CERTIFIED TEST REPORT

Cooper Power Systems

15.2/26.3 kV 200A

POSI-BREAK™

Loadbreak Connector System

Elbow - PLE225

Cap - PLPC225

Cooper Power Systems

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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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INTRODUCTION

This report details the results of Cooper's "two times rated line-to-ground partial vacuum switching test" performed on the 25 kV 200A POSI-BREAK loadbreak elbow, PLE225, and insulated protective cap, PLPC225. Also included are the results of field trials conducted to demonstrate that POSI-BREAK elbows and caps can be switched without a flashover to ground.

BACKGROUND

Users have reported occasional line-to-ground flashovers when separating loadbreak elbows and insulated protective caps on circuits with little or no load current. The cause of most of these flashovers has been attributed to what has been called the partial vacuum effect. Partial vacuum flashovers can be identified by tick marks at the back end of the probe. The flashovers occur along the 200A interface extending from the energized semiconductive insert and/or the back of the probe to the grounded semiconductive collar below the bushing shoulder.

A partial vacuum is created along the mating interfaces when separating loadbreak connectors. The partial vacuum substantially reduces the withstand voltage along the 200A interface during the first one inch of travel of the connector. The reduction of dielectric strength of air as the pressure drops is governed by Paschen's Law. Both the loadbreak elbow and insulated protective cap experience the partial vacuum effect. A partial vacuum is created in both the cuff and nosepiece clearance regions at each end of the 200A interface. The partial vacuum developed in these regions is approximately 50% to 20% of an atmosphere.

Information gathered from utilities indicates that the flashover rate due to the partial vacuum effect is greater at the higher system voltages, at colder ambient temperatures and when the connector is in a stuck condition. Separable connectors become more difficult to operate or stuck at lower temperatures and when the grease on the 200A interface has aged. Flashovers due to the partial vacuum effect typically occur under low or no load current conditions. A great majority of switching operations are performed at little or no load current during sectionalizing procedures. Data also indicates that insulated protective caps are more likely to flashover than elbows. The reason for the difference in the failure rate between caps and elbows is not fully understood. Analysis of field failures and high speed videos of flashovers have established that partial vacuum induced flashovers occur at the time when the elbow or cap has been withdrawn approximately 0.4 inches from the bushing. In summary, the flashover rate is primarily dependent on both the system voltage and the force required to separate the interfaces.

Elevated peak transient voltages can occur when switching elbow connectors resulting in an increase in the voltage stress across the 200 amp interface. During a field switching test conducted with Wisconsin Public Service (WPS) on a 14.4 kV unloaded circuit outside of Rhinelander, Wisconsin, a maximum peak transient voltage of 41 kV was measured. The 41 kV is approximately two times the peak of the rms system voltage (2 x (1.414 x 14.4 kV) = 40.7 kV).

Cooper has developed a test to insure that a loadbreak elbow and an insulated protective cap have the capability of being switched successfully without a flashover under conditions that simulate the most adverse conditions in the field. The connectors are separated at an elevated line-to-ground voltage with no load current, in a stuck condition at a low ambient temperature. The stuck or high operating force condition is created by assembling the connectors with no grease and switching them at -20^{o}C. The test procedure is similar to the procedure that Elastimold has proposed at industry meetings. The one significant difference is the test voltage. Elastimold has proposed that both 25 kV and 35 kV class products be tested at 27.5 kV line-to-ground. Cooper has proposed that the 15 kV, 25 kV and 35 kV class connectors be tested at two times rated line-to-ground voltage. The multiplier of two was selected based on the maximum voltage recorded during the field switching tests conducted at WPS. The test voltage for the 25 kV class connectors is, therefore, 30 kV (2 x 15.2). This test is referred to as the “partial vacuum switching” test. The test requirements and procedure have been submitted to the ANSI working group that is preparing the next revision to the IEEE 386 Standard.

The POSI-BREAK design enhancements improve the voltage withstand characteristics along the 200A interface during the initial two inches of travel. This improvement is achieved by increasing the strike distance from the energized components in the elbow and insulated cap and ground. The strike distance has been increased by adding a layer of insulation to the exposed surfaces at the back end of the probe and the semiconductive insert in the elbow and cap. The elbows and caps with the POSI-BREAK enhancements maintain all of the existing specified performance requirements including interchangeability with all vintages of bushings. Section views of the POSI-BREAK elbow, PLE225, and insulated cap, PLPC225, are shown in Figures 1 and 2 respectively.

PARTIAL VACUUM SWITCHING TEST

Object

To demonstrate that the POSI-BREAK loadbreak elbow, PLE225, and insulated protective cap, PLPC225, are capable of performing an opening operation under high operating force, low temperature, elevated voltage and zero load current conditions without a flashover to ground.

Procedure

- Assemble 12 loadbreak elbows, PLE225, and 12 insulated protective caps, PLPC225, to bushing inserts, LBI225, at an ambient temperature of 25°C ± 5°C without applying lubrication to the 200 amp operating interfaces.
- Chill the connector assemblies in a cold chamber at -20°C to -25°C for a minimum of 16 hours.
- Remove a connector assembly from the cold chamber and mount it to a grounded test stand. Attach ground leads to the external shields of the connectors. Adjacent grounded connector assemblies shall not be installed.
- Energize the bushing and the elbow, when applicable, to 30 kV line-to-ground.
- Separate the elbow or insulated protective cap from the bushing within 10 minutes after removal from the cold chamber.
- The opening operation shall be performed with a positive continuous motion applied by a mechanical switching actuator. The force is applied to the operating eye of the connector using a hook attachment from a typical live-line tool. The actuator shall separate the connectors at 35-40 in/sec during the initial 1.5” of travel and 80-90 in/sec thereafter.
- Repeat this procedure to test POSI-BREAK elbows, PLE225, and insulated protective caps, PLPC225, assembled to Elastimold’s non-vented bushing inserts, 2701A4.

Test Circuit

See Figure 3 for the test circuit parameters.

Acceptance Criteria

Twelve consecutive POSI-BREAK PLE225, elbows and PLPC225, insulated protective caps shall withstand one opening operation when assembled to Cooper and Elastimold bushing inserts under the specified “Partial Vacuum Switching Test” conditions without arcing to ground.

Results

TABLE 1

PARTIAL VACUUM SWITCHING TEST				
Connector	Bushing Insert	Test Voltage (kV)	Quantity Tested	% Pass
Elbow PLE225	LBI225	30	24	100
Elbow PLE225	2701A4	30	12	100
Cap PLPC225	LBI225	30	12	100
Cap PLPC225	2701A4	30	12	100

FIELD TRIALS

Object

Field trials were conducted to demonstrate the effectiveness of the POSI-BREAK design enhancements in preventing switching flashovers by operating the PLE225 elbows and PLPC225 caps in the field at relatively low ambient temperatures.

Procedure

The trials were conducted during the winter months of 1997-1998 at four locations. Two of the trials were conducted in partnership with Wisconsin Electric Power Company (WEPCO). The third trial was conducted by Missoula Electric in Montana. The fourth trial was conducted at Cooper's Edison Technical Center (ETC) in Franksville, Wisconsin. See Table 2 for a summary of the results of the field trials.

The first WEPCO site was in an undeveloped subdivision in Waterford, Wisconsin. The circuit consisted of a 14.4 kV loop with eight 1-phase feedthru padmounted transformers. POSI-BREAK elbows and caps were mated with Cooper bushing inserts, LBI225, and Cooper rotatable feedthru inserts, 2637881C01M. The connectors were installed and the circuit energized on 11/11/97. Nine caps and 16 elbows were switched on seven different occasions at this location from 11/25/97 to 3/10/98. The temperatures of the switching dates ranged from -5°F to +39°F. No flashovers occurred.

The second WEPCO site was in an industrial park in New Berlin, Wisconsin. The circuit consisted of a 14.4 kV loop with both 1-phase and 3-phase feedthru padmounted transformers. Switching flashovers attributed to the partial vacuum effect had previously occurred on this circuit. Fifteen pre-installed elbows were replaced with POSI-BREAK elbows on 2/13/98. The elbows were switched on 3/5/98 at an ambient temperature of 31°F with no flashovers.

The third trial was conducted by Missoula Electric on a test circuit set-up specifically for evaluating the POSI-BREAK elbows and caps at their Seeley Lake substation. As a control, standard caps and elbows installed adjacent to the POSI-BREAK parts were also switched. The caps and elbows were switched at varying intervals of 1, 2, 3 and 4 weeks. Switching operations were conducted on six separate occasions from 1/21/98 to 3/6/98. No flashovers of the POSI-BREAK samples occurred, but a standard cap did flashover during the last switching sequence on 3/6/98.

A fourth trial was conducted on the outdoor 14.4 kV circuit at the ETC. This circuit consists of 2-way and 4-way junctions mounted in padmounted enclosures connected in both loop and radial configurations. Lengths of unloaded cable ranging from 12 feet to 3000 feet were switched on this circuit. The cable is a jacketed #1 solid aluminum with 280 mil TRXLPE insulation. Flashovers of standard caps had been recorded on this circuit during previous tests. POSI-BREAK elbows and caps were switched on three different occasions from January to March of 1998 with ambient temperatures ranging from 27°F to 35°F. No flashovers occurred.

Results:

TABLE 2

FIELD TRIALS - WINTER 1997-1998					
Company / Location	System Voltage (kV_{L-G})	PLE225 Elbows Tested	% Pass	PLPC225 Caps Tested	% Pass
WEPCO Waterford	14.4	113	100	60	100
WEPCO New Berlin	14.4	15	100	None Installed	---
Missoula Seeley Lake	14.4	11	100	12	100
ETC Franksville	14.4	38	100	45	100
Total		177	100	117	100

Conclusion:

The Cooper Power Systems 25 kV 200A POSI-BREAK PLE225, loadbreak elbow and PLPC225, insulated protective cap have successfully demonstrated the capability of switching under the conditions of the 30 kV partial vacuum switching test and during 14.4 kV field trials without a flashover to ground. The PLE225 and PLPC225 have also demonstrated interchangeability with the standard non-vented Elastimold bushing insert, 2701A4.

FIGURE 1
25 kV Class, 200A
POSI-BREAK Elbow

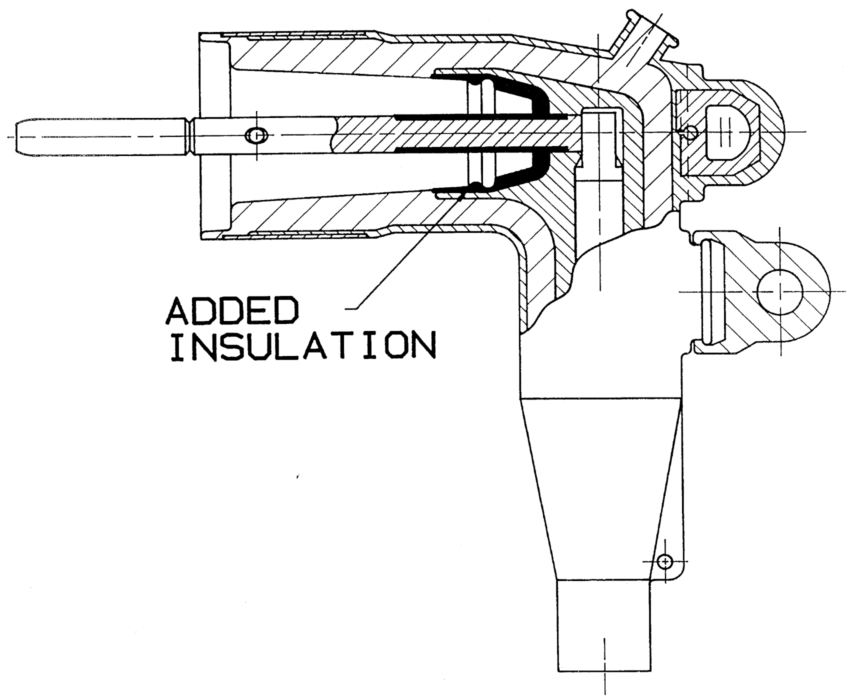


FIGURE 2
25 kV Class, 200A
POSI-BREAK Cap

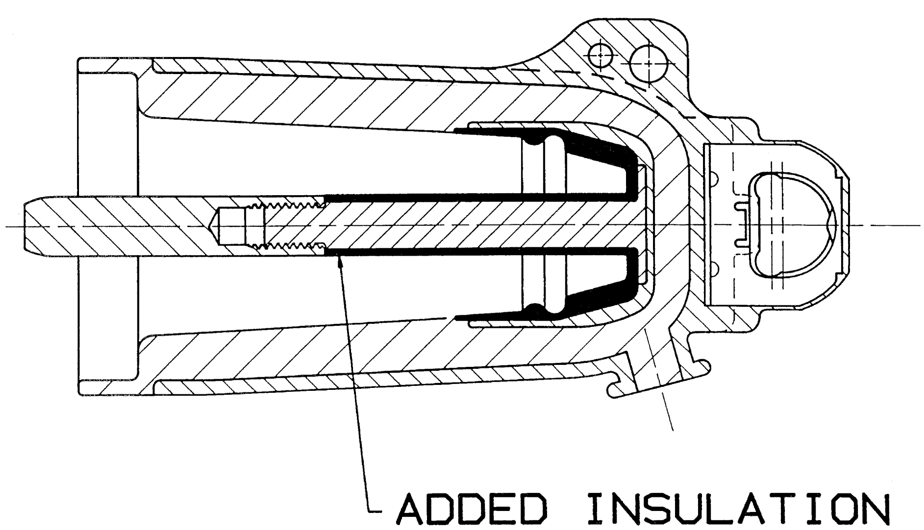
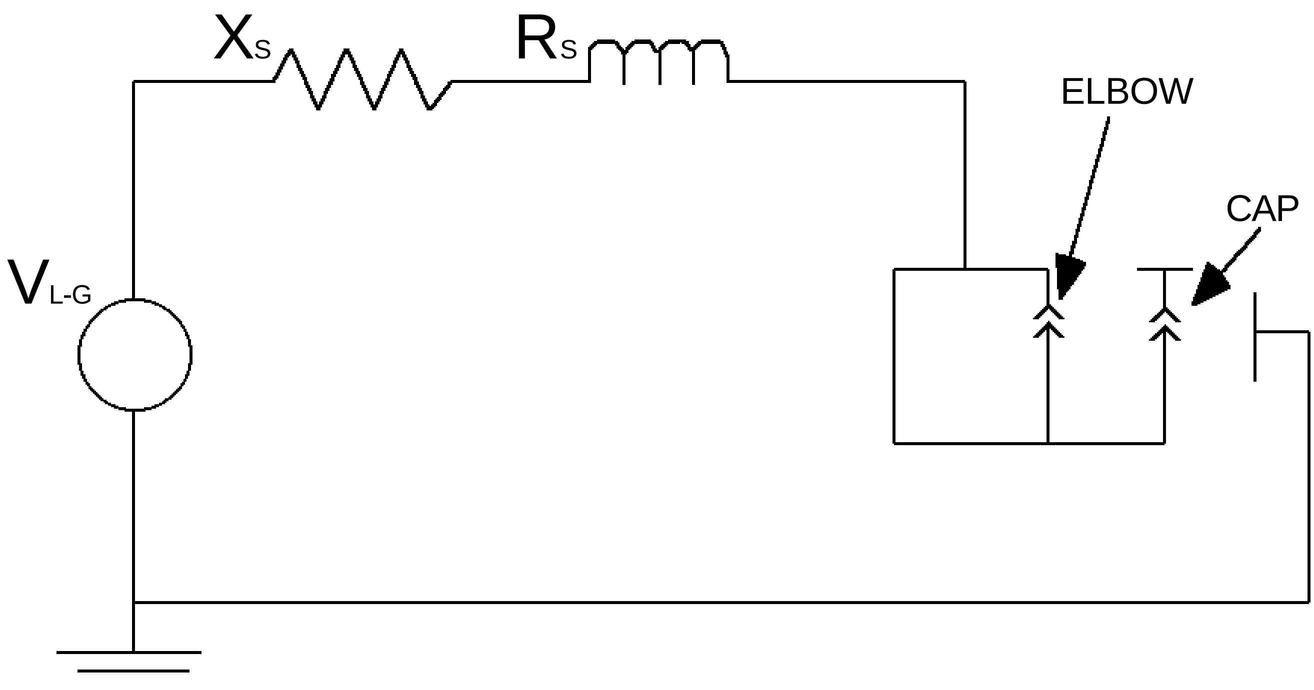


FIGURE 3

Circuit Diagram - Partial Vacuum Switching Test



V_{LG} = 2 X (Rated L-G Voltage) = 30 kV

$Z_S = X_S + R_S$ = 98.4 + 16.6 = 99.8 @ 80.45°

P.F. = 16.5%

X_S/R_S = 5.93

$I_F = V_{LG}/Z_S$ = 300 Amps