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AEROSPACE STANDARD

SAE AS440

REV. A

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Submitted for recognition as an American National Standard

AUTOMATIC PILOTS
(Turbine Powered Subsonic Aircraft)

FOREWORD

Changes in the revision are format/editorial only.

1. SCOPE:

This SAE Aerospace Standard (AS) covers automatic pilots intended for use on aircraft to automatically operate the primary and trim aerodynamic controls to maintain stable flight and/or to provide maneuvering about any of the three axes through servo control. Automatic control functions essential for primary or augmented flight control are excluded.

1.1 Purpose:

To establish essential minimum safe performance standards for automatic pilots primarily for use with turbine powered subsonic transport aircraft, the operation of which may subject the instrument to the environmental conditions specified in Section 3.3.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 NTIS Publications:

Available from NTIS, Springfield, VA 22161.

NACA Report 1235

3. GENERAL REQUIREMENTS:

3.1 Material and Workmanship:

3.1.1 Materials: Materials shall be of 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 each of the components or attached thereto:

a. Name of unit
b. SAE AS440A
c. Manufacturer's part number
d. Manufacturer's serial number or date of manufacture
e. Manufacturer's name and/or trademark
f. Range (if applicable)
g. Rating (if applicable)
h. Explosion category (if applicable)

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 as listed in Column A below and shall not be adversely affected by exposure to the temperature shown in Column B below.

TABLE 1

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

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

TABLE 2

Instrument Location	Altitude	Temperature
Power Plant Accessory Compartment	50,000 feet	80 °C
Pressurized Areas	15,000 feet	50 °C
Non-Pressurized or External Areas	50,000 feet	20 °C

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.

TABLE 3

Instrument Location	Freq. Cycles Per Second	Max. Double Amplitude Inches	Max. Accel.
Nacelle, Nacelle Mounts	5-1000	0.036	10 g
Wings, Empennage, and Wheel Wells			
		0.036	2 g
Fuselage	5-500	0.036	4 g
Forward of Spar Area	5-1000	0.036	7 g
Center of Spar Area	5-500	-----	5 g
Aft of Spar Area	500-1000		
Vibration Isolated Rack	5-1000	0.030	1 g
Instrument Panel	5-30	0.020	--
	30-1000	----	0.25 g

3.3.4 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 70 °C.

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 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:

TABLE 4

Category	Definition	Requirements
I	Explosion Proofed: case not designed to preclude flame or explosion propagation.	Paragraph 7.3.1
II	Explosion Proofed: case designed to preclude flame or explosion propagation.	Paragraph 7.3.2
III	Hermetically Sealed	Paragraphs 7.7 and 6.1.2.1
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 instrument shall not adversely affect the performance of other instruments installed in the same aircraft.

3.8 Icing:

All components except those located in pressurized areas which are mechanically coupled to the primary or trim aerodynamic controls shall function when exposed to icing as would be encountered under conditions of rapid changes in temperature, pressure and humidity.

4. DETAIL REQUIREMENTS:

4.1 Controls:

4.1.1 Disengagement: Positive means shall be provided to disengage the automatic pilot from the aircraft's aerodynamic and trim control system. This means shall not depend upon aircraft power (electric or pressure) for actuation nor its actuation precluded by electrical shorts.

4.1.2 Quick Release: Means shall be provided for a quick release of the automatic pilot by utilization of a switch located on the control wheel.

4.1.3 Controller: When a controller is provided, the design shall be such that, when installed in the aircraft, each manually operated control means which actuates the primary and/or trim aerodynamic controls shall operate in the plane with the sense of direction of motion of the aircraft. The control sensing shall be plainly identified on or adjacent to each control.

4.2 Indications:

4.2.1 Means of Indication: The means of indication required in the following paragraphs shall include any means by which the pilot is made cognizant of the condition, including control behavior and excluding control switch position.

4.2.2 Servo Input Indication: Means shall be provided to indicate the direction and relative magnitude of the surface hinge moment for the autopilot engaged condition. This may be accomplished by displaying servo input for electric servos or differential ram pressure for hydraulic or pneumatic servos. With the autopilot not engaged, the servo signals present shall be indicated.

4.2.3 Servo Power Indication: Means shall be provided to indicate when the servos are mechanically engaged but are not electrically energized, if such condition is possible.

4.2.4 Power Malfunction Indication: Means shall be incorporated in the instrument to indicate when adequate power (pressure, voltage and/or current) is not being made available to all phases required for the proper operation of the instrument. The indicating means shall indicate this malfunction in a positive manner.

4.2.5 Airborne Navigation Reference Indication: A visual means shall be provided to show the pilot when the automatic pilot is not engaged to the airborne navigation reference.

4.2.6 Automatic Pilot Disengage Indication: Means shall be provided to indicate when the autopilot has automatically disengaged due to the operation of an automatic interlock.

4.2.7 Automatic Trim Disengage Indication: If there is an automatic or manual disengage device associated with the trim system, means shall be provided for a trim disengage warning.

4.3 Control Range:

4.3.1 Corrective Control: The automatic pilot shall be capable of restoring the aircraft to the commanded attitude about the three axes throughout the following minimum ranges:

a. Pitch ±50°
b. Roll ±75°
c. Yaw ±20°

4.3.2 Commanded Control: Means shall be provided to limit maneuvering the aircraft through the automatic pilot controls, to the following maximum ranges:

a. Pitch ±30°
b. Bank ±45°
c. Turn Unlimited Angle to Right or Left

Each control shall be so arranged that smooth and gradual inputs may be made therewith.

4.4 Safety Provisions:

4.4.1 System Interlock: Means shall be provided to prevent the automatic pilot engagement until it has reached a fully operable condition.

4.4.2 Servo Force: means shall be provided to limit the maximum servo forces to a safe value as determined in specific applications. The servos shall be designed to withstand a minimum load of 2.5 times the maximum output of the servo applied in a manner similar to that found in actual installations, or as required by the actual aircraft control loads, whichever is the higher, plus any approved load applied by rigging tension.

4.4.3 Gyro Caging: If a gyro caging means is provided it shall not be capable of locking the gyro in a caged position. Any malfunction which causes the gyro to remain caged shall be indicated in a positive manner.

4.4.4 Auxiliary Controls: There shall be no objectionable electrical interference between automatic pilot and the accessory equipment designed to be operated with it. The automatic pilot shall not be the source of objectionable interference caused by radiation or feedback.

Special features incorporated as a part of the Automatic Pilot design, as integral or accessory components of the automatic pilot shall provide positive mechanical and/or electrical interlocks and sequencing in the order of engagement to preclude improper operation. For example:

a. Altitude Control - Pitch attitude correction shall be limited.

b. Flight Path Control - Pitch and roll attitude correction shall be limited.

c. Automatic Disengagement Control.

d. Automatic Trim Control.

e. Automatic Engine Power Control.

f. Automatic Mach/Airspeed Control.

g. Gyro Gaging.

h. Yaw Damper.

4.4.5 Automatic Trim: If an automatic trim system is provided, it shall disconnect for the case of a runaway malfunction if such is possible. If the malfunction is passive in that there is no automatic trim, disconnect shall occur and/or a means of indication of aircraft trim condition provided.

4.5 Reliability:

The automatic pilot system design shall be such that should a single malfunction (except gyro mechanical failures) occur in the system, sustained maximum servo control forces, as determined in Paragraph 4.4.2, shall not be applied to the aircraft in more than one primary and trim aerodynamic axis.

4.6 Power Variation:

The instrument shall properly function with plus or minus 15% variation in D.C. voltage and/or plus or minus 10% variation in A.C. voltage and plus or minus 5% variation in frequency or hydraulic pressure limits of plus or minus 30% of rated value. These values shall be steadystate conditions.

Transient variations within these limits and variations beyond these limits shall not cause unsafe control. As the specific application requires, variations beyond these limits shall not cause damage to the automatic pilot producing unsafe conditions.

5. TEST CONDITIONS:

5.1 Atmospheric Conditions:

Unless otherwise specified herein, all tests required by this Aerospace Standard shall be conducted at an atmospheric pressure of approximately 29.92 inches of mercury, an ambient temperature of approximately 25 °C and a relative humidity not greater than 85%. When tests are conducted with atmospheric pressure or temperature substantially different from these values, allowance shall be made for the variations 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 maximum vibration of 0.001 inch 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 at frequencies and amplitudes consistent with the requirements of Paragraph 3.3.3.

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 in its normal operating position.

6. INDIVIDUAL PERFORMANCE REQUIREMENTS:

All of the components of the complete system 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.

6.1.1 Insulation Resistance: The insulation resistance measured at 200 volts D.C. for 5 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.

6.1.2 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 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 5 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.

7. QUALIFICATION TESTS:

As many instruments or components as 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.

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 5 hours without operating. The instrument shall meet, at that temperature, the applicable individual performance tests (Section 6, except 6.1).

7.1.2 High Temperature Operation: The instrument shall be subjected to applicable high ambient temperature listed in Column A of Paragraph 3.3.1 for a period of 5 hours without operating. (Electrical equipment shall be energized.) The instrument shall meet, at that temperature, the applicable individual performance tests (Section 6, except 6.1).

7.1.3 Extreme Temperature Exposure: The instrument 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 3 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 3 hours while operating. The instrument shall then meet, at the conditions specified, the applicable individual performance tests (Section 6, except 6.1).

The instrument shall be exposed alternately to 50 inches Hg absolute and 3 inches Hg absolute non-operating. The instrument shall 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 subject 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, while operating shall 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 1 hour in 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 1/2 hour at any resonant mode.

When resonant frequencies are not apparent within the specified frequency range, the instrument shall be vibrated for 2 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.