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Circuit Breakers

SAE Standard
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CIRCUIT BREAKERS

1. PURPOSE:

This standard defines the test conditions, procedures and performance requirements for circuit breakers in ratings up to and including 50A. The standard includes automatic reset, modified reset, and manually reset types of circuit breakers for 6, 12, and 24V DC operation. These circuit breakers are either externally mounted in their own enclosures or internally mounted in switches or other control devices.

2. DEFINITIONS:

A circuit breaker is an overcurrent protective device that is responsive to electric current and to temperature. The types of circuit breakers covered by this standard are:

- 2.1 Type I - Automatic Reset: Automatic reset circuit breakers are cycling or continuously self resetting units which are opened by overcurrent.
- 2.2 Type II - Modified Reset: Modified reset circuit breakers are units which are opened by overcurrents and remain open as long as the power is on or until the load is removed. A number of cycles may occur prior to achieving the steady-state open condition.
- 2.3 Type III - Manual Reset: Manual reset circuit breakers are non-cycling units that are opened by overcurrents, but which remain open until manually reset.

3. TEST REQUIREMENTS:

3.1 Test Equipment and Instrumentation:

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- 3.1.1 Power Supply: Storage batteries specified below shall be used as the power supply for all tests. Means shall be provided for maintaining the specified voltage at the battery terminals during the open circuit portions of the tests.

VOLTAGE RATING	MINIMUM BATTERY RESERVE CAPACITY ¹	OPEN CIRCUIT VOLTAGE
6 V	220 min	7.0 + 0.2 V DC
12 V	110 min	14.0 ± 0.2 V DC
24 V ²		28.0 ± 0.2 V DC

¹Reference SAE J537, Storage Batteries

²Two 12 V batteries connected in series

- 3.1.2 Voltmeter: 0-30 V DC maximum range, accuracy $\pm 1/2\%$.
(Note: A digital meter having at least a 3 1/2 digit readout with an accuracy of $\pm 1\%$ plus 1 digit is recommended for millivolt readings.)
- 3.1.3 Ammeter: Capable of carrying full load current, accuracy $\pm 1\%$.
- 3.1.4 High-Voltage Breakdown Tester: Capable of providing 500 V AC - 60 Hz, accuracy $\pm 5\%$.
- 3.1.5 Thermocouple and Meter: 0-150°C maximum range, accuracy $\pm 2\%$, maximum thermocouple wire size - #24 gage (0.22 mm²).
- 3.1.6 Oven: Variable controlled temperature oven able to vary temperature at a rate of 1°C per min and control temperature $\pm 1^\circ\text{C}$ of set point accurate to $\pm 2^\circ\text{C}$.
- 3.1.7 Test Load: Variable resistor capable of varying circuit current to specified current requirements.
- 3.1.8 Test Leads: Circuit breakers shall be tested using copper wire sizes listed in Table 1. The wire length shall be 1 m for 6 and 12 V and 2 m for 24 V breakers.

RATED CURRENT	SAE METRIC CABLE SIZE	SAE WIRE SIZE
5 to 10A	1 mm ²	#16
Greater than 10 to 15A	2 mm ²	#14
Greater than 15 to 30A	3 mm ²	#12
Greater than 30 to 40A	5 mm ²	#10
Greater than 40 to 50A	8 mm ²	# 8

TABLE 1 - Recommended Wire Size

- 3.2 Test Procedures: Environmental conditions have been selected for this standard to help assure satisfactory operation under general customer use conditions.
- 3.2.1 Ambient Conditions: Circuit breakers shall be tested in still air at the temperatures indicated and allowed a 30 min soak without electrical load before testing. Where not otherwise specified, tests are to be run at 25°C, $\pm 2^\circ\text{C}$.
- 3.2.2 Current Rating Test Procedure: The circuit breaker shall be electrically connected with a pair of test leads described in 3.1.8 in series with the power supply, an ammeter, and a variable test load to provide the required current through the circuit breaker.
- 3.2.3 Maximum Voltage Drop Test Procedure: With the circuit breaker connected as described in 3.2.2, the voltage drop across the circuit breaker shall be measured at rated current.
- 3.2.4 Effective Current Limitation Test Procedure (Type I only):
- 3.2.4.1 With the circuit breaker connected as described in 3.2.2, connect a thermocouple to one of the test leads in the middle of its length. Bypass the circuit breaker and adjust the current through the test lead to the 125 or 140% level as specified. After 10 min, record the temperature of the test lead and use this figure as the indicator of the high limit.
- 3.2.4.2 With the circuit breaker connected back in the circuit, adjust the current to 200% of rated current and allow the breaker to cycle. At the end of 10 min, read the high and low peaks of temperature. Use the average of these readings as the indicator of the effective current limitation value of the circuit breaker.
- 3.2.5 Voltage Breakdown Test Procedure (externally mounted breakers only):
- 3.2.5.1 With the circuit breaker connected as described in 3.2.2, adjust the current to 400% of the circuit breaker rating. At the end of 10 min check the continuity at 440 VAC between both terminals of the circuit breaker and the cover with the breaker both open and closed.
- 3.2.6 No Current Trip and Reset Temperature Test Procedure:
- 3.2.6.1 Install the breaker in a variable controlled oven and raise the temperature at a rate not to exceed 1°C per min and record the temperature at which the contacts open. Lower the temperature at a rate not exceeding 1°C per min and record the temperature at which the contacts close. For Type II and Type III breakers the contact reclose restriction must be disabled after the contacts open to allow the breaker to reset when the temperature is lowered.

3.2.7 Endurance Test Procedure:

- 3.2.7.1 Test current for life tests shall be greater than 500% of rated current but shall not exceed 700 A for 6 and 12 V tests and shall not exceed 525 A for 24 V tests.
- 3.2.7.2 With the circuit breaker connected as described in 3.2.2, Type I externally mounted circuit breakers shall be cycled for 30 minutes. The circuit breaker shall then be subjected to 80% of the rated current for 1 hour.
- 3.2.7.3 With the circuit breaker connected as described in 3.2.2, Type I circuit breakers shall be cycled until the unit fails.
- 3.2.7.4 With the circuit breaker connected as described in 3.2.2, Type II circuit breakers shall first be subjected to 20 on-off cycles. The "on" time of each cycle shall be 60 s, during which time the circuit breaker must open, and the "off" time of each cycle shall be long enough to allow the circuit breaker to close. The "on" time of the twentieth cycle shall be 24 h with 11.3 V applied for 12 V breakers and 22.6 V for 24 V breakers. During this time, the circuit breaker contacts must remain open. The circuit breaker shall then be allowed to reclose and again subjected to the 20 cycle test, excluding the 24 h "on" time of the last cycle. The circuit breaker shall then be subjected to 80% of rated current for 1 hour.
- 3.2.7.5 With the circuit breaker connected as described in 3.2.2, Type III circuit breakers shall be cycled for 20 on-off cycles. The circuit breaker shall then be subjected to 80% of rated current for 1 hour.

4. PERFORMANCE REQUIREMENTS:

- 4.1 Current Rating: With the circuit breaker connected as described in 3.2.2, all circuit breakers shall carry 100% of rated current continuously for a minimum of 1 h, shall open at 125% of rated current within 1 h, and shall open at 200% of rated current within 1 minute. In addition, internally mounted circuit breakers shall carry 80% of rated current at 52°C, $\pm 2^\circ\text{C}$, for 1 h without opening.
- 4.2 Maximum Voltage Drop: Using the procedure described in 3.2.3, the maximum voltage drop across the circuit breaker shall be as shown in Table 2.
- 4.3 Effective Current Limitation:
- 4.3.1 Type I: Using test procedure described in 3.2.4, the maximum value of effective current passed through the automatic reset circuit breaker shall not be greater than 125% of its rated current for an externally mounted breaker or greater than 140% of its rated current for an internally mounted breaker, when cycled at 200% of its rated current.
- 4.3.2 Type II: With the circuit breaker connected as described in 3.2.2, the current passing through the modified reset circuit breaker shall not exceed 1 A after reaching a maintained open condition when subjected to 200% of rated current. The maintained open condition must be reached within 60 s of the initial opening.

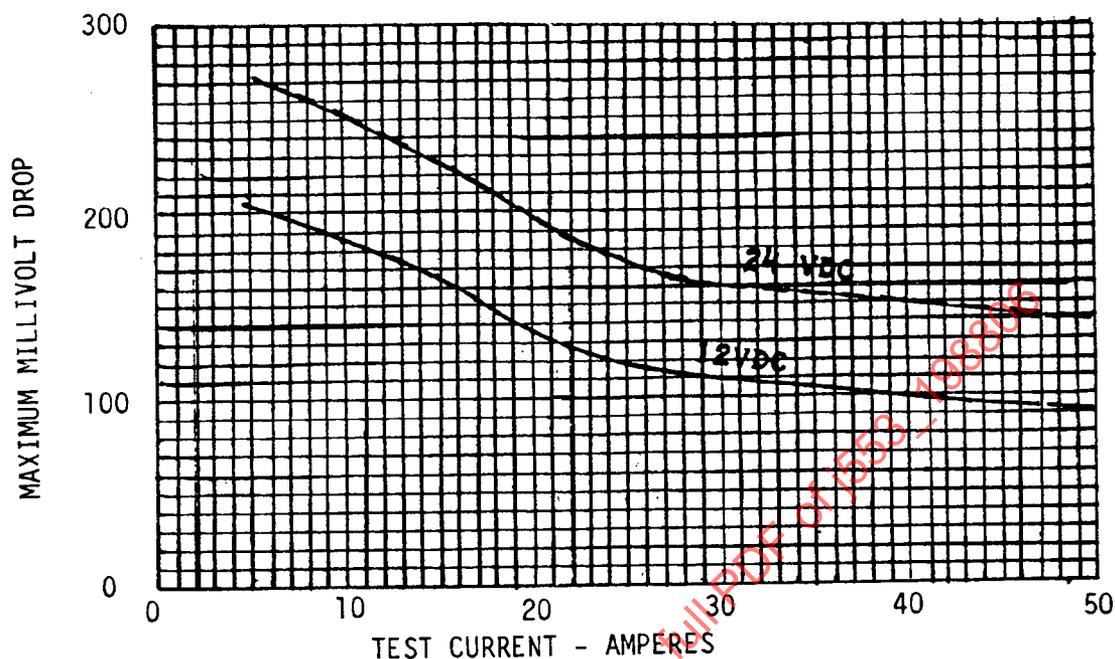


TABLE 2 - Maximum Millivolt Drop vs. Ampere Rating

- 4.3.3 Type III: With the circuit breaker connected as described in 3.2.2 and subjected to 200% of rated current, there shall be no measurable current passing through the manual reset circuit breaker after opening.
- 4.4 Voltage Breakdown: Using the test procedure described in 3.2.5 there shall be no continuity between either terminal of the circuit breaker and the cover.
- 4.5 No Current Trip & Reset Temperature: Using the procedure described in 3.2.6, all circuit breakers shall open and reclose in accordance with the following requirements.
- 4.5.1 Circuit breakers rated 10 A or less shall not open at less than 82°C and shall reclose before the temperature is below 52°C.
- 4.5.2 Circuit breakers rated above 10 A shall not open at less than 112°C and shall reclose before the temperature is below 82°C.
- 4.6 Endurance Test:
- 4.6.1 Type I externally mounted circuit breakers shall be tested as described in 3.2.7.2 and then shall continuously carry 80% of its rated current for 1 h and the millivolt drop at 80% of rated current shall not exceed the values specified in Table 2.
- 4.6.2 Type I circuit breakers shall be tested as described in 3.2.7.3 and the resulting circuit breaker failure must result in an open circuit.

- 4.6.3 Type II circuit breakers shall be tested as described in 3.2.7.4 and the millivolt drop at 80% of rated current shall not exceed the values specified in Table 2.
- 4.6.4 Type III circuit breakers shall be tested as described in 3.2.7.5 and the millivolt drop at 80% of rated current shall not exceed the values specified in Table 2.
- 4.6.5 When tested to failure with the circuit breaker connected as described in 3.2.7, the ultimate failure of all circuit breakers shall always result in an open circuit in the circuit breaker and there shall be no damage to the associated wiring. (Note: In some field applications a high circuit resistance, and/or a low current power source, may not provide enough current to assure that the ultimate failure will always result in an open circuit breaker.)
- 4.7 General Requirements:
- 4.7.1 Marking: Externally mounted circuit breakers shall be permanently and legibly marked with the current rating and voltage or identifying part number.
- 4.7.2 Application: The specific current capacity of the circuit breaker is a function of the particular electrical system being utilized. It is recommended that the actual performance be verified through testing experimentally in the proposed application. To aid in determining the actual capacity change caused by variations in circuit parameters, several factors should be considered by the application engineer.
- 4.7.2.1 Ambient Temperature: The circuit breakers covered by this standard are thermal devices. Changes in the ambient temperature will have an effect on the current carrying capacity and on the effective limitation of current during overload cycling.
- 4.7.2.2 Wire and Terminations: The connecting wires and their terminations will affect the heat dissipation characteristic of the circuit breakers. Deviations from the circuit breaker application specifications may affect the current carrying capacity or the effective limitation of current during overload cycling.
- 4.7.2.3 Voltage Rating: The voltage rating marked on the externally mounted circuit breakers is the maximum value recommended. Use at higher voltages may significantly shorten the ultimate life under overload conditions.

RATIONALE:

GENERAL REVISIONS

1. Circuit Breakers J553 is being changed from a Recommended Practice to a Standard since the Recommended Practice has been in existence for over 5 years. During this time it has been broadly accepted without the necessity for major changes.
2. Combine J258 (internally mounted circuit breakers) and J553 (externally mounted circuit breakers) into one standard, eliminating many duplications.
3. Type III circuit breakers are being added to the standard.
4. Conversion of physical units to metric where applicable.
5. The format of the entire document is being changed to conform to SAE Standards (SAE J1159).

SPECIFIC REVISIONS

1. PURPOSE: Expanded to include internally mounted and manual reset breakers.
2. DEFINITIONS: Reworded to define "modified reset" type circuit breakers as "remaining open as long as the power is on or until the load is removed" rather than "when the overload no longer exists." Also added a definition for the Type III circuit breaker.
- 3.1 TEST EQUIPMENT AND INSTRUMENTATION: This section was added to describe the test equipment required to perform the tests specified by this standard.
- 3.2 TEST PROCEDURES: This section combines test procedures that were previously included in the individual test sections and Test Procedure section. Procedures are basically unchanged from the present J553 except as described below. Also, the test procedures have been separated from the performance specifications to conform to the revised format and conversion has been made to metric units.
 - 3.2.1 AMBIENT CONDITIONS: The ambient temperature is now specified as $+2^{\circ}\text{C}$ because circuit breakers are temperature sensitive devices and larger tolerances could adversely affect the test results.
 - 3.2.5 VOLTAGE BREAKDOWN TEST PROCEDURE: Reworded from "Hi-Pot" and revised to standardized format.
 - 3.2.6 NO CURRENT TRIP & RESET TEMPERATURE TEST PROCEDURE: Reworded from "Ambient Temperature Test," eliminated the pilot indicator load, and defined the rate of temperature change during test.