

Pad-mounted voltage regulator with Quik-Drive™ tap-changer 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.

#### CAUTION

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.**

G103.3

#### 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.**

G101.0

#### 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.**

G102.1

#### 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.**

G122.3

## Product information

### Introduction

Eaton's *Service Information MN225014EN* provides the installation, operation, and maintenance instructions for its Cooper Power™ series pad-mounted voltage regulator incorporating its Cooper Power series Quik-Drive™ tap-changer.

### 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, bushings and cabinet 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 handling 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.

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### WARNING

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**Before moving the regulator, check the weight and tank capacity and condition of all lifting equipment. Do not use worn, frayed, or damaged cables or slings. Do not use lifting machinery with load capacity less than the weight of the regulator as shown on the nameplate. Improper moving or lifting may result in severe personal injury, death, or property damage.**

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### Unloading

Most of the weight of the pad-mount voltage regulator is in the main tank, which holds the core and coil assembly and the insulating fluid. The terminal compartments are largely empty and weigh relatively little. Improper use of lifts or jacks could seriously damage the regulator or its attachments or cause serious personal injury.

### Moving regulator shipped on pallets

Regulators shipped on pallets may be lifted or moved using forklift trucks of proper capacity. Pallet-mounted equipment may also be moved by crane or hoist.

### Lifting the regulator by crane or hoist

For unloading, lift lugs are provided near the top of the regulator tank. Lifting strap angles should not be over 30° from vertical. Otherwise, a spreader bar should be used to hold the lifting straps apart or damage to the tank and lift lugs may result.

Do not attempt to lift the regulator by placing a continuous loop of strapping, cable, or chain around the unit or lifting lugs.

### Moving the regulator with rollers

The regulator may be skidded or moved with rollers. When jacking a regulator to insert rollers underneath, ensure that at least two jacks are used and that two adjacent corners are raised simultaneously and evenly to avoid warping the base. Jacks may be placed only at the corners of the regulator base.

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### WARNING

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**Equipment damage. Do not place jacks under radiator, corrugate, valves or sheet metal parts. Jacking under these components will cause damage to the equipment.**

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Place jacks only under jack pads provided. When moving the pad-mounted regulator using rollers, use as many rollers as necessary to uniformly distribute the weight. To pull, attach pulling eyes to the holes in the base at either end of the regulator. Do not attach pulling lines to moldings or other sheet metal parts of the regulator.

### Standards

Eaton's voltage 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 C57.13-2008™ standard
- IEEE Std C57.15-2009™ 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

## Description

Pad-mounted 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 single-phase, 2-in-1 and 3-in-1 configurations, Eaton's pad-mounted voltage regulators are suitable for three- or four-wire underground systems. The 2-in-1 and 3-in-1 configurations consist of two or three single-phase voltage regulators in a single tank. A bypass module is available for the single-phase configuration only.

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.

Eaton manufactures two types of pad-mounted step-voltage regulators: source-side series winding (Type B) and load-side series winding (Type A). Pad-mounted voltage regulators are usually equipped with an equalizer winding. The nameplates located on the tank and control box define the power circuit.

## Standard features

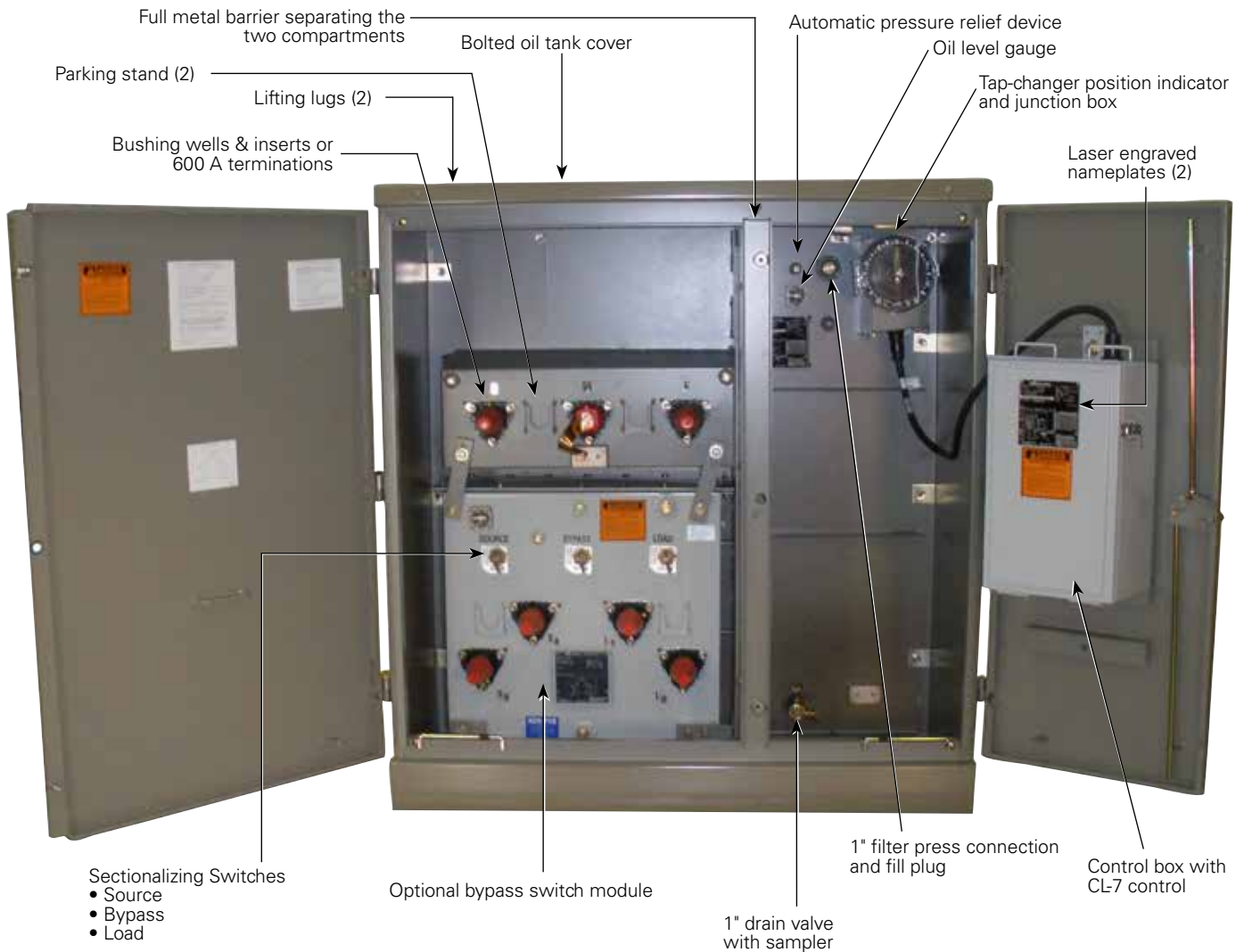
A sealed tank construction combined with a 65°C average winding rise insulation system provides a proven design for long life installations. Additional capacity is available through the ADD-AMP™ feature. Pad-mounted voltage regulators are equipped with these standard features:

- Full metal barrier separating the two compartments
- Parking stand for each S and L bushing
- Bushing wells and inserts, 600 A, or 900 A terminations
- Standard "pad-mounted green" paint (Munsell 7GY3.29/1.5)
- Internal differential PT for improved bypass safety
- Externally operated PT tap switch
- Ground pads
- Bolted tank cover
- Nameplates (2)
- Deep (31") removable cabinet



**Figure 1. Quick connect/disconnect cable.**

- Automatic pressure relief device
- Lifting lugs
- Under-oil series arrester (3 or 6 kV)
- Oil sight gauge
- Pressure/vacuum gauge provisions
- Thermometer provisions
- 1" filter press connection and fill plug
- Control box with CL-7 control
- Multi-phase CL-7 control for 2-in-1 or 3-in-1 regulators
- Junction box and position indicator
- 1" drain valve with sampler
- Control cable disconnect at junction box and control box
- Line-side lift-off door secured with two captivated bolts
- Pad-lockable lift-off control-side door with three-point latching
- Door position-retention rods



**Figure 2. External features of the VR-32 voltage regulator.**

**Available options**

Available options include:

- Bypass switch module (single-phase unit of 550 A and below ratings, grounded-wye systems only)
- Envirotemp™ FR3™ dielectric fluid
- 41" deep cabinet
- Alternate top coat color
- No barrier
- Dial-type oil level gauge\*
- Pressure/vacuum gauge\*
- Dial-type thermometer\*
- Rapid rise relay

- Pressure/vacuum bleeder valve
- Under-oil shunt arresters
- Nameplates in alternate languages and/or metric units
- Stainless steel cabinet, tank, and hardware
- Stainless steel control cabinet
- Under-oil shunt arresters
- Copper grounding bar in cabinet
- NEMA® 3RX or 3X control box

\* With or without alarm contacts

## Installation instructions

### Mounting the voltage regulator

When installing a pad-mounted voltage regulator, it should be placed on a level concrete pad. The pad should be strong enough to support the weight of the regulator.

Pad-mounted regulators are equipped with tamper resistant cabinets. To maintain full cabinet security, the regulator tank and cabinet base have provisions for installing cleats to secure them to pad. If gaps exist between the cabinet and pad after cleating the cabinet, the installation will not provide the security needed to prevent tampering by the public. When there are gaps, add a permanent mortar seal to fill the gaps.

### Connections

Bushing connections are compatible with underground distribution system bushings. A switching module is also available for pad-mounted units that enables bypass switching; the module remains on the pad as the regulator is lifted when removing it from service. Bypass modules are only available for the single-phase version of pad-mounted regulators.

### Pre-installation inspection

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

1. Check insulating fluid level sight gauge. The gasket and seals for the tank cover, gauges, bushings, etc., should be inspected for evidence of insulating fluid seepage. Leaking or improperly tightened gaskets and seals must be repaired before the regulator is placed in service.

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### WARNING

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**Internal tank pressure. The regulator tank must be vented to zero pressure using the pressure relief valve before the oil fill plug is removed. Failure to do so may result in severe personal injury, death, or property damage.**

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2. The regulator exterior should be inspected for nicks, dents, and scratches. Any damage to weather-resistant finishes should be repaired promptly.
3. Inspect bushings for damage.
4. If there is a suspicion that moisture has entered the unit, remove the cover and inspect for evidence of moisture such as rust or water tracks in the insulating fluid. If moisture has entered the tank, dry the regulator and filter the insulating fluid before putting unit in service. See Tables 4 and 5 for insulating fluid test standards. Be sure to properly replace the cover. See the **Maintenance** section of this manual for more information on internal tank inspections.
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 Tables 4 and 5.
7. Regulator may be energized at rated voltage (with caution) and an operational check performed.
8. A high-potential test may be done to ensure adequate electrical clearances to ground. This procedure is optional.



## Single-phase pad-mounted regulator system connections

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### WARNING

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**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.

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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.

### Single-phase and wye connected regulation

For a single-phase circuit and any individual phase on a 3-phase wye connected circuit, each regulator is connected with the **S** bushing connected to the source feeder and the **L** bushing connected to load feeder. The **SL** bushing is connected to the system ground. See Figure 3 for the connections when a bypass module is used. See Figure 4 for the connections when no bypass module is used.

### Open delta connected regulation

In open-delta connected regulation, all three phases are regulated up to +/-10% with two voltage regulators. When single-phase pad-mounted regulators are used in an open delta configuration, bypass modules typically cannot be used because of the connection of the SL bushings to an adjacent phase. Figure 5 shows the typical connections for two regulators connected in open delta without the use of a bypass modules.

### Close delta connected regulation

With a closed delta configuration, three voltage regulators are used to regulate each phase individually; since regulation on one phase affects the voltage on adjacent phases, regulation up to +/-15% is possible.

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### WARNING

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**Personal injury.** For closed delta connected voltage regulators, when using a bypass module without a separate SL disconnect switch, all three regulators must be bypassed in order to de-energize any single voltage regulator. Failure to bypass all three regulators will leave power on all three regulators because of the SL bushing interconnections. Severe injury or death will result from contact with live bushings that have been disconnected.

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Figure 6 shows the connection of closed delta connected voltage regulators when using a bypass module. Figure 7 shows the connections of delta connected voltage regulators without bypass switches.

### Multi-phase pad-mounted regulator system connections

Multi-phase pad-mounted voltage regulators consist of two or three voltage regulators in a single tank. These can be connected in wye, open delta or close delta configurations. Bypass modules are not available for multi-phase voltage regulators; if a method of bypassing the regulators without deenergizing the line is desired, a separate sectionalizing switch would be required.

### Wye connected 3-in-1 pad-mounted regulator

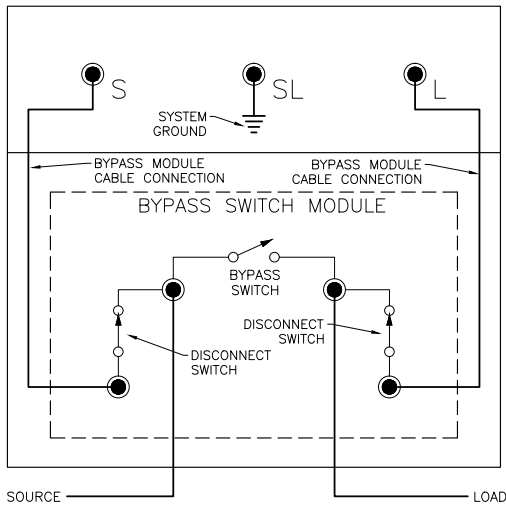
A 3-in-1 voltage regulator that is connected for a wye system will have the SL connections from each regulator internally tied and brought out through one SL bushing. A single ground connection is made to the SL bushing and the three phases are connected source to load as shown in Figure 8.

### Open delta connected 2-in-1 pad-mounted regulator

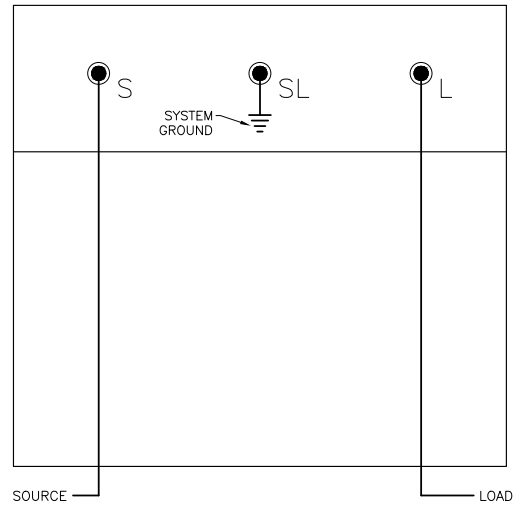
A 2-in-1 voltage regulator that is connected for an open delta system will have the SL connections from each regulator internally tied and brought out through a single SL bushing. Connections to the SL bushing will require a feed-through or bolt-T bushing to facilitate the source and load connections of the reference phase. A dual SL bushing design is also available that would eliminate the need for the feed-thru and bolt-T bushing. A diagram of the connections to the bushings is shown in Figure 9.

### Closed delta connected 3-in-1 pad-mounted regulator

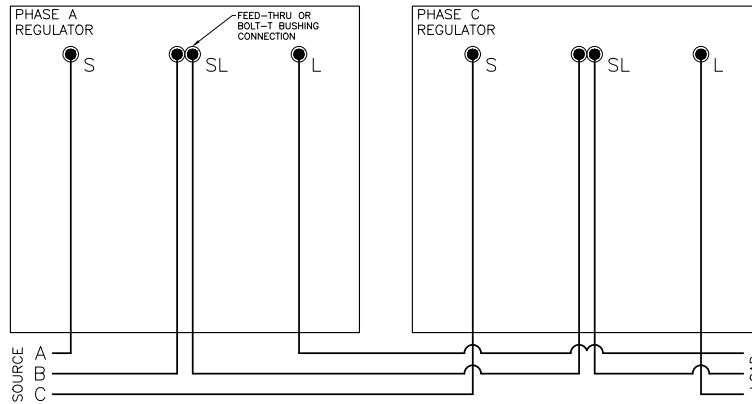
A 3-in-1 voltage regulator that is connected for a closed delta system will have the SL connections from each regulator internally configured for the delta configuration and will not have an SL bushing. A diagram of the connections to the bushings is shown in Figure 10.



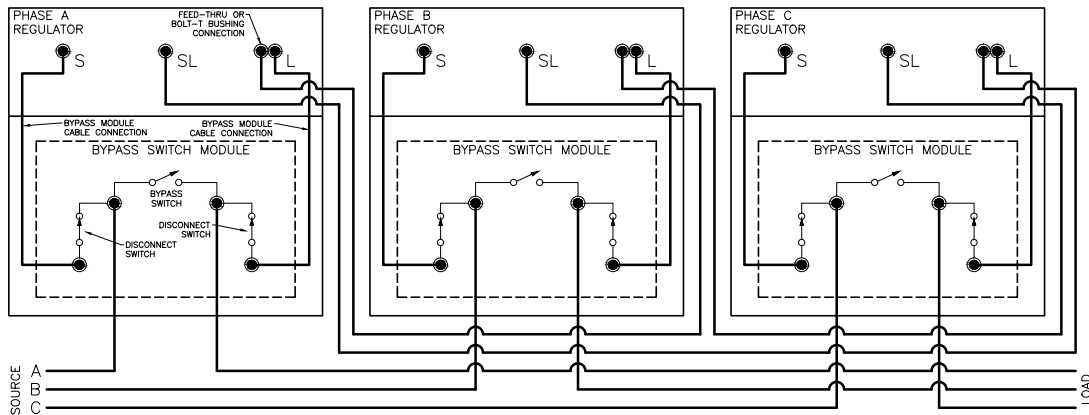
**Figure 3. Regulating a single phase circuit with a neutral or any one phase of a wye connected 3-phase circuit when using a bypass module.**



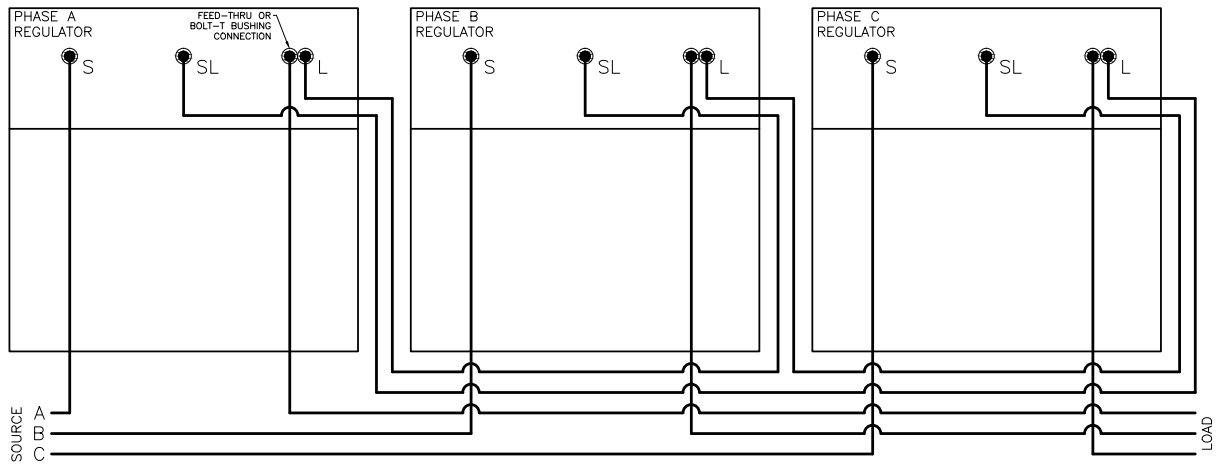
**Figure 4. Regulating a single phase circuit with a neutral or any one phase of a wye connected 3-phase circuit when not using a bypass module.**



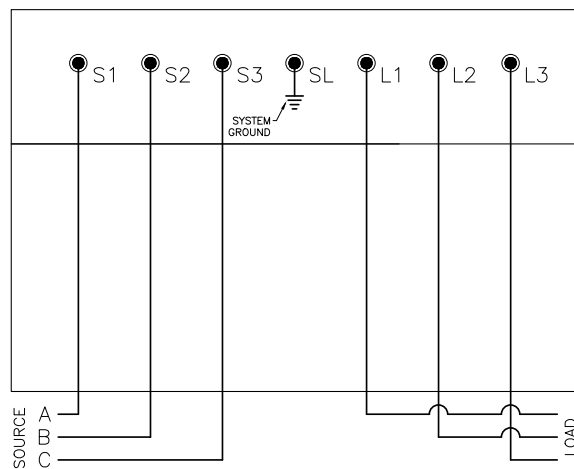
**Figure 5. Regulating a three-phase, three-wire circuit with two regulators (open delta) when not using bypass modules.**



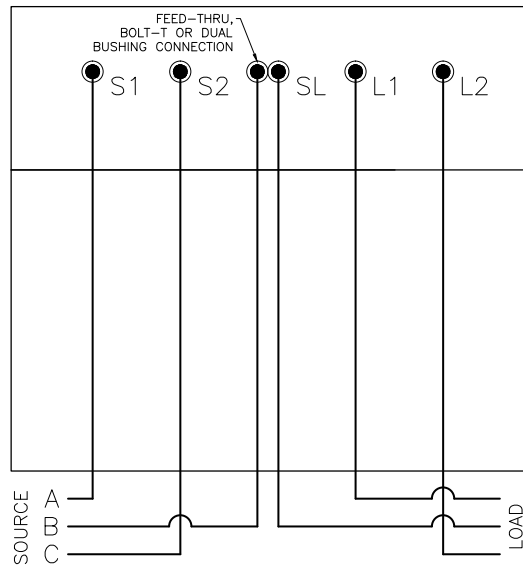
**Figure 6. Regulating a three-phase, three-wire circuit with three regulators (closed delta) when using bypass modules.**



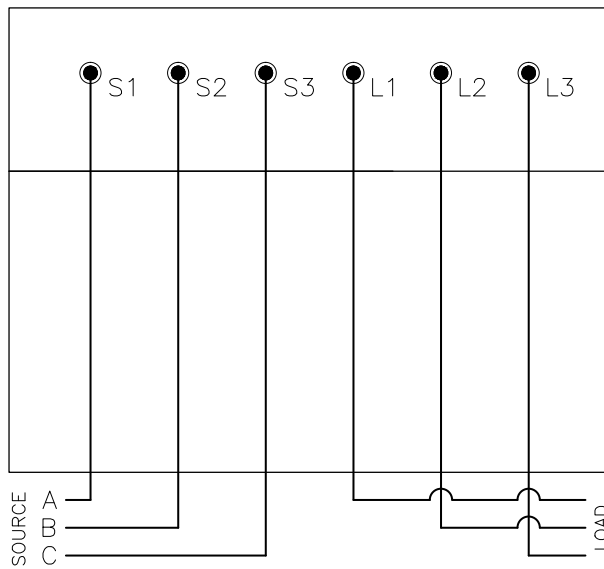
**Figure 7. Regulating a three-phase, three-wire circuit with three regulators (closed delta) when not using bypass modules.**



**Figure 8. Regulating a three-phase, four-wire circuit (wye) with a 3-in-1 voltage regulator.**



**Figure 9. Regulating a three-phase, three-wire circuit using a 2-in-1 voltage regulator (open delta).**



**Figure 10. Regulating a three-phase, three-wire circuit with a 3-in-1 regulator (closed delta).**

## Nameplates

Two anodized aluminum nameplates are provided as standard; refer to Figures 11 and 12 for examples. One nameplate is placed on the regulator tank in the right-side compartment. 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 from the nameplate for reference.

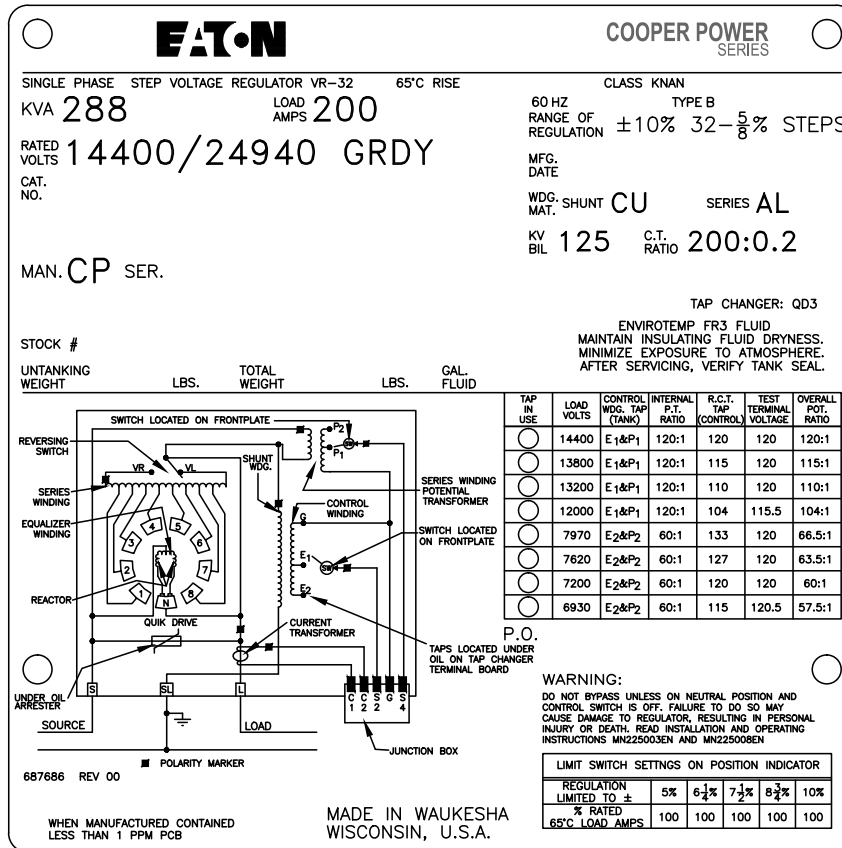


Figure 11. Typical nameplate, single-phase, wye connected.

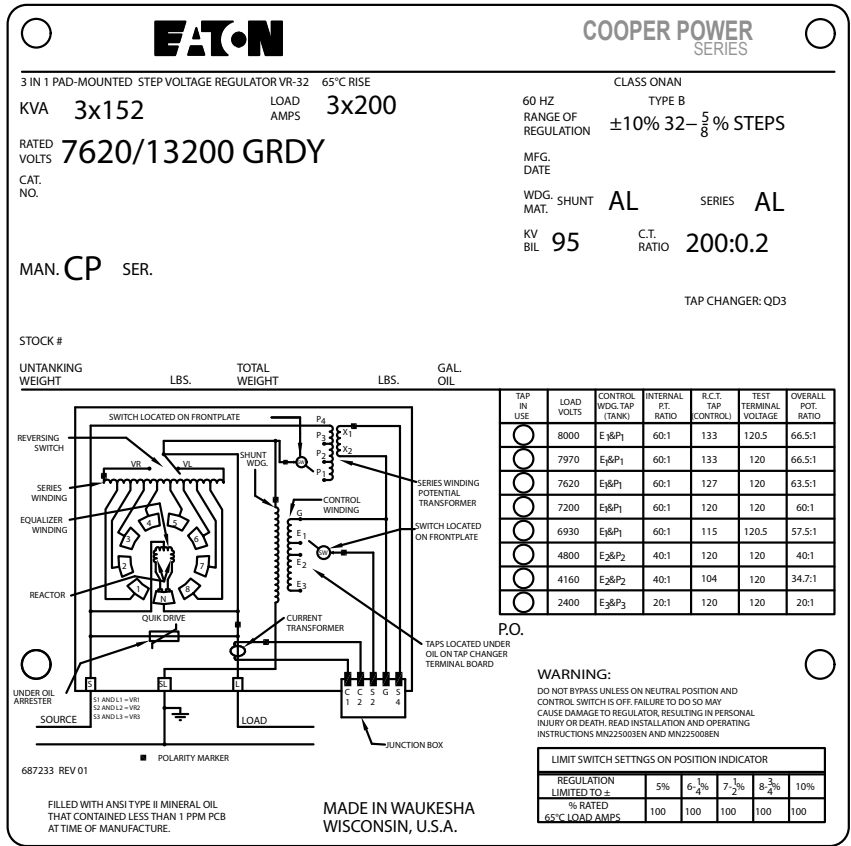


Figure 12. Typical nameplate, 3-in-1 multi-phase, wye connected.

## 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. 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**

**Hazardous Voltage.** To protect personnel from surges while operating the control, 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.** As a standard, the control box on a pad-mounted regulator is grounded to the cabinet and the cabinet is grounded to the tank. The ground pads on the tank should be connected to the system ground to complete the control box grounding. All ground straps must remain in place. A poor ground connection to the control box can result in a hazard to operators and control malfunctions. Attaching a control box to the cabinet without the ground straps in place does not insure a proper ground because of the painted surfaces of the tank and control box.

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 utilizing the bypass module or separate switchgear.

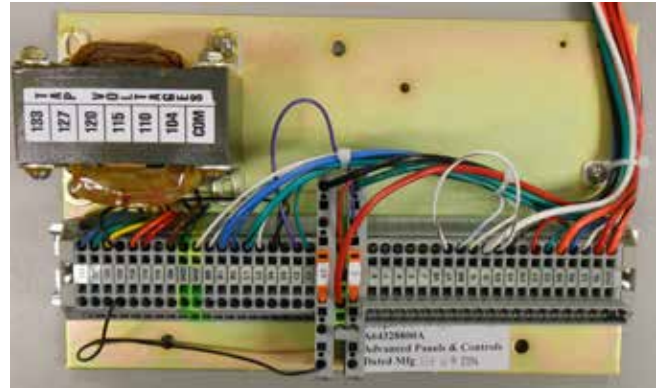


Figure 13. Typical CL-7 single-phase control back-panel.

To perform an operational check and the switching operations to install a regulator onto a service, use the **Operational check and the switching operations procedure** found in the next section.

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.

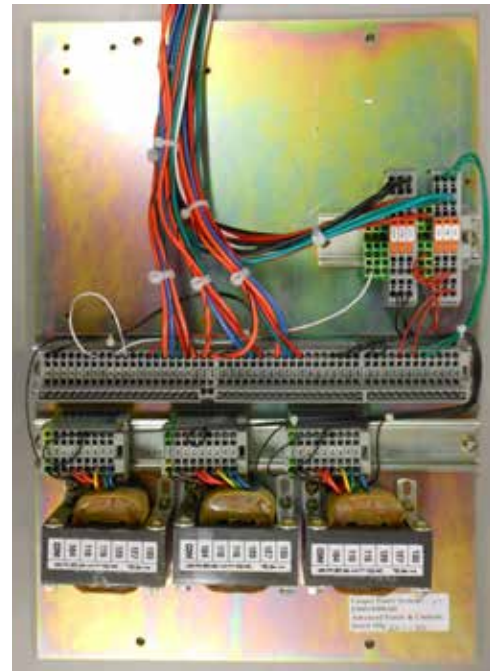


Figure 14. Typical CL-7 control multi-phase back-panel.

## Operational check and the switching operations procedure

This procedure requires the use of a bypass switch and two disconnect switches as would be found in a bypass module. If no bypass module is available, sectionalizing switchgear can be used. If no switching mechanism is available, the line must be de-energized to remove the regulators from service.

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 **V6** 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. With regulator in neutral position, set CONTROL FUNCTION switch to **OFF**, set POWER switch to **OFF**, open **V1** knife switch (and **V6** if present), and remove 6 A motor fuse.
9. Close load (L) disconnect switch.
10. Open bypass switch. The regulator is now energized.
11. Replace 6 A motor fuse, close **V1** 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

Refer to the **Construction and operation: Position Indicator and ADD-AMP Capability** section of this manual 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 15. 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, follow this procedure:

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 15. Position indicator.



## Removal from service

### Determining neutral position

Before removing from service, 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.

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### DANGER

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**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. 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.**

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### WARNING

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**Explosion Hazard. Bypass a regulator with the line energized only if the position indicator, the neutral light, and the control tap position indicate neutral and an additional method has been used to confirm neutral. 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.**

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### Return the regulator to neutral

1. Use the **Raise/Lower** switch to bring the regulator to neutral position.
2. 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.
3. Verifying the neutral position of the regulator using 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 the tap position on the control indicates neutral by using the Metering-PLUS™ key or FC 12. When in neutral, these displays will show "0" (zero).
  - C. Verify that the position indicator on the regulator is in the neutral position. The indicator should point straight up to either zero or N for Neutral.
  - D. Depending upon the equipment supplied with a pad-mounted regulator, use one of these alternatives as a fourth confirmation of neutral:
    - 1) If the voltage regulator is equipped with a

differential PT, measure the voltage between the V6 switch and ground. This voltage should be zero or millivolts. Also compare the source voltage and load voltage by viewing FC 6 and FC 7; these values should be identical. **DO NOT** use this method if the voltage regulator is not equipped with a differential PT.

- 2) If the voltage regulator is not equipped with a differential PT, after tapping the regulator to the neutral position, observe that the neutral light is on and brightly illuminated. Tap the regulator to position R1 and observe that the neutral light goes out. Tap back to neutral and observe that it goes back on. Tap to position L1 and observe that the neutral light goes out. Return to neutral and observe that the neutral light illuminates brightly once again to confirm neutral. **This method MAY be used in all cases as an additional confirmation of neutral.**

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### WARNING

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**Explosion Hazard. After placing the regulator in the neutral position for bypass switching, always disable the motor to prevent a tap change during bypassing which can result in the tap-changer stepping off of neutral. Failure to comply can cause death or severe personal injury and equipment damage.**

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### WARNING

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**Explosion Hazard. To insure a complete tapping operation when returning the tap changer to the neutral position, the CONTROL FUNCTION switch must be placed in the OFF position before the POWER switch is placed in the OFF position. Failure to comply can result in the tap changer stepping off of neutral immediately upon being energized which can result in death or severe personal injury and equipment damage.**

4. When the regulator has been placed in the neutral position, but prior to bypassing, additional safety actions must be taken to disable the tap-changer motor and ensure that the tap-changer will not inadvertently switch to an off-neutral position. This can be accomplished by doing the following in order:
  - 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 **V6** if present) located on control back panel.

### **De-energizing the regulator**

Once it has been established that the regulator is on neutral and the steps have been taken to ensure that the tap-changer motor has been disabled, immediately proceed with the following steps:

1. Close bypass switch.
2. Open load (L) disconnect switch.
3. Open source (S) disconnect switch.
4. Open source-load (SL) disconnect switch, if available.

## **Construction and operation**

Eaton pad-mounted voltage regulators are designed, manufactured, and tested in accordance with IEEE Std C57.15™-2009 or IEEE Std C57.15™-1999 standard as specified and as applicable. The regulators are rated and name-plated for 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, pad-mounted regulators**

**Bushings.** The BIL rating of the bushings is compatible with the BIL of the regulator. Pad-mounted voltage regulator will be equipped with one of the following: 1) 200 A busing wells with either 15 or 25 kV class inserts, 2) 600 A integral bushings, or 3) 900 A integral bushings. The specific bushing used for each rating can be found in Table 11 in the appendix.

**Series Arrester.** All pad-mounted voltage regulators are provided with an under-oil VariSTAR™ composite MOV 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 Gauge.** An insulating fluid level sight gauge indicates fluid color and level at 25 °C ambient.

**Position Indicator.** Located in the cabinet, the corrosion-resistant position indicator indicates the tap-changer position. It is polymer constructed and mounted on a junction box. Multi-phase pad-mounted regulators will have a separate position indicator for each regulator.

**Drain Valve with Sampler.** All regulators have a 1" drain valve with sampling device and a 1" upper filter press connection.

**Bolted Cover.** Pad-mounted voltage regulators are equipped with bolted main covers.

**Ground Provisions.** Pad-mounted voltage regulators are provided with two stainless steel ground pads, one located on the tank in each compartment. Each pad has two stainless steel 1/2"-13 UNC ground provisions. All grounding

provisions are located near the base of the regulator. An additional ground pad will also be located below the SL bushing.

Each control cabinet will be provided with a ground strap tied to the main cabinet door. The main cabinet door will be grounded to the cabinet side and the cabinet side to the front of the tank.

**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 10 psig with a flow rate of 35 SCFM.

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

The external parts of the tank are painted Bell Green, ANSI® 70 (Munsell 7GY 3.29/1.5), and meet the coating and security requirements of IEEE Std C57.12.28™-2005 and IEEE Std C57.12.31™-2010 standards. The inside of the cabinet and tank, tank and bottom of the cover are primed and/or painted.

**Thermometer.** Provisions for a tank thermometer are standard for all pad-mounted voltage regulators.

**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 Shorting Device.** Regulators equipped with quick-connect control cables are also equipped with a solid-state automatic current-transformer shorting device located in the junction box. The shorting device protects the internal CT from high voltages in the event the control cable is disconnected for cut while the voltage regulator is energized.

## 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 1, 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 1. ADD-AMP Adjustments**

Regulation (%)	Current (%)
± 10.0	100
± 8.75	110
± 7.5	120
± 6.25	135
± 5.0	160

The position indicator (see Figures 2 and 5) is mounted on the junction box inside the main cabinet 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 Tables 9 and 10 (see Appendix). 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 pad-mounted voltage regulators are equipped with an under-oil 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. An under-oil VariSTAR™ composite MOV 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 pad-mounted voltage regulators for protection of the shunt winding. Under-oil shunt arresters are available as an option. The shunt arrester is a direct-connected arrester mounted inside the tank and connected between the bushing and ground (earth). It is recommended that arresters be applied to all non-grounded bushings. Shunt arrester application data is listed in Table 2.

**Table 2. Typical Shunt Arrester Application Data\***

Regulator Voltage Rating	Recommended MOV Shunt Arrester Ratings (kV)	Regulator Voltage Rating	Recommended MOV Shunt Arrester Ratings (kV)
2500	3	14400	18
5000	6	15000	21
6600	9	19920	27
7620	10	22000	27
8660	12	33000	36
11000	15	34500	36
13800	18		

\* Contact factory for specific shunt arrester application ratings.

### Internal construction and wiring

In order to access the internal voltage regulator apparatus and wiring, the cover must be removed. After removing the cover, the oil should be pumped down to the level required in order to perform required inspection or maintenance. Untanking of the internal apparatus will require disconnection of the bushing leads.

**Tap Changer.** 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.

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.

Refer to the **Construction and Operation: Quik-Drive Tap-Changers** section of this manual for more information.

**Holding Switch.** 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 insure accurate indication of tap position and operations counting.

**Regulator Windings.** 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.

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 16) 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 17) have a separate potential transformer installed on the load side in lieu of a control winding.

**Control Windings.** 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.

**Equalizer and Bridging Reactor Windings.** Most regulators, depending upon the rating, have an equalizer winding. This winding improves contact life for high-current applications.

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.

**Current Transformer.** 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.

**Schematics.** Figures 25 and 26 (see Appendix) illustrate the typical internal wiring schematics. Molex® receptacles plugged into the junction block inside the junction box on the front panel connect the internal tank wiring to the position indicator and control. The junction box wiring is shown in Figure 27 (see Appendix). 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 28.

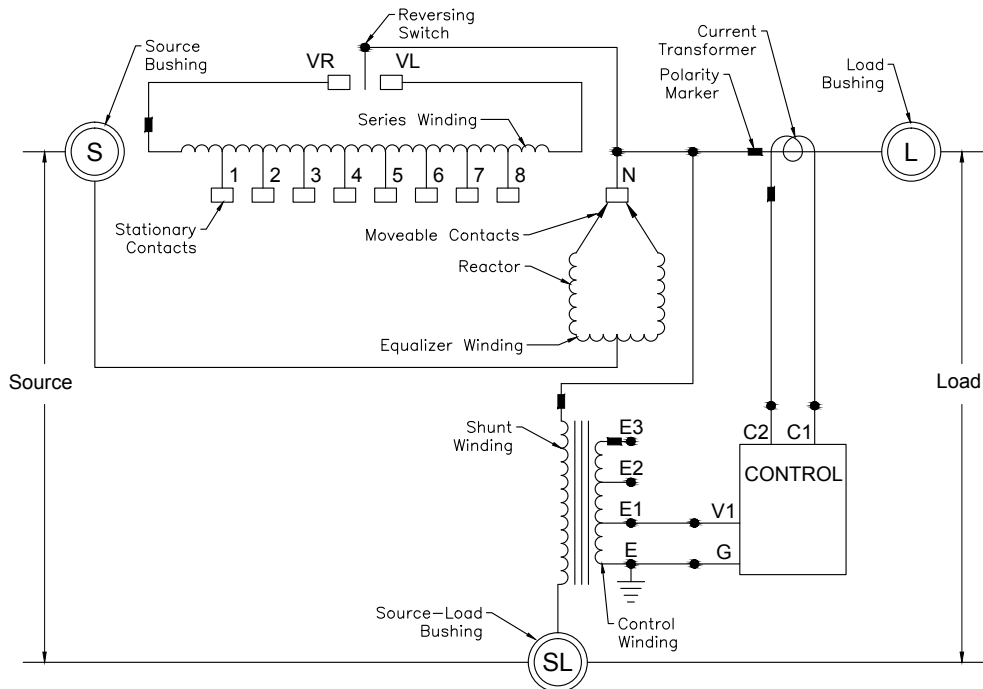


Figure 16. Power circuit—series winding located on the source-side, ANSI® Type B.

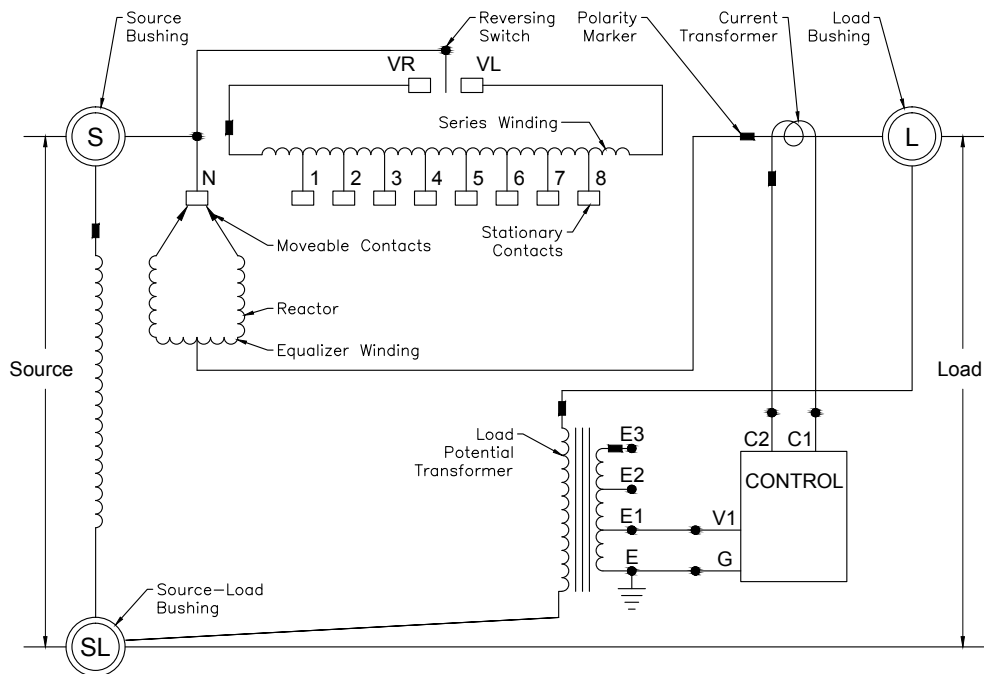


Figure 17. Power circuit—series winding located on the load-side, ANSI® Type A.

## Voltage circuits

Eaton's pad-mounted voltage regulators have provisions for operation at system voltages other than the nominal rating, as listed in Tables 7 and 8 (see Appendix).

Changing system voltages may require a change in the PT ratio. In these cases, the equipped PT will have two or three taps. On Pad-mounted voltage regulators, changing the PT tap is accomplished in one of two ways:

1. A terminal board may be supplied on the top of the tap-changer assembly, under the insulating fluid. The terminals will be marked E1, E2, or E3. The connections are made with push-on terminals and which may be accessed by removing the bolted cover.
2. A no-load tap-changer switch may be supplied inside the cabinet of the voltage regulator. The switch will look similar to that shown in Figure 18. The stenciled marking near the tap changer shows the PT tap position and tap changer switch position separated by a slash. For example, the marking E1/C would indicate that the E1 PT tap is connected by having the tap switch in the C position.

When an **internal differential potential transformer (IDPT)** is provided for Reverse Power Flow application or indication of the unregulated voltage supply, "P" taps will be indicated on the nameplate. If the taps are changed in the tank, there will be terminal connections either on the tap-changer terminal board or on a separate internal PT. If there is an external PT switch, the marking for the "P" taps will be near that switch.

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 Figures 13 and 14).

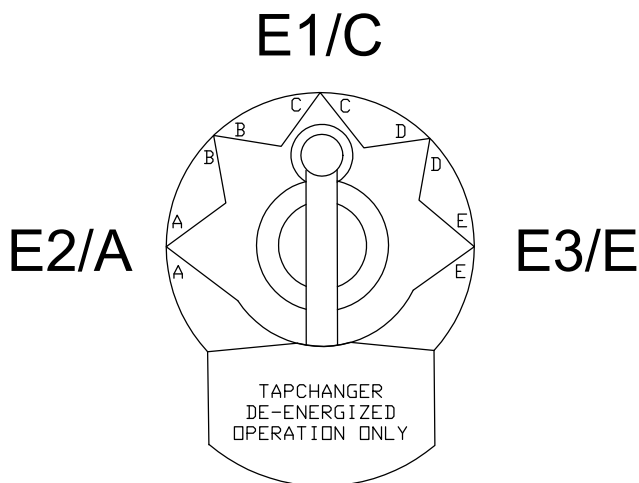


Figure 18. PT tap-changer with stencil markings.

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↓ (Internal PT Ratio). The nameplate provides settings for common system voltages (see Figures 11 and 12).

The internal PT 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** and **V6** if provided). Opening the knife switches provide 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.

For optimal reverse power operation, an IDPT is a good idea. If the voltage regulator is equipped with an IDPT, the control box would be equipped with a V6 switch to provide visible means of removing this power supply to the control.

If the voltage regulator is supplied with an auxiliary winding to provide power for fans or some other equipment, a **V2** switch will also be supplied in the control box for a visible means of removing the auxiliary power below the switch.

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.

To the regulator control 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 to power the control for programming and testing. When the power switch is in the external position, the internal supply is disconnected to prevent accidental back-feeding of the high-voltage winding and bushings. The external-source terminals are located adjacent to the voltmeter test terminals on the front of the control.

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.

Through 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.

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** WARNING**

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**Electrocution Hazard. Applying voltage to the voltmeter terminals on the voltage regulator control 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 V switches on the back panel, apply power to the external source terminals only and move the POWER switch to EXTERNAL.**

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### Current circuit

All pad-mounted voltage regulators are designed with an internal current transformer (CT) to provide a current source for the line-drop compensation calculations, power flow direction determination and for metering functions. Table 3 provides the application information for the various CTs used on Eaton's regulators. These CTs provide 200 mA output for the rated CT primary current.

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** and **V6** knife switches should also be opened. For all regulators with the quick-connect 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 control circuit board. The "high" side of the current circuit is brought to a terminal board through 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.

**Table 3. Current Transformer Applications (50 & 60 Hz)**

Regulator Current Ratings	CT Primary Current
50	50
75	75
100	100
150	150
167, 200	200
219, 231, 250	250
289, 300	300
328, 334, 347, 400	400
418, 438, 463, 500, 502	500
548, 578, 604, 656, 668	600
833, 875	1000

## Motor circuit

Motor power typically is supplied from the control PT located in the voltage regulator tank. The power will be brought into the control box through the V1 switch and RCT. The control input marked **VM** is the point through which motor power enters the control. Motor power flows through the 6 A fuse on the control to the control circuit board and then 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 fully powered.

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 are actuated by the tap-changing mechanism. Motor rotation causes switch closure (one direction or the other) and establishes a 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 CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions*.

The 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.

## Quik-Drive tap-changers

Eaton offers three Quik-Drive tap-changer models (see Figures 19 through 21). 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.



Figure 19. QD3 Quik-Drive 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  $\mu\text{F}$  capacitor for 60 Hz applications and a 15  $\mu\text{F}$  capacitor for 50 Hz applications. This motor is used on the QD3 model tap changer.

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  $\mu\text{F}$  capacitor for 50 and 60 Hz operation. This motor is used on the QD5 and QD8 models of tap changer.



Figure 20. QD5 Quik-Drive tap-changer.



Figure 21. QD8 Quik-Drive tap-changer.

## 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 switch arcing may be occurring directly on the copper surface of the contact. Movable contacts should be replaced when approximately 1/8 inch of smooth surface width remains.

## Operating sequence

When the tap-changer is in the neutral position and the control calls for a tap-change operation, 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 after which the control opens the initial circuit. At this point, 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.

## Maintenance

### Periodic inspections

Step voltage regulators are designed to provide many years of trouble-free operation. The usable life of a regulator is affected by application; periodic inspections are recommended. 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 tap-changer contacts and other mechanical components should be carried out after 4 years or 100,000 operations for a unit loaded at greater than 50% of the rated current level. For units loaded at less than 50%, first inspection should be performed at 10 years or 200,000 operations.

Another useful indicator of the need for inspection and maintenance is the Duty Cycle Monitor (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 CL-6 or later control and the control has been programmed with the correct design specification number.

### Insulating fluid

The fluid should be checked (a) prior to energizing if the regulator has not been energized for a long period of time, and (b) at normal maintenance intervals. Tables 4 and 5 contain information on acceptable insulating fluid characteristics for Envirotemp™ FR3™ fluid and mineral oil, respectively. When characteristic values fall outside of acceptable ranges, steps should be taken to filter or replace the fluid.

Voltage regulator tanks are factory-sealed to prevent ingress of ambient air and moisture. Do not remove the tank cover under any precipitation conditions.

If it is necessary to drain and refill the voltage regulator, special care should be taken to avoid the entrapment of gas bubbles in the system. Gas bubbles have lower dielectric integrity than the insulating liquid and will degrade the performance characteristics of the insulating system. To minimize the possibility of trapped air bubbles, the tank should be filled under vacuum and remain under vacuum for a minimum of one hour after filling. If vacuum filling is not possible, the regulator should remain unenergized for a minimum of 24 hours after filling.

**Table 4. Envirotemp™ FR3™ Fluid Characteristics (natural ester\*)**

	New	Used
Dielectric Strength (kV)		
ASTM D1816		
2 mm gap	≥ 45	≥ 40
1 mm gap	≥ 25	≥ 23
Interfacial Tension (mNm)		
ASTM D971-91	—	—
Water (mg/kg)		
ASTM D1533	≤ 300	**

\* Per IEEE Std C57.147™-2008 standard

\*\* Recommended limit is application- and user-specific. Suggested limit would be the same relative saturation limit used for mineral oil at a given temperature.

**Table 5. Mineral Oil Characteristics (Type II\*)**

	New	Used
Dielectric Strength (kV)		
ASTM D1816		
2 mm gap	≥ 45	≥ 40
1 mm gap	≥ 25	≥ 23
Interfacial Tension (mNm)	≥ 38	≥ 25
ASTM D971		
Water (mg/kg)	≤ 20	≤ 35
ASTM D1533		

\* Per IEEE Std C57.106™-2006 standard

### 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.

## Exterior maintenance

On an annual or more frequent interval, inspect all exposed surfaces for evidence of tampering, battered metal, gouges, etc. Dents or deformities should be repaired at once. Scratched or weathered paint or protective coatings should be touched up promptly.

Keep the area around the pad-mounted voltage regulator clean. Do not store tools, materials or equipment on or against the unit.

## Interior maintenance

### Cabinet interior maintenance



#### WARNING

**Hazardous voltage. Severe injury, death, or damage to equipment can result. Bypass the pad-mounted voltage regulator and remove from the pad or de-energized from and upstream source before doing cabinet interior maintenance. Check that all voltage regulator terminals and bushings have zero voltage. Ground the voltage regulator following industry accepted safe grounding practices.**

---

Periodically inspect the terminal compartment interior and all operating equipment. Check all gauges and controls for proper operation. Repair or replace damaged or defective equipment.

Inspect drain cocks, plugs, and switches. Look for evidence of insulating fluid seepage around tank wall gaskets, seals, etc. Repair as required.

Replacement of gaskets or seals in the tank wall may require that the tank be opened and the insulating fluid lowered to the appropriate level. For instruction on opening the tank and for draining and replacing the insulating fluid, refer to the **Maintenance: Insulating fluid** section in this manual.

### Tank internal maintenance



#### CAUTION

**Elevated Pressure. Uncontrolled release of pressure can cause personal injury or damage to voltage regulator. Release internal pressure with pressure relief device before removing tank cover.**

---



#### WARNING

**Hazardous voltage. Severe injury, death, or damage to equipment can result. Bypass the pad-mounted voltage regulator and remove from the pad or de-energized from and upstream source before doing internal tank inspection or maintenance. Check that all voltage regulator terminals and bushings have zero voltage. Ground the voltage regulator following industry accepted safe grounding practices.**

---

Service to the tap changer, bushings or equipment inside the pad-mounted voltage regulator tank will require that the tank be opened and the insulating fluid lowered to the appropriate level. Before opening the voltage regulator tank, read the **Maintenance: Insulating fluid** section in this manual. The **Maintenance: Insulating fluid** section explains safety precautions that should be taken and gives instructions on how to prevent insulating fluid contamination. Precautions must be taken to prevent dirt or moisture from entering the opened voltage regulator tank. Contamination of the insulating fluid will prevent the voltage regulator from operating properly and may cause serious damage.

Pad-mounted voltage regulators will have a bolt-on main tank cover. Bolt-on covers can be removed to access the tank interior.

### Tank cover removal and installation



#### CAUTION

**Elevated Pressure. Uncontrolled release of pressure can cause personal injury or damage to voltage regulator. Release internal pressure with pressure relief device before removing tank cover.**

---



#### WARNING

**Hazardous voltage. Severe injury, death, or damage to equipment can result. Bypass the pad-mounted voltage regulator and remove from the pad or de-energized from and upstream source before doing cabinet interior maintenance. Check that all voltage regulator terminals and bushings have zero voltage. Ground the voltage regulator following industry accepted safe grounding practices.**

---

Voltage regulators that have been system-connected should be bypassed, grounded, and disconnected before being opened for inspection. If a pad-mounted bypass module is used in conjunction with the voltage regulator, the voltage regulator should be removed from the pad to allow distance between personnel and the energized bypass module.

If the tank seal is broken, it is recommended that a leak test be performed to verify that the tank is properly sealed. To leak test, remove the pressure relief device and pressurize the headspace. The test pressure should not exceed 7 psig. The established pressure should be maintained for at least four hours to insure that all the seals are proper.

### Bolt-on tank cover removal

Pad-mounted voltage regulator tanks are factory-sealed to prevent ingress of ambient air and moisture. Do not open under any precipitation conditions.

1. Verify that tank is grounded. Bypass the voltage regulator. If the voltage regulator shares the pad with a bypass module, remove the voltage regulator from the pad. If the regulator is not equipped with a bypass module, de-energize voltage regulator from a remote upstream source. Ground all bushings and terminals before removing cover.
2. Thoroughly clean tank cover to help prevent contamination of insulating fluid when removing the cover. Remove all dirt, grease, and moisture.
3. From within the cabinet, remove the hardware (3/8" nuts using a 9/16" socket) which attaches the cover nut-guard to the faceplate.
4. Relieve internal tank pressure by operating the pressure relief valve. Remove the hardware (3/8" nuts using a 9/16" socket) which attaches the cover to the tank.
5. Gently pry the cover upward. Do not allow the cover gasket to come in contact with the insulating fluid. Allowing the gasket to contact the fluid will make it slippery and difficult to hold in position during cover installation. Lift cover straight up to prevent damage to cover, bolts, and tank gasket.
6. Note the location and orientation (up/down) of each gasket section as they are removed from the tank flange so that they can be reinstalled properly.

### Bolt-on tank cover installation

1. Return the gasket sections to their original positions and orientation.
2. Re-install the cover, using 25 ft-lbs. torque to tighten the cover hardware. After installing all the nuts, retighten the nuts to the correct torque to ensure proper torque is achieved.
3. Remove the pressure relief valve and pressurize the headspace through the pressure relief valve coupling to ensure that there are no leaks. Test pressure should not exceed 7 psig. Established pressure should be maintained for at least four hours to insure that all seals are proper.
4. Reinstall the nut-guard using 25 ft-lbs. torque to tighten nut-guard access hardware.
5. Re-install pressure relief valve.

### Tap changer maintenance

1. Verify that tank is grounded. Bypass the voltage regulator. If the voltage regulator shares the pad with a bypass module, remove the voltage regulator from the pad. If the regulator is not equipped with a bypass module, de-energize voltage regulator from a remote

upstream source. Connect all bushings and terminals to ground before removing the cover.

2. Open the tank by removing the tank cover as outlined in Tank Cover Removal and Installation section of this manual.
3. Lower insulating fluid level as outlined in the **Maintenance: Insulating fluid** section of this manual. Lower the fluid level to completely expose the tap changer.
4. Complete the maintenance as noted for each type of tap changer:
  - A. QD5 and QD8 tap changers – Basic maintenance such as contact removal and replacement may be able to be performed while tap changer is installed on the unit and in the tank. Follow the procedures as outlined in the documents *S225-12-2 (MN225012EN)*, *QD5 Quik-Drive Voltage Regulator Tap-Changer Manual* and *MN225032EN*, *QD8 Quik-Drive Voltage Regulator Tap-Changer Manual* (future release). If the tap changer must be removed, follow the procedure for QD3 tap changer removal.
  - B. QD3 tap changer – Maintenance for the QD3 tap change can only be performed with the tap changer removed from the unit. Follow the procedures as outlined in the documents *S225-12-1 (MN225031EN)*, *QD3 Quik-Drive Voltage Regulator Tap-Changer Manual*.
5. Restore insulating fluid to appropriate level as outlined in the **Maintenance: Insulating fluid** section section of this manual. Close, reseal, and leak test tank as outlined in the **Maintenance: Tank Cover Removal and Installation** section of this manual.

### Bushing removal and replacement

1. Verify that tank is grounded. Bypass the voltage regulator. If the voltage regulator shares the pad with a bypass module, remove the voltage regulator from the pad. If the regulator is not equipped with a bypass module, de-energize voltage regulator from a remote upstream source. Connect all bushings and terminals to ground before removing the cover.
2. Open the tank by removing the tank cover as outlined in **Maintenance: Tank Cover Removal and Installation** section of this manual.
3. Lower insulating fluid level as outlined in the **Maintenance: Insulating fluid** section of this manual. Lower the fluid level to completely expose the bushing.
4. Disconnect all internal and external cable and leads. Note position of all nuts, flat washers, spring washers, etc., so they can be re-installed in same locations.
5. Remove all bushing clamp hardware, noting position of all nuts, flat washers, spring washers, etc., so they can be re-installed in same locations.
6. Remove external bushing clamp, bushing, and gasket.

7. Install a new bushing and gasket. Center the bushing and gasket to obtain an effective seal. Install exterior bushing clamp and clamp hardware. Tighten clamp nuts to a torque of 40-60 in-lbs.
8. Re-connect all external and internal cables and leads. Replace all nuts, flat washers, spring washers, etc., in their original position. Tighten all connections per torque specified (3/8"-16 brass nuts: 16 ft-lbs; 5/8"-11 brass nuts: 75 ft-lbs.; 1"-14 brass nuts: 121 ft-lbs.)
9. Restore insulating fluid to appropriate level as outlined in the **Maintenance: Insulating fluid** section of this manual. Close, reseal, and leak test tank as outlined in the **Maintenance: Tank Cover Removal and Installation** section of this manual.
10. Inspect bushing-to-tank seal for leaks or seepage.

**CAUTION**

**Potential falling object. Falling objects can cause personal injury or damage to the voltage regulator. Do not open the cabinet doors when cabinet is removed from the voltage regulator tank. Opening the cabinet doors will cause the cabinet to fall forward.**

**WARNING**

**Hazardous voltage. Severe injury, death, or damage to equipment can result. Bypass the pad-mounted voltage regulator and remove from the pad or de-energized from and upstream source before doing cabinet interior maintenance. Check that all voltage regulator terminals and bushings have zero voltage. Ground the voltage regulator following industry accepted safe grounding practices.**

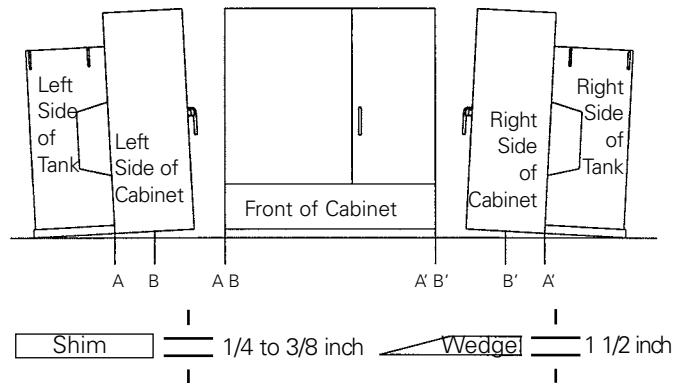
**Cabinet removal and installation**

1. Bypass the voltage regulator. If the voltage regulator shares the pad with a bypass module, remove the voltage regulator from the pad. If the regulator is not equipped with a bypass module, de-energize voltage regulator from a remote upstream source..
2. Place one 1/4 to 3/8 inch shim directly below faceplate of the voltage regulator on both sides of tank at points A and A' (see Figure 22).
3. Place one 1 1/2 inch wedge under each side of cabinet at points B and B' to relieve strain on the cabinet.
4. Note position and orientation of gasket that is between top of cabinet and tank so it can be re-installed in same fashion.
5. Disconnect center barrier if present from vertical bracket of faceplate.
6. Remove hardware attaching cabinet to faceplate on left and right sides of faceplate. Note position of all nuts, flat washers, spring washers, etc., so they can be reinstalled in same locations.
7. Fully close HV and LV doors.

8. Slide cabinet assembly away from tank.

**Cabinet installation**

Reverse the removal procedure to re-install the cabinet. Re-attach the cabinet using shims under the front of the tank and wedges under the sides of the cabinet; making sure the cabinet gasket is inserted into the cabinet back channel prior to attaching the cabinet. Tighten cabinet hardware to a torque of 20 ft-lbs.



**Figure 22. Cabinet removal diagram.**

## Spare parts

### Ordering information

When ordering replacement parts or field-installation accessories for your VR-32 voltage regulator, provide the following information:

- Regulator serial number (found on nameplate)
- Regulator catalog number (found on nameplate)
- Part number if known
- Description of each part
- Quantity of each part required

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

- *S225-12-1 (MN225031EN), QD3 Quik-Drive Voltage Regulator Tap-Changer Manual*
- *S225-12-2 (MN225012EN), QD5 Quik-Drive Voltage Regulator Tap-Changer Manual*
- *MN225032EN, QD8 Quik-Drive Voltage Regulator Tap-Changer Manual (future release)*

## Troubleshooting

For Troubleshooting instructions, refer to Section 8 of *Service Information MN225003EN CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions*.

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.

### Troubleshooting procedures and tests

#### Regulator control reverse power flow test

##### **Purpose**

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

##### **Required equipment**

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

---

#### **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 outlined in the **INSTALLATION: Removal from Service** section of this manual.

---

#### **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 Source (S) and the Load (L) 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 **V6** if present) and **C** switches on the control assembly back 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 CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions*.
8. Using the manual **Raise/Lower** switch, place the regulator on the **3 Raise** position.

---

#### **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.**

---

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 Load (L) and Source-Load (SL) 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 outlined in the **INSTALLATION: Removal from Service** section of this manual.
2. Connect a voltmeter between the “L” and “SL” bushing terminals.
3. Use a variac to apply 120 Vac between the source (S) and source-load (SL) bushing terminals.

---

#### 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.**

---

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

---

#### WARNING

---

**Electrical Shock Hazard. The V1 and V6 (if present) knife-blade switches must be open when connecting external power to the control. If 120 Vac is incorrectly applied to the voltmeter terminals and the V1 and V6 switches remain closed, rated voltage will 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.**

---

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 item 5 and 6 are computed, you will see that a 1.0 volt difference between steps will result. Doing this will simplify the ratio check.

**Table 6. Typical Meter Readings with 120 Vac Connected Between the S and SL Bushings**

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

7. Operate the tap-changer with the control switch through all 32 steps from 16R to 16L. Record the voltmeter reading at each tap position. The change in voltage should be almost the same between each step ( $\pm 0.10$  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

---

#### **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.**

---

#### **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.**

---

1. Remove the unit from service, as outlined in the **INSTALLATION: Removal from Service** section of this manual.
2. Open the back-panel knife switch marked V1.
3. 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 E1, E2 or E3; this should correspond to the PT ratio for the voltage pinned on the nameplate.
4. With the regulator in the neutral position, connect 120 Vac between the source (S) and the source load (SL) bushings.
5. 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 V1 switch and the terminal strip ground marked 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.

## Voltage regulator dry-out procedure

### Purpose

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

### 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

---

#### **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 outlined in the **INSTALLATION: Removal from Service** section of this manual.

---

#### **WARNING**

---

**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 the external source terminals and voltage source. For instruction on connecting the control to an external source, see *Service Information MN225003EN CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions*.
4. Place a jumper, rated for nominal current, between the source (S) and the load (L) bushings. A clamp-on ammeter should be used to measure the current in the shorted current path.
5. Ground the regulator tank.

---

#### **WARNING**

---

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

---

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.

## Voltage regulator current test

### **Purpose**

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

### **Required equipment**

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

---

### **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 outlined in the **INSTALLATION: Removal from Service** section of this manual.

---

### **WARNING**

---

**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.
3. Use the external source terminals and voltage source to power the control and enable tap changer operation. See the section in *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 source (S) and load (L) 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 knife switch **C** on the back panel.

- Remove the jumper from between the C2 and C3 terminals to the left of the V1 switch on the TB3 terminal board, on the back panel. See Figure 23. Place a milli-ampere meter between these terminals. See Figure 24.

---

### CAUTION

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**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

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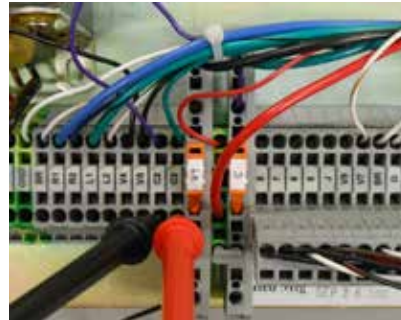
**Equipment Damage. Only an ac power supply is to be used to energize the control externally. Do not use a dc-to-ac voltage inverter. Failure to comply can cause excessive harmonics to be generated and result in damage to the front panel.**

---

- Using a variable voltage source, place approximately 120 V between the L and SL bushings until a current value is shown on the clamp-on meter.
- 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.
- 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 23. Removing jumper between C2 and C3.**



**Figure 24. Milli-ampere connection points.**

## Voltage regulator 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

---

### 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 outlined in the **INSTALLATION: Removal from Service** section of this manual.
2. Conduct this test with the regulator located in the maintenance shop or other suitable location.

**Note:** Regulator tank must be isolated from ground potential.

---

### CAUTION

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**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.**

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### CAUTION

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**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 the section in *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 knife switch **C** on the back panel.
6. Using the variac on the tester, bring the voltage up to the desired test level. Refer to the tester manufacturer instructions for guidelines on voltage test levels.
7. Read the test value in mega-ohms.

8. Compare the reading with the baseline reading.

When a lower reading is obtained, further testing and evaluation of the insulation is recommended. No further testing is indicated when the reading is the same or higher than the baseline reading.

## Procedure to free 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)

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** (CT) shorting 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.
- 

### CAUTION

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**Hazardous Voltage. The lead terminal "HS" could have 120 V present when disconnected from the terminal board. Do not touch the lead terminal or allow the terminal to make contact with any surface. Failure to comply can cause personal injury or blow a fuse.**

---

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/LOWER** switch in the direction the capacitive (higher) voltage was observed. This should allow the tap-changer to free itself. Using the **RAISE/LOWER** 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/LOWER** 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 CT shorting switch.
18. Place the **POWER** switch on **INTERNAL**.
19. Turn **CONTROL FUNCTION** control switch to **LOCAL MANUAL**.
20. Using the **RAISE/LOWER** 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 a minimum of four (4) checks are performed to confirm that the voltage regulator is in the neutral position:
  - 1) The neutral light remains on continuously;
  - 2) the position indicator points directly at N;
  - 3) the control panel position indication viewed at FC 12 reads zero;
  - 4) a voltage measurement between the S and L bushing measured using voltmeter test equipment indicates no differential voltage.

Refer to the **Installation: Remove from Service** section of this manual and *Service Information MN225003EN, CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions* for detailed service information and safe bypassing instructions.

# Appendix

**Table 7. Pad-mounted Voltage Regulator Tap Connections and Voltage Levels (60 Hz)**

Regulator Voltage Rating	Nominal Single-Phase Voltage	Ratio-Adjusting Data			Test Terminal Voltage **	Overall Potential Ratio **
		Internal Tap*	PT Ratio	RCT Tap		
1	2	3	4	5	6	7
7620	8000	E <sub>1</sub> /P <sub>1</sub>	60:1	133	120.5	66.5:1
	7970	E <sub>1</sub> /P <sub>1</sub>	60:1	133	120	66.5:1
	7620	E <sub>1</sub> /P <sub>1</sub>	60:1	127	120	63.5:1
	7200	E <sub>1</sub> /P <sub>1</sub>	60:1	120	120	60:1
	6930	E <sub>1</sub> /P <sub>1</sub>	60:1	115	120.5	57.5:1
	4800	E <sub>2</sub> /P <sub>2</sub>	40:1	120	120	40:1
	4160	E <sub>2</sub> /P <sub>2</sub>	40:1	104	120	34.7:1
	2400	E <sub>3</sub> /P <sub>3</sub>	20:1	120	120	20:1
14400	14400	E <sub>1</sub> /P <sub>1</sub>	120:1	120	120	120:1
	13800	E <sub>1</sub> /P <sub>1</sub>	120:1	115	120	115:1
	13200	E <sub>1</sub> /P <sub>1</sub>	120:1	110	120	110:1
	12000	E <sub>1</sub> /P <sub>1</sub>	120:1	104	115.5	104:1
	7970	E <sub>2</sub> /P <sub>2</sub>	60:1	133	120	65.5:1
	7620	E <sub>2</sub> /P <sub>2</sub>	60:1	127	120	63.5:1
	7200	E <sub>2</sub> /P <sub>2</sub>	60:1	120	120	60:1
	6930	E <sub>2</sub> /P <sub>2</sub>	60:1	150	120.5	57.5:1
19920	19920	E <sub>1</sub> /P <sub>1</sub>	166:1	120	120	166:1
	17200	E <sub>1</sub> /P <sub>1</sub>	166:1	104	119.5	143.9:1
	16000	E <sub>2</sub> /P <sub>2</sub>	120:1	133	120.5	133:1
	15242	E <sub>2</sub> /P <sub>2</sub>	120:1	127	120	127:1
	14400	E <sub>2</sub> /P <sub>2</sub>	120:1	120	120	120:1
	7970	E <sub>3</sub> /P <sub>3</sub>	60:1	133	120	65.5:1
	7620	E <sub>3</sub> /P <sub>3</sub>	60:1	127	120	63.5:1
	7200	E <sub>3</sub> /P <sub>3</sub>	60:1	120	120	60:1
34500	34500	E <sub>1</sub> /P <sub>1</sub>	287.5:1	120	120	287.5:1
	19920	E <sub>2</sub> /P <sub>2</sub>	165.5:1	120	120.5	165.5:1

**Table 8. Pad-mounted Voltage Regulator Tap Connections and Voltage Levels (50 Hz)**

Regulator Voltage Rating	Nominal Single-Phase Voltage	Ratio-Adjusting Data			Test Terminal Voltage **	Overall Potential Ratio **
		Internal Tap*	PT Ratio	RCT Tap		
1	2	3	4	5	6	7
11000	11600	E <sub>1</sub> /P <sub>1</sub>	91.6:1	127	119.7	96.9:1
	11000	E <sub>1</sub> /P <sub>1</sub>	91.6:1	120	120.1	91.6:1
	10000	E <sub>1</sub> /P <sub>1</sub>	91.6:1	110	119.1	84.0:1
	6930	E <sub>2</sub> /P <sub>2</sub>	55.0:1	127	119.1	58.2:1
	6600	E <sub>2</sub> /P <sub>2</sub>	55.0:1	120	120.1	55.0:1
	6350	E <sub>2</sub> /P <sub>2</sub>	55.0:1	115	120.6	52.7:1
	6000	E <sub>2</sub> /P <sub>2</sub>	55.0:1	110	119.1	50.4:1
	5500	E <sub>2</sub> /P <sub>2</sub>	55.0:1	104	115.5	47.6:1
	23000	E <sub>1</sub> /P <sub>1</sub>	183.4:1	120	125.4	183.4:1
	22000	E <sub>1</sub> /P <sub>1</sub>	183.4:1	120	120.0	183.4:1
22000	20000	E <sub>1</sub> /P <sub>1</sub>	183.4:1	110	119.0	168.1:1
	19100	E <sub>1</sub> /P <sub>1</sub>	183.4:1	104	120.2	158.9:1
	15000	E <sub>2</sub> /P <sub>2</sub>	122.3:1	120	122.7	122.3:1
	12700	E <sub>2</sub> /P <sub>2</sub>	122.3:1	104	119.9	106.0:1
	11000	E <sub>3</sub> /P <sub>3</sub>	91.7:1	120	120.0	91.7:1
	10000	E <sub>3</sub> /P <sub>3</sub>	91.7:1	110	119.0	84.0:1

\* 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.

\*\* 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 9. ADD-AMP Capabilities of 60 Hz Ratings\*\***

Rated Volts	Rated kVA	†Load Current Ratings (A)					
		Regulation Range (Wye and Open Delta)					
		± 10%	± 8.75%	± 7.5%	± 5%		
Regulation Range (Closed Delta)							
		±15%	± 13.1%	± 11.3%	± 9.4%	± 7.5%	
2500	50	200	220	240	270	320	
	75	300	330	360	405	480	
	100	400	440	480	540	640	
	125	500	550	600	668	668	
	167	668	668	668	668	668	
	250	1000	1000	1000	1000	1000	
	333	1332	1332	1332	1332	1332	
	416.3	1665	1665	1665	1665	1665	
5000	25	50	55	60	68	80	
	50	100	110	120	135	160	
	100	200	220	240	270	320	
	125	250	275	300	338	400	
	167	334	367	401	451	534	
	250	500	550	600	668	668	
	333	668	668	668	668	668	
	416.3	833	833	833	833	833	
7620*	38.1	50	55	60	68	80	
	57.2	75	83	90	101	120	
	76.2	100	110	120	135	160	
	114.3	150	165	180	203	240	
	167	219	241	263	296	350	
	250	328	361	394	443	525	
	333	438	482	526	591	668	
	416.3	548	603	658	668	668	
	500	656	668	668	668	668	
	667	875	875	875	875	875	
	833	1093	1093	1093	1093	1093	
13800	69	50	55	60	68	80	
	138	100	110	120	135	160	
	207	150	165	180	203	240	
	276	200	220	240	270	320	
	414	300	330	360	405	480	
	500	362	398	434	489	579	
	552	400	440	480	540	640	
	667	483	531	580	652	668	
	833	604	664	668	668	668	
	14400	72	50	55	60	68	80
		144	100	110	120	135	160
288		200	220	240	270	320	
333		231	254	277	312	370	
416		289	318	347	390	462	
432		300	330	360	405	480	
500		347	382	416	468	555	
576		400	440	480	540	640	
667		463	509	556	625	668	
720		500	550	600	668	668	
833		578	636	668	668	668	
19920	100	50.2	55	60	68	80	
	200	100.4	110	120	135	160	
	333	167	184	200	225	267	
	400	200.8	220	240	270	320	
	500	250	275	300	338	400	
	667	335	369	402	452	536	
	833	418	460	502	564	668	
	1000	502	552	602	668	668	
34500	172.5	50	55	60	68	80	
	345	100	110	120	135	160	
	517	150	165	180	203	240	
	690	200	220	240	270	320	

**Table 10. ADD-AMP Capabilities of 50 Hz Ratings\*\***

Rated Volts	Rated kVA	†Load Current Ratings (A)					
		Regulation Range (Wye and Open Delta)					
		± 10%	± 8.75%	± 7.5%	± 6.25%	± 5%	
Regulation Range (Closed Delta)							
		± 15%	± 13.1%	± 11.3%	± 9.4%	± 7.5%	
6600	33	50	55	60	68	80	
	66	100	110	120	135	160	
	99	150	165	180	203	240	
	132	200	220	240	270	320	
	198	300	330	360	405	480	
	264	400	440	480	540	640	
	330	500	550	600	668	668	
	396	600	660	668	668	668	
	11000	55	50	55	60	68	80
		110	100	110	120	135	160
165		150	165	180	203	240	
220		200	220	240	270	320	
330		300	330	360	405	480	
440		400	440	480	540	640	
550		500	550	600	668	668	
660		600	660	668	668	668	
15000		75	50	55	60	68	80
		150	100	110	120	135	160
	225	150	165	180	203	240	
	300	200	220	240	270	320	
	450	300	330	360	405	480	
	600	400	440	480	540	640	
	750	500	550	600	668	668	
	16000	160	100	110	120	135	160
		320	200	220	240	270	320
		22000	110	50	55	60	68
220			100	110	120	135	160
330	150		165	180	203	240	
440	200		220	240	270	320	
660	300		330	360	405	480	
880	400		440	480	540	640	
33000	165	50	55	60	68	80	
	330	100	110	120	135	160	
	495	150	165	180	203	240	
	333	231	254	277	312	370	
	660	200	220	240	270	320	

\* Regulators are capable of carrying current corresponding to rated kVA when operated at 7200 V.

\*\*These table contain standard ADD-Amp ratings. Not all of the rating are available for pad-mounted voltage regulators. Consult you Eaton representative for available ratings.

† 55/65 °C rise rating on VR-32 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.



**Table 11. Pad-mounted Voltage Regulator Ratings and Corresponding Bushing Terminations**

<b>Bushing Type</b>	<b>Voltage Class (kV)</b>	<b>V<sub>Max</sub> (Ph-Ph) (kV)</b>	<b>V<sub>Max</sub> (Ph-Gnd) (kV)</b>	<b>BIL (kV)</b>	<b>I<sub>Max</sub> (A)</b>
Well	25	28	16.2	125	200
Well	35	36.6	21.1	150	200
Integral Loadbreak	15	14.4	8.3	95	200
Integral Loadbreak	25	26.3	15.2	125	200
Integral Loadbreak	35	36.6	21.1	150	200
Integral Deadbreak	25	26.3	15.2	125	600
Integral Deadbreak	35	36.6	21.1	150	600
Integral Deadbreak	25	26.3	15.2	125	900
Insert	15	14.4	8.3	95	200
Insert	25	26.3	15.2	125	200
Insert	25	28	16.2	125	200

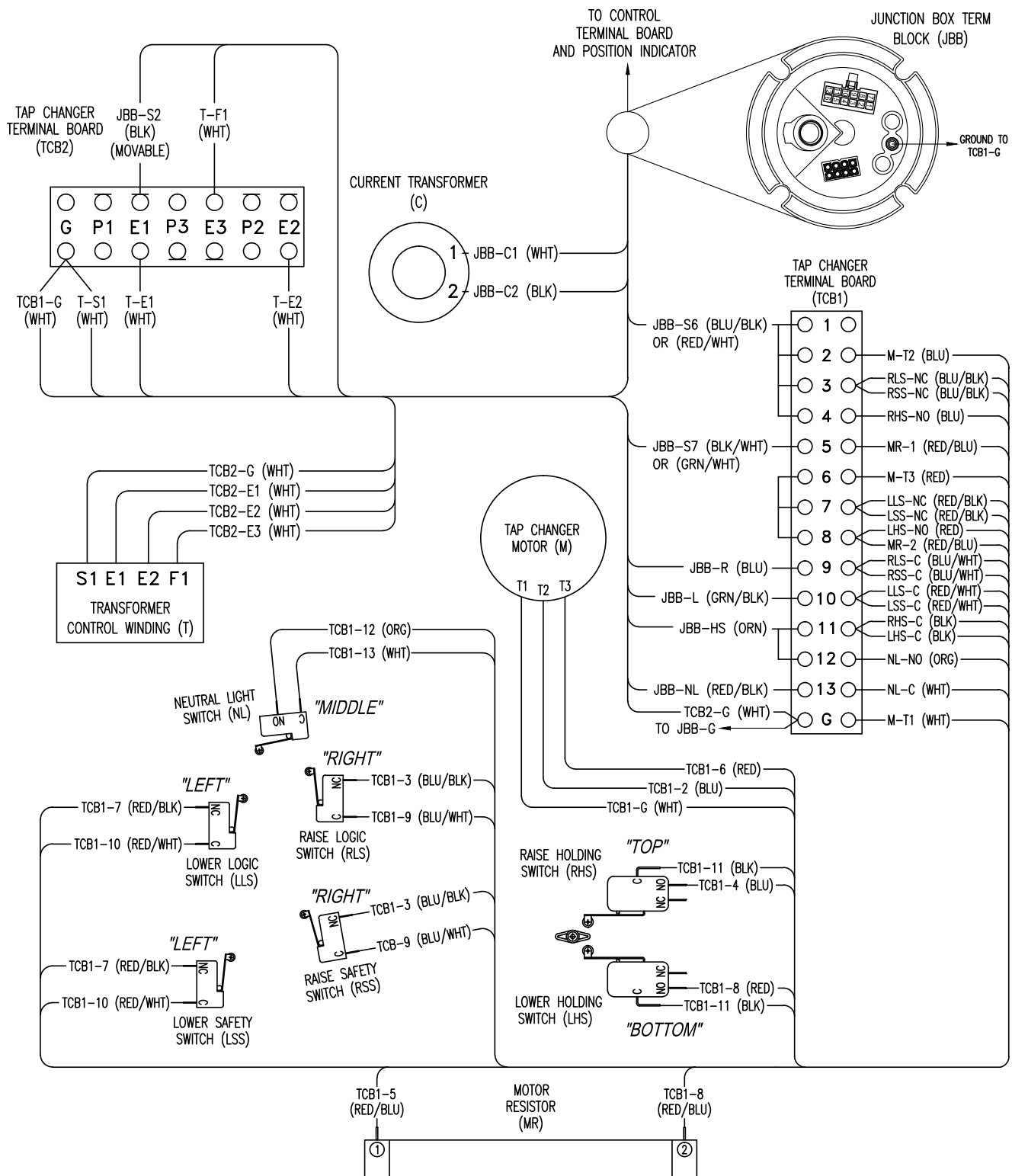


Figure 25. Typical internal wiring of voltage regulators with a QD3 tap-changer.

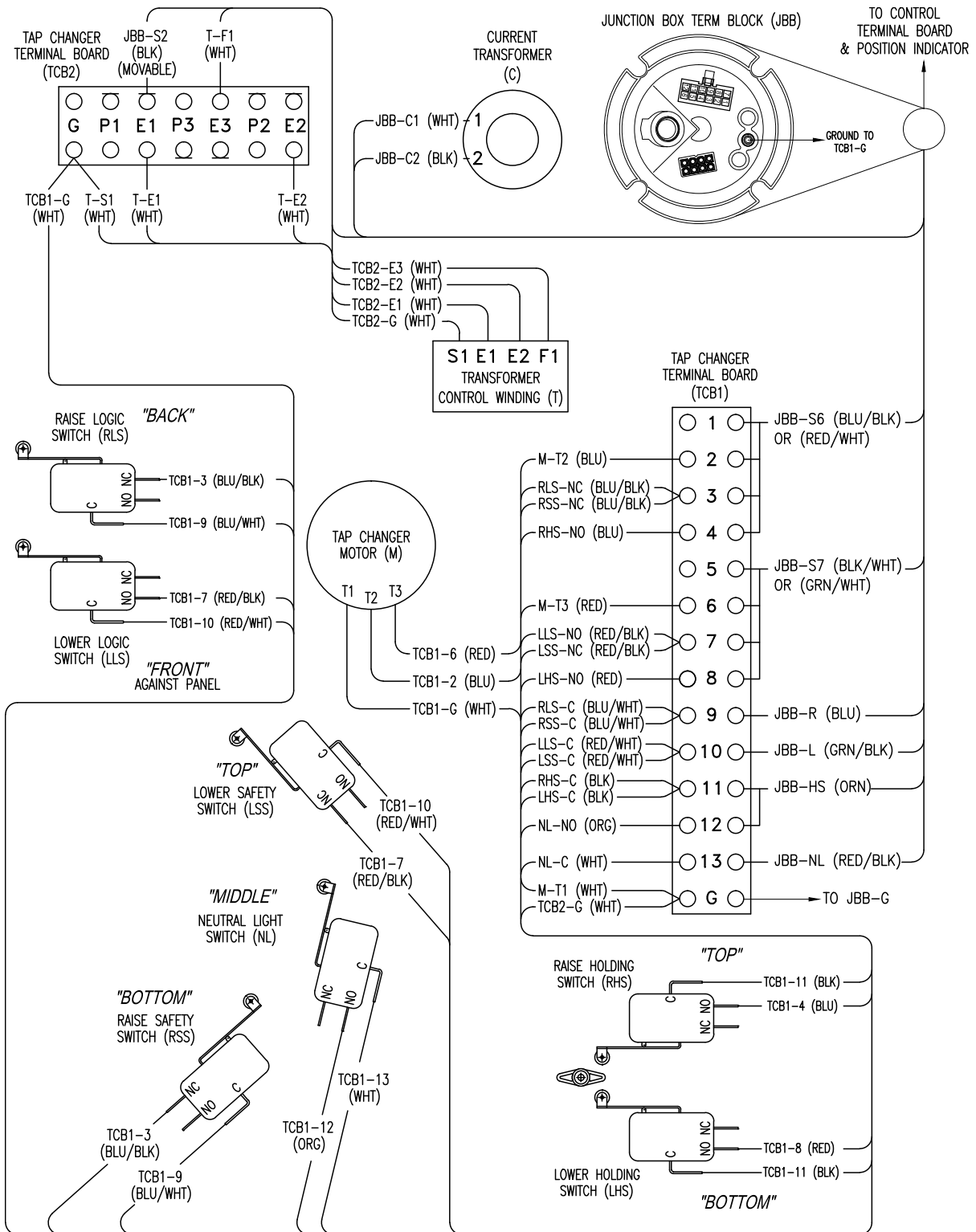


Figure 26. Typical internal wiring of voltage regulators with QD5 and QD8 tap-changers.

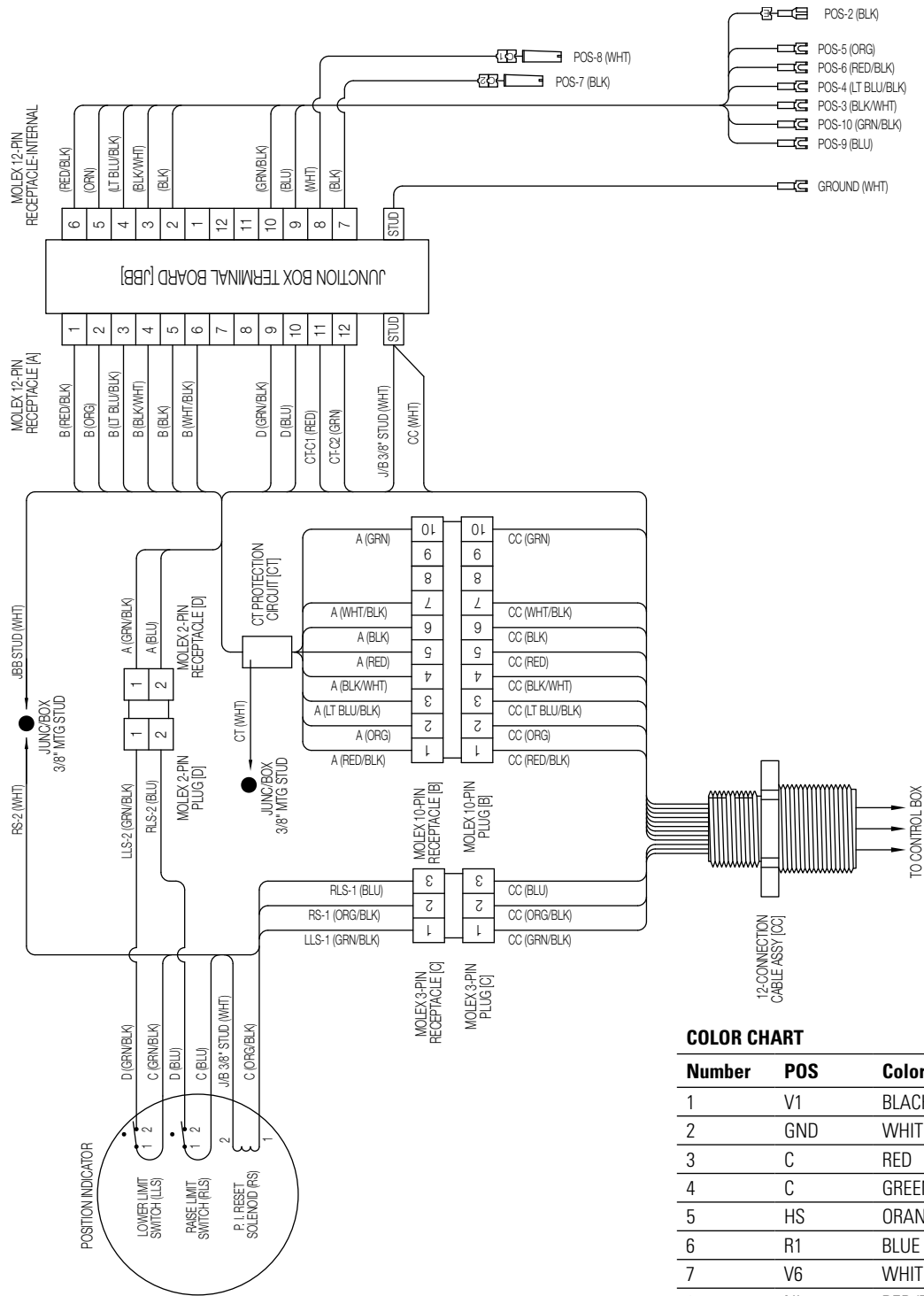
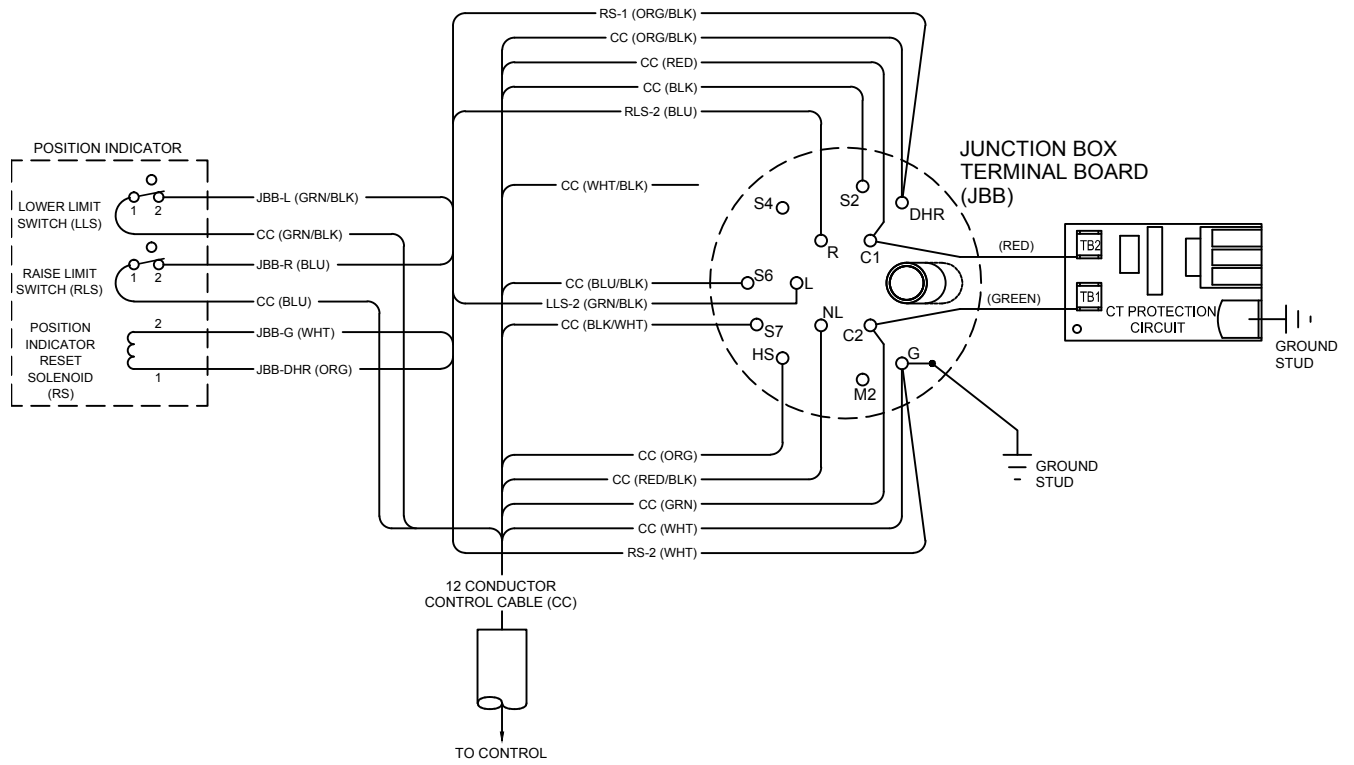
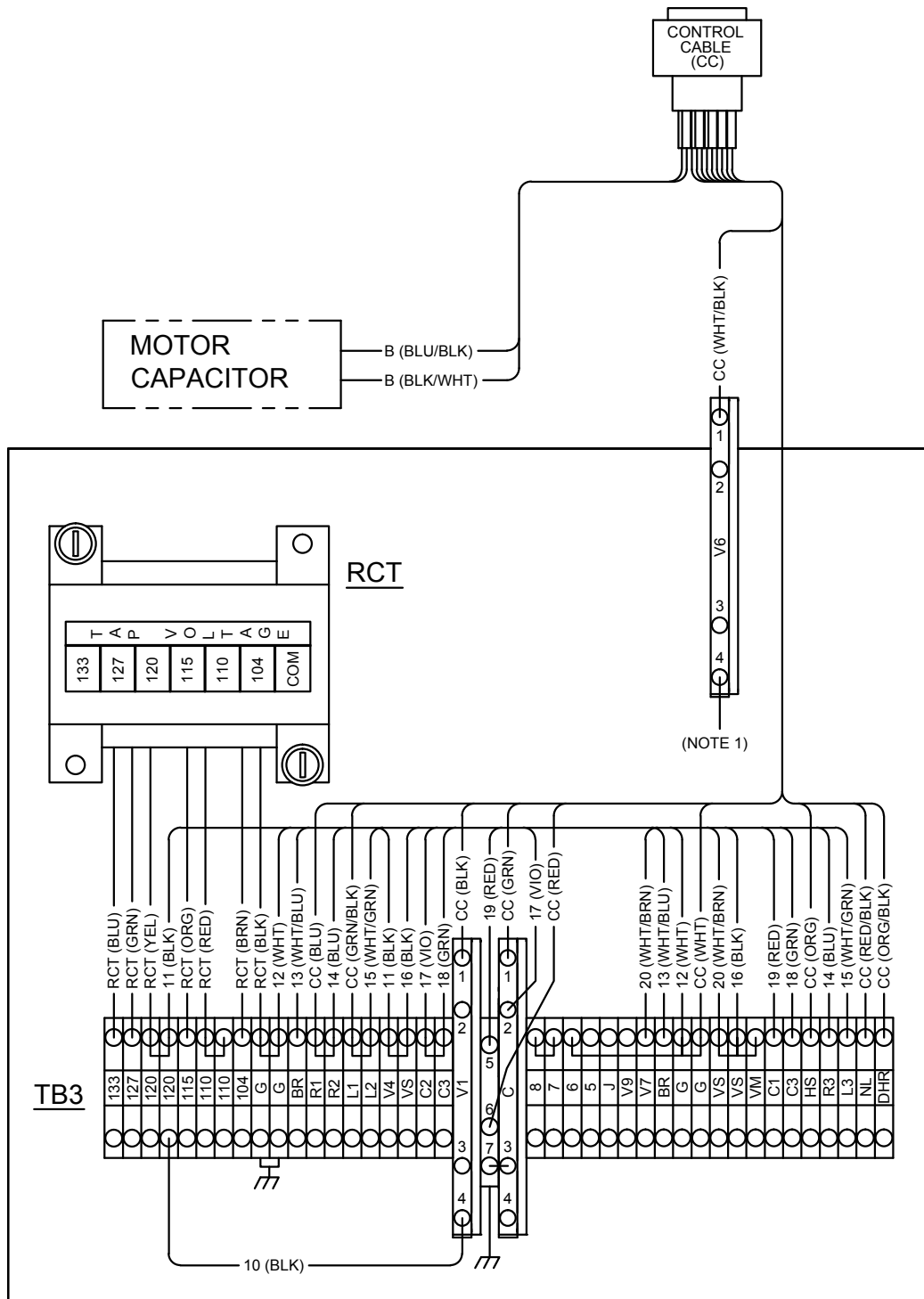


Figure 27. Junction box wiring diagram.



**Figure 28. 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.

Figure 29. Standard back panel signal circuit.

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