QC HANDBOOK: METAL CLAD CIRCUIT BREAKERS

General Guidelines

1. Two basic types of Metal Clad breakers are manufactured at Smyma 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.

VAD-3 BREAKER

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. 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.

4. 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 located along the vertical centerline of the cover. All nameplate data shall be verified for correctness prior to mounting.

5. 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. Verify the correct pins have been installed.

6. The red glastic bottle supports must be inspected thoroughly for cracking. The areas most susceptible are on the front in the area around the hardware which attaches the lower stabs and along the rear where the glastic is attached to the breaker frame.

7. The flex connector consist of two mating pieces which clamp around the bottle stem. The connector should be mounted as squarely as possible with respect the stem, not cross-threaded, and the hardware should be tightened in such a manner that the gap between the two halves in front and back are approximately equal.

8. The red glastic push-rod has a threaded rod which is screwed into the moveable end of the interrupter. To be properly tightened, the push-rod must be screwed onto the interrupter until it is snug against the interrupter. There should be not gap between the interrupter stem and the push-rod.

9. When the breaker is in the closed position, the racking lockout shutter should prevent the insertion of the racking handle. When the breaker is open, the racking handle may be inserted.

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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. Insert the racking handle and rotate the racking arms. The racking arm should fully engage the racking arm stops such that the arm can not slip past the stop.

12. 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).

13. The ground shoe clearance and the open and close roller linkage is adjusted during assembly by the use of fixturing. Verify the linkage is free to move by operation of the levers.

14. Proper operation of the test interlock is verified by observing that the interlock lever moves freely.

15. 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 no binding or hanging of the control wire bundle.

16. 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. The MOC hardware shall be snug and not over tightened.

17. 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).

18. The squareness of the breaker frame is verified through fixturing used during manufacturing and by the coordinate measurement machine (CMM).

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

20. 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.

21. Until suitable fixturing can be established to verify the dimensional accuracy of the VAD-3 breakers, each breaker will be delivered to the CMM room where a detailed dimensional check will be performed. Any dimensions found to be outside the allowable tolerances shall cause the breaker to be rejected. The responsible engineer shall be notified to provide corrective action or to approve a deviation in the tolerances.

22. 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.

VAD-3 BREAKER

A. Physical Inspection

23. 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.

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.

3. Maximum Spring Recharge Time
During the initial operations, observe the time required for the closing 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 7.34.

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.

B. Electrical Operation and Tests

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. The 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 at the end of the bias spring assembly. 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, loosen the nut and flat washer at the end of the bias spring assembly and rotate the spring retainer until the erosion indicator extends the correct distance through the spring pivot. Note: A wrench must be used to hold the push-rod stationary while loosening or re-tightening the nyloc nut or when turning the spring retainer. If the push-rod / bottle stem is allowed to be twisted, damage to the bellows may result. 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 bottom of the bottle 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. The distance over which the speed is calculated is dependent on the interrupter type (typically 0.280"). The speed specifications are given in terms of maximum allowable time. 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_g is read directly from screen. By knowing the actual contact gap and the voltage equivalent ΔV_g, a ratio can be written to calculate the voltage equivalent of the distance over which the speed is to be calculated. The voltage interval (ΔV_o) for measuring the opening speed (max. time) is determined by dividing the speed interval (0.280" typically) by the contact gap and multiplying the resultant by (ΔV_g). 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 ΔV_o previously calculated. Read the time interval (ΔT) directly from the scope.

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 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 bias springs. This produces the overshoot previously measured. As the bias springs 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 across the open contact. 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. To measure the rebound, 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.

D. Breaker Performance Tests

4. Closing Contact Speed
   The distance over which the closing speed is calculated is also determined by the interrupter type (typically 0.130"). 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_g is read directly from screen. By knowing the actual contact gap and the voltage equivalent ΔV_g, a ratio can be written to calculate the voltage equivalent of the distance over which the speed is to be calculated. The voltage interval (ΔV_c) for measuring the closing speed (max. time) is determined by dividing the speed interval (0.130" typically) by the contact gap and multiplying the resultant by (ΔV_g). To measure the opening 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.

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.

D. Breaker Performance Tests

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). Test voltage is applied for 1 minute during each test.

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. Each breaker 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.

2. Prior to final approval of the breaker, the QC technician reviews the checklist to ensure all items have been initialed or N/A'd and that all deficiencies have been corrected and verified.

3. 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.

4. 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.

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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 beneath the "charge/discharge" indicator is not closed. The switch is adjusted by loosening the mounting hardware and moving the switch up until contact is closed, then re-tighten hardware. Ensure the indicator target does not "bottomed out" on the switch body or the switch may be damaged.

2. Erosion Gap Adjustment
It should be remembered while setting the "E"-gaps that most of the opening speed comes from energy stored in the bias springs. The amount of energy stored is directly related to contact speed and overshoot on opening. To adjust the gap, loosen the nyloc nut and washer at the end of the bias spring assembly. The gap is adjusted by rotating the bias spring retainer. Note: A wrench must be used to hold the push-rod stationary while loosening or re-tightening the nyloc nut or when turning the spring retainer. If the push-rod / bottle stem is allowed to be twisted, damage to the bellows may result. Rotating the retainer in such a manner as to compress the bias spring will increase gap. Rotating the retainer to relax the bias spring will decrease the gap. Once the desired gap is achieved, re-tighten the washer and nyloc nut. After adjusting the "E"-gap, operate the breaker 3 times prior to verifying the gap. The "E"-gap is measured using pin gauges. After adjustment of the "E"-gap, the primary contact gap must be re-measured.

3. Primary Contact Adjustment
The allowable range for the contact gap is based on the vacuum interrupter type. 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 may be decreased by increasing the thickness of the "shim" plates located on the top of the drive bar. Similarly, decreasing the thickness of the shim plates will increase the total stroke of the breaker. Adjustments to the thickness of the shim plates can not be made without considering the position of the drive cam follower with respect to the drive cam. Typically, in the open position, the cam follower should come to rest near the bottom of the concave surface of the drive cam. Increasing the thickness of the shim will cause the cam follower to move toward the front edge of the cam. If the cam follower becomes too close to the front edge, the breaker may have nuisance trip-free operations during closing.

4. Contact Overshoot
During the overshoot calculation, if the maximum is exceeded the overshoot is reduced by adjusting the body of the shock "down" so that it is encountered earlier during the opening stroke.