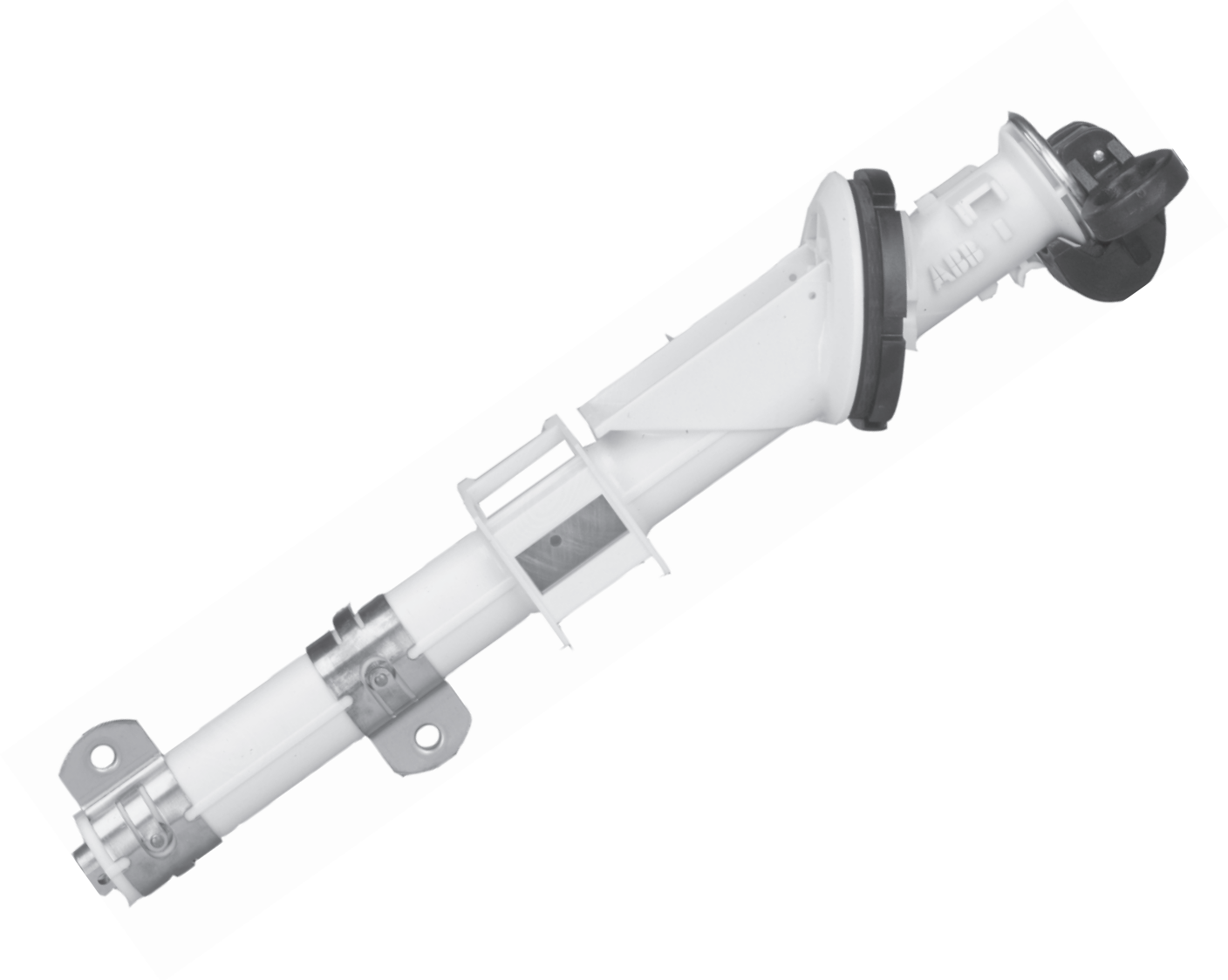
Expulsion Fuse Holder
Type DO-III, Oil Immersed Drawout
PTAP-AFH927

Standard Design Test Performed



General Description

The ABB "DO-III" fuse holder is a draw out load break expulsion fuse holder designed for use with padmounted transformers filled with transformer oil or other approved fluid. It is designed to protect the distribution system in the event of an internal transformer fault, secondary fault, or severe overload when used with properly coordinated series fuses. Following industry safety practices, the "DO-III" fuse holder can be used to break load.

Certification

To verify the ABB Type "DO-III" fuse holder assembly for transformer application, a series of electrical, mechanical, and thermal tests were conducted.

Design Tests

The design tests were divided into (7) seven parts:

1. Dielectric Tests
   - Low frequency (60 Hz) withstand test
   - Low frequency (400 Hz) withstand test
   - Impulse test
   - Chopped wave impulse test
   - Corona and RIV test
2. Load Switching Test
3. Fault Interruption Test
4. Mechanical Strength Test
   - Cam-over seal test
   - Mounting threads strength test
   - Safe transit test
   - Cantilever test
   - Check valve seal test
5. Thermal Cycle Test
6. Seal Integrity Test
   - Helium mass spectrometer test
   - Pressure powdered-chalk test
7. Contact Temperature Rise Test

1. Dielectric Tests

The purpose of these tests is to verify the insulation strength and to ensure that the component will comply with the appropriate transformer standards when installed in the transformer. Since the "DO-III" fuse holder is a fused device, two test set-ups are required for most dielectric tests. In one set-up, the dielectric strength is tested with a normal fuse where the test tank is grounded and the line-side lead is connected to the test circuit. In the other set-up, the dielectric strength is tested with a "blown" fuse where the tank and winding lead are both grounded and the line-side lead is connected to the test circuit.

- **Low Frequency (60 Hz) Withstand Test**

The "DO-III" fuse holder is mounted to the transformer tank and 60 Hz voltage is applied for one minute. The samples were tested with normal and "blown" fuses.

Test Voltages	Oil Temp.	Fuse	Comment
60 kV	25°C	Normal	Passed
		Blown	Passed

Result: The "DO-III" fuse holder passed and can be rated at 50 kV low frequency withstand as required for 150 kV BIL.

- **Low Frequency (400 Hz) Withstand Test**

This test is performed to ensure that the component will not be damaged during the 400 Hertz test that each transformer is subjected to as part of production testing.

Result: The "DO-III" fuse holder assembly passed and can be rated at 60 kV, 400 Hertz withstand required for 150 kV BIL.

- **Impulse Test**

The purpose of this test is to verify the full wave impulse withstand of the "DO-III" fuse holder. The impulse tests were performed with three successive impulse voltages at both positive and negative polarity. Both normal and "blown" fuses were tested. The same "DO-III" fuse holder assemblies used in the low frequency tests were used in this test.

Fuse	Polarity	kV	Comment
Normal	Pos., Neg	200	Passed
Blown	Pos., Neg	200	Passed

Result: All "DO-III" fuse holders passed all tests at impulse levels above the BIL rating of 150 kV.

- **Chopped Wave Impulse Test**

The purpose of this test is to verify the chopped wave impulse withstand of the " DO-III" fuse holder. The chopped wave impulse tests were performed with three successive impulse voltages at both positive and negative polarity. Both normal and "blown" fuses were tested. The same "DO-III" fuse holders used in the low frequency tests were used in this test.

Fuse	Polarity	kV	Comment
Normal	Pos., Neg	230	Passed
Blown	Pos., Neg	230	Passed

Result: All "DO-III" fuse holders passed all tests at impulse levels above the Chopped Wave rating of 200 kV.

- **Corona and RIV Test**

The purpose of these tests is to verify that the amount of partial discharge is below established levels. Both the corona and RIV tests are performed with normal and "blown" fuses. In the corona test, the test voltage is raised to 150% (34.5 kV) of rated then reduced to 125% (29 kV) where the partial discharge level must be 3 ρC or less. For the RIV test, the voltage is set at 29 kV where RIV, as measured by the standard meter, must be less than 100 μV.

Results: All "DO-III" fuse holders passed the tests with corona values less than 3 ρC and RIV was below 100 μV.

2. Load Switching Test

The purpose of this test is to verify that the "DO-III" fuse holder can be used as a load switching device. The fuse holder was mounted in an oil filled padmounted transformer tank. The circuit was energized at the specified voltage with the specified load current circulating through the "DO-III" fuse holder. The "DO-III" puller assembly was withdrawn, thereby breaking the circuit and then inserted to remake the circuit; fifty such cycles were completed.

Voltage L-L (kV)	Voltage L-G (kV)	RMS Current	Switching Operations	Power Factor	Comment
17.3	10	160 A	50	70-80%	Passed
26.8	15.5	150 A	50	70-80%	Passed
46.2	26.7	80A	50	70-80%	Passed

Results: All samples passed the test.

3. Fault Interruption Test

The purpose of this test is to verify the fault interrupting rating of the "DO-III" fuse holder. The "DO-III" fuse holder was mounted in an oil-filled padmounted transformer tank. Bolted fault tests were made to determine the available current. A fuse was inserted in the "DO-III" fuse holder and the circuit energized; the fuse melted and the current was interrupted by the fuse cartridge. The same fuse cartridge was re-fused and the test repeated five times.

Series	Voltage $(kV)_{LG}$	Current (Amps-sym)	Size	Fuse Factor	Power Comment
1	2.4	4,500	C6	12-13%	Cleared
2	8.3	3,500	C6	12-13%	Cleared
3	15.5	2,500	C6	12-13%	Cleared
4	23.0	1,000	C6	12-13%	Cleared

Result: The "DO-III" fuse holder operates properly during fault interruption for the ratings of:

2.4 kV - 4,500 A RMS symmetrical
8.3 kV - 3,500 A RMS symmetrical
15.5 kV - 2,500 A RMS symmetrical
23.0 kV - 1,000 A RMS symmetrical

4. Mechanical Strength Tests

- **Cam-Over Strength Test**

The purpose of this test is to demonstrate that the cam-over forces produced when installing the puller assembly will not compromise the integrity of the seal with a comfortable safety margin. To accomplish this the "DO-III" fuse holder is conditioned prior to leak testing, by subjecting the outer tube assembly to a hoop force that is twice the maximum hoop force generated while operating handle. Damage that may result from this test will show up as a leak during leak testing.

Result: No damage was detected during leak tests verifying that the cam-over action will not damage the housing.

- **Mounting Thread Strength Test**

The purpose of this test is to determine the strength of the mounting threads when torqued to failure using the standard mounting nut. Six samples were tested with no failures to 300 in-lbs. This value is 3 times greater than the required 100 in-lbs needed to properly seat the gasket on the "DO-III" fuse holder.

Result: The mounting threads and flange section of the "DO-III" fuse holder have adequate safety margins.

- **Safe Transit Test**

The purpose of these tests is to verify that the "DO-III" fuse holder, when mounted to the transformer or packed in the standard shipping carton, will safely withstand stresses created during shipment. Four "DO-III" fuse holders are mounted in a standard padmounted transformer tank. The transformer tank is mounted on the Safe Transit Machine's vibratory test platform for 5 hours and then inspected for damage. A standard shipping carton, filled "DO-III" fuse holders is mounted on the Safe Transit Machine's vibratory test platform for 5 hours and then inspected for damage.

Result: All four "DO-III" fuse holders in the transformer passed the Safe Transit Test. All of the "DO-III" fuse holders in the shipping carton passed the Safe Transit Test.

- **Cantilever Test**

The purpose of this test is to determine the cantilever strength of the tube with and without the puller inserted. Six samples of the "DO-III" fuse holder were mounted in the normal manner and load was applied to the end of the tube. Minimum load carried by the tube with the puller in place was 214 lbs. Minimum load carried by the tube without the puller in place was 57 lbs.

Result: The "DO-III" fuse holder's outer tube has adequate safety margins when loaded at the end (simulating transformer leads).

- **Check Valve Seal Test**

The purpose of this test is to verify that the "DO-III" fuse holder's check valve will continue to seal after 200 operations. Six "DO-III" fuse holders are mounted in a padmounted transformer tank and the tank filled with oil 2 1/2 inches above the standard fill level, and the "DO-III" fuse holder's puller is removed and inserted 10 times. Next, the oil level is lowered to the standard fill level, and the puller is removed and inserted 185 times. Finally, the oil level is raised back to the original level of 2 1/2 inches above the normal fill level, and the puller is removed and inserted 5 more times. Upon completion, the puller is removed and the "DO-III" fuse holder's check valve is examined for signs of oil leakage.

Result: After 200 puller insertion cycles, the check valve continues to seal against oil leakage.

5. Thermal Cycle Test

The purpose of this test is to verify that the "DO-III" fuse holder can withstand extreme temperature cycling without damage. The "DO-III" fuse holder is mounted in a standard test tank and placed in a thermal cycle chamber. One thermal cycle consists of heating the chamber to 135°C by gradually increasing the temperature over a 2 hour period, and maintaining this temperature for 8 hours. Next the temperature within the chamber is steadily decreased over a 4 hour period to -35°C, and held for a period of 8 hours. Finally, the cycle is completed by steadily raising the temperature within the chamber to ambient level over a 2 hour period. The samples are subjected to 20 such cycles and tested to verify that all seals are maintained using both the "Helium Mass Spectrometer Test" and a 15 psi tank "Pressure-Powdered Chalk Test".

All six "DO-III" fuse holder samples passed the Helium leak detector test, and maintained a seal against a 15 psi tank pressure and showed no signs of thermal stress.

Result: The "DO-III" fuse holder passed the Thermal Cycle Test.

6. Seal Integrity Test

The purpose of these tests is to verify that the "DO-III" fuse holder does not leak either through the plastic housing or the gasket interfaces.

- **Helium Mass Spectrometer Test**

The "DO-III" fuse holders selected for this test were first subjected to the "Internal Cam-Over Seal Test" (see above). The housing is attached to a leak test fixture which mates the holder to the helium detector (Veeco Instruments, Plainview, NY, Model #MS-180). A vacuum atmosphere is created around the external surfaces of the holder. Any leak will be detected if Helium passes into the detector through the housing or gasket interfaces. Twelve "DO-III" fuse holders were tested with no leaks faster than 1×10^{-6} atm cc/sec detected. This is well below the acceptable limit of 1×10^{-5} atm cc/sec.

Result: No leaks were detected at rates below the acceptable limit and therefore provide an oil tight seal in padmounted transformers.

- **Pressure-Powdered Chalk Test**

The "DO-III" fuse holder is mounted in a tank and the external surfaces are coated with a powdered chalk and alcohol mixture. The tank is filled with oil, sealed and pressurized to 10 psi. After a 24 hour period, the "DO-III" fuse holders were inspected for discolorations in the chalk as an indication for oil leaks. The same samples used in the helium leak test were tested. No evidence of oil leaks was detected. The test period was extended to 312 hours on additional samples and no leaks were detected.

Result: The "DO-III" fuse holder passed the Pressure-Powdered Chalk Test.

6. Contact Temperature Rise Test

The purpose of this test is to verify that the temperature rise above ambient oil temperature of the "DO-III" fuse holder's current carrying path and contact structure are within allowable limits. The various parts of the current path are instrumented with thermocouples, and several levels of current are circulated. The temperature is monitored via the thermocouples and the steady state values are recorded.

Tube & Cartridge with Bare Contacts

Current (Amperes)	Oil Temp. (C)	Average Rise Lower Contact	Average Rise Upper Contact
150	88	4.3	5.0
200	88	8.0	9.0
250	88	12.0	13.7
300	88	16.3	18.7

Extrapolation of the data reveals that at a contact temperature rise of 15°C, the maximum current rating is 270 amperes for product with bare contacts.

Tube & Cartridge with Silver Plated Contacts

Current (Amperes)	Oil Temp. (C)	Average Rise Lower Contact	Average Rise Upper Contact
150	89	3.3	3.5
200	89	5.3	6.0
250	89	8.0	8.5
300	89	10.3	11.5
350	90	14.5	14.7

Extrapolation of the data reveals that at a contact temperature rise of 15°C, the maximum current rating is 355 amperes for product with silver plated contacts.

Results: The "DO-III" fuse holder with bare contacts meets the temperature rise requirements for a continuous current rating of 270 amperes, while the continuous current rating of the silver plated "DO-III" fuse holder is 355 amperes.

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