Title/Subject:	Standard Test Procedure – Protective Transformer Test	
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1.0 PURPOSE

This test procedure is to be used by Electrical Safety Division (ESD) investigators to determine if samples of a protective transformer meet the requirements of ACRI2001 "Criteria for the Evaluation and Test of Intrinsically Safe Apparatus and Associated Apparatus," Section 9.1.

2.0 SCOPE

This Standard Test Procedure (STP) applies to transformers submitted for test as a protective transformer for use in intrinsically safe apparatus and associated apparatus evaluated, approved, or certified per 30 CFR Parts 18, 23, and 27.

3.0 REFERENCES

3.1 ACRI2001 "Criteria for the Evaluation and Test of Intrinsically Safe Apparatus and Associated Apparatus"

3.2 30 CFR Part 18 "Electric Motor-Driven Mine Equipment and Accessories"

3.3 30 CFR Part 23 "Telephones and Signaling Devices"

3.4 30 CFR Part 27 "Methane-Monitoring Systems"

4.0 DEFINITIONS

4.1 Constant Temperature – The equilibrium temperature of the device with the prescribed test parameters. This temperature is obtained when three consecutive temperature readings taken at intervals of no less than 5 minutes indicate a total change of less than 3%.

4.2 Protective Transformer- A transformer that is so unlikely to fail in a manner that will lower the intrinsic safety of the circuit that it may be considered not subject to fault when analysis or tests for intrinsic safety are made.

5.0 TEST EQUIPMENT

5.1 AC Hypot tester (Associated Research Model 4311 or equivalent)

5.2 Data recorder. This data recorder may be used to monitor the transformer's surface temperature, secondary short circuit current, and input current. Optionally, the data can be recorded manually at a duration necessary to determine the transformer's maximum temperature.

5.3 Source of power adequate for the test.

5.4 Switch adequately rated for voltage/current to the primary of the transformer.

5.5 Digital thermometer(s) using thermocouples consisting of wires not larger than No. 24 AWG. If using a data recording system, this thermometer must have an output compatible with the data recording system input (Fluke Model 2170A Digital Thermometer or equivalent).

5.6 Ammeters to monitor the primary and secondary current. Minimum resolution: 3 significant digits. If using a data recording system, a shunt resistor shall be used to determine current through the primary and secondary test circuit. The resistance value of this shunt resistor shall not exceed 1% of the dc resistance of the windings.

5.7 DC Ohmmeter to measure the resistance of the transformer windings. Minimum resolution: 3 significant digits.

6.0 TEST SAMPLES

Three samples of the protective transformer.

7.0 PROCEDURE

WARNING: HIGH VOLTAGES, HIGH TEMPERATURES DURING TESTS

7.1 Conduct the test at an ambient temperature of 25 ± 5°C.

7.2 Measure and record the dc resistance of the transformer's primary and secondary winding(s).

7.3 Perform a dielectric strength test as follows: (Reference Sections 9.1.1 and 9.6 of ACRI2001)

7.3.1 The test voltage shall be an alternating voltage of a substantially sinusoidal wave form at a frequency between 48 Hz and 62 Hz or a dc voltage with no more than a 3 percent peak to peak ripple. The

magnitude of the test voltage is given in the following chart. U_n is the highest rated voltage of any winding under test.

Test Voltage (ac_{rms})	**Test Voltage (dc)**	**Where applied**
$4U_n$ or 2500 V, whichever is greater	$5.66U_n$ or 3536 V, whichever is greater	Between input and output windings
$2U_n$ or 1000 V, whichever is greater	$2.83U_n$ or 1414 V, whichever is greater	Between all output windings and the core and shield,
$2U_n$ + 1000 V or 1500 V, whichever is greater	$2.83U_n$+ 1414 V or 2121 V, whichever is greater	Between each winding supplying an intrinsically safe circuit and every other output winding.

7.3.2 The voltage shall be increased steadily to the specified value in a period not less than 10 seconds and then maintained for at least 60 seconds.

7.3.3 The current shall not exceed 5 milliamperes and there shall be no breakdown of the insulation between the test points during each test.

7.4 Determine the type of transformer being tested in accordance with Section 7.2 of ACRI2001 and prepare it for testing according to Sections 7.4.1, 7.4.2, or 7.4.3.

7.4.1 Type 1(a) and Type 1(b) Transformers - Short circuit the transformer secondary winding(s) or load it, or them, in such a way as to give the highest input current not exceeding 1.5 times the fuse or circuit breaker rating. The protective fuse or circuit breaker in the primary circuit shall be bypassed for this purpose. If an output winding is fitted with a current-limiting resistor so arranged that a short circuit cannot occur directly across the winding, the test shall be carried out with equivalent resistance in the circuit. (Note: Primary voltage may need to be lowered during the test in order to maintain an input current of 1.5 times fuse rating.)

7.4.2 Type 2(a) Transformer - Load the secondary winding(s) to draw maximum primary current with the input winding subjected to its rated input voltage. The input current shall not be limited. (Note: An imbedded one-time thermal fuse may be used to prevent the transformer from bursting into flames.)

7.4.3 Type 3 Transformer - Operate the transformer with any or all secondary windings shorted-circuited, depending on which represents the more severe condition of heating, and with rated voltage applied to the input winding until thermal equilibrium is established. Any thermal fuse or other current or temperature-sensitive protective device shall be short-circuited during this test.

7.5 Attach a thermocouple(s) per Section 7.8 without removing encapsulating compound or similar material to:

7.5.1 The integrally applied insulation of a coil without a wrap, or

7.5.2 The outer surface of a wrap that is not more than 0.8 mm (1/32 in.) thick and consists of cotton, paper, rayon, or similar material (but not of asbestos or similar thermal insulation).

If the thermocouple(s) measurement cannot be conducted in accordance with the foregoing considerations, determine the resistance of the transformer windings and use the change-of resistance method per Section 7.11.

7.6 Connect the transformer primary to a power source capable of providing the specified primary voltage/current. Install an ammeter in the primary circuit to monitor the current, or if using a data recorder, provide a means to monitor the current into the transformer primary compatible with the data recorder's input. If a shunt resistor is used for such purposes, the resistance value shall not exceed 1% of the dc resistance of the primary windings.

7.7 Connect an ammeter to monitor the transformer's secondary current. If using a data recorder, provide a means to monitor the current through the transformer secondary that is compatible with the data recorder's input. If a shunt resistor is used for such purposes, the resistance value shall not exceed 1% of the dc resistance of the secondary windings.

7.8 Position the thermocouple(s) securely in good thermal contact with the external surface of the transformer being tested. The thermocouple(s) must be placed at the hottest point on the transformer. Preliminary testing, prior to starting the test, may be necessary to determine the hottest point, which will typically be the core.

7.9 Connect the signal output from the digital thermometer to the input of the data recorder (this step will not be performed if manually recording the temperature).

7.10 Apply power and allow the test to continue for 6 hours or until a constant temperature is attained whichever is later or until a failure is observed.

7.11 If necessary to use the resistance method, skip steps 7.8 and 7.9. and obtain the temperature rise using the following formula (windings are to be at ambient temperature at the start of the test):

$$\Delta t = \frac{R}{r} (k+t_1) - (k+t_2)$$

where:
Δt = the temperature rise, °C
R = the resistance of the coil at the end of the test, in ohms
r = the resistance of the coil at the beginning of the test, in ohms
t_1 = the room temperature, °C, at the beginning of the test
t_2= the room temperature, °C, at the end of the test
k = 234.5 for copper, 225.0 for aluminum electrical conductor (EC grade)

7.12 Perform a dielectric strength test as follows: (Reference Sections 9.1.2 and 9.6 of ACRI2001)

7.12.1 The test voltage shall be an alternating voltage of a substantially sinusoidal wave form at a frequency between 48 Hz and 62 Hz or a dc voltage with no more than a 3 percent peak to peak ripple. The magnitude of the ac test voltage shall be $2U_n$ + 1000 or 1500 volts rms whichever is greater. The magnitude of the dc test voltage shall be $2.83U_n$ + 1414 volts or 2121 volts, whichever is greater. U_n is the highest rated voltage of any winding under test.

7.12.2 The test voltage should be applied between all windings used to supply intrinsically safe circuits and all other windings.

7.12.3 The voltage shall be increased steadily to the specified value in a period not less than 10 seconds and then maintained for at least 60 seconds.

7.12.4 The current shall not exceed 5 milliamperes and there shall be no breakdown of the insulation between the test points during each test.

7.13 Repeat steps 7.2 to 7.12 on two additional samples of the protective transformer.

8.0 TEST DATA

8.1 Transformer Surface Temperature Test:

8.1.1 Type of transformer, 1(a), 1(b), 2(a), or 3.

8.1.2 Input voltage.

8.1.3 Temperature rating of the transformer insulation (Types 1(a), 1(b), and 3).

8.1.4 Current of primary and secondary with output loaded or shorted. State how the maximum current was obtained.

8.1.5 Surface temperature of the transformer being tested. State the placement of the thermocouple(s) on the transformer.

8.1.6 Test equipment with calibration due dates and serial numbers.

8.1.7 Manufacturer and model or type number of the protective transformer tested.

8.1.8 If change of resistance method is used, state the type of winding material, copper, aluminum, etc.

8.1.9 Room temperature before and after testing.

8.1.10 Cold resistance before and after testing.

8.1.11 Test Results. Pass/Fail

8.2 Transformer Dielectric Test:

8.2.1 Test equipment with calibration due dates and serial numbers.

8.2.2 Manufacturer and model or type number of the protective transformer tested, as appropriate.

8.2.3 Test voltage.

8.2.4 Length of time the voltage was applied.

8.2.5 The transformer winding or location in the transformer circuit where the voltage was applied.

8.2.6 Test results. Pass/Fail

9.0 PASS / FAIL CRITERIA

9.1 The transformer shall pass the dielectric strength test specified in Section 7.3 and 7.12.

9.2 Type 1(a) and Type 1(b) Transformers: The temperature rise of the transformer shall at no point exceed the temperature rating of the transformer insulation used when in continuous operation for at least 6 hours or up to the moment when the imbedded one-time thermal fuse, if any, functions.

9.3 Type 2(a) Transformer:

9.3.1 The transformer shall not burst into flames during the test.

9.3.2 The input winding or the output winding(s) may short-circuit to the core during this test, provided shorting of the output winding(s) to the core does not result in unacceptable energies in the hazardous location.

9.4 Type 3 Transformer:

The temperature rise of the transformer shall at no point exceed the temperature rating of the transformer insulation used.