QC HANDBOOK: METAL CLAD CIRCUIT BREAKERS

General Guidelines

1. Two basic types of Metal Clad breakers are manufactured at Smyrna Plant.
   - Sf6 breakers
     - FG-2
   - Vacuum breakers
     - VAD-2
     - VAD-3
     - VAD-4

2. Production testing is very similar for all breakers regardless of type in that all breakers received the following inspections and tests:
   - Physical Inspection
   - Mechanical Operation
   - Electrical Tests
     - Control Wire High Potential Test
     - Max./Min. Voltage Operation
     - Contact Speed Measurement
     - Coil Response Time Measurement
     - Contact Resistance Measurement
     - Primary High Potential Test

3. The primary difference in the production testing of the various type of breakers is associated with the contact speed measurement. The specific differences will be discussed in the detail instructions for each breaker type.

4. A minor difference arises when attempting to accommodate multiple standards. Depending on the end customer, the breaker may have to be tested in accordance with ANSI or IEC standards. (Example: ANSI requires the control wire high potential test to be conducted at 1800 volts ac for 1 second; IEC requires 2000 volts for 1 second. We have standardized on 2000 volts ac for 1 second for all breakers to comply with both standards.

5. Review the job folder thoroughly before inspecting the equipment to ensure all necessary drawings and documents are present. Use these as inspection guides. Refer to the Reference Legend on the previous page for a list of related documents.

6. The appropriate checklist shall be completed for every breaker prior to shipment. All items on the checklist shall be inspected. Those items that are not applicable are to be so noted. After completion of the production test, the Quality Control Technician approves the breaker for shipment by placing the "OK TO SHIP" tag on the breaker. The breaker is then delivered to the shipping department, if OEM, or to Metal Clad QC if the breaker is part of an equipment lineup order.

7. The checklist and associated documents are to be retained in a permanent job order file maintained by the Order Engineering Department. Breaker signatures captured on the oscilloscope are downloaded to a personal computer and stored as a permanent plant record.

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I. Breaker Assembly

A. The breaker assembly process is documented in accordance with the Manufacturing Quality Plan (MQP).

B. After breaker assembly has been completed and the applicable MQP documentation signed by the assembly personnel, the breaker is delivered to QC for production testing.

II. QC Inspection and Test

A. Physical Inspection

1. Visually inspect the breaker verifying all hardware has been properly tightened. Observe that all lock washers have been "flattened".

2. Painted surfaces shall have a finish free of runs, scratches, etc.,. Plated surfaces shall be free of corrosion, flaking or scaling that would indicate poor adhesion.

3. MOC, (mechanism operated contact), is optional. If MOC option is required, verify the MOC lever moves "up" while the breaker is closing, and "down" while breaker is opening.

4. A universal motor, labeled 115 Vac is used for both 120 Vac and 125 Vdc applications. The same motor is also used for 240 Vac and 250 Vdc applications by connecting a resistor (heater element) in series with the motor. Approximately one-half of the supply voltage should be dropped across the resistor. For 48 Vdc application, the same universal motor is re-wired internally. These motors will be verified by the spring recharging time. If the motor has not been re-wired, the motor will not meet the 10 second maximum.

5. Proper operation of the counter is determined by observing that the counter advances in increments of 1 for each cycle of operation.

6. Verification of breaker lubrication is made by observing the presence of Mobil 28 (red in color) grease in the locations listed on the checklist. Lubrication should be in quantities sufficient to lubricate the specified surface and not excessive to the point of causing the grease to be slung in large amounts onto surfaces not intended to lubricated.

7. Proper operation of the test position interlock is verified by lifting up on the interlock lever and observing that up and down movement is unrestricted. Also verify, by the presence of a returning force greater than normal gravitational force, that the spring has been installed.

8. Proper installation of the racking arm stops is verified by inserting the racking handle into the racking port and turning the racking arms. The stops are properly adjusted if the racking arms on both sides of the breaker touch the stops at approximately the same time. The height of the stops are set during assembly.

9. The racking mechanism interlock is verified by attempting to operate the racking mechanism with the breaker "closed". The racking handle must not be allowed to make one full revolution before encountering the interlock located on the drive bar.

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A. Physical Inspection

10. The racking arms shall have no side-to-side motion. If motion is observed, contact assembly to have additional shims installed. The verification must be made with the racking arms in mid travel and not against the stops.

11. Smooth operation of the control plug assembly is verified by grasping the secondary disconnect handle and extending the control plug. Movement shall be reasonably free with not binding or hanging of the control wire bundle.

12. The type of "guide pins" required is determined by the type of control plug that is supplied with the breaker. The two primary types of control plugs are the "AMP" and "HARTING". The pins associated with these types of plugs differ primarily by the width of the recessed ring around the pin. The width of the ring on the Harting pin is wider than the ring on the Amp pin.

13. To ensure proper installation of the flex connector block, verify the block hardware extends completely through the block. The gap between the block halves should be evenly distributed on both sides.

14. From the Engineering Standards (E.S.), determine the correct code plate configuration and verify correct code plate has been installed. Note: Care must be taken to notice the specific view that is used to show the code plate configuration (i.e., viewed from the front or rear of the breaker).

15. The interrupter type and serial numbers are recorded for liability purposes in the event of a manufacturer's recall. Special attention must be given to recording the information accurately.

B. Electrical Operation and Tests

1. Control Wire High Potential Test
   To meet the intent of both ANSI and IEC standards, breaker control wiring is high potential tested at 2000 Vac for 1 second. To reduce the testing time, a "shorted" connector has been fabricated allowing all pins in the breaker control plug to be energized simultaneously. Attach the high potential lead from the test set to the "shorted" connector and the ground lead to the frame of the breaker. Perform one test with the breaker closed and one with the breaker open.

2. Initial Breaker Operation
   The mechanism goes through a period of "settling in" during the initial operations. It is for this reason the breaker is operated 75 times (minimum) prior to final adjustments. Because of this settling, it is recommended that the erosion gaps be set at approximately maximum prior to the initial 75 operations as these gaps will decrease during the operations. For information concerning this adjustment refer to the Section C. Before energizing the breaker observe the voltage application for the charging motor, close coil, and trip coil. The voltage application is determine from the catalog number associated with the breaker. Apply the proper voltage(s) and operate the breaker 75 times.

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B. Electrical Operation and Tests

3. Maximum Spring Recharge Time
During the initial operations, observe the time required for the close springs to recharge. The time interval starts the moment the breaker closes and ends with the de-energization of the charging motor. (10 seconds maximum)

4. Maximum / Minimum Voltage Operation
ANSI requires that all breakers be operated over a range of voltages. The maximum and minimum voltage is determined based on the rated operating voltage. Additionally ANSI requires a minimum of 5 operations be performed at each voltage level. For applicable test voltages, refer to Table 1 of QCP 7.33.

5. Electrical Close-Open Operation
Electrical "trip-free", or close-open, operations are performed to simulate breaker operation that would be encountered while closing into a fault. This is accomplished by applying a trip signal to the trip coil through an "a" contact when the breaker closes.

6. Reclosing Operation
"Reclose", or open-close, operations are performed to simulate a control system incorporating a reclosing relay. This is accomplished by applying a close signal through a normally open contact of a time delay pickup relay. The time delay relay is energized by the closing of a "b" contact when the breaker opens.

7. Mechanical Trip-free
The mechanical trip-free is performed to verify that with a mechanical "trip" applied to the breaker at the time a mechanical close is initiated, that the springs will discharge without moving the main contacts. This differs from the electrical "trip-free", during which the main contacts actually close then reopen.

8. Auxiliary Contact Verification
Auxiliary contacts are used throughout the breaker control circuit to provide the status of the main contacts. "a" contacts reflect the same position of the main contacts while "b" contacts reflect the opposite position. Using a continuity meter, verify proper contact position of all auxiliary contacts with the main contacts in both the "open" and "close" position.

9. Coil Verification
The close and trip coil is verified by comparing the actual resistance of the coils to the nominal values specified in the E.S. Based on the voltage application refer to the E.S. and determine the typical value of resistance for each coil. Verify the coil resistance is within (+/-) 10% and record the actual values.

C. Mechanical Adjustment

1. Erosion Gap Setting
Erosion Gap is an indication of primary contact wear. The gap is defined as the distance between the flat washer and the spring pivot on the drive connecting link. It is important to remember that total stroke of the breaker mechanism is divided between the erosion gap and the primary contact gap. Both gaps have an allowable range. Increasing one decreases the other.

   Check the erosion gap on each pole using pin gauges and adjust as necessary to obtain an acceptable gap. To adjust the "E"-gap, remove the nut, flat and lock washer at the end of the drive connecting link and rotate the "erosion indicator" until it extends the correct distance through the spring pivot. Replace the hardware and re-tighten. After making the adjustment the breaker should be operated 2 - 3 times prior to remeasuring the gap.

2. Primary Contact Gap Setting
Primary contact gap is determined by measuring the distance between top surface of the flex connector block and the bottle adapter plate in the "open" and "closed" position and subtracting the difference. If the contact gap is not within the allowable limits, refer to Section F (General Adjustment and Troubleshooting) for proper adjustment of the primary contact gap.

D. Breaker Performance Tests

1. Contact Opening Speed
Contact speed is determined by using a digital storage oscilloscope and a linear potentiometer. The voltage appearing across the potentiometer provides a proportional representation of the actual distance traveled by the contacts. The oscilloscope plots this distance traveled versus time as a curve on the screen. By using the cursors on the oscilloscope we are able to select a known interval of distance, directly read the time required to travel the known distance, and thereby calculate a speed (i.e. $v = d/t$). The distance (d) over which the speed is calculated is 75% of the contact gap on opening and 33% on closing. The specifications are given in terms of maximum allowable time. Therefore the measurement is rather straight forward. Once the opening signature is captured on the oscilloscope, the voltage (ΔV_g) equivalent to the contact gap is determined by placing cursor #1 at a point on the curve before contact motion has started and cursor #2 is placed at a point on the curve where motion has stopped. The voltage ΔV is read directly from screen. The voltage interval for measuring the opening speed (max. time) is determined by multiplying ΔV_g by 0.75. To measure the opening time, place cursor #1 at the point on the contact status curve where contacts were last closed. Place cursor #2 on the motion curve at a point where the voltage is equal to or just greater than the 75% ΔV_g previously calculated. Read the time interval ΔT directly from the scope.

D. Breaker Performance Tests

2. Contact Overtravel
Primary contact overtravel is a measure of the maximum distance traveled by the contacts in the open direction. The maximum limit is established to protect the vacuum interrupter. If this maximum contact travel is exceeded damage to the bellows inside the interrupter may result. To measure this overtravel, cursor #1 is placed at the point on the contact status curve where contacts were last closed and cursor #2 is moved up the motion curve to point where the ΔV is at maximum. This maximum value of ΔV is divided by the ΔV_g associated with the contact gap. The resultant value is then multiplied by the contact gap of the pole being tested (typically B phase). This value is the contact overtravel.

3. Contact Rebound
As the mechanism traveling in the open direction encounters the return spring stops, the drive assembly possesses sufficient momentum to temporarily compress the bellville washers. This produces the overshoot previously measured. As the bellville washers relax the contact are thrown back toward the closing direction. This rebound limit is the minimum allowable contact gap which must be maintained during this rebound motion. This minimum gap is to ensure the arch is not re-established. The minimum allowable ΔV_m associated with the minimum gap is determined by dividing the minimum gap by the contact gap and multiplying the resultant by the ΔV_g associated with the contact gap. Cursor #1 is placed at the point on the contact status curve where contact were last closed and cursor #2 is placed at the lowest point on the motion curve after the maximum overshoot has taken place. Typically the first rebound is the largest excursion in the closed direction. Verify the ΔV at the minimum point on the motion curve is greater than the minimum allowable ΔV_m calculated above.

4. Closing Contact Speed
The distance over which the closing speed is calculated is 33% of contact gap. Once the closing signature is captured on the oscilloscope, the voltage ΔV_g equivalent to the contact gap is determined by placing cursor #1 at a point on the curve before contact motion has started and cursor #2 is placed at a point on the curve where motion has stopped. The voltage ΔV_g is read directly from screen. The voltage interval ΔV_c for measuring the closing speed (max. time) is determined by multiplying ΔV_g by 0.33. To measure the closing time, place cursor #2 at the point on the contact status curve where contacts first close. Place cursor #1 on the motion curve at a point where the voltage is equal to or just greater than ΔV_c previously calculated. Read the time interval ΔT directly from the scope.

5. Contact Bounce
Occasionally during the first 3 to 5 msec after closing, the primary contact will actually bounce open. When this occurs, the time during which the contacts are opened must be measured and must have a duration of $\leq$ 2 msec.

6. Coil Response Time
Coil response time is measured using a digital storage oscilloscope by comparing the signatures of coil voltage and contact status versus time. The time interval is measured by placing cursor #1 at the point on the coil voltage curve just prior to the coil voltage being applied and cursor #2 is placed at the point on the contact status curve just after the contacts change state. Read the time interval ΔT directly from the scope.

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D. Breaker Performance Tests

7. Primary Contact Resistance
ANSI requires that the resistance of the primary contact be measured with a test current of 100 amps (minimum). To measure the contact resistance the breaker must be in the "closed" position. The digital low resistance ohmmeter (DLRO) test set is connected to one breaker pole at a time. The test set has 4 leads, 2 current leads and 2 potential leads). Connect 1 current and 1 potential lead (both red or black, do not mix) to each end of a pole assembly as close to the contact fingers as possible. Turn the test set on, read and record the contact resistance for each pole.

8. Primary High Potential Test
A high potential test must be performed to verify proper dielectric strength from all three phases to ground, between each phase, and across the open contact of the interrupters. Test voltage is based on the system voltage. (Typically 36 kV unless specified in the special test requirements of the order document.

   Phase to Ground is verified by: closing the breaker, placing a jumper between A & B phase and B & C phase, connect the high potential lead from the test set to B phase, and connect the ground lead of the test set to the breaker frame.

   Phase to Phase is verified by: removing all jumpers, connect a jumper from A phase to ground, connect a jumper from C phase to ground, and connect the high potential lead to B phase.

   Across the Open Contacts is verified by: place breaker in the open position, place jumper between A & B and B & C phases on the top stabs as well as the bottom stabs of the breaker, connect the high potential lead to the top stabs and ground the bottom stabs.

E. Final Approval

1. Contact lubricating grease is required on all current carrying surfaces that are not bolted and capable of moving (i.e., primary contact fingers and ground shoe fingers).

2. Labels located on the front cover must be verified for correctness. Verify all labels have been located and installed properly. Physical appearance of these label is critical to the overall appearance of the breaker.

3. An engraved nameplate which contains the factory order number and pertinent data related to the electrical rating of the breaker shall be attached to each breaker. This nameplate is to be located along the vertical centerline of the cover and just above the counter viewing window. Each breaker also is assigned a unique serial number. The serial number is engraved on two metal plates. One is attached to the left side of the breaker frame and the second plate is attached directly under the rating nameplate. All nameplate data shall be verified for correctness prior to mounting.

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E. Final Approval

4. The equipment ID number and calibration due date for all test equipment used during testing shall be recorded on the checklist. If certified test reports are required by the customer, the QC technician completes the test report form, QCP 4.25, and obtains the Quality Control Test Engineer's signature. The test report is then placed in the mailing envelope with the product manual and is taped to the breaker.

5. For OEM orders, after completion of the inspection and test, an "OK TO SHIP" tag is attached to the breaker by the QC technician. The breaker is then delivered to shipping. If breaker is to be shipped with a Metal Clad Switchgear order, the breaker is delivered to Metal Clad QC to be used in testing the switchgear. The breaker will be tagged later by the Metal Clad QC technician.

F. General Adjustment and Troubleshooting

1. Initial Electrical Operation
With the breaker open and the springs discharged, the charging motor should begin running as soon as power is applied to the breaker. If not, first check the motor relay by "pushing" in on the armature. If the motor now begins to run, most likely either the motor relay has the wrong voltage coil or the motor limit switch on the left side of the mechanism is not closed. The switch is adjusted by loosening the #10 screws and moving the switch up until contact is closed, then re-tighten screws. Ensure the switch lever is not "bottomed out" on the switch body or the switch may be damaged.

2. Minimum Voltage Operation
During minimum voltage operation, if the trip coil fails to operate this is probably due to excessive "bite" of the trip latch. The trip latch is located along the centerline of the mechanism, near the bottom. With the breaker in the closed position the trip latch is wedge underneath a roller in the mechanism which is holding the breaker closed. If the latch is too far back underneath the roller, the trip coil will not have enough force to knock it out. The trip latch "sensitivity" is adjusted by an eccentric wheel on the right side of the mechanism. Always adjust this sensitivity with the breaker in the "open" position to prevent accidentally tripping the mechanism which could result in personal injury. Loosen the eccentric hardware and rotate the wheel to cause the latch to come forward. This adjustment does two things: (1)Brings the roller closer to the back edge of the trip latch, and (2) Provide more "free-travel" for the trip armature to gain momentum prior to striking the trip linkage. By this process, minimum trip should be obtained. Two secondary problem may arise as a result of adjusting the trip latch out. (1) The trip linkage may be moved far enough to disengage the "latch check" switch. If this occurs the breaker will not respond to a close signal until the switch is readjusted closed (pulled forward). (2) If the trip latch is adjusted "too far" forward, the breaker will not close. In this instance the mechanism will operate but the latch will slip out during the close operation causing the breaker to remain open ("trip-free" operation). Sometimes the adjustment between minimum voltage and "tripping-free" on closing is a very fine adjustment.

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F. General Adjustment and Troubleshooting

3. Erosion Gap Adjustment
It should be remembered while setting the "E"-gaps that most of the opening speed comes from energy stored in the bellville washers (bias springs). The amount of energy stored is directly related to contact speed on opening and contact overshoot. To adjust the "E"-gap, remove the nut, lock and flat washer at the end of the drive connecting link and rotate the "erosion indicator" until it extends the correct distance through the spring pivot. The "E"-gap is defined as the distance between the flat washer and the spring pivot at the end of the drive connecting link. Replace the hardware and re-tighten. After making the adjustment the breaker should be operated 2 - 3 times before attempting to remeasure the gap.. Use pin gauges to verify the gap.

4. Primary Contact Adjustment
The allowable range for the contact gap is based on vacuum interrupter type. Table 2 of QCP 7.33 list the acceptable range for each interrupter. If the contact gap is not within the allowable limits, the "E"-gap may be adjusted to cause the contact gap to come to within specification. Remember that an increase "E"-gap results in a decrease contact gap. In the event the contact gap is too large and the "E"-gap is at maximum, this indicates the mechanism has too much "stroke". The total stroke is determined by the height of the return spring stops above the return spring mounting box. To decrease the stroke, loosen the retaining nut at the end of the return spring shaft. Rotate the return spring stops clockwise to lower the block and thereby reducing the allowable stroke. (Nominal distance between stops and return spring mounting box is approximately 1".) Retighten the retaining nuts and recheck contact gaps. This adjustment does not affect "E"-gap. Similarly, rotating the stops counterclockwise with increase the height of the stops and therefore increase total breaker stroke.

5. Contact Overshoot
During the overshoot calculation, if the maximum is exceeded the overshoot is reduced by adjusting the shock absorber to a higher setting or by adjusting the body of the shock "up" so that it is encountered earlier during the opening stroke. Note: Care must be taken while adjusting the shock to a higher reading. This must be done gradually or damage may result to the shock.