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REVIEW OF SPACECRAFT FIRE HAZARD DETECTION TECHNIQUES

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The NASA Spacecraft Fire Hazards Steering Committee will support the following R&D:

1. Fire hazard detection.
    a. Select promising approaches to fire hazard protection which have potential for spacecraft application.
    b. Support development of hazard detection systems.
    c. Define capabilities and limitations of all fire hazard detection systems in engineering terms to guide designer.
2. Fire extinguishment.
    a. Extinguishment agent development and evaluation.
        (1) Solid and liquid combustibles.
        (2) Hypergolic combinations.
    b. Engineering of extinguishing systems for spacecraft applications.
    c. Recovery procedures following fire extinguishment.
3. Facilities' fire protection.

While fire hazard detection, item 1. above, is the principal subject of today's meeting, it is useful to emphasize at the outset that complete fire protection arrangements include:

1. Fire hazard detection system.	(Equipment)
2. Procedures and equipment for correcting conditions responsible for the developing hazard applied in time to prevent the fire.	(Training & Equipment)
3. Fire extinguishing system.	(Equipment & Training)

4. Cleanup procedures following a fire. (Training & Equipment)

The Steering Committee has surveyed existing information on the application of available fire hazard detectors, and those which merit development, to manned spacecraft. This survey included literature reviews, contacts with manufacturers, and discussions with past users. Some of the information is unreliable for the following reasons:

1. Manufacturers hold much information proprietary and it is unavailable.
2. Performance data were obtained under conditions which maximize the virtues and conceal weaknesses.
3. Sensitivity and response time of the basic detector is different than the total detector system as installed.
4. Performance data are based on highly optimistic extrapolations from simple tests with less-than-breadboard apparatus.
5. Brochuremanship.

Because toxic gases may be released by outgassing solids under normal conditions, or be released during the developing fire hazard or the fire that follows, the Steering Committee included toxic gas detection capability in its search for hazard detectors. It is the Committee's hope that a single instrument could serve the function of monitoring the toxic gas content of the normal spacecraft atmosphere while it stands ready to detect a developing fire hazard. Remarks directed at toxic gas monitoring will be included with the discussion on fire hazard detection.

Useful fire hazard detection provides warning early enough for effective application of safety measures. For spacecraft, this usually requires that means for rapid, positive, location of the hazard must be part of the detection system capability.

A useful fire hazard detection system for spacecraft must:

1. Give warning early enough for effective countermeasures.
2. Locate hazard.
3. Be free of false warnings.
4. Withstand launch stresses.
5. Require a minimum of maintenance and calibration, once installed.
6. Have acceptable size, weight and power requirements.

Ideally, fire hazards should be detected before:

1. Solids reach ignition temperatures.
2. Gases accumulate to combustible concentrations.
3. Ignition sources grow to threatening proportions.

Actually, fire may develop in spite of the installed early warning detection devices and so the complete detection system must include fire detectors which:

1. Detect and locate fire start.
2. Remain effective throughout fire to signal that the fire is extinguished.

Many fire hazard detectors exist. Each has its strengths and weaknesses. These discussions review the application of detectors to spacecraft and present our recommendations for the development of those which appear most useful and available in time for the AAP.

As an introduction to the discussion of fire hazard detectors, it is instructive to relate these detectors to the phase of the developing fire hazard to which they apply. Two general fire hazards are recognized: (1) overheated solids which reach combustible temperatures over several seconds or minutes; and (2) air-gas mixtures which accumulate to combustible concentrations at a time rate which is governed by the size of the leak or spill that exposes the combustible. Fire development following ignition of solids is slow compared with that for gas-air mixtures. Recall that fires involving solid combustibles develop through the following four phases (see figure 1). Detectors appropriate to each phase are listed below.

Phase 1 - Gases and Colloidal Particles

1. "Nuclei counters" which use classical cloud chamber principles to grow a water droplet around each invisible colloidal particle and form a visible cloud whose density is measured optically.
2. "Ion counters" which place electric charge on the colloidal particles and measure migration rate to electrically charged plates.
3. Electric circuit monitoring devices which detect abnormal overload.

4. Correlation spectro/interferometer give automatic identification of dangerous gases by adsorption spectroscopy.
5. Smell.

Phase 2 - Gases, Colloidal Particles, Visible Smokes

1. Smoke detectors which measure the smoke density by the scattering of a light beam transmitted through the smoke.
2. Nuclei and ion counters detect colloidal particles.
3. Infrared detectors detect hot source of smoke.
4. Thermistors and thermocouples.
5. Sight.

Phase 3 - Gases, Colloidal Particles, Visible Smokes, Flame

1. All previous sensors.
2. Ultraviolet.
3. Infrared.

Phase 4 - Bright Flame

1. All previous sensors.
2. Ultraviolet.
3. Infrared.

Nuclei and ion counters, and some forms of smoke detectors and correlation spectrometer/interferometer require that a sample of the monitored atmosphere be drawn into the instrument. The instrument reads on conditions in the atmosphere at the point where the sample was drawn. The time required for containment gases, vapors and smokes to reach this sampling point, and the additional time required to process the sample through the detector, constitute a serious time lag for some applications of these detectors. Likewise, as the fire precursors travel from their source to the sampling point they are diluted by the remainder of the cabin atmosphere to make their detection more difficult. Nevertheless, these detectors can be useful if properly installed and a rational strategy for reaction to their warning is devised.

For air-gas mixtures the developing hazard can be detected by the thermal conductivity bridge, catalytic wires, and the correlation spectrometer during Phase I (figure 2) during which only invisible gases are present. Once ignition occurs ultraviolet and infrared detectors can warn of the fire, but the fire grows to large size after an induction period of 40 milliseconds following ignition. Fire suppression can be achieved in this 40 millisecond period by special explosion-suppression devices which are probably unsuited for general spacecraft use.

Recommendations

Several of the fire hazard detectors are sufficiently well developed and some have adequate service experience to rate consideration for use on the AAP. The recommended hazard detectors and their suggested field of application are summarized on the accompanying chart (figure 3).

To increase the utility of these devices some improvements in design are required, along with a better understanding of their virtues and limitations. For this reason, the following program for improving design and application understanding is proposed:

Condensation Nuclei Counter

Purpose:

(a) To determine relationship between overheat and combustion of spacecraft materials and nuclei count. ERC contract with GE.

Status:

(a) Basic instrument exists; flight version is an easy extension of present instrument.

(b) Since condensation nuclei arise for sources other than overheated solids or flame, a nuclei background count exists which may mask presence of nuclei released by overheated solids or small flame. Resolution of this problem awaits outcome of present work.

(c) Long time required to draw cabin atmosphere sample into instrument remains principal drawback.

Ionization Counter

Purpose:

(a) To derive a flightweight version of present successful counter.

(b) To define its susceptibility to extraneous factors such as dust and ionization radiation.

Status:

(a) Industrial version of sensor has good service history. Present instrument could be used on spacecraft. Some saving in weight and size is possible with redesign for spacecraft application. Automatic compensation for cabin pressure and oxygen content changes has been achieved in recent models.

(b) To reduce sampling time multiple units may be required, each located close to principal sources of combustibles or site of greatest fire threat.

Smoke Detector

Purpose:

(a) To assess the sensitivity of smoke detectors whose operating principle involves the scattering of light from a beam which traverses open zones of the spacecraft, using breadboard mock-up.

(b) To build a flight version of the device for evaluation in boiler plate.

Status:

Components for assembling breadboard mock-up are available.

Continuous Wire Thermistor

Purpose:

(a) To define in engineering terms how to use continuous wire thermistors to detect overheat and fire, within a specified response time.

(b) To define the ability of the continuous wire thermistor to locate overheated components.

Status:

(a) Thermistors have been used successfully to detect fires. Excellent thermistors are available which have served well in aircraft fire detection systems.

(b) Recent improvements have overcome the false-warning problem experienced with early forms of the thermistor.

Ultraviolet Fire Detector

Purpose:

(a) To build the best design for application to spacecraft that present technology allows.

(b) To determine the capability of this build so that it may be used for fire detection in spacecraft with full knowledge of its virtues and limitations.

Status:

(a) Excellent components for such systems are available whose performance characteristics have been established.

(b) Principal difficulty with past UV sensors relate to confusion with solar ultraviolet. Spacecraft windows can be filtered against solar ultraviolet to avoid this difficulty.

Correlation Spectrometer/Interferometer

Purpose:

(a) To assess by analysis and simple experiments the performance of this technique with instruments whose size, weight, and reliability are compatible with spacecraft requirements.

(b) To build a breadboard version to test its suitability for spacecraft fire precursor detection and toxic constituents in the atmosphere.

DETECTOR APPLICATION CHART FOR FIRE THREAT FROM SOLID COMBUSTIBLES

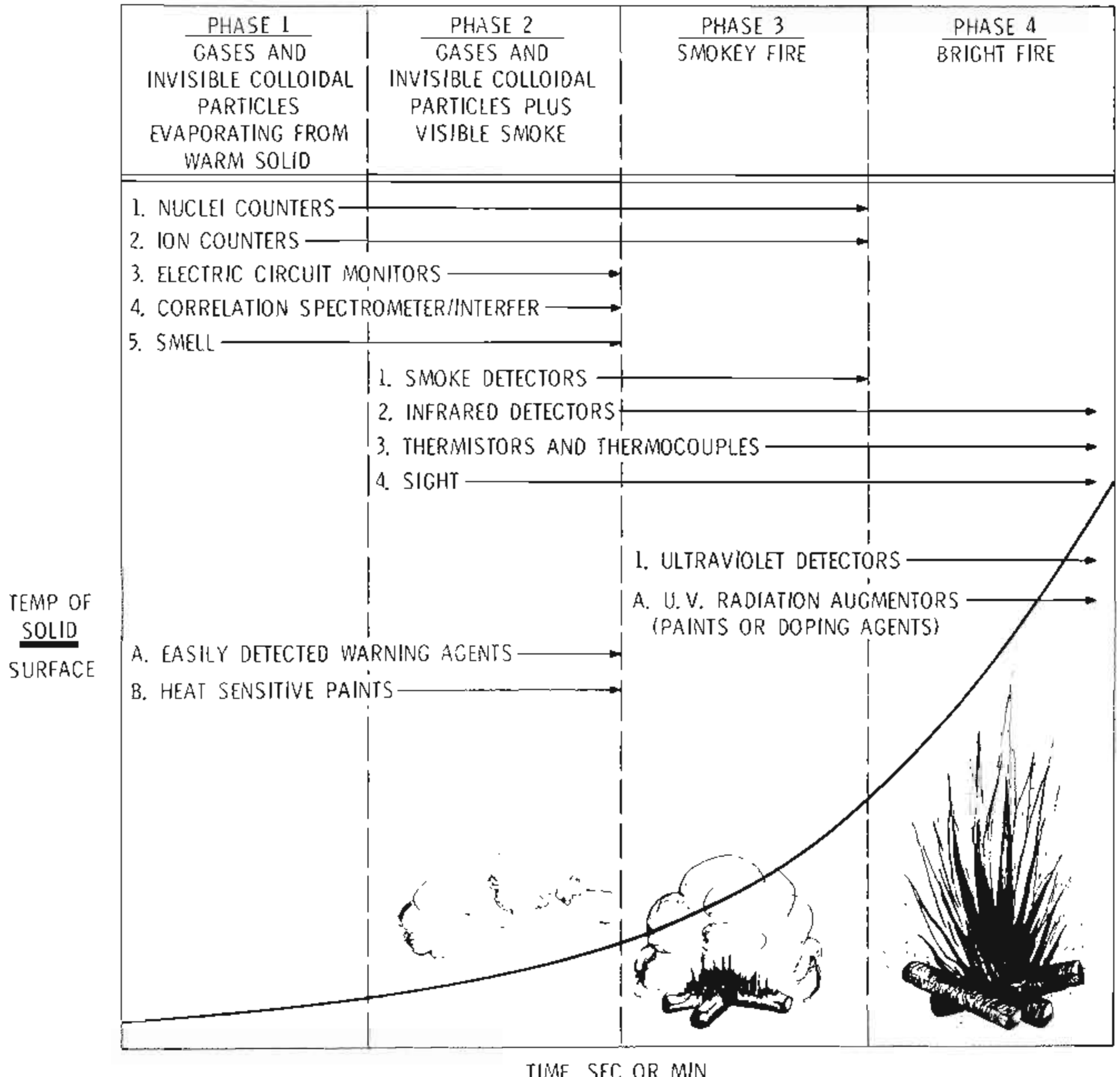

Fig. 1

DETECTOR APPLICATION CHART FOR COMBUSTIBLE GAS MIXTURES

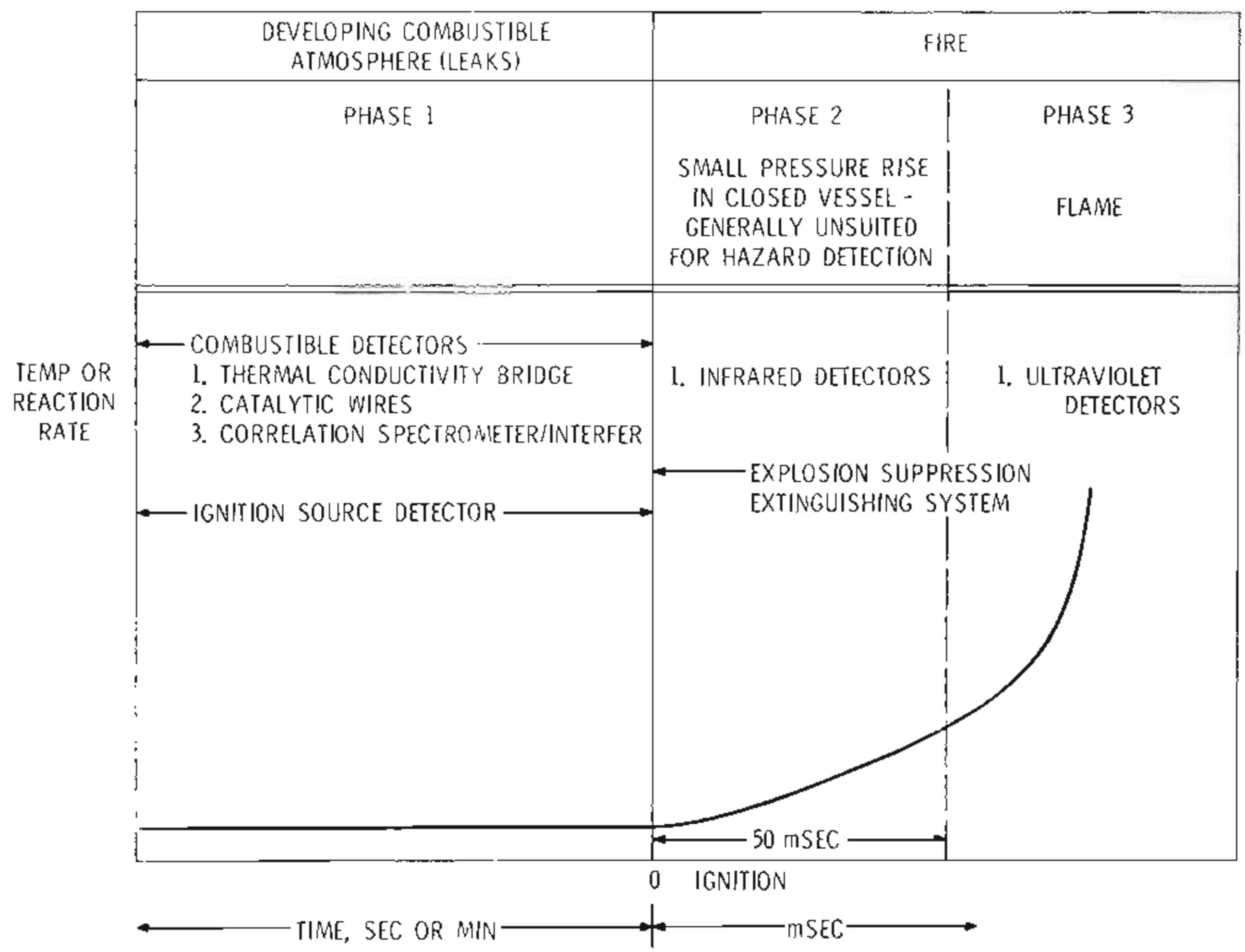

Fig. 2

PROGRAM SUMMARY

SITUATION	INCIPIENT STAGE		FIRE STAGE	
	PRESENT	FUTURE	PRESENT	FUTURE
OPEN AREA & VENTILATOR	1. COND NUC COUNTER 2. IONIZATION COUNTER 3. INFRARED	1. CORRELATION SPECTRO/INTER 2. LIGHT SCATTERING FROM PROJECTED BEAM	1. ULTRAVIOLET DETECTOR 2. INFRARED	
BLACK BOXES	CONTINUOUS WIRE/ THERMISTOR		CONTINUOUS WIRE/ THERMISTOR	
WIRING & PLUMBING DUCTS & ZONES BEHIND PANELS	1. CONTINUOUS WIRE/ THERMISTORS [2. IONIZATION COUNTER 3. COND NUC COUNTER]		1. CONTINUOUS WIRE/ THERMISTORS [2. UV DETECTOR]	
WIRE BUNDLES	CONTINUOUS WIRE/ THERMISTORS			

Figure 3