VR-32 and EVER-Tap ™ Voltage Regulator
Installation, Operation, and Maintenance Instructions
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Safety for life

Eaton meets or exceeds all applicable industry standards relating to product safety in its Cooper Power™ series products. We actively promote safe practices in the use and maintenance of our products through our service literature, instructional training programs, and the continuous efforts of all Eaton employees involved in product design, manufacture, marketing, and service.

We strongly urge that you always follow all locally-approved safety procedures and safety instructions when working around high-voltage lines and equipment, and support our “Safety For Life” mission.

Safety information

The instructions in this manual are not intended as a substitute for proper training or adequate experience in the safe operation of the equipment described. Only competent technicians who are familiar with this equipment should install, operate, and service it.

A competent technician has these qualifications:

- Is thoroughly familiar with these instructions.
- Is trained in industry-accepted high- and low-voltage safe operating practices and procedures.
- Is trained and authorized to energize, de-energize, clear, and ground power distribution equipment.
- Is trained in the care and use of protective equipment such as arc flash clothing, safety glasses, face shield, hard hat, rubber gloves, clampstick, hotstick, etc.

Following is important safety information. For safe installation and operation of this equipment, be sure to read and understand all cautions and warnings.

Hazard Statement Definitions

This manual may contain four types of hazard statements:

**DANGER**
Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

**WARNING**
Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

**CAUTION**
Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

**NOTICE**
Indicates a potentially hazardous situation which, if not avoided, may result in equipment damage only.

Safety instructions

Following are general caution and warning statements that apply to this equipment. Additional statements, related to specific tasks and procedures, are located throughout the manual.

**DANGER**
Hazardous voltage. Contact with hazardous voltage will cause death or severe personal injury. Follow all locally-approved safety procedures when working around high- and low-voltage lines and equipment.

**WARNING**
Before installing, operating, maintaining, or testing this equipment, carefully read and understand the contents of this manual. Improper operation, handling, or maintenance can result in death, severe personal injury, and equipment damage.

**WARNING**
This equipment is not intended to protect human life. Follow all locally-approved procedures and safety practices when installing or operating this equipment. Failure to comply can result in death, severe personal injury, and equipment damage.

**WARNING**
Power distribution and transmission equipment must be properly selected for the intended application. It must be installed and serviced by competent personnel who have been trained and understand proper safety procedures. These instructions are written for such personnel and are not a substitute for adequate training and experience in safety procedures. Failure to properly select, install, or maintain power distribution and transmission equipment can result in death, severe personal injury, and equipment damage.
Introduction

Eaton’s Service Information MN225008EN provides the installation, operation, and maintenance instructions for its Cooper Power™ series VR-32 voltage regulator with the Quik-Drive™ tap-changer. It also contains this information for the Eaton EVER-Tap™ voltage regulator with the VACUTAP™ RMV-SVR on-load tap-changer manufactured by Maschinenfabrik Reinhausen™.

Read this manual first

Read and understand the contents of this manual and follow all locally approved procedures and safety practices before installing or operating this equipment. Read and understand the manual detailing the installation and operation of the control used with this regulator. Refer to Service Information MN225003EN, CL-7 Voltage Control Installation, Operation, and Maintenance Instructions, for information on the CL-7 voltage regulator control.

Additional information

These instructions cannot cover all details or variations in the equipment, procedures, or processes described nor provide directions for meeting every possible contingency during installation, operation, or maintenance. For additional information, please contact your Eaton representative.

Acceptance and initial inspection

The regulator is thoroughly tested and inspected at the factory. It is carefully calibrated, adjusted, and in good condition when accepted by the carrier for shipment.

Upon receipt of the regulator shipment, before unloading, a thorough inspection should be made for damage, evidence of rough handling, or shortages. The position indicator, junction box, arrester, radiators and bushings should all be inspected for evidence of damage. Should this initial inspection reveal evidence of rough handling, damage, or shortages, it should be noted on the bill of lading and a claim should immediately be made with the carrier. Also, notify your Eaton representative.

Handling and storage

Be careful during handing and storage of equipment to minimize the possibility of damage. If the regulator will not be placed into immediate service, it can be stored with minimal precautions. Store the unit where the possibility of mechanical damage is minimized.

WARNING

Equipment Damage. Lift the entire unit only with tank-mounted lifting lugs. The cover may warp or fracture and the tank may separate from the cover if the cover-mounted lifting eyes are used to lift the entire unit causing death or severe personal injury or equipment damage.

Unloading

When an overhead crane is used for unloading, the regulator must be lifted by means of a sling and spreader bar utilizing the tank-mounted lifting lugs, which are shown in Figure 2. Do not lift the entire unit with the lifting eyes on the cover. The lifting eyes are only to be used to untank the internal assembly that is attached to the cover.

Standards

Eaton’s Cooper Power series regulators are designed and tested in accordance with the following standards:

IEEE Std C37.90.1-2012™ standard
IEEE Std C37.90.2-2004™ standard
IEEE Std C57.13-2016™ standard
IEEE Std C37.91-2011™ standard
IEEE Std C57.131-2012™ standard
EN 50081-2
EN 61000-4
IEC 60068-2
IEC 60214-1
IEC 610255-5

Quality standards

ISO 9001 Certified Quality Management System
Product information

Description

VR-32 and EVER-Tap single-phase step-voltage regulators from Eaton operate to keep voltage levels within programmed limits to improve power quality and are compatible with SCADA and automation distribution systems.

Available in pole-, platform-, and pad-mounted and substation configurations, VR-32 voltage regulators are suitable for three- or four-wire overhead and underground systems. EVER-Tap voltage regulators are manufactured primarily for installation in substations.

Eaton voltage regulators are regulating auto-transformers. They regulate rated voltage from 10% raise (boost) to 10% lower (buck) in 32 approximately 5/8% steps.

The 65 °C rise insulation system and the sealed-tank construction allow for a bonus capacity 12% above the 55 °C nominal rating without loss of normal insulation life. The bonus capacity is stated on the nameplate. For example, A 167/187 kVA rating indicates a nominal rating of 167 kVA and a bonus capacity rating of 187 kVA.

Unit construction, which suspends the internal assembly from the cover, allows for ease of inspection and maintenance.

Eaton manufactures four types of step-voltage regulators: source-side series winding (Type B), load-side series winding (Type A), series transformer (Type TX), and series auto transformer (Type AX). Eaton voltage regulators are usually equipped with an equalizer winding. The nameplates located on the tank and control box define the power circuit.

Eaton voltage regulators are supplied with the following standard features:

- CL-7 voltage regulator control (CE mark compliant)
- Dual-rated 55/65 °C average winding rise
- Measure load and source voltages
- ADD-AMP™ capability
- Sealed-tank construction
- Pressure relief device
- 18" minimum-creep bushings with clamp-type connectors
- MOV-type external series arrester
- Shunt-arrester mounting bosses
- Two aluminum, laser-etched nameplates
- Insulating fluid 25 °C level sight gauge
- Critical insulating fluid level site gauge
- Upper filter press connection
- Drain valve and insulating fluid sampling device
- Internal differential potential transformer (IDPT)
- Control cable quick connect/disconnect

Available options

Available options include:

- Extended-length control cable, lengths up to 120 feet
- Armored control cable
- Shielded control cable
- Adjustable galvanized-steel elevating structure
- Supplemental external fusing to prevent damage from reverse polarity connection to the external-source terminals
- Shunt surge arresters
- Insulating fluid thermometer with or without alarm contacts
- Insulating fluid level gauge with or without alarm contacts
- Pressure and vacuum gauge with or without alarm contacts
- Rapid pressure-rise relay
- Stainless steel tank and cover
- Envirotex™ FR3™ insulating fluid
- Tank and control enclosure ground connectors
- Alternate top-coat color
- External stainless steel hardware
- Stainless steel control enclosure
- Stainless steel nameplates
- Substation base, below 167 kVA
- Pole-mounting brackets, on 333 kVA
- Wildlife guards
- 4-hole NEMA® spade bushing connectors
- IEEE/IEC Standard universal control cable interface
Figure 2. External features of the VR-32 and EVER-Tap voltage regulator
Installation

Pre-installation inspection

Before connecting the regulator to the line, make the following inspection:

1. Check insulating fluid level sight gauge. Look for visible signs of leaking insulating fluid.
   
   Note: The sight gauge is at the 25 °C insulating fluid level. Fluid may not be visible in cold temperatures.

2. Examine series arrester for damage. If damaged, install a new arrester of same voltage rating.

3. Inspect porcelain bushings for damage or leaking seals.

4. If there is a suspicion that moisture has entered the unit, remove the hand-hole cover and inspect for evidence of moisture such as rust or water tracks in the insulating fluid. If moisture has entered the tank, dry regulator and filter the insulating fluid before putting unit in service. See Table 5 and Table 6 for insulating fluid test standards. Be sure to properly replace hand-hole cover.

5. Check position indicator for damage. When cleaning the faceplate, do NOT use solvent or fuel.

6. If the regulator has been stored for some time, test the dielectric strength of the insulating fluid according to Table 5 and Table 6 (page 26).

7. Regulator may be energized at rated voltage (with caution); you can then perform the “Operational check” on page 25. This procedure is optional.

8. A high-potential test may be done to ensure adequate electrical clearances to ground. This procedure is optional.

Systems connections

WARNING

Hazardous Voltage. Connect the “S” bushing to the source, the “L” bushing to the load. For Wye connections, connect the “SL” bushing to neutral. For Delta connections, connect the “SL” bushing to the appropriate phase. Inaccurate connections may cause excessively high or low voltage on the load side of the regulator and can cause death or severe personal injury and equipment damage.

A regulator can regulate a single-phase circuit or one phase of a three-phase wye (star) or delta circuit. Two regulators connected phase-to-phase in open delta or three regulators connected phase-to-phase in closed delta can regulate a three-phase, three-wire circuit. When connected in wye, three regulators can regulate a three-phase, four-wire, multi-grounded wye circuit. Three regulators should not be connected directly in wye on three-phase, three-wire circuits because of the probability of neutral shift, unless the neutral is connected to the neutral of a wye-connected bank of distribution transformers or to the substation transformer secondary neutral. Typical connection diagrams are illustrated in Figure 3 through Figure 7. Refer to “Shunt arresters” on page 13 for information on shunt arrester application.

Note: In the typical connection diagrams (Figure 3 through Figure 7), individual switches are shown for the bypass and disconnect functions. However, a regulator-bypass-disconnect switch can be used in each phase to perform the bypassing and disconnecting operations in sequence. Each of these switches replaces one bypass and two disconnect switches shown in the diagrams.

![Figure 3. Regulating a single-phase circuit](image1)

![Figure 4. Regulating one phase of a three-phase, four-wire circuit regulator](image2)
Figure 5. Regulating a three-phase, three-wire circuit with two regulators (Open Delta)

Figure 6. Regulating a three-phase, four-wire, multi-grounded wye (star) circuit with three regulators (Wye)

Figure 7. Regulating a three-phase, three-wire circuit with three regulators (Closed Delta)
Nameplates

Two anodized aluminum nameplates are provided as standard; refer to Figure 8 and Figure 9. One nameplate is placed on the regulator tank. The other is placed on the control box door. Nameplates provide information necessary for proper control function. Information such as CT ratio, PT ratio, regulator type, and tap-changer type can be found on the nameplates. When a control is delivered mounted onto a regulator, the nameplate data will be programmed into the control at the factory. It is recommended that this information be verified prior to placing the control and regulator into service. When calling Eaton for service or support-related issues, have the catalog number and serial number found on the nameplate for reference.

Mounting

Regulators with overhead bushings can be mounted on a pole, a cross-arm platform, or an elevating structure. Regulators are normally provided with either pole-mounting brackets or a substation base according to their rating. An elevating structure can be provided to simplify substation installation of regulators requiring a specific live part-to-ground clearance.

The regulator control can be mounted on the regulator tank or at a point remote from the unit. Various lengths of rubber-coated control cables are available up to 120 feet (36.6 meters).
**Figure 9. Typical nameplate: international 50-Hz design**

<table>
<thead>
<tr>
<th>SINGLE-PHASE STEP VOLTAGE REGULATOR</th>
<th>VDF 50-HZ DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KVA</strong></td>
<td>440/493</td>
</tr>
<tr>
<td><strong>RATED VOLTS</strong></td>
<td>22000</td>
</tr>
<tr>
<td><strong>CAT. NO.</strong></td>
<td>VRFN44PCL71000000R</td>
</tr>
<tr>
<td><strong>STOCK #</strong></td>
<td>2,851 kgs.</td>
</tr>
<tr>
<td><strong>VOLTAGE RATING</strong></td>
<td>150 V</td>
</tr>
</tbody>
</table>

**WARNING:**
- Do not operate unless on neutral position and control switch is OFF, fail-safe to OFF if possible. Risk of fire or explosion. Read installation and operating instructions M220008EN and MN220008EN.

**UNIT SWITCH SETTINGS ON POSITION INDICATOR**

<table>
<thead>
<tr>
<th>REGULATION</th>
<th>40%</th>
<th>60%</th>
<th>80%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>% RATED</td>
<td>160</td>
<td>135</td>
<td>120</td>
<td>110</td>
</tr>
</tbody>
</table>

**FILLED MIN AND TYPE II MINERAL OIL CONTAINED LESS THAN 1 ppm PCB AT TIME OF MANUFACTURE.**

**MADE IN WAUKESHA, WISCONSIN, U.S.A.**
Placing regulator into service

**DANGER**

Explosion Hazard. During bypass switching, the regulator must be in the neutral position. Prior to bypass switching: 1) The regulator must be placed in the neutral position; 2) Tap-changer operation must be disabled during the bypass switching. If the regulator is in any other position, part of the series winding will be shorted when the bypass switch is closed, resulting in high circulating current. Failure to comply will result in death or severe personal injury and equipment damage.

**WARNING**

Hazardous Voltage. To protect personnel from surges while operating the control, follow these control enclosure grounding procedures: a) If the enclosure is attached to the regulator tank or is remote from the tank but only accessible with a ladder, connect the enclosure to the regulator-to-ground rod conductor; b) If the enclosure is accessible by personnel standing on the ground, connect the enclosure directly to a ground mat and ground rod. Failure to comply can result in severe personal injury or death.

**CAUTION**

Equipment Damage. Only an AC power supply is to be used to energize the control externally. Do not use a DC-to-AC voltage inverter. Failure to comply can cause excessive harmonics to be generated and result in damage to the front panel.

**CAUTION**

Equipment Damage. When connecting external power to the voltage regulator control, make sure the polarity of the power source is correct. Reverse polarity will result in control damage.

Refer to Service Information MN225003EN, CL-7 Voltage Control Installation, Operation, and Maintenance Instructions, for information on the CL-7 voltage regulator control, including placing the control into service and initial programming.

As with all electrical equipment, proper grounding of a voltage regulator control box is essential. The voltage regulator control box must be grounded to the tank ground pad or earth ground. A poor ground connection to the control box can result in a hazard to operators and control malfunctions. Attaching a control box to the regulator tank does not ensure a proper ground because of the painted surfaces of the tank and control box. A ground pad tapped for 1/2”-13 UNC thread is provided on the side of the control cabinet to be used for grounding.

After programming the control for basic operations, perform a control operational check of manual and automatic operations before completing the installation of the regulator. Regulators can be placed into service without interrupting load continuity by installing bypass and disconnect switches.

To perform an operational check and the switching operations to install a regulator onto a system, use one of the following procedures:

- Use Procedure A when employing one bypass switch and two disconnect switches.
- Use Procedure B when employing a single-pull regulator bypass-disconnect switch.

When energizing the control from an external source, use only a 120 Vac source, unless the control is set up for 240 Vac, indicated by a decal adjacent to the terminals and the presence of a step-down auto transformer in the control box.
**Procedure A: One bypass switch and two disconnect switches**

1. Verify from regulator nameplate that control circuit is connected for proper regulated system voltage.
2. Set POWER switch to **OFF** and CONTROL FUNCTION switch to **OFF**.
3. Knife switches on back panel should be set with V1 (potential switch) (and V2, V6, and V8 if present) closed (pushed in) and C (CT shorting switch) open (pulled out).
4. Close source-load (SL) disconnect switch if available.
5. Close source (S) disconnect switch.
6. Set POWER switch to **INTERNAL** and CONTROL FUNCTION switch to **LOCAL MANUAL**.
7. Lift raise-lower switch to operate tap-changer two or three steps, then depress raise-lower switch to return tap-changer to the neutral position; these steps verify that the mechanism is functional. When on neutral, the neutral light will glow continuously and position indicator will point to zero or N for Neutral.
8. Confirm the voltage regulator has been placed in neutral before proceeding by observing these four indicators:
   a. Neutral light is illuminated continuously and brightly.

**DANGER**

Explosion Hazard. During bypass switching, the regulator must be in the neutral position. Prior to bypass switching: 1) The regulator must be placed in the neutral position; 2) Tap-changer operation must be disabled during the bypass switching. If the regulator is in any other position, part of the series winding will be shorted when the bypass switch is closed, resulting in high circulating current. Failure to comply will result in death or severe personal injury and equipment damage.

9. With regulator in neutral position, disable the motor operation by taking the following steps:
   a. Set the CONTROL FUNCTION switch to **OFF**.
   b. Set the POWER switch to **OFF**.
   c. Open the V1 knife switch (and V2, V6, and V8 switches if present), and set POWER switch to **INTERNAL**.

10. Close load (L) disconnect switch.
11. Open bypass switch. The regulator is now energized.
12. Replace 6 A motor fuse, close V1 knife switch (and V2, V6, and V8 switches if present), and set POWER switch to **INTERNAL**.
13. Refer to Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions, for information on the CL-7 voltage regulator control, including placing the control into service and initial programming.

**Procedure B: Regulator bypass-disconnect switch**

1. Verify from regulator nameplate that control circuit is connected for proper regulated system voltage.
2. Set CONTROL FUNCTION switch to **LOCAL MANUAL** and POWER switch to **EXTERNAL**.
3. Knife switches on back panel should be set with V1 (potential switch) (and V2, V6, and V8 switches if present) open (pulled out) and C (CT shorting switch) closed (pushed in).
4. Apply 120 V (or other voltage as indicated by the decal on the control) to external source terminals.
5. Lift raise-lower switch to operate tap-changer two or three steps, then depress raise-lower switch to return tap-changer to neutral position; these steps verify that the mechanism is functional. When on neutral, the neutral light will glow continuously and position indicator will point to zero or N for Neutral.
Explosion Hazard. During bypass switching, the regulator must be in the neutral position. Prior to bypass switching: 1) The regulator must be placed in the neutral position; 2) Tap-changer operation must be disabled during the bypass switching. If the regulator is in any other position, part of the series winding will be shorted when the bypass switch is closed, resulting in high circulating current. Failure to comply will result in death or severe personal injury and equipment damage.

6. Confirm the voltage regulator has been placed in neutral before proceeding by observing these four indicators:
   a. Neutral light is illuminated continuously and brightly.
   b. Tap-position indication on the control at FC 12 displays 0 for neutral.
   c. Position indicator dial pointer is pointing directly at N or 0 for neutral.
   d. Measure the voltage difference between the S and L bushings. On a de-energized voltage regulator, this can be done by applying a low voltage (for example 120 Vac) between the S and SL bushings. The measured voltage between the S and L bushings should be zero or very close to zero.

   Note: One step off of neutral with a 120 Vac input would be a 0.75 volts between S and L.

7. Remove the voltage from external source terminals.

8. With regulator in the neutral position, set CONTROL FUNCTION switch to OFF, set POWER switch to OFF, and remove 6 A motor fuse.

9. For Delta applications only: Close source-load (SL) disconnect switch.

10. Close regulator bypass-disconnect switch. The regulator is now energized.

11. Replace 6 A motor fuse, close V1 knife switch (and V2, V6, and V8 if present), open C knife switch, and set POWER switch to INTERNAL.

12. Refer to Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions, for information on the CL-7 voltage regulator control, including placing the control into service and initial programming.

Setting the manual (hard) limit switches

Note: Refer to “Position indicator and ADD-AMP capability” on page 13 for a complete discussion of these features.

Before setting the manual limit switches, be sure the new settings will not conflict with the present tap-changer position; see Figure 13. Do not set the switches below the indicated tap-changer position. For example, if the main hand is at step 12 and the change to be made is from plus or minus 10% (step 16) to plus or minus 5% (step 8), run the tap-changer back to step 7 or less, manually. Then set the limit switches for plus or minus 5% regulation.

Limit switches should be set in anticipation of the maximum deviation of primary voltage. For example, on a circuit where 7200 V is to be maintained, plus or minus 10% will permit voltages between 6480 V and 7920 V to be regulated effectively. For voltages outside this range, the regulator will not be able to return the voltage to the preselected level (7200 V). Five percent regulation would accommodate circuit voltages between 6840 and 7560 V, maintaining 7200 V for all voltages in this range.

To set the limit switches:

1. Unlatch the captive bezel and swing the cover open.

2. Lift the limit-switch adjustment lever free of the detent and slide it to the new setting allowing the lever to snap into the detent stop.

   Note: If the ADD-AMP limits have been programmed into the control (Soft ADD-AMP) and the limit switches have not been set, it is possible to manually step the tap-changer beyond the Soft ADD-AMP limit. If the unit is switched back to automatic mode, the control will step the regulator back to within the Soft ADD-AMP limits as set in the control.

Figure 13. Position indicator
Removal from service

Note: Before removing a regulator from service, you must return the regulator to neutral. Only a regulator in the neutral position can be safely removed from service without interrupting load continuity. It is recommended to use at least four methods to confirm the neutral position, as specified in step 2, below.

DANGER
Explosion Hazard. During bypass switching, the regulator must be in the neutral position. Prior to bypass switching: 1) The regulator must be placed in the neutral position; 2) Tap-changer operation must be disabled during the bypass switching. If the regulator is not in the neutral position, part of the series winding will be shorted when the bypass switch is closed, resulting in high circulating current. Failure to comply will result in death or severe personal injury and equipment damage.

WARNING
Explosion Hazard. Bypass a regulator with the line energized only if the position indicator, the neutral light, and the voltage measured between the source and the load bushings using an approved voltmeter or CL7 SAFE-TO-BYPASS feature is zero. If all indications of neutral do not agree, the line should be de-energized to avoid shorting part of the series winding and resultant high circulating current. Failure to comply can result in death or personal injury and equipment damage.

To remove a regulator from service:

1. Use the Raise/Lower switch to bring the regulator to neutral position.
   
   Note: When in neutral, the Neutral light will be continuously and brightly lit on the control front panel and the position indicator will point to zero or N for Neutral.

2. Verify the neutral position of the regulator using each of these four methods:
   
   a. Verify that the neutral indicator light on the control is indicating the neutral position. Neutral is indicated only when the light is continuously and brightly illuminated.
   
   b. Verify that the tap position on the control indicates neutral by using the Metering-PLUS™ key or FC 12. When in neutral, these display “0” (zero).
   
   c. Verify that the position indicator on the regulator is pointing straight up, either to zero or to “N” for Neutral.
   
   d. Using an approved voltmeter or CL7 SAFE-TO-BYPASS feature, verify that there is no voltage difference between the source and load bushings.

   Note: Do not proceed to step 3 until you have confirmed that the regulator is in the Neutral position using all four methods listed above.

3. Disable the tap-changer motor to ensure that the tap-changer cannot inadvertently switch to an off-neutral position:
   
   a. Place the CONTROL FUNCTION switch in the OFF position.
   
   b. Remove the motor fuse.
   
   c. Place control POWER switch in the OFF position.
   
   d. Open V1 knife switch (and V2, V6, and V8 if present) located on control back panel.

   Note: Do not proceed to step 4 until you have disabled the tap-changer motor as directed above.

4. De-energize the regulator:
   
   a. Close the bypass switch.
   
   b. Open the load (L) disconnect switch.
   
   c. Open the source (S) disconnect switch.
   
   d. Open the source-load (SL) disconnect switch, if available.

   Note: If a regulator bypass disconnect is used in place of three separate switches, step a, step b, and step c are carried out in one operation.
Construction and operation

Eaton's Cooper Power series VR-32 and EVER-Tap voltage regulators are designed, manufactured, and tested in accordance with IEEE Std C57.15-2017™/IEC 60076-21:2018-12 standard. The regulators are rated and name-plated for 55/65 °C average winding rise.

The regulators are furnished with ANSI® Type II mineral oil per ASTM D-3487, containing less than 1 part per million PCBs, at time of manufacture, as stated on the regulator nameplate. Envirotemp® FR3™ fluid is available as an option.

Standard features, regulators with over-head bushings

Bushings. The BIL rating of the bushings is compatible with the BIL of the regulator, and all ratings, 250 kVA and below, have bushings with a minimum creep distance of 18 inches. The bushing designations (S, L, and SL) are permanently marked on the regulator cover adjacent to the bushings. The S, L, and SL bushings are interchangeable with each other.

For regulators rated 1200 A and below, each bushing includes a threaded 1.125”-12 UNF-2A stud. For regulators rated 1201 A and above, each bushing includes a 1.5”-12 UNF-2A stud. Connectors are not integral to the bushing. Refer to Table 1 for standard terminals.

The threaded studs and connectors of the standard terminals are plated bronze. Four-hole spade terminals are available as an option for all current ratings.

Table 1. Standard terminals

<table>
<thead>
<tr>
<th>Rating (A)</th>
<th>Standard Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 and below</td>
<td>Clamp-type connectors for #6 to 250 MCM conductor</td>
</tr>
<tr>
<td>151-668</td>
<td>Clamp-type connectors for #6 to 800 MCM conductor</td>
</tr>
<tr>
<td>669-1200</td>
<td>4-hole spade</td>
</tr>
<tr>
<td>1201 and above</td>
<td>4-hole spade</td>
</tr>
</tbody>
</table>

Series arrester. All regulators are provided with an external UltraSIL™ Polymer-Housed Evolution™ heavy-duty bypass arrester connected across the series winding. For units rated less than 22 kV, the series arrester is rated 3 kV. For units rated 22 kV or larger, the series arrester is rated 6 kV.

Insulating fluid level sight gauges. Two insulating fluid level sight gauges to indicate fluid color and level, one at 25 °C and the other at the critical fluid levels.

Position indicator. An external, corrosion-resistant position indicator indicates the tap-changer position. The polymer-constructed position indicator is slanted downward at a 45-degree angle for ease-of-reading when the regulator is mounted above ground level.

Arrester mounting provisions. Stainless steel bosses are provided for the mounting of lightning arresters adjacent to the source (S), load (L), and source-load (SL) bushings. The bosses are fully welded around their circumference.

Drain valve with sampler. All regulators have a 1” drain valve with sampling device and a 1” upper filter press connection.

Hand-hole cover. A hand-hole on the cover of the regulator provides access for inspection purposes and to access terminals used to reconnect the regulator for operation at system voltages as shown in Table 9 (page 36) and Table 10 (page 37).

Mounting. Regulators rated 250 kVA and below are provided with welded-on hanger brackets. Regulators rated 167 kVA and above are provided with a base suitable for securing them to a pad or elevating structure. All regulators are capable of being secured to elevating structures.

Ground Provisions. Regulators without a substation base are provided with two stainless steel 1/2”–13 UNC welded ground bosses located diagonally opposite from each other. Regulators with a substation base have two stainless steel ground pads located diagonally opposite from each other. Each pad has two stainless steel 1/2”–13 UNC ground provisions. All grounding provisions are located near the base of the regulator.

Nameplates. Each regulator has two laser-etched nameplates, one mounted on the control enclosure and the other mounted on the regulator tank. The nameplates have the manufacturer code and serial number bar-coded with “3 of 9” coding with a 0.25” minimum height.

Pressure-relief device. A pressure-relief device vents at approximately 5 psig.

Tank and Cover. The sealed-tank construction permits operation at 65 °C AVR without increasing the oxidation rate of the insulating fluid.

The external parts of the tank and control enclosure are painted light gray, ANSI® 70 (Munsell 5BG7.0/0.4), and meet the coating and security requirements of IEEE Std C57.12.28™-2014 and IEEE Std C57.12.31™-2010 standards. Also, the inside of the tank and bottom of the cover are primed and/or painted.

An external electrical connection between the cover and tank allows the cover-suspended internal assembly and tank to be grounded together to eliminate voltage differentials while energized.

Thermometer. Provisions for a tank thermometer are standard for all voltage regulators with substation bases (units 167 kVA and above).

Control cable. A multi-conductor neoprene 600 V, –50 °C to 105 °C cable with disconnect plugs at each end provides the connection between the internal circuitry of the voltage regulator and the control.

Current transformer. An automatic, solid-state CT shorting device protects the internal CT from high voltages due to the control cable being disconnected or cut while the voltage regulator is energized.

Internal differential potential transformer (IDPT). The IDPT provide for a differential voltage measurement between the S and L bushings. This measurement is used by the regulator control for reverse power regulation, SAFE-TO-BYPASS feature, and enhanced tap position tracking.
Position indicator and ADD-AMP capability

Regulators rated below 668 A include an ADD-AMP feature which permits additional current-carrying capacity at reduced voltage regulation range, as shown in Table 2, but not to exceed 668 A. The ADD-AMP type adjustment is located inside the position-indicator faceplate to prevent inadvertent adjustment. In addition, a Soft ADD-AMP control feature allows adjustment by way of the keypad or interface software. An optional ADD-AMP feature maximum of 875 A is provided when specified for regulators rated 438–668 A.

Table 2. ADD-AMP adjustments

<table>
<thead>
<tr>
<th>Regulation (%)</th>
<th>Current (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 10.0</td>
<td>100</td>
</tr>
<tr>
<td>± 8.75</td>
<td>110</td>
</tr>
<tr>
<td>± 7.5</td>
<td>120</td>
</tr>
<tr>
<td>± 6.25</td>
<td>135</td>
</tr>
<tr>
<td>± 5.0</td>
<td>160</td>
</tr>
</tbody>
</table>

The position indicator (see Figure 2 and Figure 13) is mounted on the junction box on the cover of the regulator and is directly connected to the tap-changer by a flexible drive shaft passing through the junction box and terminal board via a sealing gland.

The indicator face is graduated in steps. Drag hands indicate the maximum and minimum positions attained during raise and lower operations. The drag hands are reset around the main hand position by operating the drag-hand reset switch on the control front panel.

During forward power flow, the main hand of the position indicator will be to the right of the neutral position when the regulator is boosting. During reverse power flow, the main hand will be to the left of the neutral position when the regulator is boosting.

The limit switches on the position indicator can be adjusted to limit the maximum and minimum tap positions with possible settings of raise or lower 8, 10, 12, 14 or 16. These limits correspond to percent regulation levels of 5, 6 1/4, 7 1/2, 8 3/4, and 10%. The five possible load current ratings associated with the reduced regulation ranges are summarized in Table 11 (page 38) and Table 12 (page 39). Higher regulation ranges are realized in closed delta application.

When using the limit switches, a detent stop at each setting provides positive adjustment. Settings other than those stops are not recommended. The raise and lower limits need not be the same value unless reverse power is possible. The regulator will stay within the ADD-AMP limits set forth by the control or the position indicator, whichever limit is of a lower regulation percentage.

Note: If Soft ADD-AMP limits have been programmed into the control and the position indicator limit switches have not been set, it is possible to manually step the tap-changer beyond these limits. If the unit is switched back to automatic mode, the control will step the regulator back to within the Soft ADD-AMP limits set in the control.

Surge protection

Series arrester

All Eaton voltage regulators are equipped with a bypass arrester connected across the series winding between the source (S) and load (L) bushings. This arrester limits the voltage developed across the series winding during lightning strikes, switching surges, and line faults. The series surge arrester can be seen in Figure 2. A heavy-duty MOV-type series surge arrester of 3 kV offers series winding protection on all regulators except those rated 22,000 V and greater, which have a 6 kV MOV-type series surge arrester.

Shunt arresters

A shunt arrester is a recommended accessory on Eaton voltage regulators for protection of the shunt winding. The shunt arrester is a direct-connected arrester mounted on the tank and connected between the bushing and ground (earth). It is recommended that arresters be applied to all non-grounded bushings.

For best results, locate these arresters on the mounting pads provided on the tank near the bushing. Connect the arrester and the regulator tank to the same ground connection using the shortest cable possible. Shunt arrester application data is listed in Table 3.

Table 3. Typical shunt arrester application data

<table>
<thead>
<tr>
<th>Regulator Voltage Rating</th>
<th>Recommended MOV Shunt Arrester Ratings (kV)</th>
<th>Regulator Voltage Rating</th>
<th>Recommended MOV Shunt Arrester Ratings (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500</td>
<td>3</td>
<td>14400</td>
<td>18</td>
</tr>
<tr>
<td>5000</td>
<td>6</td>
<td>15000</td>
<td>21</td>
</tr>
<tr>
<td>6600</td>
<td>9</td>
<td>19920</td>
<td>27</td>
</tr>
<tr>
<td>7620</td>
<td>10</td>
<td>22000</td>
<td>27</td>
</tr>
<tr>
<td>8660</td>
<td>12</td>
<td>33000</td>
<td>36</td>
</tr>
<tr>
<td>11000</td>
<td>15</td>
<td>34500</td>
<td>36</td>
</tr>
<tr>
<td>13800</td>
<td>18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Contact factory for specific shunt arrester application ratings.
Internal construction and wiring

Eaton regulators are designed such that they can be partially or completely untanked for inspection and maintenance without disconnecting any internal electrical or mechanical connections. External connections must be disconnected. Regulators equipped with military specification-style, quick-disconnect circular connector are also equipped with a solid-state automatic current-transformer shorting device located in the junction box.

The Quik-Drive tap-changing mechanism is completely fluid-immersed. The tap-changer, in the manual position, operates from –16L to +16R in less than 10 seconds.

Refer to “Quik-Drive tap-changers” on page 19 for more information.

The holding switch circuit is an electrical feedback circuit which monitors motor current. It is incorporated with the tap-changer motor circuit and control to ensure accurate indication of tap position and operations counting.

The regulator main coil, reactor, and potential transformer include thermally upgraded insulation to permit operation up to 65 °C rise without loss of life to the insulating system. At 65 °C rise, the regulator provides 12% extra current capacity over the base 55 °C rise current rating.

A patterned, epoxy-coated insulation paper is used in all windings. Prior to assembly of the main core and coil assembly, the windings are baked with sufficient mechanical pressure exerted on the sides of the coil winding to maximize a complete bonding of the insulation to improve its short-circuit current withstand capabilities.

The main core and coil assemblies are of the shell-form configuration. The series winding on the input (source) side of the regulator (Figure 14) allows all windings (control, shunt and series) to be located in one coil assembly. The load voltage is monitored by the control winding.

Regulators that have the series winding on the output (load) side (Figure 15) have a separate potential transformer installed on the load side in lieu of a control winding.

The control winding or separate potential transformer (PT) supplies a voltage for the tap-changer motor and the control sensing circuit. Additional taps are available in the PT for line voltages other than rated voltage.

Most regulators, depending upon the rating, have an equalizer winding. This winding improves contact life for high-current applications.

Figure 16 shows a typical regulator power circuit with a series transformer. This design is utilized when the load current rating exceeds the tap-changer rating. In this type of design, the series transformer winding losses are a function of the load alone and are independent of the tap position. Because of this, limiting the range of voltage regulation does not reduce losses and therefore the ADD-AMP feature is not applicable.

The bridging reactor is a core-form design, consisting of a coil on each leg of one core. The inside half of one coil is connected to the outside half of the other coil and vice versa, providing equal current in each half of the reactor winding.

This interlacing of the two coils lowers the interwinding leakage reactance to a very low value. The reactor is completely isolated from ground by stand-off insulators since the reactor coil is at line voltage above ground. The reactor core, core clamps, and other associated parts approach this level.

The current transformer is a toroid, through which the load current passes. It furnishes a current proportional to load current for the line-drop compensator and metering features.

The tap-changer enables the regulator to provide regulation in smooth, accurately proportioned steps at a controlled speed that minimizes arcing and extends contact life. Figure 27 (page 40) and Figure 28 (page 41) illustrate the typical internal wiring schemes. Most of the wiring is on the tap-changer itself. Molex® receptacles plugged into the junction block inside the junction box on the cover connect the internal tank wiring to the position indicator and control. The junction box wiring is shown in Figure 30 (page 43). The connections are made to the junction box terminal board using automotive-style Molex® connectors. A legacy junction box wiring diagram is shown in Figure 31 (page 44).
Figure 14. Power circuit—series winding located on the source-side, ANSI® Type B

Figure 15. Power circuit—series winding located on the load-side, ANSI® Type A
Figure 16. Power circuit – series auto transformer, Type AX (similar characteristics to Type A)

Figure 17. Power circuit – series transformer, Type TX
Voltage circuits

Eaton voltage regulators have provisions for operation at system voltages other than the nominal rating, as listed in Table 9 (page 36) and Table 10 (page 37). This is accomplished by providing taps on the control winding or PT. The taps are brought to a terminal board located on top of the tap-changer assembly, under the insulating fluid, and are marked E1, E2, or E3. (See Figure 18.) The connections are made with push-on terminals and are easily accessed through the hand hole.

![PT tap terminals on a QD3 tap-changer](Image)

**Figure 18. PT tap terminals on a QD3 tap-changer**

If an additional potential transformer is required for a Reverse Power Flow application or indication of the unregulated voltage supply, the "P" taps will be located either on a separate voltage transformer or on the tap-changer terminal board.

The PT cannot always provide adjustment of the voltage fine enough for control or motor use. A tapped autotransformer is used for fine voltage adjustment. This transformer, the Ratio Correction Transformer (RCT), has input taps at 104, 110, 115, 120, 127, and 133 V. The output tap to the control and motor is set as 120 V. The RCT is located on the control back panel (see Figure 10 and Figure 11).

To operate a regulator on a system voltage other than its nominal rating, the appropriate selection must be made for the PT and RCT taps and the control must be programmed properly at Function Code (FC) 43 (System Line Voltage), FC44 (Overall PT Ratio) and FC44\(v\) (Internal PT Ratio). The nameplate provides settings for common system voltages (see Figure 8 and Figure 9).

The internal voltage supply is brought from the tap-changer terminal board through the junction box and the control cable, into the control box, terminating at the knife switch labeled V1 and V2, V6, and V8 if provided. Opening this knife switch provides a visible means of removing all power to the control and motor circuits. From the knife switch, the voltage is ratio corrected by RCT as previously described.

Most voltage regulators are installed in circuits with well-defined power flow from source to load. However, some circuits have interconnections or loops in which the direction of power flow through the regulator may change. For optimum utility system performance, a regulator installed on such a circuit should have the capability of detecting reverse power flow and of sensing and controlling the voltage, regardless of the power flow direction. The CL-7 control has full reverse power capabilities.

Refer to Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions, for more information on the CL-7 control, reverse power operation, and source-side voltage calculation.

On the front panel, the three potentials (VS, sensing voltage; V7, differential voltage; VM, motor voltage) are all brought directly to the power switch. Without an optional source-side supply, the V7 terminal is connected to the VS terminal on the control back panel and the control software then recognizes that a source-side voltage signal is not present.

The power switch has three positions: INTERNAL, OFF, and EXTERNAL. The internal position powers the control and motor from the regulator sensing winding, and the external position permits an external supply for the same purpose. When the power switch is in the external position, the internal supply is disconnected to prevent accidentally back-feeding the high-voltage winding and bushings. The external-source terminals are prominently located adjacent to the voltmeter test terminals.

The voltmeter terminals allow the monitoring of the voltage that is applied to the control. This is the voltage output from the RCT and the voltage displayed at FC47 (Voltage Calibration). During forward power flow, the voltage at these terminals is the output voltage. During reverse power flow, the voltage at these terminals is the source-side voltage.

From the 6 A fuse, the motor potential provides power to the CONTROL FUNCTION switch, the drag-hand reset solenoid, the neutral light, and the holding switch (alternate motor source) circuits.

**WARNING**

Electrocution Hazard. Applying voltage to the voltmeter terminals on some voltage regulator controls can back-feed the voltage regulator potential transformer and create high voltage on the bushings. When applying external power to the voltage regulator control, make sure to open the V1, (and V2, V6, and V8 if present) switches on the back panel, apply power to the external source terminals only and move the POWER switch to EXTERNAL.
Current circuit

All Eaton voltage regulators are designed with an internal current transformer (CT) (see Figure 19) to provide a current source for the line-drop compensation calculations, power flow direction determination and for metering functions. Table 4 provides the application information for the various CTs used on Eaton regulators. These CTs provide 200 mA output for the rated CT primary current.

---

Motor circuit

The motor circuit power is brought from the 6 A fuse to the circuit board through a set of back-to-back diodes to the CONTROL FUNCTION switch. When this switch is set for automatic operation, motor power is applied to the relays. An appropriate relay closure then applies this power to the tap-changer motor, after first passing through the limit switch contacts in the position indicator. When the switch is set for manual operation, the power is transferred to the momentary toggle switch labeled RAISE/LOWER. By actuating this switch in one direction or the other, power is applied through the limit switch contacts, directly to the tap-changer motor, completely bypassing the control circuit board. This enables operation of the tap-changer in most circumstances, even if the control cannot be powered up fully.

Also included as a part of the motor circuit is an alternate feed to the motor called the holding switch circuit. Located on the tap-changer are switches which operate off of the tap-changing mechanism. Motor rotation causes switch closure (one direction or the other) and establishes a complete circuit for motor current until the rotation is complete and the cam drops out. During the time the holding switch is closed, motor current is monitored by way of an input on the control circuit board that permits the control to detect that a tap change is in process. The microprocessor uses this information in its decision-making process, as described under Control Operating Modes in Service Information MN225003EN (225-70-1), CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions.

Two other circuits that share the 6 A motor source are the drag-hand reset and neutral light circuits. The drag-hand reset function is accomplished simply by operating a momentary membrane switch, which applies power to the reset solenoid in the position indicator. The neutral light is energized from a neutral light switch located on the tap-changer when in the neutral tap position.

---

Table 4. Current transformer applications (50 & 60 Hz)

<table>
<thead>
<tr>
<th>Regulator Current Ratings</th>
<th>CT Primary Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>167, 200</td>
<td>200</td>
</tr>
<tr>
<td>219, 231, 250</td>
<td>250</td>
</tr>
<tr>
<td>289, 300</td>
<td>300</td>
</tr>
<tr>
<td>328, 334, 347, 400</td>
<td>400</td>
</tr>
<tr>
<td>418, 438, 463, 500, 502</td>
<td>500</td>
</tr>
<tr>
<td>548, 578, 604, 656, 668</td>
<td>600</td>
</tr>
<tr>
<td>833, 875, 1000, 1093</td>
<td>1000</td>
</tr>
<tr>
<td>1332, 1503, 1665</td>
<td>1800</td>
</tr>
<tr>
<td>2800</td>
<td>3000</td>
</tr>
</tbody>
</table>

---

Figure 19. Internal bushing-mounted current transformer

The current developed by the CT is brought through the control cable and junction box, into the control box and terminates at the knife switch labeled C. Closing the knife switch provides a visible means of shorting the CT, thus allowing the operator to work safely on the current circuitry. For additional safety measures, the V1, V2, V6, and V8 knife switches should also be opened. For all regulators with the quick-disconnect connector (Figure 1), an automatic solid-state CT shorting device is located in the junction box. This solid-state device will automatically short the CT when the cable is disconnected.

At this knife switch, one side of the CT is connected to the equipment ground and is also routed to the front panel for termination on the circuit board. The “high” side of the current circuit is brought to the top terminal board through two removable jumpers and then to the front panel for connection to the circuit board. Once this current signal is delivered to the circuit board, it is transformed into a voltage signal and converted into a digital format for processing.
Quik-Drive tap-changers

Eaton offers three Quik-Drive tap-changer models (see Figure 20, Figure 21, and Figure 22). Each device is sized for a specific range of current and voltage applications and share many similarities in their construction. The primary benefits of Quik-Drive tap-changers are: direct motor drive for simplicity and reliability; high-speed tap selection for quicker serviceability; and proven mechanical life (one million operations). Quik-Drive load tap-changers meet IEEE® and IEC standards for mechanical, electrical, and thermal performance.

Common Quik-Drive tap-changer features

- Neutral Light Switch – A switch is triggered to close by the Reversing Switch Assembly or the Main Contact Assembly to indicate to the Control that the tap-changer is in the Neutral position.

- Holding Switch – A common holding switch assembly driven by a pinion cam seals in motor power during a tap-change until the operation is complete.

- Position Indicator Drive – A common indexing mechanism is shared between the tap-changers for driving the Position Indicator.

- Safety Switches – In addition to the limit switches in the Position Indicator, microswitches are employed on the tap-changers to interrupt power to the motor so that they cannot be powered beyond the 16 Raise or 16 Lower positions. These Safety Switches are triggered by a cam that is driven from the Main Contact Assembly.

- Logic Switches (Back-Off Switches) – The Logic Switches are used in parallel with the Safety Switches, based on the polarity of the Reversing Switch, to ensure proper operation of the tap-changer.
Quik-Drive tap-changer mechanism

A tap change is initiated by the Control. After some rotation of the drive gear connected to the motor, a holding switch energizes the motor through a separate circuit until the indexing motion is completed. The indexing occurs very quickly. The total elapsed time to complete the action is approximately 250 milliseconds from the time the indexing signal is started by the control. Each full turn of the Geneva drive gear rotates the main Geneva/contact drive assembly one tap position, which is 20 degrees.

Reversing switch

The reversing switch function changes the polarity of the tapped winding. When a Quik-Drive tap-changer is in the neutral position, the reversing switch is open.

The reversing switch motion on the Quik-Drive tap-changer occurs as the main movable contacts enter or leave the neutral position. The Main Contact Assembly engages the Reversing Switch either directly or through a linkage when the main switch is in the neutral position. The first tap step in either direction rotates the Reversing Switch Assembly to engage the appropriate contacts.

Additionally, the Main Contact Assembly, or its drive, and the Reversing Switch Arm provide a mechanical stop located 320° on either side of the neutral position so that the tap-changers cannot be moved past 16 Lower or 16 Raise.

Quik-Drive motors drive systems

Either an alternating current (AC) synchronous motor or an induction motor is used on Quik-Drive tap-changers. The motors use a holding switch circuit that is activated by a pinion cam closing holding switches as the motor begins to rotate. The holding switch is engaged throughout the duration that the movable contacts are in motion to ensure that the tap change cycle is complete. Because of differences in rotational speed and braking characteristics, the AC synchronous motor uses a cam of different timing duration than the induction motor to activate the holding switch. The cam on the AC synchronous motor is engaged for 270° of rotation while the induction motor cam is engaged for 105° of rotation.

The AC synchronous motor utilizes a phase-shifting network, consisting of a capacitor and a resistor, to operate properly when powered by a single-phase source. This motor has a permanent magnet rotor that arrests the inertia of the system once power to the motor is removed; therefore, no braking mechanism is required. The AC synchronous motor uses a 12 µF capacitor for 60 Hz applications and a 15 µF capacitor for 50 Hz applications.

The induction motors use a phase-shifting capacitor and require a friction-type brake to stop the motor between tap changes. Brakes use various means to interrupt the braking action while the movable contacts are in motion so that full motor torque is dedicated to completing the tap change. The induction motors use a 50 µF capacitor for 50 and 60 Hz operation.

Contacts

Several connection conditions are satisfied by the variety of contact structures. They are divided into arcing and non-arcing.

The non-arcing contacts consist of front and rear slip rings, which serve as the connection point for opposite ends of the reactor windings and one end of the two main movable contacts. All contact surfaces are Electrical Tough Pitch (ETP) copper and all joints are riveted, bolted, or brazed to maintain a high-conductivity current path. Contact pressure between moving points is maintained by opposing steel compression springs.

There are several types of arcing contacts on a regulator tap-changer. They can be divided into two categories: main and reversing.

- The main stationary contacts are connected to the series-winding taps. The main movable contacts connect the slip rings to the main stationary contacts.
- The reversing stationary contacts are connected to opposite ends of the series winding. The reversing movable contacts connect the neutral stationary contacts to the reversing stationary contacts.

All stationary contact bodies are made of ETP copper. Copper-tungsten inserts are brazed to the edges of the stationary contacts since those contacts are subject to damage from impact or arcing duty. The main movable contacts are constructed of a copper-tungsten. The movable contacts are split to make connection on both sides of the stationary contacts. This split resists separation in the event of high-current surges.

The tap-changer stationary contact body is copper. The reversing movable contacts are the same construction as the main movable contact.

Contact erosion is a function of many variables such as system parameters, regulated and unregulated voltages, line currents, power factor, voltage and current harmonics, and reactor and main core and coil designs.

Stationary contacts should be replaced before the arcing inserts erode to the point where there may be burning on the copper. Movable contacts should be replaced when approximately 1/8 inch of smooth surface remains.
Operating sequence

When the tap-changer is in the neutral position and the control calls for a tap change, the following events occur.

1. The motor is energized and rotor begins to move.
2. The motor drives the Geneva drive.
3. The pin and roller on the Geneva drive gear enters a slot on the main Geneva/contact drive assembly and the main Geneva/contact drive assembly begins to index.
4. The holding switch closes to ensure the tap change will go to completion. The control opens the initial circuit. The motor is energized only by way of the holding switch.
5. The reversing switch pin on the main Geneva/contact drive assembly begins to drive the reversing switch arm.
6. One of the two main interrupting movable contacts slides out of engagement with the neutral stationary contact and interrupts the circuit through that branch.
7. The reversing switch arm rotates, which causes the reversing switch contacts to pivot. A bridge between the neutral contact and a stationary contact connected to one end of the series winding is thus established. No arcing occurs across the reversing switch contacts. When the reversing arm rotates, a logic switch is triggered.
8. The main interrupting contacts slide over and onto the number one stationary contact, making a bridging position from contact N to contact 1 by way of the reactor.
9. The pin on the Geneva drive gear exits the main Geneva/contact drive assembly slot. The main Geneva/contact drive assembly stops moving and is rotationally locked.
10. The holding switch opens and the motor is de-energized.
11. The magnetic rotor of the AC synchronous motor or the brake used with the AC induction motor stops the Geneva drive gear at mid-travel.
12. The elapsed time from step 1 to step 11 is approximately 250 ms.
13. If the control issues another signal to index in the same direction, the same sequence is repeated except the reversing switch is not actuated. The reversing switch does not move until the tap-changer is reversed and stepped the opposite direction back to neutral.
14. If the tap-changer is switching from position 15 to position 16, a normally closed limit switch is triggered that is connected in parallel with the logic switch. Both the limit switch and the logic switch open up, so that the control cannot make a tap change past position 16.

Ever-Tap™ voltage regulators

The Ever-Tap voltage regulator utilizes a VACUTAP® RMV-SVR-I-2000 tap changer from Maschinenfabrik Reinhausen (see Figure 23). This tap changer is rated for an industry-leading 1,000,000 operations before maintenance is required. A first inspection of the tap changer is recommended after 500,000 operations. Inherent to the vacuum interrupting design of this tap changer is that material and gas byproducts from tapping operations do not accumulate in the dielectric fluid. This preserves a clean operating environment inside the voltage regulator tank, prolongs tap changer contact and coil winding life, and significantly extends maintenance intervals.

Figure 23. Ever-Tap voltage regulator’s RMV-SVR-I-2000 tap changer

Ever-Tap® tap-changer and motor drive unit

The tap changer comprises four switch modules linked together through a common mechanism to synchronize the modules’ operations. The tap selector module and reversing switch module share functional similarities with the Quik-Drive™ tap changers with the exception that arc-resistant materials are not required on the movable or stationary tap selector contacts. The by-pass switch module (sometimes referred to as a “diverter switch”) works in coordination with the vacuum interrupter module to interrupt current to the appropriate tap selector contact prior to switching. Arcing is contained within the vacuum interrupter, thus preserving the dielectric fluid of the voltage regulator.

ETMD-A motor drive unit

The tap changer is operated by a motor drive unit comprised of a motor, gearbox, position indicator linkage, and micro switches for feedback to the voltage regulator control. Some motor drive units require the control to be equipped with an auxiliary actuator board to manage start, stop, and tap
VR-32 and EVER-Tap™ Voltage Regulator

limiting functions. Other motor drive units may be powered and controlled directly by the voltage regulator control. In either case, the voltage regulator control is responsible for initiating a tap change. The motor drive model will be listed on the voltage regulator nameplate. For all EVER-Tap™ manufactured prior to 2020, the voltage regulator was supplied with the ETMD-A motor drive unit. Function Code 49 may be used to select the motor drive or tap changer model.

The CL-7 voltage regulator control utilizes an additional actuator board for use with the ETMD-A motor drive unit to power the tap changer. A 100 µF run capacitor and a 50 µF start capacitor are required for operation of the ETMD-A with actuator board. Back panel wiring in the control box for the ETMD-A is not compatible with Quik-Drive tap changers.

The CL-7 will trigger the actuator board to make a tap change. If limit switches are not tripped, the actuator board energizes the motor. After some rotation of the drivetrain, an operating switch is engaged to signal that the motor is responding to the command. Failure to receive this signal within several seconds will cause the actuator board to abort the tap change. In approximately 2 seconds, under normal operating conditions, the operating switch will be released, triggering the actuator board to stop the motor drive unit and signal to the control that the tap change is complete.

Operating sequence

Within the interval of time the motor drive unit is rotating, the tap changer mechanism drives different linkages to sequence the switch modules’ operations. First, a bypass switch opens causing all the load current of one movable contact to flow through the vacuum interrupter. Second, the vacuum interrupter opens, stopping current through the movable contact. Third, the movable contact is moved from one stationary tap to the next tap without electrical arcing because the current was previously interrupted. Fourth, the vacuum interrupter closes and current flow is reinitiated through the movable contact. Finally, the bypass switch closes causing the load current to be shunted around the vacuum interrupter.

Reversing switch

The reversing switch function changes the polarity of the tapped winding. When an EVER-Tap tap-changer is in the neutral position through position 16 Raise, the reversing switch is in position B. When the tap selector moves between the neutral position and position 1 Lower, the reversing switch moves between position A and B.

EVER-Tap important operational information

**WARNING**

The user of this equipment should be properly trained in the operation of voltage regulators. Wiring and operation of the EVER-TAP™ voltage regulator is different than other voltage regulators equipped with CL-7 controls. Only attempt to commission and operate an EVER-TAP™ voltage regulator after thoroughly reading and understanding this document as well as the voltage regulator and control manuals.

EVER-TAP controls and control boxes

Important information pertaining to a CL-7 control and control box equipped for use with and EVER-Tap voltage regulator:

- **EVER-Tap control boxes should only be used on EVER-Tap™ voltage regulators.** The ETMD-A motor drive unit requires a special motor drive control circuitry and capacitor configuration that is different from that of Eaton’s Quik-Drive tap changers. The wiring of the back-panel inside the control box and the wire harness to the control cable are not compatible with Quik-Drive equipped voltage regulators.

- **Use the CL-7 equipped with an actuator board only with an ETMD-A motor drive unit on an EVER-Tap™ voltage regulator.** Undesirable performance and unsafe operating conditions may result if any other control configuration is used.
  - The actuator board interfaces with the motor drive to ensure proper actuation of the tap changer.
  - The actuator board monitors position limit switches and operation cycle switches.
  - Starting and stopping functionality is augmented by the actuator board.

EVER-Tap Internal/external/auxiliary power

Important information pertaining to powering of the CL-7 control when operating an EVER-Tap voltage regulator:

- Two separate internal power circuits exist for the actuator board and CL-7 sensing and power circuits.
  - The V1 knife switch powers the VS sensing circuit and VM control power circuit.
  - The V8 knife switch powers the actuator board for the tap changer motor drive.
  - Do not short V1 to V8. V1 and V8 are both nominally 120V to ground, however V1 and V8 are opposite phase resulting in a nominal 240V from V1 to V8.
  - Select INTERNAL power on both the CL-7 front panel and the auxiliary swing panel power switches.

- External power to the CL-7 control and actuator board to control the RMV-SVR tap changer may be supplied using
the power input receptacle on the auxiliary swing panel inside the control box.

- The control box must be properly grounded.
- For external power, use a 120 VAC source referenced to ground.
  - The neutral terminal is internally connected to chassis ground.
  - The power source must be capable of supplying 15 Amps.
- The power input receptacle works with a standard NEMA 5-15R extension cord set with normal polarity. Reversed polarity will short the external power supply to ground.
- After connecting the power cord, select EXTERNAL power on both the CL-7 front panel and the auxiliary swing panel power switches to power on the control.
- For permanent auxiliary power to the CL-7 control and actuator board (for example, using substation power)
- Contact the factory for a supplemental wiring schematic.
- Wiring changes will be required on the back panel to avoid back-feeding the voltage regulator from the auxiliary power source.

EVER-Tap with motor drive unit ETMD-A CL-7 control settings
- CL-7 firmware version 1.15.0 or later is required on the CL-7 front panel
- From the CL-7 front panel, use Function Code 49 and select “Eaton ETMD-A”: Alternatively, this setting may be changed using ProView NXG software.
- For normal operation using the CL-7 control in AUTO or LOCAL mode, ensure the actuator board control switch is in the “AUTO” position. This switch is near the wire harness connector to the actuator board.
- Emergency manual operation of the tap changer without a working CL-7 front panel can be performed by moving the actuator board control switch to the “MANUAL” position. A second toggle switch near the wire harness of the actuator board is used to manually trigger the actuator board to command “Raise” and “Lower” operations.
- The tap changer actuator board can be disabled by setting the control switch to the “OFF” position between “AUTO” and “MANUAL”.
- From the CL-7 front panel, manual and automatic operation is similar to that of a Quik-Drive operation. However, keep these things in mind:
  - A complete tap change cycle is approximately 2 seconds under most operating conditions. Cold temperature, especially with a low voltage supply to the control/actuator board, may result in longer cycle times.

- The actuator board is triggered from the first raise or lower signal that it receives from the CL-7 and locks out further input until the end of the tap change cycle, so a brief actuation of the raise/lower switch in “MANUAL” mode is enough to start and complete a tap change.
- It is acceptable to hold the raise/lower switch in one position if multiple tap changes are to be made in the same direction.
- Before reversing the direction of operation of the tap changer, wait for the completion of a tap change cycle.
- Due to the longer tap change cycle and differences in the internal mechanism, the user will notice that the position indicator pointer moves slowly from one position to the next compared to the rapid motion generated by a Quik-Drive tap changer.
- If the tap changer fails to operate with the actuator board in AUTO or MANUAL mode, check that all wire harness connections are tight and check the 15A fuse on the actuator board.
- In the unlikely event that the tap changer fails to move when commanded and/or stalls between taps, wait for approximately 10 seconds while the actuator board resets and then trigger the tap changer to move in the opposite direction. If the tap changer fails to move again as commanded, there is likely a mechanical jam in the tap changer or motor drive unit. It is also possible that the voltage supply and/or temperature are too low.

Maintenance

Quik-Drive tap-changers
Step voltage regulators equipped with Quik-Drive tap changers are designed to provide many years of trouble-free operation. The usable life of a regulator is affected by application, but can be extended when periodic inspections and maintenance are performed. Maintenance and inspection schedules will vary and can be different for the same voltage regulator design depending upon system conditions and loading. The best predictor of future maintenance requirements is past experience.

If past maintenance requirements are not known, a first inspection of the Quik-Drive tap-changer contacts and other mechanical components inside the tank should be carried out after 10 years or 100,000 operations.

Inspection of components inside the tank and maintenance of voltage regulator mechanisms should include the items listed below. Any problems found should be resolved before placing the units back into service. Consult the tap-changer manuals listed below or your Eaton representative for details on maintenance procedures.
Stationary contacts
- Inspect the arcing tips for excessive erosion.
- Inspect the contact surface for pitting and scoring.
- Replace excessively worn contacts.

Moveable contacts
- Inspect the contacts for adequate contact surface area.
- Run the tap-changer through all positions checking for proper alignment with stationary contacts.
- Replace excessively worn contacts.

Reversing switch contacts and mechanism
- Inspect contacts for wear.
- Inspect mechanisms for damage.
- Replace excessively worn contacts.

Stationary contact board and moveable contact arm
- Inspect for build-up of carbon on surfaces; wipe off any build-up with a rag.
- Inspect for signs of arcing or heat damage.
- Inspect the phenolic contact boards found on legacy tap-changers for scratches.
- Upgrade the phenolic moveable contact arm to the polymer version for the legacy QD8 tap-changer.

Holding switch
- Inspect for proper operation of the switch.
- Inspect contact surfaces of holding switches on spring-drive and direct-drive tap-changers for pitting and proper spacing as defined in the tap-changer manual.

Position indicator drive mechanism
- Check the position-indicator gears on the tap-changer for signs of damage or loose parts.
- Check the drive cable for damage and signs of corrosion.

General
- Inspect for any signs of arcing between contact, contact boards, brackets, tap-changer mechanisms, and any other components inside the tank.
- Check hardware for tightness.
- Check the reactor tie-rods for tightness.
- Inspect the core and coil for insulation damage and heat damage.
- Remove any loose debris.
- Evaluate an insulating fluid sample and compare the results to the requirements found in Table 5 and Table 6.

Related manuals
Review the following tap-changer manuals for additional information on contact erosion and tap-changer maintenance requirements:
- MN225072EN, QD3 Quik-Drive Voltage Regulator Tap-Changer Manual
- MN225012EN, QD5 Quik-Drive Voltage Regulator Tap-Changer Manual
- MN225011EN, QD8 Quik-Drive Voltage Regulator Tap-Changer Installation and Maintenance Instructions
- S225-10-2, Spring-Drive and Direct-Drive Tap-Changer Switches in VR-32 Operating, Maintenance, Troubleshooting and Parts Replacement Instructions

Duty Cycle Monitor (DCM)
Another useful indicator of the need for inspection and maintenance for voltage regulators equipped with Quik-Drive tap changers is the DCM control feature. Refer to Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions, for more information on the DCM feature. DCM will operate correctly only when a Quik-Drive tap-changer is paired with a CL6 or later control and the control has been programmed with the correct design specification number.

EVER-Tap voltage regulator
Consult the document MN225077EN (expected release date Q4, 2020), EVER-Tap Voltage Regulator Maintenance Instructions and the inspection recommendations below for details on maintenance procedures.

500,000 operation inspection

Vacuum interrupter
- Check the contact erosion indicator.

Bypass contacts
- Inspect the contact surface for erosion.

Stationary contacts
- Inspect the contact surface for pitting and scoring.
- Replace excessively worn contacts.
- Signs of arcing indicate a malfunctioning vacuum interrupter or tap changer mechanism.
Moveable contacts
- Run the tap-changer through all positions checking for proper alignment with stationary contacts.
- Replace excessively worn contacts.
- Signs of arcing indicate a malfunctioning vacuum interrupter or tap changer mechanism.

Reversing switch contacts and mechanism
- Run the tap-changer between neutral and position 1 Lower checking for proper alignment with stationary contacts.
- Inspect contacts for wear.
- Inspect mechanisms for damage.

Stationary contact board and moveable contact arms
- Inspect for build-up of carbon on surfaces; wipe off any build-up with a rag.
- Inspect for signs of arcing or heat damage.

General
- Inspect for any signs of arcing between contacts, contact boards, brackets, tap-changer mechanisms, and any other components inside the tank.
- Check hardware for tightness.
- Check the reactor tie-rods for tightness.
- Inspect the core and coil for insulation damage and heat damage.
- Remove any loose debris.
- Evaluate an insulating fluid sample

Position indicator drive mechanism
- Check the position-indicator linkage on the motor drive for signs of damage or loose parts.
- Check the drive cable for damage and signs of corrosion

Duty Cycle Monitor (DCM)
This feature is not available for the EVER-Tap voltage regulator.

Operational check
Proper operation of the regulator can be checked without removing the unit from service.
To perform an operational check:
1. Place the CONTROL FUNCTION switch in LOCAL MANUAL.
2. Manually run the regulator several steps in the raise direction until the OUT-OF-BAND HIGH LED illuminates continuously.
3. Place the CONTROL FUNCTION switch in AUTO/REMOTE. After the time delay expires, the regulator should return to within the band edge and the OUT-OF-BAND HIGH LED should go out.
4. Again place the CONTROL FUNCTION switch in LOCAL MANUAL.
5. Manually run the regulator several steps in the lower direction until the OUT-OF-BAND LOW LED illuminates continuously.
6. Place the CONTROL FUNCTION switch in AUTO/REMOTE. After the time delay expires, the regulator should return to within the band edge and the OUT-OF-BAND LOW LED should go out.
7. If the operations check does not complete successfully, review the troubleshooting section of this manual and refer to Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance, for more instructions.
8. If further assistance is required, contact Voltage Regulator Support at (866) 975-7347. International callers should call (262) 896-2591.
Insulating fluid maintenance

The operation of a conventional step voltage regulator includes switching of a load tap-changer. Switching of this tap-changer will result in a small amount of arcing during each operation. This is different from a typical transformer or voltage regulator equipped with a vacuum interrupter. Under normal conditions, you would expect no internal arcing in a transformer and as a result, elevated levels of arcing gases are an indication of trouble. For conventional voltage regulators, arcing occurs inside the tank on every tap change. As a result, it is expected that gas levels will build up over time.

Because of the characteristic arcing of tap-changer contacts, dissolved gas analysis (DGA) is only marginally useful when evaluating insulating fluid from single-phase step voltage regulators (SVR). There are no industry standards to evaluate DGA results for an SVR. The best method of evaluating DGA results would be to compare values between subsequent tests. Unusually rapid buildup of gases from one test to another could be a sign of internal problems. Contact your Eaton representative for further assistance in evaluating DGA results.

When performing periodic maintenance of voltage regulators, insulating fluid characteristics should be evaluated. See Table 5 and Table 6 for information on the characteristics that would be part of the evaluation and the levels to be measured against. When the fluid fails to meet the requirements shown in the tables, steps should be taken to filter or replace the fluid. These steps should be performed during normal maintenance intervals.

Table 5. Envirotemp™ FR3™ Fluid Characteristics (natural ester-)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>New</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Strength (kV) ASTM D1816:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-mm gap</td>
<td>≥ 45</td>
<td>≥ 40</td>
</tr>
<tr>
<td>1-mm gap</td>
<td>≥ 25</td>
<td>≥ 23</td>
</tr>
<tr>
<td>Interfacial Tension (mNm) ASTM D971-91</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Water (mg/kg) ASTM D1533</td>
<td>≤ 300</td>
<td>≤ 35</td>
</tr>
</tbody>
</table>

 EVER-Tap voltage regulator insulating fluid maintenance

The EVER-Tap voltage regulator is equipped with an arc interrupter. The arc occurring during tapping operations occurs inside of the vacuum bottle. As a result, the dielectric fluid will not become contaminated in the same way as a conventional voltage regulator. Dissolved gas analysis results from an EVER-Tap voltage regulator can be treated like the results from a conventional transformer or OLTC.

Table 6. Mineral Oil Characteristics (Type II-)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>New</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Strength (kV) ASTM D1816:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-mm gap</td>
<td>≥ 45</td>
<td>≥ 40</td>
</tr>
<tr>
<td>1-mm gap</td>
<td>≥ 25</td>
<td>≥ 23</td>
</tr>
<tr>
<td>Interfacial Tension (mNm) ASTM D971</td>
<td>≥ 38</td>
<td>≥ 25</td>
</tr>
<tr>
<td>Water (mg/kg) ASTM D1533</td>
<td>≤ 20</td>
<td>≤ 35</td>
</tr>
</tbody>
</table>

Sampling insulating fluid

Precautions should be taken to ensure the best specimen possible when sampling insulating fluid. Here are some recommendations:

- Liquid samples must be drawn from the sampling valve located at the bottom of the voltage regulator tank.
- A sample of the liquid should be taken when the unit is warmer than the surrounding air to avoid condensation of moisture on the liquid.
- Relieve tank pressure or vacuum by operating the pressure relief valve before taking the sample. Care should be taken to wipe the valve clean and dry before pulling the ring.
- Collect liquid into a large-mouth glass bottle that is clean and dry.
- When sampling, a metal or non-rubber hose must be used; oil will leach sulfur from rubber.
- Before collecting a sample, drain a sufficient amount of fluid from the valve to ensure that the sample collected is not from the valve, but from the bottom of the tank.
- Before collecting a sample, rinse the sampling bottle three times with the liquid being sampled.
- Do not permit the fluid to splash into the sampling container; splashing can introduce air and moisture into the fluid.
- Test samples should be taken only after the fluid has settled for at least 24 hours; longer for cold fluid.

FR3 insulating fluid application

Viscosity characteristics of FR3 necessitate a mechanism to inhibit tap-changer operations for low-temperature applications.

In such cases, a thermometer will be provided as a standard feature. The thermometer will be configured to close a contact when insulating fluid temperatures reach -10 °C.
With the contact closed, auto operation will be inhibited. The CL-7 control will illuminate the Auto Tap Blocked LED and display **Blocked: CL** or **Comm** on the Metering-PLUS Load Current screen.

Untanking the regulator

**CAUTION**

Equipment Misoperation. Do not subject tap-changer with phenolic contact boards to temperatures above 150 °F (66 °C). To do so may cause damage to the contact panels, resulting in misalignment of the contacts, and can cause personal injury and equipment damage.

**CAUTION**

Equipment Damage. Before untanking a regulator that contains a thermometer: (1) Lower the insulating fluid level below the thermometer, then; (2) Remove the thermometer well. Failure to do so will result in damage to the thermometer well and can cause spillage of the insulating fluid when the internal assembly is lifted, causing personal injury.

**CAUTION**

Equipment Damage. Do not suspend the control box using the control cable. The control cable is not designed to support the weight of the control box. The control box can fall, causing personal injury and equipment damage.

Before untanking a voltage regulator, remove it from service following the instructions found in this manual in "Removal from service" on page 11. Untanking is performed in order to inspect the internal components and perform maintenance. A voltage regulator can be partially untanked for most routine maintenance and inspections. If a more in-depth inspection or maintenance is needed, a full untanking can also be performed.

Steps for untanking:

1. Manually run the tap-changer to neutral. If that tap changer cannot be returned to neutral, record the position indicator reading before proceeding so the position indicator can be returned to the correct position before retanking.
2. Disconnect the control cable from the bottom of the junction box (see **Figure 1**).
3. Remove the series arrester to avoid damaging the arrester and bushings while lifting the internal components.
4. Release the tank pressure by pulling the ring on the pressure-relief device located on the side of the tank.
5. Free the cover by removing the cover band or cover bolts.

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**WARNING**

The lifting eyes on the top of the voltage regulator are to be used for untanking only. Attempting to lift the entire voltage regulator using the lifting eyes could cause the tank to separate from the cover and fall to the ground. This could cause death, personal injury, or property damage.

6. Attach lifting straps with a spreader bar to the lifting eyes on top of the cover.

**WARNING**

Personal Injury. Do not rely on the lifting apparatus when the internal assembly is lifted for inspection or maintenance. Blocking should be placed between the cover and the top of the tank when partially untanking the voltage regulator to keep the assembly from falling, which can cause death or severe personal injury and equipment damage.

7. Lift the assembly:

   a. **For partial untanking**: lift the assembly until the top of the coil is approximately one inch under the insulating fluid (see **Figure 24**).

   b. **For Full untanking**: lift the assembly until the bottom of the assembly clears the tank. The assembly can be suspended for a period of time until the oil dripping slows. The internal assembly can then be placed on a drip tray. Make sure to return the core and coil to oil within 4 hours.
Retanking the regulator

Steps for retanking:

1. If the core and coil assembly have been out of oil for more than 4 hours, the coil must be dried, as follows:
   a. Bake the unit at 100°C (212°F) for 24 hours.
      
      **Note:** Units equipped with a phenolic tap-changer must be baked at a maximum temperature of 66°C (150°F). A unit can be rebaked a maximum of two times over its life.
   b. After baking, check all hardware for tightness.
   c. Within four hours after baking, retank the unit and fill it with fluid.
      
      **Note:** If baking is not possible or practical, see “Regulator dry-out procedure” on page 32 for an alternative to baking.

2. Verify that the position indicator shows the present position of the tap-changer.
   
   **Note:** If the position indicator is not showing the present position of the tap-changer, proceed as follows:
   a. Remove the indicator cable in the junction box from the position indicator shaft after loosening the set screw.
   b. Rotate the indicator shaft until the proper position is reached; then tighten the set screw.
   c. Verify coordination of the position indicator with the tap-changer in the neutral position (control neutral light on).

3. Check the gasket seat surfaces on the cover and tank, and wipe clean. Wipe the gasket and position it on the tank lip.

4. Loosen the horizontal, side channel bolts to ensure proper seating of the regulator in the tank and proper cover seal.

5. Raise the cover assembly and attached components over the tank. Make certain of proper orientation.

6. Lower the unit, rotating the channels counter-clockwise into the tank guides.

7. Seat the unit in the tank. Tighten the cover band or bolts. Torque the cover band to 24.4 – 29.8 Nm (18 – 22 ft-lbs). Make sure the ends of the cover band do not touch when fully tightened. Torque the cover bolts on a square-tanked regulator to 32.5 – 35.6 Nm (24 – 26 ft-lbs).
   
   **Note:** On round tanks, tap the cover with a rubber hammer around the edge to assist in providing a good seal while tightening the cover band.

8. Check and retighten the horizontal, side-channel bolts through the hand hole; torque to 68 Nm (50 ft-lbs).
9. Properly reseal the hand-hole cover, being careful not to damage the cover or the gasket.

10. Connect the control cable to the connector at the bottom of the junction box.

11. Pull a vacuum on the unit for at least one hour (2 mm of vacuum or better) after the unit is completely refilled with fluid.

   **Note:** If vacuum processing is not available, allow the entire internal assembly to soak in fluid for at least five days before energizing.

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## Spare parts

### Ordering Information

When ordering replacement parts or field-installation accessories for your Eaton voltage regulator, provide the following information:

- Regulator serial number (found on nameplate)
- Regulator catalog number (found on nameplate)
- Part number (not required)
- Photo of part is helpful
- Description of each part
- Quantity of each part required

Refer to the following Service Information documents for information on Eaton’s Cooper Power series tap-changer maintenance and replacement parts:

- MN225072EN, QD3 Quik-Drive Voltage Regulator Tap-Changer Manual
- MN225012EN, QD5 Quik-Drive Voltage Regulator Tap-Changer Manual
- MN225011EN, QD8 Quik-Drive Voltage Regulator Tap-Changer Manual

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### Troubleshooting

**For troubleshooting instructions, refer to Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions. The procedures in this section provide terminal markings for a single-phase control. If troubleshooting is being performed on a regulator with a multi-phase control, the terminals corresponding to the phase in question should be used. See Table 7 for assistance in identifying the correct terminals.**

**Table 7. Single-phase and multi-phase control back-panel markings**

<table>
<thead>
<tr>
<th>Single-Phase Control Markings</th>
<th>Multi-Phase Control Markings</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>VR1</td>
<td>V1</td>
<td>Load-Side PT</td>
</tr>
<tr>
<td>VR2</td>
<td>V1A</td>
<td>Differential PT</td>
</tr>
<tr>
<td>VR3</td>
<td>V1B</td>
<td>CT Shorting Switch</td>
</tr>
<tr>
<td>C</td>
<td>V6</td>
<td>CT +</td>
</tr>
<tr>
<td>C1</td>
<td>V6A</td>
<td>CT +</td>
</tr>
<tr>
<td>C2</td>
<td>V6B</td>
<td>CT +</td>
</tr>
<tr>
<td>C3</td>
<td>V6C</td>
<td>CT +</td>
</tr>
<tr>
<td>R1</td>
<td>L1</td>
<td>Motor Raise</td>
</tr>
<tr>
<td>R3</td>
<td>L3</td>
<td>Motor Lower</td>
</tr>
<tr>
<td>R-B</td>
<td>L-B</td>
<td></td>
</tr>
<tr>
<td>R-C</td>
<td>L-C</td>
<td></td>
</tr>
<tr>
<td>G-B</td>
<td>G-B</td>
<td></td>
</tr>
<tr>
<td>G-C</td>
<td>G-C</td>
<td></td>
</tr>
<tr>
<td>G-H</td>
<td>G-H</td>
<td></td>
</tr>
<tr>
<td>HSB</td>
<td>HSC</td>
<td>Holding Switch</td>
</tr>
</tbody>
</table>

For additional assistance, call the Voltage Regulator Support line at 866-975-7347 (calls from outside the U.S.:262-896-2591) or e-mail questions to RES-VRSupport@Eaton.com.

### Regulator control reverse power flow test

**Purpose**

The purpose of this procedure is to test the voltage regulator and control to ensure correct operation in response to reverse power flow.

**Required equipment**

- Clamp-on ammeter
- Appropriate cable leads
- 2 – 120 V variable power supplies

**Procedure**

**WARNING**

Hazardous Voltage. This procedure must only be performed on a regulator that has been removed from service. Failure to comply can cause serious injury or death.

1. Remove the unit from service as described in “Removal from service” on page 11.
**WARNING**

Hazardous Voltage. When troubleshooting energized equipment, protective gear must be worn to avoid personal contact with energized parts. Failure to comply can cause serious injury or death.

2. Conduct this test with the regulator located in the maintenance shop or other suitable location.

**WARNING**

Hazardous Voltage. The regulator tank must be solidly earth grounded. Failure to comply can cause severe personal injury and equipment damage.

3. Ground the regulator tank.
4. Connect a cable sized for the regulator rated current between the S (Source) and the L (Load) bushings.
5. Install a clamp-on ammeter on the cable between the S and L bushings to verify the current during the test.
6. Open the V1 (and V2, V6, and V8 if present) and C switches on the control assembly back panel.

**CAUTION**

Equipment Damage. When connecting external power to the voltage regulator control, make sure the polarity of the power source is correct. Reverse polarity will result in control damage.

**CAUTION**

Equipment Damage. Only an AC power supply is to be used to energize the control externally. Do not use a DC-to-AC voltage inverter. Failure to comply can cause excessive harmonics to be generated and result in damage to the front panel.

7. Apply 120 Vac to the control EXTERNAL SOURCE terminals. For instruction on connecting the control to an external source, see Service Information MN225003EN, CL7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions.
8. Using the manual RAISE/LOWER switch, place the regulator on the 3 Raise position.
9. Check control settings and correct if necessary. Ensure that FC56 is set for bidirectional. This will allow the control to function in both the forward and reverse power flow arrangements.
10. Connect a variable source between the L and SL (Source-Load) bushings and increase the applied voltage until 50% of the current rating is reached: this should be around 55 V.
11. Depending on the polarity of the voltage applied to the L and SL bushings, the control will operate in either the forward or reverse power flow direction. If the control REVERSE POWER LED does not illuminate, the control is in the forward mode. Reversing the voltage source leads on the L and SL bushings should cause the control panel REVERSE POWER LED to illuminate, indicating the control is in the reverse power flow mode.

### Voltage regulator ratio test

**Purpose**

The purpose of this test is to:

- Confirm correct series winding tap-changer connections.
- Identify an open or short-circuit in the series or shunt windings.

**Required equipment**

- Voltmeter
- 2 - 120 V variable power supplies

**Procedure**

**WARNING**

Hazardous Voltage. This procedure must only be performed on a regulator that has been removed from service. Failure to comply can cause serious injury or death.

1. Remove the unit from service as described in “Removal from service” on page 11.
2. Connect a voltmeter between the L (Load) and SL (Source-Load) bushings.
3. Use a variac to apply 120 Vac between the S (Source) and SL bushings.

**CAUTION**

Electrical Shock Hazard. Connecting an energized variac to the bushings will expose the tester to 120 Vac. Contact with the bushings will result in an electrical shock.

**WARNING**

Electrical Shock Hazard. The V1, V2, V6, and V8 (whichever are present) knife-blade switches must be open when connecting external power to the control. With some controls, if 120 Vac is incorrectly applied to the voltmeter terminals and the switches remain closed, rated voltage could be created on the bushings. Contact with the bushings in such a case could result in death or serious injury.

**CAUTION**

Incorrect connection of an external power source to the control or supply of an over-voltage will result in damage to the control panel.
4. Connect a separate 120 Vac supply to the EXTERNAL SOURCE terminals on the control front panel. Move the control power switch to the EXTERNAL position to operate the tap-changer.

**Note:** For instruction on connecting the control to an external source, see Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions.

5. Increase the voltage on the variac to 120 Vac. This will provide 12 V on the series winding.

\[ 120 \text{ Vac} \times 10\% \text{ regulation} = 12 \text{ V} \]

6. Calculate the change in volts per tap change as follows:

\[ \frac{\text{series winding volts}}{16 \text{ steps}} = \frac{12}{16} = 0.75 \text{ V per step} \]

**Note:** If 160 Vac is applied between the S and SL bushings, the calculations in step 5 and step 6 are computed, you will see that a 1.0 volt difference between steps will result. Doing this will simplify the ratio check.

### Table 8. Typical meter readings with 120 Vac connected between the S and SL bushings

<table>
<thead>
<tr>
<th>Lower</th>
<th>Raise</th>
</tr>
</thead>
<tbody>
<tr>
<td>16L - 108.0</td>
<td>16R - 132.0</td>
</tr>
<tr>
<td>15L - 108.75</td>
<td>15R - 131.25</td>
</tr>
<tr>
<td>14L - 109.5</td>
<td>14R - 130.5</td>
</tr>
<tr>
<td>13L - 110.25</td>
<td>13R - 129.75</td>
</tr>
<tr>
<td>12L - 111.0</td>
<td>12R - 129.0</td>
</tr>
<tr>
<td>11L - 111.75</td>
<td>11R - 128.25</td>
</tr>
<tr>
<td>10L - 112.5</td>
<td>10R - 127.5</td>
</tr>
<tr>
<td>9L - 113.25</td>
<td>9R - 126.75</td>
</tr>
<tr>
<td>8L - 114.0</td>
<td>8R - 126.0</td>
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<tr>
<td>7L - 114.75</td>
<td>7R - 125.25</td>
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<tr>
<td>6L - 115.5</td>
<td>6R - 124.5</td>
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<tr>
<td>5L - 116.25</td>
<td>5R - 123.75</td>
</tr>
<tr>
<td>4L - 117.0</td>
<td>4R - 123.0</td>
</tr>
<tr>
<td>3L - 117.75</td>
<td>3R - 122.25</td>
</tr>
<tr>
<td>2L - 118.5</td>
<td>2R - 121.5</td>
</tr>
<tr>
<td>1L - 119.25</td>
<td>1R - 120.75</td>
</tr>
<tr>
<td>Neutral 120</td>
<td></td>
</tr>
</tbody>
</table>

7. Operate the tap-changer with the control switch through all 32 steps from 16 Raise to 16 Lower. Record the voltmeter reading at each tap position. The change in voltage should be almost the same between each step (± 0.10 volts). If a substantial difference in any reading exists, then there is a problem with the windings or their connection. Readings will be the same with or without the equalizer winding.

**Note:** On a type B regulator, the difference between the taps will be slightly less than calculated as the regulator is tapped toward 16 Lower. This is normal and inherent in the design of the type B regulator.

Questions about the described procedure may be directed to your Eaton representative.

### Voltage regulator potential transformer ratio test

**Purpose**
The purpose of this test is to verify proper potential transformer ratio.

**Required equipment**
- Voltmeter
- 120 V variable power supply
- Appropriate cable leads
- Calculator

**Procedure**

1. **WARNING** Hazardous Voltage. This procedure must only be performed on a regulator that has been removed from service. Failure to comply can cause serious injury or death.

2. **WARNING** Hazardous Voltage. When troubleshooting energized equipment, protective gear must be worn to avoid personal contact with energized parts. Failure to comply can cause serious injury or death.

3. Remove the unit from service as described in “Removal from service” on page 11.
4. Open the back-panel knife switch marked V1.
5. Note the correct PT ratio as given for the pinned Load Volts on the nameplate under the Internal PT Ratio column. The tap setting of the PT can be verified by inspecting the tap-changer terminal board connection through the hand-hole on the regulator cover. The tap-changer terminal board is located on the top of the tap-changer under oil. The connection will be \text{E1, E2 and E3}; this should correspond to the PT ratio for the voltage pinned on the nameplate.
6. With the regulator in the neutral position, connect 120 Vac between the S (Source) and the SL (Source Load) bushings.
7. Using the formula below, determine the expected output voltage of the PT.

\[ \text{Expected Voltage} = 120 \text{ Vac/PT Ratio} \]
6. Measure the voltage between the top of the \textit{V1} switch and the terminal strip ground marked \textit{G}. The expected voltage should equal the measured voltage. A significant difference between the expected and measured voltages indicates a problem with the PT or PT connection.

\textbf{Regulator dry-out procedure}

\textbf{Purpose}

The purpose of this procedure is to remove moisture from the paper insulation, coil, and other components of a voltage regulator.

\textbf{Required equipment and information}

- Impedance voltage value obtained from factory
- 120 V variable power supply
- Cable lead jumper rated for nominal current
- Clamp-on ammeter
- Variable power supply sufficient to apply impedance voltage
- New insulating fluid
- Insulation power factor test equipment

\textbf{Procedure}

\textbf{WARNING}

\textit{Hazardous Voltage. This procedure must only be performed on a regulator that has been removed from service. Failure to comply can cause serious injury or death.}

1. Remove the unit from service as described in “Removal from service” on page 11.

\textbf{WARNING}

\textit{Hazardous Voltage. The regulator will be energized with load current present for the duration of the procedure. The regulator must be placed in a protected area, preventing anyone from coming in contact with the unit. Failure to do so could result in injury or possible death.}

2. Perform this procedure with the regulator located in a protected area in the maintenance shop or other suitable location.

3. Place regulator on the 16 Raise position using external power. For instruction on connecting the control to an external source, see Service Information MN225003EN, \textit{CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions}.

4. Place a jumper, rated for nominal current, between the S (Source) and L (Load) bushings. A clamp-on ammeter should be used to measure the current in the shorted current path.

5. Ground the regulator tank.

6. Using a variac apply impedance voltage at 16 Raise between the S and L bushings. Raise the voltage until rated current is read on the ammeter. Impedance voltage values may be obtained from the factory. Contact your Eaton representative for assistance.

7. Let the regulator set in this condition for approximately 24 hours. This will drive the moisture out of the coil into the insulating fluid.

8. De-energize the regulator and drain the insulating fluid.

9. Refill with new insulating fluid.

10. Check the results of the procedure by performing an insulation power factor test after the regulator temperature has stabilized to the ambient temperature.

\textbf{Voltage regulator current test}

\textbf{Purpose}

The purpose of this test is to confirm operation of the current transformer (CT) and voltage regulator control current measurement.

\textbf{Note:} When performing this test on units with a multi-phase control, there will not be jumpers available, as described in step 7, to facilitate connection of an ammeter. To connect the ammeter, the green control cable wires connected to the top of the CCA, CCB, and CCC switches (for VR1, VR2, and VR3 respectively) can be disconnected and then the ammeter can be connected between the green wires and the top of the switches.

\textbf{Required equipment}

- 2 - 120 V variable power supply
- Cable lead jumper rated for nominal current
- Clamp-on ammeter
- Small needle-nose pliers
- Milli-ammeter

\textbf{Procedure}

\textbf{WARNING}

\textit{Hazardous Voltage. This procedure must only be performed on a regulator that has been removed from service. Failure to comply can cause serious injury or death.}

1. Remove the unit from service as described in “Removal from service” on page 11.
WARNING
Hazardous Voltage. When troubleshooting energized equipment, protective gear must be worn to avoid personal contact with energized parts. Failure to comply can cause serious injury or death.

2. Conduct this test with the regulator located in the maintenance shop or other suitable location.

CAUTION
Equipment Damage. When connecting external power to the voltage regulator control, make sure the polarity of the power source is correct. Reverse polarity will result in control damage.

CAUTION
Equipment Damage. Only an AC power supply is to be used to energize the control externally. Do not use a DC-to-AC voltage inverter. Failure to comply can cause excessive harmonics to be generated and result in damage to the front panel.

3. Use an external source to power the control and enable tap-changer operation. See Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions, for detailed information on powering the control externally.

4. Place a jumper, rated for nominal current, between the S (Source) and L (Load) bushings. Use a clamp-on ammeter to measure the current in the jumper during the test.

WARNING
Hazardous Voltage. The regulator tank must be solidly earth grounded. Failure to comply can cause severe personal injury and equipment damage.

5. Ground the regulator tank.

6. Close C knife switch on the back panel.

7. Remove the jumper from between the C2 and C3 terminals to the left of the V1 switch, on the back panel. See Figure 25. Place a milli-ampere meter between these terminals. See Figure 26.

8. Using a variable voltage source, place approximately 120 V between the L and SL (Source-Load) bushings until a current value is shown on the clamp-on meter.

9. Open the knife switch C on the back panel. The milli-ampere meter should indicate a current value based on the CT ratio shown on the rating plate.

10. Run the voltage regulator through all of the tap positions to check the continuity and reveal any possible intermittent opens. The current indicated on the clamp-on meter will increase or decrease as the tap-changer moves from Neutral to 16 Raise position. The current will reach its maximum value at a specific position dependent on the type and rating of the regulator. Current reduces to zero when it reaches the neutral position.

Figure 25. Removing jumper between C2 and C3

Figure 26. Milli-ammeter connection points
Insulation resistance test

Purpose
The purpose of this procedure is to describe the proper connections and procedure when performing an insulation power factor test on a voltage regulator.

Required Equipment
- 120 V variable power supply
- Cable lead jumper rated for nominal current
- Insulation power factor test equipment

Procedure

```
## WARNING
Hazardous Voltage. This procedure must only be performed on a regulator that has been removed from service. Failure to comply can cause serious injury or death.

1. Remove the unit from service as described in “Removal from service” on page 11.
2. Conduct this test with the regulator located in the maintenance shop or other suitable location.
   **Note:** The regulator tank must be isolated from ground potential.

## CAUTION
Equipment Damage. When connecting external power to the voltage regulator control, make sure the polarity of the power source is correct. Reverse polarity will result in control damage.

## CAUTION
Equipment Damage. Only an AC power supply is to be used to energize the control externally. Do not use a DC-to-AC voltage inverter. Failure to comply can cause excessive harmonics to be generated and result in damage to the front panel.

3. Place the regulator in the 16 Lower position. Power the control using an external power source to enable tap-changer operation. See Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions, for detailed information on powering the control externally.
4. Place a jumper, rated for nominal current, tying all the bushings together.
5. Close C knife switch on the back panel.
6. Using the variac on the tester, bring the voltage up to the desired test level. Refer to the instructions provided with the test equipment for guidelines on voltage test levels.
7. Read the test value in mega-ohms; then compare the reading with the baseline reading:
   - If the new reading is lower than the baseline reading, further testing and evaluation of the insulation is recommended.
   - **Note:** This test is very sensitive to contamination on the regulator bushings.
   - If the new reading is the same as or higher than the baseline reading, no further testing is indicated.
```

Freeing a stalled tap-changer

Purpose
The purpose of this procedure is to free a tap-changer that has experienced a mechanical jam that prevents operation.

Required Equipment
- Voltmeter
- Terminal-board tool
- Screwdriver (screw-type terminal boards only)

Procedure

```
1. Confirm that a stall has occurred. If the tap-changer is stalled between tap positions with the holding switch closed, a voltmeter placed between terminals R1 and G or L1 and G on the back panel will read approximately 120 Vac. The terminal measuring 120 Vac will be the direction the tap-changer was moving when stalling occurred. There will likely be a floating capacitive voltage in the other direction greater than 120 Vac. After determining the stall direction, the steps of this procedure can be used to reverse the direction of the tap-changer to free the mechanism.
2. Place the CONTROL FUNCTION switch in OFF position.
3. Place the POWER switch in OFF position.
4. Close the C switch on the back panel of the control.
5. Open the V1 disconnect switch on the back panel of the control, removing power from the control.
6. Disconnect the orange wiring harness lead from the HS terminal on the terminal board located on the back panel; this removes power from the tap-changer holding switch.
7. Close the V1 disconnect switch.
8. Place the POWER switch on INTERNAL.
```
9. Place the CONTROL FUNCTION switch on LOCAL MANUAL.

10. Jog the RAISE/LOWE switch in the direction the capacitive voltage was observed. This should allow the tap-changer to free itself. Using the RAISE/LOWE switch, run the tap-changer one or two steps. Inspect the position indicator to verify that the indicating pointer is directly over a tap position mark. If the pointer is not directly over a tap position mark, jog the RAISE/LOWE switch in the same direction as done previously. This should put the pointer in the correct position.

11. Remove the voltage regulator from service as soon as possible to determine the cause of the problem and perform maintenance.

12. Place the CONTROL FUNCTION switch on OFF.

13. Place the POWER switch on OFF.

14. Open V1 disconnect switch.

15. Reconnect the orange lead to the HS terminal restoring power to holding switch.

16. Close the V1 disconnect switch.

17. Open the C switch.

18. Place the POWER switch on INTERNAL.

19. Turn CONTROL FUNCTION control switch to LOCAL MANUAL.

20. Using the RAISE/LOWE switch, step the regulator to the neutral position.

21. Before de-energizing the regulator by bypassing to remove it from service, verify that the regulator is in the neutral position. It is recommended that you perform a minimum of four checks to confirm that the voltage regulator is in the neutral position:

- The neutral light remains on continuously.
- The position indicator points directly at N.
- The control panel position indication viewed at FC 12 reads zero.
- A voltage measurement between the S (Source) and L (Load) bushings measured using voltmeter test equipment or CL-7 control SAFE-TO-BYPASS feature indicates no differential voltage.

Refer to "Removal from service" on page 11 and Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions, for detailed service information and safe bypassing instructions.
## Appendix

### Connections and voltage levels

#### Table 9. Tap connections & voltage levels (60 Hz)

<table>
<thead>
<tr>
<th>Regulator Voltage Rating</th>
<th>Nominal Single-Phase Voltage</th>
<th>Ratio-Adjusting Data</th>
<th>Test Terminal Voltage</th>
<th>Overall Potential Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal Tap&lt;sup&gt;a&lt;/sup&gt;</td>
<td>PT Ratio</td>
<td>RCT Tap</td>
<td>Voltage</td>
</tr>
<tr>
<td></td>
<td>E&lt;sub&gt;1&lt;/sub&gt;/P&lt;sub&gt;1&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

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<th>Regulator Voltage Rating</th>
<th>Nominal Single-Phase Voltage</th>
<th>Ratio-Adjusting Data</th>
<th>Test Terminal Voltage</th>
<th>Overall Potential Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal Tap&lt;sup&gt;a&lt;/sup&gt;</td>
<td>PT Ratio</td>
<td>RCT Tap</td>
<td>Voltage</td>
</tr>
<tr>
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<td>E&lt;sub&gt;1&lt;/sub&gt;/P&lt;sub&gt;1&lt;/sub&gt;</td>
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<th>Regulator Voltage Rating</th>
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<th>Ratio-Adjusting Data</th>
<th>Test Terminal Voltage</th>
<th>Overall Potential Ratio</th>
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<tr>
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<th>Regulator Voltage Rating</th>
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<th>Ratio-Adjusting Data</th>
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<th>Overall Potential Ratio</th>
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<tr>
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<td>Internal Tap&lt;sup&gt;a&lt;/sup&gt;</td>
<td>PT Ratio</td>
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<td>Voltage</td>
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</tr>
</tbody>
</table>

### Notes:

- <sup>a</sup> P taps are used with E taps only on regulators where an internal potential transformer is used in conjunction with the control winding to provide voltage supplies to the control. See nameplate for verification of this type of control supply.
- <sup>b</sup> Test terminal voltage and overall potential ratio may vary slightly from one regulator to another. See the regulator nameplate for determining the exact values.
<table>
<thead>
<tr>
<th>Regulator Voltage Rating</th>
<th>Nominal Single-Phase Voltage</th>
<th>Ratio-Adjusting Data</th>
<th>Test Terminal Voltage</th>
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<td>127</td>
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<td>6900</td>
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<td>54.9:1</td>
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<td>E₂/P₂</td>
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<td>10000</td>
<td>E₂/P₂</td>
<td>91.7:1</td>
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</table>

a P taps are used with E taps only on regulators where an internal potential transformer is used in conjunction with the control winding to provide voltage supplies to the control. See nameplate for verification of this type of control supply.

b Test terminal voltage and overall potential ratio may vary slightly from one regulator to another. See the regulator nameplate for determining the exact values.
## ADD-AMP capabilities

### Table 11. ADD-AMP capabilities of 60 Hz ratings

<table>
<thead>
<tr>
<th>Rated Volts</th>
<th>Rated kVA</th>
<th>Load Current Ratings (A) (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Regulation Range (Wye and Open Delta)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>± 10%</td>
</tr>
<tr>
<td>2500</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>75</td>
<td>300</td>
<td>330</td>
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<tr>
<td>100</td>
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<td>440</td>
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<td>125</td>
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<tr>
<td>167</td>
<td>668</td>
<td>688</td>
</tr>
<tr>
<td>250</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>333</td>
<td>1332</td>
<td>1332</td>
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<tr>
<td>416.3</td>
<td>1665</td>
<td>1665</td>
</tr>
<tr>
<td>5000</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>50</td>
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<td>125</td>
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<td>275</td>
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<tr>
<td>167</td>
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<tr>
<td>250</td>
<td>500</td>
<td>550</td>
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<tr>
<td>333</td>
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<td>416.3</td>
<td>833</td>
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<td>7620 (^b)</td>
<td>38.1</td>
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### Table 11. (continued)

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<th>Rated Volts</th>
<th>Rated kVA</th>
<th>Load Current Ratings (A) (^a)</th>
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</thead>
<tbody>
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<td></td>
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<td>Regulation Range (Wye and Open Delta)</td>
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<tr>
<td>690</td>
<td>200</td>
<td>220</td>
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</table>

\(^a\) 55/65 °C rise rating on Eaton voltage regulators gives an additional 12% increase in capacity if the tap-changer’s maximum current rating has not been exceeded. For loading in excess of the above values, please refer to your Eaton representative.

\(^b\) Regulators are capable of carrying current corresponding to rated kVA when operated at 7200 V.
Table 12. ADD-AMP capabilities of 50 Hz ratings

<table>
<thead>
<tr>
<th>Rated Volts</th>
<th>Rated kVA</th>
<th>Load Current Ratings (A)(^a)</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Regulation Range (Wye and Open Delta)</td>
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<tr>
<td></td>
<td></td>
<td>± 10%</td>
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<td></td>
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<tr>
<td></td>
<td>825</td>
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</tbody>
</table>

\(^a\) 65/85 °C rise rating on Eaton voltage regulators gives an additional 12% increase in capacity if the tap-changer's maximum current rating has not been exceeded. For loading in excess of the above values, please refer to your Eaton representative.
Wiring diagrams

Figure 27. Typical internal wiring of voltage regulators with a QD3 tap-changer
Figure 28. Typical internal wiring of voltage regulators with QD5 and QD8 tap-changers
Figure 29. Typical internal wiring of EVER-Tap voltage regulator tap changer
Figure 30. Junction box wiring diagram
Figure 31. Legacy junction box wiring diagram
NOTES
1. LEAD 20 (WHT/BRN) CONNECTS V6-4 TO V7 INSTEAD OF VS TO V7 WHEN A DIFFERENTIAL PT IS UTILIZED.
2. CONTROL CABLES CONTAINING 14 CONDUCTORS WILL HAVE CAPACITOR WIRE COLORS OF RED/WHITE AND GREEN/WHITE.

Figure 32. Standard back panel signal circuit
Figure 33. EVER-Tap back panel signal circuit
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