SURFACE VEHICLE STANDARD

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Electrical Indicating System Specification

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE CTTC C2, Electrical Components and Systems Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. SCOPE

This SAE Standard describes those factors which affect the accuracy and reliability of voltage indicating units and electrical indicating and sending units for fuel level, pressure, and temperature suitable for off-road, self-propelled work machines as described in SAE J1116 and agricultural tractors as defined in ASAE S390. Indicating units are divided into two groups, fully sealed and partially sealed. Serviceable lighting is not covered by this document unless otherwise specified. No ISO document has been found to be compatible.

1.1 Purpose

This SAE document is to provide a set of specifications as a guideline in order to specify the performance requirements in the design goals of an electrical indicating system.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1116 Categories of Off-Road Self-Propelled Work Machines

SAE J1362 Graphical Symbols for Operator Controls and Displays on Off-Road Self-Propelled Work Machines

SAE J1455 Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications

SAE J2020 Accelerated Exposure of Automotive Exterior Materials Using a Fluorescent UV and Condensation Apparatus

Copeland, L.H. and Nock, S.E., "The Analysis and Testing of Gauge Fogging," SAE Technical Paper 941803, 1994

2.1.2 ASTM Publication

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B 117-73 Salt Spray (Fog) Testing

2.1.3 ASABE Publication

Available from ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659.

ANSI/ASAE S390 Definitions and Classifications of Agricultural Equipment

3. DEFINITIONS

3.1 System

A typical electrical indicating system consists of an indicating unit (sometimes called a receiver or gauge) and a sending unit (or sender). The indicating unit responds to a resistance presented by a sending unit which varies in proportion to parameters such as temperatures, levels, and pressures. A voltage indicating unit responds directly to the system voltage without input from a specific sending unit.

3.2 Indicating Unit

The indicating unit typically consists of a graduated dial, a pointer attached to a spindle with a magnetized armature, two or more electrical coils wound on perpendicular axes surrounding the armature, a lens, and an enclosing housing. The resistive load of the sending unit varies the relative strength of the magnetic fields of the coils. The armature rotates to align with the resultant magnetic field of the coils and the pointer position indicates the measured value on the dial graduations. In some cases a stationary magnet is provided to move the pointer below the beginning of the graduated scale when the unit is not energized. In a voltage indicating unit the input voltage varies the relative strength of the magnetic field of a coil used in conjunction with reference/fixed magnet(s). A voltage indicating unit is also referred to as a voltmeter.

3.3 Sending Unit

The sending unit usually consists of a variable resistance and a suitable mechanical linkage or, in the case of temperature sending units, a thermistor in a housing.

It is important that the sender is compatible with the indicating unit since there is more than one relation of sending unit resistance to measured parameter.

4. CALIBRATION

4.1 Indicating Unit

Accuracy is normally expressed in angular tolerance of pointer position but the indicating unit manufacturer should also provide the equivalent error expressed in units of the measured parameter.

Unless otherwise specified, the indicating unit shall be accurate to within ±1.5 angular degrees at the primary calibration point and ±3.0 angular degrees at the secondary calibration point. Light vibration or three light taps shall be used before taking readings. The indicating unit is to be checked under the following conditions:

a. Voltage: 28.00 VDC ± 0.01 VDC for 24 VDC nominal systems 14.00 VDC ± 0.01 VDC for 12 VDC nominal systems

b. Position: Dial face oriented 30 angular degrees back from the vertical

c. Ambient temperature: 25 °C ± 3 °C

The primary and secondary calibration points shall be checked with the direction of pointer motion as follows in Table 1:

TABLE 1 - INDICATING UNIT PRIMARY AND SECONDARY CALIBRATION POINTS

Type of Sending Unit	Calibration Point (Units of measured parameter) Primary	Calibration Point (Units of measured parameter) Secondary
Liquid level	Descending level	Ascending level (i.e., "full")
Pressure	Descending pressure	Descending pressure
Temperature	Ascending temperature	Ascending temperature
Voltage	Descending voltage	Ascending voltage

4.2 Sending Unit

It will be necessary to evaluate the specified range of operating resistance in order to specify calibration points with associated tolerance. The calibration points shall be defined by the manufacturer in terms of sending unit resistance tolerance and measured parameter tolerance at the primary and secondary calibration points. See Table 2 for values.

TABLE 2 - SENDING UNIT CALIBRATION POINTS VALUES

Type of Sending Unit	Calibration Point (Units of measured parameter) Primary	Calibration Point (Units of measured parameter) Secondary
Liquid Level	+0/–3% full scale travel, descending level	±12% full scale travel or +15/-0% full scale travel, ascending level
Pressure	±4% full scale pressure, descending pressure	±12% full scale pressure, descending pressure
Temperature	±3 °C, ascending temperature	±10 °C, ascending temperature or as agreed between the user and the manufacturer

5. EFFECTS OF ENVIRONMENTAL CONDITIONS

5.1 Temperature

5.1.1 Indicating Unit

The indicating unit shall be functional between –40 and +85 °C. No permanent damage shall result from operating the unit in a range of –40 and +85 °C or storage between –65 and +85 °C.

With calibration voltage applied, the indicating unit reading shall not shift more than ±2 angular degrees from –7 to +54 °C from the reading obtained at the primary calibration point per 4.1. A voltage indicating unit shall be accurate to within ±3 angular degrees at the primary and secondary calibration points.

5.1.2 Sending Unit

It will be necessary to evaluate each specific application to specify sensitivity to temperature change.

5.1.2.1 Temperature Sending Unit

The application of temperature sending units shall consider fluid flow and pressure, external air flow and temperature, external heat sources and thermistor self-heating due to indicating unit loading characteristics.

The shift in indicated temperature for a given temperature sending unit when submerged in fluid and electrically unloaded and the indicated temperature when the sending unit is normally mounted and loaded as agreed upon in 4.2 shall be no greater than two times the tolerance specified in Table 2 or as agreed between the user and the manufacturer.

Small indicated temperature differences show that the temperature sending unit is less sensitive to environmental changes.

5.2 Voltage Variation (Indicator only)

5.2.1 Normal Variation

The indicating unit reading at the primary calibration point shall not vary more than ±1 angular degree with normal operating voltage of 13 to 15 VDC for 12 VDC systems and 26 to 30 VDC for 24 VDC systems at +25 °C ± 3 °C. This does not apply to voltage indicating units.

5.2.2 Extreme Variation

The indicating unit reading at the primary calibration point shall not vary more than ±1 angular degree (+1 to –4 angular degrees for return to zero indicating units) with a voltage variation from 10 to 16 VDC for 12 VDC systems and 20 to 32 VDC for 24 VDC systems at +25 °C ± 3 °C. This does not apply to voltage indicating units

5.2.3 Voltage variations can occur due to ground potential differences between the sending unit and indicating unit. Where these differences are great enough to be objectionable, the use of an isolated grounding system is recommended. The use of an isolated grounding system can reduce the error to zero.

5.3 Abnormal Voltage Conditions (Indicating unit only)

5.3.1 Over Voltage

The indicating unit shall withstand a voltage of 200% of nominal system voltage for 5 min without damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. This applies over the functional temperature range specified in 5.1.1. A nominal sender load for mid-scale pointer position shall be applied except for voltage indicating units.

5.3.2 Load Dump Transient

The indicating unit shall withstand the load dump transients defined in Table 3 for 1 h without damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. This applies over the functional temperature range specified in 5.1.1. A nominal sending unit load for mid-scale pointer position shall be applied except for voltage indicating units.

TABLE 3 - LOAD DUMP TRANSIENTS

Nominal Voltage (Volts)	Voltage Source Characteristic-Open Circuit (Volts)	Period (sec)	Source Impedance
12	$100e^{\wedge}(-t/0.188) + 14$	50	0.95 Ω 510 mH
24	$188e^{\wedge}(-t/0.188) + 28$	50	2.91 Ω 1.54 mH

5.3.3 Low Energy Transient

The indicating unit shall withstand the low energy transients defined in Table 4 for 1 h without damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. This applies over the functional temperature range specified in 5.1.1. A nominal sending unit load for mid-scale pointer position shall be applied except for voltage indicating units.

TABLE 4 - LOW ENERGY TRANSIENTS

Nominal Voltage (Volts)	Voltage Characteristic-Input to Unit (Volts)	Period (sec)	Source Impedance
12	200e∧ (–t/0.001) + 14	5	NA NA
24	333e∧ (–t/0.001) + 28	5	NA NA

5.3.4 Inductive Load Switching

The indicating unit shall withstand the inductive load switching transients defined in Table 5 for 1 h without damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. This applies over the functional temperature range specified in 5.1.1. A nominal sending unit load for mid-scale pointer position shall be applied except for voltage indicating units.

TABLE 5 - INDUCTIVE LOAD SWITCHING TRANSIENTS

Nominal Voltage (Volts)	Voltage Characteristic-Input to Unit (Volts)	Period (sec)	Source Impedance
12	–614e∧ (–t/0.001) + 14 followed by + 80 V excursion	10	NA NA
24	–1028e∧ (–t/0.001) + 28 followed by + 80 V excursion	10	NA NA

5.3.5 Reversed Polarity

The indicating unit shall withstand reversed battery terminal polarity indefinitely within operating temperatures. There shall be no damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability.

5.4 Shock

5.4.1 Indicating Unit

The indicating unit shall be capable of withstanding the following series of shocks without damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. The unit shall be subjected to twelve shocks in each direction along each of three mutually perpendicular axes (72 total shocks), one axis to be perpendicular to the mounting plane. Each shock shall have an amplitude of 44 to 45 g and a half sine of 9 to 13 ms duration.

When specified (when agreed between the supplier and user) the indicating unit shall survive a single 0.9 m (3 ft) drop onto a concrete floor, regardless of the point of impact, with only cosmetic damage and with no permanent difference from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. See SAE J1455 for additional background. Although the drop test subjects the indicting unit to a fewer number of shocks, it is possible that the forces encountered in a handling drop test may be In excess of 80 g's.

5.4.2 Sending Unit

The sending unit shall be capable of withstanding the following series of shocks without damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per 4.2 taking into account reading repeatability. The unit shall be subjected to twelve shocks in each direction along each of three mutually perpendicular axes (72 total shocks), one axis to be perpendicular to the mounting plane. Each shock shall have an amplitude of 44 to 45 g and a half sine of 9 to 13 ms duration.

When specified (when agreed between the supplier and user) the sending unit shall survive a single 0.9 m (3 ft) drop onto a concrete floor, regardless of the point of impact, with only cosmetic damage and with no permanent difference from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. See SAE J1455 for additional background. Although the drop test subjects the sending unit to a fewer number of shocks, it is possible that the forces encountered in a handling drop test may be In excess of 80 g's.

5.5 Vibration

The indicating unit and the sending unit shall be capable of withstanding 18 h of vibration, 6 h along each of the three mutually perpendicular axes. One axis is to be perpendicular to the mounting plane. The vibration test shall be run at the double amplitude or acceleration listed in Table 6 with the frequency swept through the range of 10-2000-10 Hz at a rate of one octave per minute (approximately 15.3 min per sweep). The test shall be run at room temperature. A nominal sending unit load for mid-scale pointer position shall be applied to the indicating units. Sending units shall be run at approximately 50% of full scale measured parameter and loaded with a suitable indicating unit. During the test run of either an indicating or a sending unit, the indicating unit pointer motion shall show no signs of electrical shorting or loss of electrical continuity. After completion of the test, the indicating units and temperature sending units shall have no damage or permanent difference of calibration from the readings obtained at the primary and secondary calibration points per Section 4 taking into account reading repeatability. The pressure and fuel level sending units shall have no damage and the permanent shift of calibration shall be equal to the calibration tolerance specified in Section 4 for the primary and secondary calibration points. Note that some engine and/or mounting methods may produce engine mounted accelerations greater than specified here. The user shall reflect this in the specification for such applications.

TABLE 6 - DOUBLE AMPLITUDE OR ACCELERATION FOR THE VIBRATION TEST

Application	Frequency Range (Hz)	Double Amplitude (mm)	Acceleration (g)	Maximum Acceleration (g)
Cab[1] or Instrument panel[1] mounted indicating unit and chassis mounted sending unit	10-32.5	2.00		4.2
	32.5-2000		4.2	4.2
Engine mounted sending unit	10-70.5	2.00		20.0
	70.5-120		20.0	20.0
	120-2000		10.0	10.0

1. Cab and/or instrument panel provided with vibration isolation.

5.6 Lens Fogging (Indicating Unit)

5.6.1 Fully Sealed

Fully sealed indicating units shall pass the following test sequence. Before testing, the units shall be preconditioned as necessary to bring the moisture content of internal and external parts to equilibrium with air at 25 °C and 50% relative humidity. See SAE Technical Paper 941803 for additional background information.

a. Mount the unit in a horizontal panel, dial facing upward. Connect system voltage per 4.1 to the ignition and light terminals of the indicating unit. Connect the lowest nominal calibration resistance to the sending unit terminal of the indicating unit. The test shall be run at 25 °C ± 3 °C.

b. Cool aluminum cylinders (38.1 mm diameter x 25.4 mm long) to –40 °C. The cylinders shall be within ±5 °C of this temperature throughout their volume.

c. Place a cold cylinder from step b on the lens of the indicating unit and turn on the power to the unit.

d. After 5 min, remove the cylinder and check for fogging on the inside surface of the lens. Complete this check within 1 min.

e. Using a fresh, cold cylinder each time, repeat steps c and d two times. Leave the power on until after the last check for fogging.

f. During any of the three observations, any fogging that does occur shall not make the dial numbers unreadable.

5.6.2 Partially Sealed

The relative humidity of the ambient air and breathing of the air into the indicating unit due to temperature changes are major factors in the fogging of unsealed indicating units Therefore, the test in 5.6.1 should be modified or replaced as agreed between the user and the manufacturer.

5.7 Salt Spray

5.7.1 Indicating Unit

5.7.1.1 Fully Sealed

The exterior of the indicating unit, with proper termination attached, shall be corrosion resistant and shall withstand a salt spray (fog) test at 38 °C for 48 h duration with 5% salt solution (Reference ASTM B 117-73). At the completion of the test, the unit shall have no condensation and shall have no permanent shift of calibration from the readings obtained at the primary and secondary calibration points per 4.1 taking into account reading repeatability. Remove salt deposits before checking calibration. After calibration check, the unit shall be opened. There shall be no indication of salt or other leakage.

Red rust shall not be visible at the completion of the test. Other acceptable changes of appearance shall be as agreed between the user and the manufacturer.

5.7.1.2 Partially Sealed

The exterior of the front half of the indicating unit shall be corrosion resistant and shall withstand the requirements of 5.7.1.1. The rear half of the indicating shall be masked to prevent leakage from the rear during the test.

5.7.2 Sending Unit

Those parts of the fuel level and sealed sending units which are exposed to the external environment when installed, shall be corrosion resistant and shall withstand a salt spray (fog) test at 38 °C for 48 h duration with 5% salt solution (Reference ASTM B 117-73). The test shall be run with proper termination attached. The fuel level sending unit shall be mounted in a suitable tank and the port of the pressure sending unit shall be sealed during the test.

At the completion of the test the unit shall have no permanent shift of calibration from the readings obtained at the primary and secondary calibration points per 3.1 taking into account reading repeatability. Remove salt deposits before checking calibration. After calibration check, the fuel level sending unit shall be removed from the tank and the sealed sending units shall be opened. There shall be no indication of salt or other leakage on the tank side of the fuel sending unit or inside the sealed sending units. Red rust shall not be visible at the completion of the test.

The requirements for the parts of the fuel level sending unit exposed to the inside of the tank and for unsealed sending units shall be as agreed between the user and the manufacturer.

5.8 Water Leakage

5.8.1 Indicating Unit

5.8.1.1 Fully Sealed

With the indicating unit stabilized at –20 °C ± 5 °C for 1 h minimum, submerge the unit in water at 75 °C ± 5 °C to a depth of 200 mm ± 100 mm for 5 min. No air bubbles are permitted to escape from the unit after 5 min. Air bubbles may appear from air adhering to the outside of the unit.

5.8.1.2 Partially Sealed

The indicating unit shall be placed face down in 25 mm ± 5 mm of water at room temperature for 24 h so that the front seal is submerged at least 5 mm. When the unit is opened, there shall be no indication of leakage.

5.8.2 Sending Unit

When mounted in a suitable tank the fuel level sending unit shall withstand an internal air pressure of 41 kPa ± 4 kPa for 1 min without leakage of air. Use a soap solution or other leak detection liquid to test for leaks.

When specified, the other sending units shall meet the requirements of 5.8.1.1.

5.9 Weathering Resistance (Indicating unit only)

The indicating unit shall be tested in accordance with SAE J2020 for 500 h to determine fade resistance, lens yellowing, and coating adhesion of external and visible internal materials. Acceptance criteria shall be as agreed between the user and the manufacturer.

5.10 Fluid Compatibility

Fluid compatibility test and acceptance criteria shall be as agreed between the user and the manufacturer. Fluids to be considered include but are not limited to: engine oils and additives, hydraulic fluid, transmission fluid, gasoline, diesel fuel, fuel additives, anti-freeze water mixture, alcohol, and detergents.

5.11 Mounting Position (Indicating unit only)

Unless otherwise specified, the indicating unit reading shall not shift more than ±1 angular degree from calibration values when the dial face is oriented at any angle between horizontal and vertical.