the ability of PyroGen fire protection system to adequately extinguish fires that could occur within a typical substation electrical panel cubicles. Tests were conducted on request of Integral Energy Networks (Network Substation Assets Branch) at Integral Energy Seven Hills Service Centre in anticipation that a suitable solution to the current fire protection problem at the Transmission and Zone Substations could be identified from the tests.

All of the tests were carried out on the 4th of February 1998 and were witnessed by:

*INTEGRAL PERSONNEL:*

Mr. Steven Parker
Mr. Stephen Quinn
Mr. Jim Hickey
Mr. Noel Mahon
Mr. Ray Thèlehwic
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## 2. PYROGEN

### 2.1 Product Description

PyroGen - Pyrotechnically Generated Fire Extinguishing Aerosol - belongs to a new class of fire suppressants. It has the lowest known among commercially available agents extinguishing concentration, which is more than three times lower than that for Halon 1301 , gas like distribution and long holding times.

PyroGen has no global atmospheric environmental impacts and does not require any stored pressure cylinders or complicated piping structures. It is simply a series of suitably sized canisters, called MAG generators, strategically placed within the risk area and electrically connected to most types of Fire Control panels, manual or automatic.

PyroGen MAG generator contains four main elements:

- an electric ignition device;
- a block of aerosol-generating composition;
- a chemical coolant, and
- a delivery nozzle.

Electrical or thermal initiation of a PyroGen generator triggers a chemical reaction of combustion of solid aerosol-generating composition to produce the fire inhibiting aerosol. The aerosol propels itself through the coolant and out of the delivery nozzle into the protected zone.

As PyroGen aerosol is *self-generated* upon ignition of the solid aerosol-generating composition, it requires no pressure cylinders and, therefore, no complicated design and pipework.

PyroGen aerosol is whitish gas-like medium that is close in density to air.

PyroGen aerosol is non-conductive and non-corrosive.

As PyroGen aerosol stays in suspension, it would be removed from the protected area by any airflow. Aerosol that has settled can easily be brushed, blown or washed away.

PyroGen aerosol is suitable for the protection of a variety of potential fire hazards, including those involving flammable liquids and gases, combustible solids, oils and energised equipment. Like all total flooding agents, PyroGen aerosol is most effective when used in an enclosed risk areas.

## 2.2 Extinguishing mechanism

PyroGen aerosol is a mixture of finely divided solid particles and gaseous matter. Solids form 40 % and mainly consist of potassium bi-carbonate, whilst gases form 60 % and comprise of a nitrogen gas, carbon dioxide gas and water vapour. As aerosol is a combustion product of aerosol-generating composition and generated at high temperature, the potassium salts particles are formed in the gaseous form but as vapour cools, they condense to a liquid and then a solid. As the solid potassium salts are produced by condensation, the particles size is extremely small ( from 1 to 10 microns).

Micron size of aerosol particles, high rate of aerosol discharge and its efficient cooling ensure homogeneous gas-like distribution in a few seconds. Fine aerosol particles are exceptional fire suppressants as they have extremely high surface areas and provide long holding times.

PyroGen aerosol attacks fire both chemically and physically.

Primarily, the aerosol extinguishes the fire chemically, interfering with the flame chain reaction. At the reaction temperature the main component of PyroGen aerosol - potassium compounds dissociate into potassium radicals. Potassium radicals react with so called "chain carriers" - highly reactive molecular fragments responsible for flame propagation, removing them from the flame and thus suppressing the fire. Apart from being removed by potassium radicals, chain carriers recombine and thus eliminate themselves on the highly developed surface of aerosol particles. The chemical action of potassium radicals is similar to that of bromine radicals in Halons.

Physical action is due to heat removal from the flame. Heat is removed during the heat absorbing phase transitions of aerosol particles from solid to liquid and further to gaseous form, as well as during some heat absorbing chemical reactions involving potassium carbonates.

Mainly, physical and chemical actions take place on the surface of aerosol particles. Extremely high surface area of PyroGen aerosol particles increases the likelihood of chain carriers' removal and recombination reactions, as well as heat absorbing processes, thus ensuring rapid extinguishment with a small amount of agent. Rapid discharge, homogeneous distribution in a matter of seconds and long holding times prevent fire re-ignition.

## 2.3 Safety Limits

PyroGen is intended to be used in normally unoccupied areas only due to the high obscuration caused by the aerosol during and after discharge. Therefore, the information below refers to an inadvertent exposure to the aerosol in the event of accidental discharge.

Main ingredients of PyroGen aerosol are solid potassium carbonates, nitrogen gas, carbon dioxide gas and water vapour. At normal extinguishing concentrations these products present no health hazards to personnel. However, small amounts of potentially hazardous by-products of the aerosol-generating combustion reaction, such as carbon monoxide, nitrogen oxides and ammonia may also be produced. It should be noted that these gases are typical combustion by-products from the fire alone. Their actual concentrations depend on extinguishing concentration, conditions of discharge and configuration of the enclosure being protected.

Exposure to a PyroGen concentration of 100 $g/m^3$ under conditions of hermetically sealed enclosure for up to 5 minutes is normally considered to represent a minor risk to personnel and may cause only moderate local irritation of the upper respiratory tract and to the eyes.

Estimation of the above exposure times is based only on concentration levels of toxins that have been analysed and information on their physiological effects on humans provided in reference literature ( refer to PyroGen Toxicity Report ).

Cumulative effect of chemicals as well as high obscuration and associated possible panic reaction of personnel shall be considered.

Physiological effect of deep lung penetration is usually a concern for *insoluble* sub-micron particles as they can interfere with pulmonary functions. For *soluble* PyroGen aerosol particles it had been shown that the presence of pulmonary edema in animals subjected to the aerosol inhalation were mostly likely due to a compartmental shifts of tissue fluids due to a rapid dissolution of the highly soluble aerosol particles and not that of cell death. Effects resolved within a week of exposure with very little or no remarkable cellular damage evident.

***Inadvertent exposure to PyroGen aerosol should always be avoided.***

The other potential hazard is a high temperature ( 250-350C) of PyroGen aerosol at the end-plate nozzle. Within 0.3-0.5 metres from the nozzle the temperature does not exceed 75C.

Immediately after discharge the generators can be hot.

# 3. TEST SET-UP

## 3.1 Test Enclosure

Three discarded substation electrical panel cubicles (hereinafter referred to as Panels) had been transported by Integral Energy Test & Instrument Services from the Baulkham Hills TS to the Seven Hills Service Centre and set up for the tests.

The panel are jointed together in a non-dismountable assembly. Perforated metal partitions separate side panels from the central panel. The dimensions of the panels are as follows:

| | |
|---|---|
| Right Single End Panel: | 900 mm (W) x 530 mm (D) x 2100 mm (H), V= 1.002 $m^3$ |
| Central Panel: | 600 mm (W) x 530 mm (D) x 2100 mm (H), V= 0.668 $m^3$ |
| Left Single End Panel: | 600 mm (W) x 530 mm (D) x 2100 mm (H), V= 0.668 $m^3$ |

The relays and etc. had been removed from the panel facias and the resulting hols blanked off. Panel cubicle rear doors were included and shut for the tests.

The panels were mounted off the ground over a rectangular concrete pit, 450-600 mm deep, 450 mm wide and 4000 mm long, which simulated a cable trench to some extent. The base of the panels, where the cables would normally enter the panel from the cable trench, was open, excluding a metal sheet that had been placed in the centre of the base and served as a support for a tray with a flammable liquid. The sheet was approximately 25-30 % of the area of the base.

## 3.2 Model Fires

The panels had internal PVC wiring looms to be burned throughout. Additional 8 m cable was extended in a form of a double loop from the panel's ceiling down the base approximately 20 cm above the tray with a flammable liquid (heptane). The loop was connected to a short circuited CT transformer producing 500-600 Amps.

## 3.3 PyroGen installation

PyroGen system consisted of 1 MAG-3 generator installed in a single panel. The generator was mounted at the centre of the enclosure ceiling with a delivery nozzle directed downwards onto the heptane fire.

## 3.4 PyroGen activation

Integral is more interested in thermal activation of PyroGen via an in-built fire conducting cord rather than electric activation via detection and control circuits, due primarily to the extra costs involved with the use of the later. However, since electric manual activation allows better control of fire conditions, both activation mechanisms were demonstrated.

Electric activation of PyroGen generator was effected manually via a remote push button activation panel after approximately 30 seconds of pre-burn time.

Thermal activation of PyroGen generator was effected automatically via a fire conducting cord which ignites at temperature of 175 °C or when in contact with a naked flame and propagates ignition to the aerosol-generating element inside PyroGen generator. Prior to installation a piece of the fire conducting cord of approximately 1.5 meters long was pulled through a special metal spiral and knotted at the threaded end of the spiral. The spiral was then screwed with its threaded end into a generator's nozzle so that the external fire conducting cord was brought into a contact with an in-built fire conducting cord attached to the aerosol-generating element inside the generator. The external cord was prolonged along the side walls of the panel in their upper parts so that sufficient time would be allowed for the model fire to develop before the heat produced by the flame or flame itself would automatically ignite the cord and activate the PyroGen generator.

## 3.5 Instrumentation

### *3.5.1 Temperature*

Three "K" type thermocouples were installed to measure fire temperatures (extinguishment time) - two thermocouples were attached to the cables and one thermocouple was secured above the tray with heptane. One thermocouple was secured at the nozzle of PyroGen generators to indicate the aerosol release as well as its discharge time. Thermocouple outputs were recorded by means of a Data Logger connected to a computer to collect data at a rate of 10 times per second and permit the subsequent print out of fire out times and enclosure temperature curves. Pressing of a push button on the activation panel is marked as a "start" on printed-out graphs.

### *3.5.2 Recording*

A video camera and a thermovision camera were set up by Test & Instrument Services to record each test sequence for reference purposes. A clock function was available and switched on to enable an on screen time reference.

# 4. TEST PROTOCOL

## 4.1 Test No 1: Right Single End Panel: 1 MAG-3 Electric Ignition

In this test the blanking plate was fitted to blank off the perforated metal partition between the right end and central panels.

The test sequence was as follows:

- Video equipment was set up, recording started
- Heptane was ignited;
- 10 seconds later the power was supplied from the transformer to the cable loop;
- 4-5 seconds later the wire became an open circuit cutting off the power;
- 20 seconds pre-burn time was allowed to ensure ignition of PVC wiring looms and that a required strength of the fire had been established;
- The door of the panel was shut;
- PyroGen generator was manually activated by a remote electric push button.
- Holding time of one minute was allowed;
- The door was open and the result of extinguishment was observed.

## 4.2 Test No 2: Central Panel: 1 MAG-3 Thermal Ignition

In this test two blanking plates were fitted to blank off the perforated metal partitions between the end panels and central panel.

The test sequence was as follows:

- Video equipment was set up, recording started
- Heptane was ignited;
- 10 seconds later the power was supplied from the transformer to the cable loop;
- 4-5 seconds later the wire became an open circuit cutting off the power;
- Approximately 7 seconds pre-burn time was allowed to ensure ignition of PVC wiring looms and that a required strength of the fire had been established;
- The noise of the fire conducting cord catching the fire was heard and the door of the panel was quickly shut;
- PyroGen generator was automatically activated by the burning cord. The noise of PyroGen discharge was heard as it commenced its operation.
- Holding time of one minute was allowed;
- The door was open and the result of extinguishment was observed.

### 4.3 Test No 3: Central Panel: 1 MAG-3 Thermal Ignition

Test No 2 was repeated with an attempt to extend 7 seconds pre-burn time prior to PyroGen operation, as strength of the established fire and involvement of wiring looms in the fire were considered insufficient.

The external fire conducting cord was run closer to the ceiling so that it could allow longer pre-burn time prior to automatic ignition of the cord and operation of PyroGen generator.

The test sequence was as follows:

- Video equipment was set up, recording started
- Heptane was ignited;
- 10 seconds later the power was supplied from the transformer to the cable loop;
- 4-5 seconds later the wire became an open circuit cutting off the power;
- Approximately 10 seconds pre-burn time was allowed to ensure ignition of PVC wiring looms and that a required strength of the fire had been established;
- The noise of the fire conducting cord catching the fire was heard and the door of the panel was quickly shut;
- PyroGen generator was automatically activated by the burning cord. The noise of PyroGen discharge was heard as it commenced its operation.
- Holding time of one minute was allowed;
- The door was open and the result of extinguishment was observed.

### 4.4 Test No 4: Central Panel: 1 MAG-3 Electric Ignition

Tests No 2 and 3 were repeated with electric operation of PyroGen generator since thermal operation proved to be too quick for demonstration purposes and did not allow to achieve the required strength of the fire and desired involvement of wiring looms in the fire.

The test sequence was as follows:

- Video equipment was set up, recording started
- Heptane was ignited;
- 10 seconds later the power was supplied from the transformer to the cable loop;
- 4-5 seconds later the wire became an open circuit cutting off the power;
- 20 seconds pre-burn time was allowed to ensure ignition of PVC wiring looms and that a required strength of the fire had been established;
- The door of the panel was shut;
- PyroGen generator was manually activated by a remote electric push button.
- Holding time of one minute was allowed;
- The door was open and the result of extinguishment was observed.

## 4.5 Test No 5: Central Panel: 1 MAG-3 Electric Ignition; Blanking Panels Removed

In this tests two blanking plates were removed from both sides of the panel. The purpose of the test was to establish whether under the above conditions of perforated metal partitions 1 MAG-3 generator would extinguish fire occurring in central panel and no-reignition would occur. The test conditions were considered extremely unfavourable as 1 MAG-3 had been designed for protection of one panel only, whereas with blanking plates off, aerosol dissipated into side panels and, therefore, amount of PyroGen aerosol available for a reliable extinguishment in the central panel was drastically reduced.

It was anticipated that if test proved to be successful the following solution of the panels fire protection could be suggested. If a fire occurs in one panel of the above assembly of three, only one MAG-3 generator could be activated without necessity to waste two other generators as it would normally be required in accordance with PyroGen design criteria. Not until fire spreads into adjacent panels or heat generated by flames is sufficient to activate the fire conducting cord in the adjacent panels, generators installed in those panels would be activated.

## 5. TEST RESULTS

Table 1 gives a summary of the test results, including the generators location, the enclosure geometry, design factor and other parameters.

*Table 1: A summary of test results*

| Test | No 1 | No 2 | No 3 | No 4 | No 5 |
|---|---|---|---|---|---|
| Enclosure Dimensions, mm | 900 mm (W) x 530 mm (D) x 2100 mm (H), | 600 mm (W) x 530 mm (D) x 2100 mm (H), | 600 mm (W) x 530 mm (D) x 2100 mm (H), | 600 mm (W) x 530 mm (D) x 2100 mm (H), | 600 mm (W) x 530 mm (D) x 2100 mm (H), |
| Enclosure volume, $m^3$ | 1.002 | 0.668 | 0.668 | 0.668 | 0.668 |
| Blanking panels | fitted | fitted | fitted | fitted | ***removed*** |
| PyroGen: Location | ceiling of the panel; nozzle is directed downwards | ceiling of the panel; nozzle is directed downwards | ceiling of the panel; nozzle is directed downwards | ceiling of the panel; nozzle is directed downwards | ceiling of the panel; nozzle is directed downwards |
| PyroGen : Amount | 1 MAG-3 | 1 MAG-3 | 1 MAG-3 | 1 MAG-3 | 1 MAG-3 |
| PyroGen: Design Factor $g/m^3$ | 200 | 300 | 300 | 300 | 300 |
| Extinguishment, s | immediate | immediate | immediate | immediate | immediate |
| Re-ignition | No | No | No | No | No |

Graphs temperature-time showing extinguishment times, discharge of the aerosol and operation time of the generator for each test are presented in Figures 1-5.
Video of the tests, including thermoimaging, is available upon request.

## 6. DISCUSSION AND CONCLUSION

Design factor for PyroGen total flooding applications for class B (flammable liquids) and surface class A (non-smouldering solid materials) fires is 100 $g/m^3$. For smouldering class A fires, such as electrical cables, PyroGen design factor proved to be higher - 250-300 $g/m^3$.

PyroGen application in substation electrical panel cubicles as tested cannot be considered a total flooding application, as base of the panel is fully open and causes a significant loss of the extinguishant, not allowing to establish and maintain its concentration in the protected enclosure. The above application should be considered a local application, where agent is discharged directly onto the identified hazard, and as such PyroGen design factors listed for total flooding applications could be used as a guide only.

Successful application of 1 MAG-3 generators in a single panel provides design factor from 200 $g/m^3$ to 300 $g/m^3$ , which is in good concurrence with PyroGen design criteria for total flooding applications for electrical cable fires.

Instantaneous extinguishment of heptane and energised cable fires under conditions of open circuit and large area of unclosable openings, as well as absence of re-ignition under conditions of extremely short holding time (1 minutes compared to accepted 10 minutes for class A fires), clearly indicates that the design methodology, including limitations and installation instructions, provides large safety margin and ensures reliable extinguishment of the above types of fire in a typical substation electrical panel cubicle.

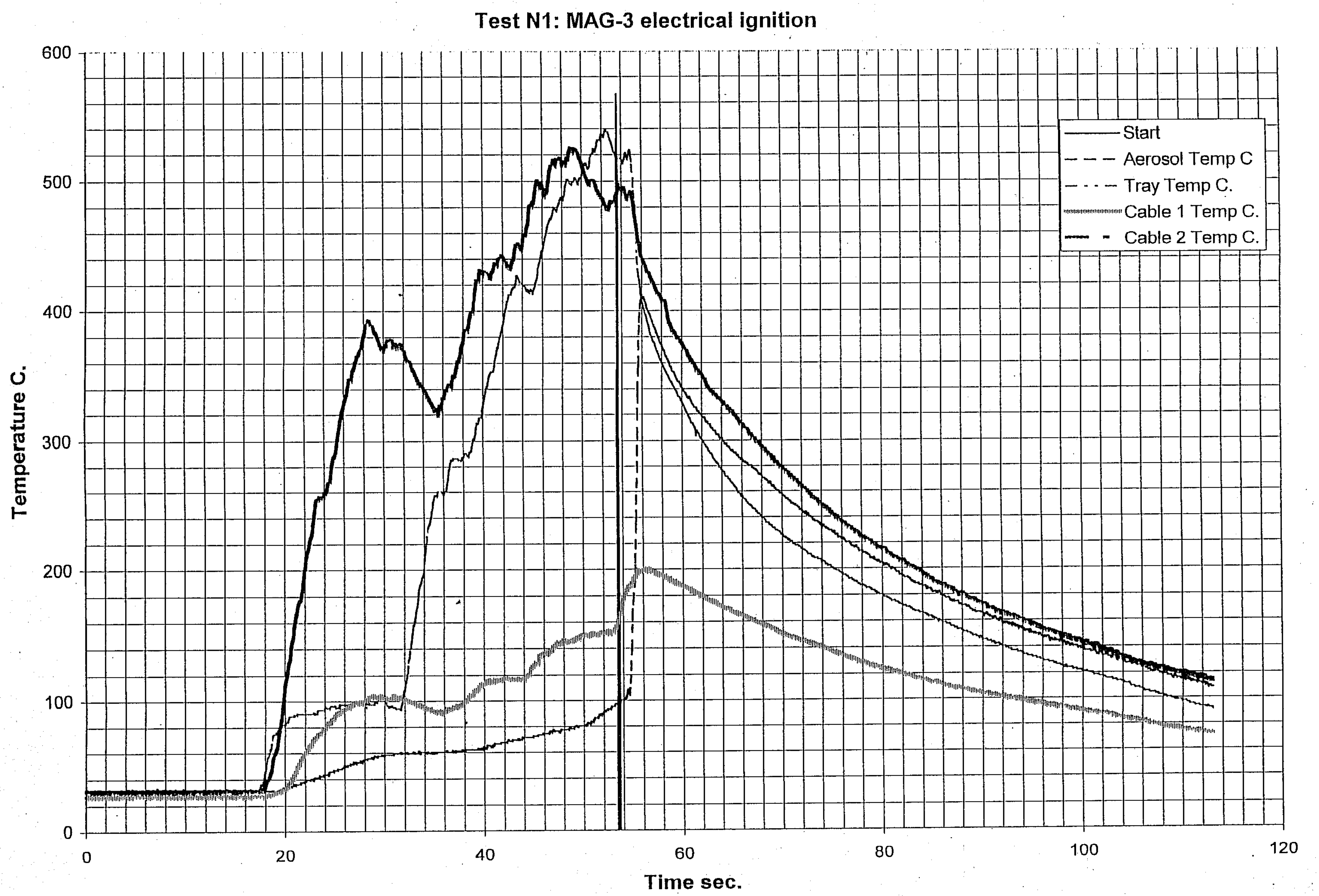
Based on the above test results, 1 MAG-3 generator is recommended for a reliable protection of a single cubicle either 600 mm or 900 mm wide.

As shown by a demonstration test with blanking panel having been removed, if fire occurs in one panel of the assembly of three, only one MAG-3 generator could be activated without necessity to waste two other generators as it would normally be required in accordance with PyroGen design criteria. Not until fire spreads into adjacent panels or heat generated by flames is sufficient to activate the fire conducting cord in the adjacent panels, generators installed in those panels would be activated.

Operation of MAG-3 generators could be either electrical or thermal. Thermal operation via a fire conducting cord has been demonstrated to be reliable, quick and effective, although additional tests would be recommended to establish a required response time of the fire conducting cord and its correct installation inside the panel.

Report prepared by: Dr. Julia Berezovsky, PhD Chem.

7 February 1998


Test N1: MAG-3 electrical ignition
Temperature C.
Time sec.
Start
Aerosol Temp C
Tray Temp C.
Cable 1 Temp C.
Cable 2 Temp C.
0
100
200
300
400
500
600
0
20
40
60
80
100
120