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SAE J1299 AUG82

Electrical Propulsion Control — Off-Road Dumpers

SAE Recommended Practice
Issued August 1982

an American National Standard

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OFF-HIGHWAY MACHINERY PRACTICE

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ELECTRICAL PROPULSION CONTROL - OFF-ROAD DUMPERS

1. PURPOSE:

This recommended practice establishes requirements for the control circuits and control devices of the electric propulsion system of an electric drive dumper. Criteria are established for environmental service conditions, control systems requirements, control device operational requirements, and control device tests.

2. SCOPE:

This recommended practice applies to the control circuits and devices associated with the electrical propulsion system used on electric drive dumpers. Dumper is defined in SAE J1057. The recommended practice does not apply to auxiliary equipment control systems such as:

(a) Battery charging systems

(b) Engine wiring and control

(c) Monitoring and control circuits not directly affecting the operation of the electric propulsion and retarding system

(d) Lighting

(e) Accessory systems (heating, air conditioning, horns, radios, emergency steering, fire protection, and similar functions).

3. DEFINITION OF TERMS:

3.1 Dynamic Retarding: A method of slowing the dumper, or controlling its speed downgrade, by the controlled conversion of the dumper's kinetic energy to electrical power. A commonly used method is to dissipate this electrical power as heat through retarding resistors. These resistors may be:

Natural Convection Retarding Resistors which dissipate heat to air circulated through the resistors by natural convection; or

Forced Convection Retarding Resistors which dissipate heat to air forced through the resistors by a blower or fan.

3.2 Extended Range Retarding: The shunting out of a portion of the retarding resistors to maintain a high level of dynamic retarding effort at low dumper speeds.

3.3 Overspeed Retarding: The automatic application of dynamic retarding at, or above, a selected dumper speed.

3.4 Routine Tests: Tests carried out on all electromechanical control devices and electronic assemblies prior to shipping by the supplier.

3.5 Type Tests: Tests carried out on one or more electromechanical control devices and electronic assemblies of a new or modified functional design to determine conformance to design requirements.

3.6 U: Represents rated value of supply voltage (nominal voltage).

4. SERVICE CONDITIONS:

The control shall perform within the design limits at altitudes up to 3000 m above sea level and at ambient temperatures between -40 and +50°C.

Special arrangements shall be agreed upon between user and manufacturer to cover the case of service conditions more severe than those mentioned above.

5. CONTROL SYSTEM:

5.1 Main Control Enclosure: When locating and/or constructing the main control enclosure, malfunctions due to the environment, dust, material spillage, fluid leakage, and/or rejected heat from other equipment shall be considered.

Equipment should be accessible for service, monitoring, and/or replacement.

5.2 Arrangement of Equipment: Components within the enclosure should be arranged in groups corresponding to voltage level of the circuit which they control. For example:

(a) Traction power and retarding transmission systems

(b) Excitation systems

(c) Control systems

Individual components shall be identified indicating their function within the system. The designation shall be readily visible on, or closely adjacent to, the component.

5.3 Operator's Controls: Both propel and retarding mode selection and modulation should be foot operated except in the special application of trolley assist.

Dumper direction control should be hand operated and shall, in addition to forward and reverse, include a neutral position.

Voltage in excess of 100 V shall not be used on the operator's controls.

5.4 Circuit Requirements: The circuitry to accomplish the retarding function shall not be disabled by equipment protection devices unless provided with an override either automatic or accessible to the operator while driving.

The circuitry shall provide for the override of the propel function by the retarding function. Otherwise, except as may be required for the braking systems, the propel function shall be completely under the manual control of the operator at all times. If the propel function is disabled when the service brakes are applied, a manual override of this disable feature shall provide for forward operation of the dumper. The propel function shall not be latched except in the special applications of trolley assist. This paragraph does not apply to remote controlled dumpers.

The transition time between the propel and retarding functions shall not exceed 8 s and is preferrably less than 4 s.

Alarm systems which indicate equipment failures for the operator shall have indicators which can be heard and/or seen while operating the dumper.

The circuit shall ensure that there shall be no torque output from the traction motors with the direction control in neutral or with the direction control in forward or reverse and propel control not actuated.

Automatic overspeed retarding shall be provided.

Provision may be made for extended range retarding for applications which require additional retarding at low speed.

5.4 (Continued):

On rear dumpers, the reverse propel function shall be disabled during dumping.

If the forward propel function is disabled during the dumping function, a manual override of this disable feature shall provide for forward operation of the dumper.

6. CONTROL DEVICES:

6.1 Power Conditioning Devices: Devices used to convert AC power to DC power and to control DC power shall be mounted in such a way so as to be accessible for inspection and/or replacement.

6.2 Retarding Resistors: The resistors shall be located on the dumper such that their rejected heat will not damage other equipment.

The time-current rating of the resistors, as qualified by the degree of ventilation provided, shall be available from the manufacturer.

6.3 Temperature Rise Limits: The temperature rise limits of insulated windings and control devices shall be such as to provide a minimum service life of 50 000 engine hours. Service life is that service time period resulting in 50% of the windings or control devices still being functional.

6.4 Limits in Variation of Supply Air Pressure: When apparatus is pneumatically or electro-pneumatically operated, it shall function satisfactorily at an air pressure of 50% through 110% of the regulated pressure setting.

6.5 Limits of Variation of Supply Voltage: The electrical, electronic, electro-pneumatic, or electromagnetic equipment shall operate satisfactorily at any value of supply voltage between 75% and 110% of the rated value.

7. CONTROL DEVICE TEST:

7.1 Categories of Tests: There are two categories of tests:

(a) Routine tests (See Definitions)

(b) Type tests (See Definitions)

7.2 Lists of Tests: The principal tests to be carried out on control devices prior to installation on dumper are set out in Table 1, together with the clause numbers to which reference should be made.

TABLE 1 - List of Tests

Nature of Test	Type Test	Routine Test
1. Mechanical Test for Control Devices		
Mechanical Operation (Limits of Variation)	7.4.1	7.4.2
Mechanical Endurance (Life)	7.5	
Vibration and Shock (Strength)	7.6	
2. Electrical Test for Control Devices		
Measurement of Resistance and Impedance		7.7
Temperature Rise Test	7.8	
Breaking and Making Capacities Test	7.9	
Component Dielectric Test		7.10
Voltage Transient Susceptibility of Electronic Assemblies	7.11	

7.3 Measurement Accuracy: The error of measurement techniques shall be less than 5% of the quantity measured, unless otherwise specified. Temperature measurement accuracy shall be ±2°C.

7.4 Mechanical Operation Tests: This section describes type tests and routine tests for electro-mechanical and electro-pneumatic control devices.

7.4.1 Mechanical Operation Type Test: Type test shall be carried out at both the lowest and highest ambient temperature as defined in section 4 with the devices at temperature stabilized condition. These tests consist of operating twenty times in succession, for each combination, to verify that the apparatus will operate correctly within the limits of air pressure and supply voltage specified in 6.4 and 6.5.

7.4.1.1 A test shall also be made to verify that the operation of the equipment is still satisfactory when carried out under the most unfavorable combination of temperature, air pressure, and voltage obtainable within the limits specified in 6.3, 6.4, and 6.5.

7.4.2 Mechanical Operation Routine Tests: Routine tests consist of one actuation only of the tests described in 7.4.1 at local ambient temperature only.

NOTE: In the case of electromagnetic or electro-pneumatic apparatus, operation shall be considered to be satisfactory if the apparatus operates normally when it is supplied with 75% of rated voltage.

7.5 Tests for Mechanical Endurance: These are type tests for mechanical endurance of electromechanical and electro-pneumatic control devices which shall be made at the rated regulated supply voltage of the control circuit and at the rated air pressure for apparatus with electro-pneumatic control, the apparatus operating at no-load. These tests are as follows:

2 000 000 cycles minimum for contactors and relays used in the main power transmission (which includes retarding) system.

750 000 cycles minimum for reversers.

20 000 cycles minimum for all other devices.

Mechanical endurance tests shall be carried out:

(a) At a rate consistent with the minimum cycle time of the control device.

(b) With the control device mounted in a manner consistent with its normal application.

(c) With a method of lubrication consistent with recommended preventative maintenance practices.

The apparatus shall be considered as having successfully passed the mechanical endurance tests if, after the tests, they are capable of operating normally without special attention, other than cleaning and lubrication.

7.6 Test for Withstanding Vibration and Shock for Control Devices: These tests are type tests to be carried out on all control devices. The control device is secured in a suitable position to a machine producing vibrations of sinusoidal form with adjustable amplitude and frequency and is then subjected to the tests given below. The test is carried out successively in each of the three directions: vertical, longitudinal, and transverse.

7.6.1 The Determination of Resonant Frequencies: To determine the possible existence of critical frequencies producing resonance, the frequency shall be varied progressively between 1 and 50 Hz with the displacement (a), expressed in millimeters given as a function of frequency (f), in the equation:

$$a = 14e^{-f/11.2} \quad (e = 2.718. \ . \ . \ .)$$

If resonance is produced, the corresponding frequency shall be maintained and the device monitored for change of state per 7.6.2.

7.6.2 Tests With Sustained Vibration: The control device, at no-load, is subjected to a test with sustained vibration for a period of 4 h:

(a) either at the critical frequency, if any such well defined frequency has been detected in the course of the test of 7.6.1,

(b) otherwise, at a frequency of 10 Hz.

In the case of relays, circuit-breaking equipment, etc., the test is carried out during the first and second hours in the "open" position; and in the third and fourth hours in the "closed" position.

The test is considered to be satisfactory if there is no resulting damage or abnormality in operation.

7.6.3 Tests to Simulate the Effect of Shocks: The de-energized control device is to be subjected to three successive shocks to the base of the device in each of three directions (vertical, longitudinal, and transverse) with an acceleration of at least 10 g of 11 ms duration per shock.

If the device is designed for mounting on shock absorbing devices, these shall be in place during the test.

The test is considered to be satisfactory if there is no resulting malfunction or abnormality in operation.

7.7 Measurement of Resistance and Impedance: These are routine tests made on all electro-pneumatic or electromagnetic control device windings when cold.

The measurement obtained for any given winding, when corrected to a temperature of 20°C, shall not vary by more than ±10% from the specified value or, alternatively, from the mean of the values measured on the first ten units tested.

The measurements of resistance are also made when cold on the various resistances inserted in the power transmission control circuits. The allowable tolerances which vary according to the application shall be agreed upon between the parties concerned.

For apparatus in AC circuits or in DC circuits where correct operation depends on the impedance, measurements of impedance shall be carried out with AC at the specified frequency.

The following relationship should be used to correct resistance measurements to 20°C;

$$\frac{R1}{R2} = \frac{T1 + 234.5}{T2 + 234.5} \rightarrow R1 = R2 \frac{(254.5)}{(T2 + 234.5)}$$

Where: R1 (ohms) and T1 (°C) are values at 20°C
R2 (ohms) and T2 (°C) are actual values measured

7.8 Temperature Rise Tests:

7.8.1 General: These are type tests. They are applied to constituent parts of equipment: windings, blow-out coils, main contacts, flexible connections, and regulating and protective resistances.

The apparatus to be tested shall be mounted so as to reproduce approximately the normal service conditions on the dumper, particularly with regard to ventilation. For apparatus ventilated by dumper motion, artificial ventilation reproducing conditions similar to those encountered in service may be applied.

Each test shall be carried out for a period of time sufficient to enable the temperature rise to reach a steady-state value. In practice, this condition is fulfilled when the temperature variation does not exceed 5°C per hour.

7.8.2 Insulated Windings: Temperature tests on insulated windings shall be made at the continuous rated voltage.

7.8.3 Bare Windings, Main Contacts, and Flexible Connections: Temperature-rise tests on blow-out coils, the windings of relays constructed of a single layer of heavy section turns, contact tips and their flexible connections are to be carried out with continuous rated current.

7.9 Breaking and Making Capacity Tests:

7.9.1 General: These are type tests applicable to all current-break equipment and are performed at the rated voltage of the device.

The apparatus to be tested is to be located in surroundings representing as closely as possible the specified conditions of installation (clearance from dumper frame, volume of air, method of mounting, etc.).

In the test circuit of appropriate resistance, an inductance of suitable value is to be inserted so as to obtain the power-factor or time constant specified. The polarity of the circuit and the position of the apparatus in the circuit are to be chosen in accordance with the conditions of use, the test impedance being substituted for that of the circuit to be supplied.

The tests to be carried out on the various categories of equipment and the methods to be employed are given below.

7.9.2 AC Current Breaking Apparatus: The apparatus under test is to be connected in a circuit so adjusted to obtain a power factor of 0.75-0.85, and a current equal to the rated breaking capacity of the apparatus. The apparatus shall perform 180 interruptions at a maximum of one minute intervals between interruptions.

7.9.3 DC Current Breaking Apparatus: The apparatus under test is to be connected in a circuit so adjusted as to obtain a current equal to the rated breaking capacity of the apparatus and a time constant of 15 ms, ±10%. The apparatus shall perform 180 interruptions at a maximum of one minute intervals between interruptions.

7.10 Component Dielectric Tests:

7.10.1 General: These are routine tests for electromechanical and electro-pneumatic control devices.

The test voltage is to be applied for a period of 1 min.

7.10.2 Control Devices Applied in Circuits With a Rated Voltage Equal to or Exceeding 100 V DC or 100 V AC:

(a) For all control devices intended to break a circuit, the test shall consist of the application between the input and output sides of the device - with contacts open and arc chutes in position - of a voltage of an rms value equal to: 2 U + 1500.

For all breaking apparatus connected in parallel with a resistor, the test voltage shall be limited to 0.75 times the value mentioned above.

(b) For all apparatus, a dielectric test at a voltage equal to:

2 U + 1000: where rated insulation voltage does not exceed 600 V
2.5 U + 2000: where rated insulation voltage exceeds 600 V

shall be applied between main circuits and component frame, between main circuits and interlocks, and between main circuits and operating coils.

7.10.3 Apparatus Applied in Circuits with Rated Voltages Below 100 V DC or 100 V AC: Dielectric tests of apparatus and component parts shall be made to component frame at a voltage of 1500 V rms.

However, for apparatus applied in circuits of rated voltage less than 30 V, the test shall be carried out at 600 V.

7.11 Transient Voltage Susceptibility Tests:

7.11.1 General: These tests are type tests for electronic assemblies and power conversion components.

Devices must be capable of withstanding without failure a transient of two times maximum DC operating volts decaying to 5% or less of peak DC volts in 8-10 ms when connected across the terminals identified below. Tests should be conducted with both polarities and consistent with energy rating of the control devices.