

SOCIETY OF AUTOMOTIVE ENGINEERS, Inc.
485 LEXINGTON AVENUE
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AEROSPACE STANDARD

AS 411A

MANIFOLD PRESSURE INDICATING INSTRUMENTS

Issued 11-1-48
Revised 4-15-63

1. Purpose: This Aerospace Standard establishes the essential minimum safe performance standards for manifold pressure 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 3.3.
2. Scope: This Aerospace Standard covers two basic types of manifold pressure instruments as follows:
 - Type I - Direct Indicating
 - Type II - Remote Indicating
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 attached thereto:
 - (a) Name of instrument
 - (b) SAE AS411A
 - (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, vacuum, etc.)
 - (h) Explosion rating
 - 3.3 Environmental Conditions: The following conditions have been established as minimum design requirements. Tests shall be conducted as specified in Sections 5, 6, and 7.
 - 3.3.1 Temperature: When installed in accordance with the instrument manufacturer's instructions, the instrument shall function over the range of ambient temperature shown in Column A below and shall not be adversely affected by exposure to the range of temperature shown in Column B below:

Section 8.3 of the SAE Technical Board rules provides that: "All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

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<u>Instrument Location</u>	<u>A</u>	<u>B</u>
Power Plant Compartment	-30 to +100°C	-65 to +100°C
Heated Areas (Temperature Controlled)	-30 to +70°C	-65 to +70°C
Unheated Areas (Temperature Controlled)	-55 to +70°C	-65 to +70°C
Power Plant Accessory Compartment	-30 to +100°C	-65 to +100°C

3.3.2 Altitude: When installed in accordance with the instrument manufacturer's instructions, the instruments shall function and shall not be adversely affected following exposure to a pressure and temperature range equivalent to -1000 to 40,000 feet standard altitude, per NACA Report 1235, except as limited by the application of Paragraph 3.3.1. The instrument shall not be adversely affected when subjected to an ambient pressure of 50 inches of mercury absolute.

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

<u>Instrument Location in Airframe</u>	<u>Cycles Per Sec.</u>	<u>Max. Double Amplitude (In.)</u>	<u>Maximum Accel.</u>
Power Plant Mounted	5-150	0.100	20g.
Wings and Empennage	5-500	0.036	10g.
Fuselage	5-500	0.036	5g.
Panel or Rack (Vibration Isolated)	5-50	0.020	1.5g.

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

3.4 Explosion Category: The instrument component, when intended for installation either in uninhabited areas of non-pressurized aircraft or in non-pressurized areas of pressurized aircraft, shall not cause an explosion when operated in an explosive atmosphere. The component shall meet the requirements applicable to the explosion category below. Specifically, any instrument component which can be an ignition source and is intended for installation in an area in which combustible fluid or vapor may result from abnormal conditions, e.g., fuel line leakage, shall meet the requirements of Category I. If the intended location is an area where combustible fluid or vapor can occur during normal operation, e.g., fuel tank, the instrument component shall meet the requirements of Category II listed below:

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<u>Category</u>	<u>Definition</u>	<u>Requirement</u>
I	Explosion proofed: Case not designed to preclude flame or explosion propagation	Paragraph 7.10.1
II	Explosion proofed: Case designed to preclude flame or explosion propagation	Paragraph 7.10.2
III	Hermetically sealed	Paragraph 6.6
IV	Instrument not capable of causing an explosion	Shall not be capable of producing a capacitive or inductive spark of more than 0.2 millijoules of energy or a contact spark of more than 4.0 millijoules of energy.
3.5	<u>Fire Hazard:</u> The instruments shall be so designed 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.	
3.6	<u>Radio Interference:</u> The instruments shall not be the source of objectionable interference, under operating conditions at any frequencies used on aircraft, either by radiation or feed, in electronic equipment installed in the same aircraft as the instruments.	
3.7	<u>Magnetic Effect:</u> The magnetic effect of the instruments shall not adversely affect the performance of other instruments installed in the same aircraft.	
3.8	<u>Range:</u> This Aerospace Standard covers two ranges of manifold pressure indicating instruments: 10 to 75 inches Hg 15 to 100 inches Hg	
3.9	<u>Pressure Extremes:</u> The instruments shall not be adversely affected by exposures to pressures to two inches of mercury absolute and five inches of mercury in excess of the full scale reading.	

Detail Requirements

- 4.1 Indicating Means: The pressure instrument shall indicate by means of a visual display such as pointer (s) moving over a fixed dial, digital counter, etc.

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- 4.1.1 Finish: Unless otherwise specified by the user, matte white material shall be applied to all graduations, numerals, pointers and indication means. Non-functional surfaces and markings shall be durable dull black.
- 4.1.2 Graduations: The graduations shall be arranged to provide the maximum 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 ("In. Hg. Abs.") shall appear on the dial in lettering noticeably smaller than either the numerals or title.
- 4.1.5 Visibility: The indicating means and all markings shall be visible from any point within the frustum of a cone, the side of which makes an angle of at least 30 degrees with the perpendicular to the dial and the small diameter of which is the aperture of the instrument case. The distance between the dial and the cover glass shall be a practical minimum.
- 4.2 Cover Glass: The cover glass of the instrument shall be clear, flat, colorless, and free from flaws which would adversely affect the readability of the instrument.
- 4.3 Operation: The transmitter shall be capable of operating in either the horizontal or vertical position.
- 4.4 Overpressure Stop: An overpressure stop shall be provided and shall be designed to restrain the prime mover. The stop shall allow the pointer of the instrument or test instrument to travel beyond full scale to a point approximately midway between the last and the first graduation.
- 4.5 Noncorrosive Sealing: Where applicable, the instrument mechanism shall be sealed from the pressure compartment by a metal diaphragm or bellows to prevent corrosive or explosive vapors from coming in contact with the mechanism.
- 4.6 Power Variation: The instrument shall properly function with plus or minus 15 per cent variation in D.C. voltage and/or plus or minus 10 per cent variation in A.C. voltage and plus or minus 5% variation in frequency.
- 4.7 Hermetic Sealing: When hermetically sealed, the case shall be filled with a dry inert gas free of dust particles. The gas shall be sufficiently dry so that fogging of the instrument cover glass does not occur during the fogging test of this Aerospace Standard.

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4.8 Synchro Requirements: The synchro requirements shall be in accordance with the conditions specified in ARP 461A.

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 inches of mercury, an ambient temperature of approximately plus 25C and a relative humidity of not greater than 85%. When tests are conducted with the atmospheric pressure or temperature substantially different from tests values, allowance 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 inch 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 Vibration Equipment: Vibration equipment shall be used which will provide frequencies and amplitudes consistent with the requirements of Paragraph 3.3.3 with the following characteristics:

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.

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

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

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

5.6 Test Medium: The medium used for applying pressure during the tests shall be the medium with which the instrument is intended to be used or its equivalent.

6. Individual Performance 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:

6.1 Dielectric: Each instrument shall be tested by the method of inspection listed in Paragraphs 6.1.1 and 6.1.2.

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6.1.1 Insulation Resistance: The insulation resistance measured at 200 volts DC for five seconds between all electrical circuits connected together and the metallic case shall not be less than 5 megohms. Insulation resistance measurements shall not be made for 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.

6.1.2 Overpotential Tests: The instruments 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 a R.M.S. value of five times the maximum circuit voltage, or per Paragraphs 6.1.2.1 or 6.1.2.2 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 reduced 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 windings, resistors, capacitors, etc.

6.1.2.1 Hermetically sealed instruments shall be tested at 200 volts, R.M.S.

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

6.2 Scale Error at Room Temperature: The direct reading and transmitter instruments shall be tested for scale errors. The test shall be made by subjecting the instrument to the pressure required to produce the test points first with the pressures increasing, then with the pressures decreasing. With the pressures increasing, the pressure shall be brought up to, but shall not exceed the pressure specified to give the desired reading; and with the pressure decreasing, the pressure shall be brought down to, but shall not fall below the pressure specified to give the desired reading. The scale errors at room temperature of direct reading instruments shall not exceed Table I and transmitters shall not exceed Table I. The scale errors or remote indicators shall be determined by applying the specified electrical inputs. The scale errors at room temperature shall not exceed + 0.5% of the full scale value.

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TABLE I

SCALE ERRORS AT ROOM TEMPERATURE

<u>PRESSURE</u> <u>INCHES Hg</u>	<u>SCALE ERROR - DIRECT READING</u> <u>+ INCHES Hg - MAX.</u>		<u>SCALE ERROR - TRANSMITTER</u> <u>+ INCHES Hg - MAX.</u>	
	<u>75 In Range</u>	<u>100 In Range</u>	<u>75 In Range</u>	<u>100 In Range</u>
30	0.3	0.4	0.2	0.3
25	0.4	0.5	0.3	0.4
20	0.4	0.6	0.4	0.5
15	0.5	0.7	0.5	0.6
10	0.6	0.7	0.6	0.6
20	0.4	0.6	0.4	0.5
30	0.3	0.4	0.2	0.3
35	0.3	0.4	0.2	0.3
40	0.3	0.4	0.2	0.3
45	0.3	0.4	0.2	0.3
50	0.4	0.5	0.4	0.4
55	0.4	0.5	0.4	0.4
60	0.4	0.6	0.4	0.5
65	0.5	0.6	0.5	0.5
70	0.6	0.7	0.6	0.6
75	0.6	0.7	0.6	0.6
80		0.8		0.7
85		0.9		0.8
90		0.9		0.8
95		1.0		0.9
100		1.0		0.9

- 6.3 **Friction:** The instrument shall be tested for friction at each test point. The pressure shall be so increased as to bring the pointer of the direct reading instrument or test instrument (for test of transmitters) approximately to the desired reading and then held constant while two readings are taken, the first before the direct reading instrument or transmitter is tapped and the second after the instrument is tapped. The difference between any such readings is the friction error and shall not exceed 0.5 inch of mercury for the 75 inch gage and 0.6 inch for the 100 inch gage. The friction of remote indicators shall be determined in a similar manner by applying suitable electrical inputs. The friction shall not exceed 0.5% of the full scale value.
- 6.4 **Position Error:** With sufficient pressure applied to obtain a reading of approximately mid-scale, the direct reading instrument or transmitter shall be held in each of several different positions. The change in the reading of a direct reading instrument or test instrument (for test of transmitters), with change in position from the normal test position shall not exceed + 0.2 inch of mercury for the 75 inch gage or + 0.3 inch of mercury for the 100 inch gage. The position error of remote indicators shall be determined in a similar manner by applying suitable electrical inputs. The position error shall not exceed 0.5% of the full scale value.

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- 6.5 Leakage (Pressure Element): With pressure applied to produce a full scale reading, the connection tubing shall then be sealed at a point within 2 inches of the pressure connection. During a period of 5 minutes, there shall be no change in reading.
- 6.6 Sealing: Hermetically sealed instruments shall be tested for leaks by means of a mass spectrometer type of helium leak detector or equivalent. The leak rate shall not exceed 76 micron cubic foot per hour at a pressure differential of one atmosphere.
7. 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 recommendation.

7.1 Temperature Characteristics:

- 7.1.1 Low Temperature Operation: The instrument shall be subjected to the applicable low ambient temperature listed in Column A of Paragraph 3.3.1 for a period of five hours without operating. The instrument shall be subjected to at that temperature, a scale error test and the scale errors of direct reading instruments shall not exceed the values in Table I by more than + 0.3 inch of mercury for the 75 inch range or + 0.4 inch of mercury for the 100 inch range. The scale error of transmitters shall not exceed the values in Table II. The scale error of remote indicators shall not exceed + 1.0% of the full scale value.

TABLE II

<u>Pressure Inches Hg</u>	<u>Low and High Temperature Scale Error ± Inches of Mercury</u>	
	<u>75 Inch Range</u>	<u>100 Inch Range</u>
10	0.8	0.9
20	0.6	0.7
30	0.4	0.6
40	0.4	0.6
45	0.4	0.7
50	0.5	0.7
55	0.5	0.8
60	0.6	0.8
65	0.6	0.8
70	0.8	0.9
75	0.8	0.9
80		1.0
85		1.1
90		1.1
95		1.2
100		1.2

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- 7.1.2 High Temperature Operation: The instrument shall be subjected to the applicable high ambient temperature listed in Column A of Paragraph 3.3.1 for a period of five hours without operating. (Electrical equipment shall be energized). The instrument shall be subjected to, at that temperature, a scale error test and the scale errors of direct reading instruments shall not exceed the values in Table I by more than ± 0.3 inch of mercury for the 75 inch range or ± 0.4 inch of mercury for the 100 inch range. The scale error of transmitters shall not exceed the values in Table II. The scale errors of remote indicators shall not exceed $\pm 1.0\%$ of the full scale value.
- 7.1.3 Extreme Temperature Exposure: The instrument shall be exposed to the applicable low and high temperatures listed in Column B of Paragraph 3.3.1 for a period of 24 hours at each extreme temperature, without operating. After a delay of three hours at room temperature, the instrument shall meet the applicable individual performance tests (Section 6, except 6.1) at room temperature. There shall be no evidence of damage as a result of exposure to the extreme temperatures specified.
- 7.1.4 Altitude: The instrument shall be subjected to the ambient temperature and pressure listed in Paragraph 3.3.2 for a period of three hours while operating. The instrument shall meet the requirements of Paragraphs 7.1.1 and 7.1.2 while at these conditions. The instrument shall be exposed alternately to 50 inches Hg. absolute and three inches Hg. absolute, nonoperating. The instrument shall then meet the applicable individual performance tests (Section 6, except 6.1) at atmospheric pressure following this test.
- 7.2 Vibration:
- 7.2.1 Resonance: The instrument while operating shall be subjected to a resonant frequency survey of the appropriate range specified in Paragraph 3.3.3 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 3.3.3. The instrument shall then be subjected to vibration at the appropriate maximum double amplitude or maximum acceleration specified in Paragraph 3.3.3 at the resonant frequency for a period of one hour along each axis. If more than one resonant frequency is encountered with 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 mode. 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 3.3.3) at the maximum double amplitude and the frequency to provide the maximum acceleration.