SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS413

REV. B

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Temperature Instruments
(Reciprocating Engine Powered Aircraft)

FOREWORD

This document has been declared "NONCURRENT". It is recommended, therefore, that this document not be specified for new designs. "NONCURRENT" refers to those documents which have previously been widely referenced and may continue to be required on some existing designs. "NONCURRENT" documents are available from SAE upon request.

1. PURPOSE:

   This Aerospace Standard establishes the minimum safe performance standards for electrical type temperature instruments primarily for use with reciprocating engine powered transport aircraft, the operation of which may subject the instruments to the environmental conditions specified in Section 3.4.

2. SCOPE:

   This Aerospace Standard covers two basic types of temperature instruments as follows:

   TYPE I: Ratiometer type, actuated by changes in electrical resistance of a temperature sensing electrical resistance element; the resistance changes being obtained by temperature changes of the temperature sensing resistance element.

   TYPE II: Millivoltmeter type, operated and actuated by varying E.M.F. output of a thermocouple; the varying E.M.F. input to the instrument being obtained by temperature changes of the temperature sensing thermocouple.

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3. GENERAL REQUIREMENTS:

3.1 Materials and Workmanship:

3.1.1 Materials: Materials shall be of a quality which experience and/or tests have demonstrated to be suitable and dependable for use in aircraft instruments.

3.1.2 Workmanship: Workmanship shall be consistent with high grade aircraft instrument manufacturing practice.

3.2 Identification:

The following information shall be legibly and permanently marked on the instrument or nameplate attached thereto:

a. Name of Instrument (Temperature Instrument)
b. SAE AS 413B
c. Manufacturer's Part Number
d. Manufacturer's serial number or date of manufacture
e. Manufacturer's name and/or trademark
f. Range
g. Rating (Electrical)
h. FAA TSO C-43

3.3 Compatibility of Components:

If components are individually acceptable but require matching for proper operation, they shall be specified accordingly.

3.4 Environmental Conditions:

The following conditions have been established as minimum design requirements. Tests shall be conducted as specified in Sections 6, 7, and 8.

3.4.1 Temperature: When installed in accordance with the instrument manufacturer's instruction, the instrument shall function over the range of ambient temperatures shown in Column A below and shall not be adversely affected by exposure to the range of temperature shown in Column B below:

Instrument Location	A	B
Heated Areas (Temperature Controlled)	0 to 50C	-65 to 70C

NOTE: Should cooling be required to reduce the maximum operating temperature below the values specified above for proper operation of the equipment, it shall be the responsibility of the equipment manufacturer to either provide such cooling or to notify the user that such cooling is required.

3.4.2 Altitude: When installed in accordance with the instrument manufacturer's instructions, the instrument shall function and shall not be adversely affected following exposure to a pressure and temperature range equivalent to -1000 to 40,000 ft standard altitude per NACA Report 1235, except as limited by the application of paragraph 3.4.1. The instrument shall not be adversely affected when subjected to an ambient pressure of 50 and 3 in. Hg absolute.

3.4.3 Vibration: When installed in accordance with the instrument manufacturer's instructions, the instrument shall function and shall not be adversely affected when subjected to vibration of the following characteristics:

Instrument Location In Airframe	Cycles Per Sec.	Max. Double Amplitude (in.)	Maximum Acceleration
Panel or Rack (Vibration isolated)	5-50	0.020	1.5 G.

3.4.4 Humidity: The instrument shall function and shall not be adversely affected following exposure to any relative humidity in the range of 0 to 95% at a temperature of approximately 70C.

3.5 Fire Hazard:

The Instrument shall be so designed as to safeguard against hazards to the aircraft in the event of malfunction or failure, and the maximum operating temperature of surfaces of any instrument component contacted by combustible fuel or vapor shall not exceed 200C due to self heating.

All materials shall be non-combustible and shall not liberate gases or fumes which will result in such corrosion as to cause malfunction of equipment or discoloration of dials or indicia, nor shall toxic gases or fumes that are detrimental to performance of the aircraft or health of personnel be liberated under the operating conditions specified herein.

3.6 Radio Interference:

The instruments shall not be the source of objectionable interference under operating conditions at any frequencies used on the aircraft, either by radiation or feed back, in electronic equipment installed in the same aircraft as the instrument, in accordance with Specification MIL-I-6181, latest revision.

3.7 Magnetic Effect:

The magnetic effect of the instruments shall not adversely affect the performance of other instruments installed in the same aircraft.

3.8 Decompression:

When installed in accordance with the instrument manufacturer's instructions, the instrument shall function and not be adversely affected following exposure to a pressure decrease from 22 to 2 in. of mercury in 2 sec.

3.9 Interchangeability:

Instruments and components which are identified in accordance with paragraph 3.2 shall be directly and completely interchangeable.

3.10 Definitions:

Definitions shall be in accordance with AS 425A - Flight Control Compartment Nomenclature and Abbreviations, and as noted in the glossary of terms defined in paragraph 9.

4. DETAIL REQUIREMENTS:

4.1 Instrument Markings:

4.1.1 Finish: Unless otherwise specified by the user, matte white material shall be applied to all graduations, numerals and indications means.

Non-functional surfaces and markings shall be durable dull black.

4.1.2 Graduations: The graduations shall be arranged to provide the maximum degree of readability consistent with the accuracy of the instrument.

4.1.3 Numerals: The display shall include sufficient numerals to permit quick and positive identification of each graduation.

Numerals shall distinctly indicate the graduation to which each applies.

4.1.4 Instrument Title: The instrument title, when used, shall be of the same approximate size but no larger than the numerals. The title may be of the same finish as the numerals. The units of measure (deg C or deg F x 100, as applicable) shall appear on the dial in lettering noticeably smaller than either the numerals or the title. All letters and numerals shall conform to Military Standard Drawing MS33558.

4.1.5 Visibility: The indicting means (indicia, pointers, counters etc.) shall be completely visible from all points within a space defined by a surface generated by lines making angles of at least 30 deg with a perpendicular to the display surface and diverging from the perimeter of the instrument window aperture. The distance between the dial and the cover glass shall be a practical minimum.

4.2 Function, Indicating Means:

The function shall be indicated by means of one or more pointers, dials, tapes, drums or other types of moving elements. Relative motion of the index with respect to the scale (either the index or the scale may be the moving element) shall be clockwise, up or to the right for increasing function.

4.3 Internal Lighting:

Red internal lighting shall be in accordance with ARP 582A - Lighting, Integral, for Aircraft Instruments; Criteria for Design. White internal lighting shall be in accordance with ARP 798, Design Criteria for White Incandescent Lighted Aerospace Instruments.

4.4 Power Variation:

The instrument shall properly function with ± 15% variation in D.C. voltage and/or ±10% variation in A.C. voltage and 5% variation in frequency. This applies to type I instruments only.

4.5 Hermetic Sealing:

When hermetically sealed, the case shall be filled with an inert gas, free of dust particles, and sufficiently dry so that fogging of the indicator glass does not occur during the low temperature and fogging tests of this Aerospace Standard. Helium gas shall not be used for integrally lighted units.

4.6 Case Markings:

Type II instrument terminal posts shall be different sizes and shall be distinctly marked to indicate plus for either iron wire, copper wire, or chromel wire connections, and minus for either the constantan or alumel wire connections. External resistance of the lead and thermocouple shall be plainly marked. The thermocouple type shall also be identified.

4.7 Resistance versus Temperature Equivalents:

Unless otherwise specified, Type I instruments shall be calibrated to indicate temperature in accordance with the temperature versus resistance values listed in Table I.

4.8 E.M.F. versus Temperature Equivalents:

Unless otherwise specified, Type II instruments shall be calibrated to indicate temperature in accordance with the E.M.F. versus temperature values as established by the National Bureau of Standards Circular 561, issued April 27, 1955.

4.9 Adjustment:

When provided, the zero adjustment shall have sufficient friction so that it will not change its adjustment due to vibrations encountered in service.

4.10 Limitation of Pointer Travel:

The pointer shall be free to move a minimum of two angular degrees beyond the ends of the scale travel and may be limited by stops.

5. TEST CONDITIONS:

5.1 Atmospheric Conditions:

Unless otherwise specified herein, all tests required by this Aerospace Standard shall be made at an atmospheric pressure of approximately 29.92 in. of mercury, an ambient temperature of approximately 25C and a relative humidity of not greater than 85%. When tests are conducted with the atmospheric pressure or temperature substantially different from these values, allowances shall be made for the variation from the specified conditions.

5.2 Vibration to Minimize Friction:

Unless otherwise specified herein, all tests for performance may be conducted with the instrument subjected to a vibration of 0.002 to 0.005 in. double amplitude at a frequency of 25 to 33 cycles per second. The term double amplitude, as used herein, indicates the total displacement from positive maximum to negative maximum.

5.3 Power Conditions:

Unless otherwise specified herein, all tests shall be conducted at the power rating recommended by the manufacturer.

5.4 Position:

Unless otherwise specified herein, all tests shall be conducted with the instrument in its normal operating position.

6. INSTRUMENTATION FOR PERFORMANCE CHECKS:

6.1 Vibration Equipment:

Vibration equipment shall be used which will provide frequencies and amplitudes consistent with the requirements of paragraph 3.4.3, with the following characteristics:

6.1.1 Linear Motion Vibration: Vibration equipment shall be such as to allow vibration to be applied along each of three mutually perpendicular axes of the instrument.

6.1.2 Circular Motion Vibration: Vibration equipment shall be such that a point on the instrument case will describe a circle, in a plane inclined 45 deg to the horizontal plane, the diameter of which is equal to the double amplitude specified.

6.2 Other Instrumentation:

All other instrumentation used in the tests in this Standard should have an accuracy of at least ten times better than the tolerances specified for the instrument under test.

7. INDIVIDUAL PERFORMRANCE REQUIREMENTS:

All instruments shall be subjected to tests by the instrument manufacturer to demonstrate specific compliance with this Aerospace Standard, including the following requirements where applicable:

7.1 Type I Attitude Error:

7.1.1 No Voltage: With no voltage applied to Type I instruments, the pointer shall remain slightly off-scale at the low temperature end while the instrument is in each of the following positions:

1. Normal operating position.
2. Instrument rotated clockwise around its X (longitudinal) axis, 90 deg from its normal position.
3. Instrument rotated clockwise around its X (longitudinal) axis, 180 deg from its normal position.
4. Instrument rotated counter-clockwise around its X (longitudinal) axis 90 deg from its normal position.

7.1.2 Voltage: The test specified for “No Voltage” shall be repeated on Type I instruments with the test voltage applied. This test may be performed at any indication. The change in pointer indication shall not exceed 2% of the total scale span in temperature degrees. When power to the instrument is cut off, the pointer shall return to the no voltage position.

7.2 Type II Attitude Error:

Type II instruments shall be electrically energized and a reading shall be taken while the instrument is in each of the following positions:

1. Normal operating position.
2. Instrument rotated clockwise around its X (longitudinal) axis, 90 deg from its normal position.
3. Instrument rotated clockwise around its X (longitudinal) axis, 180 deg from its normal position.
4. Instrument rotated counter clockwise around its X (longitudinal) axis, 90 deg from its normal position.

The maximum change in reading from the normal shall not exceed 2.5% of the total scale span in temperature degrees.

7.3 Friction:

7.3.1 Type I Instruments: The difference in readings of Type I instruments shall be noted after a slow change in indication before and after tapping or vibrating. This test may be performed at any point on the scale. The change in pointer indication shall not exceed 2% of total scale span in temperature degrees.

7.3.2 Type II Instruments: The friction test on Type II instruments may be conducted in conjunction with the scale error test. The voltage shall be slowly increased up to each test point. The instrument reading shall be noted before and after the instrument is lightly tapped or vibrated and the friction shall not exceed 4% of the total scale span in temperature degrees. The procedure shall be repeated for decreasing voltage values. The movement of the pointer shall be smooth when the applied voltage is varied uniformly.

7.4 Scale Error at Room Temperature:

7.4.1 Type I Instruments: Type I instruments shall have connected to the resistance bulb terminals the appropriate resistance of the temperature versus resistance curve. When the test voltage is applied, the scale errors shall be determined at a minimum of five test points for the instrument under test except that instruments having less than five major graduations shall be tested at each major graduation. The overall average accuracy shall not exceed two per cent of the total scale span in temperature degrees, or 2C, whichever is the greater error.

7.4.2 Type II Instruments: Type II instruments shall be subjected to a constant room temperature for a period of not less than one hour. Millivoltage shall then be applied to the terminals of the instrument through the specified external resistance in series with the instrument. This millivoltage, corrected for ambient temperature using an EMF Vs. temperature table, shall correspond to the critical temperature the instrument is to read in its particular application. The pointer shall be set to this critical temperature point on the scale by means of the zero corrector. The instrument shall then be subjected to the scale error test by applying the correct millivoltage for the selected test points.

Readings shall be taken at a minimum of five test points. The errors at the Set Point shall not exceed 1% of the total scale span in temperature degrees. The average error of all test point readings shall not exceed 2% of the total scale span in temperature degrees.

7.5 Dielectric:

Each instrument shall be tested by the method of inspection listed in paragraphs 7.5.1 and 7.5.2.

7.5.1 Insulation Resistance: The insulation resistance measured at 200 volts D.C. for five seconds between all electrical circuits and the metallic case shall not be less than 5 megohms. Insulation resistance measurements shall not be made to circuits where the potential will appear across elements such as windings, resistors, capacitors, etc., since this measurement is intended only to determine adequacy of insulation.

7.5.2 Overpotential Tests: The instrument shall not be damaged by the application of a test potential between electrical circuits, and between electrical circuits and the metallic case. The test potential shall be a sinusoidal voltage of a commercial frequency with an R.M.S. value of five times the maximum circuit voltage, or per paragraph 7.5.2.1 or 7.5.2.2, whichever applies. The potential shall start from zero and be increased at a uniform rate to its test value. It shall be maintained at this value for five seconds and then returned at a uniform rate to zero.

Since these tests are intended to insure proper electrical isolation of the circuit components in question, these tests shall not be applied to circuits where the potential will appear across elements such as winding, resistors, capacitors, etc.

7.5.2.1 Hermetically sealed instruments shall be tested at five times the maximum circuit voltage up to a maximum of 200 volts RMS.

7.5.2.2 Circuits that operate at potentials below 15 volts are not to be subjected to overpotential tests.

7.6 Sealing:

Hermetically sealed components containing helium shall be tested for leaks by means of a mass spectrometer type of helium leak detector or equivalent. The leak rate shall not exceed 0.0434 micron cu ft per hr per cu in. of filling gas at a pressure differential of one atmosphere.

NOTE: A micron cu ft per hour leak rate is defined as that gas leakage which would change the pressure of a one cu ft volume by the amount of one micron (one millionth of a meter of mercury) in one hour at a pressure differential of one atmosphere.

Hermetically sealed components filled with an inert gas other than helium shall be tested for leaks by being immersed in a suitable liquid such as water. The absolute pressure of the air above the liquid shall then be reduced to approximately 1 in. Hg and maintained for 1 min. or until air bubbles substantially cease to be given off by the liquid, whichever is longer. The absolute pressure shall then be increased to 2-1/2 in. Hg. Any bubbles coming from within the component case shall be considered as leakage and shall be cause for rejection. Bubbles which are the result of entrapped air on various exterior parts of the case shall not be considered as a leak.

8. QUALIFICATION TESTS:

As many instruments or components deemed necessary by the manufacturer to demonstrate that all instruments will comply with the requirements of this section shall be tested in accordance with his recommendations.

8.1 Reduced Voltage Operation:

The Type I instrument shall be tested with 85% of D.C. test voltage, and 90% of A.C. test voltage. The indications at the reduced voltage shall not differ from the indications at normal test voltage by more than 2.5% of full scale span in temperature degrees or 3.5 deg. C (6.3 deg. F) whichever is greater error.

8.2 Bulb Lead Resistance Effect:

On Type I instruments when the negative voltage is connected at the bulb, there shall not be over 1.5% of the full scale span change in indication at any point of the scale, when the total balanced lead resistance is changed from 0 to 4 ohms (2 ohms in each lead).

8.3 Temperature Characteristics:

8.3.1 Low Temperature Operation: The instrument shall be subjected to the applicable low ambient temperature listed in Column A of paragraph 3.4.1 for a period of three hours without operating. At the end of this time and while the instrument is still at the low temperature, resistance and/or voltage shall be applied as specified for scale error at room temperature (7.4). The scale errors shall not exceed ±5% of the total scale span in temperature degrees or 3C, whichever is the greater error.

8.3.2 High Temperature Operation: The instrument shall be subjected to the applicable high temperature listed in Column A of Paragraph 3.4.1 for a period of three hours without operating (electrical equipment shall be energized). At the end of this time and while the instrument is still at the high temperature, resistance and/or voltage shall be applied as specified for scale error at room temperature (7.4). The scale errors shall not exceed ±5% of the total scale span in temperature degrees, or 3C, whichever is the greater error.

8.3.3 Extreme Temperature Exposure: The instrument shall be exposed to the applicable low and high temperatures listed in Column B of paragraph 3.4.1 for a period of 24 hr at each extreme temperature, without operating. After a delay of three hours at room temperature, the instrument shall be subjected to the scale error at room temperature test (7.4). The scale errors shall not exceed ±3% of the total scale span in temperature degrees or 3C whichever is the greater error. There shall be no evidence of damage as a result of exposure to the extreme temperatures specified.

8.3.4 Altitude: The instrument shall be subjected to the ambient temperature and pressure listed in paragraph 3.4.2 for a period of three hours while operating. At the end of this time and while the instrument is still at this temperature and pressure, resistance and/or voltage shall be applied as specified for scale error at room temperature (7.4). The scale errors shall not exceed 5% of the total scale span in temperature degrees or 3C, whichever is the greater error.

The instrument shall be exposed alternately to 50 in. Hg absolute and 3 in. Hg absolute, non-operating. Following this exposure, resistance and/or voltage shall be applied as specified for scale error at room temperature, at atmospheric pressure. The scale errors shall not exceed 2% of the total scale span in temperature degrees, or 2C, whichever is the greater error. The time required to change from one pressure extreme to the other shall not exceed 4 minutes.

8.4 Vibration:

8.4.1 Resonance: The instrument, while operating, shall be subjected to a resonant frequency survey of the appropriate range specified in paragraph 3.4.3 in order to determine if there exists any resonant frequencies of the parts. The amplitude used may be any convenient value that does not exceed the maximum double amplitude and the maximum acceleration specified in paragraph 3.4.3.

The instrument shall then be subjected to vibration at the appropriate maximum double amplitude or maximum acceleration specified in paragraph 3.4.3 at the resonant frequency for a period of one hour along each axis. If more than one resonant frequency is encountered with the vibration applied along any one axis, a test period may be accomplished at the most severe resonance, or the period may be divided among the resonant frequencies, whichever shall be considered most likely to produce failure. The test period shall not be less than one-half hour at any resonant made. When resonant frequencies are not apparent within the specified frequency range, the instrument shall be vibrated for two hours along each axis in accordance with the vibration requirements schedule (paragraph 3.4.3) at the maximum double amplitude and frequency to provide the maximum acceleration.

8.4.2 Cycling: The instrument, while operating, shall be tested with the frequency cycled between limits specified in paragraph 3.4.3 in 15 min. cycles for a period of one hour along each axis at an applied double amplitude specified in paragraph 3.4.3, or an acceleration specified in paragraph 3.4.3, whichever is the limiting value.

While the instrument is being vibrated, the pointer oscillation shall not exceed 3% of the total scale span in temperature degrees. The pointer variation shall not exceed 3% of the total scale span in temperature degrees.

After the completion of this vibration test, no damage shall be evident and the instrument shall be subjected to the scale error at room temperature test (paragraph 7.4) (without resetting the zero corrector on Type II instruments). The change in indications between this test and the initial room temperature scale error test shall not exceed 1.5% of the total scale span in temperature degrees, or 2C, whichever is the greater error.

8.5 Humidity:

The instrument, unless hermetically sealed, shall be mounted in a chamber maintained at a temperature of 70, ± 2C and a relative humidity of 95 ± 5% for a period of 6 hours. After this period the heat shall be shut off and the instrument allowed to cool for a period of 18 hr in this atmosphere in which the humidity rises to 100% as the temperature decreases to not more than 38C. This complete cycle shall be conducted one time for components located in controlled temperature areas.

Immediately after cycling, there shall be no evidence of damage or corrosion which affects performance. Following this test the instrument shall be subjected to the scale error at room temperature test of paragraph 7.4. The change in reading between this test and the original scale error at room temperature test shall not exceed 2% of the total scale span in temperature degrees, or 2C, whichever is the greater error.

8.6 Magnetic Effect:

The magnetic effect of the instrument shall be determined in terms of the deflection of a free magnet, approximately 1-1/2 in. long in a magnetic field with a horizontal intensity of 0.18 (± 0.01) gauss, when the instrument is held in various positions on an east-west line with its nearest part 12 in. from the center of the magnet. With the instrument operating, the maximum deflections of the free magnet shall not exceed 5 deg. from any indicating or reference position.

8.7 Fogging (Hermetically Sealed Instruments Only):

The instrument, while operating, shall be exposed to a 70C ambient for a minimum of 30 minutes. While at this temperature, the external face of the cover glass shall be reduced to a temperature of 20C or less. No moisture or other material shall be deposited on the internal face of the cover glass as a result of this test.