CERTIFIED TEST REPORT

COOPER POWER SYSTEMS
FOUR POSITION SECTIONALIZING LOADBREAK SWITCH

16 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.

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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 of these applications. Consequently, the requirements must be drawn from industry standards applicable to both transformers and switchgear. These include:

- IEC 60265-1 (R1998) High-voltage Switches – Part 1: Switches for rated voltages above 1 kV and less than 52 kV
- IEC 60694 (R1996 + A1: 2000 and A2: 2001): Common specifications for high-voltage switchgear and controlgear standards
- IEC 76-3 (R2000): Power Transformers – Part 3: Insulation Levels and Dielectric Tests
- IEEE Std C57.12.00-2000: IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

The industry standards have evolved to include specific inherent transient recovery voltage (TRV) levels for 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 meet these specified TRV requirements.

Additionally, the product covered in this certified test report has been fully tested at 15 and 24 kV in three different dielectric fluids; mineral oil, R-Temp®, and Envirotemp® FR3™; and tested at 38 kV only in mineral oil. 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. The following tests fall into this category:

- 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 and the results were published in certified test reports. 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-IMNC-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. Certified Test Reports are referenced in each section and available upon request.

2. Scope

The family of four position sectionalizing switches of Base Part Number LS4____16_, covered by the testing summarized herein can be described functionally as:

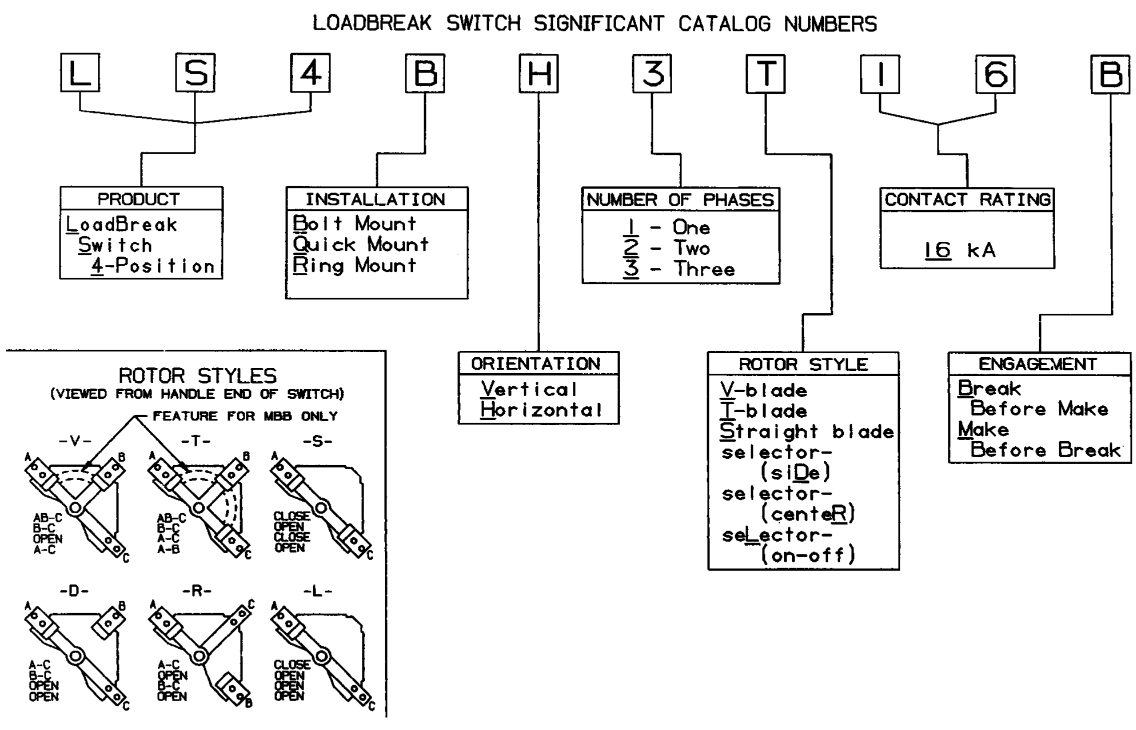
A mounting system consisting of either a self-supporting or bolt-in switch body.

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 configuration with the most current interchanges was selected for the continuous current thermal tests ("V" blade type). The switch configurations that required the most and least force to actuate for each mechanism variation were used for the mechanical life testing. The switch configuration that impressed all arc energy across only one contact gap was used for switching tests (typically Selector blade type).



For convenience of testing, the type tests were grouped per IEC 60694 (R2001) into the following categories:

Group 1 – Switching Tests
Group 2 – Short-time and Peak Withstand Current and Thermal Tests
Group 3 – Dielectric Tests
Group 4 – Mechanical Tests
Group 5 – Other Tests

The ratings for the switches discussed in this test report were obtained from preferred ratings defined by industry standards and user requests. Except where noted otherwise, testing was conducted with test levels, duration, and procedures as defined in IEC 60691 (R2001) and IEC 60265-1 (R1998) for the following general ratings:

Category:	Mechanical Class M2, Electrical Class E1 General Purpose Switches
Short Circuit Current:	16kA
Continuous Current/Voltage Rating:	630A/15kV, 400A/24kV, 200A/36kV

3. Certification Statement

Design tests conducted and the data presented in this document are in accordance with all applicable sections of IEC 60694, 60691, and 60265-1 standards pertaining to 16kA and 200A/36kV Mechanical Class M2, Electrical Class E1 General Purpose Switches. Cooper Power Systems LS4 Type switches rated 630A/15kV, 400A/24kV, and 200A/36kV meet or exceed all applicable requirements of the above referenced standards in accordance with the following sections of the documents.

4. Certification Summary

4.1. Switching Tests

4.1.1. Mainly Active Load Breaking Tests (Test Duty 1)

Requirements

IEC 60265-1 clause 6.101 and Table 5 establish the following requirements for an Electrical Class E1 General Purpose switch to verify that the switch is capable of closing and interrupting currents within its ratings:

630A, 15kV Switch

Number of Operations		Test Current	TRV Peak/Time
Closing	Opening		
10	10	630 Amperes	25.7kV/72μs
20	20	31.5 Amperes	25.7kV/72μs

400A, 24kV Switch

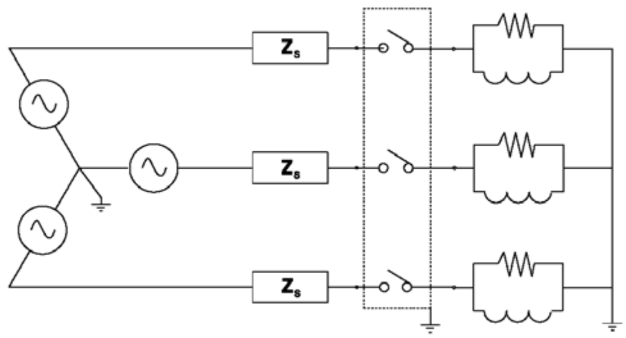
Number of Operations		Test Current	TRV Peak/Time
Closing	Opening		
10	10	400 Amperes	41kV/88μs
20	20	20 Amperes	41kV/88μs

200A, 36kV Switch

Number of Operations		Test Current	TRV Peak/Time
Closing	Opening		
10	10	200 Amperes	62kV/108μs
20	20	10 Amperes	62kV/108μs

Procedures

Test set-up and methods were per IEC 60265-1 clause 6.101. 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 published installation instructions. A travel trace device was attached to the rear shaft to monitor contact position during switching. Voltage 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 75-80% lagging, and to obtain the required TRV (Transient Recovery Voltage). The source frequency was 60 Hz. 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 same switch sample. No filtering of the fluid was done.

Test Results

All samples successfully passed the switching tests.

Number of Close/Open Operations and Breaking Current (avg)	Test Voltage (min – max)	TRV Peak Voltage and Time (avg)	Fluid	CTR Reference #
20 C/O at 638 A 20 C/O at 32.4 A	16.03 – 16.12 kV 15.79 – 15.92 kV	26.6 kV 62 µs	Transformer Oil	SCL-03-086
20 C/O at 643 A 20 C/O at 33.9 A	16.23 – 16.31 kV 15.70 – 16.00 kV	26.6 kV 62 µs	R-Temp	SCL-03-086
20 C/O at 634 A 20 C/O at 33.0 A	15.77 – 15.88 kV 15.53 – 15.66 kV	28.8 kV 63 µs	EFR3	SCL-03-042
20 C/O at 411 A 21 C/O at 22.0 A	24.90 – 25.20 kV 25.40 – 25.70 kV	42.0 kV 87 µs	Transformer Oil	SCL-02-079
20 C/O at 413 A 21 C/O at 22.0 A	24.50 – 25.40 kV 25.00 – 25.70 kV	42.0 kV 87 µs	R-Temp	SCL-02-079
20 C/O at 417 A 20 C/O at 20.4 A	24.99 – 25.33 kV 24.96 – 25.13 kV	42.0 kV 87 µs	EFR3	SCL-03-033
20 C/O at 202 A 40 C/O at 25.7-27.1 A	39.0 – 39.2 kV 39.1 – 39.7 kV	65.0 kV 105 µs	Mineral Oil	SCL-02-062

The current readings recorded above were taken immediately prior to switch interruption. The voltage readings recorded above were taken immediately after interruption.

IEC 60265-1 requires only 10 close/open operations. Note that a minimum of 20 close/open operations was performed at 100% current. Per IEC 60265-1 clause 6.101.9 Note 1, the Closed-loop Distribution Circuit Switching tests (test duty 2a) are not required when 10 additional operations are conducted on Electrical Class E1 switches.

4.1.2. Capacitive Circuit Switching Tests (Test Duty 4a and 4b)

Requirements

IEC 60265-1 clause 6.101.8.4 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 and overhead distribution lines. Three separate tests are required: cable charging at 100% of the specified current, cable charging at 20% to 40% of the specified current, and line charging. The current levels are defined in Table 1 of the Standard.

630A, 15 kV Switch

Number of Operations		Test Current (A)
Closing	Opening	
10	10	10
10	10	2 – 4
10	10	1

400A, 24 kV Switch

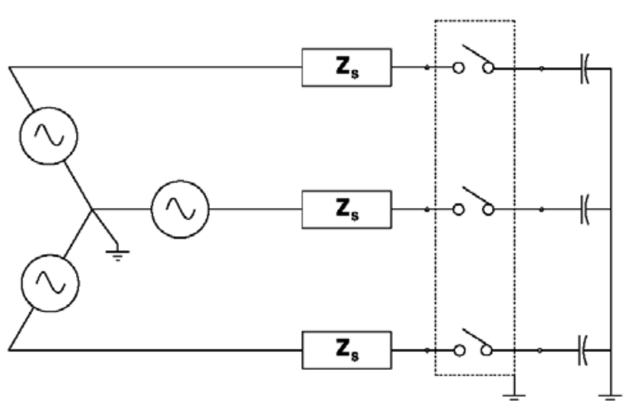
Number of Operations		Test Current (A)
Closing	Opening	
10	10	16
10	10	3.6 – 7.2
10	10	1.5

200A, 36 kV Switch

Number of Operations		Test Current (A)
Closing	Opening	
10	10	20
10	10	4 – 8
10	10	2.0

Procedures

Test set-up and methods were per IEC 60265-1. All testing was performed using the switch samples, test tanks, and fluid from Mainly Active Load Current switch testing. Switch samples were horizontally mounted per published installation instructions. A travel trace device was attached to the rear shaft to monitor contact position during switching. Voltage Transformers were employed to monitor arcing voltage, re-strikes and switch clearing time. The close and open operations were randomly timed relative to source voltage. The source frequency was 60Hz. The following test circuit was used:



Test Results

All samples successfully passed the switching tests.

100% Cable Charging Tested Value	20% - 40% Cable Charging Tested Value	Line Charging Tested Value	Fluid	CTR Reference #
11 C/O at 10.5 A	11 C/O at 3.1 A	11 C/O at 1.0 A	Mineral Oil	SCL-03-086
11 C/O at 10.5 A	11 C/O at 3.1 A	11 C/O at 1.0 A	R-Temp	SCL-03-086
10 C/O at 10.1 A	10 C/O at 3.0 A	10 C/O at 1.0 A	EFR3	SCL-03-042
10 C/O at 17.2 A	10 C/O at 4.7 A	10 C/O at 1.5 A	Mineral Oil	SCL-02-079
10 C/O at 17.1 A	10 C/O at 4.7 A	10 C/O at 1.5 A	R-Temp	SCL-02-079
10 C/O at 17.4 A	11 C/O at 4.8 A	10 C/O at 1.6 A	EFR3	SCL-03-033
10 C/O at 25.7 A	10 C/O at 6.0 A	10 C/O at 2.0 A	Mineral Oil	SCL-02-062

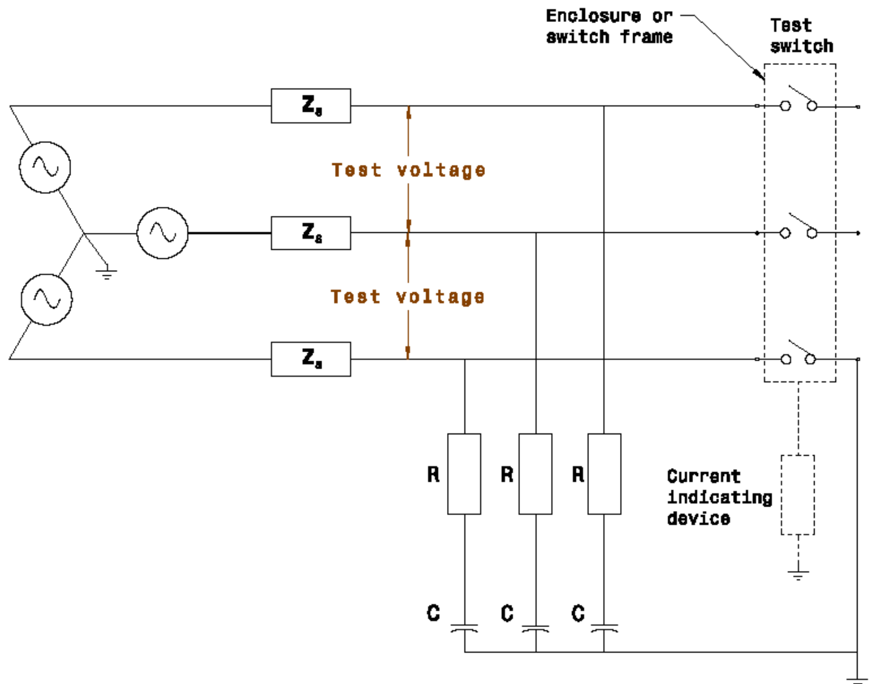
4.1.3. Earth Fault Switching Tests (Test Duty 6a)

Requirements

This switch has been designed for use on systems with isolated neutrals. IEC 60265-1 clauses 1.101 and 6.101.8.6 require the breaking current be determined when the switch is operated during a phase-to-earth fault on one phase. Isolated neutral systems have a high impedance circuit path for earth fault currents, resulting in very low currents. The standards do not specify a required minimum value for I_{6a} and this test establishes the rating of the switch for the specified fault condition.

Procedures

Test set-up and methods were per IEC 60265-1 clause 6.101.8.5 and Figure 8. All testing was performed using the switch samples, test tanks, and fluid from Mainly Active Load Current and Capacitive Current switch testing. Switch samples were mounted horizontally per published installation instructions. A travel trace device was attached to the rear shaft to monitor contact position during switching. Voltage transformers were employed to monitor arcing voltage, re-strikes and switch clearing time. The close and open operations were randomly timed relative to source voltage. The source frequency was 60Hz. The following test circuit was used:



Test Results

All samples successfully passed the switching tests.

Number of Operations and Breaking Current (min – max)	Test Voltage (min – max)	Fluid	CTR Reference #
10 C/O at 0.88 – 0.89 A	15.90 – 15.98 kV	Mineral Oil	SCL-03-086
10 C/O at 0.88 – 0.89 A	15.91 – 15.96 kV	R-Temp	SCL-03-086
10 C/O at 1.41 – 1.45 A	15.52 – 15.66 kV	EFR3	SCL-03-042
10 C/O at 10.3 – 10.4 A	24.20 – 24.70 kV	Mineral Oil	SCL-02-079
10 C/O at 10.3 – 10.4 A	24.20 – 24.50 kV	R-Temp	SCL-02-079
10 C/O at 30.3 – 31.0 A	24.90 – 25.56 kV	EFR3	SCL-03-033
10 C/O at 7.6 – 8.6 A	38.0 – 39.4 kV	Mineral Oil	SCL-02-062

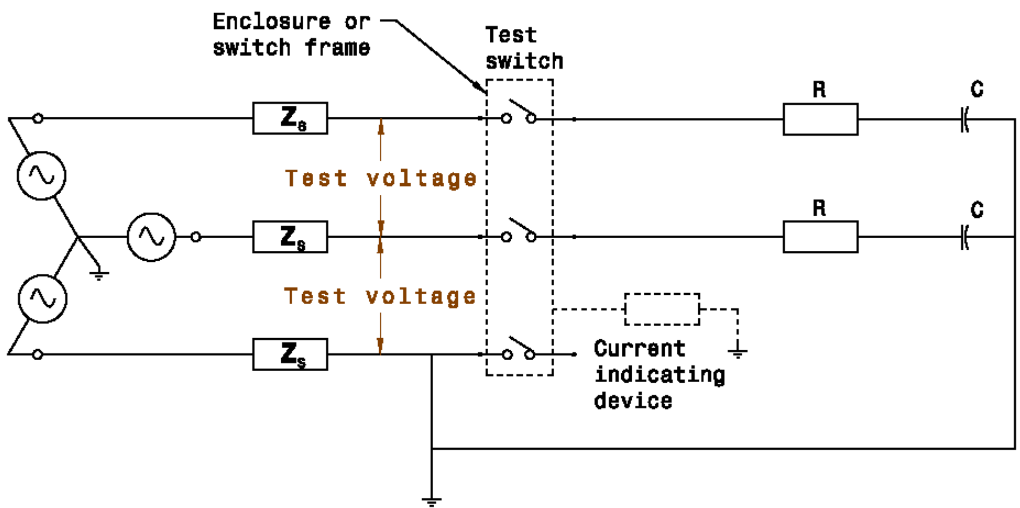
4.1.4. Cable and Line-charging Current Under Earth Fault Tests (Test Duty 6b)

Requirements

This switch has been designed for use on systems with isolated neutrals. IEC 60265-1 clauses 1.101 and 6.101.8.6 require the breaking current be determined when the switch is operated during a downstream phase-to-phase fault on underground cables. Isolated neutral systems have a high impedance circuit path for earth fault currents, resulting in very low currents. The standards do not specify a required minimum value for I_{6b} and this test establishes the rating of the switch for the specified fault condition.

Procedures

Test set-up and methods were per IEC 60265-1 clause 6.101.8.6 and Figure 9. All testing was performed using the switch samples, test tanks, and fluid from Mainly Active Load Current and Capacitive Current switch testing. Switch samples were mounted horizontally per published installation instructions. A travel trace device was attached to the rear shaft to monitor contact position during switching. Voltage transformers were employed to monitor arcing voltage, re-strikes and switch clearing time. The close and open operations were randomly timed relative to source voltage. The source frequency was 60Hz. The following test circuit was used:



Test Results

All samples successfully passed the switching tests.

Number of Operations and Breaking Current (min – max)	Test Voltage (min – max)	Fluid	CTR Reference #
11 C/O at 18.22 – 18.39 A	16.13 – 16.44 kV	Mineral Oil	SCL-03-086
14 C/O at 18.29 – 18.49 A	16.22 – 16.50 kV	R-Temp	SCL-03-086
10 C/O at 17.55 – 17.68 A	15.94 – 16.05 kV	EFR3	SCL-03-042
10 C/O at 17.0 A min.	24.9 kV min.	Mineral Oil	SCL-02-079
10 C/O at 17.0 A min.	24.9 kV min.	R-Temp	SCL-02-079
10 C/O at 2.07 – 2.26 A	24.90 – 25.27 kV	EFR3	SCL-03-033
10 C/O at 25.7 – 27.1 A	39.1 kV min.	Mineral Oil	SCL-02-062

4.1.5. Short-time Withstand Current and Peak Withstand Current Tests

Requirements

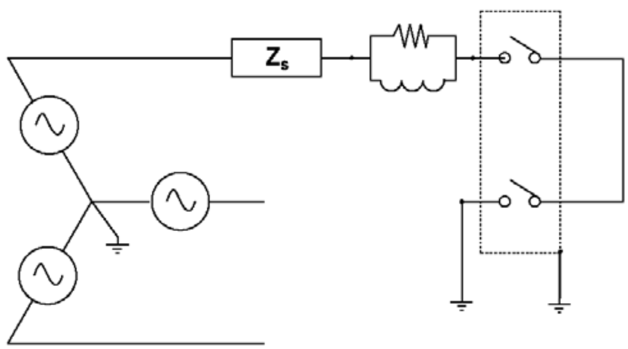
IEC 60265-1 clause 6.6 establishes the requirement to verify that the switch is capable of withstanding the high currents encountered when the system experiences a down stream fault while the switch is in the closed position. IEC

60694 clause 4.7 establishes the duration of the short circuit to be 1 second. The magnitude of the short circuit current is as follows:

Switch Rating	Test Current	Duration	Energy
All LS4_16	16 kA rms sym./41.6kA peak	1 second	256×10^6 A^2s

Procedures

Test set-up and methods were per IEC 60694 clause 6.6. All testing was performed using new switch samples. Switch samples were mounted horizontally per published installation instructions. Testing was conducted with the switch contacts in the closed position using a single-phase source with two phases connected in series. The source frequency was 60Hz. The following test circuit was used:



Test Results

All samples successfully passed the test. No contact welding or separation was observed, and contact resistance did not increase beyond 20% of initial. The switches all subsequently carried rated current of 630A with a maximum temperature rise over ambient oil temperature of 35°C. The tested values were:

Test Current	Test Voltage	Duration	Energy	CTR’s
16.03 kA rms sym.	35.4 V	2.05 seconds	527×10^6 A^2s	AA01 030 2B 3A 4D
13.56 kA rms sym.	206 V	3.04 seconds	553×10^6 A^2s	AA02 036 2B 3A
18.54 kA rms sym.	273 V	1.03 seconds	354×10^6 A^2s	AA03 006 3A 6D
20.59 kA rms sym.	45 V	1.03 seconds	438×10^6 A^2s	AA04 025 3A 4D 6D

4.1.6. Short-circuit Making Current Tests

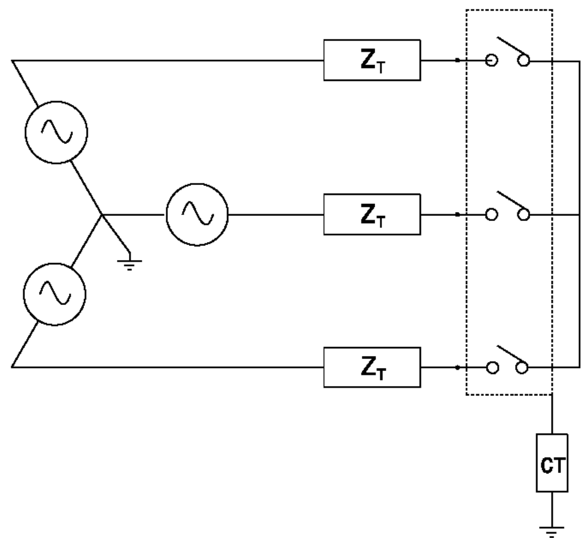
Requirements

IEC 60265-1 establishes the following requirements to verify that the switch is capable of closing into a faulted circuit. Two operations are required with a minimum duration of 0.2 seconds (12 cycles) each. The minimum magnitude of the short circuit voltage and currents are as follows:

Switch Rating	Test Current
15 kV	16 kA rms sym./41.6kA peak
24 kV	16 kA rms sym./41.6kA peak
36 kV	16 kA rms sym./41.6kA peak

Procedures

Test set-up and methods were per IEC 60265-1 clause 6.101.7 and 6.101.10. All testing was performed using the switch samples, test tanks, and fluid from Mainly Active Load Current and Capacitive Current switch testing. Switch samples were mounted horizontally using published installation instructions. The source frequency was 60Hz. The maximum peak current was obtained from current transformer readings. The following test circuit was used:



Test Results

Each sample was subjected to two operations.

Test Current (RMS)	Test Current (max peak)	Line-to-Ground Test Voltage	Line-to-Line Test Voltage (RMS)	Fluid	CTR Reference #
16.24 kA	43.87 – 45.61 kA	8.81 – 9.20 kV	15.78 kV	Mineral Oil	AP 034-02
				R-Temp	AP 034-02
				EFR3	AP 008-03
16.07 kA	43.23 – 45.61 kA	13.88 – 14.15 kV	28.13 kV	Mineral Oil	AP 034-02
				R-Temp	AP 034-02
				EFR3	AP 008-03
16.52 kA	50.48 – 53.02 kA	21.79 – 22.28 kV	38.50 kV	Mineral Oil	AP 034-02

Condition of Switch Samples After Completion of All Switching Tests

Upon completion of all switching tests, the samples were visually inspected for contact wear and the switches mechanically operated to insure all mechanisms were in proper working order. The insulation properties were verified by application of a power frequency withstand test as described below. Additionally, the samples were subjected to Thermal testing to insure the contact temperatures stabilized.

Based upon the above criteria, all switch samples successfully passed switching tests.

4.2. Dielectric Tests

4.2.1. Power Frequency Withstand Tests

Requirements

IEC 60265-1 and IEC 60694 Table 1a, 1b, and Annex F define the withstand test voltage requirements to verify the low frequency dielectric capabilities of the design. The dielectric components of the switch have been designed for use on both solidly earthed and other than solidly earthed systems through 38 kV. Consequently, the design must be tested to its highest rating.

Switch Rating	Across Open Contacts Test Voltage*	Across Isolating Distance Test Voltage*
36 kV	70 kV rms	80 kV rms

* ± 3% allowable tolerance per IEC 60694, D.2.3.1.

Procedures

Test set-up and methods were per IEC 60694 and IEC 60060-1. Samples were tested prior to any aging tests in clean fluid. Each sample was tested with the contacts open and with the contacts closed. The tank was earthed 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 earthed. Voltage was applied at 60 Hz for one minute. Polarities on decks were reversed and the test repeated. When the contacts were open, one side of the switch had contacts A and C energized and contact B earthed, and the other side had A and C earthed with B energized. Again, the voltage was applied at 60 Hz for one minute. Polarities on decks were reversed and the test repeated.

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

All samples successfully passed this test.

Phase-to-Earth Test Voltage	Between Phases Test Voltage	Across Open Contacts Test Voltage	Across Isolating Distance Test Voltage	CTR #
43.9 kV rms	43.9 kV rms	69.1 kV rms	79.5 kV rms	AA01-031-1D1E-1F

4.2.2. Impulse Withstand Tests

Requirements

IEC 60694 Table 1a and 1b defines the 1.2 x 50 microsecond waveform withstand test voltage requirements to verify the high frequency dielectric capabilities of the design. Additionally, the IEC and ANSI/IEEE transformer standards require chopped wave impulse testing. Of these two standards, the ANSI/IEEE requirement is deemed more severe because the peak value must be 1.15 times the peak value of the 1.2 x 50 waveform. The requirement for time to flashover was also taken from the ANSI/IEEE standards (1μs to 3μs). The dielectric components of the switch have been designed for use on both solidly earthed and other than solidly earthed systems through 36 kV. Consequently, the design must be tested to its highest rating.

Rated Voltage (Range I, Series I)	Common Value (kV Peak) *	Across the Isolating Distance (kV Peak) *
36.0 kV	170kV	195 kV

* ± 3% allowable tolerance per IEC 60694, D.2.3.1.

Procedures

Test set-up and methods were per IEC 60265-1 and IEC 60694 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 earthed 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) earthed. On the other side of the switch, A and C contacts were earthed 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 earthed and the tank and the switch mechanism earthed. 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

All samples successfully passed this test.

1.2 x 50μ Sec Wave		Chopped Wave		Fluid	CTR Reference #
Common Value (kV Peak)	Across the Isolating Distance (kV Peak)	Common Value (kV Peak)	Across the Isolating Distance (kV Peak)		
169.7 kV Pos 169.6 kV Neg	195.9 kV Pos 193.4 kV Neg	196.0 kV Pos 196.7 kV Neg	224.5 kV Pos 225.0 kV Neg	Mineral Oil	AA01-031-1D1E-1F

4.3. Thermal Tests

Requirements

IEC 60265-1 and IEC 60694 establish the temperature rise limits for the current carrying parts of new samples in Table 3. Note that the LS4____16_ switches use silver-coated parts and that switches are used in fluid, for determinations of allowed temperatures.

Contact Temperature Maximum	Contact Temperature Rise Maximum	Connection Temperature Maximum	Connection Temperature Rise Maximum	Terminal Temperature Maximum	Terminal Temperature Rise Maximum
90°C	50°K	100°C	60°K	105°C	65°K

Procedures

Test conditions and procedures were per IEC 60694 clause 6.5. Sample was 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 stationary contact, the outgoing termination connection and the outgoing lead. Thermocouples were also placed in the oil 50 mm below the current carrying members and in the ambient air. For new switch samples, Table 3 of standard IEC 60694 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.

Test Results

Temperatures were recorded on the incoming and outgoing conductors.

Contact Temp Rise	Connection Temp Rise	Terminal Temp Rise	Fluid	CTR Reference #
27.4°C, 31.5°C	36.0°C, 36.4°C	30.0°C, 31.4°C	Mineral Oil	AA-01-030-2B-3A-4D

4.4. Mechanical Tests

4.4.1. Mechanical Operations Test

Requirements

IEC 60265-1 clause 6.102 requires the switches designated Mechanical Class M2 to withstand 5000 opening and closing operations without maintenance or replacement of any parts or components.

After completion, all parts of the switch shall be in good condition and shall not show excessive wear.

Procedures

Test conditions and procedures were per IEC 60265-1 clause 6.102 for Mechanical Class M2 switches. No maintenance or lubrication was performed during the tests.

Test Results

All samples successfully completed 5000 operation mechanical operation testing. Resistance measurements stabilized below 200 micro-ohms, and operating torque remained under 27 Nm.

Current Interchange Resistance	AC Withstand Tested Voltage	Operating Torque	CTR Reference #
200 micro-ohm max	70 kV	25.1 Nm Open 25.0 Nm Close	AA01-030-2B-3A-4D

4.4.2. Pressure Test

Requirements

IEC 60265-1 and IEC 60694 require that the switch sample maintain its tank seal and remain operable after being subjected to tank pressure extremes. Further, the standards for transformers require the tank to remain sealed through an operating pressure range of -50 kPa to +80 kPa. The bottom of this range is established by calculating the internal tank pressure when the fluid temperature is -5°C. The top of this range was established by the cracking pressure of the pressure relief device.

Procedure

Samples of the Bolt-in, Ring Mount and Quick Mount switches were installed into tanks in the horizontal position using recommended mounting. Internal tank pressures of -100 kPa and +100 kPa 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.

4.5. Other Tests

4.5.1. 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 450 mm high x 300 mm wide x 550 mm deep test tank. Accelerometers were mounted on the switch shaft and 0.9 kg 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 100 kPa, the switch tested for mechanical operation and visually inspected.

Sine Sweep Test – Input vertical acceleration of 0.5 g (g = 9.8 m/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 at the following accelerations and durations:

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 100 kPa 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. Datasyst has A2LA and ISO 17025 Certification pending.

4.5.2. 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, Quickmount, 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.

4.5.3. 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 34 Nm of torque to move from one position to the next.

Procedure

One sample each of a three phase Selector Blade, V-Blade, and T-Blade was 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 24 to 38 Nm of torque, which is well within normal ergonomic limits. When operated at a higher speed typical of that observed when the switch is operated by utility personnel, the operating force falls to 20 to 34 Nm.

4.5.4. 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 the 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.

Quality from
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REVISION TABLE

REVISION NO.	DATE	WHAT WAS ADDED/CHANGED
1	10/12/04	Added 20 kA short circuit rating
2	12/3/04	Section 4.4 Mechanical Tests, changed milli-ohms to micro-ohms in text and table