U. S. NUCLEAR REGULATORY COMMISSION

REGION V

SPECIAL INSPECTION REPORT

Report Nos.: 50-528/92-15, 50-529/92-15, 50-530/92-15

Docket Nos.: 50-528, 50-529, 50-530

License Nos.: NPF-41, NPF-51, and NPF-74

Licensee: Arizona Public Service Company
P. O. Box 53999, Station 9012
Phoenix, Arizona 85072-3999

Facility Name: Palo Verde Nuclear Generating Station
Units 1,2, and 3

Inspection at: Palo Verde Nuclear Generating Station
Wintersburg, Arizona

Inspection Conducted: April 4-10, 1992

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Inspection Summary:

Inspection on April 4-10, 1992 (Report Nos. 50-528/92-15, 50-529/92-15, and 50-530/92-15)

Areas Inspected: Special inspection of failure of Westinghouse Type DS-206 reactor trip breaker to open during routine surveillance test, and failure of General Electric Type AKR-30 reactor trip breaker to close after routine maintenance.

During this inspection, Inspection Procedure 92700 was used.

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Results:

General Conclusions and Specific Findings:

1. The inspection concluded that the licensee's incident investigation was thorough, and clearly defined the mechanical causes of failure of both circuit breakers.

2. The inspection found that both types of circuit breakers had a combination of mechanical misalignments of the breaker mechanisms. The inspection concluded that these misalignments had caused the breakers to fail.

3. The inspection found that partially incomplete, outdated, and incorrect maintenance practices had been used for the circuit breakers. The inspection concluded that these improper practices had allowed, if not caused, the breaker mechanism misalignments which were found.

4. The inspection found that the initial troubleshooting of these breakers was informal. The inspection concluded that the breakers were not preserved in their failed condition as well as was possible.

Significant Safety Matters:

The licensee's apparent failure to implement the latest vendor information into the reactor trip breaker maintenance program, use of improper lubricants for the reactor trip breakers, and initially uncontrolled troubleshooting for these components, are indications of significant weakness in these programs.

Summary of Violations and Deviations:

Based on the results of this inspection two apparent violations were identified: Improper corrective action for deficiencies in the reactor trip breakers, and failure to implement formal troubleshooting of the Westinghouse reactor trip breaker when the failure initially occurred.

Open Items Summary: Two apparent violations were identified.

DETAILS

1. Persons Contacted

*A. Alan Johnson, Supervisor, Compliance
*T. R. Bradish, Manager, Compliance
*G. T. Shanker, Manager, Station Operating Experience Department (SOED)
*S. Quan, Shift Technical Advisor
*D. Smyers, SED Supervisor, Systems Engineering Department
*T. J. Fitzpatrick, Supervisor, Maintenance Standards
*H. W. Riley, Supervisor, Systems Engineering Department
*D. A. Hettick, Supervisor, Station Operating Experience Department
*K. M. Johnson, Vice President, Failure Prevention, Inc.
*C. N. Russo, Manager, Quality Control
*R. N. Prabhakar, Manager, Quality Engineering

The inspectors also interviewed other licensee personnel, including electricians, operators, and engineers during this inspection.

* Personnel present at the exit interview on April 10, 1992.

2. Chronology of the Events

A. Failure of the Westinghouse DS-206 Reactor Trip Breaker to Open

On March 31, 1992, at approximately 11:18 pm (MST), the Palo Verde Unit 3 Channel C reactor trip breaker (RTB) failed to open on demand from the control room during the performance of a routine surveillance test, 36ST-9SB04, "PPS Functional Test - RPS/ESFAS Logic." In conducting the test, operators had attempted to trip the breaker using a manual push button in the control room. After pushing the trip button, the operators observed conflicting control room indications for the breaker.

Annunciator alarm window 4A7B "REAC SWGR CKT BKR OPEN" was lit, and the control room monitors and alarm printer indicated the Channel C breaker was tripped. The phase current light 1-3 on the control board and on the Plant Protection System (PPS) panel did not go out. Plant electricians measured the breaker phase currents, and concluded that the "A" and "C" phases were still passing current and the "B" phase was open. The closed and open indicating lights were deenergized for Channel C at three locations: the PPS panel, the local breaker panel and the Supplementary Protection Logic Assembly (SPLA) cabinet, for Channel C. At the breaker, the position flag indicated an intermediate position.

A second attempt to open the breaker again both from the control room and locally failed. The operators then tripped open the Channel A RTB, which was in series with the Channel C breaker. This was done to comply with Technical Specification 3.3.1 which required the reactor trip breakers to be either operable or open. Since the Channel C breaker could not be opened, the reactor trip breaker in series with it was opened. (The inspectors concluded this action was appropriate.)

The Shift Supervisor then conferred by telephone with the duty STA, who had been asleep in his quarters. The STA had no objection to the actions taken. Also, he offered no advice on how to proceed. He specifically did not require quarantining of the Channel C breaker, as he was required to do by the licensee's program (see paragraph 6.B.(3) for additional detail).

The Unit 3 Operations Supervisor was on site, and came to the control room to assist the Shift Supervisor. The Shift Supervisor authorized informal troubleshooting to proceed, with the proviso that it would be videotaped. The Shift Supervisor was concerned that the surveillance interval for 36ST-9SB04 might be exceeded. He was also concerned that the expedient of tripping the Channel A reactor trip breaker in lieu of the Channel C breaker was not in strict conformance with the wording of Technical Specification 3.3.1. The electricians assigned to continue troubleshooting researched the licensee's version of the Westinghouse technical manual, called their supervisor at home, and developed an informal troubleshooting plan. They decided to manually charge the breaker's closing springs. After doing this, they attempted to open the breaker locally and were unsuccessful. They then attempted to close the breaker locally with the manual close pushbutton at the breaker. The closing springs discharged. The discharging of the closing springs provided sufficient vibration to open the circuit breaker. The actual opening of the breaker was not videotaped because the electrician operating the camera had set it down temporarily to assist his coworker.

Subsequent to opening the breaker, the breaker was cycled open and closed eight times. Then it was removed from its cubicle, and replaced with a spare breaker. The breaker which had failed was cycled approximately 100 more times, according to its cycle counter, before formal troubleshooting was imposed. This was done by the electrical maintenance department in an attempt to repeat the failure.

Throughout the event, the unit remained at 100% power with power to the control element drive mechanisms (CEDM) provided via the parallel path Channel B and D RTBs.

B. Failures of the General Electric AKR-30 Reactor Trip Breakers to Close

The General Electric AKR-30 reactor trip breaker was installed in Unit 3 Channel A. It was Serial Number N2689500011. It had initially been installed in Unit 1, Channel B in April 1985. In April 1991 it had been installed in Unit 3 Channel A. On March 10, 1992, during the performance of 36ST-9SB44, "RPS Matrix Relays to Reactor Trip Response Time Test," the breaker was observed to not stay closed (trip free) once in four attempts. A period of informal troubleshooting of the breaker ensued.

On March 11 the breaker operated normally in the test position, but would not close on three consecutive attempts when connected into its cubicle. The breaker was removed from its cubicle for further troubleshooting. Its trip latch was adjusted, and it closed two out of three times. On

March 12, it closed one out of three times. The undervoltage (uv) coil was observed to be binding in the trip free position, and an adjustment was made. The breaker then operated correctly 11 times. On March 13, it was reinstalled, tested satisfactorily, using 36ST-9SB44 and declared operable.

On March 25, during performance of 36ST-9SB04, the breaker again did not stay closed. During additional testing on March 26 and 27, it tripped free four out of 15 times that it was attempted to be closed. Informal troubleshooting of the breaker continued until the licensee's incident investigation imposed formal troubleshooting controls on April 2, 1992.

3. Review of Generic Correspondence

The inspectors reviewed the generic correspondence related to the failure of Westinghouse and General Electric reactor trip breakers to operate.

A. Generic Letter 83-28

NRC Generic Letter (GL) 83-28, "Required Actions Based on Generic Implications of Salem ATWS Events," was developed after reactor trip breakers at the Salem plant failed to open in 1983. After extensive review of reactor trip breakers at all facilities, some inadequate preventive maintenance of reactor trip breakers for both Westinghouse and General Electric circuit breakers was identified. Requirements for reactor trip breaker maintenance were specified in Enclosure 4.2 to GL 83-28, "Reactor Trip System Reliability (Preventive Maintenance and Surveillance Program for Reactor Trip Breakers)." As part of its initial licensing, the licensee's preventive maintenance program for reactor trip breaker maintenance was reviewed and approved by the NRC.

B. IE Bulletin 83-01

Prior to the issuance of the Generic Letter, the NRC also issued IE Bulletin No. 83-01, "Failure of Reactor Trip Breakers (Westinghouse DB-50) to Open on Automatic Trip Signal." This bulletin requested the applicant (Palo Verde was under construction at the time) to review the information in the bulletin. The bulletin provided Westinghouse Technical Bulletin NSD-TB-74-1 as an attachment. This bulletin in turn recommended the use of a dry or near-dry molybdenum disulfide lubricant for occasional light, sparing lubrication of the front and back faces of the undervoltage device vertical travelling latch of Westinghouse DB type breakers. The licensee improperly concluded in an internal memorandum dated April 4, 1983 (File No. 83-047-419) that lubrication of <u>all</u> metal sliding surfaces in both its GE and W reactor trip breakers was appropriate every six months using dry molybdenum disulfide lubricant (Molykote 321 R).

The inspectors observed that this was a large, unjustified extrapolation of the Westinghouse NSD-TB-74-1 recommendation. Moreover, to implement this decision, the licensee deleted the vendor manual lubrication recommendations throughout the licensee version of the vendor's manual,

substituting Molykote 321 R as the required lubricant. Subsequently, when detailed maintenance procedures were implemented, Molykote 321 R was specified as the lubricant to be used. The inspectors noted that the licensee had modified its vendor manual lubrication requirements, and requested the licensee to inquire about the suitability of Molykote 321 R as a lubricant for the breakers replacing the vendor specified Mobil 28 (GE) and Molykote BR2 Plus (W) lubricants.

In a letter dated April 8, 1992, the Dow Corning Corporation, current vendor for the Molykote product line, stated that use of Molykote 321 R as a substitute for Molykote BR 2 Plus was inappropriate, and could lead to gumming of the system (if applied over an existing grease), or excessive buildup (if applied too frequently).

Moreover, in a November 7, 1989 letter received from the GE Apparatus Service Group concerning two of the licensee's GE reactor trip breakers which had been sent to GE for refurbishment, the licensee was informed:

> "Breaker mechanism was heavily coated with graphite. This lubricate is not recommended by GE for use on breakers. Mechanism failure could occur due to the graphite. Already indications of teflon bushing deterioration were noted."

The inspectors concluded that the licensee's lubricant substitution of MolyKote 321R for Mobil 28 (GE) and MolyKote BR2 Plus (W) based on Westinghouse TB 74-1 was erroneous.

The inspectors also concluded that the licensee had not followed up on the 1989 report from GE warning of the mislubrication of the breakers. The failure to revise the GE and Westinghouse reactor trip circuit breaker maintenance procedures in response to the GE report is part of an apparent violation (Violation 50-530/92-15-02) (See Paragraph 3.D). The inspectors noted that the effect of this substitution was difficult to evaluate, but may have contributed to increased friction of the Westinghouse breaker mechanism which failed to operate. The inspectors also noted that the licensee promptly initiated a program to properly lubricate all reactor trip breakers, within two weeks of the event.

C. NRC Bulletin No. 88-01

On February 5, 1988, the NRC issued NRC Bulletin No. 88-01, "Defects in Westinghouse Circuit Breakers". This Bulletin described a pole shaft weld failure in the mechanism of Westinghouse Type DS-416 circuit breakers at the McGuire facility. The Bulletin required frequent inspection of the pole shaft welds on all circuit breakers of similar configuration, including Type DS-206 breakers. Alternately, the pole shafts could be replaced.

The licensee initially performed these inspections, but later elected to replace the pole shafts. The C reactor trip breaker which failed to open had its pole shaft replaced by APS using the instructions provided in Westinghouse Technical Bulletin NSID-TB-87-11, "Westinghouse Circuit

Breakers Type DS/DSL: Welds on Breaker's Pole Shaft," dated December 1, 1987. This work was performed using Work Order 302396 on July 21, 1989. The inspectors noted that the replacement of the pole shaft required disconnection and reconnection of the insulating links. Reconnection of the links required tightening an adjusting nut against the threads on the end of the insulating link, while preventing rotation of the insulating link around the threads. Westinghouse cautioned in TB 87-11 that failure to prevent rotation of the insulating link could permit the link to rub against other parts of the mechanism, causing binding and friction in the mechanism.

One of the findings of the licensee's incident troubleshooting (see paragraph 4.B(4)) was that the phase B insulating link had not been properly reassembled, in that it was cocked around its long axis, and binding the mechanism to some degree. However, this error by maintenance personnel did not appear to have caused enough additional mechanism friction to prevent operation of the breaker. As part of their corrective action for this event, the licensee inspected all of the other reactor trip breakers. No other breakers with cocked insulating links were identified. The inspectors concluded that the licensee's modification of the DS-206 reactor trip breakers had not been performed correctly in this instance. Also, the inspectors concluded that the licensee's subsequent corrective action satisfactorily identified and corrected the earlier error.

D. Westinghouse Technical Bulletin NSD-TB-91-06-RO

On October 18, 1991, Westinghouse issued TB NSD-TB-91-06-RO, "DS-206 and DSL-206 Breakers - Mechanical Friction of Main Contact Assemblies," to ensure proper opening of DS-206 circuit breakers. In the introduction to this bulletin, Westinghouse stated:

> "If the contact adjustment procedures given in the referenced Instruction Bulletin are not followed, then the potential exists for the breaker to only partially open due to excessive friction in the main contact assemblies."

Westinghouse representatives stated that TB NSD-TB-91-06-RO had been developed in response to a previous failure of a DS-206 circuit breaker to open at the Byron nuclear plant. TB NSD-TB-91-06-RO recommended removing the breaker's reset spring and verifying the contacts parted using only the opening (main contact) springs. Westinghouse had concluded that verifying a circuit breaker would open with the reset spring removed would provide margin to ensure that it would not fail to open with the spring attached.

The licensee had not implemented TB 91-06's recommendations at the time of the inspection. The licensee had concluded that it was inapplicable, since no failures of DS-206 circuit breakers to open had been experienced.

The licensee's Vice President of Nuclear Production received this technical bulletin and on November 2, 1991, requested that the Director of Site Technical Support determine if PV used this style of circuit breaker and determine what needed to be done. Independently on October 30, 1991, the Director of Site Technical Support had directed his staff to determine if this technical bulletin was applicable to Palo Verde.

On November 26, 1992 the site engineering staff issued memorandum number 226-01569-JSS which determined that no PV action was required.

The inspectors concluded that the licensee's failure to take corrective action to inspect their Westinghouse reactor trip breakers for proper adjustment in accordance with TB 91-06 was an apparent violation (Violation 50-530/92-15-02).

4. Review of Westinghouse Breaker Performance

A. Description of Operation

Two of the four reactor trip circuit breakers in each Unit at Palo Verde were Westinghouse Type DS-206. Figure 1 shows a Westinghouse DS-206 circuit breaker. Westinghouse designed these circuit breakers to be installed in low voltage metal enclosed switchgear of the drawout type. These breakers were rated for 800 amps.

Figure 2 shows the arrangement of the principal mechanical parts of a DS-206 circuit breaker. Figure 3 shows the four basic positions of the circuit breaker mechanical linkage. Figures 4 and 5 show the main and arcing contacts and their adjustments.

Appendix A contains a detailed description of the DS-206 closing and opening (tripping) mechanisms. Briefly, closing springs operate mechanical linkages which drive and hold the main circuit breaker contacts closed and charge the opening springs. In this closed position, the moving arcing contacts wedge into the stationary device as shown in the top left drawing of Figure 5. By design, the opening (main contact) spring force is greater than the gripping force on the wedged arcing contacts. The opening (main contact) springs are shown in Figures 4 and 5.

As shown in Figure 3, a trip signal rotates the trip shaft, piece 7, and releases the trip latch, piece 5. The trip latch rotates and removes all mechanical force from the linkage. As shown in Figures 3 and 5, the opening springs extend (discharge) and open the circuit breaker. The reset spring, shown in Figure 2, pulls the linkage to the fully open position, once the moving contact assemblies have moved free of the stationary arcing contacts.

B. Discussion of Test Results

The licensee's root cause team developed a detailed investigative procedure. The investigative procedure attempted to determine why DS-206 circuit breaker serial number 02YN140-15 failed to open. The initial steps of this procedure did not modify the circuit breaker as-found conditions. However, as noted earlier, the circuit breaker had been cycled about 100 times since its failure, due to informal troubleshooting by the Electrical Maintenance Department. The investigative procedure contained steps recommended in Westinghouse Information Bulletin (IB) 33-790-1G, "Instructions for Low-Voltage Power Circuit Breakers Types DS and DSL;" Westinghouse Technical Bulletin (TB) NSD-TB-91-06-RO, dated September 24, 1991, "DS-206 and DSL-206 Breakers - Mechanical Friction of Main Contact Assemblies;" and verbal recommendations from Westinghouse technical representatives acting as part of the root cause team.

As discussed in Section 3.B, TB NSD-TB-91-06-RO was developed to ensure proper opening of DS-206 circuit breakers. Westinghouse had concluded that verifying that a circuit breaker would open with the reset spring removed would provide margin to ensure that it would not fail to open with the spring attached. The root cause team incorporated this method of checking for proper breaker opening force into the investigative procedure. The licensee performed a dry run of the procedure using a training DS-206 circuit breaker.

The inspectors reviewed the investigative procedure and found it adequate.

The licensee performed the investigative procedure. The circuit breaker would not open with the reset spring removed. The inspectors observed the work. The work was well controlled and documented.

The investigative procedure identified four problems which impeded proper circuit breaker opening. These problems were: opening spring force adjustment, arcing contact wedge dimensions, lubrication, and insulating linkage binding. The investigation revealed no problems with the tripping mechanism. The following paragraphs discuss the opening problems.

(1) Opening Spring Force Adjustment

Westinghouse IB 33-790-1G required that the force on the opening spring be adjusted by making the faces of the main stationary contact fingers and leading edge of the vertical stationary contact bar parallel on each phase. See dimension B, Figure 5. Westinghouse TB NSD-TB-91-06-RO contained an additional measurement of opening spring compression by using the "X" and "Y" dimension shown on Figure 5. This TB indicated proper spring compression was achieved when X = Y. The Westinghouse representative indicated that the "X" and "Y" dimensions were added due to the difficulty of visually determining that the surfaces of dimension B were parallel. A locknut on the insulating link provided a means for adjusting the "X" and "Y" dimensions by increasing or decreasing the length of the linkage.

The investigation determined that phases A and C were under-parallel (X<Y) by one nut flat of adjustment. The nut had 6 flats and a pitch of 1/32 of an inch.

The inspectors concluded that the as-found condition would have compressed the opening springs less than recommended by TB 91-06, and, thus, lowered the opening force available.

(2) Arcing Contact Wedge Dimensions

Westinghouse IB 33-790-1G required dimensional checks of the arcing contact wedge dimensions in both the open and closed positions. See dimensions A and C, Figure 5. This IB contained only a minimum value of 0.02 inches for dimension A. Westinghouse TB NSD-TB-91-RO added a maximum of 0.07 inches for dimension A.

The investigation determined that dimension A was above the maximum of 0.07 inches for dimension A for all three phases. The left side of phase A was 0.079 inches, the left side of phase B was 0.072 inches, the right side of phase C was 0.075 inches and the left side of phase C was 0.077 inches. Dimension C was within the specified 0.42 plus or minus 0.08 inches but for all three phases these dimensions were less than 0.39 inches.

The inspectors concluded that the out of tolerance dimension "A" indicated that the moving arcing contacts were gripped with more force than if the dimension had been within the tolerance specified by Westinghouse TB NSD-TB-91-06-RO. Overcoming this gripping force required additional opening spring force.

(3) Lubrication

Westinghouse IB 33-790-1G and Westinghouse TB NSD-TB-91-RO both required use of lubricant Molykote BR-2 Plus by Dow Corning on non-electrical moving parts. The IB specified nine locations for lubrication. The TB added two additional lubrication points, one requiring a special conductive grease. The licensee was using Dow Corning 321R lubricant in lieu of the BR-2 Plus. See Section 3.A for a discussion of the use of this different lubricant.

The investigation originally determined that the nine locations specified in the information bulletin were lubricated and the two locations added by TB NSD-TB-91-RO were not. Both of the locations added by TB NSD-TB-91-RO were on the moving contact linkage. Later disassembly identified what appeared to be a small amount of lubricant on one of the locations added by TB NSD-TB-91-RO.

Based on the discussion in Section 3.A, the inspectors concluded that the licensee was using an inappropriate lubricant. The Westinghouse representative stated that lubrication of the two locations specified in TB NSD-TB-91-RO would reduce the linkage friction which opposed the opening spring force.

(4) Insulating Linkage Binding

A main drive (insulating) link is shown in Figure 3, piece 14.

The investigation determined that the insulating link on phase B was rotated around an axis along its length, and binding (See Section 3.C above). Westinghouse Technical Bulletin NSD-91-06-RO required that the insulating link be firmly held while adjusting a locknut for correct opening spring compression.

The inspectors concluded that this binding contributed to the frictional forces opposing opening spring force. The inspectors concluded that this was a maintenance error.

After completion of the initial inspection, the licensee corrected the insulating linkage binding. The circuit breaker would still not open with the reset spring removed. However, approximately 1/16 of an inch more moving contact travel was noted. The licensee adjusted the phase A and C locknuts one flat to make the "X" and "Y" dimensions equal. The circuit breaker would still not open, but additional moving contact travel was noted.

Westinghouse TB NSD-TB-91-06-RO recommended obtaining additional force to open the circuit breaker by increasing the "X" dimension by up to a full turn on the adjusting locknut. The investigative action determined that the circuit breaker would successfully open without the reset spring with an additional adjustment of one flat (1/6th turn) on each phase.

The inspectors concluded that all four breaker opening conditions discussed above contributed to the actual failure. The inspectors noted that performance of Westinghouse TB NSD-TB-91-06-RO would have identified that DS-206 circuit breaker serial number 02YN140-15 had several deficiencies which could have potentially caused it to fail to open upon demand.

5. Review of General Electric Breaker Performance

A. Description of Operation

Two of the four reactor trip breakers in each unit at Palo Verde were General Electric Type AKR-30. General Electric designed these circuit breakers to be installed in low voltage metal enclosed switchgear of the drawout type. The breakers were rated for 800 amps.

Appendix B contains a detailed description of the AKR-30 closing and opening (tripping) mechanisms. Figure 7 shows the arrangement of the primary contact positioning mechanism. Figure 8 shows a side view of this mechanism in the closed, tripped and reset configurations. Figure 9 shows the main contact structures.

Briefly, closing springs operated mechanical linkages which drove and held the main circuit breaker contacts closed and charged the opening and main contact springs. The gear motor, piece 9 in Figure 7, charged the closing springs. A trip signal rotated the trip shaft, piece 10 in Figure 7, which released the trip latch, piece 11 in Figure 7, which allowed contact springs, Figure 9, and the opening spring, piece 15 in Figure 7, to move the mechanism to the tripped position, Figure 8. Small springs in the mechanism moved the mechanism from the tripped to the reset position, Figure 8.

B. Discussion of Test Results

The licensee's root cause team developed a detailed investigative procedure. The investigative procedure attempted to determine why the AKR-30 circuit breaker, Serial Number N2689500011, failed to remain closed, while preserving the existing circuit breaker adjustments. The investigative procedure contained checks recommended in General Electric Maintenance Manual GEK-64459B "Low-Voltage Power Circuit Breakers Types AKR-30/50 and AKRT-50," as well as GEK-7310, "Power Circuit Breakers," GEI-86134, "Power Circuit Breakers," GEF-4527D, "Maintenance Procedures for GE AKR-30/50 Circuit Breakers with Undervoltage Devices," Combustion Engineering (CE) letter V-CE-19157 "Arizona Nuclear Power Project Under Recommended Reactor Trip Switchgear" Modifications, ADP Infobulletin, "Maintenance Procedures for GE AKR-30/50 Circuit Breakers with Undervoltage Devices," Service Advice 175 9.15, "AKR-30/50 Low Voltage Power Circuit Breakers with Undervoltage Devices - Maintenance Procedures," Service Advice 175 9.20, "Maintenance and Upgrade of AK-25 Circuit Breakers with Undervoltage Trip Devices Used as Reactor Trip Breakers," Service Advice 175 9.3, "AK15/25/50/75/100 Low Voltage Power Circuit Breaker with Undervoltage Trip Device," and on-site vendor verbal recommendations. The licensee performed a dry run of the procedure using a training AKR-30 circuit breaker prior to implementing it on the breaker which failed in service.

The inspectors reviewed the investigative procedure and found it thorough and complete.

The licensee performed the investigative procedure and additional troubleshooting actions documented in work order 550423. The inspectors observed a portion of the work. Based on observation of the work, the inspectors concluded that the work was well controlled and documented. with one exception associated with the manual trip actuation button as described below.

The licensee's investigation identified six problems which could have. contributed to the failures of the breaker to stay closed. These problems were: low undervoltage device armature to trip paddle assembly clearance, bent flux shift trip device trip rod, low flux shift trip device trip rod to trip paddle clearance, low manual trip actuation button travel, insufficient trip latch adjustment, and low (but within tolerance) trip shaft torque. Other results which the inspectors agreed had minimal impact on the breaker's failure to close included minor trip latch misalignment, more pronounced burn marks on the "A" phase main arcing contact than on phases "B" and "C," potentially excessive shunt trip armature to trip paddle clearance, misalignment of the shunt trip paddle, broken "A" phase arc chute, axial free play in the trip shaft, and minor bending of the charge/discharge indicator arm and drawout mechanism. The problems which the inspectors concluded could have contributed to the failures of the breaker to close are discussed further in the following paragraphs.

(1) Low Undervoltage Device Armature to Trip Paddle Assembly Clearance

No specification existed for this measurement in the vendor technical manuals used by the licensee nor were any in GEK-64459B. In a letter from General Electric dated April 16, 1992 (J. E. Kusky to J. Bailey), GE specified a minimum trip shaft paddle to undervoltage armature clearance specification of 0.030 inches.

The investigation determined that the as found clearance was only 0.011 inches, and that by restoring this measurement to 0.030 inches, the frequency of failures of this breaker to close was reduced significantly.

One possible contributor to this low clearance may have been the guidance in GEK-7310 which stated "If the undervoltage device does not have positive tripping ability, the adjustment screw of the trip paddle assembly may be turned in increments of half turns until the check is successful." The inspectors noted that GEK-64459B has the same guidance but also contains several other measurements which can also affect the positive tripping check.

The inspectors concluded that this low clearance would have increased the likelihood of the breaker failing to close.

(2) Bent Flux Shift Trip Device Trip Rod

While no specification existed for the straightness of the flux shift trip device trip rod, the inspectors noted that description of the flux shift trip device in the technical manual depicted the rod as straight.

The investigation determined that the flux shift device trip rod was slightly bent, showed signs of wear, and that metal shavings were present in the area of the flux shift trip device. Measurements of the flux shift trip device trip rod to trip paddle were not changed by varying the orientation of the bent trip rod.

The inspectors concluded that the bending of the trip rod had little impact on the breaker failing to close.

(3) Low Flux Shift Trip Device Trip Rod to Trip Paddle Clearance

The vendor technical manual used by the licensee (GEK-7310) contained GEI-86134, which specified this clearance to be 0.125 inches +/- 0.015 inches. GEK-64450B contains the same guidance.

The investigation determined that the as found clearance was 0.095 inches. This was 0.015 inches or 12 percent below the minimum specification.

The inspectors concluded that this low clearance would have increased the likelihood of the breaker failing to close.

(4) Low Manual Trip Actuation Button Travel

The vendor technical manual used by the licensee did not contain any criterion for this measurement. GEK-64459B also did not contain any criterion for this measurement. Field discussions with the vendor representative identified a criterion of 0.31 inches manual trip button travel to trip the breaker with the front escutcheon plate installed.

The investigation initially measured the clearance between the end of the manual trip rod and the trip paddle. The as found trip button travel was not documented in the work order. A licensee engineer on the investigation team stated that the as found manual trip actuation button travel was approximately 0.2 inches. During the investigation, blueing dye was applied to the actuating devices for the manual trip, flux shifter, positive interlock, and shunt trip, to see if these devices were contacting their respective trip paddles. After breaker operation, all but the positive interlock did show blueing die transfer, suggesting that the manual trip, flux shift, and shunt trip devices were contacting their respective paddles without intentional actuation.

The inspectors concluded that if the manual trip button actuator clearance had been low initially, it would have increased the likelihood of the breaker failing to close. Since the as found measurement was not recorded, the inspectors concluded that the actual impact of this actuator clearance was indeterminate. The inspectors further concluded that the blueing die transfer marks which were found on the manual trip paddle without action to depress the manual trip button provided some evidence of insufficient clearance for this actuator.

(5) Insufficient Trip Latch Adjustment

The vendor technical manual in use by the licensee, GEK-7310, specified that the trip latch adjustment was correct if three and one-half turns of the adjustment screw caused a closed breaker to trip. GEI 64459B had the same specification.

The investigation found the initial trip latch adjustment to be three and one-quarter turns. The licensee concluded that this was a contributory cause of the breaker failing to close.

The as found adjustment would have caused the breaker to trip with a smaller trip shaft rotation than it would have taken had this adjustment been in accordance with the vendor guidance. The inspectors concluded that this would have increased the likelihood of the breaker failing to close.

(6) Low Normal Trip Shaft Torque

The vendor technical manual used by the licensee specified a maximum trip shaft torque of 1.5 inch-pounds. This value was measured and trended every six months as part of the licensee's preventive maintenance program.

The as-found trip shaft torque was found to be 0.6, 0.49, and 0.6 inch-pounds in three successive measurements. The inspectors noted that the licensee's trending program showed that the minimum value ever observed for a General Electric reactor trip breaker at Palo Verde was 0.1 inch pounds, with more than 15 other occasions when the trip shaft torque was observed to be less than the value observed for this affected breaker.

A low as-found trip shaft torque would permit an inadvertent impact on a trip paddle to result in a breaker trip more easily than if the trip shaft torque were higher. With no minimum criterion and frequent observations of trip shaft torque lower than what was observed on this breaker, the inspectors did not conclude that the observed trip shaft torque was low.

The licensee and vendor concluded that the root cause of the breaker tripping was low clearances between the trip shaft paddles and the trip levers of the actuating devices.

After this troubleshooting, the licensee reset the breaker to the specifications of the vendor manuals in use on site at the time of the failure. The breaker was cycled one hundred times. Two close attempts resulted in the breaker closing and then immediately tripping. The cause for this continued failure was determined by the licensee to be insufficient clearance between the undervoltage trip device trip paddle adjustment screw and the trip shaft clamp. This clearance is also the clearance between the undervoltage device armature and the trip paddle assembly. This clearance was reset to the vendor's recommendation in their letter of April 16, 1992, and the breaker operated satisfactorily.

The inspectors agreed with the licensee's assessment.

6. Review of Reactor Trip Breaker Maintenance Program

A. Review of Reactor Trip Breaker Maintenance Procedures

(1) Westinghouse DS-206 Circuit Breakers

Procedure 32MT-9SB01, Revision 5, "Maintenance of Westinghouse Reactor Trip Switchgear," contained the licensee's procedure for maintaining Westinghouse reactor trip circuit breakers. The licensee was accomplishing Procedure 32MT-9SB01 every six months. This procedure listed Westinghouse Instruction Manual IB 33-790-1G, dated September 1989 as a developmental reference. A Westinghouse technical representative reported that this was the correct manual for the licensee's DS-206 reactor trip circuit breakers.

The inspectors compared the requirements and recommendations in Westinghouse Manual IB 33-790-1G and other commitments and standards with the licensee's maintenance procedure. The inspectors noted five differences between the licensee's procedure and the applicable vendor information in the procedure. These five differences were: 1) The licensee had authorized use of Dow Corning (Molykote) 321R lubricant in place of the Westinghouse required Dow Corning Molykote BR-2 (See Section 3.B), 2) the licensee was removing the closing springs to accomplish selected visual examinations, 3) the licensee was not measuring trip shaft torque, 4) the licensee was not measuring and adjusting trip latch overlap, and 5) the licensee had not incorporated the maintenance recommendations of Westinghouse TB NSD-TB-91-06. Problem numbers 2, 3 and 4 are discussed in more detail in Appendix C.

The licensee had performed an evaluation in 1983 that Dow Corning (DC) 321R was an acceptable lubricant for the undervoltage coil moving armature, but had no evaluation for other moving parts. DC 321R was a spray type dry lubricant. The licensee contacted Dow Corning. Dow Corning provided a letter that stated that DC 321R was an appropriate lubricant for clean and dry metal surfaces only. The letter indicated that DC 321R would not be effective if sprayed over surfaces previously greased and could tend to make the grease ineffective. The Westinghouse representative stated that lubrication points listed in IB 33-790-1G were factory greased. Maintenance records indicated that the licensee was applying DC 321R to reactor trip breakers.

The inspectors concluded that the use of DC 321R was not technically correct for previously greased surfaces. The licensee committed to use the Westinghouse recommended lubricant pending a more detailed lubrication review.

Westinghouse TB NSD-TB-91-06 also contained several maintenance instructions not contained in either Westinghouse IB 33-790-1G or 32MT-9SB01.

The inspectors concluded that the checks and adjustments of TB NSD-TB-91-06 were valid maintenance checks and adjustments with specific tests to ensure that breaker opening force was sufficient. The licensee committed to incorporate TB NSD-TB-91-06 in a routine maintenance procedure.

Based on the findings discussed in Appendix C the inspectors concluded that: 1) Dow Corning 321R was not an appropriate lubricant, 2) removal and reinstallation of the closing springs was unnecessary and had the potential for damaging the circuit breaker, 3) measuring trip shaft torque was warranted, 4) measuring and adjusting trip latch overlap was warranted, and 5) incorporating the instructions of TB-NSD-TB-91-06 was warranted. The licensee agreed to evaluate these five potential problems and incorporate the results in maintenance procedures.

(2) General Electric AKR-30 Circuit Breakers

Procedure 32MT-9SB02, Revision 1, Preliminary Change Notice Number 6, "Maintenance of General Electric Reactor Trip Switchgear," contained the licensee's procedure for maintaining General Electric (GE) AKR-30 reactor trip circuit breakers. The licensee was accomplishing Procedure 32MT-9SB02 every six months. This procedure listed GE Maintenance Manual GEK-7310C and supplement GEI-86134 as developmental references. A GE technical representative was invited to Palo Verde by the licensee to assist in the investigation. He stated that GEK-7310C/GEI-86134 was not the latest GE maintenance manual for the GE reactor trip circuit breakers. The GE representative stated that the latest GE manual for AKR-30 circuit breakers was GEK-64459B. According to the licensee, GEK-64459B "Low-Voltage Power Circuit Breakers, Types AKR-30/50 and AKRT-50," had been onsite since January 1990, for use with GE AKR-50 circuit breakers. APS had sought definition of the latest guidance for the GE AKR-30 circuit breakers from GE in April 1988. They received no response and queried CE in November 1988. CE's response to this query in January 1989 stated that CE believed that the licensee "had been informed of all other known Service Information Letters and Advisories concerning" AKR-30 circuit breakers. After receipt of the newer manual in January 1990, the licensee took no further action to determine its applicability. The inspectors observed that the title of GEK-64459B made it appear that this publication applied to the AKR-30 reactor trip breakers, and the licensee recognized that the newer technical information for the GE reactor trip breakers existed, but the licensee from January 1990, did not confirm the applicability of this information to their maintenance procedures for GE reactor trip circuit breakers until this inspection. Therefore, the licensee had not received specific guidance from General Electric to use this manual at the time of the breaker failures. During the inspection the licensee received a letter dated April 16, 1992 (J. E. Kusky to J. Bailey) which confirmed that GEK-64459B was the current technical manual.

The inspectors compared the requirements and recommendations in GE GEK-7310C and GEK-64459B with the licensee's maintenance procedure. The inspectors noted five potential problems in the procedure. These five problems were: 1) the licensee had authorized use of Dow Corning (Molykote) 321R lubricant in place of the GE required Mobilgrease 28 (see Section 3.B), 2) the licensee procedure authorized removal and replacement of the UV trip device after all mechanical UV device adjustments had been completed without rechecking those adjustments, 3) the licensee did not check for adequate mechanical margin for shunt trip device tripping, 4) the licensee was not checking buffer alignment, 5) the licensee's procedure specified UV device adjustments, checks, and acceptance criteria which were different than GE's latest criteria contained in GE manual GEK-64459B. These five problems are discussed in more detail in Appendix C.

Based on the findings discussed in Appendix C, the inspectors concluded that: 1) Dow Corning 321R was not an appropriate lubricant, 2) Procedure 32MT-9SB02 incorrectly sequenced work and could not ensure proper UV device mechanical adjustment, 3) measuring of shunt trip device mechanical margin was warranted, 4) measuring buffer alignment may be beneficial, and 5) incorporating UV device adjustments, checks, and acceptance criteria contained in GEK-64459B was warranted. The licensee agreed to verify that GE Manual GEK-64459B was the correct manual for GE AKR-30 breakers and to incorporate this manual in maintenance procedures. The licensee also agreed to evaluate the five potential problems listed above.

B. Review of Reactor Trip Breaker Maintenance History

The inspectors reviewed the maintenance experience, trending program, and preservation of evidence during troubleshooting for reactor trip breakers since unit startup.

(1) Maintenance History

A selection of approximately 100 corrective maintenance Work Orders (WOs) for both Westinghouse and General Electric breakers in all three units were reviewed.

One immediate difficulty noted was that work orders identified equipment by plant location only, and not also by equipment serial number. This made tracing maintenance history by breaker very difficult since breakers had been replaced and moved between units. The licensee constructed a time line of breaker serial number locations in unit cubicles. The history was completed and available for NRC review seventeen days after the effort began.

(a) Westinghouse Reactor Trip Breaker Maintenance History

The most significant repeat corrective maintenance issue for Westinghouse reactor trip breakers was undervoltage (UV) device

failures. Two failures occurred in 1987, and two more occurred in 1991. One of these failures was a failure of the UV device to trip, even after power was removed completely. The other three UV trip device failures involved a bent linkage, a weak device and a failure of the device to meet the acceptance criteria for UV dropout voltage. Westinghouse representatives who were on site to assist troubleshooting stated that this was an above average rate of failure.

The remaining maintenance history did not indicate any specific trends or concerns, and was typical of what the Westinghouse representatives had seen before. The Westinghouse representative indicated that a linkage could have been bent when closing springs were reattached following a slow close test. (See Appendix C, Paragraph 1 for more discussion of this possibility)

The inspectors concluded that the maintenance history did not suggest any specific maintenance practice or trend that would impact directly on the failure of the Westinghouse reactor trip breaker to trip.

(b) General Electric Reactor Trip Breaker Maintenance History

The most significant repeat corrective maintenance issue for General Electric reactor trip breakers was UV device failures. The inspectors did not identify as failures the eight corrective maintenance work orders for the recognized generic failure of General Electric UV devices to reset after the breaker was tripped resulting in subsequent Trip-Free operation of the breaker. APS evaluated this in EER 86-SB-101 (which referenced CE letter V-CE-30333 and ADP Info Bulletin 83-13) These documents concluded that this was a known problem with the breaker which had little impact on the safety function of the breaker.

In addition to this known failure mechanism, three Work Orders identified General Electric UV device failures necessitating replacement. Four others needed adjustment more frequently than the 18 month UV device replacement interval.

One WO identified a General Electric breaker with an out-of-specification high trip shaft trip torque measurement with corrective action to lubricate the bearings with Dow Corning Molykote BR 321. This was in contrast to General Electric Bulletin 9-20 which stated that when high trip shaft torque was identified, the bearings should be replaced. The licensee indicated that this was a new breaker that had new trip shaft bearings packed with Mobil 28 grease. Also, the breaker had been sitting in the warehouse for approximately two years prior to this out of specification measurement. Therefore, the licensee did not consider it appropriate at the time to replace

the breaker's bearings. The inspectors concluded, however, that lubricating these sealed bearings with Dow Corning BR 321 was inappropriate. The licensee agreed with the inspector's comments.

The remaining maintenance history did not indicate any additional trends or concerns. The inspectors noted that the variety of out of specification conditions identified on the malfunctioning breakers may have resulted from electricians adjusting the UV trip paddle assembly adjusting screw as indicated in the vendor manual used by the licensee, GEK-7310C. The inspectors noted that work orders did not contain sufficient detail to document whether or not this adjustment had been made. The inspectors concluded that this UV trip paddle adjustment was the only maintenance practice which might have affected the failure of this breaker to close.

(2) Trending Program

A review of the System Engineer trending program revealed numerous failures of the UV trip device to meet the Westinghouse specified as found and as left dropout voltages. The Westinghouse procedure, 32MT-9SB01, "Maintenance of Westinghouse Reactor Trip Switchgear," specified a 37.5 - 75 volt dropout specification. The System Engineer for these breakers stated that this was not a Westinghouse requirement, that Westinghouse undervoltage device dropout voltage settings were not adjustable, and, therefore, no action had been taken in response to those out of specification values.

The licensee was not trending Westinghouse reactor trip breaker trip shaft torque. At the time of the inspection, Westinghouse representatives recommended that trip shaft torque be measured and trended. The licensee agreed to evaluate trending trip shaft torque.

The inspectors concluded that no trends were apparent in the maintenance history to indicate a deteriorating condition that might have contributed to the failures observed with the Westinghouse & General Electric reactor trip breakers.

(3) Control of Troubleshooting

Licensee procedure 40AC-9OP18, "Technical Specification Component Condition Record," required the Shift Technical Advisor (STA) to either initiate a Root Cause of Failure Condition Report/Disposition Request or obtain system engineer concurrence that one is not needed. Licensee procedure 70DP-0EE01, "Equipment Root Cause of Failure," Paragraph 3.3.1, required the duty STA to initiate a formal request to the applicable department to preserve evidence for a failure investigation. Interviews with the duty STA on March 31, 1992 when Unit 3 "C" reactor trip breaker failed to open at 11:18 PM revealed that the STA did not come to the control room or to the

switchgear immediately after the reactor trip breaker failed to trip. Rather, he agreed with the assistant shift supervisor that no STA support was needed during the night. During the night the breaker was racked out, cycled eight times in the test position, moved to the shop, and cycled additional times prior to the development of a formal troubleshooting plan. Interviews with the duty STA for March 31, 1992 and the relieving STA for April 1, 1992 revealed that neither STA was aware of any STA responsibility for attempting to preserve as-found evidence. The inspectors concluded that this represents poor control of troubleshooting activities early after the failure occurs. This is an apparent violation (Violation 50-530/92-15-01).

The inspectors noted that, in Inspection Report 92-10, there had been similar failures to control troubleshooting activities. These were the failures of: a General Electric Magne-Blast breaker where the breaker was removed from the cabinet and tested without a troubleshooting plan, a containment isolation purge valve where the valve was adjusted prior to an inspection or a troubleshooting plan, a Potter & Brumfield relay which was cycled in the shop prior to being shipped to the vendor for root cause of failure determination, and an auxiliary feedwater pump turbine control relay which was discarded before any root cause of failure data could be identified. The inspectors reemphasized the need for control of root cause of failure data. The licensee acknowledged the inspector's comments.

7. Review of Breaker Actuation System

A. Performance Requirements of the Breaker Actuation Circuitry

The inspectors reviewed the performance requirements of the breaker actuation circuitry. Two motor-generator sets supplied power to the control element drive mechanisms (CEDM). The power interruption devices were the Supplementary Protection Logic Assembly (SPLA) contactors and two parallel paths of breakers. Each of the parallel paths consisted of a General Electric Type AKR-30 breaker in series with a Westinghouse Type DS-206 breaker. The interruption of power was designed to occur when either the SPLA contactors opened or a break occurred in both parallel branches.

In the Westinghouse breaker, there were three electrical tripping mechanisms: the UV trip, the shunt trip, and the solid state overcurrent trip. Any one of the three devices would actuate the trip shaft to rotate to trip the breaker contacts open. The design of the electrical control circuit was to simultaneously deenergize the UV trip coil and energize the shunt trip coil to actuate the trip shaft to open the breaker. Any one of the three trip signals, the PPS trip, SPLA trip, or the manual reactor trip push button in the control room, could activate the opening of the breaker.

Auxiliary contacts on the breaker provided the status of the breaker position on the local breaker panel, the PPS panel, and the SPLA cabinet. The auxiliary contacts of the breaker also provided one input to the control room annunciation system which actuated the annunciator window, the three monitor displays, and the alarm printer. The control room annunciation system monitored the opening of an auxiliary contact (which would be in an open state when the breaker opened). A mechanical linkage in the breaker rotated the auxiliary contacts. When the mechanical linkage did not complete its rotation or was misaligned, it was possible for the closed position contact to open while the open position contact was not yet closed. The indications provided by the auxiliary contacts were not conclusive evidence of breaker position.

Each phase current of the Motor-Generator output was monitored by an inductive pickup coil. Any one of the three phases conducting would energize the phase current light on the PPS panel and on the control board in the control room. The phase current light at these locations was a direct and positive indication of whether the breaker was open or not.

The inspector concluded that the breaker indication and actuation circuits for the reactor trip breakers appeared to perform according to their intended functions and did not appear to be the cause of the failure of the Unit 3 Westinghouse breaker to trip open.

B. Inspection of Installed Equipment

The inspector walked down the breaker indications in the control room, the Reactor Trip Switchgears (RTSG's), and the SPLA cabinets in all three units.

Unit 1 plant was in a refueling outage. The licensee removed the Westinghouse reactor trip breaker from Unit 1 Channel C and put the breaker in Unit 3 Channel C for temporary replacement. Meanwhile, a spare breaker from the warehouse was checked. The inspectors observed that the counter reading on the spare breaker was 557 on April 4, 1992.

The counter reading on the Westinghouse breaker indicated the number of open-and-close cycles that each breaker had undergone. During the walkdown on April 5, 1992, the inspectors surveyed the counter reading of the Westinghouse reactor trip breakers. The counter readings of the installed breakers ranged from a low reading of 378 to a high reading of 1130. The Unit 1 Channel D breaker had a low counter reading of 378. The Unit 1 Channel C breaker, now being a temporary replacement for Unit 3 Channel C breaker, had a counter reading of 834. The counter readings for Unit 2 Channels C and D were 949 and 925 respectively. The Unit 3 Channel D had a high counter reading of 1130. The inspectors concluded that none of the circuit breakers had been cycled excessively.

The inspectors also observed that some flags indicated that spring conditions were not aligned with the windows. The flag indicating "Spring Discharged" on Channel D breaker of both Units 2 and 3 was not aligned with the window and showed approximately one-fifth of the yellow portion of the charged condition at the bottom of the window. Unit 2 Channel C showed approximately one-tenth of the yellow portion at the bottom of the window. After the walkdown, the inspectors attempted to resolve the meanings of these misaligned flags. The inspectors observed the charging of the closing springs at the training breaker. The rotation of the flag was not a continuous but a snap-action type of rotation. The Westinghouse representative indicated to the inspectors that the breaker would trip open even with the closing spring partially or fully charged if the trip signal was present. The licensee demonstrated the ability of the breaker to trip open when the closing spring was either partially or fully charged on the training breaker. The inspector concluded that the misaligned flag indication of the spring condition appeared to have no potential significance in causing the failure of the breaker to trip open.

8. Review of Reactor Trip Switchgear Design

The inspectors reviewed the reactor trip system design to understand the vendor's design approach, and the reasons for the circuit breaker component selections. The inspectors reviewed an April 4, 1992 letter from Asea Brown Boveri (ABB) Combustion Engineering (CE) to the licensee providing the vendor's overview of the reactor trip switchgear history. In addition, the inspectors discussed the history with the onsite CE representative, and four cognizant personnel in CE headquarters.

Figure 10 provides a schematic of the CE System 80 standard reactor trip switchgear design. This was the design used at Palo Verde. This design was completed in the early 1970s and sold to three other utilities: Washington Public Power Supply System, Tennessee Valley Authority, and Boston Edison. However, the licensee was the only System 80 design which was completed, the others being canceled. A similar modified System 80 design is under construction in Korea (Yongwang 3,4) using only Westinghouse Type DS-206 circuit breakers. The System 80 design was an evolution from the previous CE design (CE 3410 style).

The System 80 design made use of air circuit breakers from two different manufacturers: General Electric (Type AKR-30) and Westinghouse (Type DS-206). The control element drive mechanism (CEDM) motor generator (MG) sets for this design were rated at 601 amps, an increase from the previous CE design (CE 3410) rating of 515 amps.

The reactor trip breakers within the reactor trip switchgear are used to interrupt power from the output of the MG to the input of the CEDM control system. The trip function of the breakers is activated by the reactor protection system.

However, the previous design was a nine breaker design (Figure 11) using General Electric AK-2-25 type breakers. These breakers were rated at 600 amps. The CE 3410 design CEDM motor generators had a design output of 515 amps. Each breaker only had to interrupt approximately half of this current to trip the CEDM motor generator output.

Therefore, to accommodate the larger current interrupting requirements of the new design, the next larger circuit breaker size available was chosen. The next frame size available from both manufacturers was 800 amps, the Type AKR-30 (GE) and Type DS-206 (W).

CE stated that two different breaker vendors were chosen to improve protection against common mode failure concerns should they exist. This design was approved by the NRC in a letter to the licensee dated February 24, 1987. That letter stated that:

> "The Palo Verde design allows online testing of the reactor trip system, including independent testing of undervoltage and shunt trip attachments of the reactor trip breakers, and meets the staff position."

The inspectors were informed by the Westinghouse circuit breaker technical representative present for the incident investigation that Westinghouse did not use Type DS-206 circuit breakers in its reactor trip switchgear designs. Instead, a 1600 amp frame size breaker (Type DS 416) was used. This breaker used a very similar operating mechanism which differed principally in the use of four main contact springs per phase rather than the one used for the DS-206 breaker. The representative stated that these four springs provided approximately three times the opening force of the spring in the DS-206 breaker. He further stated that it was for this reason that the Westinghouse Technical Bulletin NSD-TB-91-06-RO referenced earlier in this report was not applicable to DS 416 reactor trip breakers. The CE representatives stated that the DS-416 breaker had not been used since the DS-206 met all of the design requirements, and was from a reputable breaker manufacturer.

The inspectors concluded that the licensee's reactor trip breaker switchgear design was an NRC approved design. They noted that the Westinghouse Type DS-206 breaker, used only at Palo Verde and Yongwang, had a potential failure mode which the Type DS-416 breaker used at many Westinghouse reactors was not susceptible to. The Yongwang design only used DS-206 breakers. The inspectors were also informed by the licensee that the GE AKR-30 circuit breakers were only in use as reactor trip breakers at Palo Verde.

9. <u>Exit Interview</u>

The inspectors met with the licensee personnel identified in paragraph 1 on April 10, 1992 to summarize the scope and findings of the report. The inspectors emphasized the available conclusions and findings detailed in this report. Licensee representatives acknowledged the team's findings, and agreed to review whether or not the DS-206 breakers should be modified to the DS-416 configuration as part of their long term corrective action program for this incident.

Appendix A

Westinghouse DS-206 Circuit Breaker Operating Principles

The operating mechanism of the DS-206 circuit breaker was a spring charged stored energy type. It consisted of two major parts, a spring-charging mechanism and a closing and opening mechanism. The following paragraphs contain a brief discussion of the spring-charging mechanism and a more detailed discussion of the closing and opening mechanism.

1. Spring-Charging Mechanism

Figure 2 shows that rotation of the motor crank, piece 24, pushed the oscillator arm counterclockwise forcing the oscillator pawl, piece 9, to push a tooth in the ratchet wheel, piece 10. The ratchet wheel rotated slightly more than one tooth and was captured by the hold pawl, piece 11. This process repeated until the closing springs were charged. Figure 6 shows the charging springs in both the charged and discharged positions.

2. Closing and Opening Mechanism

The circuit breaker close and opening (trip) linkages can have four steady state conditions, as shown in Figure 3. The angular position of the close cam in Figure 3a corresponds to the angular position of the drive plates and closing spring crank arms shown in Figure 6b. These figures show the trip latch in the tripped position. The trip latch resets to the latched position at the end of the spring charging stroke.

Figure 3b shows the lower end of the main drive link, with the main roller, swung upward and toward the left, pushing the trip latch constraining link so as to rotate the trip latch back to the reset position. This action will occur the same time that the spring charge is completed and just before the close cam stop roller strikes the spring release latch. The position of the cam in Figure 3b corresponds to the position of the drive plates in Figure 6a, with spring charged, breaker open.

The breaker mechanism is now ready for closing. Counterclockwise rotation of the spring release latch started the closing cycle. This rotation removed the hold on the close cam stop roller, and allowed the force of the closing springs to rotate the close cam counterclockwise and close the breaker. Figure 3c shows a circuit breaker in the closed position with closing springs discharged. The close cam has rotated about 180 degrees during the closing cycle.

The breaker mechanism is now ready for opening (tripping). The breaker is tripped open by counterclockwise rotation of the trip shaft. The trip shaft extends across the left hand part of the breaker and is rotated by a shunt trip device, an undervoltage device, a device for measuring faults, and a manual device.

In the closed position, the main contact springs produced a clockwise twisting force on the pole shaft. This force was transmitted by the center pole lever downward through the main drive link to the main roller. The main drive link at the main roller connects to the trip latch by the roller constraining link.

The downward force on the main drive link resulted in a pulling force on the roller constraining link. This force tends to rotate the trip latch counterclockwise, but the trip latch is kept from rotating by overlap of the latch surface on the trip shaft. For tripping, a very small rotation of the trip shaft releases the trip latch to rotate counterclockwise to the position shown in Figure 3a. Figure 3e shows enlarged views of the trip shaft and trip latch tip in the closed and tripped positions. The entire linkage collapses under the force of the main contact springs. A reset spring, Figure 2, piece 19, pulls the linkage to the fully open position.

Appendix B

General Electric AKR-30 Circuit Breaker Operating Principles

The operating mechanism of the AKR-30 circuit breaker was of the spring charged stored energy type. It consisted of three major parts, a spring-charging mechanism, a closing and opening mechanism, and a trip shaft and trip devices mechanism. The following paragraphs contain a discussion of these three mechanisms.

1. Spring-Charging Mechanism (See Figure 7)

The spring charging mechanism rotated the top of the camshaft, piece 4, backwards toward the front of the breaker pulling on closing springs, piece 1. This was accomplished by the eccentric output shaft of the gearmotor, piece 9, causing the driving pawl, piece 8, to reciprocate, pushing the ratchet wheel enough past the distance of one tooth so the holding pawl, piece 6, could engage the next tooth holding the ratchet wheel, piece 7, against increasing spring force. This action continued until the springs were charged.

2. Closing and Opening Mechanism (See Figures 7 and 8)

The circuit breaker mechanism had three configurations, tripped, reset, and closed, as shown in figure 8. The transition from one configuration to the next is described.

From a reset configuration, the discharge of the charging springs rotated the cam, piece 3, until it engaged the cam roller. This force rotated the main shaft, piece 13, pushing the insulated coupling, piece 12, forcing the movable contact arm into the stationary contact assembly which closed the breaker. Once the breaker was fully closed, the spring charging mechanism charged the closing spring which rotated the cam back to its reset position.

With the breaker closed, a trip initiator rotated the trip shaft, item 10, clockwise as seen in figure 8, which allowed the secondary latch, item 14, to pivot clockwise allowing the cam roller, item 5, to collapse down to the left. This allowed the main shaft, item 13, to rotate counter clockwise pulling the insulated coupling, item 12, and the movable contact arm to move to the right breaking the circuit with the stationary contacts. Arcing contacts, arc runners and arc chutes were present to dissipate the arc.

With the breaker tripped, the opening springs discharged, and the opening springs charged, small lever springs on the secondary latch, item 14, and cam roller, item 5, reposition the linkage back to the reset position as shown in figure 8.

3. Trip Shaft and Trip Devices Mechanism

The trip latch was attached to the trip shaft. This shaft was supported by bearings and had trip paddles attached at intervals along the shaft. The trip devices released some force to push the trip paddle to rotate the trip shaft so the trip latch rotate away from the secondary latch resulting in an opening sequence as described above. Each trip device is described below.

a. Undervoltage Trip Device

The undervoltage device was a spring loaded armature restrained by an electromagnet. When the voltage to the electromagnet reduced to approximately 60 percent of rated voltage, the spring pulled the armature up from the coil causing it to engage with a trip paddle assembly. The trip paddle assembly contained a fixed and a floating paddle. The undervoltage device armature pushed on the floating paddle and the floating paddle would rotate until it engaged the fixed paddle to rotate the trip shaft. An adjusting screw on the trip paddle assembly would vary the clearance between the armature and the floating paddle.

b. Shunt Trip Device

The shunt trip device was an spring loaded armature actuated by an electromagnet. When voltage was applied to the electromagnet, the armature was pulled by the electromagnet against spring force. This movement pulled the armature against a trip paddle rotating the trip shaft.

c. Flux Shift Trip Device

The flux shift trip device was a spring loaded plunger held against spring force by a permanent magnet. When a trip actuation signal was generated, an opposing magnetic field allowed spring force to overcome the magnetic force of the permanent magnet allowing the trip rod to impact a trip paddle rotating the trip shaft. As the breaker opened, reset linkage attached to the main shaft reset the trip rod for the next trip signal.

d. Manual Trip Button

A manual trip button was located on the front of the breaker. The button was attached to a manual trip rod which was held away from a trip paddle by a spring. Pressing the manual trip button overcame spring force allowing the manual trip rod to push on the trip paddle rotating the trip shaft.

e. Racking Mechanism Interlock

The racking mechanism interlock was a mechanical link which prevented the racking screw cover from being pushed aside without first depressing the manual trip button. This prevented the breaker from being racked either in or out without first tripping the breaker.

f. Disconnect Position Interlock

The disconnect position interlock was a mechanical link which blocked the racking screw cover in the open position when the breaker was in the disconnected position. This prevented the breaker from being closed in the disconnected position as a result of the racking mechanism interlock.

g. Positive Interlock

The positive interlock was a was a lever on the side of the breaker. This lever was linked to the trip shaft and was actuated by a ramp cam in the cubicle to rotate the trip shaft when the breaker was moved from the connected to the test position.

Appendix C

Evaluation of Westinghouse Reactor Trip Breaker Maintenance Procedure 32MT-9SB01

1. Closing Spring Removal

During observation of the investigation of the failed breaker discussed in Section 3.B of this report, the inspectors observed removal and reinstallation of the closing springs. Craft personnel had no difficulty removing the springs but had some difficulty reinstalling the springs. Craft personnel hammered the springs back into position using a screwdriver and a hammer. Craft personnel applied the screwdriver blade to the end of the closing spring at a large angle and hammered the spring back onto its shaft. The inspectors noted that a small slip of the screwdriver blade could result in damage to circuit breaker mechanical devices.

The inspectors reviewed why it was that these inspections were being done. They determined that these inspections were initiated following a previous problem with pole shaft weld cracks. However, as noted in Section 5.B, all the DS-206 reactor trip breakers had new type pole shafts, so this inspection was no longer necessary.

The inspectors concluded that removal of the closing springs every 6 months to inspect for a previously corrected condition was not appropriate based on the potential for circuit breaker damage. The inspectors discussed this issue with the Westinghouse representative. The Westinghouse representative agreed that the inspection appeared to be technically unnecessary after pole shaft replacement. The inspectors reviewed this item with the licensee. The licensee committed to evaluate this issue along with other procedure recommendations resulting from the root cause team's findings.

2. Trip Shaft Torque Measurement

The licensee was not measuring trip shaft torque for Westinghouse reactor trip breakers. Westinghouse IB 33-790-1G did not contain this check but the Westinghouse representative recommended it be accomplished.

Because the vendor representative recommended it, and because it was an objective measurement of the breaker's margin to trip which could provide an early indication of degraded breaker performance, the inspectors concluded that trip shaft torque measurement was a valid maintenance test which was not being performed by the licensee. Licensee representative committed to evaluate incorpation of this measurement into their maintenance procedures.

3. Trip Latch Overlap

The licensee was also not measuring trip latch overlap. Westinghouse IB 33-790-1G provided a procedure to perform this adjustment but noted that the procedure should only be necessary when parts were reassembled after dismantling. Discussion with the Westinghouse representative indicated that Westinghouse now considered this check to be valid for routine maintenance.

The inspectors noted that a Westinghouse reactor trip circuit breaker had previously failed to close due to the trip latch overlap being out of adjustment. In addition, the licensee found that the trip latch adjustment on the failed circuit breaker was out of adjustment by 1/2 turn. As discussed in Section 3.B, subsequent investigation of the failed breaker indicated that the trip latch overlap adjustment did not contribute to the failure.

The inspectors concluded that measuring the trip latch overlap was a valid check for routine maintenance. The licensee agreed to evaluate including this check in the maintenance procedure.

Appendix D

Evaluation of GE Reactor Trip Breaker Maintenance Procedure 32MT-9SB02

1. Lubrication (See Section 3.B)

The licensee had a 1983 evaluation that Dow Corning (DC) 321R was an acceptable lubricant for the undervoltage coil moving armature but had no evaluation for other moving parts. DC 321R was a spray type dry lubricant. The licensee contacted Dow Corning. Dow Corning provided a letter that stated that DC 321R was an appropriate lubricant for clean and dry metal surfaces only. The letter indicated that DC 321R would not be effective if sprayed over surfaces previously greased and could tend make the grease ineffective. GE manual GEK-64459B specified Mobilgrease 28. The GE representative stated that the breakers were factory lubricated with a grease. Maintenance records indicated that the licensee was applying DC 321R to GE reactor trip breakers.

The inspectors concluded that the use of DC 321R was not technically correct for previously greased surfaces. The licensee committed to perform a review of lubrication used in GE AKR-30 circuit breakers.

2. Procedure Sequencing

Procedure 32MT-9SB02, Section 8.6, "Undervoltage Device Positive Trip Check and Adjustment," adjusted and tested the UV device mechanical linkage. The next section of the procedure, Section 8.7, "Verification and Adjustment of UV Device Setting," checked and adjusted UV device pick-up and drop-out voltage. Section 8.7 directed that the UV device be removed, adjusted, and replaced if the pick-up voltage was not correct. There were no instructions in Section 8.7 to repeat Section 8.6 if the UV device were removed.

The inspectors concluded that this procedure was inadequate to ensure proper UV trip device mechanical adjustment since the UV device was potentially removed from the breaker after its linkage had been adjusted and tested.

Procedure 32MT-9SB02, Step 8.7.14 measured and recorded the as-found UV device drop-out voltage. However, previous steps authorized removal of the UV device, and adjustment of the UV device pick-up voltage. The licensee was trending the as-found data. In addition, the as-found trip torque was taken after the circuit breaker had been cleaned, lubricated and cycled a number of times.

The inspectors concluded that Procedure 32MT-9SB02 was not clearly measuring as-found UV device drop-out voltage or trip shaft torque. The licensee agreed to evaluate the recording of as-found data. Section 5 of this Appendix discusses additional concerns with UV device adjustments contained in Procedure 32MT-9SB02.

3. Shunt Trip Check

GE manuals GEK-64459B and GEK-7310C provided a test to ensure margin existed in the shunt trip device mechanical linkage. These procedures verified the shunt trip device would trip the circuit breaker with a 1/32 inch restraint.

The shunt trip check procedure in GEK-64459B also included an adjustment to ensure that nuisance tripping did not occur. These checks were not included in the licensee's maintenance procedure.

The inspectors concluded that the shunt trip check provided an easy method to ensure margin existed in the shunt trip device tripping mechanism. The inspectors discussed the benefits of the shunt trip check with the licensee. The licensee agreed to evaluate including this check in a maintenance procedure.

4. Buffer Alignment

The buffer in the GE AKR-30 circuit breakers had two uses. It prevented the mechanism from overdriving the contacts when the circuit breaker closed and it absorbed the opening energy of the mechanism when the circuit breaker opened. GE manual GEK-64459B provided instructions to measure and adjust the buffer setting. This instruction was not contained in the licensee's procedure.

The inspectors concluded that an improper buffer setting could increase the potential for mechanical failure of the circuit breaker. The inspector discussed measurement of the buffer setting with the licensee. The licensee agreed to evaluate including this check in a maintenance procedure.

5. UV Trip Device Adjustments and Checks

GE manual GEK-64459B included adjustments and checks of the UV trip device which were not included in Procedure 32MT-9SB02. In addition, the drop-out voltage acceptance criteria specified in GEK-64459B was different than Procedure 32MT-9SB02.

Based on discussions with the GE technical representative assisting the licensee in the root cause analysis of the GE AKR-30 circuit breaker closing problem, the inspectors concluded that the adjustments, checks, and acceptance criteria of GEK-64459B were the latest GE instructions for performance of UV device maintenance. The inspectors concluded that this information should be included in the licensee's maintenance procedure. The inspectors discussed these concerns with the licensee. The licensee agreed to verify that GE Manual GEK-64459B was the correct manual for GE AKR-30 breakers and to incorporate this manual in maintenance procedures.

WESTINGHOUSE TYPE DS-206 CIRCUIT BREAKER

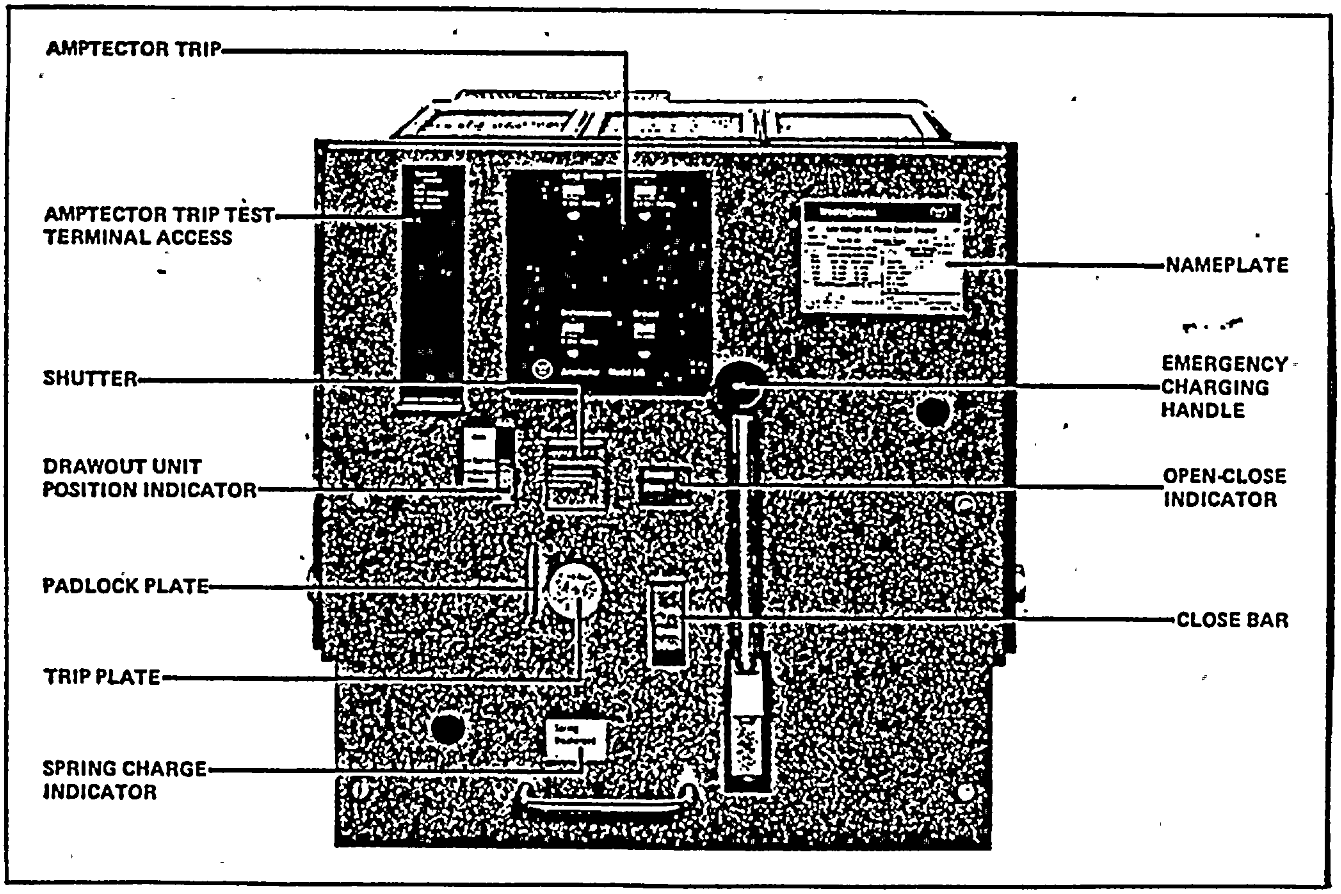
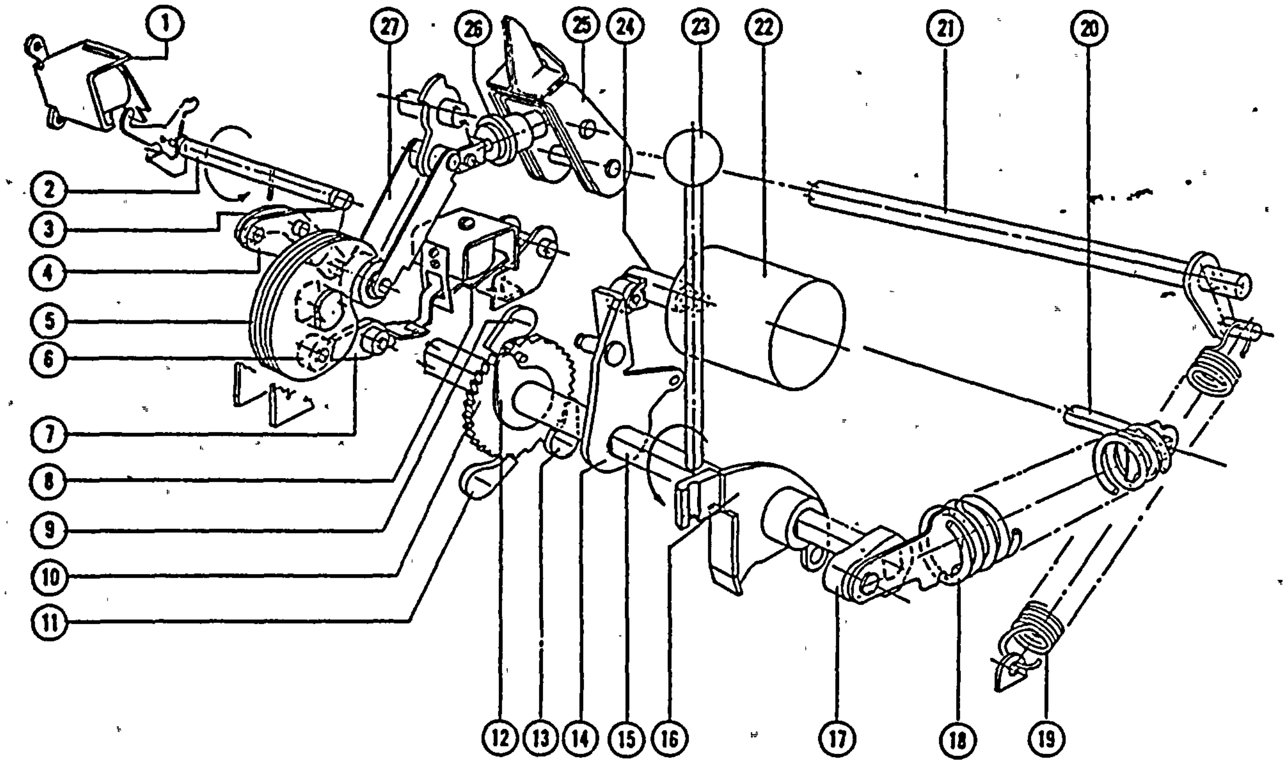


FIGURE 1

WESTINGHOUSE TYPE DS-206 CIRCUIT BREAKER
POWER OPERATED MECHANISM



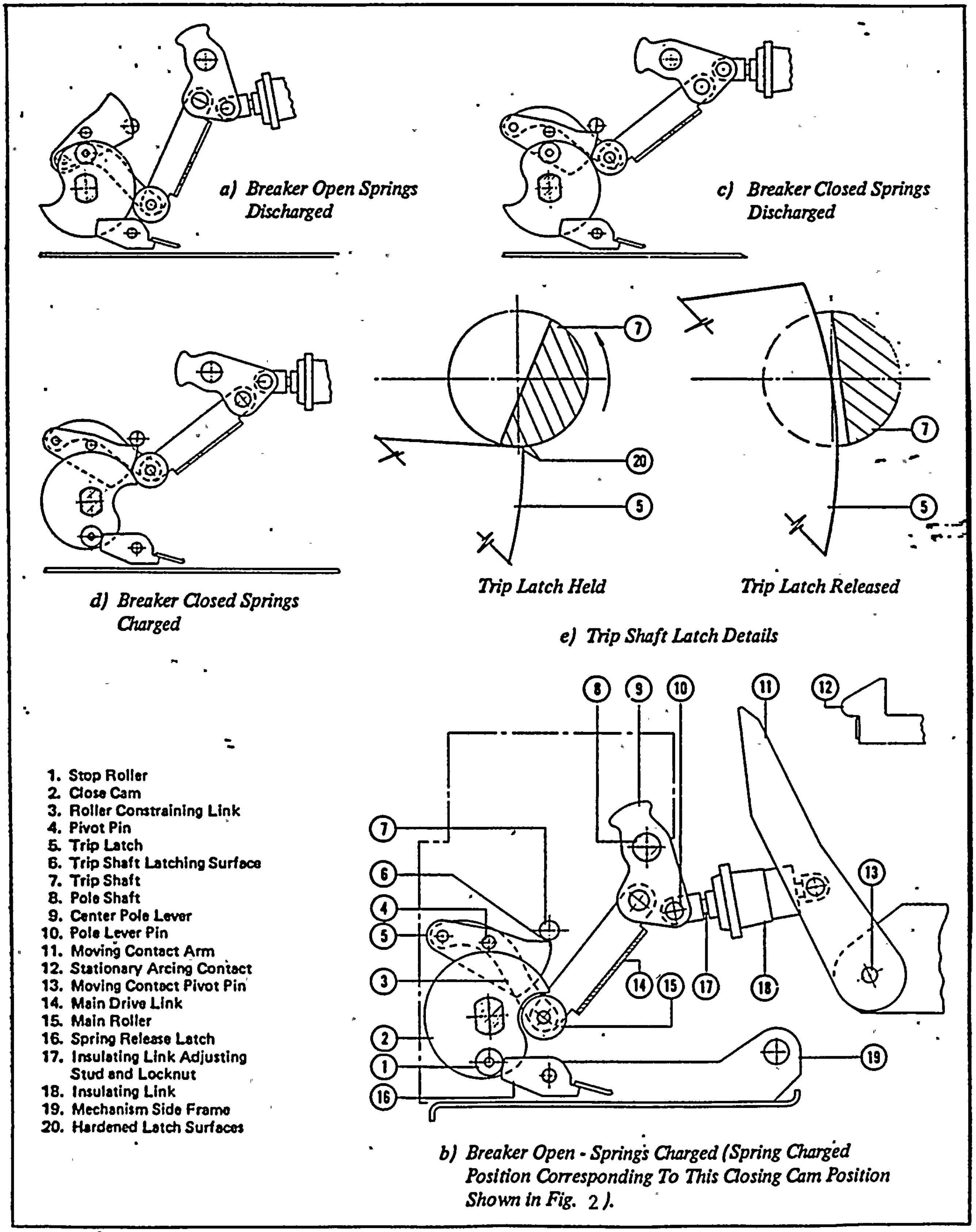
1. Shunt Trip Device
2. Trip Shaft
3. Roller Constraining Link
4. Trip Latch
5. Close Cam
6. Stop Roller
7. Spring Release Latch
8. Spring Release Device
9. Oscillator Pawl
10. Ratchet Wheel
11. Hold Pawl
12. Drive Plate
13. Emergency Charge Pawl
14. Oscillator
15. Crank Shaft
16. Emergency Charge Device
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 2

CLOSE SPRING IS SHOWN CHARGED

WESTINGHOUSE TYPE DS-206 CIRCUIT BREAKER

FOUR BASIC POSITIONS OF CIRCUIT BREAKER LINKAGE



a) Breaker Open Springs Discharged

c) Breaker Closed Springs Discharged

d) Breaker Closed Springs Charged

Trip Latch Held

Trip Latch Released

e) Trip Shaft Latch Details

1. Stop Roller
2. Close Cam
3. Roller Constraining Link
4. Pivot Pin
5. Trip Latch
6. Trip Shaft Latching Surface
7. Trip Shaft
8. Pole Shaft
9. Center Pole Lever
10. Pole Lever Pin
11. Moving Contact Arm
12. Stationary Arcing Contact
13. Moving Contact Pivot Pin
14. Main Drive Link
15. Main Roller
16. Spring Release Latch
17. Insulating Link Adjusting Stud and Locknut
18. Insulating Link
19. Mechanism Side Frame
20. Hardened Latch Surfaces

b) Breaker Open - Springs Charged (Spring Charged Position Corresponding To This Closing Cam Position Shown in Fig. 2).

FIGURE 3.

WESTINGHOUSE TYPE DS-206 CIRCUIT BREAKER

POLE ASSEMBLY

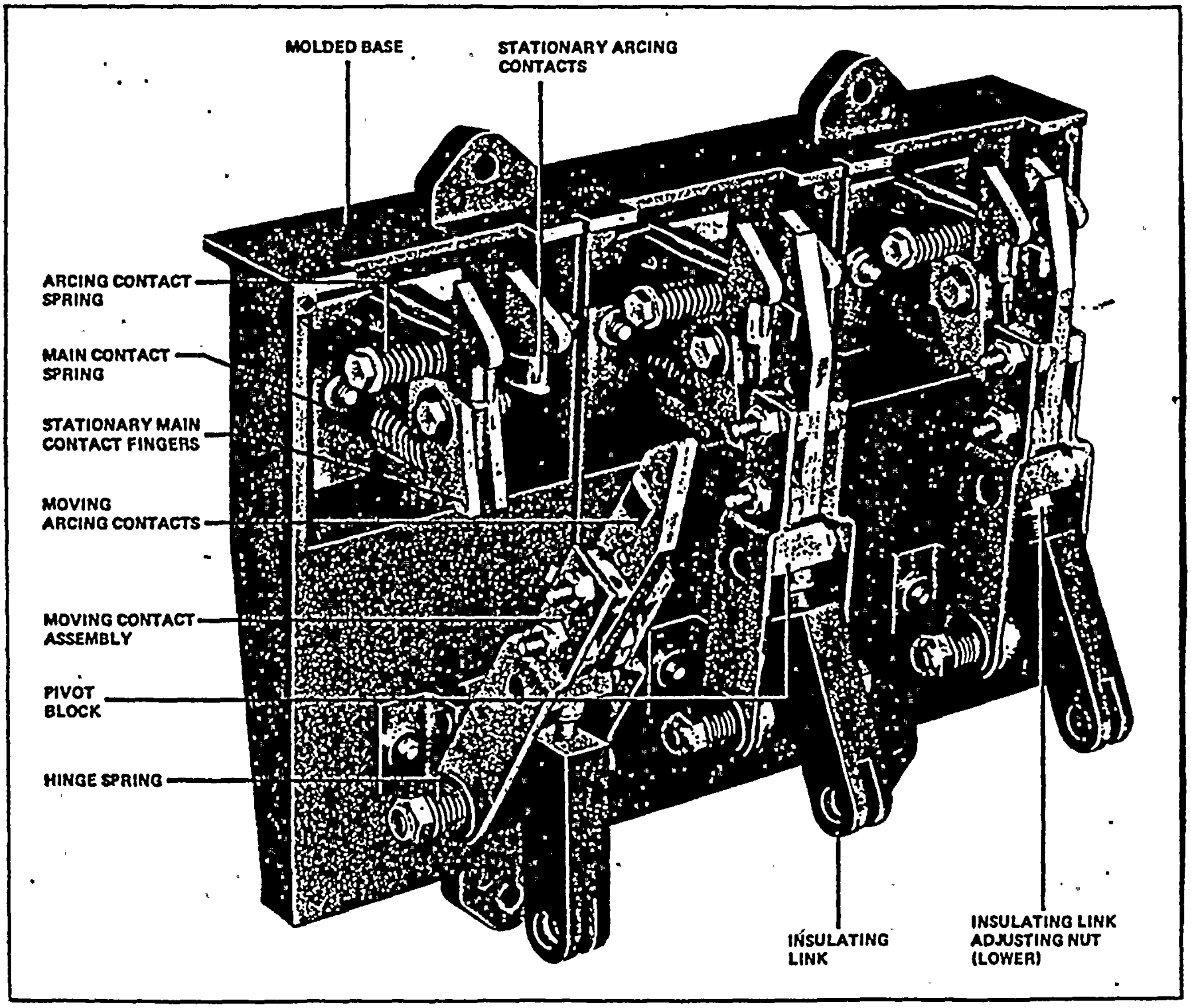


FIGURE 4

WESTINGHOUSE TYPE DS-206 CIRCUIT BREAKER

CONTACT ARRANGEMENT

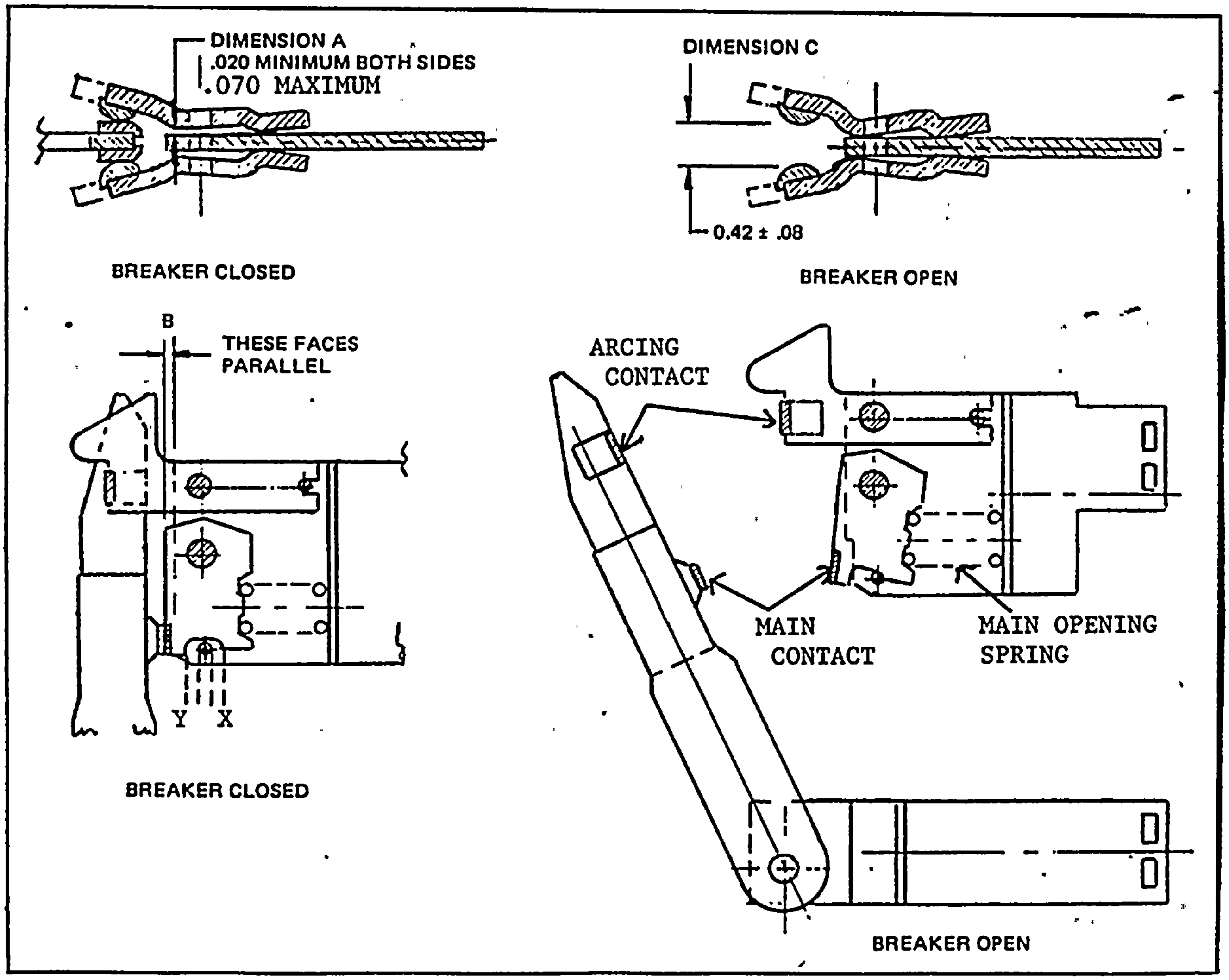
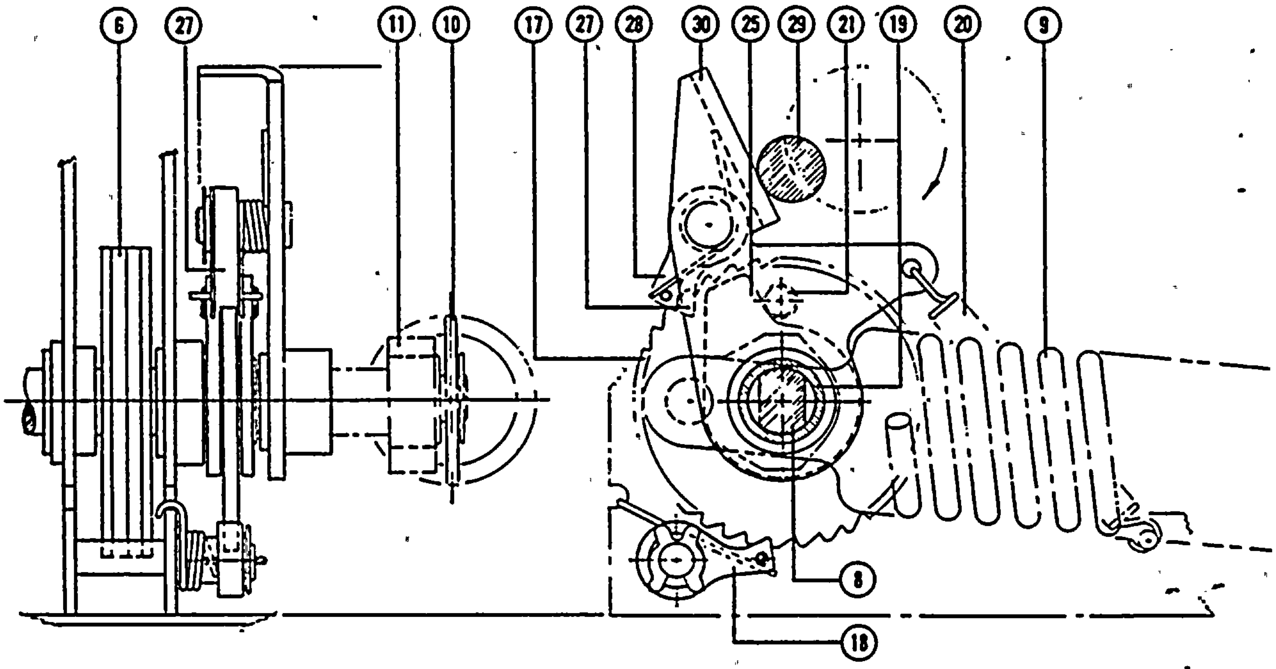


FIGURE 5

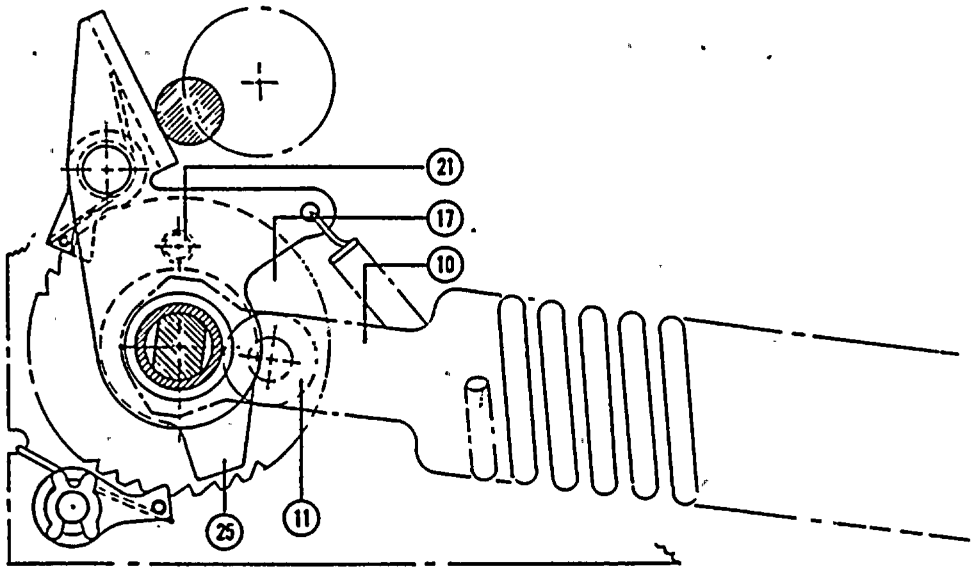
WESTINGHOUSE TYPE DS-206 CIRCUIT BREAKER

POWER OPERATED SPRING - CHARGE DETAILS



a) Spring Charged

Note: Main cam position for this crank shaft position is shown in Fig. 3 a

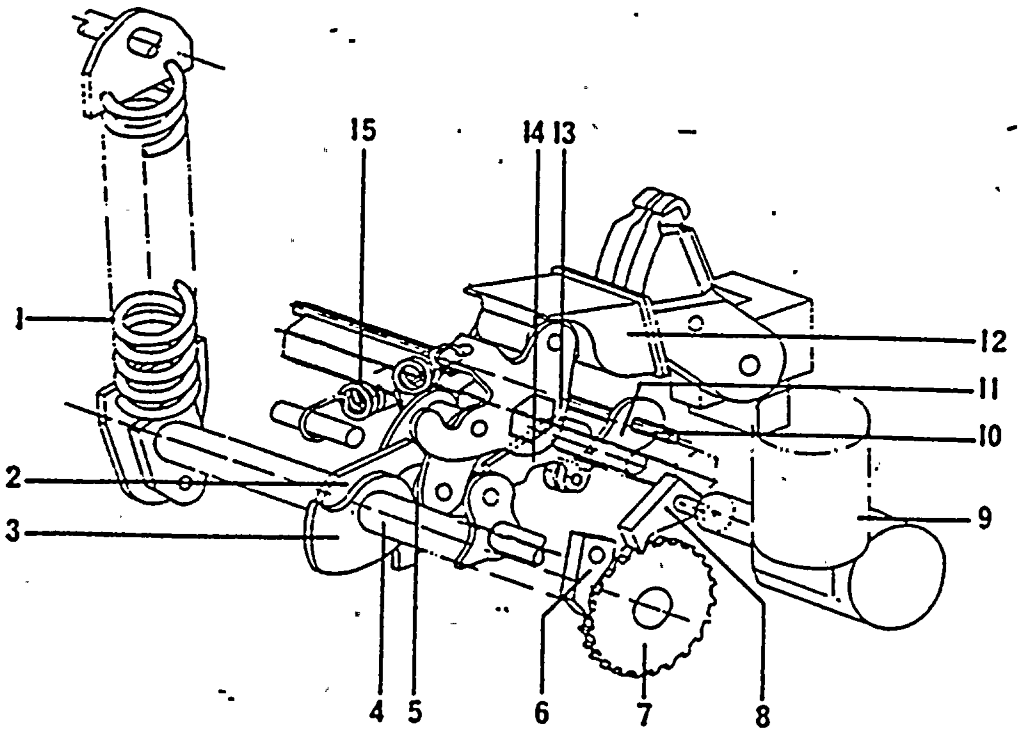


b) Spring Discharged

6. Close Cam
8. Crank Shaft
9. Closing Spring
10. Spring End
11. Crank Arm
17. Ratchet Wheel
18. Hold Pawl
19. Oscillator Bushing
20. Oscillator Spring
21. Ratchet Wheel Pin
25. Drive Plate
27. Pawl Lifter
28. Oscillator Pawl
29. Motor Crank Roller
30. Oscillator

FIGURE 6

GENERAL ELECTRIC TYPE AKR-30 CIRCUIT BREAKER

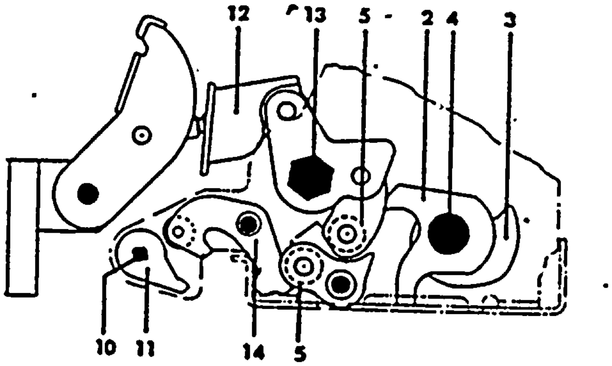


1. Closing Spring
2. Prop
3. Cam
4. Camshaft
5. Cam Roller
6. Holding Pawl
7. Ratchet Wheel
8. Driving Pawl
9. Gearmotor
10. Trip Shaft
11. Trip Latch
12. Insulated Coupling
13. Main Shaft
14. Secondary Latch
15. Opening Spring

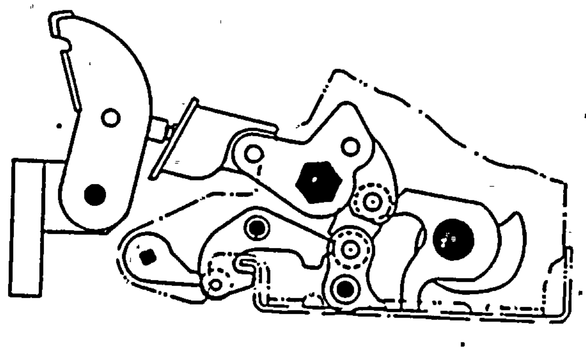
Fig. 7. (108D8131) Electrical breaker mechanism

GENERAL ELECTRIC TYPE AKR-30 CIRCUIT BREAKER

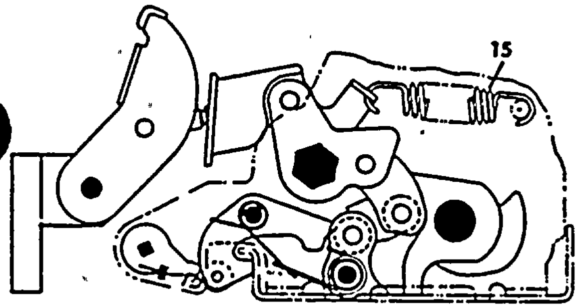
MECHANISM



TRIPPED



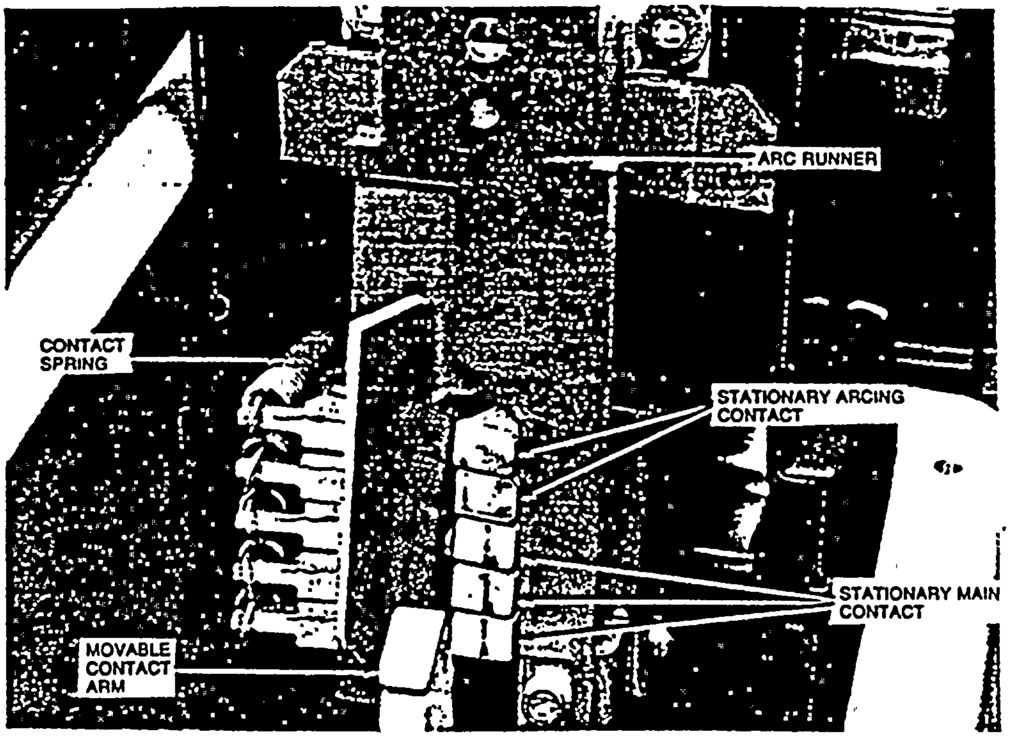
CLOSED



RESET

2. Prop	11. Trip Latch
3. Cam	12. Insulated Coupling
4. Camshaft	13. Main Shaft
5. Cam Roller	14. Secondary Latch
10. Trip Shaft	15. Opening Spring

FIGURE 8



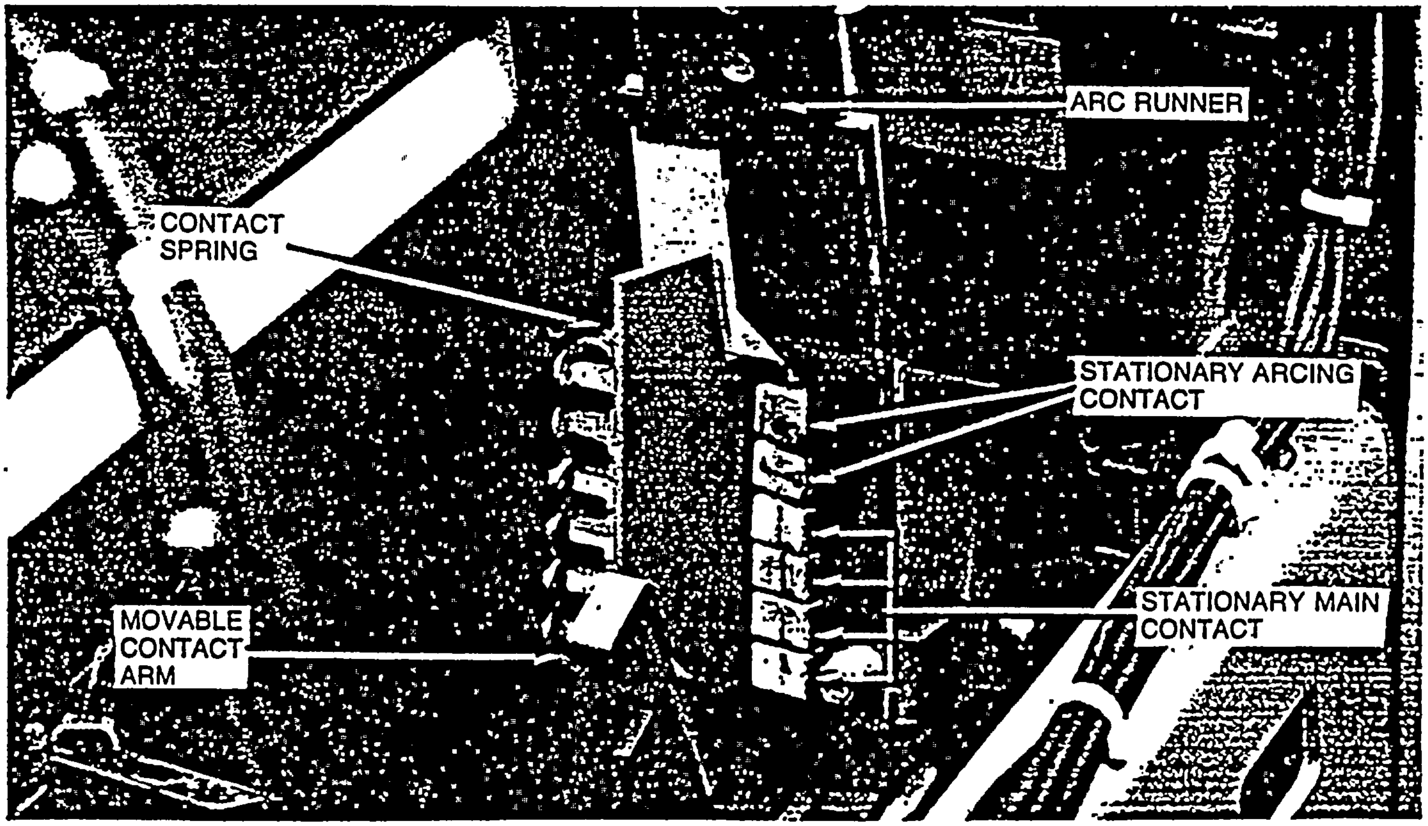
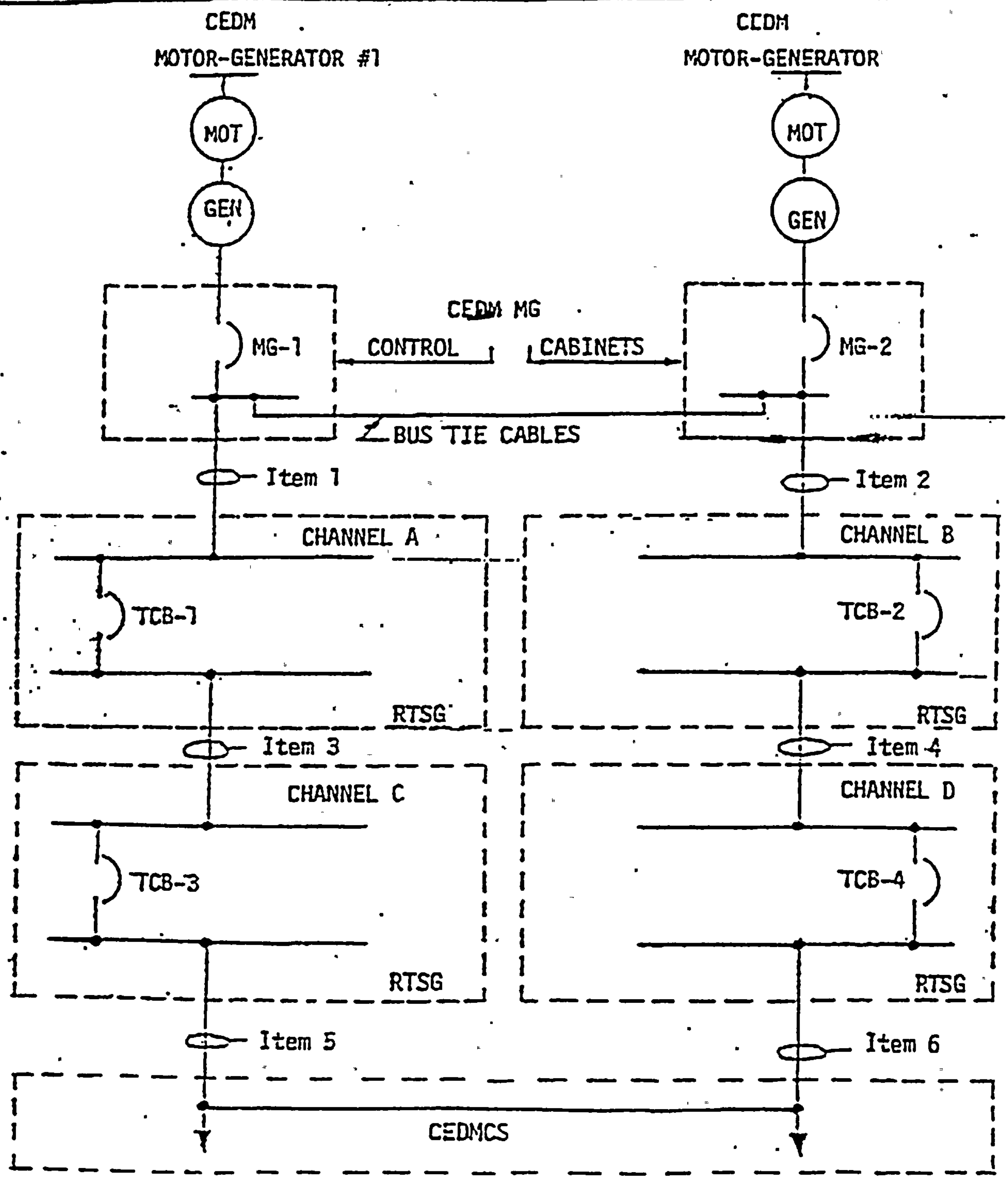


FIG. 9 — AKR 30H
800 AMP CONTACT STRUCTURES

PROJECT: SYSTEM 80 STANDARD DESIGN
SERVICE: REACTOR TRIP SWITCHGEAR SYSTEM:



TCB-1 and TCB-2 are of diverse manufacture from TCB-3 and TCB-4.
Item 1 and Item 2 shall be kept separate from Item 5 and Item 6.

Figure 10
RTSG ONE-LINE DIAGRAM

PROJECT: GENERIC
SERVICE: REACTOR TRIP CIRCUIT BREAKER

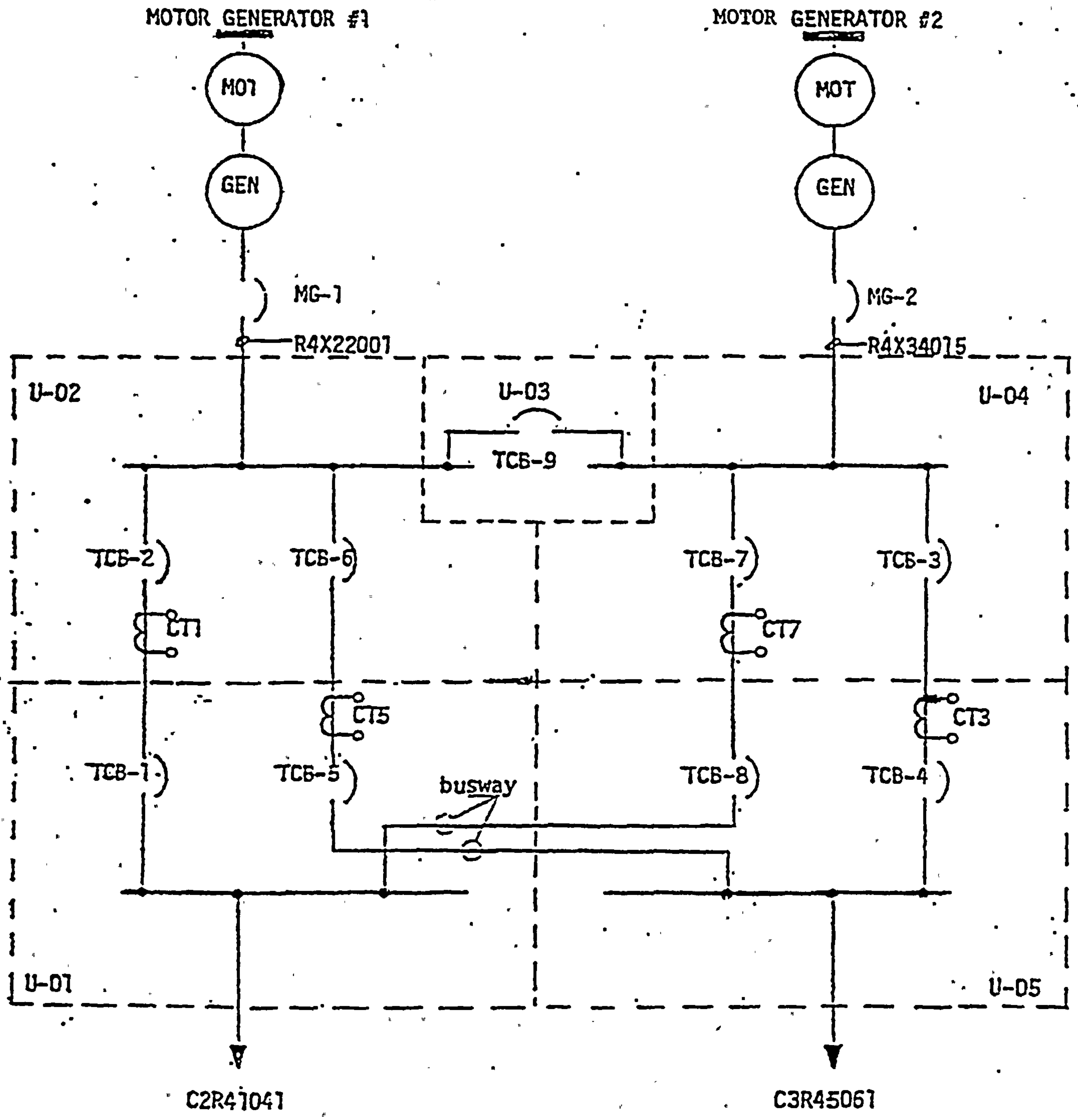


Figure 11
RTSG ONE-LINE DIAGRAM
3410 STYLE