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LIFE TESTING OF A LOW VOLTAGE AIR CIRCUIT BREAKER*

Mano Subudhi
Department of Nuclear Energy
Brookhaven National Laboratory
Upton, New York 11973

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DE92 014173

and

Satish Aggarwal
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ABSTRACT

A DS-416 low voltage air circuit breaker manufactured by Westinghouse was mechanically cycled to identify age-related degradation in the various breaker subcomponents, specifically the power-operated mechanism. This accelerated aging test was performed on one breaker unit for over 36,000 cycles. Three separate pole shafts, one with a 60-degree weld, one with a 120-degree weld, and one with a 180-degree weld in the third pole lever were used to characterize cracking in the welds. In addition, during the testing three different operating mechanisms and several other parts were replaced as they became inoperable. Among the seven welds on the pole shaft, #1 and #3 were found to be critical ones whose fracture can result in misalignment of the pole levers.This can lead to problems with the operating mechanism, including the burning of coils, excessive wear in certain parts, and overstressed linkages. Furthermore, the limiting service life of a number of subcomponents of the power-operated mechanism, including the operating mechanism itself, were assessed. Based on these findings, suggestions are provided to alleviate the age-related degradation that could occur as a result of normal closing and opening of the breaker contacts during its service life. Also, cause and effect analyses of various age-related degradation in various breaker parts are discussed.

INTRODUCTION

Low voltage air circuit breakers used to control and protect circuits up to 600 volts in an electrical system, are the subject of this paper. Among the safety applications of these breakers in the nuclear power industry, one of the most important functions is to supply electric power to the reactor control rods of Pressurized Water Reactors (PWRs). Interruption of the power to the rod control cabinet causes the control rods to fall by gravity into the reactor core, thereby causing the reactor to shutdown. The three prime manufacturers

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*Work done under the auspices of the U.S. Nuclear Regulatory Commission.

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and suppliers of these breakers are Westinghouse, General Electric, and Brown Boveri Electric Company. This paper discusses the findings of the aging research performed on two models of Westinghouse DS-series breakers that are typically used in Class 1E applications in nuclear power plants.

The two models, DS-206 and DS-416, are similar in design, however, each has a different current rating. Figure 1 illustrates DS-416 breaker assembly. The DS-206 model is rated for 800 amps, while the DS-416 is rated for 1600 amps. This requires a different number of contact fingers to the supply bus bar for each model. The primary components, including the power-operated mechanism, structural components, contact assembly, and all other control devices are identical for these breakers.

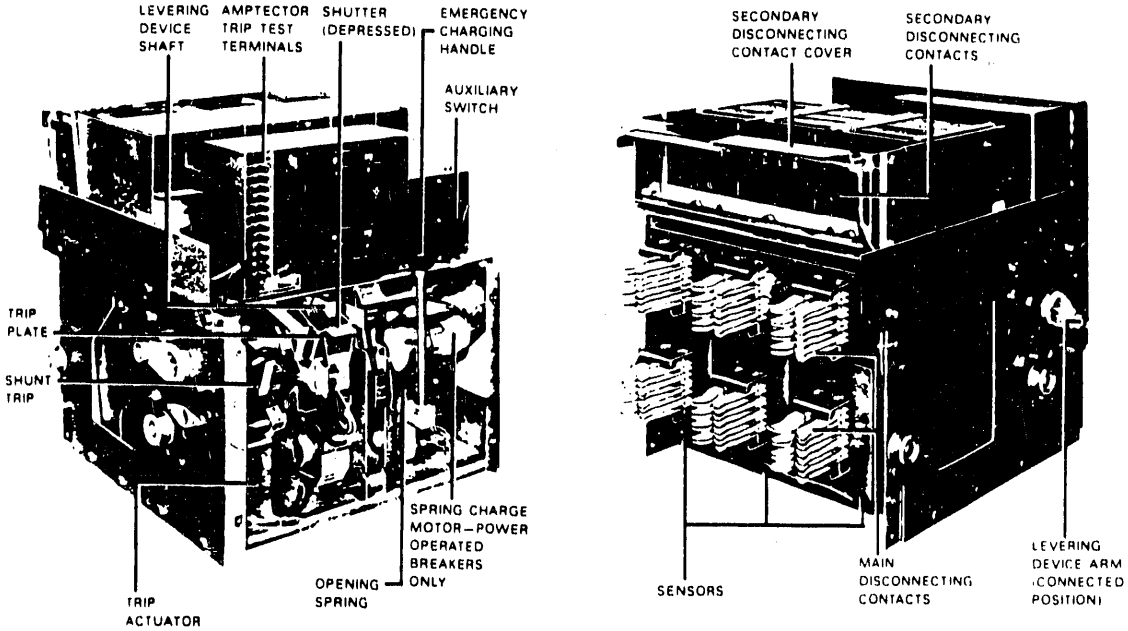


Figure 1. Front and back views of a Westinghouse DS-416 circuit breaker

During the seventies and early part of the eighties, these breakers, specifically the reactor trip breakers (RTBs) were reported to exhibit problems with their undervoltage trip attachments (UVTAs). This often resulted in failure of the breakers to trip on demand from the control room. This problem was later diminished after adopting design changes and maintenance activities recommended by both the manufacturer and the regulating agency. In recent years, a number of age-related problems occurred, including cracking of welds on pole shaft levers, weld failures in the secondary contact bracket, non-uniform wear on the closing cam segments, misalignment of the main roller, broken spring release latch-levers, broken trip latch pivot pin, insufficient clearances between the breaker moving parts, and loss of spring tension in the cell-switch spring-return mechanism.

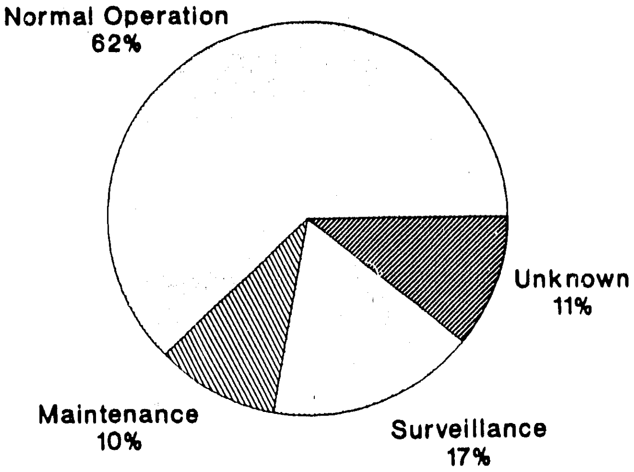


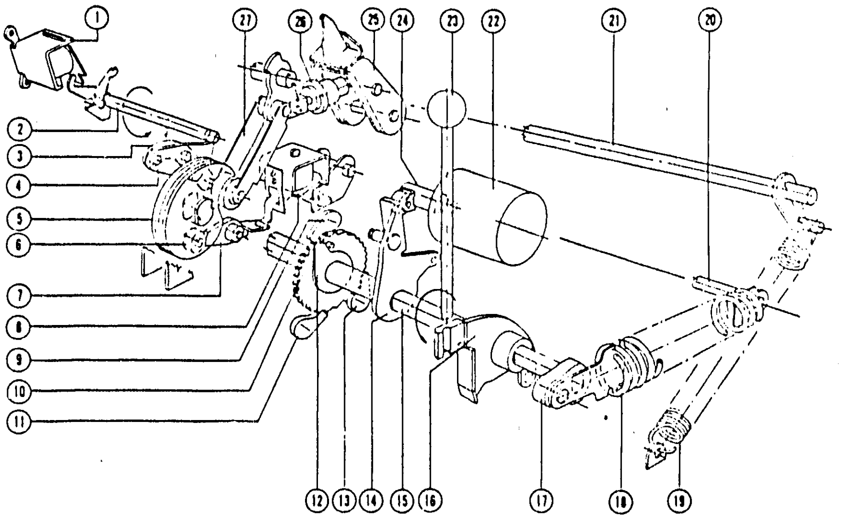
Figure 2. System operating status at the time of breaker failure

Operating experience reported to the Nuclear Plant Reliability Data System (NPRDS) shows that a large percentage of these aging problems were detected while the system was in normal operation (Figure 2). Current maintenance activities adequately address age-related degradation of the contact assembly, caused by erosion and burning due to electrical arcing. However, measures which could alleviate aging problems in the power-operated mechanism (shown in Figure 3) are lacking. Furthermore, this component consists of a number of parts vulnerable to aging and is responsible for charging, closing, and tripping the breaker contacts.

To understand aging within the power-operated mechanism and to determine appropriate mitigating methods prior to reaching the end of life, one DS-416 breaker was subjected to accelerated mechanical cycles. Three different pole shafts were used in the test; each shaft containing a different third lever weld configuration (Figure 4). In addition, three operating mechanisms, two charging motors, and other parts of the power-operated mechanism were used during the test as they became inoperable. Metallurgical examinations of fractured components, mechanical tests of worn surfaces, and other analytical studies of failed parts were conducted to determine the failure causes and the aging mechanisms that contributed to the component failures. Finally, the useful life of each component vulnerable to aging was assessed to help establish recommended replacement schedules prior to failure.

DESCRIPTION OF THE TEST PROGRAM

The overall integrity of the breaker is dependent on the condition of various structural, mechanical, and electrical components within the breaker assembly. Two dominant factors that can induce degradation of these components are the environment of the surroundings and the operating cycles. Since the



1. SHUNT TRIP DEVICE
2. TRIP SHAFT
3. ROLLER CONSTRAINING LINK
4. TRIP LATCH
5. CLOSE CAM
6. STOP ROLLER
7. SPRING RELEASE LATCH
8. SPRING RELEASE DEVICE
9. OSCILLATOR PAWL
10. RATCHET WHEEL
11. HOLD PAWL
12. DRIVE PLATE
13. EMERGENCY CHARGE PAWL
14. OSCILLATOR
15. CRANK SHAFT
16. EMERGENCY CHARGE DEVICE
17. CRANK ARM
18. CLOSING SPRING
19. RESET SPRING
20. CLOSING SPRING ANCHOR
21. POLE SHAFT
22. MOTOR
23. EMERGENCY CHARGE HANDLE
24. MOTOR CRANK AND HANDLE
25. MOVING CONTACT ASSEMBLY
26. INSULATING LINK
27. MAIN DRIVE LINK

Figure 3. An exploded view of power-operated mechanism

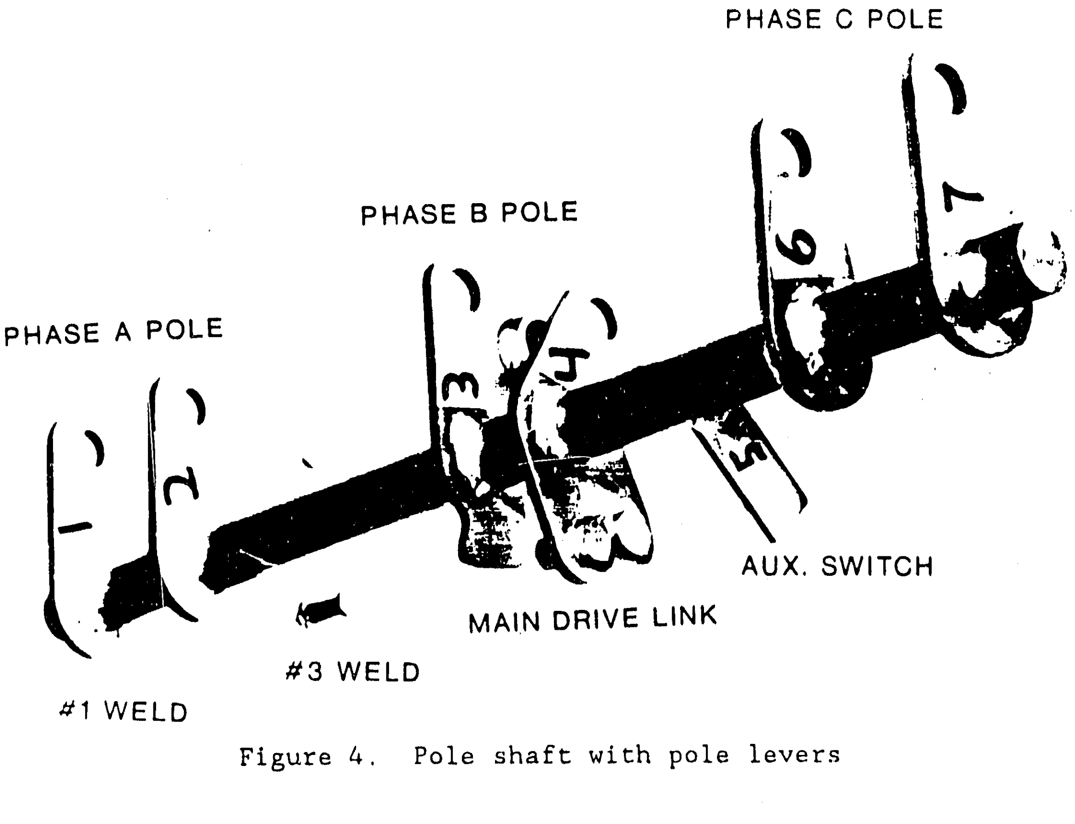


Figure 4. Pole shaft with pole levers

environment of a breaker in a nuclear power plant is relatively benign,* it has a minimal effect on the degradation of the breaker's components. The operating cycles, however, induce degradation attributed to heating generated by full load operation, and arcing associated with the closing and opening (or tripping) of the breaker. Problems stemming from this heating are typically associated with the burning and erosion of contact surfaces and arc chutes. From the various maintenance recommendations found in industry standards or in manufacturers' manuals, it is evident that these problems are better understood by the utilities. In addition, the cycling itself imposes various aging degradation in the power-operated mechanism and the pole shaft. Review of operating experience data from the NPRDS revealed that aging of various parts within the power-operated mechanism, including the pole shaft, had dominated the recent breaker failures. The current inspection, monitoring, and testing activities failed to identify degradation of these subcomponents at their incipient stages. Since the failure of substandard pole lever welds on a reactor trip breaker at the McGuire nuclear power station in 1987 prompted this research, this testing was limited to mechanical cycling to assess the adequacy of the inspection program delineated in NRC Bulletin 88-01 for verifying the structural integrity of all seven welds on the pole shaft, as shown in Figure 4.

The Westinghouse DS-416 circuit breaker was subjected to accelerated charge-close-open cycles following guidelines provided in the ANSI/IEEE C37.50-1981 standard for circuit breaker life testing. The test breaker, while under no electrical load, was cycled mechanically over 36,000 cycles to accelerate the aging processes normally expected during operation. The close/open period for the breaker between cycles was a minimum of two minutes. Every 500 cycles minor maintenance was performed to keep the breaker in operational condition. This included visual inspection and lubrication at recommended locations. After every 1000 cycles several breaker diagnostic tests were performed to obtain the component aging parameters for assessment of breaker performance. These parameters were then trended to determine the aging characteristics of the breaker as a function of operating cycles. Each time a subcomponent was found inoperable, it was replaced. However, when the pole shaft or the operating mechanism was found to reach its end of life, in addition to replacing the subcomponent the breaker was thoroughly examined, overhauled, photographed, and refurbished before the next test sequence was initiated.

Figure 5 shows the experimental setup for this life testing. A controller was designed and installed to automatically actuate the breaker for a predetermined number of cycles. This controller was also used to record the test cycles, stop and start the breaker, provide mountings for other meters and measuring devices, and most importantly, harness all electrical connections to insure both electrical integrity and quick disconnects. Periodic measurements of various breaker components included dropout voltage for the UVTA, dimensional stability of the contact assemblies, contact and circuit resistances, coil resistance and temperature, tripping ability of shunt coils at 55% of the rated coil voltage, forces/torques on the pole shaft, clearances, spring stiffnesses, and distortions of mechanical linkages. Other physical

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*Typically clean, free of dusts or contaminants, room temperature, low humidity.

parameters measured included cleanliness, wear, sluggishness, alignments, and cracks. With exception to torque measurements on the pole shaft, the parameter measurements required no elaborate instrumentation. The forces/torques on the center pole lever weld were monitored with strain gages mounted on the pole shaft between the #2 and #3 levers, and by observing both static and dynamic stress signals displayed on an oscilloscope while the breaker was operating. Since the primary objective of this test was to characterize aging within various breaker components, operational limits, such as response time, were not monitored during testing.

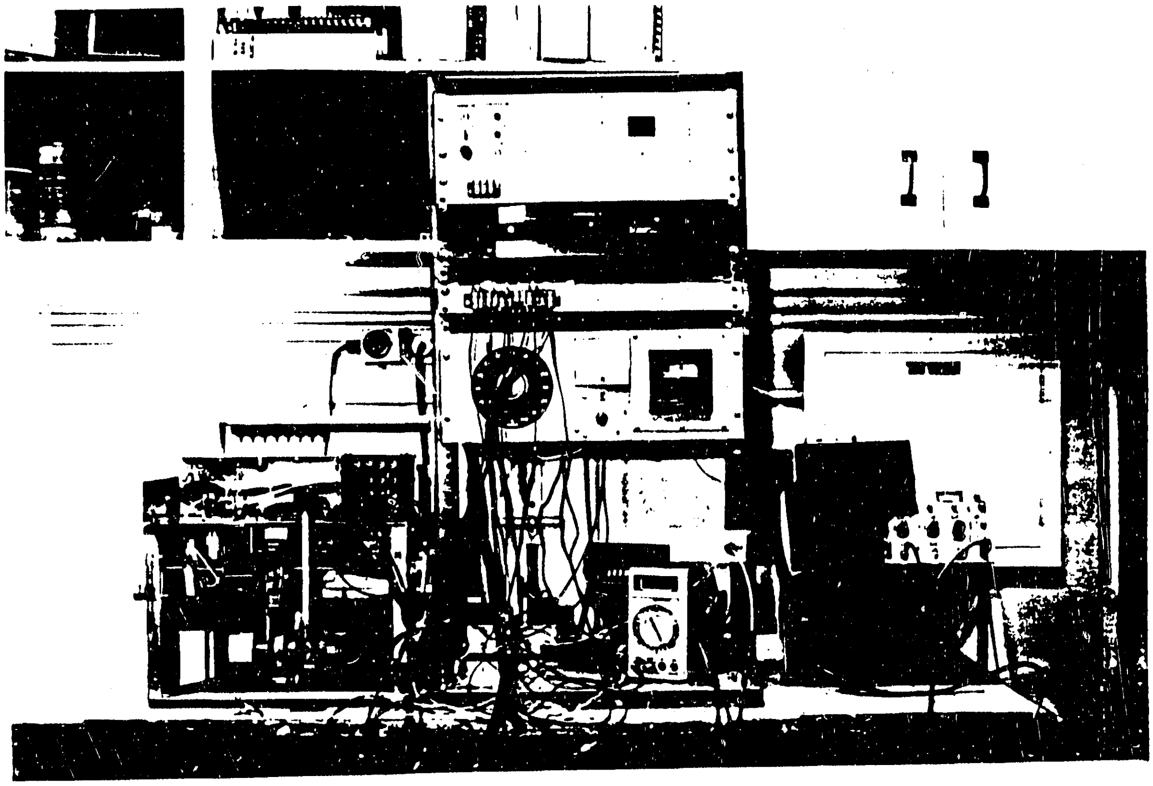
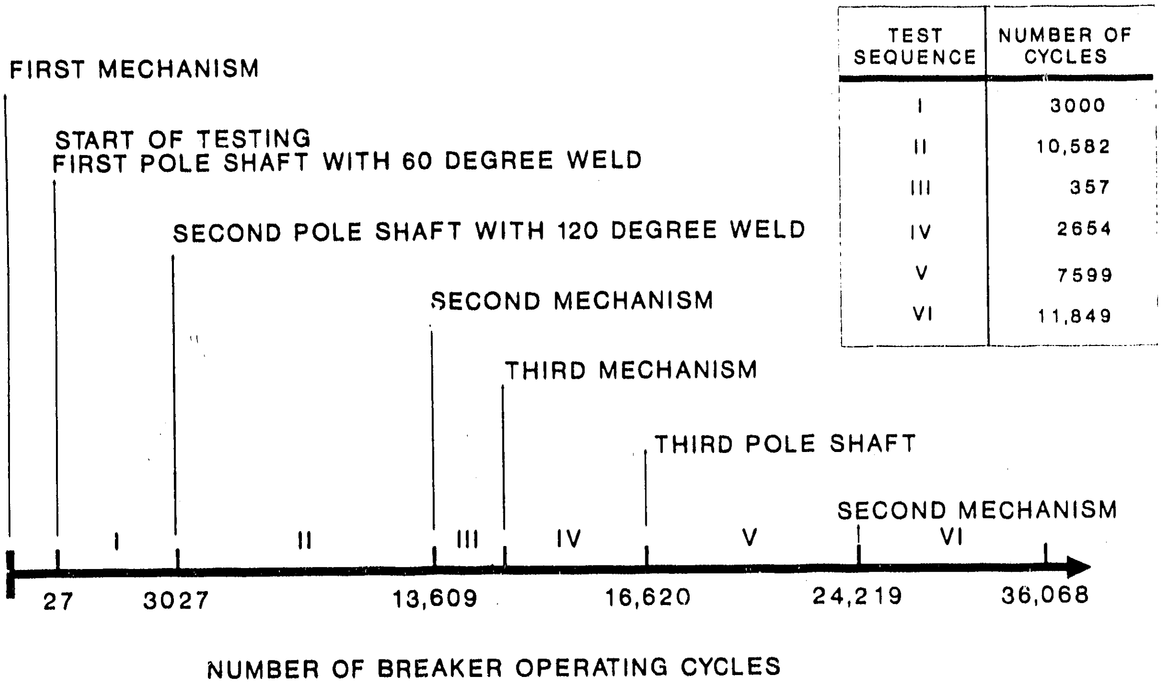


Figure 5. Experimental set up

Three different pole shafts were used in the test to characterize the effects of breaker cycles on weld size. The first shaft was cut to simulate a weld size of 60-degree at the #3 lever. Since the welds on some of the pole shafts procured for the test program were made substandard, the second and third shafts having a 120-degree and 180-degree welds at the #3 lever respectively were chosen; the third one simulating a good (or as-designed condition) weld.

Figure 6 illustrates the sequence of major events that took place during the nine months of test. The first 27 cycles occurred during the pre-testing period with the first operating mechanism in place. Next, the first pole shaft with a 60-degree weld at the #3 lever was installed. The shaft failed after 3000 cycles of operation when the center pole lever (#3 lever) was completely separated from the shaft. The test resumed with the second shaft containing a

120-degree weld, while the operating mechanism remained the same. After an additional 10,582 cycles, the first operating mechanism failed. The second mechanism was installed and the test was resumed. Because of a burr on the crank shaft due to poor quality assurance during manufacturing, the mechanism was replaced after 357 cycles with the third mechanism. After an additional 2654 cycles, the second pole shaft developed cracks in the #3 and #1 lever welds causing misalignment between the five levers connected to the three pole contacts. A third shaft with a set of good welds at all the levers replaced the second shaft for the next 7599 cycles, when the third mechanism was declared inoperable. The refurbished second mechanism was then reinstalled and the test was continued for another 11,849 cycles when this mechanism failed. The welds on the #3 and #1 levers had developed crack sizes of 10.5mm and 6.15mm respectively, after experiencing 19,448 cycles of operation. These cracks did not cause any problems with breaker operation.



TEST SEQUENCE	NUMBER OF CYCLES
I	3000
II	10,582
III	357
IV	2654
V	7599
VI	11,849

Figure 6. Sequence of major events

TEST RESULTS

Degradation induced by breaker cycling are related to deterioration of mechanical parts and loss of dielectric strength in electrical coils. Understanding these types of age-related degradation, and estimating the useful service life of the breaker component are still areas where little information is available. However, these areas are important to the utilities for improving breaker performance.

Structural Components and Contact Assembly Integrity

The carbon steel structural components exhibited the least susceptibility to aging, even after over 36,000 test cycles. Similar findings were also noted when both the moving and the stationary contact elements were examined for misalignment. However, the alignment of the three moving contacts had changed when either the welds of the pole levers separated from the pole shaft, as discussed later, or the fasteners and other spring elements maintaining contact pressure weakened with age.

Pole Shaft Welds

The high force/torque on the #3 pole lever weld is the critical reason why a crack in this weld developed first in the pole shaft with 60-degree weld; as shown in Figure 7. The #3 lever was completely detached from the shaft before transferring any load to other welds. Up until 2000 cycles, the effect of the crack in this weld was not noticed. For the next 1000 cycles, however, several problems associated with the operating mechanism were observed, including jamming of the trip mechanism, failure of the breaker to lock in or trip, and sluggish operation.

Figure 7. Complete detachment of #3 pole lever at 3027 test cycle

For the second and third shafts, where the weld lengths were larger, cracks were found to develop in both the #3 and #1 pole lever welds simultaneously. On the second shaft, both cracks grew at almost the same rate. After reaching a size of one-fourth their original weld length, misalignment between the five levers connecting to the three poles occurred, as illustrated in Figure 8. This misalignment later caused the phase A pole pin to fracture. Other problems included failure of the first mechanism and burning of the charging motor. Similar symptoms were noted in the third shaft. However, in this case the cracks never grew large enough to cause misalignment problems. Nevertheless, both these shafts functioned satisfactorily for the first 10,000 test cycles.

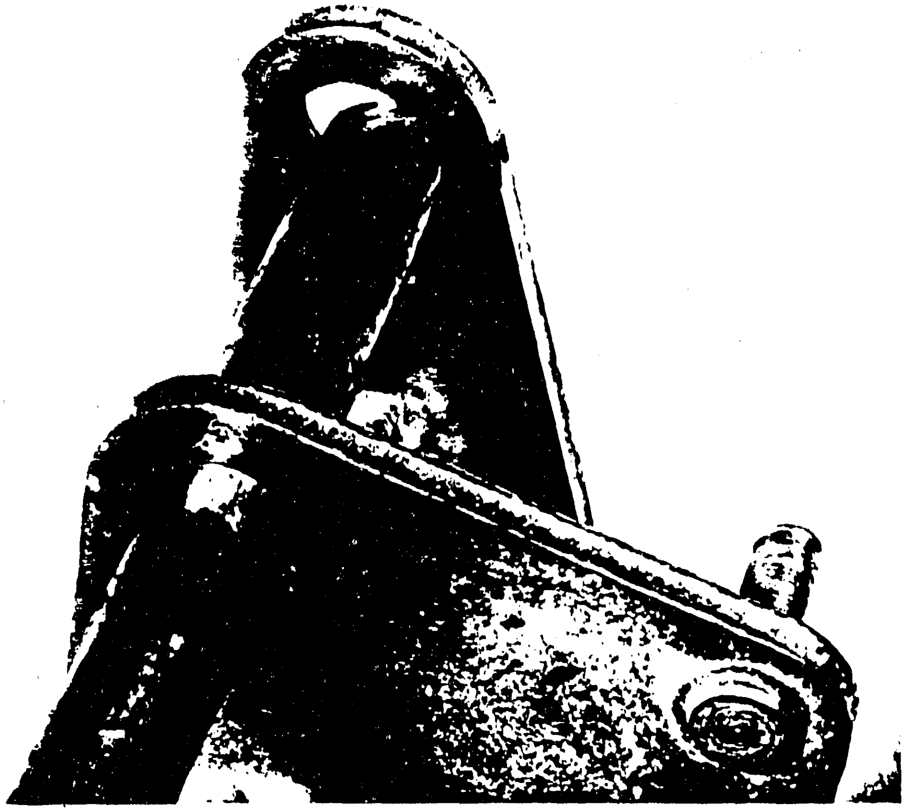


Figure 8. Pole lever misalignment

Charging Components

The motor crank and handle, oscillator, drive plate, and ratchet wheel and holding pawls performed satisfactorily up to 10,000 cycles, beyond which they exhibited severe wear at the contact surfaces. The ratchet wheel started slipping from the holding pawls, while the oscillator surface was found to be grooved by the motor crank and handle. All parts were badly worn prior to being replaced.

The groove on the first oscillator surface was not that deep when compared with that of the third oscillator which was purchased as spare parts (see Figure 9). A hardness test on all three oscillators indicated that the original, which came with the breaker, had a Rockwell 'B' Hardness number of 57.7, as compared to 38.7 and 45.5 for the second and third units. This suggests that the new oscillators are made out of a softer material than the older unit.

First Mechanism
(End of 13,609 Cycles)

Third Mechanism
(End of 10,253 Cycles)

Figure 9. Wear on oscillator surface

Each time the charging motor is energized, the oscillator pawl reset spring goes through a number of expansions and contractions. The original unit had a smooth transition bend in the neck of the end hooks, while that of a newly procured unit did not (see Figure 10). The new spring, with a sharper bend, failed after 2286 test cycles, while the original unit never failed even after experiencing over 10,000 cycles.

The stator insulating system of the charging motor burned out twice; first after 13,609 cycles, and then after 10,715 cycles. In between, there were several problems associated with the carbon brushes, including cracking, uneven wear , and excessive carbon deposits on the armature contact surface. Throughout the test, the springs holding the brushes were adjusted, and the armature surfaces were cleaned as part of the 500-cycle maintenance program.

Operating Mechanism

This mechanism consists of a close cam, main drive link, spring release latch, stop roller and closing coil. It is responsible for transferring the force from the charging motor and the trip bar to the pole shaft, which provides the appropriate motion to the moving contact elements. Three different units were used in the test; the first one failed after 13,609 cycles, the second after 10,253 cycles and the third after 12,206 cycles. Thus, the life of the operating mechanism was assessed to be above 10,000 cycles.

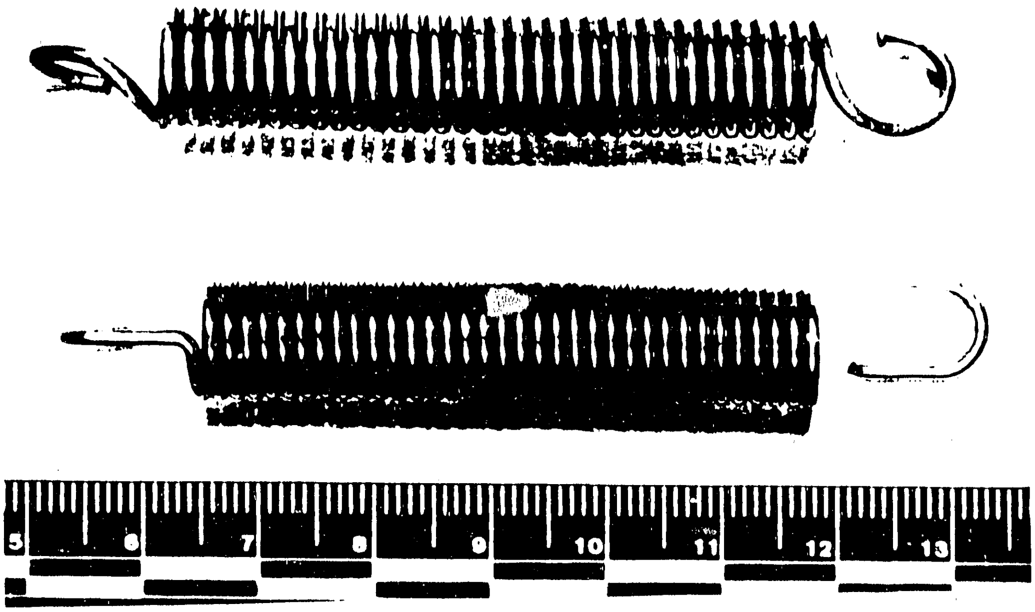


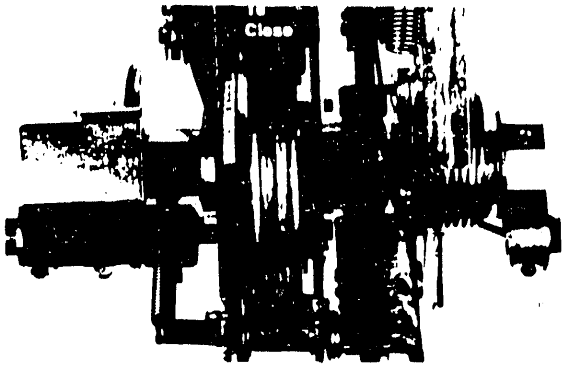
Figure 10. Oscillator pawl reset springs

Figure 11 shows the severity of aging as the first mechanism underwent test cycles: the wear on the four cam segments increased with the number of cycles. In addition, the cam assembly loosened and developed a little play within the housing. Grooving in the stop roller and on the cam itself were also evident after disassembling the unit, as illustrated in Figure 12. Further, the inner two cam segments were worn more than the two outer plates.

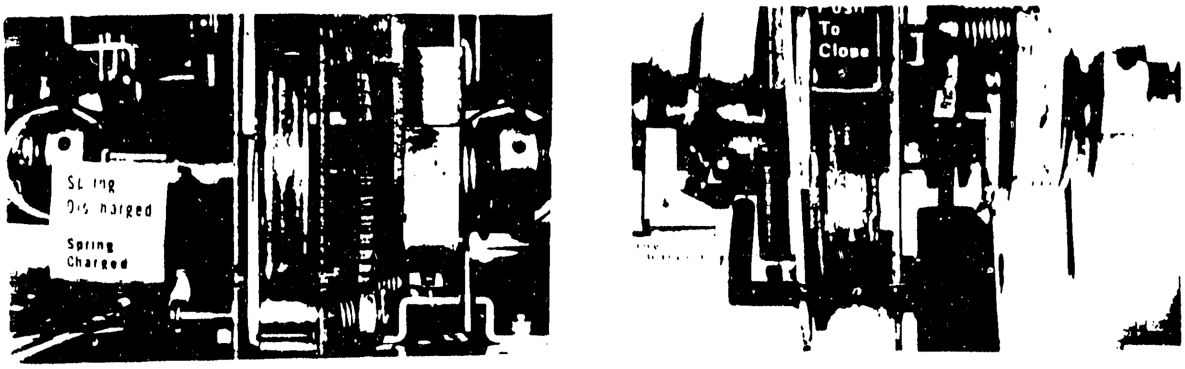
The closing coil of the spring release device burned out after it had been through 20,724 cycles. Within another 468 cycles, a newly replaced coil also burned out. These incidents were further investigated to determine the root causes. Both incidents occurred when the currently installed operating mechanism was showing significant aging and was running sluggish or was jammed. Examining the trend data pertaining to the coil conditions, it is concluded that these coils failed due to jamming of the mechanical linkage attached to them.

Tripping Components

The trip bar, trip latch, and roller constraining link are connected to tripping devices, such as the shunt trip attachment (STA) and/or under-voltage trip attachment. There was no indication of burn out or malfunction of these attachments during the test. Temperature rise, insulation resistance, and threshold voltage (STA was tested for pick up at a voltage of 55% of the rated value and the UVTA was tested for drop out voltage) tests indicated no significant change warranting replacement. However, for the first 10,000 cycles the dropout voltage for the UVTA was closer to the upper limit of 28.8 volts, while for the remaining life it was closer to the lower limit of 14.4 volts (see Figure 13).



Almost New
(<1000 Cycles)



After 4000 Cycles

End of 13,609 Cycles

Figure 11. Wear on cam assembly

A newly purchased trip indicator reset spring failed after 5861 cycles for the same reason as discussed earlier for the oscillator pawl reset spring. The trip latch and the roller constraining link had some minor wear and did not cause any problem during the test.

ANALYSIS OF TEST RESULTS

The primary function of a circuit breaker is to close the contacts when supplying electric power to a component and to open the contacts to disconnect the power supply. Therefore, the breaker should be able to charge, close, and trip the breaker whenever needed, and the contacts should be able to transfer or break the electric power. This, in turn, requires that the three integrities (structural components, power-operated mechanism, and the contact assemblies) of the breaker should be maintained. The results from this testing, revealed significant aging in parts associated with the power-operated mechanism.

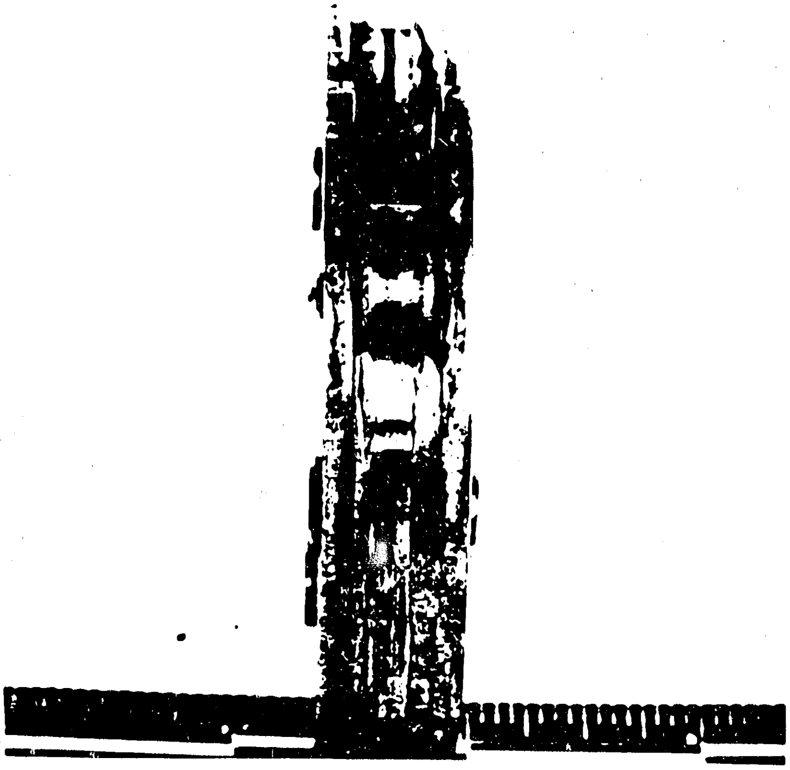


Figure 12. Severe wear in cam segments and grooving in stop roller

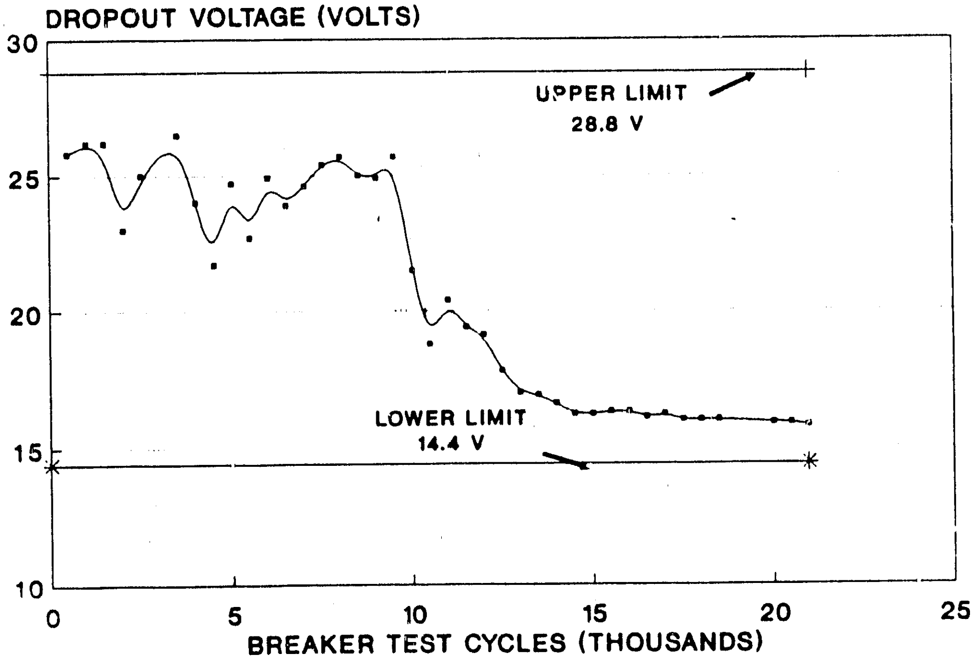


Figure 13. Dropout voltage test on UVTA

Pole Shaft and Levers

The failure of the pole shaft weld, which recently received a great deal of attention, is analyzed separately. The strain-gage plots suggest that the peak torques experienced by the pole shaft and the tripping time spans change with the age of the breaker. The torque signatures are influenced both by the pole lever weld cracks and aging of various parts within the operating mechanism assembly. Analyzing the test results for the three test shafts, the following two failure modes are associated with pole shaft failures:

(1) If the quality of the weld in the lever #3 is very bad (i.e., an effective weld size less than 90 degrees, or the presence of cleavages or slags in the weld), complete separation of lever will occur.

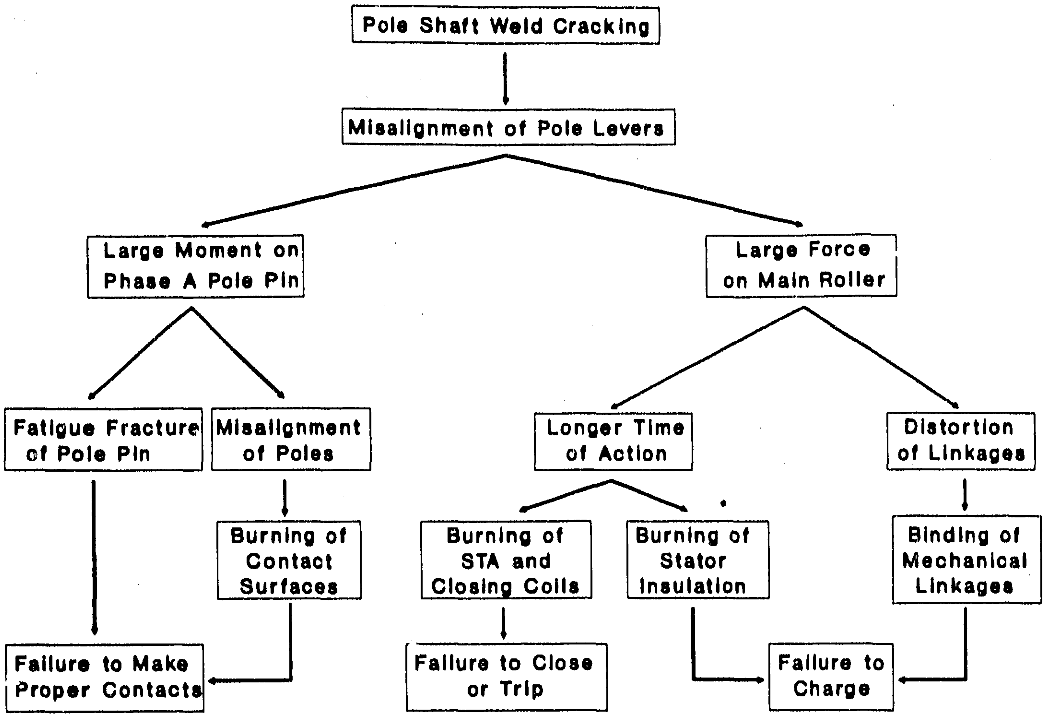
(2) If the quality of the weld in the lever #3 is normal (i.e., an effective weld size is at least 90 degrees with some level of imperfection such as porosity), cracks in the #1 and #3 welds will develop.

In either mode, once the cracks reach a certain size the five levers on the pole shaft become misaligned. The torque transferred by the main drive link is then redistributed nonuniformly among the three poles via their associated pole levers (i.e., #1 and #2 for pole A, #3 for pole B, and #6 and #7 for pole C).

The effects of the torque redistribution and the misalignment of pole levers, disrupts the bending moment on the pole pins connected between two adjacent levers supporting the insulating link and the moving contact assembly. Since the shaft is connected to one opening spring at the lever #7, phase A levers (#1 and #2) experience the largest torque while the phase C (#6 and #7) levers experience the least. However, the center pole (phase B) being the point where the main drive link is attached, experiences large enough torque to produce the largest weld cracks for the second and third test shafts.

The force on the main drive link and the connecting parts of the power-operated mechanism are also changed due to the cracks in the pole shaft weld. The two significant effects are the longer time of action during the tripping cycle, and the distortion of the linkages. These, in turn, lead to the burning of the motor winding and control coils. Figure 14 illustrates the sequential events that appear to have occurred as a result of weld cracking in the pole shaft.

Provided the welds on the pole shaft are good (as designed or passed NRC Bulletin 88-01 requirements), the life of the pole shaft can be well over 12,000 mechanical cycles. Thus, after complying with the NRC Bulletin inspection programs cracking in the pole shaft weld should not be a concern for safety. However, monitoring for possible cracks in the welds #1 and #3 during a breaker overhaul or maintenance would be a good practice.



•only if the closing springs are recharged after the breaker is closed

Figure 14. Cause and effect analysis of failure of pole shaft weld

<u>Power-Operated Mechanism</u>

The principal parts of a power-operated mechanism assembly, that have shown some aging due to mechanical cycling, are listed in three groups. Others, not included in this list, such as the closing and opening springs, crank shaft performed their design functions throughout the test. Group 1 components are responsible for charging the unit while the closing springs store the potential energy for closing the contacts, group 3 components are responsible for tripping the breaker, and group 2 components are responsible for closing the contacts and also providing controlled motion for the three operations (i.e., charging, closing, and tripping) of the breaker.

The two predominant modes of failure include the jamming of all linkages and the slipping of the crank shaft which prevented the breaker from charging. Based on the test results, the average life of this assembly is about 12,000 cycles. However, indications of aging were observed somewhere around 9500 cycles. These indications are presumed to reflect the synergic effects of parts of this assembly and the cracking of the pole shaft welds. Therefore, for the second mechanism where the pole shaft contained good welds, no particular early sign was noted until the final 500 cycles.

Excessive wear of the teeth in the ratchet wheel and the rounding of pawl and the drive plate edges caused the ratcheting action to slip when the electric motor began to crank. Furthermore, the grooving on the oscillator surface and wearing of the motor crank and handle caused irregular motion of the crank shaft. Finally, deterioration of insulation in the motor stator windings was a factor in the loss of motive power to the charging components. As a result of those aging problems, the breaker failed either to crank or to hold the ratchet wheel at its proper positions. thus, eventually the breaker failed to rotate the cam assembly to appropriate positions. Figure 15 illustrates the root-cause analysis of parts associated with components responsible for charging the breaker.

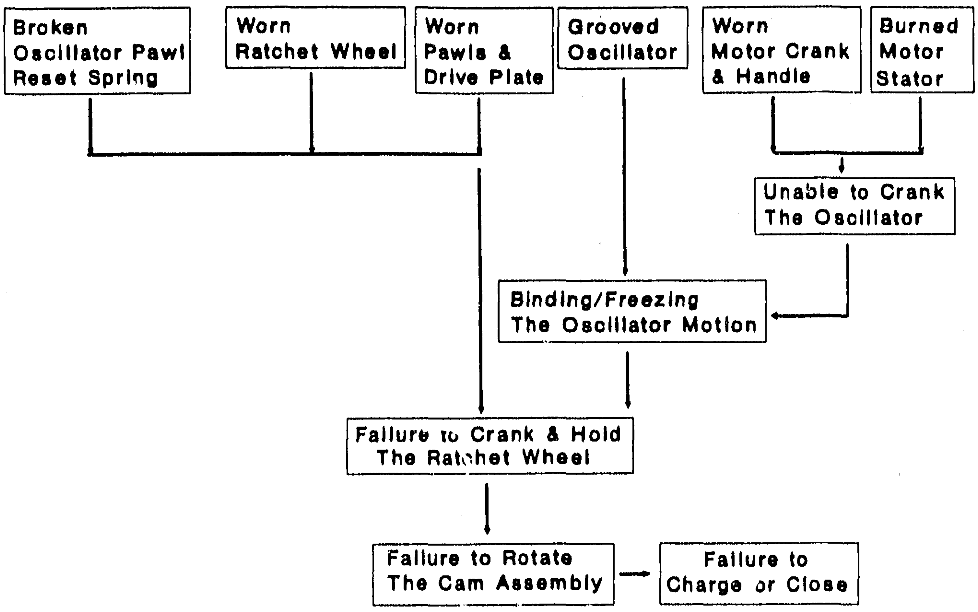


Figure 15. Cause and effect analysis of parts responsible for charging the breaker

For the parts within the operating mechanism, wear in the cam assembly and the stop roller reduced the ability of the cam to transfer appropriate control to the main drive link. The constant rolling action of the main roller over the cam surfaces, which can be further accentuated by the redistribution of forces on the main drive link by either failure of the pole shaft weld or misalignment, is primarily responsible for wear on the cam. The main roller attached to the main drive link showed some wear and distortion. Aging in all these components often leads to a binding force on the spring release latch which, in turn, leads to burning of the closing coil. Figure 16 shows the cause and effects analysis for this group of components.

Finally, among all parts within the tripping assembly, the roller constraining link or the trip latch indicated some wear. In addition, there are two small springs, on attached to the left end of the trip shaft, and the other linked to the "trip" indicator plate. Both springs are used to reset the trip bar. Metallurgical examination of the fractured surfaces of the broken trip indictor spring revealed that because of the sharp bend at the ends, a high stress probably initiated the crack, which grew under cyclic action of this spring. Under these conditions, the trip shaft failed to reset the breaker. Although this never happened in this test program, dwelling of the trip shaft in one position could lead to burning of the STA coils. Figure 17 shows the root cause analysis for this group of breaker components.

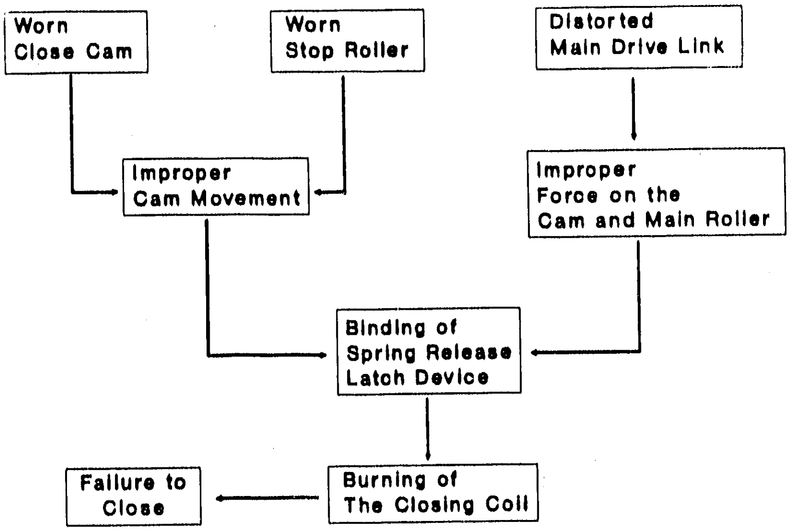


Figure 16. Cause and effect analysis of parts in the operating mechanism

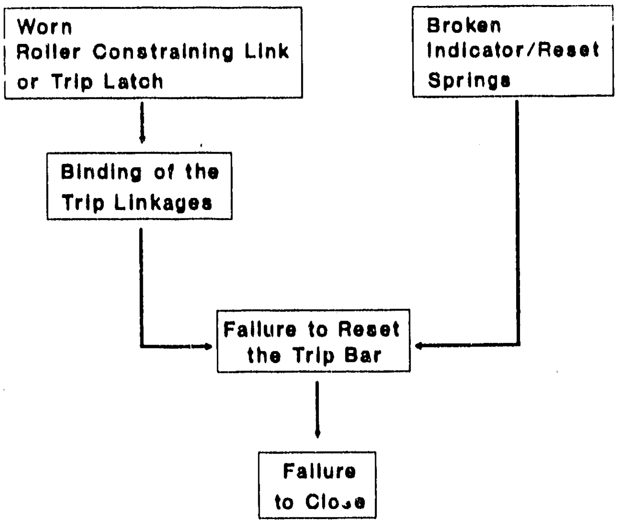


Figure 17. Cause and effect analysis of parts in the tripping assembly

SUMMARY AND CONCLUSIONS

Mechanical cycling of a breaker without the power circuit being energized, causes significant aging in various parts of the power-operated mechanism, including the pole shaft. If the breaker is procured with all parts manufactured to the standard of their design requirements, the breaker can last for over 10,000 cycles, which is far in excess of the 3,200 mechanical cycles required by ANSI Standard C3716. For example, the pole shafts should have 3/16 inch fillet welds for a length of 180 degrees for all pole levers (specifically for the #3 and #1 levers), the reset springs should have smooth transition bends at the end hook areas, and quality manufacturing of all parts, including electroplating and machining of surfaces.

A cause and effect analysis of age-related degradation in various components of the power-operated mechanism was performed to understand the aging processes and how to mitigate them. All three coils (spring release device or closing coil, UVTA, STA) in the control circuit of the breaker were found to perform satisfactorily throughout the test. However, when the attaching levers or linkages to these devices were jammed, higher current inrush into these coils is likely to occur, causing burning of the insulating materials.

Cracking of Welds at the #3 and #1 levers leads to misalignment among the five levers attaching the three poles, as well as the main drive link. This results in an uneven moment on the three pole connections; with the Phase A pole pin experiencing the worst. This could lead to improper surface-to-surface contact with the stationary contacts. In addition, the misalignment could cause an excessive force on the main drive link, which could accelerate the degradation process in the operating mechanism causing the breaker to fail.

Significant aging in the group of components responsible for charging the breaker could lead to improper rotation of the cam assembly, causing the breaker to fail to charge or close. Similar results are also expected when aging in the operating mechanism components becomes noticeable. The components used for tripping are also subjected to aging, and their degradation could also lead to failure of the breaker to close.

Most premature failures experienced during the test stemmed from poor manufacturing control, such as substandard welds on the pole shaft and sharp bends on control spring hooks. If these components were manufactured properly, the life of the breaker could have been extended further than that found during the test. On the other hand, the life estimates of those components, whose operating conditions were assessed based on age-related degradation, far exceed the required number of cycles by the industry standards. Predicting the actual life of a breaker component under normal operating condition is beyond the scope of this study. However, the useful life of a breaker is assessed assuming normal operating condition and maintenance practices.

Based on the results of this test, the structural components and the contact assembly units are least susceptible to aging due to mechanical cycling of the breaker. During the test, the performance of the power-operated mechanism, including the charging motor was satisfactory for the first 10,000 cycles. It is, therefore, concluded that under actual plant condition with the power circuit energized, the breaker should have a useful life of 5000 cycles (assuming a factor of safety of 2 to account for the effects of heating due to arcing and environmental conditions). ANSI standard 37.16-1980 defines the life of a Westinghouse DS-416 breaker model as 4000 cycles, and that of a DS-206 model as 12,500 cycles. However, since the construction of both these models, specifically the components vulnerable to aging, is very similar, the life of both these models should be the same.

To alleviate problems stemming from aging of various breaker components, a maintenance program should include periodic walkdowns and inspections of parts that are vulnerable to aging, in addition to regular maintenance activities. Parts exhibiting noticeable degradation should be replaced or repaired. Additional tests for developing operational limits for aged components are necessary in order to identify degradation during routine tests and surveillance.

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