

ECLSS TOPICS	TECHNOLOGY FOR SPACE STATION EVOLUTION JANUARY 16-19, 1990	FIRE AND TOXIC GAS DETECTION
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# INCREASED FIRE AND TOXIC CONTAMINANT DETECTION RESPONSIVITY BY USE OF DISTRIBUTED, ASPIRATING SENSORS

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517

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As Space Station Freedom evolves and matures over its lifetime, it is anticipated that there will be a need to enhance its habitable region fire and toxic contaminant responsivity and sensitivity, especially in those regions of low air circulation rates. Such regions may include unpowered equipment racks, storage bins, etc. The use of distributed sensors with centralized detectors is suggested as an efficient means for accomplishing this goal. The use of the concept described herein for Space Station application was suggested by Matt Cole of the NASA Johnson Space Center. The concept has been outlined in Reference 1.

The use of more sensitive detectors and, possibly, detection devices of different types can produce enhanced fire signature information leading to reduced false alarms. The concept described herein is not intended to replace already planned fire detection devices, but is meant to supplement them with increased information.

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Reference 1: Youngblood, W.W. and Vedha-Nayagam, M.: Advanced Spacecraft Fire Safety: Proposed Projects and Program Plan. NASA CR 185147, October 1989.

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**TECHNOLOGY FOR SPACE STATION EVOLUTION  
JANUARY 16-19, 1990**

**FIRE AND TOXIC  
GAS DETECTION**

**OBJECTIVES:**

- **ENHANCE FIRE AND TOXIC CONTAMINANT DETECTION RESPONSIVITY  
IN HABITABLE REGIONS OF SPACE STATION**
- **REDUCE SYSTEM WEIGHT AND COMPLEXITY THROUGH CENTRALIZED  
DETECTOR/MONITOR SYSTEMS**
- **INCREASE FIRE SIGNATURE INFORMATION FROM SELECTED  
LOCATIONS IN A SPACE STATION MODULE**
- **REDUCE FALSE ALARMS**

ECLSS TOPICS	TECHNOLOGY FOR SPACE STATION EVOLUTION JANUARY 16-19, 1990	FIRE AND TOXIC GAS DETECTION
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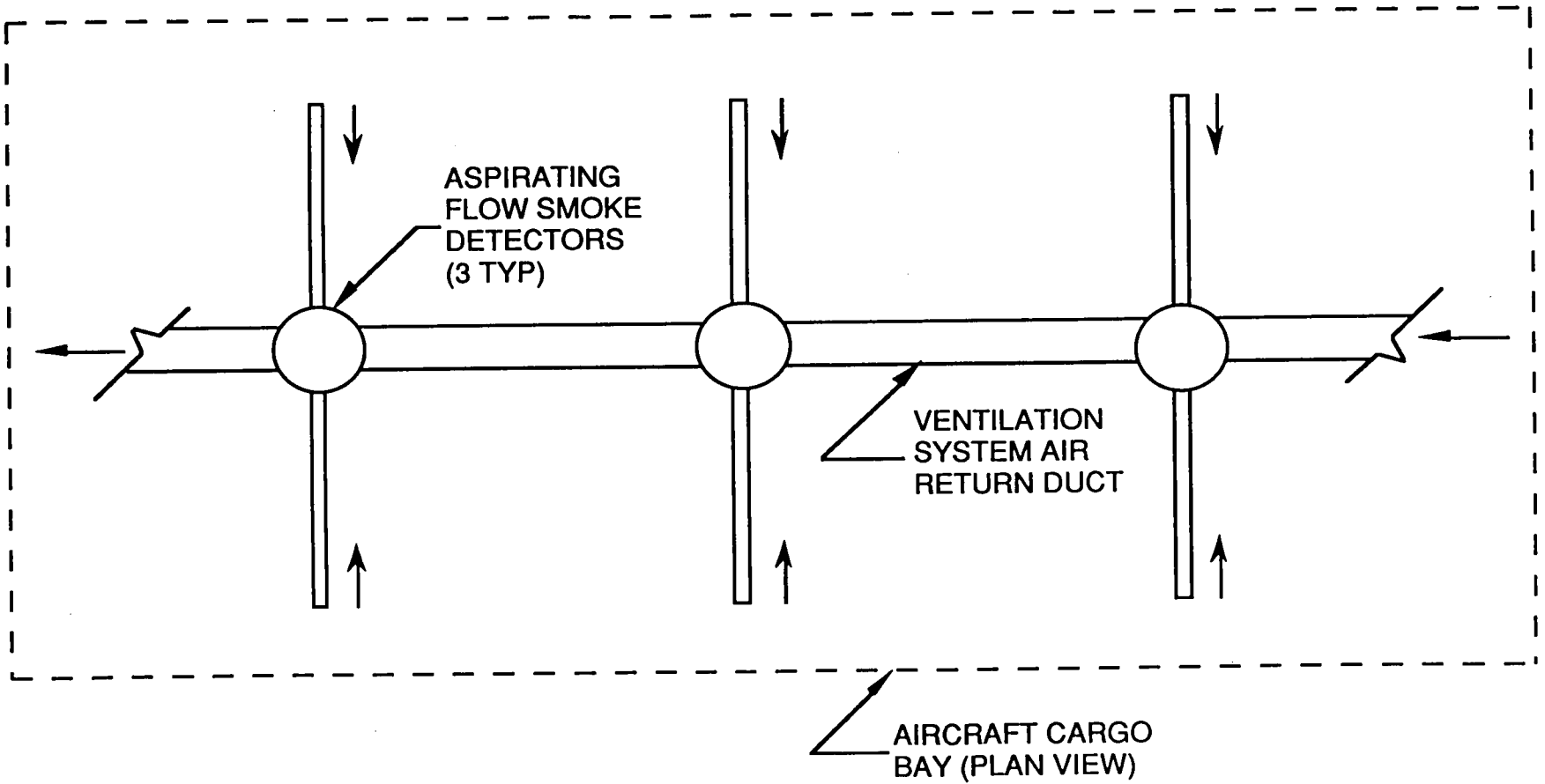
The concept of fire detection by means of aspirating flow through long tubes is commonly used in earth-based systems. Fenwal Inc. markets the VESDA (Very Early Smoke Detection Apparatus) fire detection system which draws air through a long tube to a central detector for the early detection of incipient fires in such critical areas as computer rooms (Reference 2). The Brunswick Corporation has developed aspirating flow tube sensors for mining activities such as underground haulageways (Reference 3). Tube lengths in this case measure up to several hundreds of meters. More recently, the Systron/Donner Co. has marketed an aspirating flow smoke detector for use in aircraft cargo bays. This system uses the aircraft ventilation system to induce flow through ionization-type smoke detectors from specific regions of the cargo bay (see accompanying figure).

520

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- Reference 2: Johnson, P.F.: Fire Detection In Computer Facilities. Fire Technology, Volume 22, No. 1, February 1986, pp. 14-32.
- Reference 3: Thomas, E.D.: A Pneumatic Sampling Fire Detection System In An Underground Haulageway. IEEE Transactions, Industrial Applications, Volume IA-19, No. 3, Part 1, May-June 1983, pp. 440-444.

### ASPIRATING SMOKE DETECTORS: AIRCRAFT CARGO BAY

521

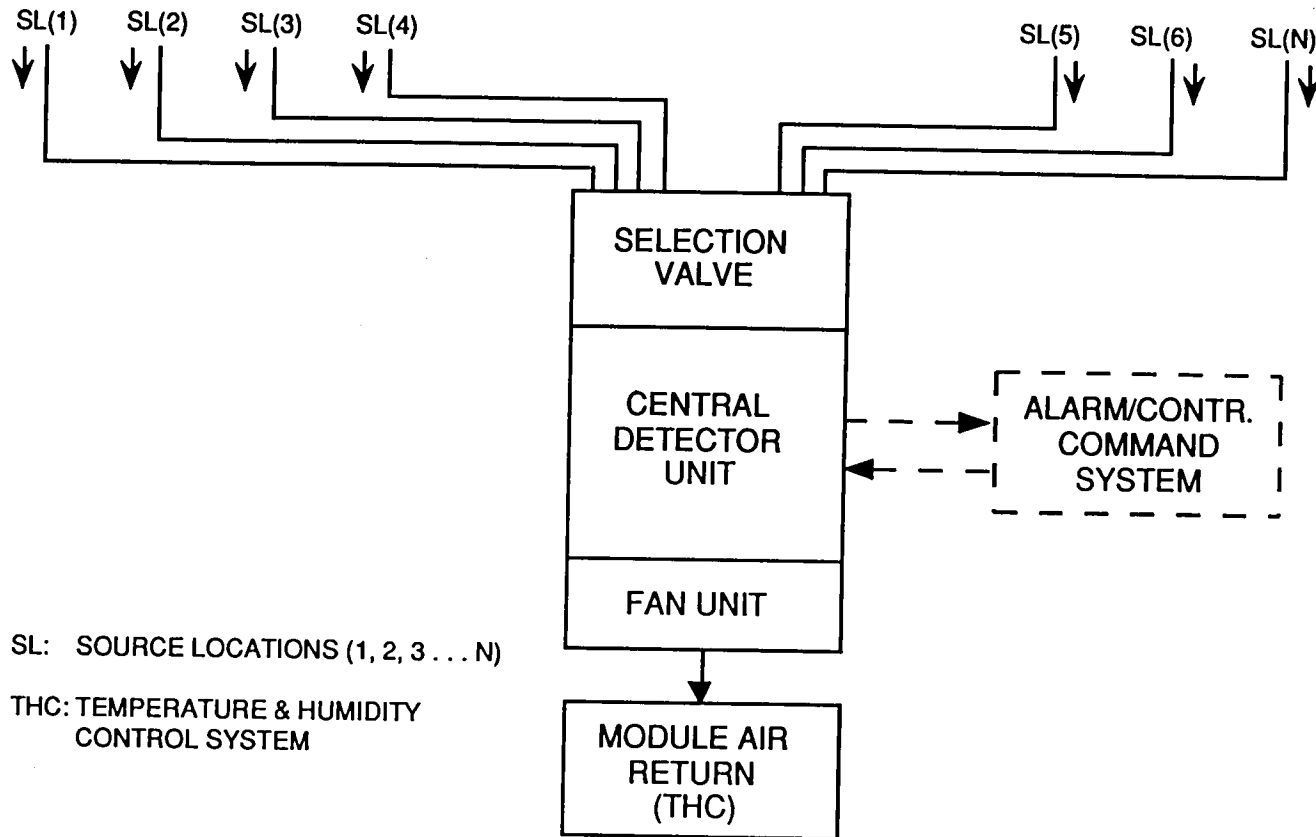


ECLSS TOPICS	TECHNOLOGY FOR SPACE STATION EVOLUTION JANUARY 16-19, 1990	FIRE AND TOXIC GAS DETECTION
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The schematic of the centralized detector/monitor concept shows a number of distributed sensors (SL(1), SL(2) . . . SL(N)) feeding into a central detector unit via a programmable selection valve. The sensors consist of small diameter tubes through which air from selected locations is induced to flow by means of a fan unit and/or connection to a ventilation system air return duct.

The concept described herein is not intended to replace fire detection devices in powered equipment racks and other potentially hazardous regions. The distributed sensor concept is designed to monitor quiescent regions of spacecraft modules and provide enhanced monitoring of gaseous contamination.

### GENERAL SCHEMATIC OF CENTRALIZED DETECTOR/MONITOR CONCEPT



The centralized detector/monitor can include one or more types of fire detectors and/or contamination monitors. Typically, the ionization-type smoke detectors are currently used in pressurized regions of spacecraft and aircraft.

The centralized detector/monitor concept allows the addition of other detector types, i.e., photo-extinction smoke detectors, and specific gas sensors such as those sensitive to CO and CO<sub>2</sub>. In addition, the use of the centralized detector as a source for a mass spectrometer (MS) or gas chromatograph/mass spectrometer (GC/MS) would provide additional fire signature information. Further, the source location of gaseous contamination (especially toxic species) could be more closely determined.



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**CANDIDATE TYPES OF FIRE/GASEOUS CONTAMINATION  
DETECTION DEVICES FOR CENTRALIZED MONITORING:**

- **SMOKE DETECTORS**
  - IONIZATION
  - PHOTO-EXTINCTION (LIGHT SCATTERING)
  - PARTICLE COUNTERS
- **GAS SENSORS**
  - CO, CO<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>
  - OTHER
- **GC/MS**

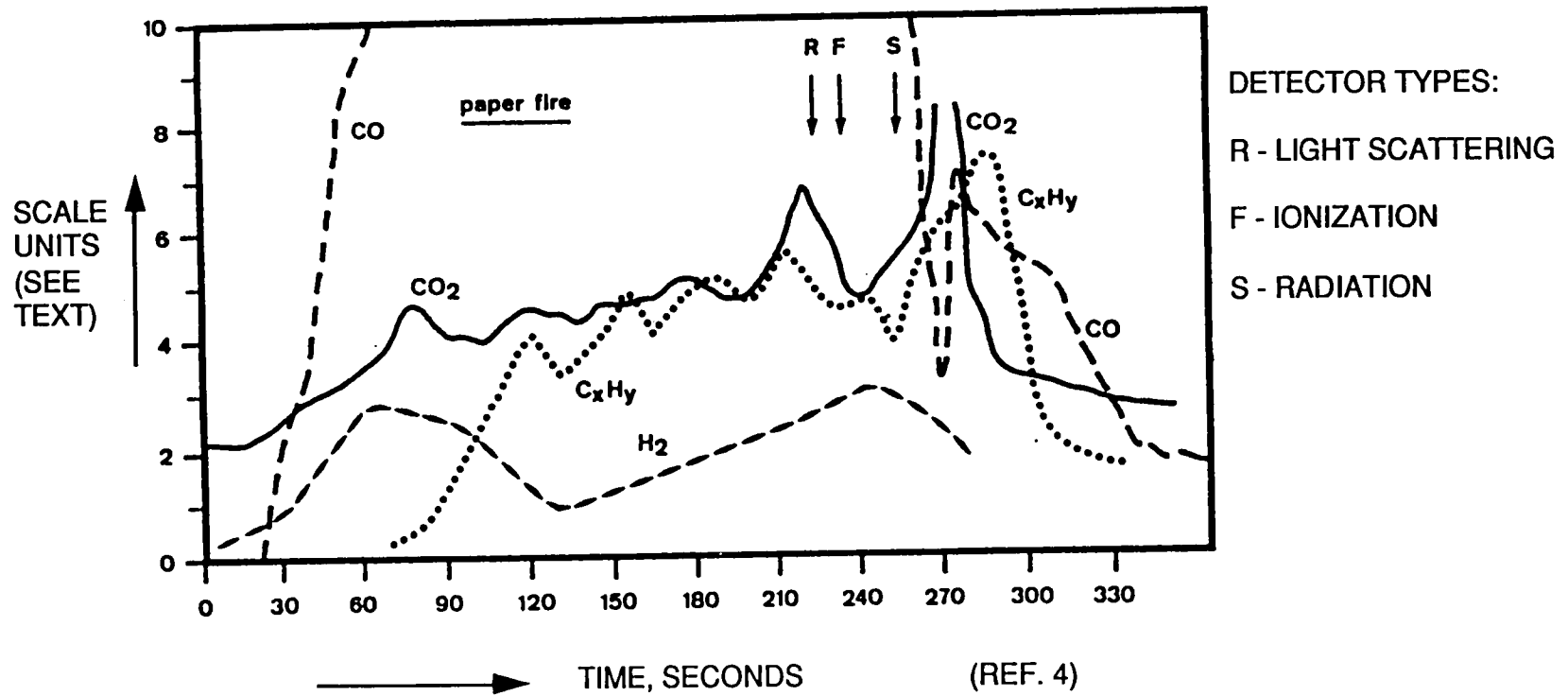
The paper fire signature response, shown opposite (based on UL 217, Test A), is representative of a slowly pyrolyzing process followed by flaming combustion at about 240 seconds in the example. The results shown are from one of several tests on various materials, all of which were intended to illustrate the relative response of different types of fire detectors exposed to different fire scenarios (Reference 4). Also, the test results lend support to the premise that fires may be detected in their early stages by solid state sensor detection of selected smoke gases. In all of the tests related by Reference 4, the standard types of fire detection devices tested (i.e., ionization and light-scattering smoke detectors, UV sensors, and thermal response sensors) lagged in response behind the production and detection of rapid increases in CO and/or CO<sub>2</sub>.

Note that the scale units for the ordinate of the figure shown opposite are as follows: CO<sub>2</sub> (200 ppm/unit), CO (10 ppm/unit), C<sub>x</sub>H<sub>y</sub> (12 ppm/unit), H<sub>2</sub> (10 ppm/unit).

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Reference 4: Pfister, G.: Detection of Smoke Gases By Solid State Sensors -- A Focus on Research Activities. Fire Safety Journal, Volume 6, No. 3., 1983, pp. 165-174.

PAPER FIRE - UL 217, TEST A (OUTBREAK OF FIRE AT ~240 SEC.)



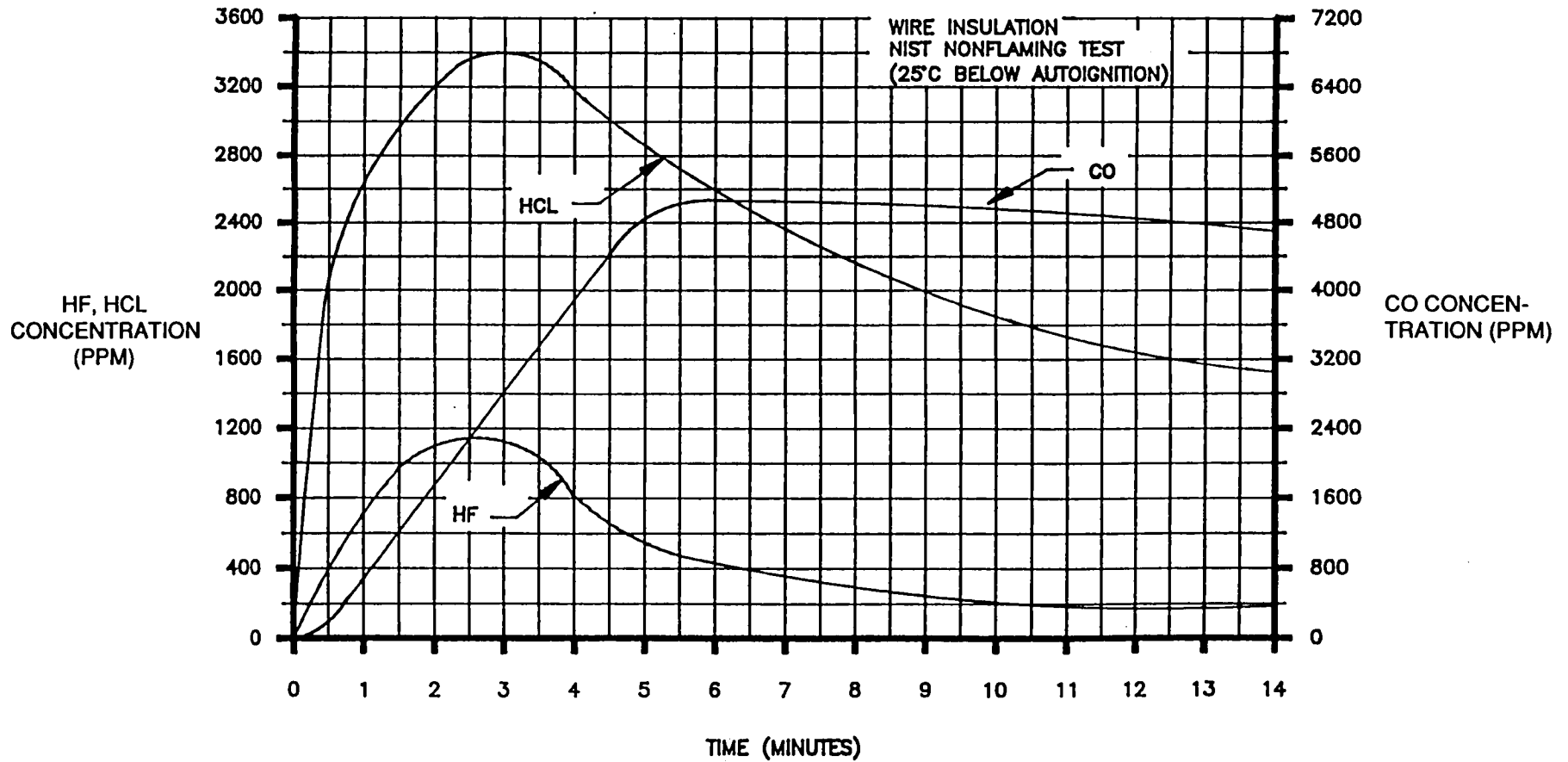
ECLSS TOPICS	TECHNOLOGY FOR SPACE STATION EVOLUTION JANUARY 16-19, 1990	FIRE AND TOXIC GAS DETECTION
-----------------	---	---------------------------------

528

Standard combustion tests are routinely performed on a wide variety of materials to evaluate the lethality of the gases evolved from the process. The figure shown opposite illustrates the production of CO, HCL and HF from a nonflaming combustion test of a specific wire insulation material. The proprietary results were obtained from a standard NIST test wherein the material was inserted into a preheated oven at 25°C below autoignition temperature and maintained in that environment for 30 minutes.

The results shown are not meant to imply that there are universal and unambiguous fire signatures for all fire scenarios in terms of the gaseous species produced. However, the detected increase in any of a number of gases, i.e., CO, CO<sub>2</sub>, H<sub>2</sub>, HCL, HF, HCN, etc., can be an independent indication of an unwanted or threatening event. The indicated event could be a gaseous spill or leak, a severe thermal degradation, a smoldering combustion, etc.

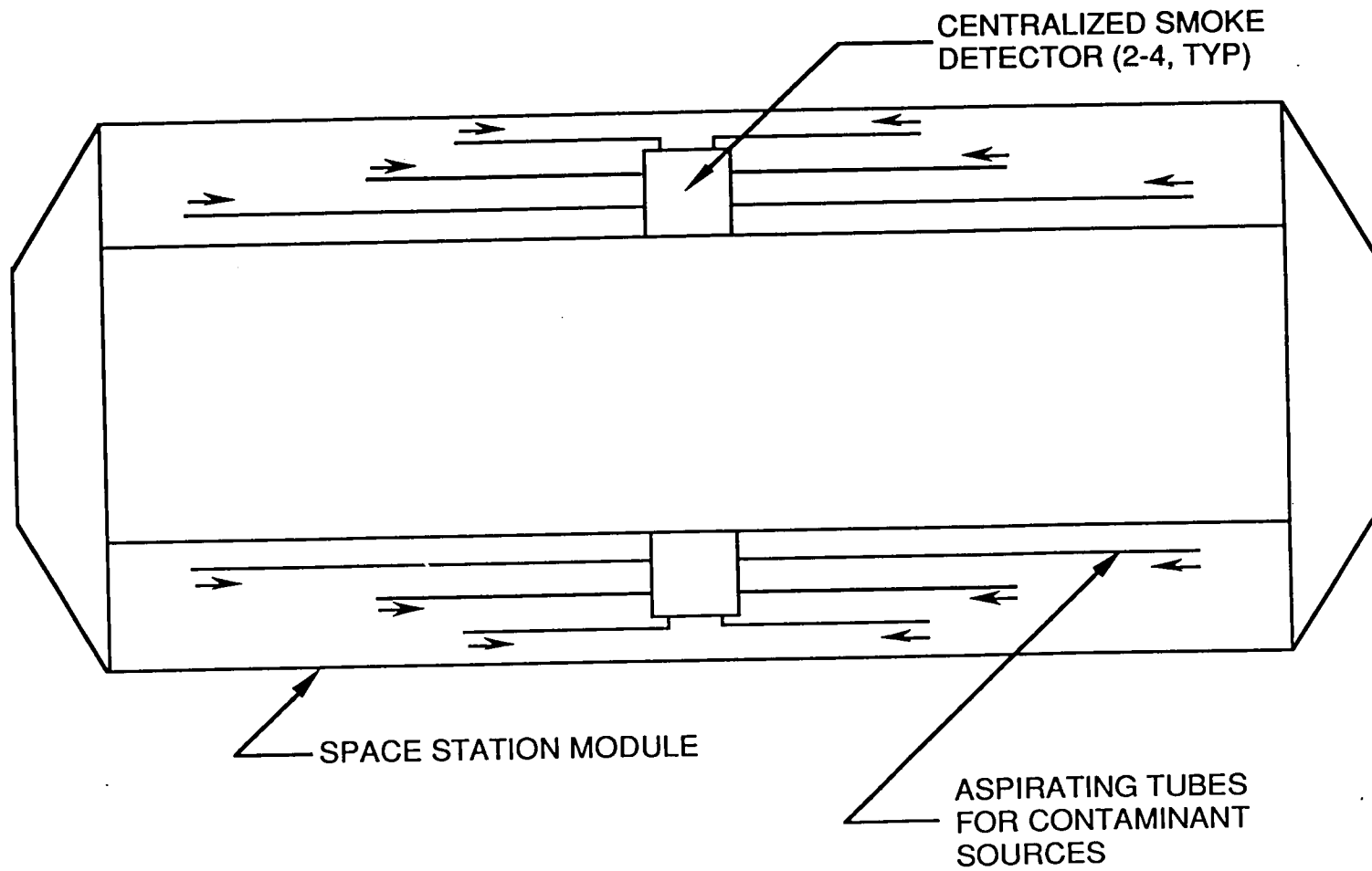
NONFLAMING COMBUSTION OF A POLYMERIC WIRE INSULATION



The accompanying figure illustrates the concept wherein multiple sensing tubes are connected to one or more centralized detector/monitor units located in a Space Station module. The sensing tubes may be made of small diameter ( $\leq 0.64 - 0.95$  cm), light-weight materials compatible with all spacecraft safety requirements. Air from the sensing locations is induced to flow to the central unit by means of a fan unit or, alternatively, by connecting the outlet of the unit to the low pressure region of the ECLSS air handling return ducting.

Ideally, no more than one or two central detector/monitor units would be required for each module to supplement the other fire detection and contaminant monitoring devices already planned for Freedom. The time required to sense all of the distributed locations will be determined as a "trade-off" between what is desired and what can be accomplished given the transit times for each sensing tube.

### CENTRALIZED SMOKE DETECTORS/MONITORS: SPACE STATION APPLICATION



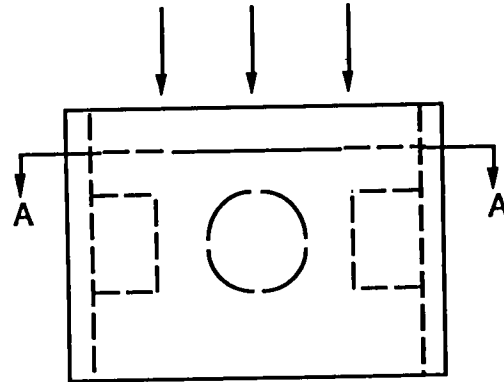
A simplified schematic of a centralized detector/monitor is shown in the figure opposite. Current ground-based systems of this concept typically utilize only the smoke detectors -- usually of the ionization or photo-extinction/light-scattering type. The concept shown in the schematic is somewhat idealized since it assumes the availability of small, solid-state gas detectors sensitive to CO and CO<sub>2</sub>.

The inclusion of a mass spectrometer (MS) or gas chromatograph (GC)/MS makes the centralized detector/monitor especially attractive. Most enclosed, habitable spaces on earth do not have, or cannot afford the luxury of a GC/MS. Its inclusion on Space Station Freedom greatly enhances the use of "expert systems" to interpret and communicate the existence of an incipient fire or some other event producing off-nominal aerosols and/or gaseous contaminants.



### CANDIDATE DETECTORS FOR INCLUSION IN CENTRALIZED MONITOR

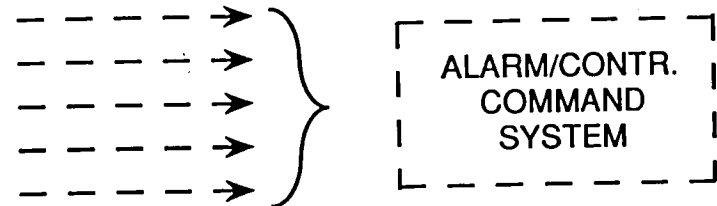
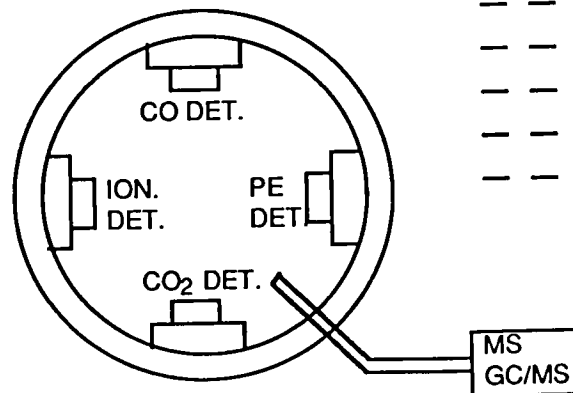
ASPIRATING AIR FLOW FROM  
SELECTED SOURCE LOCATIONS



533

DETECTORS:

- GASEOUS
  - CO<sub>2</sub>, CO
  - MS, GC/MS
- SMOKE
  - IONIZATION (ION.)
  - PHOTO-EXTINCTION (PE)



VIEW A-A

<b>ECLSS TOPICS</b>	<b>TECHNOLOGY FOR SPACE STATION EVOLUTION JANUARY 16-19, 1990</b>	<b>FIRE AND TOXIC GAS DETECTION</b>
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TOPICS**

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**SOME PRACTICAL CONCERNS RELEVANT TO USE OF  
DISTRIBUTED SENSING TUBES:**

- **RESPONSE (TRANSIT) TIMES MUST BE REASONABLY  
SHORT**
- **EXIT SIGNATURES MUST CLOSELY MATCH SENSING  
REGION CONDITIONS**
- **SENSING TUBES MUST NOT INTERFERE WITH OTHER  
SYSTEMS OR OPERATIONS**

ECLSS TOPICS	TECHNOLOGY FOR SPACE STATION EVOLUTION JANUARY 16-19, 1990	FIRE AND TOXIC GAS DETECTION
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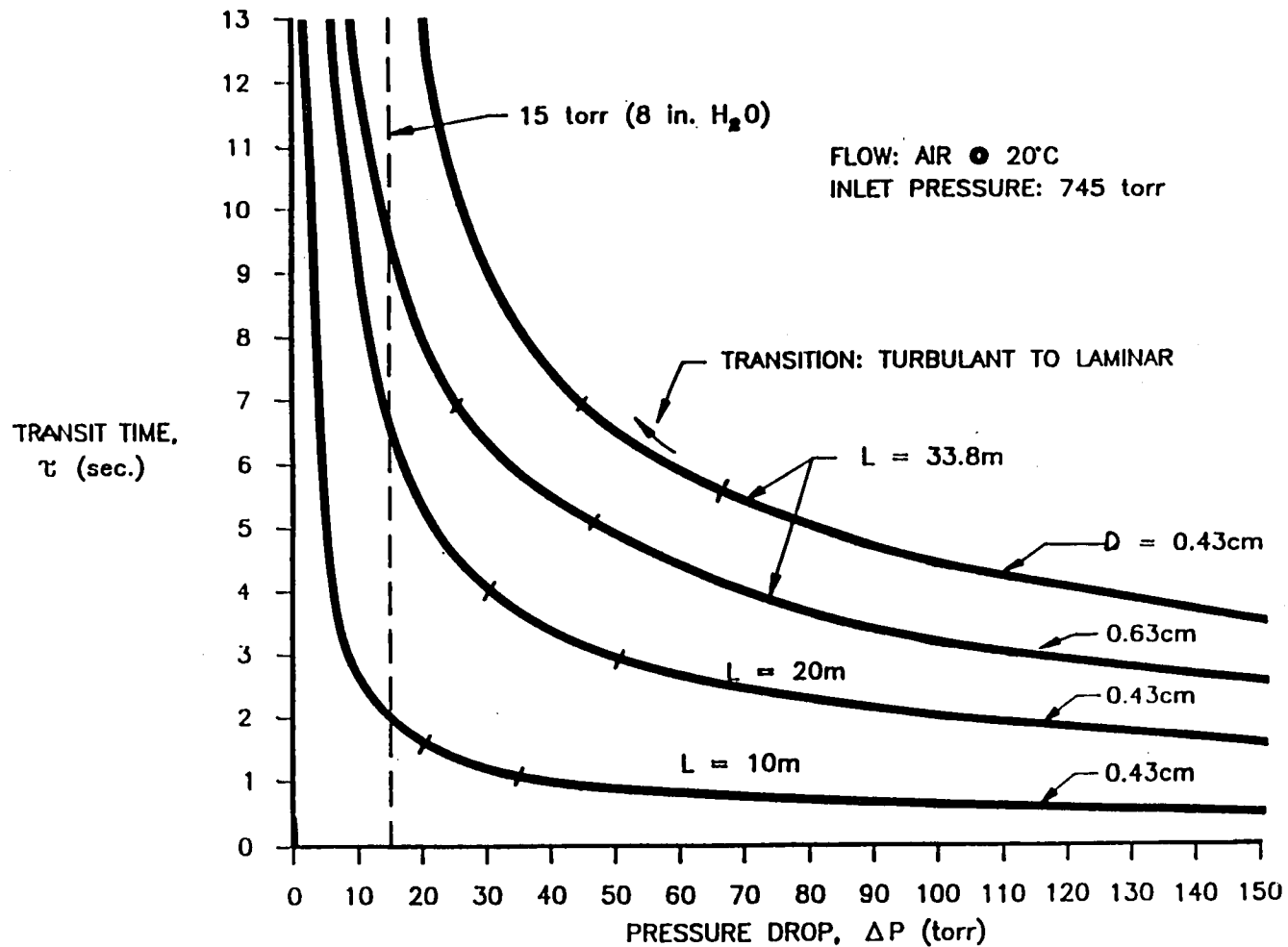
Some effort has already been expended to determine the transit times for smoke laden air through small diameter tubing (e.g., Reference 5). The induced flow may be either turbulent or laminar depending on the tube diameter and mass flow rate through the tube. For very large pressure drops, the flow may correspond to compressible conditions rather than incompressible as normally assumed for air at low velocities and low pressure drops (i.e.,  $< 100$  torr  $\Delta P$ ).

The accompanying figure illustrates some approximate transit times based on relationships derived in Reference 5. For spacecraft applications, it is suggested that transit times of ~ 5-7 seconds may be appropriate.

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Reference 5. Hertzberg, M. and Litton, C.D.: Multipoint Detection of Products of Combustion With Tube Bundles. BuMines Report RI 8171, USDI, September 1976.

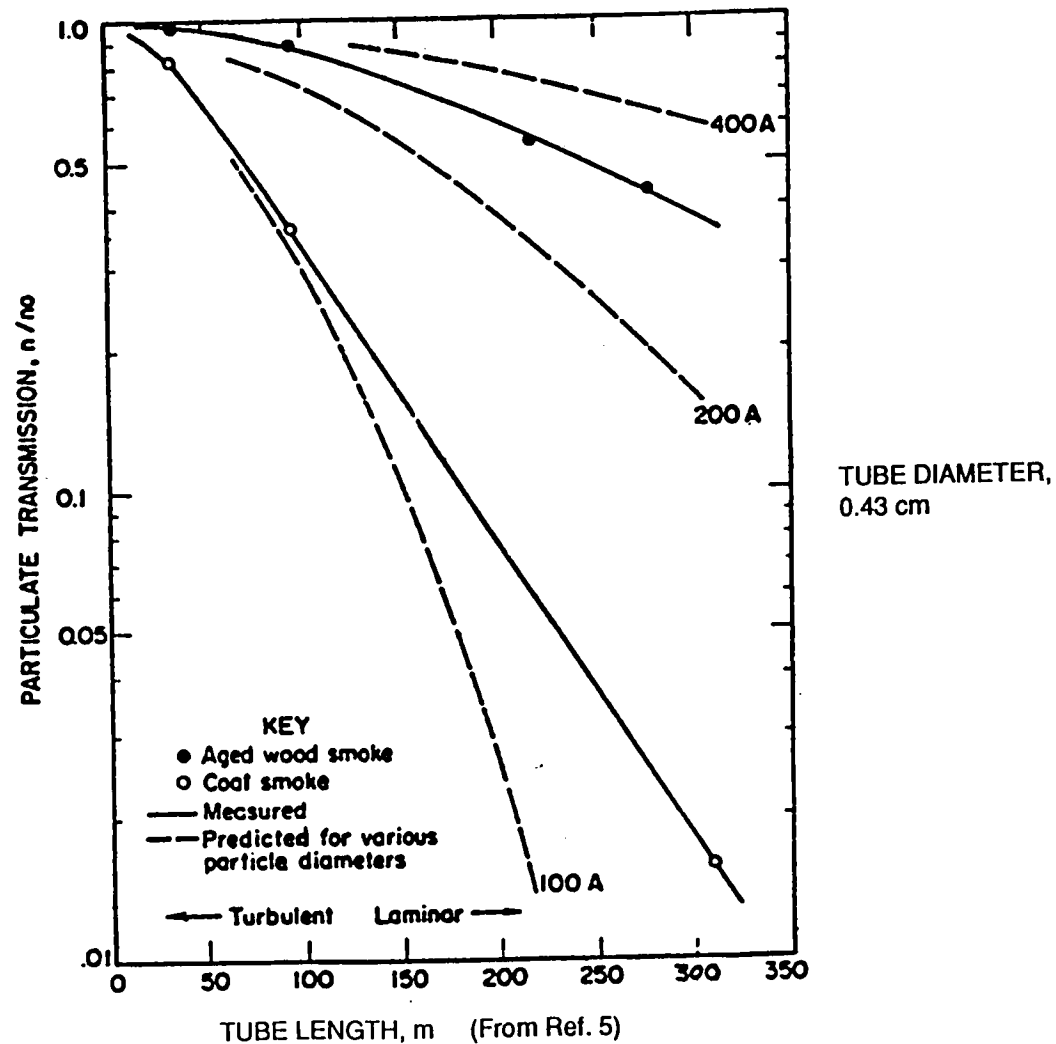
### TYPICAL TRANSIT TIMES FOR AIR THROUGH SMALL DIAMETER TUBING



During the transmission of smoke laden air through very long ( $> 100$  m) unheated tubes, some agglomeration and wall condensation will occur with the result that a large percentage of the smallest, submicrometer smoke particles may be "lost." This is especially important to sensing tube systems used in underground mines and haulageways where the tube length may be several hundred meters. This transmission loss is illustrated by the accompanying figure taken from Reference 5 for a tube ID of 0.43 cm.

The short tube lengths anticipated for a spacecraft such as Freedom should pose no significant particle loss problem. However, experimental determination must be undertaken to evaluate both transit times and particle losses for practical spacecraft tube lengths, tube diameters, flow rates, type of smoke, etc.

MEASURED AND PREDICTED SUBMICROMETER  
PARTICULATE TRANSMISSIONS



<b>ECLSS TOPICS</b>	<b>TECHNOLOGY FOR SPACE STATION EVOLUTION JANUARY 16-19, 1990</b>	<b>FIRE AND TOXIC GAS DETECTION</b>
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**RECOMMENDATIONS:**

1. **PERFORM DETAILED ESTIMATES OF SENSING TUBE TRANSIT TIMES AND PARTICULATE LOSSES FOR VARIOUS SENSOR SCENARIOS.**
2. **REVIEW CURRENTLY AVAILABLE SMOKE DETECTORS AND GAS DETECTORS (e.g., CO<sub>2</sub> , CO, H<sub>2</sub>) FOR USE WITH THE CENTRALIZED DETECTOR/MONITOR CONCEPT.**
3. **ASSESS VIABILITY OF GC/MS SMOKE-GAS DETECTION IN THE CENTRALIZED DETECTOR/MONITOR CONCEPT.**
4. **CONSTRUCT AND TEST A BREADBOARD SYSTEM FOR EVALUATION OF THIS CONCEPT.**
5. **ESTABLISH SYSTEM OPERATIONAL REQUIREMENTS FOR SPACE STATION FREEDOM USE.**
6. **ENCOURAGE THE DEVELOPMENT OF VERY SMALL, SOLID-STATE GAS DETECTORS FOR SPACECRAFT USE.**

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