COMBUSTIBLE GAS DETECTORS

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Detection of a combustible gas in the atmosphere of a spacecraft is an essential part of a complete spacecraft fire protection system. Two similar but different techniques may be useful in this respect. These two techniques are commonly referred to as:

1. Combustible gas detector.
2. Thermal conductivity detector.

Both methods use the change in electrical resistance of a metal wire or nonmetallic thermistor due to changes in temperature. They are different in the phenomena employed to cause the temperature change of the sensor.

For the combustible gas detector, the combustible gas is caused to react with the oxygen present in the atmosphere on the surface of the sensor. The heat of reaction causes the temperature of the sensor to increase. The sensor may or may not have a catalytic coating. The catalysts can be a metal of the platinum family, but for many commercially available detectors the catalyst used is proprietary. Without a catalytic coating, the temperature of the sensor must be maintained above the ignition temperature of the combustible gas to be detected. The ignition temperature is different for various combustible gases and fuel-oxidant ratios. For catalytic sensors, the temperature required to initiate an exothermic reaction is lowered, but different catalytic surfaces may be required for different combustible gases.

For the thermal conductivity detector, changes in thermal conductivity of the atmosphere, due to the presence of a gas with a thermal conductivity different than the calibrating atmosphere, produce the temperature change in the sensor. In this detector, the sensor, metal wire or nonmetallic thermistor, is heated to a temperature above ambient atmospheric temperature but below the ignition temperature of any combustible gas expected to be present.

To make the detector insensitive to ambient temperature changes, the sensors are used in a Wheatstone bridge circuit. The bridge circuit consists of four resistance elements (figure 1), two each in series in two parallel circuits across a voltage source, V_s. The voltage source, V_s, can be either direct or alternating. The resistors, R_1 and R_2, are identical and fixed. R_s is the sensor and R_r is the reference resistor. The sensor, R_s, is exposed to the ambient atmosphere while the reference, R_r, is enclosed in a reference atmosphere which is maintained at ambient atmospheric temperature. The sensor and reference have identical resistance at a given temperature and have the same temperature coefficient of resistance. Both resistances are heated to the same temperature when the ambient atmosphere is identical to the reference atmosphere. When the sum of the resistances R_s and R_1 equals the sum of the resistances R_r and R_2, there is no voltage output, V_o. If the resistance of the sensor changes due to either the combustion of a gas around it or a change in the thermal conductivity of the ambient atmosphere, then a voltage appears at the output of the bridge. This output voltage by proper circuitry can be used to initiate an alarm or indicating system.

Since the sensors are hot in both types of detectors and combustion occurs in the combustible gas detector, they could act as ignition sources. To prevent this, the sensors are enclosed in a flame arrester. The arresters are usually made of porous sintered bronze or steel.

In general, neither of the detectors is specific in its indication when more than one foreign gas (gas not in the calibrating or reference gas) is present in the atmosphere. The combustible gas detector will respond to all combustible gases whose ignition temperatures are below the temperature of the sensor or which are activated by the catalyst. Detector, however, can be built which will respond only to hydrogen, since hydrogen has some unique combustion characteristics compared to other combustible gases. The thermal conductivity detector will detect any gas whose thermal conductivity is different from that of the reference gas. This detector, however, is well suited to detect hydrogen in air (or oxygen-nitrogen mixtures) because of its relatively high thermal conductivity compared to air. Helium also has a high value of thermal conductivity and would, therefore, give the same indication as hydrogen. It should be mentioned that the thermal conductivity of a gas mixture cannot be determined analytically from the composition and thermal conductivities of the components, because the thermal conductivity is not a simple weighted average of the thermal conductivities of the components on either a volume or mass basis. In some cases, the thermal conductivity of a mixture can be intermediate to, less than or greater than those of the components. The lower limit of sensitivity or threshold concentration for hydrogen in air for both detectors is fairly good, 0.02% for the combustible gas detector and $5 \times 10^{-4}\%$ for the thermal conductivity detector.

There are problems associated with both detectors. Some problems may be caused by normal operation in a spacecraft while others are inherent in the detectors. Ambient pressure changes for both detectors could shift the detection threshold, produce false alarms and damage to the sensor element by overheat. Wide changes in atmosphere composition could shift the detection threshold through changes in combustion characteristics and/or heat transfer rates and produce false alarms by changing the thermal conductivity of the atmosphere. Partial compensation for pressure and atmospheric composition changes may be attained by changing pressure and composition of the reference gas. Power to the sensor and reference resistor may have to be changed with pressure changes to avoid damage and to maintain sensitivity.

Deterioration of the performance of a catalyst may occur with time due to poisoning of the catalyst by contaminates in the air. Catalysts can be poisoned by inorganic solids, vaporized metals, some halogenated hydrocarbons and additive in silicone paints.

Both detectors are point detectors, that is, they determine the presence of a foreign gas only if it is adjacent to the sensor. Thus these detectors suffer the same sampling problems as other point sensors, namely, time lag and dilution of concentration. Both problems arise because the detectable gas must be transported from the source to the detector. Transportation of a gas is by either diffusion or convection. Diffusion and free convection can be slow and erratic and result in concentration dilution due to divergence and mixing. Forced convection by ventilating equipment may shorten the transport time, but dilution may be excessive. The use of sampling tubes with intake ports near the source of gas could reduce the transport time. The flow velocity, however, across the sensor cannot be too great because the heat transfer at the sensor will change from conduction to convection which is greater. This would change the detection threshold for both detectors and possibly result in false alarms for the thermal conductivity detector.

Both types of detector are commercially available from several manufacturers. None of the detectors have been designed especially for spacecraft but all the manufacturers listed have designed and built detectors for hydrogen. Both portable and stationary units are available. The cost ranges from $100 to $3000 for single channel units to $5500 for units with 10 and 12 channels.

Neither of the detectors completely fulfills the requirements for a combustible gas detection system on a spacecraft, but they could be used in conjunction with other types of detectors for verification of a hazardous condition.

COMBUSTIBLE GAS DETECTOR

THERMAL CONDUCTIVITY OR CATALYTIC WIRE BRIDGE

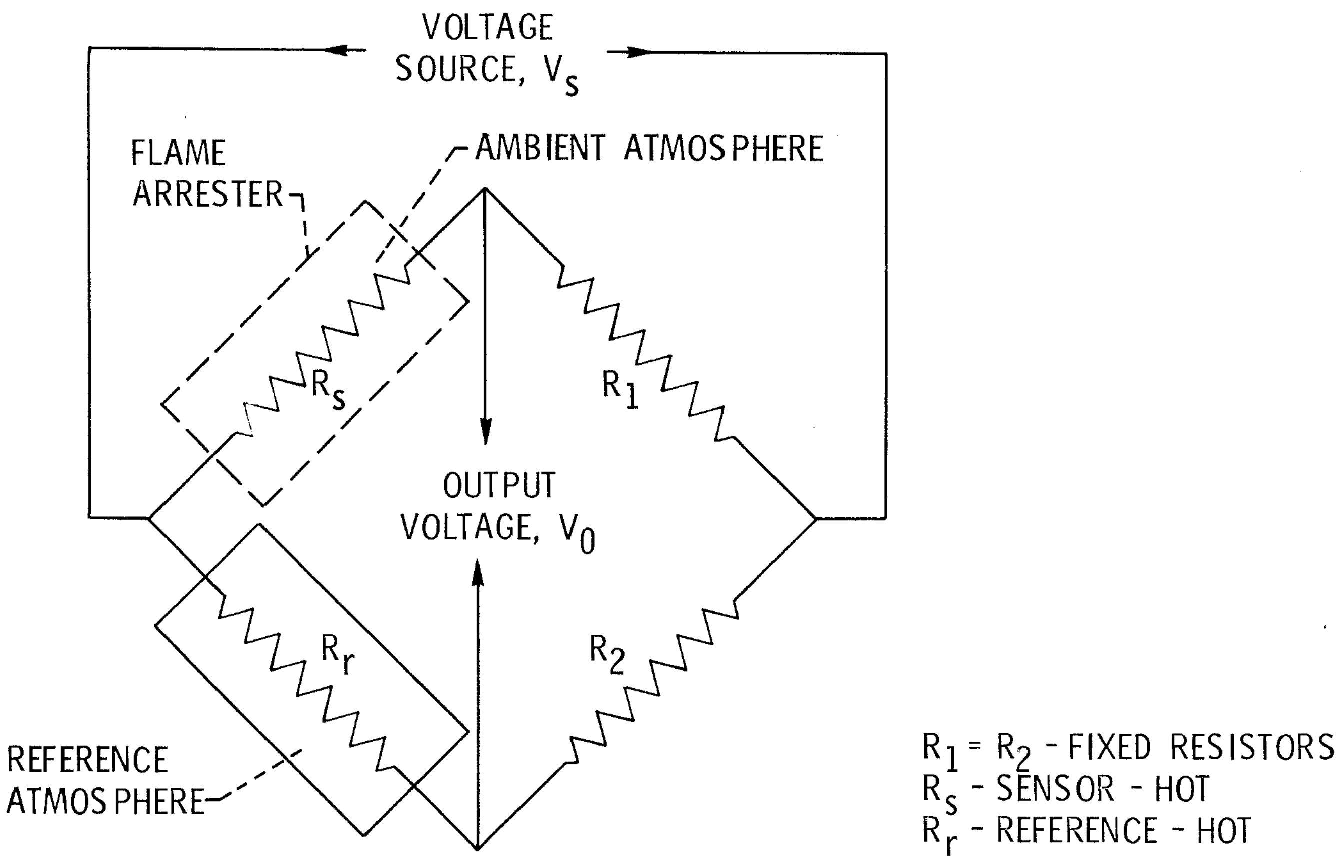

Fig. 1