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AEROSPACE STANDARD

AS 431A

TRUE MASS FUEL FLOW INSTRUMENTS

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1. PURPOSE: This Aerospace Standard establishes the essential minimum safe performance standards for True Mass Fuel Flow Instruments primarily for use with turbine powered, subsonic 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 three basic types of true mass flow indicating instruments. Each may consist of an indicator, transmitter and other auxiliary means such as a power supply or amplifier as required.

Type I - Rate Indication
Type II - Integration
Type III - Rate Indication and Integration

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, AS 431
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
h. Explosion category

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 temperatures listed in Column A below and shall not be adversely affected by exposure to the range of temperatures listed in Column B below:

Instrument Location	A	B
Power Plant Accessory Compartment	-30 to 150C	-65 to 150C
Pressurized Areas	-30 to 50C	-65 to 70C
Non-pressurized or External Areas	-55 to 70C	-65 to 70C

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3.3.2 Altitude: When installed in accordance with the instrument manufacturer's instructions, the instrument shall function from sea level up to the altitudes and temperatures listed below. Altitude pressure values are per NACA Report 1235.

Instrument Location	Alt. Ft.	Temp.
Power Plant Accessory Compartment	60,000	80C
Pressurized Areas	15,000	50C
Non-pressurized or External Areas	60,000	40C

The instrument shall not be adversely affected following exposure to extremes in ambient pressure of 50 and 3 inches HG absolute, respectively.

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

Instrument Location on Airframe	Cycles per sec.	Max. Double Amplitude	Max. Accel.
Nacelle & Nacelle Mounts, Wings, Empennage and Wheel Wells	5-1000	0.036"	10g
Fuselage			
Forward of Spar Area	5-500	0.036"	2g
Center or Spar Area	5-1000	"	4g
Aft of Spar Area	5-500	"	7g
	500-1000	--	5g
Vibration Isolated Rack	5-1000	0.030"	1.0g
Instrument Panel	5-30	0.020"	-
	30-1000	--	0.25g

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

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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:

Category	Definition	Requirement
I	Explosionproofed: case not designed to preclude flame or explosion propogation.	Paragraph 7.13.1
II	Explosionproofed: case designed to preclude flame or explosion propogation.	Paragraph 7.13.2
III	Hermetically Sealed	Paragraph 6.3.7.7
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 Fire Hazard: The instrument 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 200 C due to self-heating.

3.6 Radio Interference: The instrument shall not be the source of objectionable interference, under operating conditions at any frequencies used on the aircraft, either by radiation or feedback, in electronic equipment installed in the same aircraft as the instrument.

3.7 Magnetic Effect: The magnetic effect of the indicator shall not adversely affect the performance of other instruments installed in the same aircraft.

4. DETAIL REQUIREMENTS:

4.1 Indicating Method: One of the following methods of indication shall be employed. A single instrument may be employed embodying the features of both the Type I and Type II instruments.

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4.1.1 Type I Instruments: Rate of fuel flow shall be indicated by means of one or more moving pointers or dials and/or digital counter. Relative movement of the pointer with respect to the dial shall be clockwise for increasing rate of flow.

4.1.2 Type II Instruments: Fuel Consumed or quantity remaining shall be indicated by means of a digital counter or one or more moving pointers or dials.

4.1.3 Type III Instruments: Rate of fuel flow shall be indicated by means of one or more moving pointers, dials, or counters. Relative movement of the pointer with respect to the dial shall be clockwise for increasing rate of flow.

Fuel consumed or quantity remaining shall be indicated by means of a digital counter or one or more moving pointers or dials.

4.2 Display Markings:

4.2.1 Finish: Unless otherwise specified by the user, matte white material shall be applied to all major graduations, numerals, and indication means. Non-functional surfaces and markings shall be durable dull black.

4.2.2 Graduations: Major graduations shall be used at intervals not to exceed 10% of full scale value.

4.2.3 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.

4.2.4 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 shall appear on the dial in lettering noticeably smaller than either the numerals or title.

4.2.5 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.

4.3 Power Variations: All instruments shall function properly with ± 15% variation in the DC voltage and/or ± 10% variation in AC voltage and ± 5% variation in frequency. When the accuracy of the instrument is dependent upon the frequency regulation of the aircraft AC power, the manufacturer's recommendations shall be followed to obtain the specified performance.

4.4 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 AS.

4.5 Synchro Requirements: The synchro requirements should be in accordance with the conditions specified in ARP461 as applicable.

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4.6 Additional Output Signals: If required, additional sources of output signals, e.g., synchros, linear transformers, potentiometers, etc., may be included in the system to provide information to computers or to other equipment.

4.7 Flow Direction: The direction of flow through the transmitter shall be permanently and legibly marked thereon.

4.8 Fuel Characteristics: The system shall be designed for operation with turbine engine fuels (JP4, JP5, JP6), for operation with kerosene type fuels, and fuels including 30% aromatics.

4.9 Safety Provisions:

4.9.1 Fuel Flow During Malfunction: In case of malfunctioning during flight, each transmitter shall permit adequate fuel to flow either by means of an automatic by-pass or a mechanism which cannot offer a deleterious restriction to flow.

4.9.2 Flame Resistance: The flowmeter transmitter shall be flame resistant, i.e., it shall not support combustion to the point of propagation of a flame after removal of the ignition source.

5. TEST CONDITIONS:

5.1 Atmospheric Conditions: Unless otherwise specified herein, all tests required by this AS shall be conducted at an atmospheric pressure of approximately 29.92 inches of Mercury and at an ambient temperature of approximately 25C and relative humidity not exceeding 85%. When tests are conducted with the atmospheric pressure or the temperature substantially different from these values, allowance shall be made for the variation from the specified conditions.

5.2 Vibration (To Minimize Friction): Unless otherwise specified, all tests for performance may be conducted with the instrument subjected to a vibration of 0.001 inch maximum double amplitude at a frequency of 10 to 60 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 such as to allow vibration to be applied along each of three mutually perpendicular axes of the instrument.

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

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

5.6 Test Fuel: Unless otherwise specified, the fuel used in test shall be Grade JP4 fuel. However, a noninflammable or higher flashpoint fluid of relatively equivalent properties may be used to reduce imminent fire hazard.

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6. INDIVIDUAL PERFORMANCE REQUIREMENTS: All instruments, transmitters and indicators shall be subjected to tests by the instrument manufacturer to demonstrate specific compliance with this AS, including the following requirements where applicable:

6.1 Scale Error at Room Temperature:

6.1.1 Transmitter: The transmitter scale error shall be determined at all the flow rates deemed necessary to demonstrate compliance with the controlling purchaser requirements specification. This test shall be conducted by subjecting the instrument first to increasing rates of flow, then to decreasing rates of flow. With the rate of flow increasing, the rate shall be brought up to, but shall not exceed the rate specified to give the desired reading, and with the rate of flow decreasing, the rate shall be brought down to but shall not fall below the rate specified to obtain the desired reading. The error at each flow point shall not exceed the tolerances listed in Table I and Table II. The difference between the reading on increasing rate of flow and the reading on decreasing rate of flow shall not exceed 1/2% of full scale reading.

6.1.2 Indicator: The indicator scale error shall be determined at all major graduations. Two readings shall be taken - the first before, and the second after the instrument is tapped. The difference between the first and second readings shall not exceed 1/2% of full scale. The second reading shall not deviate from the ideal value in excess of the tolerances shown in Table I and Table II. In addition, the minimum tolerance shall be consistent with the readability of the instrument.

6.1.3 Auxiliary Means: Auxiliary power supplies or intermediate devices shall be tested at room temperature in accordance with the manufacturer's recommendations.

6.2 Dielectric: Ungrounded instruments or grounded instruments prior to connection of internal ground wire shall be tested by either the method of inspection of paragraph 6.2.1 or 6.2.2.

6.2.1 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 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.

6.2.2 Overpotential Tests: Equipment 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 RMS value of five times the maximum circuit voltage or per paragraphs 6.2.2.1 or 6.2.2.2 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.

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6.2.2.1 Hermetically sealed instruments shall be tested at 200 volts RMS.

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

6.3 Sealing: Hermetically sealed components shall be tested for leaks by means of a mass spectrometer type of helium leak detector or equivalent. The leak rate shall not exceed 0.1 micron cubic foot per hour at a pressure differential of one atmosphere.

6.4 Room Temperature Leak Test: The transmitter shall be tested for leaks by applying a non-shock hydraulic pressure to the inlet connection with the outlet connection bled free of air and capped and the pressure rapidly applied 5 times at room temperature. After the last application or pressure, there shall be no indication of leaks for a period of five minutes at the test pressure. There shall be no noticeable pressure drop as shown by a pressure gage readable to 10 psi, or as shown by visual leakage of a colored test fluid. Transmitters designed for high pressure service shall be tested at 1600 psi. Those designed for low pressure service shall be tested at 200 psi.

6.5 Position Error: Recording of the appropriate mid-scale indicated value shall be made with the test instrument in the normal position. Readings obtained with the test instrument turned 90 degrees in any direction shall not vary from the reading taken in the normal position by an amount in excess of 1/2% of full scale.

7. QUALIFICATION TESTS: As many instruments as deemed necessary to demonstrate that all instruments will comply with the requirements of this section shall be tested in accordance with the manufacturer's recommendations. After completion of all other qualification tests, each instrument shall be tested and shall meet the requirements of paragraph 6.2 Dielectric. See 7.10.

7.1 High and Low Temperature: The complete instrument system shall be placed within a test chamber and maintained at the proper temperature in accordance with column A, para. 3.3.1 for a minimum period of 4 hours (transmitter filled with fuel but not flowing) and shall then be tested at this temperature for scale error. The over-all errors shall not exceed the tolerances shown in Table I and Table II. During scale error tests, the temperature of the fuel shall be as tabulated below:

High Temperature ..... +38C
Low Temperature ..... -40C

The components of the complete instrument, e.g., indicator, transmitter, etc., may be tested separately provided they meet the performance requirements of Table I and Table II.

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7.2 Altitude: The indicator shall be subjected to the ambient temperature and pressure listed in paragraph 3.3.2 for a period of 3 hours while operating. The indicator shall then meet, at the conditions specified, the applicable Individual Performance tests of paragraph 6.1.

The indicator shall be exposed alternately to 50 inches Hg absolute and 3 inches Hg absolute, non-operating. The indicator shall meet the applicable Individual Performance Tests of Paragraph 6.1.

7.3 Extreme Temperature Exposure: The instrument components shall be exposed alternately 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 of paragraph 6.1 at room temperature. There shall be no evidence of damage as a result of exposure to the extreme temperatures specified. During exposure, the transmitter shall be filled with fuel, but not flowing.

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

7.5 Humidity: The instrument, unless hermetically sealed, shall be mounted in the normal operating position in a chamber and maintained at a temperature of 70 ± 2C and a relative humidity of 95 ± 5% for a period of six hours. After this period, the heat shall be shut off and the instrument allowed to cool for a period of eighteen hours 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:

a. Five times for instruments located in uncontrolled temperature areas.
b. Once for instruments located in controlled temperature areas.

Immediately after cycling, there shall be no evidence of damage or corrosion which affects performance. The performance of the instrument shall not be adversely affected as a result of this humidity cycling.

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7.6 Vibration:

7.6.1 Resonance: The instrument, while operating at approximately one-half scale, 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 frequency 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 double amplitude or maximum acceleration specified in paragraph 3.3.3 at the resonant frequency for a period of one hour in each axis. When 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 in 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.

7.6.2 Cycling: The instrument, while operating shall be tested with the frequency cycled between the limits specified in paragraph 3.3.3 in 15-minute cycles for a period of one hour in each axis at an applied double amplitude specified in 3.3.3, or an acceleration specified in 3.3.3, whichever is the limiting value. The pointer position may be changed every twenty to thirty minutes during this test.

After completion of the vibration test, no damage shall be evident and the instrument shall meet the appropriate "Scale Error at Room Temperature" test in paragraph 6.1.

7.7 Thermal Shock: This test shall apply to hermetically sealed instruments only. The indicator shall be subjected to four cycles of exposure to water at 85C ± 2C and 5 ± 2C without evidence of moisture penetration or damage to enclosure. Each cycle of the test shall consist of immersing the indicator in water at 85 ± 2C for a period of 30 minutes and then within 5 seconds of removal from the bath, immersing the indicator for a period of 30 minutes in the other bath maintained at 5C. This cycle shall be repeated continuously, one cycle following the other until four cycles have been completed.

Following this test, the indicator shall be subjected to the Sealing test specified in 6.3.

7.8 Pressure Drop: The transmitter pressure drop when measured by any suitable method shall not exceed 1.0 psi for transmitters ranging up to 1500 pph full scale and 3.0 psi for transmitters ranging up to 20,000 pph full scale.

The transmitter shall not have appreciably more pressure drop under any fuel flow condition when inoperative due to malfunction or faulty operation than when it is operating normally, or means shall be provided to prevent critical engine starvation under these conditions.

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