SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARD

SAE J553 | REV. APR96

Issued 1951-11
Revised 1996-04

Superseding J553 JUN92

Submitted for recognition as an American National Standard

CIRCUIT BREAKERS

Foreword—This Document has also changed to comply with the new SAE Technical Standards Board format.

1. Scope—This SAE Standard defines the test conditions, procedures, and performance requirements for circuit breakers in ratings up to and including 50 A. The document includes externally or internally mounted automatic reset, modified reset, and manually reset types of circuit breakers for 12 V and 24 V DC operation. Some circuit breakers may have dual voltage ratings (AC and DC), however, this document evaluates DC performance only.

2. References

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

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J537—Storage Batteries
SAE J561—Electrical Terminals—Eyelet and Spade Type
SAE J858a—Electrical Terminals—Blade Type
SAE J1171—External Ignition Protection of Marine Electrical Devices
SAE J1211—Recommended Environmental Practices for Electronic Equipment Design
SAE J1428—Marine Circuit Breakers
SAE J1455—Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J258—Circuit Breaker—Internal Mounted—Automatic Reset
SAE J554—Electric Fuses (Cartridge Type)
SAE J1284—Blade Type Electric Fuses
SAE J1888—High Current Time Lag Electric Fuses
SAE TSB 002—Preparation of SAE Technical Reports

2.2.2 CSA PUBLICATIONS—Available from CSA Sales Department, 178 Rexdale Boulevard, Etobtcoke, Ontario, M9W 1R3.

CSA C22.2 No. 14-M1987Industrial Control Equipment
CSA C22.2 No. 235-M89Supplementary Protectors

2.2.3 U.S. GOVERNMENT PUBLICATION—Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-202FTest Methods for Electronic and Electrical Component Parts

2.2.4 UNDERWRITER LABORATORIES PUBLICATION—Available from Underwriter Laboratories, 333 Pfingsten Road, Northbrook, IL 60062.

U.L. 1077—Standard for Supplementary Protectors for use in Electrical Equipment

2.2.5 OTHER PUBLICATIONS

National Electric Code—NEC Article 551
Recreational Vehicle Industry Association—RVIA Handbook

2.2.6 APPENDICES

Appendix ACircuit Protection Application Guidelines
Appendix BGlossary of Document Terminology

3. Definitions

3.1 Circuit Breakers—are overcurrent protective devices, responsive to electric current and to temperature.

3.2 Externally Mounted Breakers—are defined as self-contained devices which are mounted individually or in combination via brackets, bus bars, plugged into terminal blocks, or panel mounted.

3.3 Internally Mounted Breakers—are defined as subcomponent devices which are integral with a related unit such as a breaker/switch combination, within a motor housing for motor protection, etc. There are no implied restrictions on package design, provided the thermal circuit breaker exhibits performance characteristics and range of current rating as is covered by this document. While applications are generally found in motor vehicle electrical systems, other usages in DC circuit protection for accessories related or unrelated to the motor vehicle industry, may find this document of value for performance evaluation.

3.4 There are three general classes of breaker, defined as follows:

3.4.1 TYPE I—AUTOMATIC RESET—Automatic reset circuit breakers are cycling or continuously self-resetting units which are opened by overcurrent.

3.4.2 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.

3.4.3 TYPE III—MANUAL RESET—Manual reset circuit breakers are non-cycling units that are opened by overcurrents, but which remain open until manually reset.

4. Test Requirements

4.1 Test Equipment and Instrumentation

4.1.1 POWER SUPPLIES

4.1.1.1 A current and voltage regulated DC power supply shall be used for all tests except 4.2.7 Interrupt Test. The supply shall be capable of delivering 14 VDC and 28 VDC during open circuit portion of tests and have sufficient current output capacity to meet highest load requirements. Voltage and current settings shall be accurate to within ±1% of set point or better. Power transient response shall be such that a 30% step increase in power demanded by the load shall cause a transient in the regulation output which shall typically recover to within 3% of the final value within 100 ms or better. The power supply shall be operated with controlling circuitry to achieve all necessary test conditions. DC output shall have sufficient impedance via power resistors for buffering of load switching to prevent transitory output spikes.

4.1.1.2 Storage batteries specified in Table 1 shall be used as the power supply for 4.2.7 Interrupt Test. Open circuit voltage as specified shall be maintained by a battery charger or power supply with voltage regulated per Table 1 and current output restricted to 30 A or less.

TABLE 1—STORAGE BATTERIES

Voltage Rating	Minimum Battery Reserve Capacity(1)	Open Circuit Voltage
12 V	110 minutes	14.0 VDC ± 1% VDC
24 V(2)		28.0 VDC ± 1% VDC

1. Reference SAE J537 (Types SAE 24-385/2, 24-410, 60-630, 74-410, or equivalent.)
2. Two 12 V batteries connected in series.

4.1.2 VOLTMETER—0 to 30 VDC maximum range, accuracy ±1/2%.

NOTE—A digital meter having at least a 3-1/2 digit readout with an accuracy of ±1% plus 1 digit is recommended for millivolt readings.

4.1.3 AMMETER—Capable of displaying full load current with an accuracy of ±1%. A calibrated shunt shall be used in series with the test circuit to minimize circuit resistance.

NOTE—Digital meter having at least a 3-1/2 digit readout with an accuracy of ±1% plus 1 digit is recommended for amperage readings when used in conjunction with a millivolt output calibrated shunt.

4.1.4 HIGH-VOLTAGE BREAKDOWN TESTER—Capable of providing 500 VAC RMS - 60 Hz, accuracy ±5%.

4.1.5 THERMOCOUPLE AND METER—0 to 150 °C minimum range, accuracy ±2%, maximum thermocouple wire size – 0.22 mm^2 (#24 gage).

NOTE—A digital thermometer is recommended, with an accuracy of ±1 degree.

4.1.5.1 Two ambient observations are necessary during test cycles: ambient of test room and ambient of test chamber containing breakers under test.

4.1.5.2 Delta heat rise of terminations shall be calculated during 4.2.2.1 testing (at the tester's discretion).

4.1.6 OVEN—Variable controlled temperature oven able to vary temperature at a rate of 1 °C per minute and control temperature ±1 °C of set point accurate to ±2 °C.

4.1.7 TEST LOAD—Variable resistor(s) capable of varying circuit current to specified current requirements in conjunction with a power supply. Test circuit by-passes may be employed to verify current settings.

NOTE—Use of current regulated power supply would make it possible to use fixed resistors and achieve adjustment via the supply; however, voltage must be allowed to rise to either 14 VDC or 28 VDC during open circuit portion of tests when voltage rise is specifically required.

4.1.7.1 For transient current cycling tests, 12 VDC automotive lamps (such as sealed beams) shall be used in sufficient total wattage and quantity to meet test load requirements of 4.2.6.6.

4.1.8 TEST LEADS—Circuit breakers shall be tested using copper wire sizes listed in Table 2. The wire length shall be 1.22 m (48.0 in) for all voltages tested and insulation shall be rated 105 °C or better.

TABLE 2—TEST LEAD SIZES

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

4.1.8.1 *Termination of Test Leads*—All test leads shall use standard commercially available terminals; ring terminals for threaded studs or screw type terminals, quick connect terminals for blade type terminations. To avoid secondary heat generation and/or adverse millivolt drop, it is recommended that test lead terminals be crimped and soldered; also, connections to breakers must be repeatable and uniform. Terminals shall be attached to breakers with screw threads to a specified torque value that is generally recommended for the particular thread size. Terminals applied to quick connect blades shall have an established minimum insertion and withdrawal force for test purposes to reduce the chance of marginal connections from fatigued test lead terminal materials. Secureness values shall be obtained from the terminal manufacturer. For custom terminations, consult the circuit breaker manufacturer.

NOTE—See SAE J858a and/or SAE J561 for a limited terminal listing.

4.1.9 TEST ENCLOSURE—Provide for a draft and convection air current free test chamber with a volume of approximately 5.66×10^4 cm^3 (2.0 ft^3). Chamber must allow for test lead access, internal chamber temperature monitoring, and indirect venting if needed to assure requirements of 4.2.1 are met.

4.2 Test Procedures

4.2.1 AMBIENT CONDITIONS—Environmental conditions have been selected for this document to help assure satisfactory operation under general customer use conditions. Circuit breakers shall be tested in still air at the temperatures indicated and allowed a 30 min soak without electrical load before testing (and repeated 30 min soaks for individual breakers that are involved in more than one test condition). Equipment listed in 4.1.9 fulfills the still air requirement. Where not otherwise specified, tests are to be run at 25 °C ± 2 °C 77 (°F ± 3 °F). If room ambient is unstable or unregulated and an environmental chamber is employed, breakers under test must be isolated from chamber forced air currents. Paragraph 4.1.9 test enclosure shall be used within the chamber compartment and temperatures monitored per 4.1.5.1.

NOTE—Breakers stored in environments below 15 °C (59 °F) or above 35 °C (95 °F) shall be allowed a minimum of 1 h soak at the specified test temperature prior to initiation of any testing.

4.2.1.1 Test leads and terminations subject to thermal rise from test operations shall be allowed to restabilize to ambient conditions before starting a new test. Alternating between duplicate sets of leads is suggested.

4.2.2 CURRENT RATING TEST PROCEDURE—The circuit breaker shall be electrically connected with a pair of test leads described in 4.1.8 in series with the power supply as described in 4.1.1.1, a shunt with ammeter as described in 4.1.3, and an appropriate test load as described in 4.1.7 to provide the required current pass through the circuit breaker. Refer to Figure 1A for all tests except 4.2.6.6 and 4.2.7. Refer to Figure 1B for 4.2.6.6 only. Refer to Figure 1C for 4.2.7 only.

4.2.2.1 *Maximum Voltage Drop Test Procedure*—With the circuit breaker connected as described in 4.2.2, the voltage drop across the circuit breaker shall be measured while the breaker is passing full rated current and has achieved equilibrium (typically after 15 to 20 min of continuous operation at 100% of rated current, exhibited by no appreciable increase in voltage drop). If after 1/2 h of continuous operation at 100% of rated current, equilibrium has not been attained, continue testing until equilibrium has been attained and voltage drop is within acceptable limits, or, unit exceeds voltage drop limits and/or trips out.

NOTE—For applications sensitive to heat-rise at the circuit breaker terminations, thermocouple leads may be affixed to the terminations. General practice is to place the thermocouple lead on that portion of the terminal which is likely to come in contact with the wire lead insulation. Benchmark maximum values for delta heat rise (observed thermocouple temperature minus ambient temperature) are 65 °C delta for factory wired terminations and 50 °C delta for field wired terminations. Results of this testing will assist the user with circuit design and proximity considerations for breaker installation.

4.2.2.2 *Overload Trip Rating Test*—After a 30 min soak, reconnect the breaker as described in 4.2.2. Operate at 135% of rated current and record the elapsed time in seconds for the breaker to trip. If breaker has not opened after 1/2 h, discontinue the test. Repeat 30 min soak, operate at 200% of rated current and record elapsed time for the breaker to trip. If breaker has not opened after 60 s, discontinue the test.

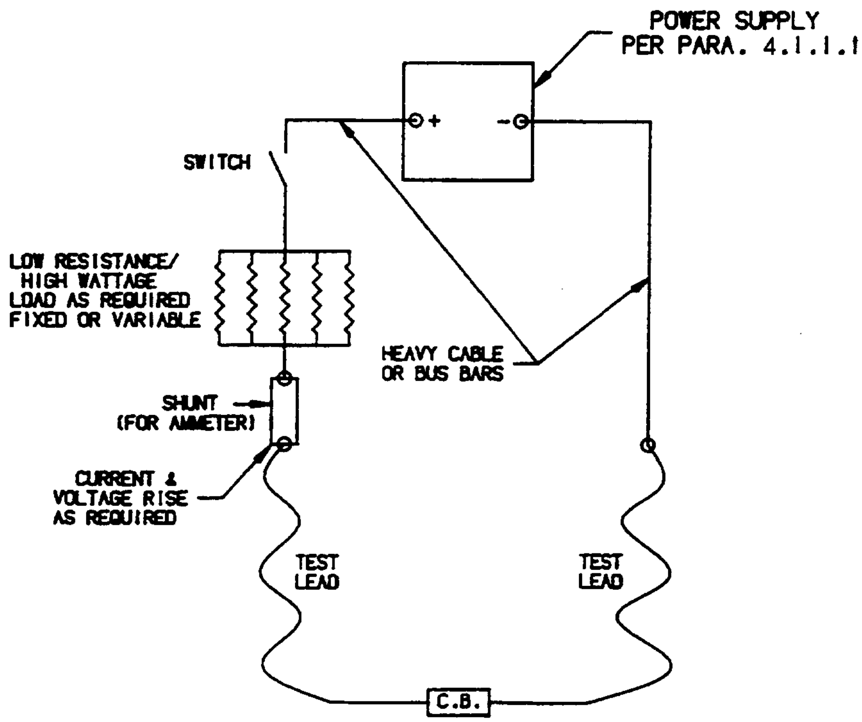

FIGURE 1A—CURRENT RATING TEST CIRCUIT

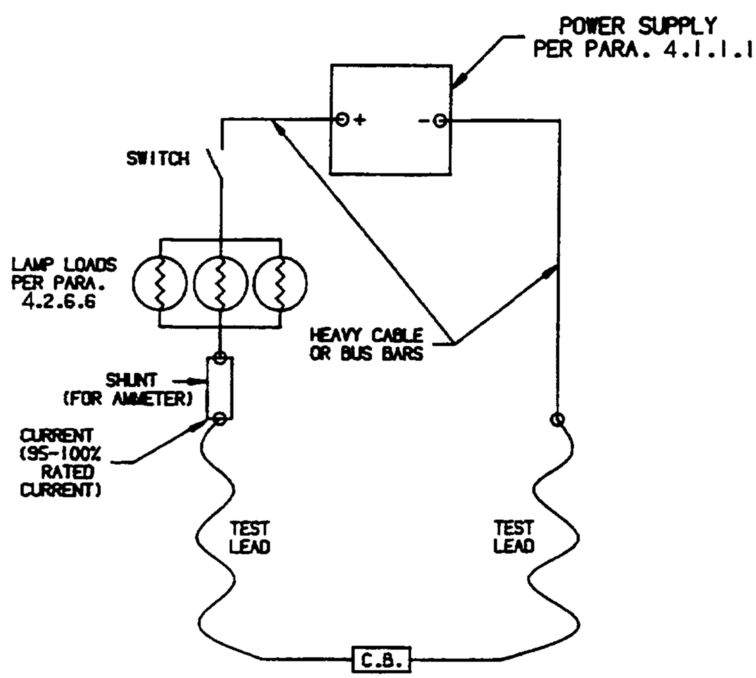

FIGURE 1B—TRANSIENT CYCLING TEST CIRCUIT

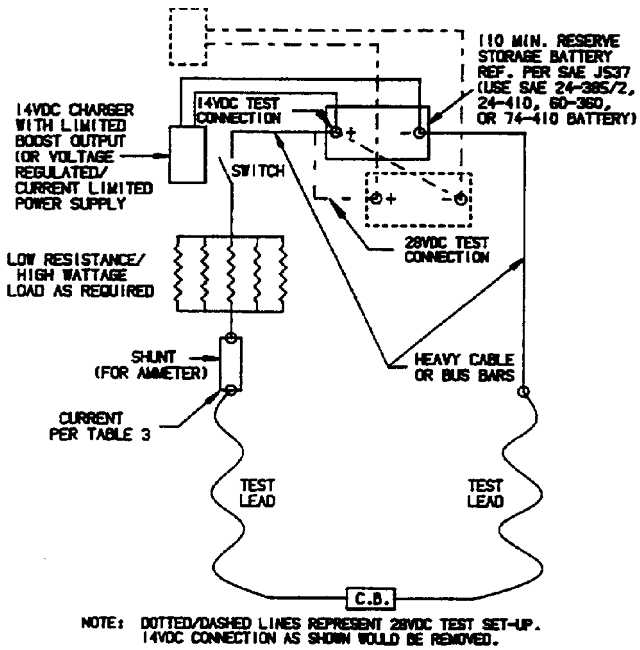

FIGURE 1C—INTERRUPT CYCLING TEST CIRCUIT

4.2.3 EFFECTIVE CURRENT LIMITATION TEST PROCEDURE

4.2.3.1 *Type 1 Only*—With the circuit breaker connected as described in 4.2.2 and test current set at 200% of rated current, allow the breaker to cycle. At the end of 10 min (600 s), record the total elapsed time (in seconds) during which the breaker passed current. Multiply this figure by the 200% value of rated current used and divide the product by 600 s. The resulting quotient will represent the effective current for that particular breaker.

4.2.3.2 *Type II Only*—With the circuit breaker connected as described in 4.2.2 and test current set at 200% of rated current, allow the breaker to cycle. Begin timing the test from when the breaker initially trips and continue application of test current for 1 min (60 s). Count the number of cycles (one trip and one reset equals one cycle) that the breaker passed 200% of rated current. At the end of the 1 min (60 s) time period, observe if the breaker has stopped cycling and if it is passing a reduced current value. If so, record the reduced current value, expressed either in milliamps or tenths of an amp. If not, continue the cycling at 200% until cycling stops and a reduced current value is displayed for recording, or, terminate the test if 5 min elapses and the breaker is still cycling. For this particular test, the open circuit voltage must rise to 14 VDC ± 1% VDC for 12 VDC breakers 28 VDC ± 1% VDC for 24 VDC breakers and remain stable during reset portions of the cycling, and at the end of the 1 min (60 s) test duration when the reduced current value is measured (or until 5 min test termination limit if necessary).

4.2.3.3 *Type III Only*—Disable the trip indicator/reset mechanism in such a fashion as to allow the breaker to perform as a Type I style. Perform the same test instructions as in 4.2.3.1.

NOTE—If the Type III breaker is constructed in such a way that depression of the reset button does not allow the thermal element to cycle as if a Type I design, but rather trips and resets by definite mechanical action only, then this test is not required.

4.2.4 VOLTAGE BREAKDOWN TEST PROCEDURE (EXTERNALLY MOUNTED TYPE I AND TYPE II BREAKERS ONLY)

4.2.4.1 With the circuit breaker connected as described in 4.2.2, adjust the current to 400% of the circuit breaker rating and allow the breaker to cycle. At the end of 10 min, check the continuity at 440 VAC between each terminal of the circuit breaker individually and the cover of the breaker with the breaker in both an open and closed circuit condition.

NOTE—This test is not required on devices utilizing nonmetallic, nonconductive covers.

4.2.5 NO CURRENT TRIP AND RESET TEMPERATURE TEST PROCEDURE

4.2.5.1 Place the circuit breaker(s) in a variable temperature controlled environmental chamber heated to 10 °C below the minimum opening temperature (use 72 °C starting point for 10 A and below rated breakers and 102 °C starting point for above 10 A rated breakers) and soak at the starting temperature for 30 min. Utilize the test enclosure as described in 4.1.9 to shield the breaker(s) under test from environmental chamber convection currents (forced air models). After soak, raise temperature at a rate not exceeding 1 °C per minute. When the temperature has exceeded the minimum temperature the breaker(s) must endure without opening, continue elevating the temperature at the same rate of increase and record the temperature at which the breaker(s) opens. A test termination point at 200 °C is suggested. If a breaker under test fails to open by 200 °C, reevaluate performance per 4.2.2.2. Once the breaker has opened (or all breakers have opened if testing in multiples) decrease the temperature at a rate not exceeding 1 °C per minute and record the temperature at which the breaker(s) closes.

NOTE—If electrically operated indicators are employed to signal opened and closed states, voltage and current shall be at trace levels—6 V/100 mA maximum to prevent heating of breaker thermal elements if they are part of the indicator circuit loop, and to prevent operation of Type II heating circuits during ambient induced open cycles.

4.2.6 ENDURANCE TEST PROCEDURE

4.2.6.1 Test current for endurance tests shall be 600% of rated current, except where specified otherwise. Utilize Figure 1A test circuit except for 4.2.6.6.

4.2.6.2 With the circuit breaker connected as described in 4.2.2, Type I externally mounted circuit breakers shall be cycled for 30 min. The circuit breaker shall then be capable of passing 80% of rated current for 1/2 h, without tripping. Record voltage drop as in 4.2.2.1 at 80% current.

4.2.6.3 Using the circuit breaker from 4.2.6.2 (assuming 4.2.6.2 requirements were met), reconnect as described in 4.2.2 and cycle Type I breaker until failure as defined in 5.6.2.

NOTE—At tester's discretion, or as published by the manufacturer, an arbitrary minimum cycle time may be established as a milestone threshold for termination of the test (e.g., 8 h, 12 h, etc.), to aid in test throughout.

4.2.6.4 With the circuit breaker connected as described in 4.2.2, Type II circuit breakers shall first be subjected to 30 on-off cycles. The "on" time of each cycle shall be 60 s, during which time the circuit breaker must open at least once, with repeated cycling possible and open circuit voltage rising to 14 VDC for 12 V breakers/28 VDC for 24 V breakers. The "off" time of each cycle shall be long enough to allow the circuit breaker to close by de-energizing the test circuit prior to initiating a subsequent "on" cycle. The "on" time of the thirtieth cycle shall be 24 h with voltage reduced to 11.3 V for 12 V breakers and 22.6 V for 24 V breakers once breakers are in a steady-state open circuit as induced by the heating circuit. During this time, the circuit breaker contacts must remain open. The circuit breaker shall then be allowed to reclose and again be subjected to the 30 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 1/2 h. Record voltage drop as in 4.2.2.1 at 80% current.

NOTE—For purposes of evaluating heater circuit endurance exclusive of cycling, a supplemental test is suggested in which the breakers are cycled until remaining open from heater circuit operation at 14 VDC for 12 V units and 28 VDC for 24 V units and are kept energized for 100 h elapsed time, observing for uninterrupted operation.

4.2.6.5 With the circuit breaker connected as described in 4.2.2, Type III circuit breakers shall be cycled for 100 on-off cycles utilizing the trip indicating/reset mechanism of the breaker. Means shall be provided to detect when the breaker is capable of resetting in order to initiate the next cycle. The circuit breaker shall then be subjected to 80% of rated current for 1/2 h. Record voltage drop as in 4.2.2.1 at 80% current.

4.2.6.6 *Transient Current Cycling Endurance Test*—At the option of the tester, a transient current cycling endurance test shall be performed as is herein described. With the circuit breaker connected as described in 4.2.2 and utilizing Figure 1B test circuit, apply a transient current cycling waveform as shown in Figure 2 through the breaker for 25 000 cycles. The lamps employed for the test load as described in 4.1.7.2 shall be sufficient to create a current level of 95% to 100% of the circuit breaker rating. Lamp aging which diminishes load over time is acceptable; however, lamps that fail must be replaced immediately. This test procedure is applicable to all breaker types.

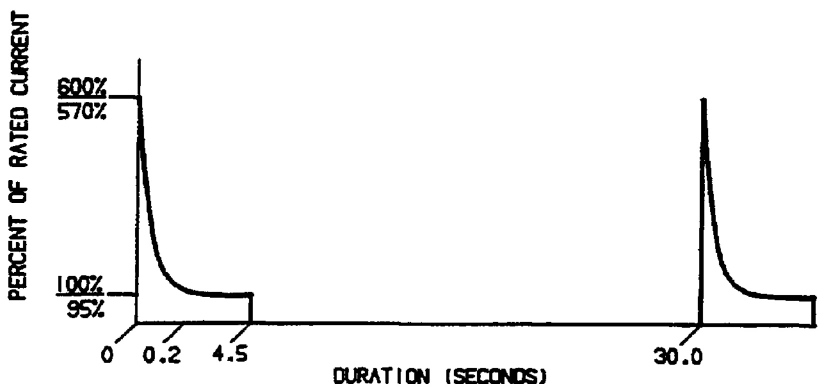

FIGURE 2—TRANSIENT CURRENT CYCLING WAVEFORM

4.2.7 INTERRUPT TEST PROCEDURE

4.2.7.1 Using the power source described in 4.1.1.2, test current shall be in accordance with Table 3. Refer to Figure 3 for interrupt cycle definition and Figure 1C test circuit.

TABLE 3—INTERRUPT TEST CURRENT REQUIREMENTS

Rated Current	12 VDC Amps	24 VDC Amps
5 to 10A	150	100
Greater than 10 to 15A	225	150
Greater than 15 to 20A	300	200
Greater than 20 to 30A	450	300
Greater than 30 to 40A	600	400
Greater than 40 to 50A	750	500

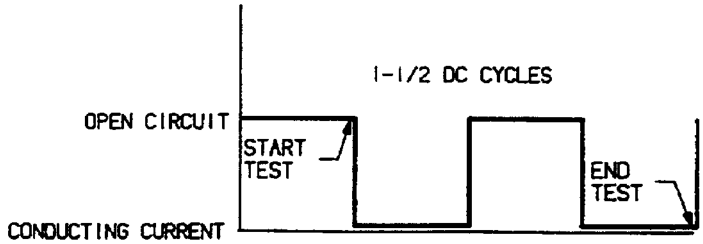

FIGURE 3—INTERRUPT CYCLE DEFINITION

4.2.7.2 With the circuit breaker connected as described in 4.2.2 (utilizing 4.1.1.2 power source), Type I circuit breakers shall be subjected to 1-1/2 cycles of interrupt current.

4.2.7.3 With the circuit breaker connected as described in 4.2.2 (utilizing 4.1.1.2 power source), Type II circuit breakers shall be subjected to 1-1/2 cycles of interrupt current. If the breaker does not reset after 1/2 cycle due to its normal Type II function, terminate the test at that point.

4.2.7.4 With the circuit breaker connected as described in 4.2.2 (utilizing 4.1.1.2 power source), Type III circuit breakers shall be subjected to 1-1/2 cycles of interrupt current. Procedure shall be to apply fault current for first 1/2 cycle. The next 1/2 cycle shall consist of allowing the unit to come into the "ready to reset" mode. As soon as reset capability is enabled, the reset mechanism shall be activated to restore the circuit, at which time the last 1/2 cycle of interrupt current will be present.

4.2.8 ENVIRONMENTAL TESTS

4.2.8.1 Since end use applications may differ, the following tests are recommended, but not mandatory to determine general suitability of components. All tests shall follow the guidelines as set forth in SAE J1211 or SAE J1455 unless otherwise specified.

4.2.8.1.1 Temperature Test

a. Motor Vehicles—Perform per SAE J1211, 4.1.3. Minimum temperature shall be –40 °C, maximum temperature shall be 105 °C. Cycle per SAE J1211 Figure 2B for a total elapsed time of 96 h.
b. Heavy-Duty Trucks—Perform per SAE J1455, 4.1.3. Test as described for temperature cycling, thermal shock, and thermal stress at the specified test temperatures and in accordance with the temperature transition charts.

4.2.8.1.2 Humidity Test

a. Motor Vehicles—Perform per SAE J1211, 4.2.3 using the 10 day soak method at 95% relative humidity, temperature at 38 °C.
b. Heavy-Duty Trucks—Perform per SAE J1455, 4.2.3 in accordance with recommended test procedures and environmental conditions.

4.2.8.1.3 Salt Fog Test

a. Motor Vehicles—Perform per SAE J1211, 4.3. Alternate standard would be MIL-STD-202F, Method 101D, with a 5% salt concentration at 35 °C for an elapsed time of 48 h minimum.
b. Heavy-Duty Trucks—Perform per SAE J1455, 4.3.3. Time duration may vary, from 24 to 96 h, depending on anticipated location of breaker and potential for exposure to saline solutions.

4.2.8.1.4 Immersion and Splash Test—For general guidelines refer to SAE J1211, 4.4 (Motor Vehicles) or SAE J1455, 4.4 (Heavy-Duty Trucks).

NOTE 1—Immersion testing shall apply only to devices which are stated as being "waterproof," "sealed," "watertight," etc. Test procedures per SAE J1171, Section 5 may be followed for basic test requirements.

NOTE 2—Splash testing shall apply only to devices which are stated as being "splashproof," "water resistant," weatherproof," etc. Test procedure in SAE J1428, 5.1.3 may be used. Devices passing immersion testing do not require splash testing.

NOTE 3—Chemicals used for testing shall be restricted to water for immersion and splash. Evaluation of external identification marking shall be conducted by splash testing utilizing commonly encountered chemicals which shall include: engine oil, power steering fluid, windshield washer solvent, gasoline, diesel fuel, antifreeze, steam, and salt water.

4.2.8.1.5 Mechanical Vibration Test

a. Motor Vehicles—Perform per SAE J1211, 4.7.3. Test shall be for 1 h in each of three mutually perpendicular primary axes using the suggested current practice per SAE J1211, Figure 4.
b. Heavy-Duty Trucks—Perform per SAE J1455, 4.9.4. Test shall be for 1 h in each of three mutually perpendicular primary axes using the suggested current practice per SAE J1455.

4.2.8.1.6 Drop Test

a. Motor Vehicles—Test breakers shall be dropped onto a steel plate 6.35 mm (1/4 in) thick in one of six different directions along three mutually perpendicular primary axes from a height of 1.0 m ± 0.01 m.
b. Heavy-Duty Trucks—Perform per SAE J1455, 4.10.3.1.

4.2.8.1.7 Environmental Extremes Test

a. Motor Vehicles—For reference, see SAE J1211, 5.1 and 5.2. Actual test shall be to soak test breakers at 150 °C ± 2 °C for 240 h without any electrical load.
b. Heavy-Duty Trucks—Generally handled in 4.2.8.1.1, but the motor vehicle test as described may be performed if deemed appropriate.

5. Performance Requirements

5.1 Current Rating—With the circuit breaker connected as described in 4.2.2, all circuit breakers shall pass 100% ± 1.5% of rated current continuously for a minimum of 1/2 h, shall open at 135% ± 1.5% of rated current within 1/2 h, and shall open at 200% ± 1.5% of rated current within 1 min. In addition, internally mounted circuit breakers shall pass 80% ± 1.5% of rated current at 52 °C ± 2 °C for 1/2 h without opening.

5.2 Maximum Voltage Drop—Using the procedure described in 4.2.2.1, the maximum voltage drop across the circuit breaker shall be within the limits shown in Figure 4.

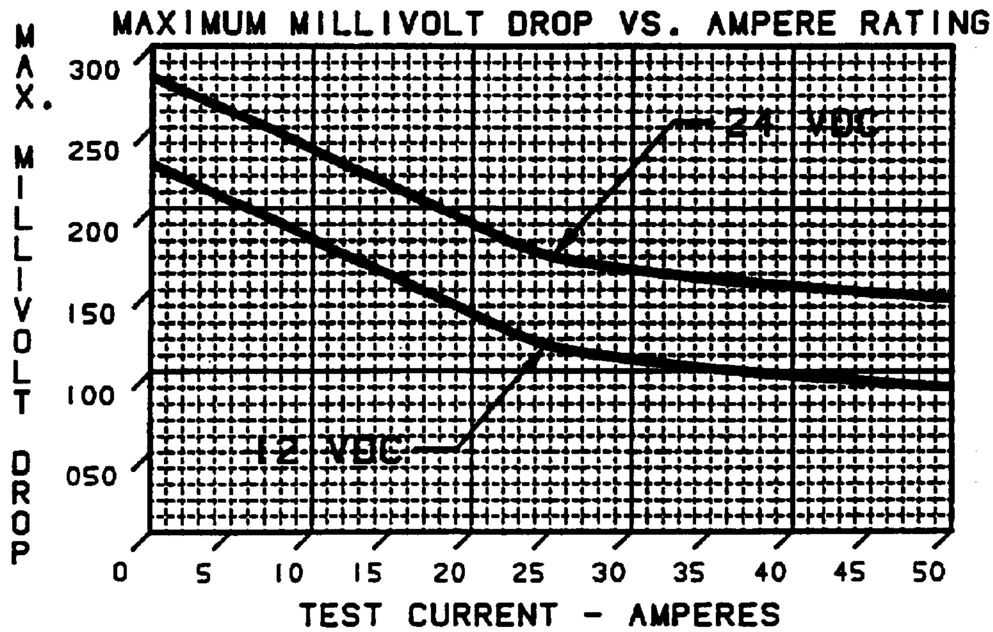

FIGURE 4—VOLTAGE DROP CURVES

5.3 Effective Current Limitation

5.3.1 TYPE I—Using the test procedure described in 4.2.3.1, the maximum value of effective current passed through the automatic reset circuit breaker shall not be greater than 135% of its rated current for an externally mounted breaker or greater than 150% of its rated current for an internally mounted breaker.

5.3.2 TYPE II—Using the test procedure described in 4.2.3.2, the current passing through the modified reset circuit breaker shall not exceed 1 A (1000 mA) after reaching a maintained open condition. The maintained open condition shall be reached within 60 s after the breaker initially opens. Breakers that exceed 60 s, but maintain open condition prior to 5 min test termination, shall be reported as variant. Suitability should be evaluated with regard to intended application.

5.3.3 TYPE III—Using the test procedure described in 4.2.3.3, the maximum value to effective current passed through the manual reset breaker (with disabled reset mechanism) shall not be greater than 135% of its rated current for an externally mounted breaker or greater than 150% of its rated current for an internally mounted breaker.

5.4 Voltage Breakdown—Using the test procedure described in 4.2.4, there shall be no continuity between either terminal of the circuit breaker and the cover.

5.5 No Current Trip and Reset Temperature—Using the procedure described in 4.2.5, all circuit breakers shall open and reclose in accordance with the following requirements:

NOTE—Recognizing device design variations as well as the possibility of ambient compensating mechanisms, it is recommended that manufacturers' temperature derating curves be consulted for application considerations. Consequently, the test procedure of 4.2.5 and performance requirements of 5.5 may, at the tester's discretion, be omitted from the test program.

5.5.1 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.

5.5.2 Circuit breakers rated above 10 A shall not open at less than 112 °C and shall reclose before the temperature is below 82 °C.

5.6 Endurance Test

5.6.1 Type I externally mounted circuit breakers shall be tested as described in 4.2.6.2 and then shall continuously pass 80% ± 1.5% of rated current for 1/2 h and the millivolt drop at 80% of rated current shall be within the limits specified in Figure 4 at the 80% rating value.

5.6.2 If failure occurs with the circuit breaker connected as described in 4.2.6.3, the ultimate failure of all circuit breakers shall result in an open circuit in the circuit breaker, and there shall be no damage to the associated wiring. Failure falls into three general categories: catastrophic failure—part of the electrical contacts and/or thermostatic material burns up and the circuit path is broken (contained with breaker housing/no external manifestations); operational fatigue—thermostatic material loses original form, no longer cycles or chatters (trip/reset excursions less than 1 s in duration), or loses contact pressure resulting in circuit discontinuity; contact failure—electrical contact material erodes or carbons to a level of nonconductance or high resistivity, causing inability to pass current (or trace levels only, below 1 A).

NOTE—In some instances, a high circuit resistance, and/or low current power source, may not provide enough fault current to assure that ultimate failure will always result in an open circuit breaker, or prevent wiring insulation breakdown near breaker terminations.

5.6.3 Type II externally mounted circuit breakers shall be tested as described in 4.2.6.4 and then shall continuously pass 80% ± 1.5% of rated current for 1/2 h and the millivolt drop at 80% of rated current shall be within the limits specified in Figure 4 at the 80% rating value. If performing suggested heater circuit endurance test, desired performance shall be 100 h of continuous heater circuit function, exhibiting no incidence of primary breaker circuit reclosure. Heater circuit performance may vary due to design, therefore, performance limits are advisory.

5.6.4 Type III externally mounted circuit breakers shall be tested as described in 4.2.6.5. The breaker shall trip and reset without failure. There shall be no measurable current passing through the breaker while in the tripped position for the 100 cycles. It shall then continuously pass 80% ± 1.5% of rated current for 1/2 h and the millivolt drop at 80% of rated current shall be within the limits specified in Figure 4 at the 80% rating value.

5.6.5 All breakers when tested as described in 4.2.6.6 shall maintain continuity for the 25 000 cycles.

5.7 Interrupt Test

5.7.1 When tested as described in 4.2.7, the preferred performance is for the circuit breaker to demonstrate continuity and functionality by passing 80% ± 1.5% of rated current for 1/2 h. Breakers which clear the circuit but cease to function shall be examined according to the guidelines of 5.6.2.

5.8 Environmental Tests

5.8.1 TEMPERATURE TEST (THERMAL SHOCK)

5.8.1.1 After completion of test as described in 4.2.8.1.1, the circuit breaker shall exhibit no signs of physical damage and be capable of passing 80% ± 1.5% of rated current for 1/2 h.

5.8.2 HUMIDITY TEST

5.8.2.1 After completion of test as described in 4.2.8.1.2, the circuit breaker shall perform in accordance with 5.1 and 5.2 at 100% ± 1.5% of rated current.

5.8.3 SALT FOG TEST

5.8.3.1 After completion of test as described in 4.2.8.1.3, the circuit breaker shall perform in accordance with 5.1 and 5.2 at 100% ± 1.5% of rated current. Physical corrosion shall not prevent proper fit and function of the breaker.

5.8.4 IMMERSION AND SPLASH TEST

5.8.4.1 *Immersion Test*—After completion of test as described in 4.2.8.1.4, pass/fail criteria of SAE J1171, Section 5 shall apply.

5.8.4.2 *Splash Test*—After completion of test as described in 4.2.8.1.4, pass/fail criteria of SAE J1428, 5.1.3 shall apply.

5.8.5 MECHANICAL VIBRATION TEST

5.8.5.1 While testing as described in 4.2.8.1.5, the circuit breaker shall continuously pass 80% ± 1.5% of rated current during the last 1/2 h with no loss in continuity. Loss of continuity is defined as a resistance across the circuit breaker terminals in excess of 100 W, or a voltage rise across the terminals exceeding 50% of test circuit unloaded voltage for longer than 5 ms.

5.8.6 DROP TEST

5.8.6.1 After completion of test as described in 4.2.8.1.6, the circuit breaker shall not exhibit any physical damage. It shall be capable of passing 80% ± 1.5% of rated current for 1/2 h minimum and comply with 5.2.

5.8.7 ENVIRONMENTAL EXTREMES TEST

5.8.7.1 After completion of testing described in 4.2.8.1.7, there shall be no significant degradation of product materials, such as softening of plastics, creep, or other deformations that could alter product performance or reliability. If test unit is suspect, perform tests per 4.2.2, 4.2.3, 5.1, and 5.2.

5.9 General Requirements

5.9.1 MARKING—Externally mounted circuit breakers shall be permanently and legibly marked with the current rating and voltage as well as any other identifying part numbers. Circuit breaker exterior package designs, which may appear identical in Type I or Type II versions, shall be marked in a consistent fashion to provide distinction between Type I or Type II. Date coding is strongly recommended. Marking shall be generally resistant to common contaminants and chemicals. Evaluate suitability during 4.2.8.1.4 testing.

NOTE—Specifying of marking information, use of color codes, or custom information shall be the responsibility of the O.E.M.

5.9.2 APPLICATION—The specific current capacity of the circuit breaker is a function of the particular electrical system being utilized. It is recommended that 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.

5.9.2.1 *Voltage Rating*—The voltage rating marked on the externally mounted circuit breaker is the maximum value recommended (system, not charging voltage). Use at higher voltages may significantly shorten the ultimate life under overload conditions and/or destroy Type II components.

5.9.2.2 *Current Rating*—The current rating marked on externally mounted circuit breakers is the maximum value/ultimate rating but is subject to redefinition based on the application analysis. It is generally not desirable to specify circuit protection where the breaker will pass 100% of rated current during normal continuous circuit load. Application engineers generally specify circuit protection such that normal continuous circuit loads are approximately 75 to 80% of the circuit breaker current rating. Paragraphs 5.9.2.3 and 5.9.2.4 explain why.

5.9.2.3 *Ambient Temperature*—The circuit breakers covered by this document 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. Therefore, the application engineer needs to consider environmental conditions to which the breaker will be subject during operation and make use of derating curve information if available.

5.9.2.4 *Wire and Terminations*—The connecting wires and their terminations will affect the heat dissipation characteristics of the circuit breaker. Deviations from the circuit breaker application specifications may affect the current carrying capacity or the effective limitation of current during overload cycling. Heat sources associated with poor interfacing terminations that connect with the circuit breaker may be a cause of abnormal circuit resistance, excessive millivolt drop, damage to associated wiring, and ultimately, significant derating.

6. Qualification Test Sequence

6.1 Test Programs—There shall be two separate test sequences; a basic test cycle which covers all core requirements, and an expanded test cycle, which in addition to core requirements, includes all possible tests (most of which are considered optional and are designated by a dotted line border). Figure 5 outlines the basic test cycle and Figure 6 the expanded test cycle.

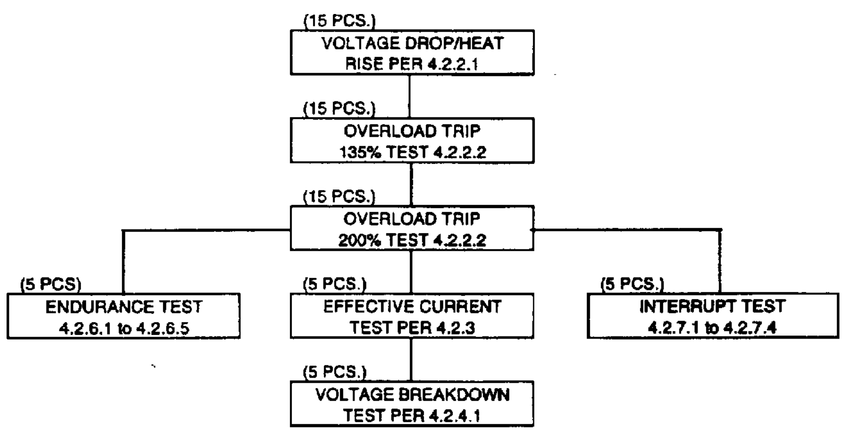

FIGURE 5—BASIC TEST CYCLE

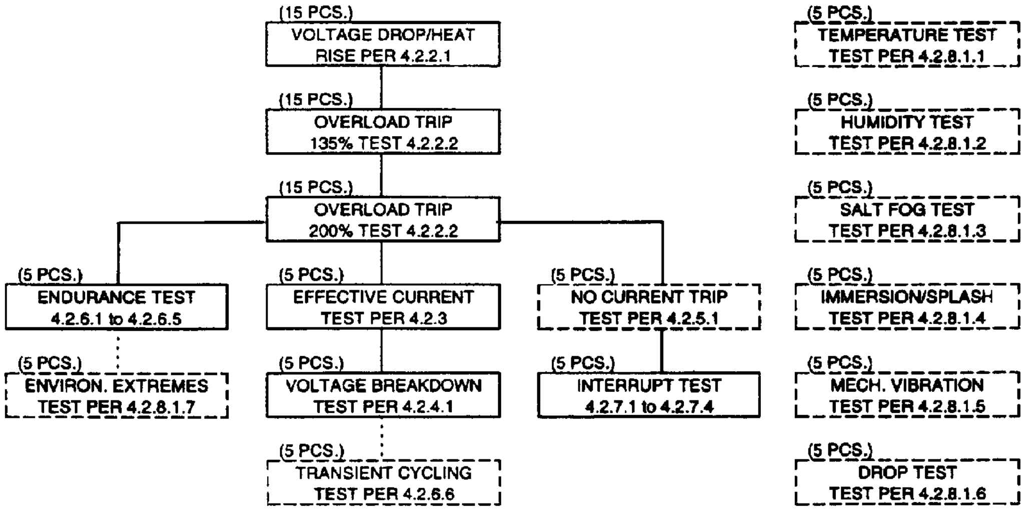

FIGURE 6—EXPANDED TEST CYCLE

6.2 Sample Sizes—Basic test cycle requires 15 samples. All 15 receive the first three tests. Afterwards the group is divided by 3 into 5 piece subgroups for the remaining tests. The expanded test cycle requires 45 samples. Fifteen are treated the same as in Figure 5. The other 30 are divided into six groups for the environmental tests.

7. Notes

7.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE TRUCK AND BUS CIRCUIT PROTECTION SUBCOMMITTEE
OF THE SAE TRUCK AND BUS ELECTRICAL AND ELECTRONICS COMMITTEE

APPENDIX A

CIRCUIT PROTECTION APPLICATION GUIDELINES FOR THERMAL CLASS CIRCUIT BREAKERS

A.1 Scope—Appendix A provides technical commentary regarding the use of thermal design circuit breakers in vehicular and/or motor vehicle accessory (service equipment or components) applications and certain limitations to consider. This document does not set forth any tests or performance criteria. Test and evaluation specifications are found in the preceding sections of this document.

A.2 Definitions

A.2.1 Circuit breakers for purposes discussed here are overcurrent protective devices that are responsive to electric current and to temperature. As thermally classified circuit breakers, their protective action is based largely on an ability to respond predictably to temperature change induced by elevated current pass through the circuit breaker's thermally active element. The activity of the thermal circuit breaker (making or breaking continuity) is primarily a function of varying rates of heating or cooling. The source of the heating or cooling should ideally be limited to changes in electrical current passing through the thermally active element. However, other sources of heating or cooling may impact the operation of the thermal circuit breaker in conjunction with varying rates of current pass.

A.2.2 There are three general classes of thermal circuit breakers, defined as follows:

A.2.2.1 TYPE I—AUTOMATIC RESET—Automatic reset circuit breakers are cycling or continuously self resetting devices that open by combinations of overcurrent and elevated temperatures.

A.2.2.2 TYPE II—MODIFIED RESET—Modified reset circuit breakers are devices that are opened by overcurrent and remain open as long as the power is on to the affected circuit or until the load is removed. A number of cycles may occur before achieving a steady-state open circuit condition.

A.2.2.3 TYPE III—MANUAL RESET—Manual reset circuit breakers are non-cycling devices that open by overcurrent and elevated temperatures, but remain open until manually reset into a conducting state. A trip-free designated manual reset circuit breaker indicates that any forced restriction of the reset mechanism in the operating mode does not prevent cycling of the thermally active element under fault current. This means that an operator or technician cannot create a condition where the circuit breaker must pass current continuously in the presence of fault current on the protected circuit.

A.2.2.4 TYPE III—SWITCHABLE MANUAL RESET—Functions as a conventional manual reset circuit breaker as defined in A.2.2.3, but also has a mechanism, which when exercised at the discretion of the user, permits opening of the breaker internal circuit to stop current flow. The breaker is reset to its normal operating condition by the manual reset function, whether tripped unattended by a real fault condition or by the user. A trip-free designated switchable manual reset circuit breaker indicates that any forced restriction of the reset mechanism in the operating mode does not prevent cycling of the thermally active element under fault current. This means that an operator or technician cannot create a condition where the circuit breaker must pass current continuously in the presence of fault current on the protected circuit.

A.3 Application Considerations

A.3.1 General Considerations

A.3.1.1 ELECTRICAL

A.3.1.1.1 Voltage—Thermal circuit breakers are typically rated for a standard voltage. For vehicular use, the two most frequently used ratings are 12 VDC and 24 VDC. These ratings refer to the standard system nominal voltage specification. In actual conditions, system voltages may range from 9 to 16 VDC and 18 to 32 VDC, respectively. Just as voltage fluctuations may adversely affect electronic components, abnormally low or high system voltages may adversely affect thermal circuit breakers. Examples: a Type II circuit breaker that uses a resistive element to create the maintained open state upon overload may not generate adequate heat due to low source voltage; a Type I breaker may fail prematurely under cycling conditions due to abnormally high source voltage that induces excessive arcing between the electrical contacts; and, a Type II heater element may be destroyed by excessively high voltage (or if a Type II 12 VDC rated unit is installed in a 24 VDC system).

A.3.1.1.2 Current—The current rating on a thermal circuit breaker is the maximum value (sometimes referred to as the ultimate rating) the breaker is capable of passing without tripping, for an indefinite time. The current rating assigned is based upon performance under standardized conditions in a nominal ambient environment of 25 °C. The current rating, while a specification of its maximum continuous current pass capability, is not generally considered to be the sole basis for application specification. Circuit designers must consider other thermal factors that directly or indirectly impact upon the circuit breaker's environment. The sum of these factors will determine the breaker's true rating as it applies to a specific application or installation.

A.3.1.1.3 Wiring and Terminations—The connecting wires and their terminations will affect the heat dissipation characteristics of the thermal circuit breaker. Terminals, whether screwed on, plugged on, welded on, soldered on, or integral to a mating interface terminal block or harness, act in some fashion as heat sinks to a thermal circuit breaker. Poor connections, whether the result of inadequate design, looseness, corrosion, or other induced elevated resistivity, cause elevated voltage drop and hot spots in the presence of high current conditions. If poor connections are sufficiently adverse, derating and premature tripping of the thermal circuit breaker will occur.

A.3.1.2 ENVIRONMENTAL

A.3.1.2.1 Ambient Temperature Conditions—The environmental temperature conditions prevalent both where the circuit breaker is used (as in geographical climatic conditions) and relative to its installation (as in proximity to other sources of heat and cold), have a considerable bearing on the selection of the appropriate amperage rating. In some instances, circuit design changes, relocation of circuit breaker mounting, or ventilation or insulation from other sources of ambient altering environments must occur.

A.3.1.2.1.1 Examples of potentially detrimental environmental conditions relative to temperature: mounting a breaker or multiple breaker harness near heat sources such as exhaust manifolds, coolant hoses, heater cores, or external oil reservoirs and or filtering systems; mounting a breaker or multiple breaker harness in a restricted space without even convection ventilation possible; mounting a breaker or multiple breaker harness exposed externally to wind chill effects.

A.3.1.2.2 Other Environmental Factors—While temperature conditions are the most significant factor affecting breaker performance, other conditions may with sufficient severity and duration of exposure negatively impact circuit performance, reliability, and longevity. Typical environmental conditions of this sort may include: thermal shock, high humidity, salt fog or spray, immersion or splash of liquids (water-based compounds and petroleum-based compounds), mechanical vibration, and sudden impact. Positioning of circuit breakers so that environmental factors are managed is crucial to ensuring dependable service.

A.3.1.2.2.1 Examples of other environmental factor negative effects: chemically induced corrosion deteriorates terminal connections causing elevated resistance, intermittent continuity, or total loss of continuity; unusually persistent or severe cyclic harmonic vibration induces momentary loss of continuity between the circuit breaker electrical contacts.

A.3.1.3 INTERFACING COMPONENT MATERIALS

A.3.1.3.1 When circuit breakers are interfaced with wiring harnesses via terminated plastic distribution modules, heat generation factors resulting from normal as well as potential abnormal circuit breaker operation must be considered when specifying the plastic materials to be used in such proximity. Low grade plastics that lend themselves to design flexibility and reduced costs can pose performance problems if heat wicking from circuit breakers causes softening or more severe degradation from long-term exposure to elevated temperatures.

A.3.1.3.1.1 Higher performance plastics with respect to heat indices should be used for test purposes during circuit breaker performance evaluations. Radiant heat characteristics developed by circuit breakers should be thoroughly considered in the design phase of plastic-based terminal blocks intended for interface with circuit breakers.

A.3.2 Circuit Breaker Type Considerations

A.3.2.1 TYPE I CIRCUIT BREAKERS

A.3.2.1.1 Type I circuit breakers are the most basic design of the thermal circuit breaker family. As cycling or continuously resetting devices, their use is best applied protecting loads controlled by momentary switches or other self-limiting means. In select situations, they protect circuits where cycling of an overloaded circuit is preferred over complete disruption of service until the fault condition is corrected for reasons of operator safety or other compelling interest.

A.3.2.1.2 The plus aspects of Type I circuit breakers are: simplicity of design; lower cost as a component; nothing to reset after a trip event; and are available for applications requiring complete waterproofing.

A.3.2.1.3 The minus aspects of Type I circuit breakers are: cycling may not be conducive for adequate protection of sensitive equipment for repetitive fault current exposure; the cycling condition may encourage operators or technicians to unwisely delay correction of a fault; cycling may continue for extended periods and drain storage batteries below minimum cranking capacity; and extended cycling without proper attention may create conditions that lead to damage of peripheral components or wiring harnesses.

A.3.2.2 TYPE II CIRCUIT BREAKERS

A.3.2.2.1 Type II circuit breakers initially function with great similarity to Type I breakers. Upon presentation of fault current the breaker will react under the same time constraints as a Type I and after an initial trip may cycle (trip and reset) several times, appearing to perform as if a Type I design. During this initial period of reaction to the fault current, a secondary circuit within the breaker construction is creating a heat source each time the breaker has tripped. Within a relatively short time span (typically 60 s and up to 300 s) this secondary heating circuit will have developed sufficient heat radiation to maintain the breaker's thermal element in a tripped state. Once in the maintained tripped state, a reduced current value (typically 1 A or less) is consumed by the heating circuit. Virtually no current is passed on through to the fault site. Type II circuit breakers are reset by disconnecting or switching off the power source to the protected circuit for a time period long enough to allow the breaker components to cool off and the thermal element to revert to its conducting state. This cooling off may require several minutes until a stable conducting state is achieved.

A.3.2.2.2 Type II circuit breakers may be used instead of Type I circuit breakers where the possibility of long-term cycling during faults is not desirable or the location of the breaker prevents easy access for resetting if a Type III circuit breaker had been preferred over Type I.

A.3.2.2.3 The plus aspects of Type II circuit breakers are: simpler design alternative to Type III breakers when Type I usage is undesirable; can be reset from any point in the same circuit where power switching is possible; less likely to drain storage batteries before fault is detected and corrected; and encourages timely maintenance since components affected are not functional even intermittently as with Type I.

A.3.2.2.4 The minus aspects of the Type II circuit breaker are: cannot be reset without shutting circuits down; extreme low source voltage may prevent successful Type II function rendering the breaker into a Type I operation; extreme high voltage may radically shorten Type II function; tripped Type II breaker may radiate excess heat and derate other breakers in a confined close proximity installation; and time between initial trip and maintained open state may still be too long for the level of protection necessary to prevent further equipment damage where the fault has occurred.

A.3.2.3 TYPE III CIRCUIT BREAKERS

A.3.2.3.1 Type III circuit breakers differ significantly from both Type I and Type II breakers in that they provide a complete interruption of circuit continuity once tripped. Continuity restoration will not occur until a conscious decision is made by a responsible party to initiate circuit breaker resetting. This is typically accomplished by inspecting the breaker for visual indication of a tripped state (a button or lever extended or moved from a normal operating location) and manually with physical force replacing the indicator to its original state.

A.3.2.3.1.1 In the case of switchable Type III circuit breakers, circuit continuity can be broken by the breaker on a manual basis without the presence of fault current by the definite choice of an operator or technician.

A.3.2.3.2 Type III circuit breakers are used where no cycling after a fault is desired or deemed safe and where an immediate investigation of fault causes is the most appropriate course of action.

A.3.2.3.3 The plus aspects of Type III circuit breakers are: highly unlikely to permit damage to wiring or interfaces from long-term fault exposure; brings human element of analysis into the decision to reset or not; can provide circuit interruption for maintenance or investigation (if with switchable feature); and provides operators with a sense of control and awareness over electrical systems.

A.3.2.3.4 The minus aspects of Type III circuit breakers are: cannot be reset unattended; mounting requirements (access to reset mechanism) may restrict location options; higher initial cost to install likely; and may not be practical for some circuits due to shared components being protected dictating that some power coming through is better than no power at all.

A.4 Limitations of Performance

A.4.1 Failure Modes

A.4.1.1 GENERAL FAILURE MODES

A.4.1.1.1 All styles of simple thermal circuit breakers once exposed to varying levels of fault current begin to experience decay with regard to the integrity of their functioning components. The rate of degradation is in proportion to the severity and duration of fault current exposures. Random events of moderate intensity that are quickly detected (i.e., within minutes) and corrected are far less likely to seriously impair breaker function for future events. Specific events of moderate to severe intensity that are left unattended for extended periods (i.e., hours to days) are very likely to result in breaker destruction and potential collateral damage. Emphasis on operator awareness for quick fault detection and correction is essential to electrical system integrity.

A.4.1.1.2 The following describes more common reasons why circuit breakers eventually cease to function.

A.4.1.1.2.1 Catastrophic Failure—Part of the electrical contacts and/or thermostatic material burns up and the circuit path becomes discontinuous.

A.4.1.1.2.2 Operational Fatigue—The thermally active element loses its original form and stress biases, loses the ability to cycle from aging, changes occur in contact relationships, and circuit discontinuity eventually occurs.

A.4.1.1.2.3 Contact Failure—Electrical contact material erodes and/or carbonizes from long-term cycling resulting in circuit discontinuity.

A.4.1.1.2.4 Environmental Contamination—Chemical gases or liquids attack active elements and corrode or oxidize current-carrying portions resulting in circuit discontinuity.

A.4.1.1.2.5 Extreme Shocks—Radical temperature swings or violent mechanical force exposures before or after breaker installation dislodge critical alignments of components resulting in circuit discontinuity.

A.4.1.2 CIRCUIT BREAKER TYPE FAILURE MODES

A.4.1.2.1 Type I Circuit Breakers

A.4.1.2.1.1 As cycling or continuously resetting units, Type I circuit breakers are the most susceptible style concerning unpredictable or undesirable failure modes when cycled for extended time periods. During cycling under less than direct short conditions, they are most likely to fail from fatigue and/or contact erosion. Unattended long-term cycling can lead to other phenomena such as contact sticking or welding that permits excessive duration of fault current into connective conductors, leading to collateral damage.

A.4.1.2.1.2 Type I circuit breaker design for vehicular applications (functional design, not package design) has remained basically unchanged since post World War II. Therefore, any design effort to make cycling duration more predictable with a bias towards achieving a fail safe mode would be a positive contribution.

A.4.1.2.2 Type II Circuit Breakers

A.4.1.2.2.1 Type II circuit breakers are vulnerable to failure at two fundamental points. When initially exposed to fault currents, they must survive the initial bursts of current to develop the maintained open circuit state. While in the maintained open circuit state for extended periods of time, the secondary heater circuit could eventually fail and the breaker would revert to Type I like operation, subject to Type I like failure modes.

A.4.1.2.3 Type III Circuit Breakers

A.4.1.2.3.1 Because of the necessity for manual resetting after a trip event, Type III breakers are less likely to endure the repetitive long-term fault exposure that Types I and II encounter.

A.4.1.2.3.2 Type III circuit breakers may experience failure for mechanical reasons such as: insulating trip mechanism jams electrical contacts or contaminates them to where re-establishment of the current path is prevented, contact insulating mechanism fails to insulate contacts and the unit acts as if a Type I breaker, or reset mechanism becomes jammed or otherwise inoperative preventing the re-establishment of continuity.

A.4.2 Preventions to Safe Failures

A.4.2.1 In the 1988 revision to SAE J553 Circuit Breakers, the following advisory was first published: "In some instances, a high circuit resistance, and/or low current power source, may not provide enough fault current to ensure that ultimate failure will always result in an open circuit breaker, or prevent wiring insulation breakdown near breaker terminations."

A.4.2.1.1 The preceding quotation was not intended solely as a generic disclaimer, but served to summarize historical experience. This notice draws attention to the reality that durability of breakers to high current and long-term fault conditions can create vulnerability to low current or high resistive conditions, particularly with Type I style circuit breakers. The electrical circuit designer must consider the risk factors when specifying circuit protection and deciding on which Type (I, II, or III) breaker to utilize.

A.4.3 Other Agency Concerns

A.4.3.1 R.V.I.A. (RECREATION VEHICLE INDUSTRY ASSOCIATION)—This association publishes an R.V.I.A. Standards Handbook that expresses technical information pertinent to the manufacture of recreational vehicles and associated equipment. While the standards employed are directed to a specific industry with unique concerns, the cautions noted deserve mention. The following excerpt was circulated by R.V.I.A. on December 31, 1990, before 1991 handbook revisions.

A.4.3.1.1 "Type I, automatic reset circuit breakers are self resetting or continuously cycling units. They are designed for circuits where, for safety reasons, it is important to reestablish continuity quickly after an overload occurs. Because of heat wicking, protection of conductors during a dead short cannot be guaranteed due to the constant cycling of these types of circuit breakers. Heat wicking is caused by a conductor carrying away heat from the circuit breaker and the breaker resetting when the cable near it has cooled to 54 °C. Depending on the location of the fault and whether someone is around to disconnect the power, the cycling may continue until there is a fire."

A.4.3.1.2 The preceding quotation may reflect extreme situations and perhaps be alarmist in tone. However, this should help the circuit designer to be more reflective regarding where to best specify Type I breakers.

A.4.3.1.3 The concern over Type I failure modes by R.V.I.A. is another good reason to favor development and use of Type I circuit breakers exhibiting a predisposition to fall safe, with more emphasis on that rather than ad infinitum cycling durability.

A.5 Application Considerations of Thermal Breakers for Circuit Protection

A.5.1 Master Circuit Breakers and/or Disconnect Devices

A.5.1.1 Extensive power distribution systems may warrant the use of mastering devices to provide a means of interrupting all electrical power from the source. In motor vehicles, source power is typically the DC storage batteries in combination with charging circuits.

A.5.1.2 Depending on the load requirements and service use, master disconnects may be accomplished with high amperage rated circuit breakers, high capacity mechanical DC switches, solenoid switches, manual disconnects, and fusible links.

A.5.1.2.1 High amperage rated circuit breakers are suitable for protecting an entire electrical system with the exception of the starter circuits. They provide master short circuit protection in the event severe and persistent faults occur or where an excess of electrical utilization exceeds maximum system parameters. Switchable breakers add the flexibility of interrupting system power at will for maintenance, security, or emergency.

A.5.1.2.1.1 Master breakers are not suggested to include starter circuit protection because the high inrush and sustained current during cranking cycles may be of a magnitude sufficient to induce a breaker trip before motor starting has successfully concluded.

A.5.1.2.2 High-capacity DC mechanical switches are available in various current-carrying capacities. The highest rated switches are suitable to disconnect power to every circuit including starting circuits. A switch may be desirable to unload the entire system for maintenance, security, or prevention of battery discharge from parasitic loads. A master circuit breaker may still be warranted as protection for all accessory and auxiliary circuits.

A.5.1.2.3 Solenoid switches for circuit control are high-amperage DC operated switches. The solenoid switch is typically a single-pole, normally open switch. Heavy-duty electrical contacts are brought together by a magnetic solenoid operation initiated by a DC control circuit. Nominal DC voltage is required with approximately 1 A of current utilized to hold the switch in the closed position. The drawback to the solenoid switch is that electrical power is required to use it; so, if an on-board storage battery is severely discharged, external power would be necessary to activate the switch and permit current flow.

A.5.1.2.4 Manual disconnects are similar to high-capacity switches except that make and break is accomplished by the installation or removal of a bridging conductor apparatus. This type of device is seldom used in vehicular applications because the bridging conductor as a separate component may be lost after removal and not convenient to replace or be substituted for.

A.5.1.2.5 Fusible links are specially designed sections of primary wire that act as fuse elements when subjected to a threshold of fault current for sufficient duration. They are not circuit breakers, nor are they true fuses. They are generally used to protect accessory circuits, but only under extreme short-circuit conditions. Their activation results in disruption of their fusible section.

A.5.2 Cascading

A.5.2.1 Cascading refers to the strategy employed when designing circuit protection extending from master circuit breakers to branch circuit protection. The method is utilized to avoid situations where a branch or sub-branch overload triggers circuit breakers at higher branch levels unnecessarily, when the fault was initially and adequately contained at the breaker nearest to the fault.

A.5.2.1.1 *Example*—A 20 A branch circuit breaker is ahead of three sub-branch circuits, each protected by a 10 A circuit breaker and/or fuse-breaker combination. Nominal load of each sub-branch has been calculated at 5 A each for a total nominal branch load of 15 A. This represents 75% of the rated current of the 20 A branch circuit breaker. With a 20 A branch circuit breaker in this example, any combination of greater than nominal loads in the sub-branches exceeding 20 A could eventually trip the breaker, disrupting service to all three sub-branches even if one or more sub-branches are still within design parameters concerning above normal load demand.

A.5.2.1.2 From the preceding example, it would make more sense to at a minimum have the branch circuit breaker rating equal to or greater than the sum of the rated value for the sub-branches as opposed to using calculated nominal rated load values only. In the example, each sub-branch had a 10 A protection device. A 30 A main branch would have been a better choice just from calculation of the total rated values for the three branches (10 x 3 = 30). Another consideration would be based on the typical must trip values for the sub-branch devices; must trip values typically range from 125 to 135% of rated current. Using this approach, the branch circuit breaker rating choice would be close to either 35 or 40 A (10 x 1.25 = 12.5, 12.5 x 3 = 37.5; or, 10 x 1.35 = 13.5, 13.5 x 3 = 40.5).

A.5.3 Additional Factors Based on Ambient Environments

A.5.3.1 DERATING AND RERATING

A.5.3.1.1 Derating and rerating are terms to describe the affect of elevated or reduced ambient temperature upon the continuous current-carrying capability of a thermal circuit breaker.

A.5.3.1.2 Thermal style circuit breakers operate by their construction with thermally sensitive alloys. Any source of temperature change, whether induced by electrical current throughput or simply by environmental change, or a combination of both, is all that is necessary to affect its operation relative to current-carrying capacity. The higher the temperature gets, the sooner the breaker trips at a constant rate of overload. The cooler the temperature gets, the longer the breaker takes to trip at a constant rate of overload.

A.5.3.1.3 Circuit breaker amperage ratings are generally determined at an ambient air temperature of 25 °C. When the ambient temperature increases above 25 °C, the amperage rating begins to decrease along an increasingly sharper curve until it reaches a capacity of 0 A. When the ambient decreases below 25 °C, the amperage rating begins to increase to as much as double its 25 °C rating and then levels off.

A.5.3.1.4 Determining the operating environment in which a thermal circuit breaker will be installed is helpful in choosing the appropriate amperage rating to cover the spectrum of loads, temperatures, and derating or rerating factors. Curves are usually published by manufacturers of thermal devices to aid in initial evaluations and determinations of appropriate amperage ratings for specific installations.

A.5.4 Circuit Breakers and Fusing

A.5.4.1 Each type of protection device has performance qualities attractive to the circuit designer.

A.5.4.2 Fuses are fast acting at virtually all overloads but require replacement to reinitiate electrical power. Circuit breakers are slower to trip at minor overloads but can be reset without replacement.

A.5.4.3 For components that are extremely intolerant to overloads of almost any level and are best quickly isolated from faults, fusing is more appropriate for that component or device. Use of a fuse in-line to a specific component does not preclude that circuit from being tied to a sub-branch or branch protected by a breaker.

A.5.5 Circuit Breaker Ganging

A.5.5.1 Circuit breaker ganging is a practice where typically two breakers are placed together electrically in parallel to achieve a higher overall amperage rating based on the sum of the two individual breakers; e.g., two 50 A breakers bussed together in parallel equaling in theory a 100 A rating.

A.5.5.2 This practice has fallen into disfavor and is generally discouraged by manufacturers and agencies.

A.5.5.2.1 When ganged circuit breakers begin to cycle under overload, they quickly become asynchronous and the individual breakers start to take the brunt of the fault independently even though electrically paralleled. This subjects the breakers to faster deterioration and catastrophic failure. It also subjects the protected circuit to more pulses of fault current due to the alternating make and break of the ganged circuit breaker assembly once it becomes asynchronous.

A.5.5.2.2 Selecting an appropriately rated single breaker is the preferred approach over ganging. Whereas DC circuit breakers have been available in single unit ratings up to 150 A and even higher, ganging should not be considered. Another approach would be splitting the load into several smaller branches each protected by single master circuit breakers.

A.6 Practical Considerations

A.6.1 The Circuit Breaker as a Safety Device

A.6.1.1 In most instances, when a circuit breaker trips while protecting a circuit under load, this is an indication that something is amiss with a component, wiring, or both. It could also result from misapplication (wrong rating for the load) or derating (environment too hot).

A.6.1.2 A circuit breaker that trips should not be the initial focal point of investigation. The real question to be answered is what condition down line from the circuit breaker initiated a fault condition. Identify and correct the fault. The circuit breaker did its job by reacting as a safety device.

A.6.2 Sacrificial Nature of Circuit Breaker Components

A.6.2.1 Circuit breakers subjected to repetitive faults or cycled for extended periods eventually lose ability to function. Mechanical stresses develop, leading to various forms of metal fatigue. Electrical contacts erode from wiping action and electrical arc discharge erosion.

A.6.2.2 Circuit breakers as protection devices are designed to give up their "lives" in the process of saving other components. Their eventual sacrificial failure must be anticipated and cannot be viewed as atypical or outside of design parameter.

APPENDIX B

GLOSSARY OF DOCUMENT TERMINOLOGY

B.1 This appendix contains definitions of basic electrical terms employed in the document. The terms listed here are not inclusive of all possible terms used, but do include several terms that may be derivatives of other terms or otherwise subject to misinterpretation. For comprehensive listings of terminology, the reader is recommended to obtain a good electronics dictionary.

B.2 Glossary

B.2.1 Ambient Compensating Mechanism—Refers to a circuit breaker in which designed components have been modified or augmented to provide a counteracting effect when temperatures rise. The effect is to restrict thermal activity of the breaker's thermostatic element(s), thus elevating the switch temperature. The purpose is to allow more current throughput at elevated ambient (lessening derating effects). The effect cannot be extreme or trip action is compromised and/or ultimate rating of the breaker at lower ambients becomes overly biased (breaker requires excessive overload currents to trip).

B.2.2 Ambient Temperature—Temperature of the prevailing environment indoors or outdoors. Temperature of air or liquid surrounding any electrical part or device. Usually refers to the effect of such temperature in aiding or retarding removal of heat by radiation or convection from the part or device in question. As used in the document, it typically relates to room temperature, as in a test lab or enclosed office where environment is under controlled conditions by means of HVAC.

B.2.3 Amperage—The number of amperes flowing in an electrical conductor or circuit.

B.2.4 Ampere—A unit of electrical current or rate of flow of electrons. One volt across 1 Ω of resistance causes a current flow of 1 A.

B.2.5 Conductor—A bare or insulated wire or combination of wires not insulated from one another, suitable for carrying an electric current. A material, such as copper or aluminum, which offers low resistance or opposition to the flow of electric current.

B.2.6 Current—The movement of electrons through a conductor; usually measured in amperes, milliamperes, or microamperes.

B.2.7 Delta Heat Rise—A measurement of actual temperature change caused by a heating source, such as electrical current flowing through a conductor. The stabilized temperature change minus the ambient temperature equals the delta figure of heat rise.

B.2.8 Derating—A value assigned to a circuit breaker amperage rating usually expressed as a percentage to indicate the change in capability to pass current on an indefinite basis in elevated ambient temperature environments. As the percentage value changes in correlation to elevated ambient, the derating follows a curve. Typically at room ambient (25 °C) a circuit breaker will pass 100% of current rating indefinitely. As ambient temperature rises, the percentage of current capability decreases along a curve until it reaches 0%, indicating a temperature in which the thermal element of the circuit breaker deflects to a discontinuous state whether any electrical current is present or not.

B.2.9 Dissipation—Loss of electrical energy as heat.

B.2.10 Effective Current—For purposes of circuit breakers, this value represents an average quantification of current flow under a prescribed overload condition in which cycling is occurring.

B.2.11 Endurance Test—Refers to longevity cycling of a circuit breaker under less than direct short conditions.

B.2.12 **Factory Wired Terminations—**Refers to circuit breakers that may be supplied with pig-tail wire leads already affixed permanently or other specialized connecting conductors and have already been installed in the circuitry under protection or component device subassembly. Generally applies to circuit breakers installed by original equipment manufacturers.

B.2.13 **Field Wired Terminations—**Refers to circuit breakers supplied as components to be installed and connected by users as add-ons, replacements, or non-factory supervised modifications or customizations. Generally applies to circuit breakers installed by end consumers, independent service agents, electrical or audio custom houses, etc.

B.2.14 **Heater—**A resistor that converts electrical energy into heat.

B.2.15 **Heating Element—**A resistor that is used in a heating circuit or heating device.

B.2.16 **Interrupt Test—**Refers to a test method or prescribed condition under which a breaker, when subjected to a direct short of high amplitude, is evaluated for either survivability and/or success in preventing (interrupting) current flow to a protected circuit.

B.2.17 **Splashproof, Water Resistant, or Weatherproof—**Circuit breakers designed such that a toleration exists to momentary exposure from sprays of streams or fluids; such momentary exposures tolerable without rapid or substantial migration of moisture into internal cavities and workings of the circuit breaker.

B.2.18 **Storage Battery—**Two or more storage cells connected in series and used as a unit.

B.2.19 **Switch Temperature—**The temperature value within a confined range in which a thermostatic alloy as is used in a thermal design circuit breaker deflects to an alternate shape or position. The switch temperature is dependent upon imparted stresses to the piece of thermostatic alloy, its overall mass, and the relative difference in expansion rates between alloys used in sandwiched composites (as in thermostatic bimetals or trimetals).

B.2.20 **Terminal—**A point of connection for two or more conductors in an electrical circuit. A device attached to a conductor to facilitate connection to another conductor.

B.2.21 **Ultimate Rating—**Generally refers to the maximum current-carrying capacity of a circuit breaker without experiencing a trip excursion at room ambient conditions.

B.2.22 **Voltage—**Electrical pressure; i.e., the force which causes current to flow through an electrical conductor.

B.2.23 **Voltage Drop—**The difference in voltage between two points, due to the loss of electrical pressure as a current flows through an impedance.

B.2.24 **Waterproof, Sealed, or Watertight—**Circuit breakers designed such that if immersed or submerged in fluid (e.g., water), no fluid shall infiltrate the internal cavities and workings of the circuit breaker.

B.2.25 **Wire-Lead Termination—**The method by which wire leads are fastened at a circuit termination; for example, soldering, wire wrapping, or crimping.

Rationale—In 5.2 referenced 4.2.3. Changed to 4.2.2.1.

The whole document was put into SAE/ISO guidelines.

Definitions became Section 3 instead of 2.3.

Appendix A and B added.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Standard defines the test conditions, procedures, and performance requirements for circuit breakers in ratings up to and including 50 A. The document includes externally or internally mounted automatic reset, modified reset, and manually reset types of circuit breakers for 12 V and 24 V DC operation. Some circuit breakers may have dual voltage ratings (AC and DC), however, this document evaluates DC performance only.

Reference Section

SAE J258—Circuit Breaker—Internal Mounted—Automatic Reset

SAE J537—Storage Batteries

SAE J554—Electric Fuses (Cartridge Type)

SAE J561—Electrical Terminals—Eyelet and Spade Type

SAE J858a—Electrical Terminals—Blade Type

SAE J1171—External Ignition Protection of Marine Electrical Devices

SAE J1211—Recommended Environmental Practices for Electronic Equipment Design

SAE J1284—Blade Type Electric Fuses

SAE J1428—Marine Circuit Breakers

SAE J1455—Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)

SAE J1888—High Current Time Lag Electric Fuses

SAE TSB 002—Preparation of SAE Technical Reports

CSA C22.2 No. 14-M1987Industrial Control Equipment

CSA C22.2 No. 235-M89Supplementary Protectors

MIL-STD-202FTest Methods for Electronic and Electrical Component Parts

U.L. 1077Standard for Supplementary Protectors for use in Electrical Equipment

National Electrical CodeNEC Article 551

Recreational Vehicle Industry AssociationRVIA Handbook

Developed by the SAE Truck and Bus Circuit Protection Subcommittee

Sponsored by the SAE Truck and Bus Electrical and Electronics Committee