De-enegized Switches
Tap Changers
1 and 3 Phase

De-energized Switches

Standard Design Test Performed on
De-energized Switches Tap Changers

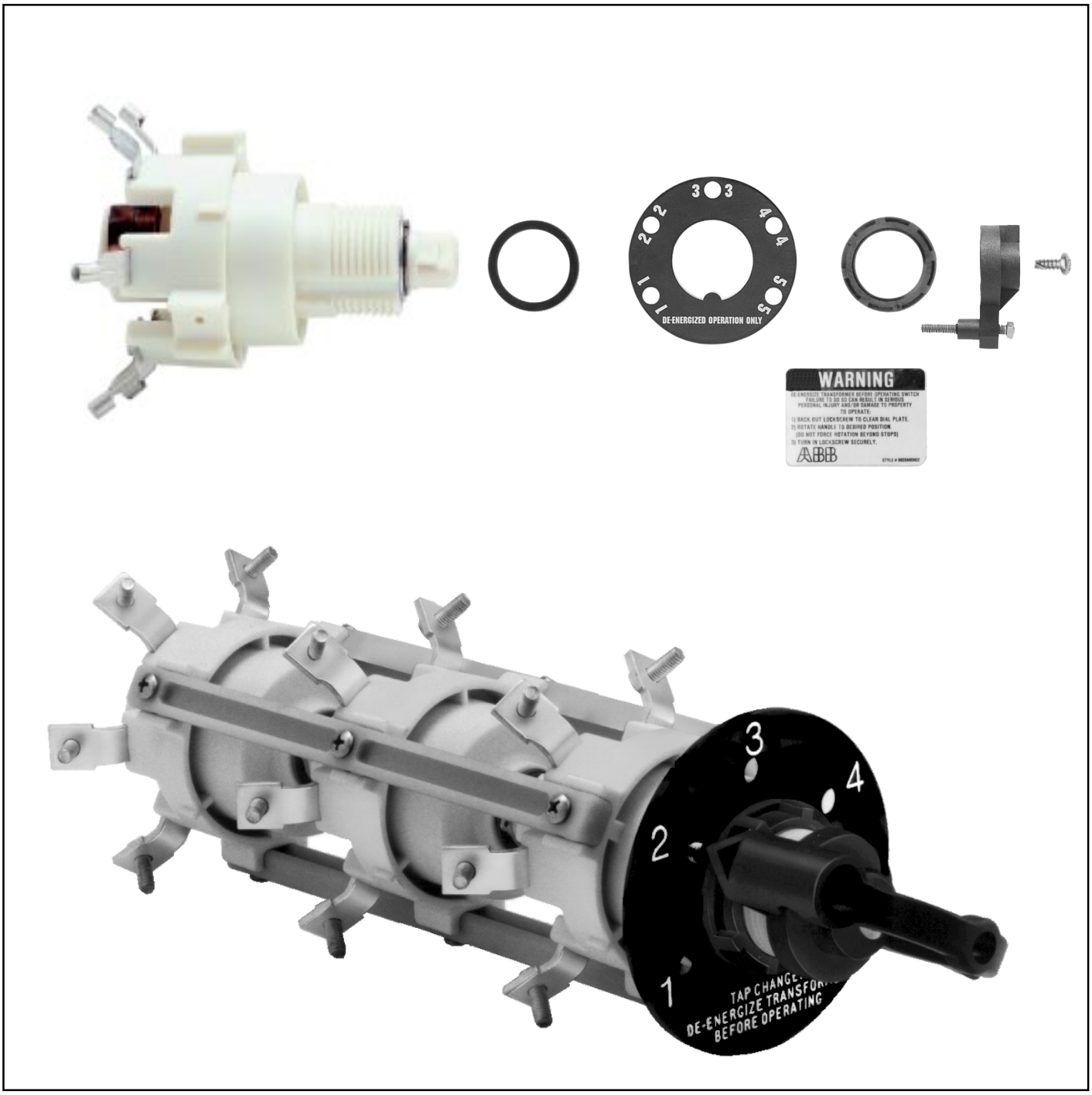

ABB Inc.

Introduction
The ABB "D" series of tap changers are de-energized, rotary-type switches, suitable for use in distribution transformers, both pole and pad mounted. The switches are mounted through the tank wall and are operable from outside the transformer. They are available in single and multi-deck configurations with various types of coil lead connector styles so that they can be used in a wide variety of transformer applications.

Certification
To certify the product ratings for the tap changer a series of electrical, mechanical, thermal, and seal integrity tests were made. The testing was performed at the ABB Engineering Laboratories in Athens, Georgia and Hubbell Chance Centralia, Missouri.

The tap changers were designed to meet the requirements for use in oil filled distribution and small power transformers as defined in ANSI/IEEE Standard #C57.12.00 – 2000. **General Requirements for Liquid Immersed Distribution, Power and Regulating Transformers.** All tests were structured to demonstrate compliance to the intent of the transformer standards.

Design Tests
The following test were performed to demonstrate that:
a) The switch meets its performance ratings.
b) The switch will operate satisfactorily under normal service conditions.
c) The switch conforms to the requirements of the appropriate Industry Standards.

1. Dielectric Tests:
Low Frequency Withstand
400 Hertz Withstand
Full Wave Lightning Impulse
Corona and RIV

2. Mechanical Strength Tests:
Mounting Flange Strength
Mechanical Life
Safe Transit
Cantilever Load
Shaft Torque
Side Thrust

3. Thermal Tests:
Contact Temperature Rise
Thermal Runaway
Thermal Cycle Withstand
Coil Oven Bake Test

4. Short Circuit Tests

5. Seal Integrity Testing
Helium Leak Method
Pressure-Powdered Chalk Method

1. Dielectric Tests
The purpose of these tests is to verify the insulation strength of the tap changer.

Low Frequency Withstand Tests
The Low Frequency Withstand test is performed at two different oil temperatures: 25°C and 80°C. Testing at elevated temperatures is not required by the ANSI transformer standards, but it is standard practice for ABB to conduct the test at temperatures above ambient. Sample tap changers were twice subjected to 60 hertz voltage for one minute. The voltage was applied to each tap changer for one minute, a minimum rest period of one minute (voltage = 0) followed, and then the test voltage was reapplied for one minute. The samples must withstand both voltage applications to pass.

Impulse Tests
The impulse withstand test voltage test consisted of three positive and three negative full wave voltage impulses without puncture or flashover. The voltage impulse used was a 1.2 x 50 microsecond wave having a crest value of the specified voltage. Each switch successfully passed this test.

Corona Test and RIV Test
The purpose of the Corona test is to verify that any partial discharge created by over voltage surges will subside to a negligible level when the voltage is returned to normal. The switches were energized to 150% of rated phase voltage to establish discharges. The voltage was then reduced to 125% of rated voltage. At the 125% level, the partial discharge level was 3 picocoulombs or less.

The purpose of the Radio Influence Voltage test is to verify that the maximum RIV level is less than 100 microvolts at normal voltage after the switch is subjected to over voltage surges. Three switch assemblies were tested under all of the conditions described above. Corona values were below the 3 picocoulomb level as required and the RIV was below 100 microvolts as required.

400 hertz Withstand Test
This test is performed to insure that the tap changer will withstand the routine transformer 400 hertz test.

To make this test the three phase switch is mounted to the transformer tank in the normal manner. The tank and the second deck of the switch are connected to ground so that the test voltage will be applied between the first deck and at the same time, between decks. The electrical contacts of the first and third decks are energized with 400 hertz voltage at the specified level. The test duration was 18 seconds.

The switch passed this test at the 50 kV level.

2. Mechanical Strength Tests

Mounting Flange Strength Test
The purpose of this test is to determine the ultimate strength of the mounting threads and or mounting flange when torqued to failure using the standard mounting nut.

The switch was mounted to a steel plate to simulate the transformer tank wall. The standard gasket, dial plate, and mounting nut were used. The nut was screwed down until failure occurred. Twelve samples were tested. Torque values ranging from 200 inch-pounds to 315 inch-pounds were required to fail the samples.

The torque value required to seat the gasket and securely attach the switch to the tank wall is 100 to 120 inch-pounds. This indicates that the mounting threads and flange section of the switches have an adequate safety factor.

Shaft Torque Test
The purpose of this test is to verify that these switches can successfully withstand the torsional forces encountered when the switch is rotated.

The switches were mounted into a test frame simulating standard transformer mounting. The operating handle was rotated against the stops and torque was applied until failure occurred. The minimum failure torque is 140 in-lbs.

Side Thrust Test
Side thrust tests were performed on both types of handles, i.e., hook stick handle and pointer type handle. The purpose of the test was to determine what type of side load (perpendicular to the shaft axis) could be tolerated by the switch for either handle configuration.

Test procedure, hook stick handle: A load bar was inserted into the locking screw recess. The load bar extended away from the switch axially for a distance of 12 inches. A fish scale was attached to the end of the 12 inch length and pulled so that a bending force perpendicular to the axis of the rotor was applied to the shaft through the hook stick handle. The force was increased until failure occurred.

Test Procedure, pointer handle: A universal test machine was used to do this test. The switch was mounted into a test plate to simulate tank mounting; the test plate was rigidly attached to the lower beam of the test machine. The upper beam of the test machine was outfitted with a “push” rod such that an axis of the push rod was aligned with the side of the pointer handle. The push rod was made to travel slowly downward until failure occurred.

Test Results, hook stick handle: The minimum force needed to cause something to fail was 18 foot-pounds.

Test Results, pointer handle: The minimum force needed to cause failure was 600 pounds.

Conclusion:
Switch can withstand external side thrusts in excess of those encountered in normal operation of the switch.

Mechanical Life Test
The purpose of this test is to verify that operational ability of the switch after being subjected to 100 operations in air.

Three switches of each design type were mounted in a steel test plate, simulating a transformer tank wall. Each switch was operated at least 100 times then inspected for any signs of damage. As an added inspection measure, the resistance of each switch was measure both before and after the operational test.

All switches passed the test. There were no visible signs of damage on any of the switches. It should be noted that the resistance values remained consistent with the values measured both before and after the operational test.

Safe Transit Test
A standard test is performed to determine if the switch when mounted to the transformer will safely withstand the stresses created during shipping. Two switches of each design type were mounted into a test fixture simulating a standard transformer mounting. The fixture was then placed onto the vibratory test

platform and tested for 5 ½ hours. At the end of this test, the switches were inspected for damage. There was no sign of damage on any of the switches after the 5 ½ hour vibration period.

All of the switch designs passed the Safe Transit Test.

Cantilever Load Test
The purpose of this test is to verify that the switch, when assembled in a 2 or 3 deck configuration, can successfully withstand the cantilever loading created by the attached transformer leads. Three 3 deck switches and three 2 deck switches were each mounted into a test fixture simulating a standard transformer mounting. Weights were attached to the switches via copper leads that were in turn attached to the stationary contacts of each switch. The distance from the test fixture, tank wall, to each weight was noted. The switches were left under load for a period of seven days. All two deck and three deck switches operated successfully after being subjected to the cantilever loads in excess of 30 ft-lbs. The switch meets all cantilever loading requirements present in a typical installation.

3. Thermal Test

Contact Temperature Rise and Thermal Runaway Test
The purpose of this test is to determine the maximum continuous current rating of the two contact structures used on Tap Changer designs (150 ampere and 100 ampere).

A tap changer is horizontally mounted in a test tank in the standard manner. The bridging contacts and stationary contacts of the switch are instrumented with thermocouples to measure the steady state temperature values at various current levels. The connecting leads are sized per standard industry practice. A constant current is circulated through the circuit while the top oil temperature is held at approximately 80° C. The temperature of the current path elements is monitored and once the temperature has stabilized, the temperature at each thermocouple is noted. This procedure is repeated for the various levels of current specified.

Both current rating versions of the tap changer were tested and the results are presented in the tables below.
Note that in both versions, the contact temperature rise is thermally stable even when the current is significantly greater than the rated value.

Thermal Cycle Witstand Test
The purpose of this test is to evaluate the effect of extreme temperature cycling on the switch components. In particular, the effect of temperature cycling on the seals is evaluated.

The thermal cycle test is performed as follows: The switches are mounted in oil in a test tank containing an immersion heater to simulate mounting in an oil filled transformer. The test tank is placed in a temperature controlled thermal cycle chamber. The oil in the test tank is heated to 135C by the immersioin heater while simultaneously heating the entire test chamber to 80C. The immersion heater is turned “off” and the chamger is cooled to -35C. The duration of the cycles are such that the test pieces will be subject to the test temperature for a minimum of 3 hours. After 20 cycles, the specimens are examined for signs of thermal stress (cracks, distortioin, etc..). The gaskets are tested to verify

that satisfactory seals can still be maintainid between the transformer tank and the switch.

Twenty switches were tested. There were no signs of leaks or any visible damage to any of the test samples.

Coil Oven Bake Test
The purpose of this test is to verify that the switch will withstand the oven bake process that transformer components are subjected to during the normal transformer core-coil processing in production.

Two switches of each design were baked in an oven at 150C for 48 hours. All switches were closely examined and found to be not damaged.

The switch can safely withstand the ove bake cycle of a transfomrer core and coil assembly.

Short Circuit Tests
The switch is intended for use in Category I and II transformers as defined in ANSI/IEEE C57.12.00 - 2000. The purpose of these tests is to verify the tap changer's ability to withstand high current surges.

The test switch is mounted in an oil filled test tank simulating standard transformer mounting procedures. Symmetrical current is then applied to each specimen for a minimum of 0.25 seconds. After each high current sequence, the switch is manually operated to verify it's operational ability.

The tests were conducted by Hubbell Chance in Centralia, Missouri. All switches were operable after being subjected to symmetrical currents as follows: for the 150 A switch, 3,800 A and for the 100 A switch, 3,500 A.

The ANSI/IEEE Standard C57.12.00 - 2000 specifies a maximum short circuit withstand level for Category I transformers of 40, 35, and 25 times rated current, depending on transformer kVA, for 0.25 seconds. The same standard specifies a withstand level for Category II transformers equal to the maximum current available when limited by the transformer's impedance for 0.25 seconds.

For example a 100 kVA single phase transformer with a 2400 volt primary must withstand 35 times rated current for 0.25 seconds according to ANSI/IEEE Standard C57.12.00 - 2000. The rated current for this transformer is 42 amperes and short circuit withstand requirement is 1,458 amperes. Therefore the switch exceeds the requirement by 2,041 amperes.

Conclusion: All of the switch designs meet ANSI Standards requirments for Category I and Category II transformer applications.

5. Seal Integrity Testing

Helium Mass Spectrometer Test:
The purpose of this test is to verify the seal capability of the gasketed and O-ring interfaces of the switch. The detector used is model #MS-180, manufactured by Veeco Insturments Inc., Plainview, NY. This device is capable of detecting helium liak rates greater than $1x10^{-9}$ atm-cc/s.

Switches for this seal integrity test are first subjected to 25 operations in air. The specimens are then attached to a leak test fixture which mates the switch to the leak fixture which mates the switch to the leak detector. A vacuum is then pulled on the external portion of the swithch to simulate a pressurized transformer tank environment. A helium atmosphere is then created around the internal surfaces of the specimen. Any leak (within the sensitivity of the detector) will be detcted as the helium molecules pass through the leak and into the detector.

Fifty randomly selected switches were tested. No leaks were detected at rates faster than 1×10^{-7} atm cc/s.

The gasget and O-ring designs for the external tap changer product line far exceed the requirements necessary to maintain an oil tight seal.

Pressure-Powdered Chalk Test
This test is used as a leak detecting means by some transformer manufacturers. The test piece is mounted in a tank in a manner similar to its actual application. All external surfaces are coated with a powerdered chalk and alcohol mixture. The tank is filled with oil, sealed and pressuized to the specified pressure. Oil leaks are easily detected as discolorations in the chalk. The test is typically run for 24 hours.

Four switch assemblies are mounted into a test tank simulating the standard mounting procedures. Once the switch assemblies are mounted, the tank is filled with transformer oil and sealed. The external surfaces the switch and the tank in the vicinity of each switch are coated with the chalk-alcohol mixture. The tank is then pressuized to 7 psi and left for 24 hours. At the end of the 24 hours period, the chalk is inspected for signs of oil leak as evidensed by discoloratioin of the chalk.

Four of the switch assemblies that were subjected to the helium leak test were tested using the powdered chalk pressure test. No coloration of the chalk was observed after the 24 hourhold time. The assemblies did not leak.

It is our observation that the powered chalk test produced evidence of leaks when the leak rate (for helium) was in the range of 1×10^{-5} atm cc/s. This test seems to be much more sensitive than bubble testing, yet it is not as sensitive as helium mass spectrometer testing.

All switch designs passed the Pressure-Powdered Chalk Test.