# *CERTIFIED TEST REPORT*

## COOPER POWER SYSTEMS
## FOUR POSITION SECTIONALIZING
## LOADBREAK SWITCH

### 12.5 kA Momentary and Making Rating

# CERTIFICATION

*Statements made and data shown are, to the best of our knowledge and belief, correct and within the usual limits of commercial testing practice.*

***Patrick H. Pride***
***Senior Design Engineer***

***John M. Makal***
***Chief Product Engineer***

***Brian T. Steinbrecher***
***Manager, Cable Accessories Engineering***

WISCONSIN
BRIAN TODD STEINBRECHER
E-25607
MADISON
WI
PROFESSIONAL ENGINEER

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# 1. Introduction

Continuous improvement is an ongoing objective and activity of Cooper Power Systems. Design improvements are initiated to integrate new design concepts and/or new technology, support continuous improvement, help maintain product competitiveness and provide features requested by customers. Recent changes to industry standards have affected the testing requirements for load break devices mounted in fluid filled tanks. Additionally, a new dielectric fluid has been introduced and verification of switch performance in this fluid is also required.

## 1.1. Applicable Industry Standards

The four position sectionalizing switch discussed herein has been designed for applications in padmounted transformers and switchgear. No single industry standard has been published that includes the performance criteria and test regimen for both these applications. Consequently, the requirements must be drawn from industry standards applicable to both transformers and switchgear. These include:

- IEEE Std C37.71-2001 IEEE Standard for Three-Phase, Manually Operated Subsurface and Vault Load-Interrupting Switches for Alternating-Current Systems
- IEEE Std C57.12.00-2000 IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

The Switchgear Committee of the IEEE Power Engineering Society has worked to better define the test requirements and methods for products under its charge. Most significant has been the inclusion of specific inherent transient recovery voltage (TRV) levels to the load switching tests. The power system response to current interruption generates TRV. Circuits with high TRV are more difficult to interrupt. The design of the product covered in this certified test report has been fully tested to the new TRV requirements.

Additionally, the product covered in this certified test report has been fully tested in three different dielectric fluids; transformer oil, R-Temp®, and Envirotemp® FR3™. The dielectric fluid surrounding the switch serves to insulate the current carrying parts from each other and ground. It also plays a critical role in controlling and extinguishing the arcs generated during switching tests. Different fluids will vary in their reaction to arcs and this necessitates testing to insure the design compensates for these differences.

## 1.2. Additional Mechanical Tests

The regimen for design verification testing consists of tests defined by industry standards and tests defined by the manufacturer, but influenced by the safety and product reliability needs of the user. Over time, the users have expressed interest in certain tests falling within the later category of testing. The methods and procedures for these tests are not defined by industry standards, but have been developed through years of design experience and summarized in this report. These tests are included in this report and include:

- Vibration Test
- Packaging Test
- Operating Force Test
- Operating Travel Test

## 1.3. Independent Laboratories

The Industry Standard switching tests were performed by third party certified laboratories. The following accredited testing facilities were used for electrical testing:

**Thomas A. Edison Power Test Lab**
**Franksville, WI**
A2LA Laboratory Certification #: 145701

**Laboratorio de Pruebas de Equipos y Materiales (LAPEM)**
**Irapuato, Mexico**
NMX-EC-17025-1MNC-2000 number EE-012-093/03

The following report summarizes testing completed on production samples to verify that published electrical and mechanical ratings to prescribed industry standards were attained.

## 2. Scope

The family of four position sectionalizing switches of Base Part Number LS4_ _12_, covered by the testing summarized here-in can be described functionally as:

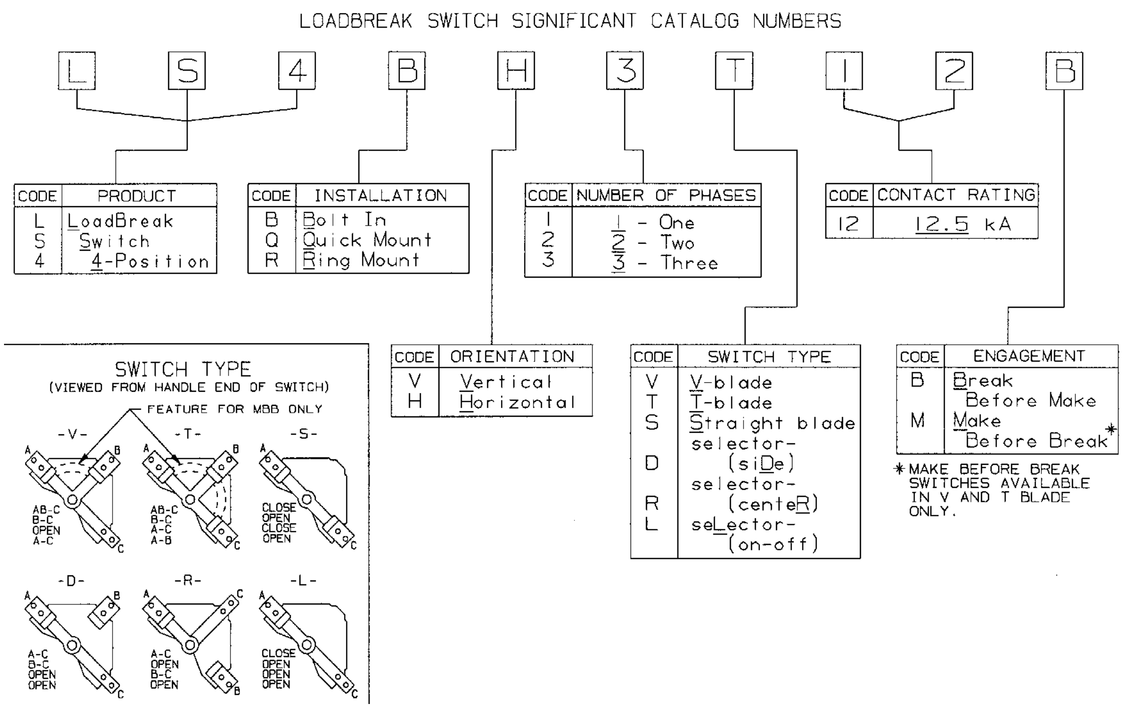
A mounting system consisting of either a self-supporting or bolt-in switch body.

An operating/actuating system common to all switch assemblies, except the stored energy increases with increasing number of decks (phases) and increasing number of contacts engaged.

A dielectric system of insulation and switch body parts common to all switch assemblies.

A current carrying system consisting of conductors (blades, terminals, etc.) of a material and cross-section common to all switch assemblies including Break-Before-Make and Make-Before-Break “V” and “T” blade type switches, and a current interchange specific to “V” and “Selector Blade” switch configurations.

The switch samples tested incorporated each of the systems described above. Combinations of systems were selected to validate the design to the most onerous application. For example, the switch configurations that include both types of current interchanges (“V” or Selector blade types) were selected for the continuous current thermal tests. The switch configurations that required the most (“T” blade type) and least (Selector blade type) force to actuate for each mechanism variation were used for the mechanical life testing. The switch configurations that impressed all arc energy across only one contact gap (“V” or Selector blade types) were used for switching tests.




Wherever possible, the preferred ratings for the switches were obtained from industry standards. The preferred ratings that most closely match the applications for the switch family are defined in Table 2 of IEEE Std C37.71-2001 for Class 1 “Tap Switch” (not to be confused with tap changer switches used to adjust the turns ratio of transformers). However, testing was completed at higher than established ratings in two significant categories:

Line 5 of Table 2 requires Continuous Load Interrupting Current to be 200A at 27kV. The switch family described herein was tested to 300A at 27kV. This value was established by interpolation when the switch was first introduced in the 1970’s and has been subsequently specified by many users.

Line 8 of Table 2 requires a Short-time Current of 10kA symmetrical at 38kV. The switch family described herein has been tested to 12.5kA symmetrical at 38kV.

A switch capable of withstanding 16kA symmetrical momentary and making currents has been fully tested per IEC 60265-1998. See Certified Test Report CP0313 for more information on this switch.

# 3. Certification Statement

Design tests conducted and the data presented in this document are in accordance with all applicable sections IEEE Std C37.71-2001. Cooper Power Systems Four Position Sectionalizing Loadbreak switches rated 600A/15kV, 300A/27kV, 200A/38kV meet or exceed all applicable requirements of the above referenced standard in accordance with the following sections of this document.

# 4. Certification Summary

## 4.1. Interrupting Current Tests

### 4.1.1. Load Current Tests

***Requirements***

IEEE C37.71-2001 clause 6.2.1 establishes the following requirements to verify that the switch is capable of closing and interrupting currents within its ratings:

**600A Switch**

| Number of Operations | | Test Current – Based on 600 Amps Continuous Current Rating |
|---|---|---|
| Closing | Opening | |
| 20 | 20 | 600 Amperes |
| 30 | 30 | 240 to 360 Amperes |
| 10 | 10 | 30 to 120 Amperes |

**300A Switch**

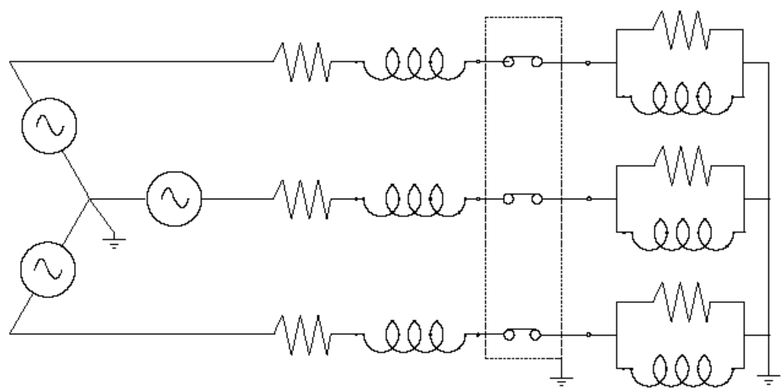
| Number of Operations | | Test Current – Based on 300 Amps Continuous Current Rating |
|---|---|---|
| Closing | Opening | |
| 20 | 20 | 300 Amperes |
| 30 | 30 | 120 to 180 Amperes |
| 10 | 10 | 15 to 60 Amperes |

**200A Switch**

| Number of Operations | | Test Current – Based on 200 Amps Continuous Current Rating |
|---|---|---|
| Closing | Opening | |
| 20 | 20 | 200 Amperes |
| 30 | 30 | 80 to 120 Amperes |
| 10 | 10 | 10 to 40 Amperes |

***Procedures***

Test set-up and methods were per IEEE C37.71-2001 clause 6.2.1. All testing was performed using three phase versions of the switch. A different switch sample was used for each test series table described above. Switch samples were horizontally mounted in a 95-gallon test tank and immersed in fluid. Switch mounting was performed in accordance with recommended mounting practices published in Cooper Power Systems Installation Instructions S800-64-2. A travel trace device was attached to the rear shaft to monitor contact position during switching. Voltage (potential) Transformers were employed to monitor arcing voltage, re-strikes and switch clearing time. Current Transformers were located to record load current in each phase. The test circuit was loaded to provide a load power factor of 70% to 80% lagging, and to obtain the required TRV (Transient Recovery Voltage). The following test circuit was used:



After completion of the tests on each switch, the fluid was pumped from the tank and reserved for reuse on future tests on the sample. No filtering of the fluid was done.

***Test Results***

| Number of Close/Open Operations and Breaking Current (avg.) | Test Voltage (min – max) | TRV Peak Voltage and Time (avg.) | Fluid |
|---|---|---|---|
| 20 C/O At 638 A<br>30 C/O At 331 A<br>10 C/O At 63 A | 15.65-15.97 kV<br>15.63-15.74 kV<br>15.65-15.74 kV | 4.3 kV<br>137 μs | Transformer Oil |
| 21 C/O At 644 A<br>30 C/O At 334 A<br>10 C/O At 59 A | 15.75-15.89 kV<br>15.70-15.93 kV<br>15.66-16.15 kV | 4.19 kV<br>141.35 μs | R-Temp |
| 21 C/O At 639 A<br>30 C/O At 333 A<br>10 C/O At 59 A | 15.50-15.68 kV<br>15.73-15.89 kV<br>15.62-15.74 kV | 4.19 kV<br>141.35 μs | EFR3 |
| 24 C/O At 307 A<br>30 C/O At 157 A<br>10 C/O At 50 A | 28.15-28.50 kV<br>27.88-28.09 kV<br>27.97-28.24 kV | 9.95 kV<br>288.34 μs | Transformer Oil |
| 23 C/O At 307 A<br>32 C/O At 157 A<br>10 C/O At 50 A | 28.15-28.50 kV<br>27.88-28.09 kV<br>27.97-28.24 kV | 9.95 kV<br>288.34 μs | R-Temp |
| 22 C/O At 305 A<br>30 C/O At 156 A<br>10 C/O At 50 A | 27.7-28.5 kV<br>27.9-28.1 kV<br>27.9-28.2 kV | 8.97 kV<br>270.52 μs | EFR3 |
| 21 C/O At 204 A<br>30 C/O At 102 A<br>11 C/O At 29 A | 38.0-38.4 kV<br>38.1-38.6 kV<br>38.1-38.7 kV | 15.56 kV<br>409.62 μs | Transformer Oil |
| 21 C/O At 207 A<br>30 C/O At 103 A<br>10 C/O At 30 A | 38.3-39.4 kV<br>38.4-38.7 kV<br>38.2-38.6 kV | 16.14 kV<br>406.34 μs | R-Temp |
| 23 C/O At 205 A<br>30 C/O At 103 A<br>10 C/O At 30 A | 38.1-38.7 kV<br>38.4-38.8 kV<br>38.3-38.5 kV | 16.14 kV<br>406.34 μs | EFR3 |

### 4.1.2. Magnetizing Current Tests

***Requirements***

IEEE C37.71-2001 clause 6.2.2 establishes the following requirements to verify that the switch is capable of closing and interrupting currents present when switching highly inductive loads such as motors or transformers.

**15.5 kV Switch Rating**

| Number of Operations | | Test Current – Based on 15.5 kV Switch Rating |
|---|---|---|
| **Closing** | **Opening** | |
| 10 | 10 | 21 Amperes |

**27.0 kV Switch Rating**

| Number of Operations | | Test Current – Based on 27.0 kV[(1)] Switch Rating |
|---|---|---|
| **Closing** | **Opening** | |
| 10 | 10 | 10.5 Amperes |

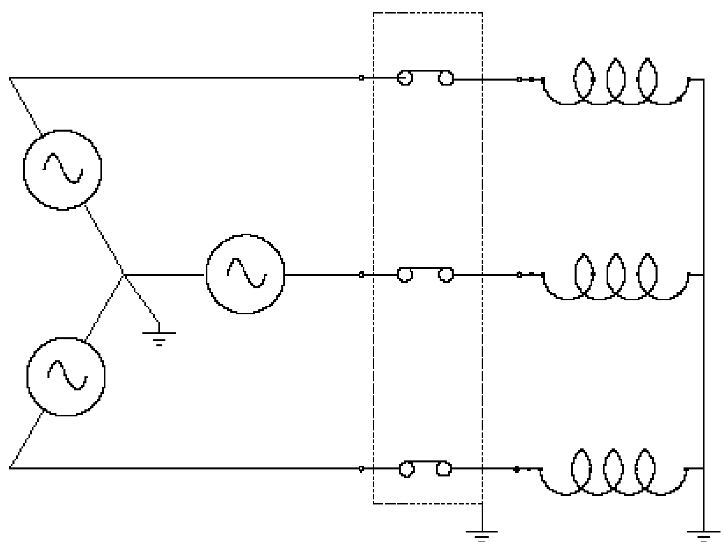
Note 1: For a continuous current rating of 300A, the Magnetizing current was derived by interpolation.

**38.0 kV Switch Rating**

| Number of Operations | | Test Current – Based on 38.0 kV Switch Rating |
|---|---|---|
| Closing | Opening | |
| 10 | 10 | 7 Amperes |

***Procedures***

Test set-up and methods were per IEEE C37.71-2001 clause 6.2.2. All testing was performed using the switch samples, test tanks, and fluid from Load Current switch testing. A travel trace device was attached to the rear shaft to monitor contact position during switching. Voltage (potential) Transformers were employed to monitor arcing voltage, re-strikes and switch clearing time. The test circuit was loaded to provide a load power factor of 5% to 10% lagging. The following test circuit was used:



***Test Results***

| Number of Close/Open Operations and Breaking Current (avg.) | Test Voltage (min – max) | Fluid |
|---|---|---|
| 10 C/O at 21.2 A | 15.9-16.7 kV | Transformer Oil |
| 10 C/O at 21.17 A | 15.76-15.95 kV | R-Temp |
| 10 C/O at 21.16 A | 15.77-15.87 kV | EFR3 |
| 12 C/O at 11.5 A | 27.85-27.97 kV | Transformer Oil |
| 13 C/O at 11.5 A | 27.85-27.97 kV | R-Temp |
| 10 C/O at 11.7 A | 28.0-28.2 kV | EFR3 |
| 11 C/O at 7.7 A | 37.6-38.6 kV | Transformer Oil |
| 15 C/O at 7.9 A | 38.3-39.5 kV | R-Temp |
| 11 C/O at 7.6 A | 38.0-38.4 kV | EFR3 |

### 4.1.3. Cable Charging Current Tests

***Requirements***

IEEE C37.71-2001 clause 6.2.3 establishes the following requirements to verify that the switch is capable of closing and interrupting currents present when switching highly capacitive loads such as underground distribution cable.

**15.5kV Switch Rating**

| **Number of Operations** | | **Test Current – Based on 15.5 kV Switch Rating** |
|---|---|---|
| **Closing** | **Opening** | |
| 10 | 10 | 10 Amperes |

**27.0kV Switch Rating**

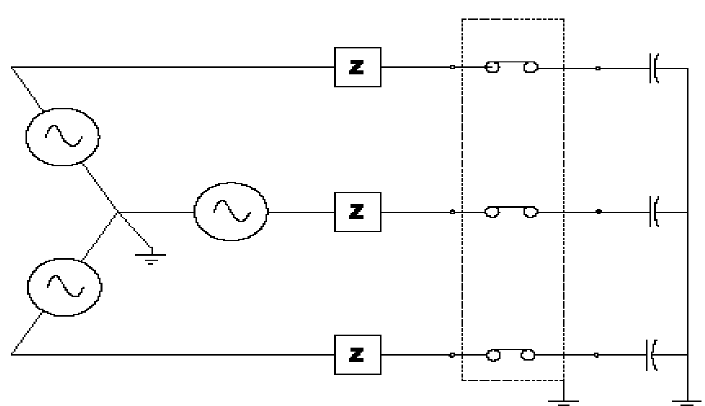
| **Number of Operations** | | **Test Current – Based on 27.0 kV Switch Rating** |
|---|---|---|
| **Closing** | **Opening** | |
| 10 | 10 | 25 Amperes |

**38.0 kV Switch Rating**

| **Number of Operations** | | **Test Current – Based on 38.0 kV Switch Rating** |
|---|---|---|
| **Closing** | **Opening** | |
| 10 | 10 | 40 Amperes |

***Procedures***

Test set-up and methods were per IEEE C37.71-2001 clause 6.2.3. All testing was performed using the switch samples, test tanks, and fluid from Load Current switch testing. A travel trace device was attached to the rear shaft to monitor contact position during switching. Voltage (potential) Transformers were employed to monitor arcing voltage, re-strikes and switch clearing time. A capacitor bank was used to load the test circuit. The following test circuit was used:



***Test Results***

| Number of Close/Open Operations and Breaking Current (avg.) | Test Voltage (min – max) | Fluid |
| --- | --- | --- |
| 20 C/O at 10.3 A | 15.5-15.8 kV | Transformer Oil |
| 20 C/O at 10.26 A | 15.57-15.71 kV | R-Temp |
| 20 C/O at 10.25 A | 15.53-15.73 kV | EFR3 |
| 20 C/O at 25.3 A | 27.87-28.15 kV | Transformer Oil |
| 20 C/O at 25.3 A | 27.98-28.19 kV | R-Temp |
| 20 C/O at 25.3 A | 28.0-28.3 kV | EFR3 |
| 20 C/O at 40.8 A | 38.2-38.4 kV | Transformer Oil |
| 20 C/O at 41 A | 38.2-38.3 kV | R-Temp |
| 20 C/O at 41 A | 38.2-38.4 kV | EFR3 |

## 4.2. Momentary Current Tests

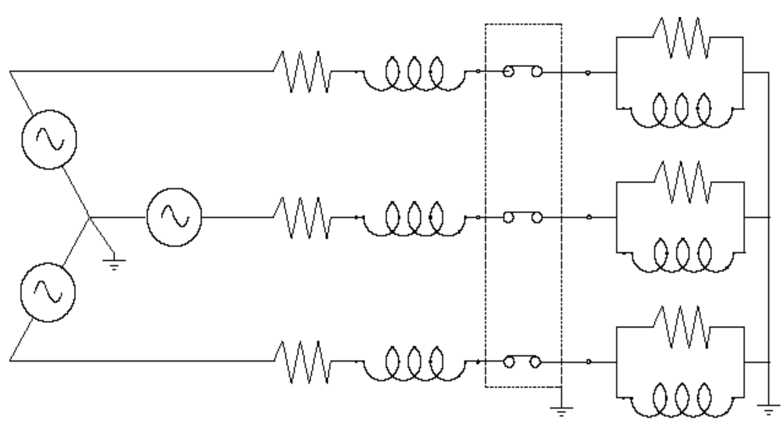
***Requirements***

IEEE C37.71-2001 clause 6.3.1 establishes the following requirements to verify that the switch is capable of withstanding through fault currents that may be present during down stream recloser operation. Three sets of three periods of current flow, with 10 seconds (+/-1) between each period, and 10 minutes between each set are required. Test voltage is required to be 50 volts minimum.

| Switch Rating | Test Current and Duration |
| --- | --- |
| 15.5 kV | 12 kA rms Sym., 18.6 kA rms Asym., 31.2 kA peak, 10 Cycles |
| 27.0 kV | 12 kA rms Sym., 18.6 kA rms Asym., 31.2 kA peak, 10 Cycles |
| 38.0 kV | 10 kA rms Sym., 15.5 kA rms Asym., 26.0 kA peak, 10 Cycles |

***Procedures***

Test set-up and methods were per IEEE C37.71-2001 clause 6.3.1. After Interrupting Tests and prior to Momentary Tests, each switch was operated de-energized for fifty close-open operations. All testing was performed using the switch samples, test tanks, and fluid from Interrupting Current switch testing. The following test circuit was used:



***Test Results***

| No. of Operations | Test Voltage | Tested Values * | | Fluid |
|---|---|---|---|---|
| | | rms Sym | rms Asym | |
| 9 | 5.8 kV | 12.50-16.0 kA | 21.7-23.2 kA | Transformer Oil |
| 9 | 5.9 kV | 12.50-15.69 kA | 21.91-23.10 kA | R-Temp |
| 9 | 5.9 kV | 12.64-16.15 kA | 21.84-23.04 kA | EFR3 |
| 9 | 5.8 kV | 12.50-15.64 kA | 20.33-22.14 kA | Transformer Oil |
| 9 | 5.8 kV | 12.50-15.70 kA | 20.18-21.63 kA | R-Temp |
| 9 | 5.8 kV | 12.57-16.06 kA | 22.3-23.0 kA | EFR3 |
| 9 | 5.8 kV | 12.66-15.96 kA | 21.4-23.3 kA | Transformer Oil |
| 9 | 5.8 kV | 12.50-15.68 kA | 22.58-22.71 kA | R-Temp |
| 9 | 5.8 kV | 12.50-15.50 kA | 20.84-22.23 kA | EFR3 |

***** Values of 12,500 A rms Sym. and 19,375 A rms Asym. were targeted as minimums in order to demonstrate the ability of the switch to withstand the slightly higher current specified in IEC 60265-1998.

## 4.3. Making Current Tests

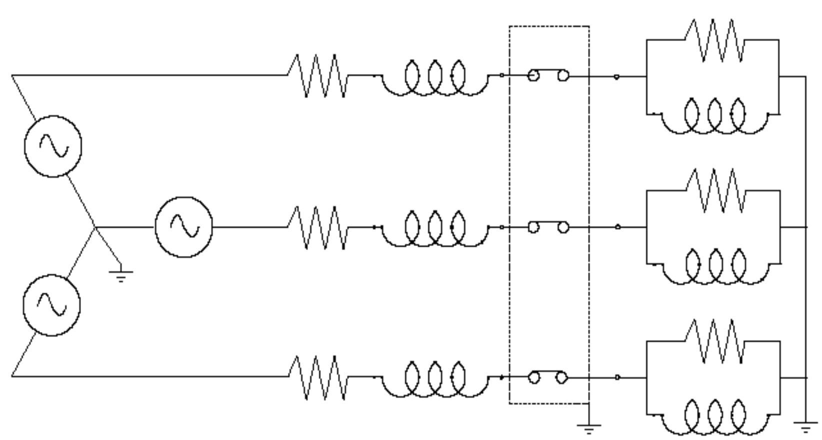
***Requirements***

IEEE C37.71-2001 clause 6.3.2 establishes the following requirements to verify that the switch is capable of closing into a faulted circuit. Three operations are required with a minimum duration of 10 cycles each.

| Switch Rating | Test Current |
|---|---|
| 15.5 kV | 12 kA rms Sym., 18.6 kA rms Asym, 31.2 kA peak |
| 27.0 kV | 12 kA rms Sym., 18.6 kA rms Asym, 31.2 kA peak |
| 38.0 kV | 10 kA rms Sym., 15.5 kA rms Asym., 26.0 kA peak |

***Procedures***

Test set-up and methods were per IEEE C37.71-2001 clause 6.3.2. All testing was performed using the switch samples, test tanks, and fluid from Interrupting and Momentary Current switch testing. The following test circuit was used:



***Test Results***

| No. of Operations | Minimum Cycles of Operation Duration | Test Voltage | Tested Current Value * | Fluid |
|---|---|---|---|---|
| 3 | 10 | 15.80 kV | 12.54 kA | Transformer Oil |
| 3 | 10 | 15.63 kV | 12.53 kA | R-Temp |
| 3 | 10 | 15.63 kV | 12.53 kA | EFR3 |
| 3 | 10 | 28.16 kV | 12.60 kA | Transformer Oil |
| 3 | 10 | 28.16 kV | 12.60 kA | R-Temp |
| 3 | 10 | 28.03 kV | 12.62 kA | EFR3 |
| 3 | 10 | 38.15 kV | 12.58 kA | Transformer Oil |
| 3 | 10 | 38.15 kV | 12.58 kA | R-Temp |
| 3 | 10 | 38.15 kV | 12.58 kA | EFR3 |

***** Values of 12,500 A rms Sym. and 19,375 A rms Asym. were targeted as minimums in order to demonstrate the ability of the switch to withstand the slightly higher current specified in IEC 60265-1998.

## 4.4. AC Withstand Tests

***Requirements***

IEEE C37.71-2001 Table 1, column 3 defines the withstand test voltage requirements to verify the low frequency dielectric capabilities of the design.

| Switch Rating | 4.4.1 New Switch Sample Test Voltage | 4.4.2 Aged Switch Sample Test Voltage |
|---|---|---|
| 15.5 kV | 35 kV rms | 34 kV rms |
| 27.0 kV | 60 kV rms | 40 kV rms |
| 38.0 kV | 70 kV rms | 50 kV rms |

***Procedures***

4.4.1

Test set-up and methods were per IEEE C37.71-2001 clause 6.4.5. Samples were tested prior to any aging tests in clean fluid and then again after switching tests. Each sample was tested with the contacts open and with the contacts closed. The tank was grounded for all tests. When the contacts were closed the A and C phases (the front and back deck) were energized and the B phase (the center deck) was grounded. Voltage was applied for one minute. When the contacts were open, one side of the switch had contacts A and C energized and contact B grounded, and the other side had A and C grounded with B energized. Again, the voltage was applied for one minute.

4.4.2

After completing the switching tests detailed in Section 4.1, 50 additional close-open operations, the momentary current tests detailed in Section 4.2 and the making tests per Section 4.3, the applied voltage tests described above were repeated. While the standards allowed for the test voltage to be reduced for the aged switch samples, the tests were conducted to the higher test voltages required for new switch samples. The same fluid used in the switching, momentary and making tests was also used for these tests.

***Test Results***

4.4.1

| Phase-to Earth Test Voltage | Phase-to-Phase Test Voltage | Across Open Contacts Test Voltage | Across Isolating Distance Test Voltage |
|---|---|---|---|
| 70.2 kV rms | 70.2 kV rms | 70.2 kV rms | 70.2 kV rms |

4.4.2

All switch samples successfully passed the 50 open/close operations test.

| Switch Rating | Tested Value | Fluid |
|---|---|---|
| 15.5 kV | 35 kV | Transformer Oil |
| | 60 kV | R-Temp |
| | 60 kV | EFR3 |
| 27.0 kV | 60 kV | Transformer Oil |
| | 60 kV | R-Temp |
| | 60 kV | EFR3 |
| 38.0 kV | 70 kV | Transformer Oil |
| | 70 kV | R-Temp |
| | 70 kV | EFR3 |

## 4.5. Thermal Tests

***Requirements***

IEEE C37.71-2001 clauses 5.3.1 and 5.3.2 establish the temperature rise limits for testing of new samples. Clause 6.5.5 further requires “aged” switch samples to operate at continuous rated current and a stable contact temperature after being subjected to the interrupting, momentary current, and making current switch testing.

***Procedures***

Test conditions and procedures were per IEEE C37.71-2001 clause 6.5. Samples were mounted into a fluid-filled tank, following recommended installation practices. Thermocouples were added to the incoming cable, the termination connection, the incoming stationary contact, the switchblade, the outgoing terminal, the outgoing termination connection and the outgoing lead. Thermocouples were also placed in the oil 2” below the current carrying members and in the ambient air. For new switch samples, Table 4 of standard IEEE C37.71 defines the continuous current temperature rise limits of current carrying parts. Successful completion of the test requires the temperature rise to stabilize at a value below those published in the table.

For aged switch samples there are no temperature rise constraints specified by the standards. Rather, successful completion of the test requires the temperature rise to stabilize. A stable temperature is defined as no change in temperature for three consecutive readings at 30-minute intervals.

***Test Results – Continuous Current – New Switch Samples***

| | Contact Temp Rise | Blade Temp Rise | Terminal Temp Rise | Fluid |
|---|---|---|---|---|
| Rise over top oil | 8.3°C | 7.0°C | 0.8°C | Transformer Oil |
| Rise over ambient | 34.1°C | 32.8°C | 26.6°C | |

Current was 630 Amperes.

***Test Results – Thermal Runaway – Aged Switch Samples***

| Contact Temp Rise | Connection Temp Rise | Terminal Temp Rise | Fluid |
|---|---|---|---|
| 7.3°C | 8.8°C | 4.0°C | Transformer Oil |
| 12.8°C | 15.3°C | 8.7°C | R-Temp |
| 9.4°C | 8.9°C | 4.7°C | EFR3 |
| 9.1°C | 8.8°C | 4.1°C | Transformer Oil |
| 13.6°C | 13.7°C | 7.3°C | R-Temp |
| 10.3°C | 10.3°C | 4.1°C | EFR3 |
| 8.3°C | 9.1°C | 4.5°C | Transformer Oil |
| 11.1°C | 13.7°C | 7.4°C | R-Temp |
| 13.2°C | 13.2°C | 6.4°C | EFR3 |

All switches stabilized within 24 hours. Current was 630 Amperes. Temperature rises shown are over top oil temperature.

## 4.6. Mechanical Operations Tests

***Requirements***

IEEE C37.71-2001 clause 6.6 requires the switch sample to withstand 200 opening and closing operations without maintenance or replacement of any parts or components. It is performed after completion of the thermal runaway test, which in turn is done after completion of all other electrical and mechanical aging tests.

After completion, the switch should be capable of carrying rated current as evidenced by resistance measurements. The maximum resistance allowed in Cooper Power Systems internal production process is 240 micro-ohms. The switch must also be capable of passing the 60 Hertz Withstand voltage in Table, column 4. The 15.5 kV class switches require a withstand of 34 kV, the 27 kV class require 40 kV and the 38 kV require 50 kV.

***Procedures***

Test conditions and procedures were per IEEE C37.71-2001 clause 6.6. The same procedure as in Section 4.4 was employed.

***Test Results***

All switches were operated deenergized for 200 open-close operations. All switches subsequently passed AC Withstand and Resistance tests.

| Switch Rating | Current Interchange Resistance (Maximum) | AC Withstand Tested Voltage | Fluid |
|---|---|---|---|
| 15.5 kV | 89 micro-ohms | 60.2 kV * | Transformer Oil |
| | 139 micro-ohms | 60.2 kV * | R-Temp |
| | 127 micro-ohms | 60.2 kV * | EFR3 |
| 27.0 kV | 136 micro-ohms | 60.2 kV * | Transformer Oil |
| | 190 micro-ohms | 60.2 kV * | R-Temp |
| | 88 micro-ohms | 60.2 kV * | EFR3 |
| 38.0 kV | 133 micro-ohms | 60.2 kV | Transformer Oil |
| | 102 micro-ohms | 60.2 kV | R-Temp |
| | 158 micro-ohms | 60.2 kV | EFR3 |

* All switches were tested to the required value for a 38 kV switch.

## 4.7. Impulse Withstand Tests

***Requirements***

IEEE C37.71-2001 Table 1, column 2 defines the 1.2 x 50 microsecond waveform withstand test voltage requirements to verify the high frequency dielectric capabilities of the design. Additionally, IEEE C57.12.00 – 2000 Table 5 defines the chopped wave withstand test voltage requirements.

| Switch Rating | 1.2 x 50μ Sec Peak Test Voltage | Chopped Wave Peak Test Voltage |
|---|---|---|
| 15.5 kV | 95 kV rms | 110 kV rms |
| 27.0 kV | 125 kV rms | 145 kV rms |
| 38.0 kV | 150 kV rms | 175 kV rms |

***Procedures***

Test set-up and methods were per IEEE C37.71-2001 clause 6.4. Samples were tested prior to aging tests in clean fluid. Each sample was tested with the contacts open and with the contacts closed. The tank was grounded for all tests. With the contacts open, voltage was applied to contacts A and C phases (first and third deck) on one side of the switch, with B phase (second deck) grounded. On the other side of the switch, A and C contacts were grounded and voltage was applied to B. Three positive polarity and three negative polarity impulses were applied.

With the contacts closed, voltage was applied to A and C phases with the B phase grounded and the tank and the switch mechanism grounded. Three positive polarity and three negative polarity impulses were applied.

All models of the switch share the same dielectric design features (materials, spacing, etc.). Consequently the design was verified to its highest rating and testing conducted at this rating only.

***Test Results***

| 1.2 x 50μ Sec Tested Value | Chopped Wave Tested Value | Fluid |
|---|---|---|
| 169.6 kV | 196.0 | Transformer Oil |

## 4.8. DC Withstand Tests

***Requirements***

IEEE C37.71-2001 Table 1, column 5 defines the withstand test voltage requirements to verify that the switch is capable of withstanding the DC test voltages that may be applied to installed cable systems.

| Switch Rating | Test Voltage |
|---|---|
| 15.5 kV | 53 kV |
| 27.0 kV | 78 kV |
| 38.0 kV | 103 kV |

***Procedures***

Test set-up and methods were per IEEE C37.71-2001 clause 6.8. Test voltage was applied and held for 15 minutes at 103 kV. The test tank was grounded, as was the switch stored energy mechanism. Three separate tests were done:

1) With the contacts open, one side of the switch was energized with the contacts on the other side grounded.
2) With the contacts open, A and C phases (first and third deck) on one side of the switch and B phase (second deck) on the other side were energized with all the other contacts grounded.
3) With the contacts closed, A and C phases were energized and B phase grounded.

All models of the switch share the same dielectric design features (materials, spacing, etc.). Consequently the design was verified to its highest rating and testing conducted at this rating only.

***Test Results***

| Tested Value | Fluid |
|---|---|
| 103 kV | Transformer Oil |

## 4.9. One-second Current Test

***Requirements***

IEEE C37.71-2001 clause 6.3.3 requires the switch to withstand a single current carrying test of a minimum of one-second duration at the rated momentary current level of 12.0 kA. After completion, the switch must be operable and capable of carrying rated current (630A) within rated temperature maximum of 75°C.

***Procedures***

Leads were connected to wire the A, B, and C phase together in series. With the contacts in the closed position, 12,500 amperes of current were passed through the circuit for one second. A value of 12,500 A was used in order to demonstrate the ability of the switch to withstand the slightly higher current specified in IEC 60265-1998. A two-second duration was used to satisfy a specific user request.

***Results***

| Test Voltage | Current Duration | Momentary Test Current | Heat Run Current | Switch Max Temp | Fluid |
|---|---|---|---|---|---|
| 240 V | 2 sec | 12,740 A | 630 A | 59.4°C | Transformer Oil |

At the conclusion of the test, the switch was operated 200 times mechanically and subjected to a heat run to ensure that the current carrying ratings were not affected.

## 4.10. Pressure Test

***Requirements***

IEEE C37.71-2001 clause 6.9 requires that the switch samples maintain its tank seal and remain operable after being subjected to positive and negative tank pressures. Further, the product standards for padmounted transformers (IEEE C57.12.22-1993, IEEE C57.12.25-1990, and IEEE C57.12.26-1992) require the tank to remained sealed through an operating pressure range of -7 psig to +12 psig. The bottom of this range is established by calculating the internal tank pressure when the fluid temperature is -5°C. The cracking pressure of the pressure relief device established the top of this range.

***Procedure***

Samples of the Bolt-in, Ring Mount and Quick Mount switches were installed into tanks in the horizontal position using recommended mounting procedure. Internal tank pressures of -15 psig and +15 psig were used. Soap solutions, chalk and observations for liquids leaking from shafts or gasketed surface were used to determine seal integrity. Switches were operated while the tanks were at pressure extremes and after the pressure was relieved to check for any untoward effects of the pressurization.

***Results***

There was no sign of leakage. Switches operated normally during positive and negative tank pressure extremes and after the pressures were relieved.

## 4.11. Vibration Test

***Requirements***

The industry standards for HV switches do not define test requirements for vibration testing. However, utilizing methods developed for military and automotive applications, a procedure has been developed to test the product at frequencies and accelerations that can be anticipated as well as identifying and testing at the product's resonant frequency. The switch has been designed for horizontal mounting in a fluid filled tank. After installation in the tank, it must survive the forces associated with handling and shipping that tank.

***Procedures***

A switch sample with Quick Mount mounting system was installed in a 18"H x 12"W x 22"D test tank. Accelerometers were mounted on the switch shaft and 2-pound weights were secured to each of the switch terminals. The tank was filled with water and sealed. The tank and switch were secured to a vibration table and a series of accelerations applied. Upon completion of the tests, the tank seal was pressure tested to 15 psig, the switch tested for mechanical operation and visually inspected.

Sine Sweep Test – Input vertical acceleration of 0.5 g (g= 32.16 ft/sec$^2$) at frequencies from 5 Hz through 60 Hz to determine the resonant (highest output acceleration) frequency.

Resonant Frequency Endurance Test – Using the resonant frequency vibration test at the following accelerations and durations:

| Input Acceleration | Duration |
|---|---|
| 0.5 g | 100,000 cycles |
| 0.75 g | 100,000 cycles |
| 1.0 g | 100,000 cycles |

High Frequency Endurance Test – The following frequencies, accelerations and durations were used:

| Input Acceleration | Frequency | Duration |
|---|---|---|
| 0.5 g | 120 Hz | 2,000,000 cycles |
| 0.5 g | 240 Hz | 2,000,000 cycles |
| 0.5 g | 360 Hz | 2,000,000 cycles |

***Results***

The resonant frequency was found to be 33 Hz. After all testing was completed, the tank was pressure tested at 15 psig for 24 hours and no leaks were found. The switch sample was mechanically tested and visually inspected and no anomalies were found. Test results are documented in test report AA-02-055-4G and Datasyst Engineering and Testing Services Project Report C115-10497.

## 4.12. Packaging Test

***Requirements***

The industry standards do not include this test regimen. However, these switches will be supplied to transformer manufacturers throughout the world. Consequently, the switch must be packaged to survive shipment to these manufacturers.

***Procedure***

A three phase, Quick Mount, Selector blade switch assembly and packaged hardware (handle, mounting nut, gasket, etc.) were packaged at the production facility and sent to Great Northern Corporation (GNC) for vibration, handling, and drop testing. The tests were conducted in accordance with ISTA (International Safe Transit Association) procedure 1A for packaged products weighing 68 kg or less.

***Results***

The entire assembly, including packaged handle hardware was tested at GNC's ISTA certified lab and passed the test regimen with no signs of damage. Test results are documented in test report AA-03-017-4T.

## 4.13. Operating Force Test

***Requirements***

The industry standards do not include these test regimens. Cooper Power Systems has developed internal requirements that the switch must require less than 25 foot-pounds (34 N m) of torque to move from one position to the next.

***Procedure***

One sample each of three phase Selector Blade, V-Blade, and T-Blade switches were horizontally mounted in an empty test tank using published installation instructions. A specially designed socket was placed over the operating handle. Torque was applied and measured with a digital recording torque wrench. Operating forces were checked while operating the switch as slowly as possible and also as rapidly as possible.

***Results***

When operated very slowly, the switch requires 18 to 28 foot-pounds (24 to 38 Newton-meters) of torque, which is well within normal ergonomic limits. When operated at a higher speed typical of that observed when utility personnel operate the switch, the operating force falls to 15 to 25 foot-pounds (20 to 34 Newton-meters).

## 4.14. Operating Travel Test

***Requirements***

The industry standards do not include this test regimen. Cooper Power Systems has established specifications that require that the switch must move from one position to the next with less than a 135° rotation.

***Procedure***

Using the same test set-up and a sample from the Operating Force Test, a protractor was centered on the tank wall used to mount he switch. As the switch was operated, the angular displacement needed to cause actuation was noted and recorded.

***Results***

The switch typically requires 115° to 125° to switch from one position to the next.





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**Cooper Industries**
P.O. Box 1640, Waukesha, WI 53187

# REVISION TABLE

| REVISION NO. | DATE | WHAT WAS ADDED/CHANGED |
|---|---|---|
| 1 | 12/3/04 | Section 4.6 Mechanical Operations Tests, changed milli-ohms to micro-ohms in text and table |