Date: January 26, 2000

From: Dave Schroeder

Subject: Failure of TR. 77 at TSS 114, Northwest on July 30, 1999
Federal Pacific 45/60/75 MVA; S/N 70018-2

At 3:47 p.m. on Friday July 30, 1999, Transformer 77 at TSS 114, Northwest was de-energized automatically due to transformer protective relay operation. Preceding the tripout of Tr. 77 was the failure of Tr. 78 at TSS 114 at 1:18 earlier that same afternoon. As a result of the Tr. 78 failure, increased loading was distributed to the remaining in-service 75 MVA transformers. The root cause failure analysis of Tr. 78, due to a through-fault caused by a secondary cable failure, has been previously documented in a Memorandum dated November 9, 1999. Unlike the Tr. 78 failure, no apparent system disturbances preceded the tripout of Tr. 77 at 3:47 p.m.

Dissolved Gas-in-oil analysis (DGA) after the tripout indicated a considerable increase in Tr. 77 total combustibles from the previous reading; most notably in acetylene from previously not found to 13 ppm. After the completion of field electrical tests, and in conjunction with the DGA results, Tr. 77 was declared unfit for service.

The subject transformer was manufactured by Federal Pacific in 1975, S/N 70018-2, and is rated 45/60/75 MVA, OA, FA, FA; 132 kV – 13.2 kV Y- 13.2 kV Y. Each 13.2 kV winding (one designated “X” ; one “Y”) is equipped with a Reinhausen type load tap changer, and each “X” and “Y” winding is rated at 22.5/30/37.5 MVA. Transformer 77 has been in service at TSS 114, Northwest since January, 1998. Prior to the installation at TSS 114, it was located at TSS 150, Calumet and classified as a system spare since June 1988. Before being classified as a system spare, the unit had been in service as Tr. 74 at TSS 150 Calumet between September 1, 1978 and June 27, 1988.

Transformer 77 was removed from TSS 114, Northwest and shipped to the Southwest Electric transformer repair facility in Oklahoma City, Oklahoma. A teardown inspection of the unit was performed during January 11-14, 2000 to determine the root cause of failure. The teardown inspection was conducted by Mr. Charles McDonald, and Mr. John H. Ugo, representing ComED, with the assistance of design engineers from Southwest Electric. The entire transformer was disassembled during the inspection, and each winding, lead and internal component inspected.

Typical winding development for TR.77 is shown in Sketch #1, on an individual phase basis with all phases identical in construction. The dual low voltage winding requirements of TR. 77 dictate that all respective “X” and “Y” segments be identical in design; and each corresponding winding be aligned vertically on the same cylinder, one above the other.

Observations, prior to disassembly of the main core and coil assembly, showed no sign of the debris normally associated with a failure. The core and coils were, for the most part, clean and free of sludge, carbon, copper bee bees and burnt paper. Incoming test results conducted at Southwest Electric prior to the start of the teardown indicated a short on the B phase leg. The teardown inspection did reveal a B phase high voltage (138 KV) winding failure involving two disk sections in the lower “Y” winding segment. All high

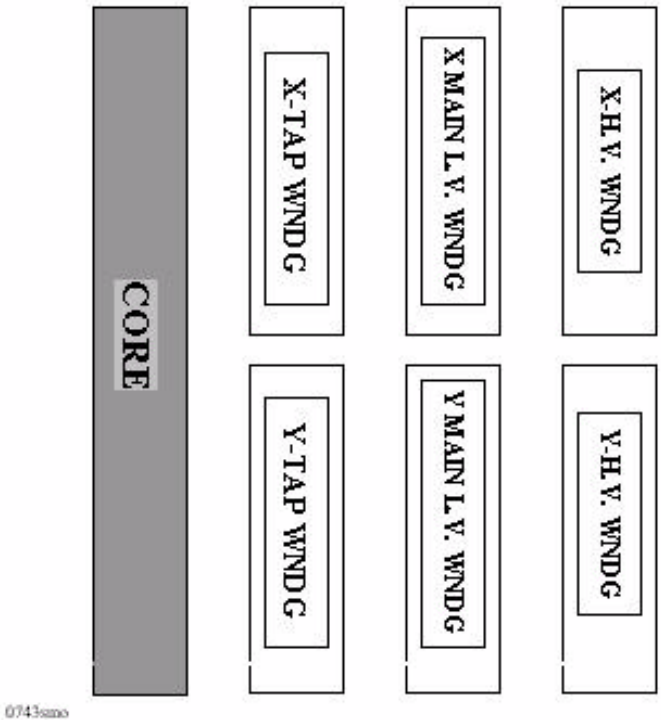
voltage winding turns in disk sections #18 and #19 (as referenced from the bottom of the coil) were shorted by a steel washer that had bridged the inner turns of both disk sections and had broken through the paper insulation covering the respective conductors. Construction of the subject high voltage disk sections is comprised of 22 conductors radially per disk with each individual conductor a complete electrical turn. All conductor used is rectangular copper strands that are individually insulated with paper. Essentially, 44 high voltage turns were shorted by the washer at the point of the failure.

A clearance of approximately ½ inch space exists between the inner conductors of the high voltage disks and an insulating cylinder, which was located immediately to the inside of the winding. This clearance permits oil flow for winding cooling during normal transformer operation. It was within this ½ inch clearance that the washer migrated upward on the inner diameter of the "Y" high voltage winding. Movement of the steel washer continued upward until its further movement was blocked by an inner oil guide collar extending inward from disk section #19. The purpose of the collar is to channel or direct oil flow throughout disk sections of the high voltage winding. The washer remained in this position until the disc potential of 4200 volts compromised the conductor insulation and welded the washer into place causing a fault and protective relay trip. (Photos 1 & 2) The type of steel washer found matches exactly hardware used in the structure that supports the load tap changer (LTC) leads in the upper area of the transformer. In 1991, the original LTC was replaced with one having a higher current rating. Part of that LTC replacement involved dismantling a portion of the upper structure for ease of modifying and extending the LTC leads to accommodate the new LTC. It is conceivable that the washer was inadvertently dropped at that time and never retrieved from the bottom of the unit. The LTC replacement was completed by a contractor during the period that this transformer was classified as a system spare, while located at our TSS 150, Calumet Substation. It is also conceivable that this washer was dropped to the bottom of the transformer while the unit was originally being manufactured in 1975. In 1998, due to a failure of the previous TR. 77 at TSS 114, Northwest, the subject transformer was relocated to TSS 114 and installed in the TR. 77 position. It remained in service as TR. 77 until the failure of July 30, 1999.

The migration of the washer to the transformer failure location appears to be a result of several factors. First, the move of the transformer from TSS 150, Calumet to the Northwest substation may have relocated the washer further into the oil duct area. Sixty (60) hertz vibration of the transformer while in service at TSS 114, and the oil flow within this area brought the steel washer into the magnetic and electrostatic influences of the "Y" segment high voltage winding. A carbonized tracking pattern could be observed on the inner conductors of disk sections immediately below the failure area. Insulation burning was noted on these conductors indicating an arcing or "spitting" between the washer and conductors had occurred as the washer migrated to the eventual failure location. The insulation damage on these lower disk sections was not sufficient to cause a turn to turn failure, but rather indicated that the apparent repulsion of the washer caused by the "spitting" against the lower inner conductors further assisted the washers upward movement. (Photos 1 & 2)

No additional abnormalities were found during the teardown inspection that contributed to the transformer failure. The failed transformer will not be repaired as a system spare, but will be replaced with a new unit.

Sketch #1



Photo’s #1 & #2, High Voltage Winding

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