

U. S. DEPARTMENT OF COMMERCE
CIVIL AERONAUTICS ADMINISTRATION
WASHINGTON 25, D. C.

TECHNICAL STANDARD ORDER
Regulations of the Administrator
Part 514

SUBJECT: AIRSPEED INDICATOR (PITOT STATIC)

TSO-C2b

Part 514—Technical Standard Orders for Aircraft Materials,
Parts, Processes, and Appliances

Under section 601 of the Civil Aeronautics Act of 1938 and the delegation of authority from the Civil Aeronautics Board in §§ 3.18, 4a.31, 4b.18, 6.18, and 7.18 of the Civil Air Regulations, the Administrator of Civil Aeronautics is authorized to adopt performance standards and specifications of materials, parts, processes, and appliances used in aircraft as he may find necessary to implement provisions of the Civil Air Regulations. The Administrator adopted the Technical Standard Order system as a means to carry out this delegated authority. This system, in brief, provides for CAA-industry cooperation in the development of these performance standards, and a form of self-regulation by industry in demonstrating compliance with these standards. Since the original adoption of this part, which contains the C series TSO's, it has been found desirable to make clarifying editorial and format changes. Hence, Part 514 of the Regulations of the Administrator is being amended to provide two subparts. Subpart A contains the general requirements applicable to all Technical Standard Orders, such as "Method of Conformance," "Marking," and "Deviations." Subpart B contains the technical specifications to which a specific product must conform.

SUBPART A—GENERAL

§ 514.1 *Basis and purpose*—(a) *Basis*. Section 601 of the Civil Aeronautics Act of 1938, as amended, and §§ 3.18, 4a.31, 4b.18, 6.18, 7.18 of the Civil Air Regulations.

(b) *Purpose*. The purpose of this part is to establish minimum performance standards for aircraft materials, parts, processes, and appliances which are to be used on civil aircraft of the United States, and to prescribe the manner by which the manufacturer must show compliance with such performance standards.

§ 514.2 *Method of conformance*. A manufacturer of an aircraft material, part, process, or appliance for which standards are established in Subpart B of this part, prior to distribution for use on a civil aircraft of the United States, shall furnish a written statement of conformance certifying that the material, part, process, or appliance meets the applicable performance standards established in this part. The statement of conformance shall be signed by a person duly authorized by the manufacturer, and shall be furnished to the Chief, Aircraft Engineering Division, Office of Aviation Safety, Civil Aeronautics Administration, Washington 25, D. C.

If complaints of nonconformance with the requirements of this Order are brought to the attention of the CAA and investigation indicates that such complaints are justified,

the Administrator will take appropriate action to restrict the use of the product in civil aircraft.

§ 514.3 *Marking*. Materials, parts, processes, and appliances for which a statement of conformance has been submitted, shall be legibly and permanently marked with the following information:

(a) Name and address of the manufacturer responsible for compliance,

(b) Equipment name, or type or model designation,

(c) Weight to the nearest pound and fraction thereof,

(d) Serial number and/or date of manufacture, and

(e) Applicable Technical Standard Order (TSO) number.

§ 514.4 *Deviations*. No deviation will be granted from the performance standards established in Subpart B. Requests for deviation from other requirements of this part should be addressed to the Aircraft Engineering Division, Office of Aviation Safety, Civil Aeronautics Administration, Washington 25, D. C.

Technical Standard Orders are obtainable without charge from the CAA, Special Services Division, Inquiry Unit, Washington 25, D.C.

SUBPART B

§514.12 Airspeed indicator (pitot static)--TSO-C2b--(a) Applicability--(1) Minimum performance standards. Minimum performance standards are hereby established for airspeed indicators which specifically are required to be approved for use in civil aircraft of the United States. New models of airspeed indicators (pitot static) manufactured for installation on civil aircraft on or after November 1, 1957, shall meet the standards set forth in SAE Aeronautical Standard AS-391B, "Airspeed Indicator (Pitot Static)," dated December 15, 1954.^{1/} Airspeed indicators (pitot static) approved by the Civil Aeronautics Administration prior to November 1, 1957, may continue to be manufactured under the provisions of their original approval.

(b) Marking. In lieu of the marking requirement of paragraph (c) of §514.3 the range shall be shown.

(c) Data requirements. One copy of manufacturer's operating instructions, schematic diagrams, and installation procedures shall be furnished the Chief, Aircraft Engineering Division, Civil Aeronautics Administration, Washington 25, D. C., with the statement of conformance.

(d) Effective date. November 1, 1957.

^{1/} Copies may be obtained from the Society of Automotive Engineers,
485 Lexington Avenue, New York 17, New York.

Society of Automotive Engineers, Inc.
29 West 39th Street
New York City

AERONAUTICAL STANDARD AS 391B

AIRSPPEED INDICATOR
(PITOT STATIC)

Issued 7-1-47
Revised 12-15-54

1. PURPOSE: To specify minimum requirements for Pitot Static Pressure Type of Airspeed Indicators for use in aircraft, the operation of which may subject the instruments to the environmental conditions specified in Section 3.3.
2. SCOPE: This Aeronautical Standard covers five basic types of airspeed instruments with indication range essentially as follows:

TYPE I - 1 revolution
TYPE II - 1 revolution (unequal scale)
TYPE III - 1-1/2 to 1-3/4 revolutions
TYPE IV - 7 revolutions
TYPE V - 1-3/4 to 2 revolutions

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 (Airspeed Indicator)
- (b) SAE Aeronautical Standard AS 391
- (c) Manufacturer's part number
- (d) Manufacturer's serial number or date of manufacture
- (e) Manufacturer's name and/or trademark
- (f) Range

- 3.3 Environmental Conditions: The following conditions have been established as design requirements only. 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 from -30C to 50C and shall not be adversely affected by exposure to temperatures of -65C and 70C.
 - 3.3.2 Humidity: The instrument shall function and shall not be adversely affected when exposed to any relative humidity in the range from 0 to 95 per cent at a temperature of approximately 32C.
 - 3.3.3 Altitude: The instrument shall function and shall not be adversely affected when subjected to a pressure and temperature range equivalent to -1000 feet to 40,000 feet standard altitude, except as limited by the application of 3.3.1.
 - 3.3.4 Vibration: When installed in accordance with the instrument manufacturer's instructions, the units shall function and shall not be adversely affected when subjected to vibrations of the following characteristics:

<u>Type of Component Mounting</u>	<u>Cycles Per Minute</u>	<u>Maximum Double Amplitude</u>	<u>Maximum Acceleration</u>
Shock Mounted Panel	300- 3,000	.020"	1.5 g.

Section 7C of the SAE Technical Board rules provides that: "All technical report use by anyone engaged in industry or trade is entirely voluntary. There is no agreement 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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3.4 Magnetic Effect: The magnetic effect of the indicator shall not adversely affect the operation of other instruments installed in the same aircraft.

4. DETAIL REQUIREMENTS:

4.1 Pressure Equivalents: These instruments shall be calibrated to indicate airspeed in accordance with the following pressure equivalents. (TABLE I)

TABLE I

DIFFERENTIAL PRESSURES - KNOTS AND MPH

Mercury at 0°CWater at 15.8°CDifferential Pressures for KnotsDifferential Pressures for MPH

Pounds Per Square Inch	Inches of Water	Inches of Mercury	Calibrated Air Speed	Inches of Mercury	Inches of Water	Pounds Per Square Inch
.0094	.261	.0192	20	.0145	.197	.0071
.0377	1.05	.0768	40	.0579	.788	.0284
.0590	1.63	.120	50	.0905	1.23	.0444
.0850	2.35	.173	60	.130	1.77	.0640
.116	3.21	.236	70	.178	2.42	.0872
.151	4.19	.308	80	.232	3.16	.114
.192	5.31	.390	90	.294	4.00	.144
.237	6.56	.482	100	.363	4.94	.178
.342	9.47	.696	120	.524	7.13	.257
.467	12.9	.950	140	.715	9.73	.351
.612	17.0	1.25	160	.936	12.7	.460
.777	21.5	1.58	180	1.19	16.2	.583
.964	26.7	1.96	200	1.47	20.0	.723
1.17	32.5	2.39	220	1.79	24.3	.878
1.40	38.8	2.85	240	2.13	29.1	1.05
1.65	45.8	3.37	260	2.52	34.2	1.24
1.93	53.5	3.93	280	2.93	39.9	1.44
2.23	61.8	4.54	300	3.38	46.0	1.66
2.73	75.6	5.56	330	4.13	56.2	2.03
3.29	91.0	6.69	360	4.95	67.4	2.43
4.13	114.3	8.40	400	6.20	84.3	3.04
5.35	148.2	10.89	450	7.98	108.7	3.92
6.78	187.8	13.80	500	10.06	136.9	4.94
8.44	234.0	17.19	550	12.44	169.3	6.11
10.37	287.4	21.12	600	15.17	206.4	7.45
12.60	349.0	25.64	650	18.27	248.6	8.97
15.14		30.83	700	21.79	296.5	10.70

4.2 Indicating Method: These airspeed instruments shall indicate by a means of a pointer moving over a fixed dial. Sensitive types shall have, in addition, an under dial visible through an aperture in the fixed dial for indicating hundreds of miles or knots per hour. Clockwise pointer motion shall indicate increasing airspeed.

4.3 Visibility: The pointer and all dial markings shall be visible from any point within the frustum of a cone whose side makes an angle of not less than 30 degrees with the perpendicular to the dial, and whose small diameter is the aperture of the instrument case. The distance between the dial and the cover glass shall be a practical minimum and shall not exceed 0.187 of an inch.

4.4 Dial Markings:

4.4.1 Finish: Unless otherwise specified luminescent (self activating) material shall be applied to all major graduations, numerals and pointer.

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- 4.4.2 Graduations: Graduations shall be used which will provide maximum dial readability. Where practical minor graduations shall be used at intervals not to exceed 5 miles per hour or 5 knots as applicable and major graduations shall be used at intervals not to exceed 10 miles per hour, or 10 knots.
- 4.4.3 Numerals: Sufficient numerals shall be marked to positively and quickly identify all graduations. Numerals shall distinctly indicate the graduations to which each applies.
- 4.4.4 Instrument Name: The word "Airspeed" shall be marked and may be the same finish as the numerals. The inscription "MPH" or "KNOTS" shall appear on the dial.
- 4.5 Limitation of Pointer Movements: The pointer movement shall be limited by stops in the mechanism in such a way that the pointer will not be permitted to rotate more than 10 degrees beyond the last graduation on the dial. Stops may also be incorporated in the instrument mechanism to limit counterclockwise motion of the pointer.
- 4.6 Back of Case Markings: The back of the case, adjacent to the connections shall be marked as follows:

P - Pitot Pressure Connection
S - Static Pressure Connection

5. TEST CONDITIONS:

- 5.1 Atmospheric Conditions: Unless otherwise specified, all tests required by this aeronautical standard shall be conducted at an atmospheric pressure of approximately 29.92 inches of mercury and at an ambient temperature of approximately 25C. When tests are conducted with the atmospheric pressure or the 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, 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 1500 to 2000 cycles per minute. The term double amplitude as used herein indicates the total displacement from positive maximum to negative maximum.
- 5.3 Preconditioning: No pressure shall be applied to the diaphragm or any actuating element of the instrument, nor shall the diaphragm or other actuating element be flexed or exercised for a period of 24 hours prior to the start of the tests of Section 6.
- 5.4 Vibration Equipment: Vibration equipment shall be used which will provide frequencies and amplitudes consistent with the requirements of Section 3.3.4 with the following characteristics.
- 5.4.1 Circular Motion Vibrations: Vibration equipment for shock mounted panel instruments shall be such that a point on the instrument case will describe, in a plane inclined 45 degrees to the horizontal plane, a circle, the diameter of which is equal to the double amplitude specified.
- 5.5 Position: Unless otherwise specified, all tests shall be conducted with the instrument mounted in its normal operating position.

6. INDIVIDUAL PERFORMANCE REQUIREMENTS:

All instruments shall be subjected to whatever tests the manufacturer deems necessary to demonstrate specific compliance with this specification including the following requirements where applicable.

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- 6.1 Scale Error: The instrument shall be tested for scale errors at approximately 12 essentially equal scale intervals per pointer revolution for Type I, II, III and V. For Type IV the test shall be made at approximately 17 essentially equal intervals of the entire range. The tests shall be conducted by subjecting the instrument to the pressure specified to produce these readings, first with pressure increasing, then with pressure decreasing. With pressure increasing, the pressure shall be brought up to, but shall not exceed, the pressure specified to give the desired reading. With pressure decreasing, the pressure shall be brought down to, but shall not fall below the pressure specified to give the desired reading. The errors at the test points shall not exceed the tolerances specified in Table II.
- 6.2 Friction: The instrument shall be tested for friction at approximately four essentially equal scale intervals. The pressure shall be brought up to the desired reading and then held constant while two readings are taken; the first reading being taken before the instrument is vibrated, and the second one after the instrument is vibrated. The difference between any two readings shall not exceed the tolerance in Table III.
- 6.3 Position: A pressure equivalent to one quarter, one half and three quarters scale deflection shall be applied. The change in reading at each deflection produced by rotating the instrument from the dial vertical to the dial horizontal position, and 90 degrees to the right and left, while the instrument is vibrated shall not exceed the tolerance specified in Table II.
- 6.4 Leak: With both the pitot pressure and static pressure connections simultaneously evacuated to 15 inches of mercury, the leakage shall not cause more than 0.4 inch of mercury pressure drop during a 10 second period. With the static pressure connection open, and pressure equivalent to full scale pointer deflection applied to the pitot pressure connection, the leakage shall not cause more than 1 MPH or 1 knot decrease in indication during a one minute period. This test shall be made with test apparatus containing the minimum practical volume.

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.

- 7.1 Low Temperature: The instrument shall be subjected to a temperature of -30C for a period of three hours. With the temperature held at -30C, the instrument shall be tested for scale errors as described in paragraph 6.1. The errors at the test points shall not exceed the tolerances of Table II by more than the amount specified in Table III.
- 7.2 High Temperature: The instrument shall be subjected to a temperature of 50C for a period of three hours. With the temperature held at 50 C, the instrument shall be tested for scale errors as described in paragraph 6.1. The errors at the test points shall not exceed the tolerances of Table II by more than the amount specified in Table III.
- 7.3 Extreme Temperature Exposure: The instrument shall, after alternate exposures to ambient temperatures of -65C and 70C for periods of 24 hours each and a delay of 3 hours at room temperature following completion of the exposure, meet the requirements of paragraph 6.1. There shall be no evidence of damage as a result of exposure to the extreme temperatures specified herein.
- 7.4 Vibration: With a pressure applied, sufficient to give half scale deflection, the instrument shall be subjected to vibrations of all frequencies within the appropriate range specified in paragraph 3.3.4 in order to determine if there exists any natural frequencies of any parts, that lie within the specified range. The amplitude used may be any convenient value that does not exceed the maximum double amplitude specified in paragraph 3.3.4 and such as not to exceed the maximum acceleration specified in paragraph 3.3.4.

The instrument shall then be subjected to vibration at the appropriate maximum double amplitude or maximum acceleration specified in paragraph 3.3.4 at each of the above determined natural frequencies for a period of three hours. If no natural frequencies occurred in the appropriate frequency range, the appropriate frequency and double amplitude for this endurance test shall be determined from the following table:

	<u>Cycles Per Minute</u>	<u>Double Amplitude</u>
Shock Mounted Panel	3000	.010

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While the instrument is being vibrated at a double amplitude of .003 to .005 inch at a frequency as specified in paragraph 3.3.4, the drift of the pointer shall not exceed the tolerance of Table III and the instrument pointer shall not oscillate more than the tolerance in Table III.

After completion of the exposure, no damage shall be evident and the instrument shall meet the requirements of Section 6.

- 7.5 Seasoning: The instrument shall be subjected to one hundred applications of a differential pressure sufficient to produce approximately full scale deflection. Not less than one hour following this test, the instrument shall be tested for scale errors as described in paragraph 6.1, except that the scale error test shall not exceed the tolerance specified in Table II by more than the amount specified in Table III.
- 7.6 Drift: The instrument shall be subjected to a differential pressure sufficient to produce approximately 3/4 scale deflection. After being subjected to the pressure for a period of one hour, the instrument shall be tested as described in paragraph 6.1 except scale errors shall be determined for increasing pressure only. The reading of the instrument shall not have increased by more than the amount specified in Table III.
- 7.7 Low Temperature Exposure: The instrument shall be subjected to a temperature of -65C for a period of 24 hours. With the temperature held at -65C, the instrument shall function. In addition, after the temperature is raised to -30C and held for a period of three hours, the instrument shall meet the requirements of paragraph 7.1.
- 7.8 Magnetic Effect: The magnetic effect of the instrument 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, plus or minus 0.01 gauss, when the indicator is held in various positions on an east-west line with its nearest part five inches from the center of the magnet. (An aircraft compass with the compensating magnets removed therefrom may be used as the free magnet for this test). The maximum deflection of the magnet shall not exceed one degree for any pointer deflection.
- 7.9 Humidity: The instrument shall be mounted in its normal operating position (with simulated installation conditions by connecting 10 feet of coiled copper tubing to each connection in such a manner that moisture can drain out the open end) 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 shall be allowed to cool for a period of 18 hours in this atmosphere in which the humidity rises to 100% as the temperature decreased to not more than 38C. This complete cycle shall be conducted once.

Immediately after cycling the instrument shall be subjected to the scale error at room temperature test of 6.1.

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TABLE II
TOLERANCES
PERCENT FULL SCALE READING

Type I	First 1/2 scale	1.0
	Last 1/2 scale	1.4
Type II	Expanded scale	1.0
	Compressed scale	2.5
Type III	First 1/3 scale	.7
	Last 2/3 scale	1.2
Type IV	First 1/4 scale	.4 *
	Middle 2/4 scale	.7
	Last 1/4 scale	.9
Type V	First 360 degrees of scale	.7
	Last 270 degrees of scale	1.4

* 50 knot or mph - .6%

TABLE III
TOLERANCES
% FULL SCALE READING

Test	Reference Paragraph	TYPE				
		I	II	III	IV	V
Friction	6.2	1.0	1.2 (expanded scale)	.8	.5	2.7 (1st 1/4 rev.)
			1.2 (compressed scale)			2.0 (2nd 1/4 rev.)
Position	6.3	1.0	1.0	.65	.4	1.7
Vibration	7.3					
Pointer Oscillation		.75	.8	.5	.25	1.5
Pointer Change		.75	.8	.5	.4	1.5
Temperature	7.1	1.2	1.2 (expanded scale)	1.2	.5	1.7 (1st rev.)
	7.2		1.7 (compressed scale)			2.4 (remainder of scale)
Drift	7.5	.5	.9	.4	.4	No Test
Seasoning	7.4	.75	.6 (expanded scale)	.5	.4	1.0
			.9 (compressed scale)			