CERTIFIED
TEST REPORT

Cooper Power Systems

15 kV & 25 kV Class
ENCAPSULATED FUSE

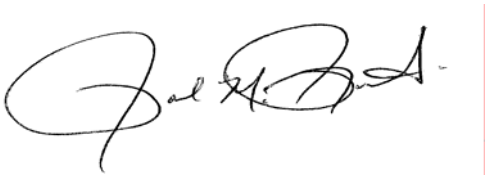
Cooper Power Systems

15 kV & 25 kV Class

ENCAPSULATED FUSE

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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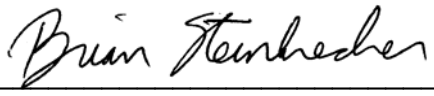

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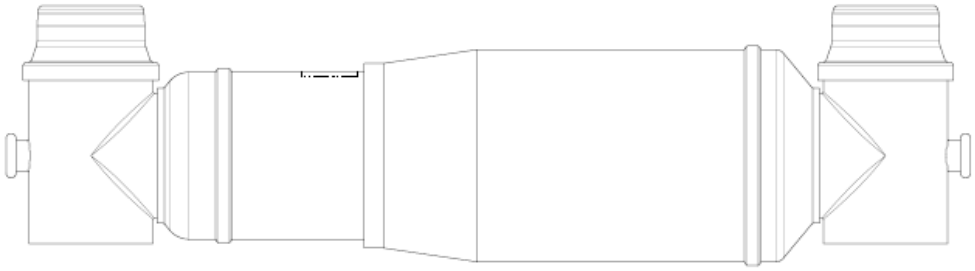
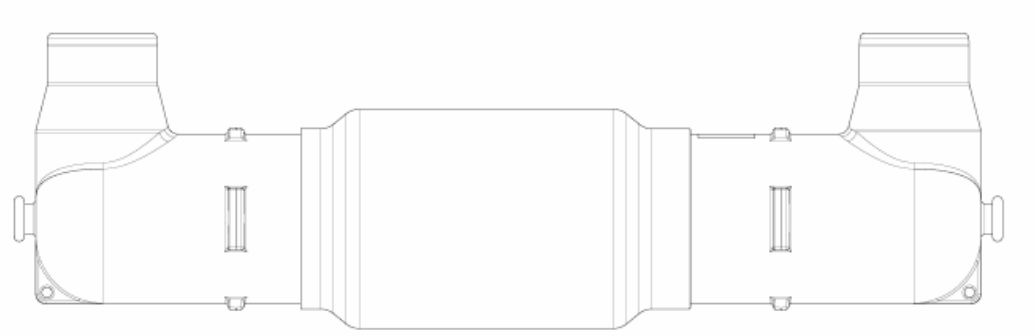
INTRODUCTION

The Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuses are fully shielded and insulated in-line fuses for use in deadfront, overhead or underground cable distribution systems.

This report certifies that all components used for the Encapsulated fuses were installed according to all applicable instructions and tested to the applicable design test procedures given in IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600A, designated as IEEE Standard 386-2006, ANSI/IEEE fuse standards C37.41-2000 and C37.47-2000, and Cooper Power Systems internal design tests.



Gen I Configuration



Gen II Configuration

TEST PROGRAM

Object

To demonstrate that the Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuses meet the applicable requirements of IEEE Standard 386-2006, ANSI/IEEE standard C37.41-2000, ANSI standard C37.47-2000, and the requirements of the Cooper Power Systems “Multi-stress” and “Sequential Life Test” tests.

Procedure

Design tests were performed on the Encapsulated fuse per the applicable design tests specified in Table 4 of IEEE Standard 386-2006, ANSI/IEEE C37.41-2000, ANSI C37.47-2000, and Cooper Power Systems “Multi-stress” and “Sequential Life Test” tests.

Design Tests - IEEE Std. 386-1995

A. Corona Voltage Level .....Section 7.4
B. Alternating Current Withstand Level .....Section 7.5.1
C. Direct Current Withstand Level .....Section 7.5.2
D. Impulse Withstand Voltage .....Section 7.5.3

Design Tests - Cooper Power Systems

E. Multi-stress Test .....CPS requirement
F. Sequential Life Test .....CPS requirement

Design Tests

G. Interruption Tests .....ANSI/IEEE C37.41-2000, Series 1, 2 and 3
H. Temperature Rise Tests .....ANSI/IEEE C37.41-2000, Section 11
I. Time Current Curves .....ANSI C37.47-2000

Summary

The representative Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuses met all the applicable requirements as specified in the IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600V, designated as IEEE Std. 386-2006 and the requirements of fuse standards ANSI/IEEE C37.41-2000 and ANSI C37.47-2000.

In addition, the Cooper Power Systems 15 kV & 25 kV Class 200 Amp Separable Connector System products met all requirements as specified for the Cooper Power Systems “Multi-stress” and “Sequential Life Test” tests.

Test A

15.2/26.3 kV
CORONA VOLTAGE LEVEL TEST
Section 7.4

Object

To demonstrate that the Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies meet or exceed the IEEE Standard 386-2006, Section 7.4, minimum corona voltage level of 19 kV rms.

Procedure

Ten Encapsulated fuse assemblies were tested with mating parts for a 25 kV class minimum corona voltage level of 19 kV rms. The test voltage is gradually increased to 20% above the 19 kV corona level (22.8 kV). If the corona exceeded 3pC, the voltage was decreased to the corona voltage level of 19 kV and maintained between 3 and 60 seconds. The corona shall not exceed 3pC at the specified 19 kV corona voltage level.

Results

For all ten samples of each product tested the corona level was less than 3pC at the specified minimum corona extinction voltage level of 19 kV rms.

Conclusion

The representative Cooper Power Systems 15 kV & 25 kV Class encapsulated fuse assemblies met or exceeded the IEEE Standard 386-2006, Section 7.4, minimum corona voltage level of 19 kV rms.

Test B

15.2/26.3 kV
ALTERNATING CURRENT WITHSTAND VOLTAGE TEST
Section 7.5.1

Object

To demonstrate that the Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies meet the IEEE Standard 386-2006, Section 7.5.1, 60 Hz, one minute ac withstand level of 40 kV rms.

Procedure

Ten Encapsulated fuse assemblies were tested with mating parts by raising the 60 Hz ac test voltage to 40 kV rms in less than 30 seconds, then maintaining the voltage at 40 kV rms for one minute.

Results

All ten Encapsulated fuse assemblies withstood a 40 kV rms, 60 Hz ac one minute voltage withstand without a puncture or flashover.

Conclusion

The representative Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies met the IEEE Standard 386-2006, Section 7.5.1, 60 Hz, one minute ac voltage withstand level of 40 kV rms without a puncture or flashover.

Test C

15.2/26.3 kV
DIRECT CURRENT WITHSTAND VOLTAGE TEST
Section 7.5.2

Object

To demonstrate that the Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies meet the IEEE Standard 386-2006, Section 7.5.2, 15 minute dc withstand level of 78 kV.

Procedure

Ten Encapsulated fuse assemblies were tested with mating parts by connecting the negative dc voltage terminals to the test specimen and raising the test voltage to 78 kV, then holding the voltage at 78 kV for 15 minutes.

Results

All ten Encapsulated fuses withstood a 78 kV rms 15 minute dc withstand without a puncture or flashover.

Conclusion

The representative Cooper Power Systems 15 kV & 25 kV Class 200 Amp Encapsulated fuse assemblies met the IEEE Standard 386-2006, Section 7.5.2, 15 minute dc voltage withstand level of 78 kV without a puncture or flashover.

Test D

15.2/26.3 kV
IMPULSE WITHSTAND VOLTAGE TEST (BIL)
Section 7.5.3

Object

To demonstrate that the Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies meet the IEEE Standard 386-2006, Section 7.5.3, impulse level of 125 kV.

Procedure

Ten Encapsulated fuse assemblies were tested with mating parts and subjected to an impulse voltage having 1.2/50 microsecond wave and crest value of 125 kV BIL. Each sample was subjected to three positive and three negative full wave impulses with wave shape tolerances as shown in Table 1.

Table 1 - Impulse Wave Shape Tolerance

Measured Quantity	*Tolerance ±%*
Crest Value	3
Front Time	30
Time to Half Value	20
Nominal Rate of Rise of Wave Front	20

Results

All ten Encapsulated fuse assemblies withstood three positive and three negative full wave impulses with 125 kV crests without a puncture or flashover.

Conclusion

The representative Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies met the IEEE Standard 386-2006, Section 7.5.3, impulse withstand voltage level of 125 kV without a puncture or flashover.

Test E

15.2/26.3 kV
MULTI-STRESS TEST
CPS Requirement

Object

To demonstrate that the Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies are capable of meeting the requirements of Cooper's long term multi-stress accelerated aging test. The multi-stress aging test is designed to verify that the base design, materials and manufacturing processes are capable of producing connector components that meet normal requirements for longevity in use.

Standard

Cooper Power Systems Multi-Stress Test E9120 Rev. 01, 11/12/93. The connector assemblies shall withstand the multi-stress accelerated aging conditions for a minimum of 2,000 hours without a puncture or flashover.

Procedure

Two Cooper Power Systems 25 kV Class Encapsulated fuse assemblies were prepared with the 200 Amp interface of the inserts mated with LE225M elbows and LPC225 protective caps. The Encapsulated fuse assemblies were submerged in a water filled tank, with the water supplied directly from the tap without any treatment.

The water was heated to between 85°C and 95°C using emergent resistance heater coils. The surface of the water was covered to reduce the rate of evaporation. Water was added regularly to maintain coverage of the test specimens.

A continuous 60 Hz ac test voltage of 1.5 times the rated line-to-ground voltage was applied to the assemblies. The test voltage for 25 kV Class connectors is 22.5 kV (1.5 x 15.2 kV).

Tan delta and capacitance was measured to monitor the stability of the insulation system of each Encapsulated fuse assembly. The tan delta and capacitance of the Encapsulated fuse were measured using an unaged protective cap and elbow. The same unaged components were used throughout the test for measuring the capacitance and tan delta of the Encapsulated fuse assemblies.

An initial tan delta and capacitance measurement of each Encapsulated fuse assembly was taken prior to the start of the accelerated aging regimen. Periodically, the Encapsulated fuse assemblies were de-energized, removed from the water and allowed to cool to room ambient temperature. Tan delta and capacitance measurements were then taken.

Results

The two Encapsulated fuses withstood 2,000 hours of the multi-stress accelerated aging test without a puncture or a flashover. The tan delta and capacitance of each insert demonstrated stability throughout the duration of the test.

Conclusion

The representative Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies met the requirements of the Cooper Power Systems Multi-stress Test.

Test F

15.2/26.3 kV
SEQUENTIAL LIFE TEST
CPS Requirement

Object

To demonstrate that the Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assemblies meet the Cooper Power Systems sequential life test voltage withstand requirements.

Procedure

An Encapsulated fuse assembly with a 100A rated fuse was tested per the following test sequence with a test current of 95A ± 3A.

Table 2 - Sequential Life Test

Test Number	Test Description	Test Requirement
1	Partial discharge at ambient temperature	<3pC at 21.5kV
2	DC voltage dry withstand	103kV for 15 minutes
3	AC voltage dry withstand	45kV for 1 minute
4	Partial discharge at ambient temperature	<10pC at 21.5kV
5	Impulse voltage ambient temperature	125kV, 10 impulses at each polarity
6	Electrical heat cycling in air	3 cycle with 30kV applied
7	Partial discharge at elevated temperature	<10pC at 21.5kV
8	Impulse voltage elevated temperature	125kV, 10 impulses at each polarity
9	Partial discharge at ambient temperature	<10pC at 21.5kV
10	Electrical heat cycling in air	27 cycles with 30kV applied
11	Electrical heat cycling in water	30 cycles with 30kV applied
12	Partial discharge at elevated and ambient temperatures	<10pC at 21.5kV
13	Impulse voltage at ambient temperature	125kV, 10 impulses at each polarity
14	AC voltage dry withstand	45kV for 1 minute

1/0 aluminum stranded, 260-280 mil insulation cable to be used for the test.

Results

The Encapsulated fuse assembly with the 100A fuse met all the applicable test requirements as listed in Table 2 without puncture or flashover where applicable.

Conclusion

The representative Cooper Power Systems 15 kV & 25 kV Class Encapsulated fuse assembly met the Cooper Power Systems sequential life test voltage withstand requirements as listed in Table 2.

Test G

5.5, 8.3, 15.5 and 17.2kV
Test Series 1, 2 & 3
INTERRUPTION TESTING, INCLUDING MAXIMUM APPLICATION TEMPERATURE

Object

To demonstrate that the Cooper Power Systems 5.5, 8.3, 15.5 and 17.2 kV Encapsulated fuses can meet the Series 1, 2 and 3 test requirements as defined by the IEEE C37.41-2000 standard. The fuses included in the testing are as follows: 5.5/8.3kV 10 – 200A, 15.5kV 8 – 125A and 17.kV 8 – 100A Encapsulated fuses. This testing will also prove that the Encapsulated housing, which has specifically designed internal shielding, properly interacts with fuse operation.

Procedure

All Interruption testing for Series 1 & 2 and high crossover was completed at the Edison Technical Center in Franksville, WI and at Powertech Labs in Surrey, BC. Series 3 and low crossover testing was completed at the CPS North Street Lab. Long-term withstand testing was completed at the Link Lab in Pewaukee, WI.

Results

All tests met the requirements of Table 12 and the homogeneous series requirements detailed in section 6.6.4 of IEEE standard C37.41-2000.

Table 3 - 5.5/8.3 kV Testing

These fuses have elements that both increase in number and cross section	Test Series	Fuse Units Tested				
		10A	25A	100A	125A	200A
	1	3/3	N/A	3/3	3/3	3/3
	2	3/3*	N/A	3/3*	3/3*	3/3*
	High crossover	2/2	N/A	2/2	2/2	2/2
	Low crossover	2/2	N/A	2/2	2/2	2/2
	3	2/2	2/2	2/2	2/2	2/2

Notes:

1. All Series 2 and 3 testing, was performed with the fuses heated to 65°C, the maximum ambient temperature for the fuse assembly, for 24 hours prior to testing. The fuses were heated to 65°C during testing for the series 3 tests only.
2. *All Series 2 testing was performed at both 5.5kV and 8.3kV in order to account for the differences in peak arc voltage that would be experienced at the different voltage levels.
3. All Encapsulated fuses successfully experienced the withstand voltages post interruption for the required times as defined in IEEE standard C37.41-2000, table 12.
4. Two samples each of the highest rated fuses at 8.3 kV from the Series 2 and 3 testing were placed on a 72-hour, or longer, withstand. All of the samples successfully passed the 72-hour withstand without experiencing dielectric breakdown.
5. Peak arc voltage requirements were met by the fuses throughout the duration of testing.

Table 4 - 15.5/17.2 kV Testing

These fuses have elements that both increase in number and cross section	Test Series	Fuse Units Tested					
		8A	**25A**	**65A**	**80A**	**100A**	**125A***
	1	3/3	N/A	3/3	3/3	3/3	3/3*
	2	3/3	N/A	3/3	3/3	3/3	3/3*
	High crossover	2/2	N/A	2/2	2/2	2/2	2/2
	Low crossover	2/2	N/A	2/2	2/2	2/2	2/2
	3	2/2	2/2	2/2	2/2	2/2	2/2

Notes:

1. All Series 2 and 3 testing, was performed with the fuses heated to 65°C, the maximum ambient temperature for the fuse assembly, for 24 hours prior to testing. The fuse were heated to 65°C during testing for the series 3 test only.
2. All Encapsulated fuses successfully experienced the withstand voltages post interruption for the required times as defined in IEEE standard C37.41-2000, table 12.
3. Two samples each of the highest rated fuses at 15.5 and 17.2 kV from the Series 2 and 3 testing were placed on a 72-hour, or longer, withstand. All of the samples successfully passed the 72-hour withstand without dielectrically breaking down.
4. Peak arc voltage requirements were met by the fuses throughout the duration of testing.
5. *All testing was performed at 17.2kV with the exception of the 125A fuse, which was tested at 15.5kV for both Series 1 and 2.

The following tables contain the Minimum Melt, Total Clear, and Max. Interrupting capacity for each fuse:

Table 5 - 5.5kV Performance Characteristics

Base Catalog #	Fuse Rating		Minimum Melt I^2t	Total Clear I^2t	Max. Interrupting Rating (Amps symmetric) at 8.3kV
	kV	A			
55F010 EMF	5.5	10	1,495	11,747	50,000
55F015 EMF	5.5	15	2,335	17,047	50,000
55F020 EMF	5.5	20	2,335	17,047	50,000
55F025 EMF	5.5	25	3,363	22,530	50,000
55F030 EMF	5.5	30	9,341	56,980	50,000
55F040 EMF	5.5	40	9,341	56,980	50,000
55F050 EMF	5.5	50	13,451	73,980	50,000
55F065 EMF	5.5	65	17,277	84,657	50,000
55F080 EMF	5.5	80	38,873	174,929	50,000
55F100 EMF	5.5	100	69,108	281,777	50,000
55F125 EMF	5.5	125	83,167	576,333	50,000
55F150 EMF	5.5	150	119,760	761,674	50,000
55F200 EMF	5.5	200	212,907	1,233,333	50,000

Table 6 - 8.3kV Performance Characteristics

Base Catalog #	Fuse Rating		Minimum Melt I^2t	Total Clear I^2t	Max. Interrupting Rating (Amps symmetric) at 8.3kV
	kV	A			
83F010 EMF	8.3	10	1,495	20,900	50,000
83F015 EMF	8.3	15	2,335	30,358	50,000
83F020 EMF	8.3	20	2,335	30,358	50,000
83F025 EMF	8.3	25	3,363	40,353	50,000
83F030 EMF	8.3	30	9,341	102,750	50,000
83F040 EMF	8.3	40	9,341	102,750	50,000
83F050 EMF	8.3	50	13,451	134,509	50,000
83F065 EMF	8.3	65	17,277	155,493	50,000
83F080 EMF	8.3	80	38,873	310,985	50,000
83F100 EMF	8.3	100	69,108	473,667	50,000
83F125 EMF	8.3	125	83,167	1,024,667	50,000
83F150 EMF	8.3	150	119,760	1,431,133	50,000
83F200 EMF	8.3	200	212,907	2,480,000	50,000

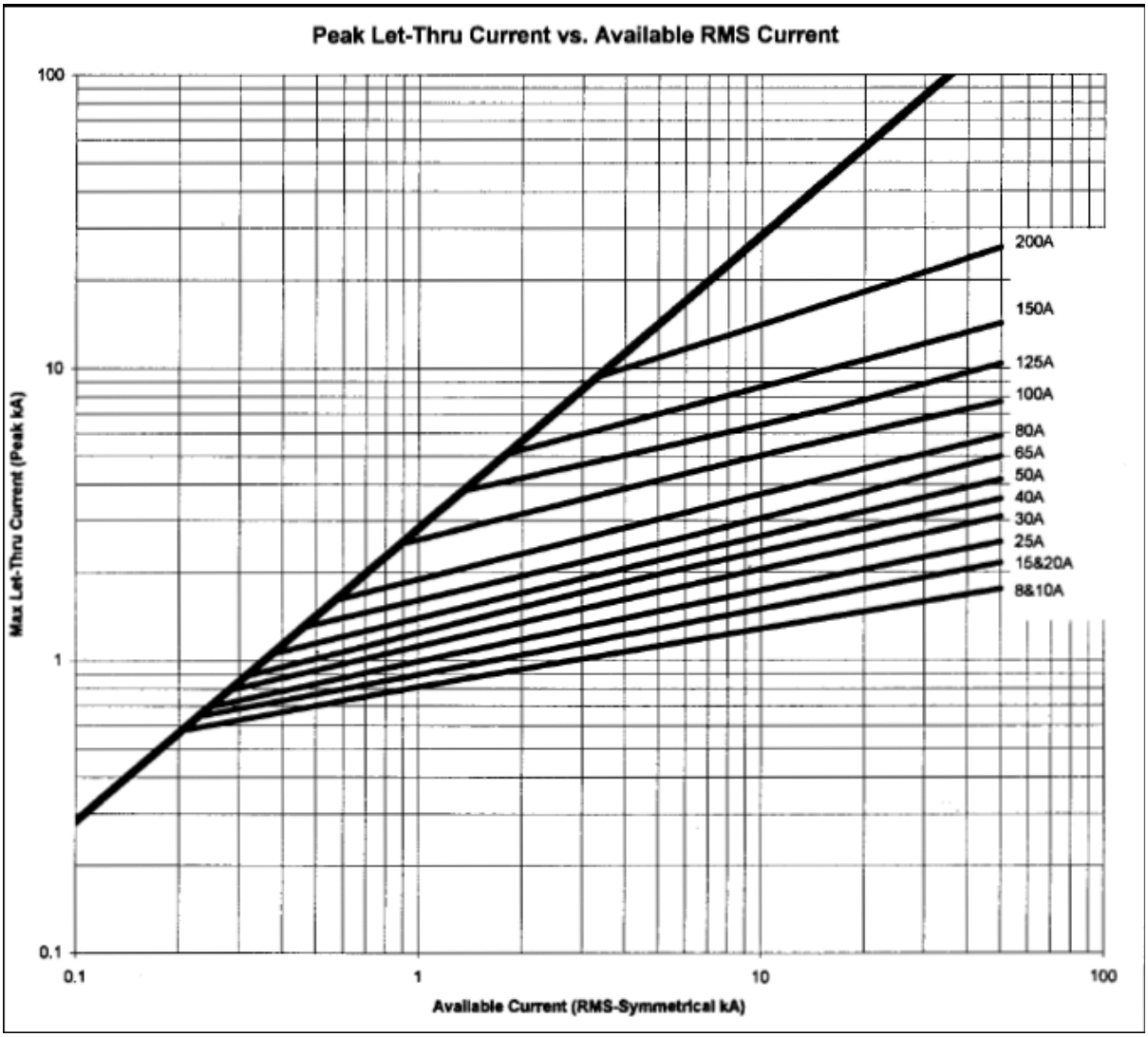
Table 7 - 15.5kV Performance Characteristics

Base Catalog #	Fuse Rating		Minimum Melt I^2t	Total Clear I^2t	Max. Interrupting Rating (Amps symmetric) at 15.5kV
	kV	A			
155F010 EMF	15.5	10	1,495	9,124	50,000
155F015 EMF	15.5	15	1,495	9,124	50,000
155F020 EMF	15.5	20	2,335	14,595	50,000
155F025 EMF	15.5	25	2,335	14,595	50,000
155F030 EMF	15.5	30	3,363	21,521	50,000
155F040 EMF	15.5	40	9,341	62,117	50,000
155F050 EMF	15.5	50	9,341	63,518	50,000
155F065 EMF	15.5	65	13,451	92,408	50,000
155F080 EMF	15.5	80	17,277	119,596	50,000
155F100 EMF	15.5	100	29,940	330,000	50,000
155F125 EMF	15.5	125	53,227	680,000	50,000

Table 8 - 17.2kV Performance Characteristics

Base Catalog #	Fuse Rating		Minimum Melt I^2t	Total Clear I^2t	Max. Interrupting Rating (Amps symmetric) at 15.5kV
	kV	A			
172F010 EMF	17.2	10	1,495	16,233	43,000
172F015 EMF	17.2	15	1,495	16,233	43,000
172F020 EMF	17.2	20	2,335	26,155	43,000
172F025 EMF	17.2	25	2,335	26,155	43,000
172F030 EMF	17.2	30	3,363	38,840	43,000
172F040 EMF	17.2	40	9,341	110,223	43,000
172F050 EMF	17.2	50	9,341	112,558	43,000
172F065 EMF	17.2	65	13,451	166,791	43,000
172F080 EMF	17.2	80	17,277	219,667	43,000
172F100 EMF	17.2	100	29,940	426,000	43,000

The following table contains Peak let-thru vs. available RMS currents:



Conclusion

The 5.5/8.3kV 10 – 200A, 15.5kV 8 – 125A and 17.kV 8 – 100A Encapsulated fuses successfully completed all interruption tests per C37.41-2000.

Test H

TEMPERATURE RISE TESTS

Object

The Encapsulated fuse must carry rated current continuously without exceeding the temperature rise requirements as specified in C37.41-2000, Section 11.

Procedure

Temperature rises were measured with thermocouples placed directly on the fiberglass body of the fuse tube. Engineering has defined the maximum continuous operating temperature of the Encapsulated body to be 150°C. Note the maximum temperature of EPDM is not currently defined in section 11 of the C37.41-2000 ANSI standard. The fuse caps, and connection parts were also measured with thermocouples. Three thermocouples were used to determine the ambient temperature.

Results

The highest rated current fuse of each homogeneous series has been determined to generate the most heat. Since the package size is the same for all of the series, the 100 and 200A fuses will provide the highest operating temperatures for the 5.5/8.3kV voltage classes and the 65 and 125A fuses will be used for the 15.5/17.2kV voltage classes.

The cap, connection parts, and tubes had temperature rises that were less than the maximum allowed temperatures detailed in Table 1 of IEEE Standard C37.41, when the largest fuse of each homogeneous series was carrying its rated current. They require a 6% current reduction for a 40°C ambient. All fuses can be used in an environment up to 65°C with a 20% reduction in continuous operating current. Note that the Encapsulated fuse has a thermal time constant of 110 minutes. The fuse will reach 95% of its ultimate operating temperature in a constant operating environment within 5 hours, 30 minutes.

Conclusion

The Encapsulated fuse has successfully completed all temperature rise tests as defined by IEEE C37.41-2000.

Test I

TIME CURRENT CHARACTERISTICS FOR THE ENCAPSULATED FUSE

Object

To create Time Current Characteristic curves for the CPS Encapsulated fuse. The homogeneous series at 5.5/8.3kV are 10 through 100A and 125 through 200A fuses and at 15.5/17.2kV the homogeneous series are 8 through 65A and 80 through 125A.

Procedure

During the interrupting tests, TCC response was measured and recorded in order to create TCC curves for the Encapsulated fuses. The fuses were tested using a low voltage source at .1 and 100 seconds. Melt times were also measured both above and below the 'knee' of the curve from the high and low crossover testing.

Results

The 10, 100, 125 and 200A fuses for the 5.5/8.3kV voltage class as well as the 8, 65, 80 and 125A fuses for the 15.5/17.2kV voltage class were tested. All tested melt and clear times were within the band created by the melt and clear curves for the fuse.

Conclusion

Time Current Curves were created for the Encapsulated fuses, which are published for CPS under R240-91-161 and R240-91-162.

REVISION TABLE

REVISION NO.	DATE	WHAT WAS ADDED/CHANGED
1	7/27/04	Changed all 15.5 kV ratings to 17.2 kV
2	8/5/04	Added 8.3 kV fuses
3	8/25/05	Added 15 kV Class fuses
4	9/14/07	Added Generation II fuses; removed Generation I