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AEROSPACE RECOMMENDED PRACTICE

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Superseding ARP485

Temperature Measuring Devices Nomenclature

RATIONALE

ARP485A has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) defines the nomenclature of temperature measuring devices. General temperature measurement related terms are defined first, followed by nomenclature specific to temperature measuring devices, particularly thermocouples.

2. REFERENCES:

There are no referenced publications specified herein.

3. OBJECTIVE:

To establish the nomenclature and related terminology of temperature measuring devices as applied to aircraft gas reaction type power plants for use by:

a. Power plant manufacturers
b. Airframe manufacturers
c. Procurement organizations
d. Equipment organizations
e. Service and maintenance personnel
f. Other interested organizations

4. TEMPERATURE:

The temperature of a body is its thermal state considered with reference to its ability to communicate heat to other bodies.

4.1 Static Temperature (Gas and Thermal Equilibrium):

Static temperature is a measurable property which is directly proportional to the mean kinetic energy of the particles. In a moving gas, the static temperature would be indicated by a conventional error free instrument moving in the same direction and at the same velocity as the gas.

4.2 Total Temperature (Gas and Thermal Equilibrium):

Total temperature is the temperature indicated by an error free instrument having a fixed position in the gas stream and is the sum of the static temperature and the temperature rise due to the conversion of kinetic energy to heat, as the compression occurs at the sensing element.

5. TEMPERATURE MEASUREMENT:

Temperature measurement is the observation of the relative heat energy present as it affects engine performance and/or life (i.e., bearing, compressor inlet, turbine in or out, blade temperature, and any other pertinent material or gas temperature).

6. TEMPERATURE MEASUREMENT SYSTEM:

A temperature measurement system is a system consisting of one or more measuring elements to quantitatively measure temperature by heat transfer including a means of transmitting the resultant single output to and including the indicator, and if applicable, to the engine control device.

6.1 Temperature Indicating System:

A temperature indicating system is that part of the temperature measurement system extending physically from the engine-airframe disconnect up to and including the aircraft cockpit indicator.

6.2 Temperature Sensing System:

A temperature sensing system is that part of the temperature measurement system extending physically from and including the temperature measuring element to the engine-airframe disconnect and if applicable to the engine control.

6.3 Temperature Measuring System Engine-Airframe Disconnect:

Self-explanatory.

7. TEMPERATURE MEASURING ELEMENT:

A temperature measuring element is that element or portion of a temperature measuring system which yields a measurable signal that is reproducible as a function of temperature.

a. Probe: A probe is an immersion type temperature measuring element.

b. Contact Element: A contact element is a temperature measuring element used in intimate contact with the solid state body to be measured.

c. Remote Measuring Element: A remote measuring element is a temperature measuring device removed from the medium to be measured.

7.1 Thermometer:

A thermometer is an immersion or contact type device whose operation is based on thermal equilibrium between the sensitive measuring element and the medium to be measured. Types of thermometers include thermocouples, resistance bulbs, thermistors, bi-metallic elements, vapor pressure elements, etc.

7.1.1 Thermocouple: A thermocouple is a pair of dissimilar electrically conducting materials joined together at the ends so that a difference in temperature between the ends generates an EMF. Typical combinations of wire are as follows:

a. Chromel (positive) versus Constantan (negative)
b. Iron (positive) versus Constantan (negative)
c. Copper (positive) versus Constantan (negative)
d. Chromel (positive) versus Alumel (negative)
e. Platinum/Rhodium (positive) versus Platinum (negative)
f. Iridium/Rhodium (positive) versus Iridium (negative)

7.1.2 Resistance Bulb: A resistance bulb is a temperature sensitive device composed of a material whose resistance increases in a reproducible manner as the temperature increases with negligible hysteresis.

7.1.3 Thermistor: A thermistor is a temperature sensitive device composed of a material whose resistance decreases in a reproducible manner as the temperature increases with negligible hysteresis.

7.1.4 Bi-Metallic Element: A bi-metallic element is a temperature sensitive device composed of two materials having different thermal coefficients of expansion resulting in a proportional movement of the free segment of the device with changes in temperature.

7.1.5 Vapor Pressure Element: A vapor pressure element is a temperature sensitive device whose signal is proportional to pressure of vapor in coexistence with its liquid phase and independent of the specific volume.

8. RADIATION PYROMETER TEMPERATURE MEASUREMENT SYSTEM:

A radiation pyrometer temperature measurement system is a system located remotely from the medium whose temperature is to be measured and depending for its indication on the intensity of radiation from the medium to the measuring element of the pyrometer.

9. THERMOCOUPLE TYPE TEMPERATURE MEASUREMENT SYSTEM:

A thermocouple type temperature measurement system is a thermocouple and associated supporting structure, electrical insulation up to and including the indicator and if applicable, to the control device. This system as applied to exhaust gas temperature measurement may include one or more thermocouple assemblies, a thermocouple harness, thermocouple harness lead, reference junction, resistance spool, and indicator.

9.1 Thermocouple Sensing System:

A thermocouple sensing system is that part of the thermocouple type measurement system extending physically from and including the thermocouple assembly to the engine-airframe disconnect, and if applicable to the engine control.

9.1.1 Thermocouple Assembly: A thermocouple assembly is that part of the thermocouple sensing system including all components from the measuring junction to the electrical connector or to the harness junction box as is the case with the integral harness.

9.1.1.1 Measuring Junction: A measuring junction is that junction of a thermocouple sensing system immersed or in contact with the medium whose temperature is to be observed.

9.1.1.1.1 Types of Junctions:

a. Twisted
b. Looped
c. "V"
d. "U"
e. Stirrup
f. Pencil

See Appendix A.

9.1.1.2 Support Tube: The support tube is the portion of the thermocouple assembly immersed in the medium to be measured and provides support for the measuring junction and lead wires.

9.1.1.3 Mechanical Mounting: Self-explanatory.

9.1.1.4 Thermocouple Lead: A thermocouple lead is that portion of the thermoelements from the electrical connector to the measuring junction.

9.1.1.5 Electrical Connector: Self-explanatory.

9.1.1.6 Types of Thermocouple Assemblies:

9.1.1.6.1 Bare or Exposed Junction: An exposed junction thermocouple assembly has no shielding or support tube covering of any type over the measuring junction.

9.1.1.6.2 Stagnation: A stagnation thermocouple assembly is designed to measure a temperature which approximates the total temperature value.

9.1.1.6.3 Sampling: A sampling thermocouple assembly has means for sampling gases at two or more points and for mixing these at the measuring junction so as to give a useful representative value.

9.1.1.6.4 Aspirated: An aspirated thermocouple assembly is constructed so that the rate of heat transfer to the measuring junction is increased by causing the gas to flow over the junction at a rate which is higher than the free stream velocity.

9.1.1.6.5 Sonic: A sonic thermocouple assembly is designed so that the gas can be made to flow over the measuring junction at Mach 1 resulting in maximum heat transfer to the junction.

9.1.1.6.6 Shielded: A shielded thermocouple assembly is one in which the measuring junction is partially or completely enclosed by a housing, the primary purpose being to reduce the radiation error.

9.1.2 Thermocouple Harness: A thermocouple harness is an assembly that physically supports, protects, and insulates the conductors extending from the thermocouple assemblies to the thermocouple output harness connector.

9.1.2.1 Thermocouple Harness Construction:

9.1.2.1.1 Rigid Thermocouple Harness: A rigid thermocouple harness is an assembly in which the lead supporting and protective structure is firm and nonpliant and requires application of appreciable force in order to obtain deflection.

9.1.2.1.2 Flexible Thermocouple Harness: A flexible thermocouple harness is an assembly in which the lead supporting and protective structure is easily bent and adapts itself readily to change of shape.

9.1.2.2 Thermocouple Harness Circuitry: The thermocouple harness circuitry is the complete electrical path designed to conduct the output EMF's generated by the individual temperature measuring junctions into a single useable value.

9.1.2.2.1 Common Junction Circuit: A common junction circuit is a circuit in which each temperature measuring junction is paralleled by means of individual leads to a common point.

9.1.2.2.2 Equal Resistance Branch Circuit: An equal resistance branch circuit is a circuit in which the temperature measuring junctions are paired in parallel and symmetrically arranged about junction points, so that equal resistance paths are maintained around each loop.

9.1.2.2.3 Ladder Circuit: A ladder circuit consists of temperature measuring junctions geometrically and electrically paralleled to two bus bars.

9.1.2.2.3.1 Open Ladder Circuit: An open ladder circuit is a parallel circuit in which the bus bars are electrically discontinuous.

9.1.2.2.3.2 Closed Ladder Circuit: A closed ladder circuit is a parallel circuit in which the bus bars are electrically continuous.

9.1.2.2.3.3 Resistance Compensated Ladder Circuit: A resistance compensated ladder circuit is a parallel circuit in which compensating resistors have been inserted so that the output voltage of the circuit will equal the arithmetical average of the voltages of the several individual measuring junctions.

9.1.2.3 Thermocouple Assembly Extension Lead: A thermocouple assembly extension lead is an assembly that physically supports, protects, and insulates the conductors extending from the thermocouple assembly to a point within the thermocouple harness.

9.1.3 Thermocouple Harness Extension Lead: A thermocouple harness extension lead is an assembly that physically supports, protects, and insulates the conductors extending from the thermocouple harness output connector to the engine-airframe disconnect and/or engine control.

9.2 Thermocouple Indicating System:

A thermocouple indicating system is that part of the thermocouple type measurement system extending physically from the engine-airframe disconnect to and including the cockpit indicator.

9.2.1 Reference Junction: A reference junction is that union of the two dissimilar wires which is maintained at a known signal level.

9.2.1.1 The Compensated Reference Junction: The compensated reference junction is a level junction maintained at a known signal output level by circuitry designed to compensate for changes in ambient temperature.

9.2.2 The Indicating Lead: The indicating lead is that portion of the thermocouple indicating system from the engine-airframe disconnect to the reference junction.

9.2.3 The Resistance Spool: The resistance spool is a variable resistance used to adjust the resistance of the thermocouple measurement system to a predetermined value under given conditions.

9.2.4 Cockpit Indicator: A cockpit indicator is an instrument used to translate the EMF from a temperature measurement system into a visual indication of measuring junction temperature.

9.2.4.1 Temperature Indicator: A temperature indicator is a device which responds to a signal from a temperature measuring system to provide a reproducible indication of the signal level.

9.2.4.2 Null Balance Indicator: A null balance indicator is a cockpit indicator which provides a visual indication by means of a potentiometer circuit whose accuracy is not affected by external resistance.

10. TEMPERATURE MEASURING ELEMENT CHARACTERISTICS:

10.1 Thermocouple Calibration:

Thermocouple calibration is the plot of the EMF output of a temperature measuring junction versus known temperatures.

10.1.1 Thermocouple Calibration Accuracy: Thermocouple calibration accuracy is the ratio, expressed in percentage, of the difference between the EMF output of a temperature measuring junction at a given temperature and the specified EMF for that temperature, to that specified EMF.

$$\text{Accuracy}\ (\%) = \frac{(\text{EMF}_{\text{test}} - \text{EMF}_{\text{ref}})}{\text{EMF}_{\text{ref}}} \times 100 \qquad \text{(Eq.1)}$$

10.2 Recovery Factor:

Recovery factor is the ratio of the difference in indicated temperature and static temperature to the difference in total temperature and static temperature.

10.2.1 Recovery Ratio: Recovery ratio is the ratio of the indicated temperature to the total temperature.

10.3 Radiation Error:

Radiation error is that difference between the gas temperature and the sensed temperature caused by radiant heat transfer between the sensing element and surrounding areas.

10.4 Conduction Error:

Conduction error is the difference between the gas temperature and the sensed temperature caused by conduction of heat along the thermocouple assembly support tubes and leads.

10.5 Standard Response Time:

Standard response time is the time required for a temperature measuring element to register 63.2% of a step change in temperature of a gas stream flowing at a rate of 6 $lb/ft^2/s$.

10.6 Standard Steady-State Reproducibility Factor:

Standard steady-state reproducibility factor is the ratio, expressed in percent, between the indicated gas temperature and a standard indicated temperature for that design under predetermined gas temperature, radiation, and conduction losses and mass flow conditions over the range of in-flight engine operations.