

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer Installation, Operation, and Maintenance Instructions



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Contents

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITY	II	TROUBLESHOOTING	26
SAFETY FOR LIFE	IV	Regulator control reverse power flow test	26
SAFETY INFORMATION	IV	VR-32 voltage regulator ratio test	27
Safety instructions	iv	VR-32 voltage regulator potential transformer ratio test	29
INTRODUCTION	1	Regulator dry-out procedure	29
Read this manual first	1	VR-32 voltage regulator current test	30
Additional information	1	Insulation resistance test	31
Acceptance and initial inspection	1	Freeing a stalled tap-changer	32
Handling and storage	1	APPENDIX	33
Unloading	1	Connections and voltage levels	33
Standards	1	ADD-AMP capabilities	35
Quality standards	1	Wiring diagrams	37
PRODUCT INFORMATION	2		
Description	2		
Available options	2		
INSTALLATION	4		
Pre-installation inspection	4		
Systems connections	4		
Nameplates	6		
Mounting	6		
Placing regulator into service	8		
REMOVAL FROM SERVICE	11		
CONSTRUCTION AND OPERATION	12		
Standard features, regulators with over-head bushings	12		
Position indicator and ADD-AMP capability	13		
Surge protection	13		
Internal construction and wiring	14		
Quik-Drive tap-changers	19		
MAINTENANCE	21		
Periodic inspections	21		
Operational check	22		
Insulating fluid maintenance	23		
Sampling insulating fluid	23		
FR3 insulating fluid application	23		
Untanking the regulator	24		
Retanking the regulator	25		
SPARE PARTS	26		
Ordering Information	26		



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.

G122.2

Introduction

Eaton's Service Information MN225008EN provides the installation, operation, and maintenance instructions for its Cooper Power™ series VR-32 voltage regulator with the Quik-Drive™ tap-changer.

Read this manual first

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

Additional information

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

Acceptance and initial inspection

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

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

Handling and storage

Be careful during 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.

WARNING

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

VR-T218.0

Unloading

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

Standards

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

- IEEE Std C37.90.1-2012™ standard
- IEEE Std C37.90.2-2004™ standard
- IEEE Std C57.13-2008™ 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

Product information

Description

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

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

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

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

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

Eaton manufactures four types of step-voltage regulators: source-side series winding (Type B), load-side series winding (Type A), series transformer (Type TX), and series auto transformer (Type AX). VR-32 voltage regulators are usually equipped with an equalizer winding. The nameplates located on the tank and control box define the power circuit.

VR-32 voltage regulators are supplied with the following standard features:

- Dual-rated 55/65 °C average winding rise
- ADD-AMP™ capability
- Sealed-tank construction
- Pressure relief device
- 18" minimum-creep bushings with clamp-type connectors
- MOV-type external series arrester
- Shunt-arrester mounting bosses
- Two aluminum, laser-etched nameplates
- Insulating fluid 25 °C level sight gauge
- Upper filter press connection
- Drain valve and insulating fluid sampling device
- CE mark compliant control
- Control cable quick connect/disconnect



Figure 1. Quick connect/disconnect cable

Available options

Available options include:

- Extended-length, quick-connect cable in various lengths up to 120 feet.
- Armored cable
- Shielded cable
- Adjustable galvanized-steel elevating structure
- Supplemental external fusing to prevent damage from reverse polarity connection to the external-source terminals
- Shunt surge arresters
- Insulating fluid thermometer with or without alarm contacts
- Insulating fluid level gauge with or without alarm contacts
- Pressure and vacuum gauge with or without alarm contacts
- Rapid pressure-rise relay
- Stainless steel tank and cover
- Envirotemp™ FR3™ fluid
- Tank and control enclosure ground connectors
- Alternate top-coat color
- External stainless steel hardware
- Stainless steel control enclosure
- Stainless steel nameplates
- Substation base, below 167 kVA
- Pole-mounting brackets, on 333 kVA
- Wildlife guards
- 4-hole NEMA® spade bushing connectors

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

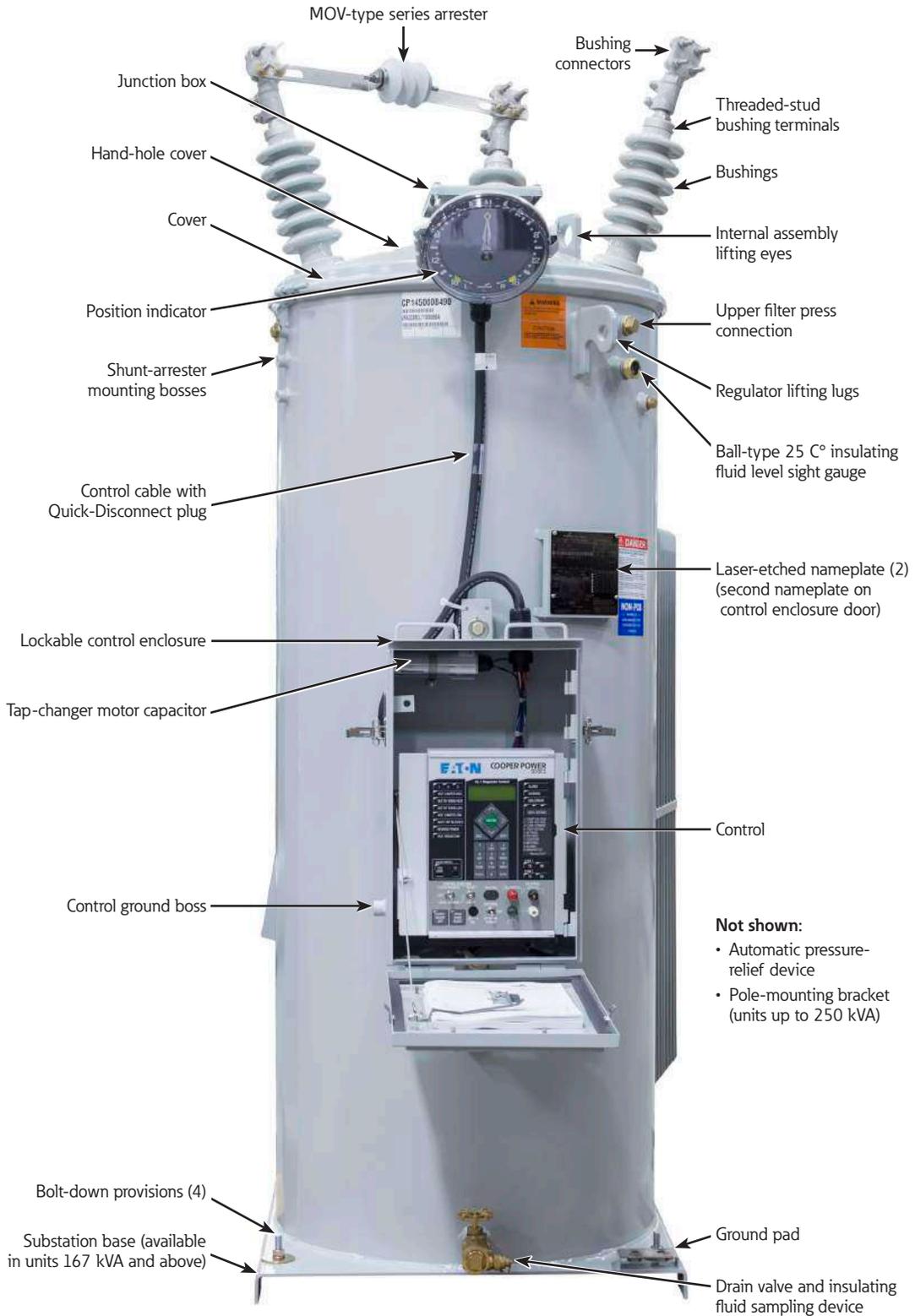


Figure 2. External features of the VR-32 voltage regulator

Installation

Pre-installation inspection

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

1. Check insulating fluid level sight gauge. Look for visible signs of leaking insulating fluid.

Note: The site gauge is at the 25 °C insulating fluid level. Fluid may not be visible in cold temperatures.
2. Examine series arrester for damage. If damaged, install a new arrester of same voltage rating.
3. Inspect porcelain bushings for damage or leaking seals.
4. If there is a suspicion that moisture has entered the unit, remove the hand-hole cover and inspect for evidence of moisture such as rust or water tracks in the insulating fluid. If moisture has entered the tank, dry regulator and filter the insulating fluid before putting unit in service. See Table 5 and Table 6 (page 23) for insulating fluid test standards. Be sure to properly replace hand-hole cover.
5. Check position indicator for damage. When cleaning the faceplate, do NOT use solvent or fuel.
6. If the regulator has been stored for some time, test the dielectric strength of the insulating fluid according to Table 5 and Table 6 (page 23).
7. Regulator may be energized at rated voltage (with caution); you can then perform the “Operational check” on page 22. This procedure is optional.
8. A high-potential test may be done to ensure adequate electrical clearances to ground. This procedure is optional.

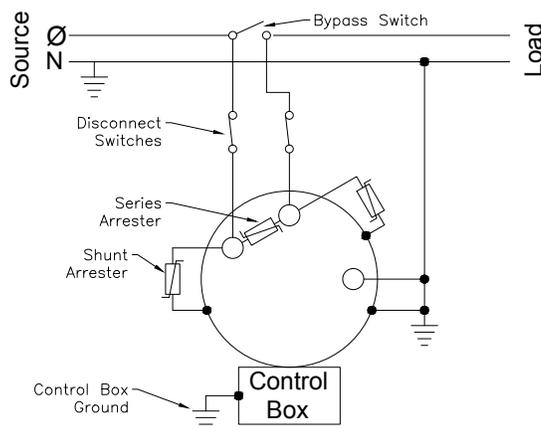


Figure 3. Regulating a single-phase circuit

Systems connections

⚠ WARNING

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

VR-T219.0

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

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

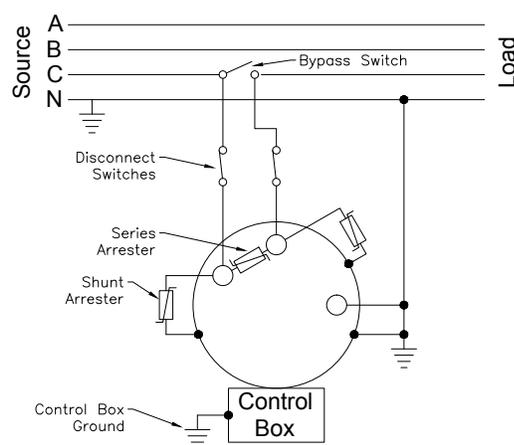


Figure 4. Regulating one phase of a three-phase, four-wire circuit regulator

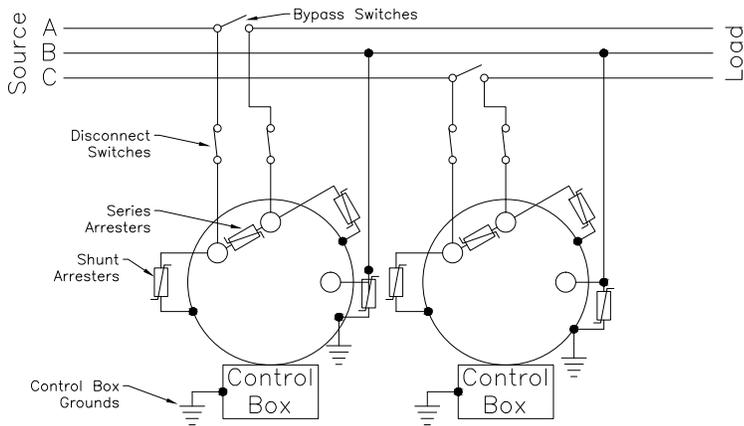


Figure 5. Regulating a three-phase, three-wire circuit with two regulators (Open Delta)

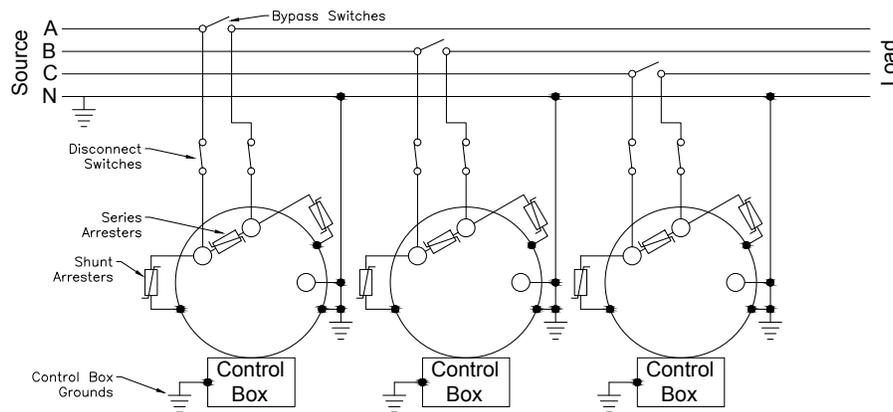


Figure 6. Regulating a three-phase, four-wire, multi-grounded wye (star) circuit with three regulators (Wye)

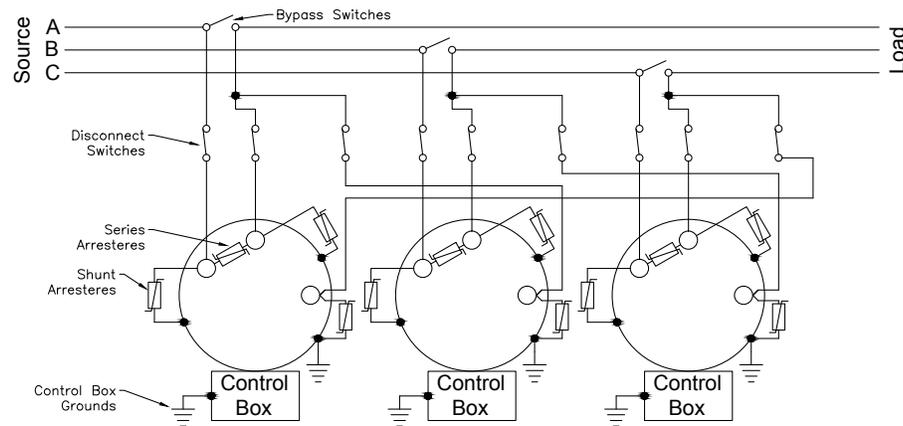


Figure 7. Regulating a three-phase, three-wire circuit with three regulators (Closed Delta)

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

Nameplates

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

Mounting

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

Pad-mounted regulators are equipped with tamper resistant cabinets and bushing connections compatible with underground distribution systems. A switching module is also available for the pad-mounted units that enables bypass switching; the module remains on the pad as the regulator is lifted when removing it from service.

The regulator control can be mounted on the regulator tank or at a point remote from the unit. Various lengths of rubber-coated control cables are available up to 120 feet (36.6 meters).

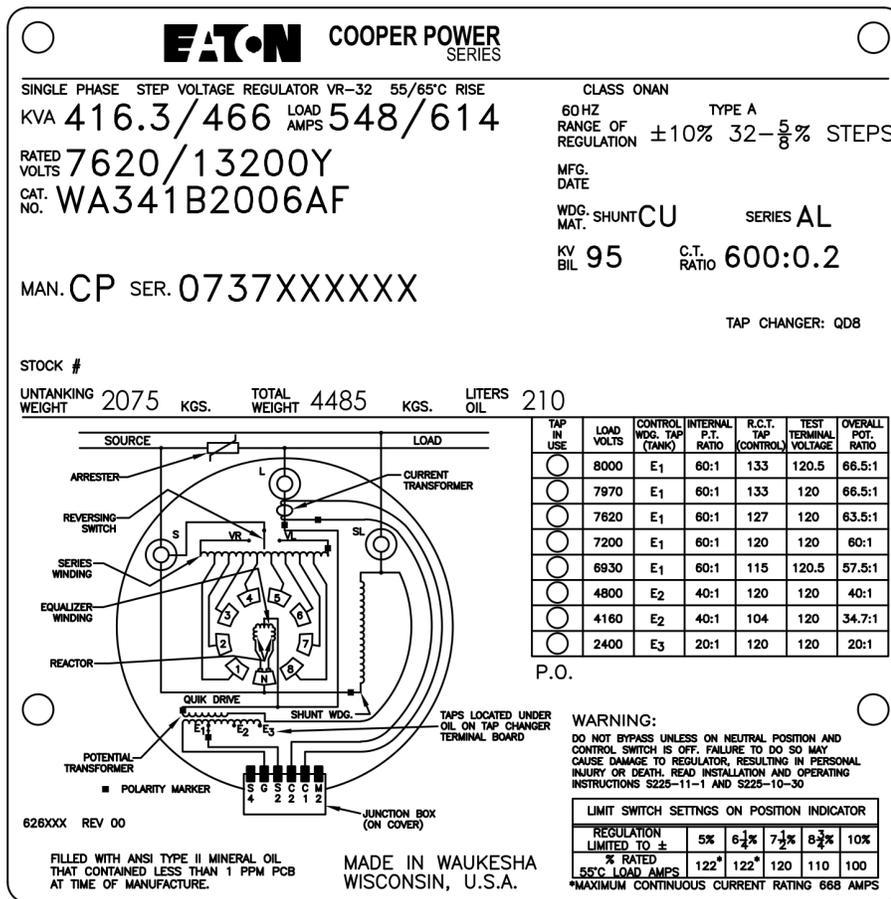


Figure 8. Typical nameplate: Domestic 60-Hz design

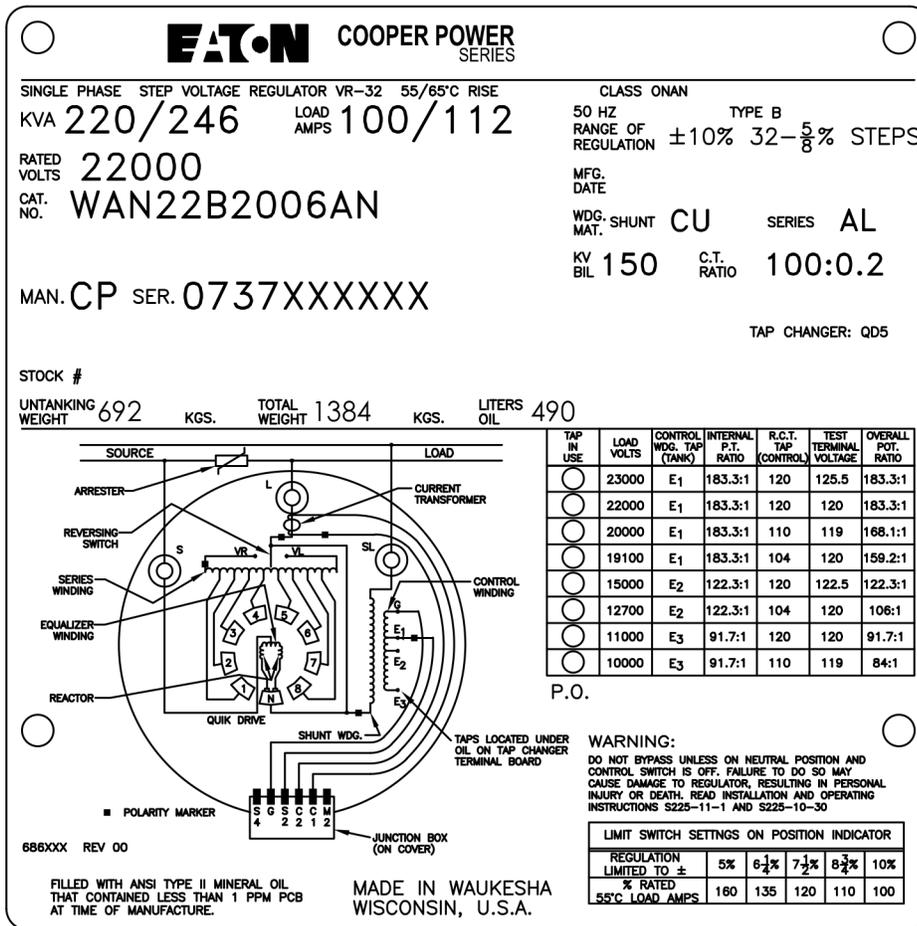


Figure 9. Typical nameplate: international 50-Hz design

Placing regulator into service

⚠ DANGER

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

VR-T205.0

⚠ WARNING

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

VR-T202.0

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.

VR-T204.1

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.

VR-T231.0

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

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

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

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

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

When energizing the control from an external source, use only a 120 Vac source, unless the control is set up for 240 Vac, indicated by a decal adjacent to the terminals.

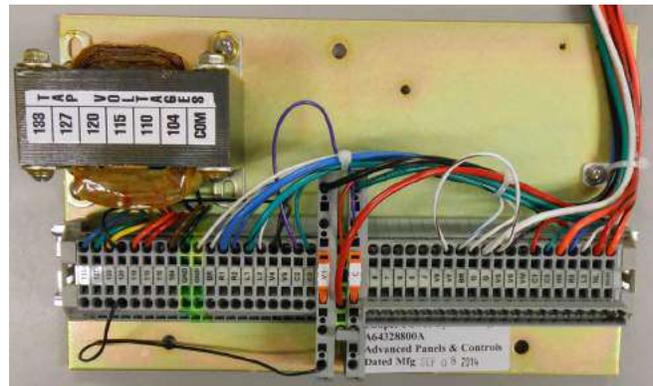


Figure 10. Typical CL-7 single-phase control back-panel



Figure 11. Typical CL-7 control multi-phase back-panel

Procedure A: One bypass switch and two disconnect switches

1. Verify from regulator nameplate that control circuit is connected for proper regulated system voltage.
2. Set POWER switch to **OFF** and CONTROL FUNCTION switch to **OFF**.
3. Knife switches on back panel should be set with **V1** (potential switch) (and **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.

Procedure B: Regulator bypass-disconnect switch

1. Verify from regulator nameplate that control circuit is connected for proper regulated system voltage.
2. Set CONTROL FUNCTION switch to **LOCAL MANUAL** and POWER switch to **EXTERNAL**.
3. Knife switches on back panel should be set with **V1** (potential switch) (and **V6** if present) open (pulled out) and **C** (CT shorting switch) closed (pushed in).
4. Apply 120 V (or other voltage as indicated by the decal on the control) to external source terminals.
5. Lift raise-lower switch to operate tap-changer two or three steps, then depress raise-lower switch to return tap-changer to neutral position; these steps verify that the mechanism is functional. When on neutral, the neutral light will glow continuously and position indicator will point to zero or N for Neutral.
6. Remove the voltage from external source terminals.
7. With regulator in the neutral position, set CONTROL FUNCTION switch to **OFF**, set POWER switch to **OFF**, and remove 6 A motor fuse.
8. For Delta applications only: Close source-load (SL) disconnect switch.
9. Close regulator bypass-disconnect switch. The regulator is now energized.
10. Replace 6 A motor fuse, close **V1** knife switch (and **V6** if present), open **C** knife switch, and set POWER switch to **INTERNAL**.
11. 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.

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

Setting the manual (hard) limit switches

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

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

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

To set the limit switches:

1. Unlatch the captive bezel and swing the cover open.
2. Lift the limit-switch adjustment lever free of the detent and slide it to the new setting allowing the lever to snap into the detent stop.

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



Figure 12. Position indicator

Removal from service

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

DANGER

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

WARNING

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

WARNING

Explosion Hazard. To ensure 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.

To remove a regulator from service:

1. Use the **Raise/Lower** switch to bring the regulator to neutral position.

Note: When in neutral, the **Neutral** light will be continuously and brightly lit on the control front panel and the position indicator will point to zero or N for Neutral.

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

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

WARNING

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.

3. Disable the tap-changer motor to ensure that the tap-changer cannot inadvertently switch to an off-neutral position:
 - a. Place the CONTROL FUNCTION switch in the **OFF** position.
 - b. Remove the motor fuse.
 - c. Place control POWER switch in the **OFF** position.
 - d. Open **V1** knife switch (and **V6** if present) located on control back panel.
4. De-energize the regulator:
 - a. Close the bypass switch.
 - b. Open the load (L) disconnect switch.
 - c. Open the source (S) disconnect switch.
 - d. Open the source-load (SL) disconnect switch, if available.

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

Construction and operation

Eaton's Cooper Power series VR-32 voltage regulators are designed, manufactured, and tested in accordance with IEEE Std C57.15-2009™ standard. The regulators are rated and name-plated for 55/65 °C average winding rise.

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

Standard features, regulators with over-head bushings

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

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

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

Table 1. Standard terminals

Rating (A)	Standard Terminals
150 and below	Clamp-type connectors for #6 to 250 MCM conductor
151-668	Clamp-type connectors for #6 to 800 MCM conductor
669-1200	1.125"-12 UNF-2A with 4-hole spade
1201 and above	1.5"-12 UNF-2A with 4-hole spade

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

Insulating fluid level sight gauge. An insulating fluid level sight gauge indicates fluid color and level at 25 °C ambient.

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

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

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

Hand-hole cover. A hand-hole on the cover of the regulator provides access for inspection purposes and to access terminals used to reconnect the regulator for operation at system voltages as shown in Table 8 (page 33) and Table 9 (page 34).

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

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

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

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

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

The external parts of the tank and control enclosure are painted light gray, ANSI® 70 (Munsell 5BG7.0/0.4), and meet the coating and security requirements of IEEE Std C57.12.28™-2005 and IEEE Std C57.12.31™-2010 standards. Also, the inside of the tank and bottom of the cover are primed and/or painted.

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

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

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

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

Position indicator and ADD-AMP capability

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

Table 2. ADD-AMP adjustments

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

The position indicator (see Figure 2 and Figure 12) is mounted on the junction box on the cover of the regulator and is directly connected to the tap-changer by a flexible drive shaft passing through the junction box and terminal board via a sealing gland.

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

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

The limit switches on the position indicator can be adjusted to limit the maximum and minimum tap positions with possible settings of raise or lower 8, 10, 12, 14 or 16. These limits correspond to percent regulation levels of 5, 6 1/4, 7 1/2, 8 3/4, and 10%. The five possible load current ratings associated with the reduced regulation ranges are summarized in Table 10 (page 35) and Table 11 (page 36). 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 VR-32 voltage regulators are equipped with a bypass arrester connected across the series winding between the source (S) and load (L) bushings. This arrester limits the voltage developed across the series winding during lightning strikes, switching surges, and line faults. The series surge arrester can be seen in Figure 2. A heavy-duty MOV-type series surge arrester of 3 kV offers series winding protection on all regulators except those rated 22,000 V and greater, which have a 6 kV MOV-type series surge arrester.

Shunt arresters

A shunt arrester is a recommended accessory on the VR-32 voltage regulator for protection of the shunt winding. The shunt arrester is a direct-connected arrester mounted on the tank and connected between the bushing and ground (earth). It is recommended that arresters be applied to all non-grounded bushings.

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

Table 3. Typical shunt arrester application data^a

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		

^aContact factory for specific shunt arrester application ratings.

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

Internal construction and wiring

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

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

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

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

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

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

The main core and coil assemblies are of the shell-form configuration. The series winding on the input (source) side of the regulator (Figure 13) 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 14) have a separate potential transformer installed on the load side in lieu of a control winding.

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

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

Figure 15 shows a typical regulator power circuit with a series transformer. This design is utilized when the load current rating exceeds the tap-changer rating. In this type of design, the series transformer winding losses are a function of the load alone and are independent of the tap position. Because of this, limiting the range of voltage regulation does not reduce losses and therefore the ADD-AMP feature is not applicable.

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

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

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

The tap-changer enables the regulator to provide regulation in smooth, accurately proportioned steps at a controlled speed that minimizes arcing and extends contact life. Figure 26 (page 37) and Figure 27 (page 38) illustrate the typical internal wiring schemes. Most of the wiring is on the tap-changer itself. Molex® receptacles plugged into the junction block inside the junction box on the cover connect the internal tank wiring to the position indicator and control. The junction box wiring is shown in Figure 28 (page 39). 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 29 (page 40).

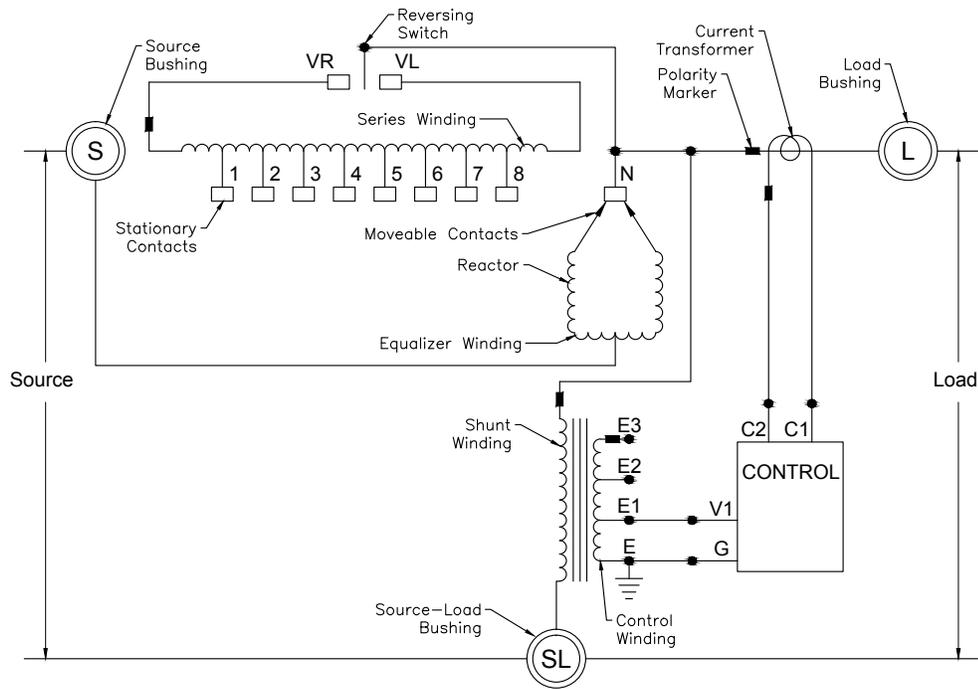


Figure 13. Power circuit—series winding located on the source-side, ANSI® Type B

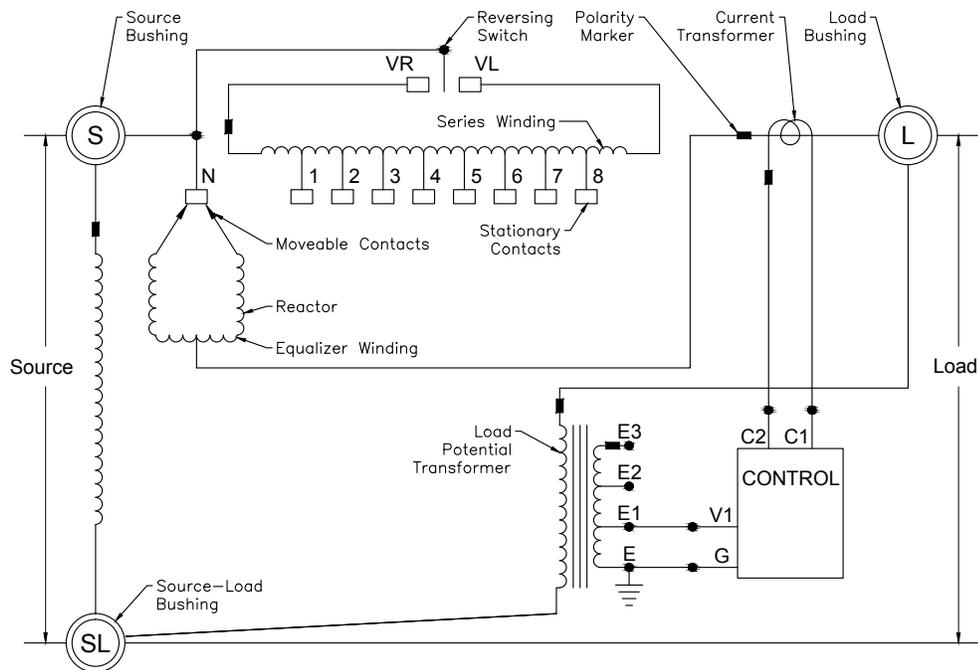


Figure 14. Power circuit—series winding located on the load-side, ANSI® Type A

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

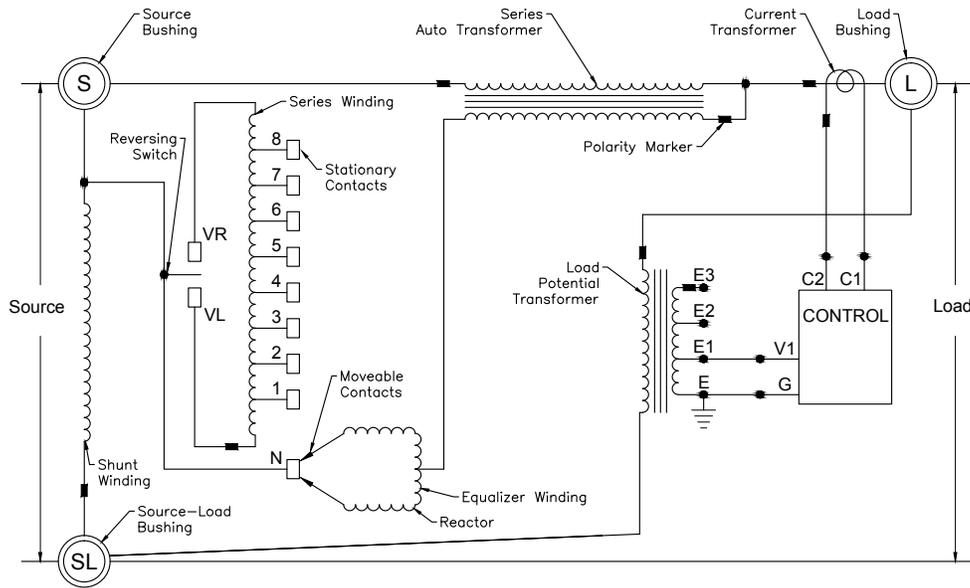


Figure 15. Power circuit – series auto transformer, Type AX (similar characteristics to Type A)

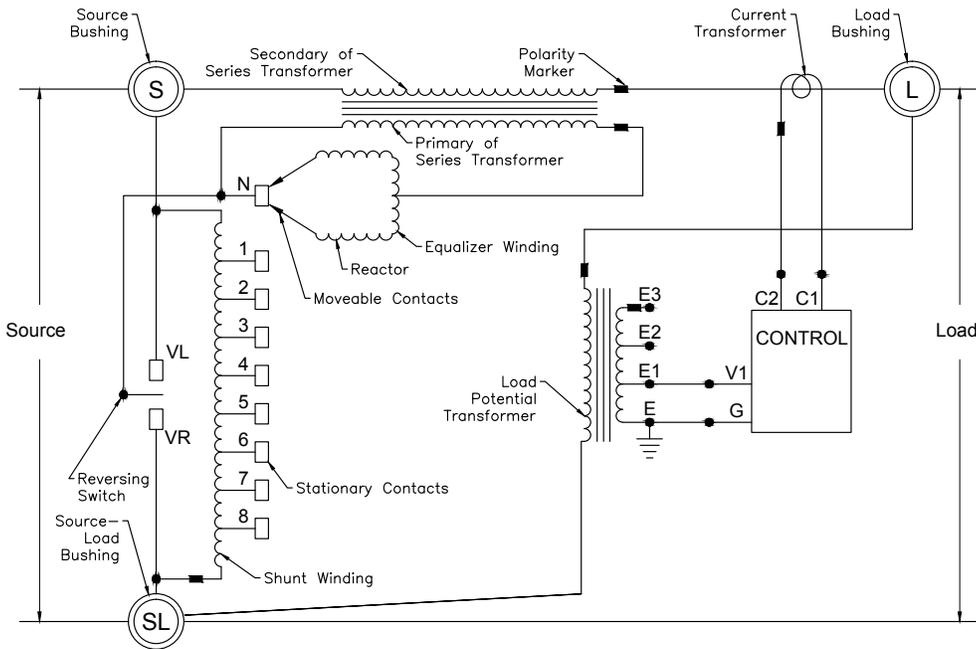


Figure 16. Power circuit – series transformer, Type TX

Voltage circuits

VR-32 voltage regulators have provisions for operation at system voltages other than the nominal rating, as listed in Table 8 (page 33) and Table 9 (page 34). This is accomplished by providing taps on the control winding or PT. The taps are brought to a terminal board located on top of the tap-changer assembly, under the insulating fluid, and are marked **E1**, **E2**, or **E3**. (See Figure 17.) The connections are made with push-on terminals and are easily accessed through the hand hole.

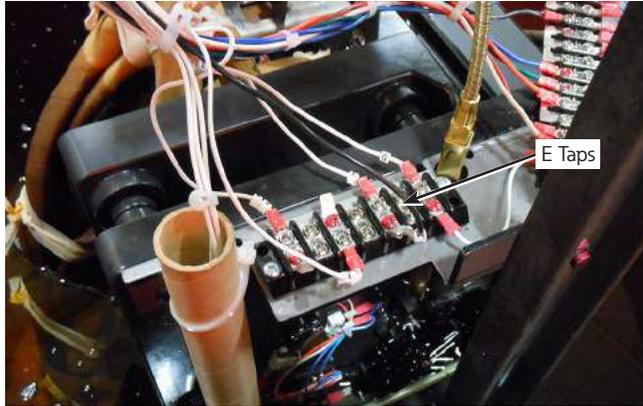


Figure 17. PT tap terminals on a QD3 tap-changer

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

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

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

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

Most voltage regulators are installed in circuits with well-defined power flow from source to load. However, some circuits have interconnections or loops in which the direction of power flow through the regulator may change. For optimum utility system performance, a regulator installed on

such a circuit should have the capability of detecting reverse power flow and of sensing and controlling the voltage, regardless of the power flow direction. The CL-7 control has full reverse power capabilities.

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

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

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

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

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

⚠ WARNING

Electrocution Hazard. Applying voltage to the voltmeter terminals on 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.

VR-T234.0

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

Current circuit

All VR-32 voltage regulators are designed with an internal current transformer (CT) (see Figure 18) to provide a current source for the line-drop compensation calculations, power flow direction determination and for metering functions. Table 4 provides the application information for the various CTs used on Eaton regulators. These CTs provide 200 mA output for the rated CT primary current.



Figure 18. Internal bushing-mounted current transformer

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

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

Table 4. 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, 1093	1000
1332, 1503, 1665	1600
2800	3000

Motor circuit

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

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

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

Quik-Drive tap-changers

Eaton offers three Quik-Drive tap-changer models (see Figure 19, Figure 20, and Figure 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



Figure 20. QD5 Quik-Drive tap-changer



Figure 21. QD8 Quik-Drive tap-changer

VR-32 Voltage Regulator with 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 µF capacitor for 60 Hz applications and a 15 µF capacitor for 50 Hz applications.

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

Contacts

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

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

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

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

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

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

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

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

Operating sequence

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

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

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, but can be extended when periodic inspections are performed. Maintenance and inspection schedules will vary and can be different for the same voltage regulator design depending upon system conditions and loading. The best predictor of future maintenance requirements is past experience.

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

Inspection of components inside the tank and maintenance of voltage regulator mechanisms should include the items listed below. Any problems found should be resolved before placing the units back into service. Consult the tap-changer manuals listed below or your Eaton representative for details on maintenance procedures.

Stationary contacts

- Inspect the arcing tips for excessive erosion.
- Inspect the contact surface for pitting and scoring.
- Replace excessively worn contacts.

Moveable contacts

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

Reversing switch contacts and mechanism

- Inspect contacts for wear.
- Inspect mechanisms for damage.

Stationary contact board and moveable contact arm

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

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

Holding switch

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

Position indicator drive mechanism

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

General

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

Related manuals

Review the following tap-changer manuals for additional information on contact erosion and tap-changer maintenance requirements:

- S225-12-1, *QD3 Quik-Drive Voltage Regulator Tap-Changer Manual*
- MN225012EN, *QD5 Quik-Drive Voltage Regulator Tap-Changer Manual*
- MN225011EN, *QD8 Quik-Drive Voltage Regulator Tap-Changer Installation and Maintenance Instructions*
- S225-10-2, *Spring-Drive and Direct-Drive Tap-Changer Switches in VR-32 Operating, Maintenance, Troubleshooting and Parts Replacement Instructions*

Duty Cycle Monitor (DCM)

Another useful indicator of the need for inspection and maintenance is the DCM control feature. Refer to Service Information MN225003EN, *CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions*, for more information on the DCM feature. DCM will operate correctly only when a Quik-Drive tap-changer is paired with a CL-6 or later control and the control has been programmed with the correct design specification number.

Operational check

Proper operation of the regulator can be checked without removing the unit from service.

To perform an operational check:

1. Place the CONTROL FUNCTION switch in LOCAL MANUAL.
2. Manually run the regulator several steps in the raise direction until the OUT-OF-BAND HIGH LED illuminates continuously.
3. Place the CONTROL FUNCTION switch in AUTO/REMOTE. After the time delay expires, the regulator should return to within the band edge and the OUT-OF-BAND HIGH LED should go out.
4. Again place the CONTROL FUNCTION switch in LOCAL MANUAL.
5. Manually run the regulator several steps in the lower direction until the OUT-OF-BAND LOW LED illuminates continuously.
6. Place the CONTROL FUNCTION switch in AUTO/REMOTE. After the time delay expires, the regulator should return to within the band edge and the OUT-OF-BAND LOW LED should go out.
7. If the operations check does not complete successfully, review the troubleshooting section of this manual and refer to Service Information MN225003EN, *CL-7 Voltage Regulator Control Installation, Operation, and Maintenance*, for more instructions.
8. If further assistance is required, contact Voltage Regulator Support at (866) 975-7347. International callers should call (262) 896-2591.

Insulating fluid maintenance

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

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

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

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

Characteristic	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	^b
^a Per IEEE Std C57.147™-2008 standard		
^b 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 6. Mineral Oil Characteristics (Type II^a)

Characteristic	New	Used
Dielectric Strength (kV) ASTM D1816:		
2-mm gap	≥ 45	≥ 40
1-mm gap	≥ 25	≥ 23
Interfacial Tension (mNm) ASTM D971	≥ 38	≥ 25
Water (mg/kg) ASTM D1533	≤ 20	≤ 35
^a Per IEEE Std C57.106™-2006 standard		

Sampling insulating fluid

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

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

⚠ WARNING

Equipment damage, personal injury or death possible. Do not lower fluid in tank below the critical fluid level. Insufficient fluid risks unit failure, which could result in severe personal injury or death to exposed personnel.

FR3 insulating fluid application

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

In such cases, a thermometer will be provided as a standard feature. The thermometer will be configured to close a contact when insulating fluid temperatures reach -10 °C.

With the contact closed, auto operation will be inhibited. The CL-7 control will illuminate the Auto Tap Blocked LED and display **Blocked: CL** or **Comm** on the Metering-PLUS Load Current screen.

Untanking the regulator

WARNING

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

VR-T220.0

CAUTION

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

VR-T221.0

CAUTION

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

VR-T222.1

CAUTION

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

VR-T223.0

Remove the regulator from service (see "Removal from service" on page 11) and untank the unit to verify contact wear, insulating fluid dielectrics, etc. The fluid should be checked (a) prior to energizing if the regulator has not been energized for a long time period and (b) at normal maintenance intervals. Table 5 and Table 6 contain information on acceptable insulating fluid characteristics for Envirotemp™ FR3™ fluid and mineral oil, respectively.

1. Manually run the tap-changer to neutral, if possible. If not, record the position indicator reading before proceeding to untank.
2. Disconnect the control cable from the bottom of the junction box (see Figure 1).
3. Remove the series arrester.
4. Release internal pressure using the pressure-relief device on the side of the regulator tank.
5. Free the cover by removing the clamping ring or the cover bolts.

6. Attach a sling or hooks with a spreader bar to the lifting eyes and raise the cover, with the attached core-and-coil assembly, until the top of the coil is approximately one inch under the insulating fluid (see Figure 22).

Note: As a safety precaution, use blocking between the cover and the tank lip until inspection of the tap-changer or other maintenance is complete.

Note: A service cable assembly is available for operating an untanked regulator from the mounted control cabinet if the connection cable is not long enough. Contact your Eaton representative for availability.

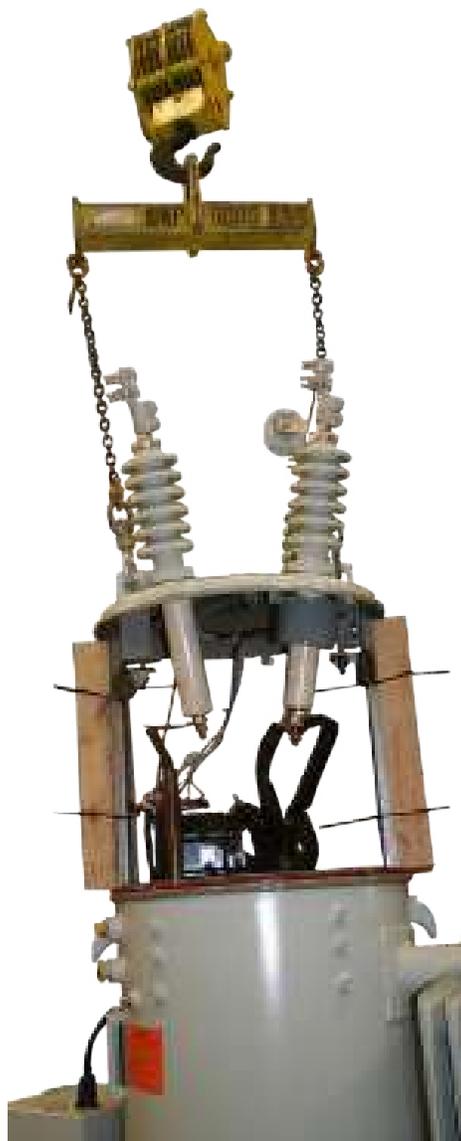


Figure 22. Untanking the voltage regulator

Retanking the regulator

Retank the regulator as directed below. Refer to Figure 22.

1. If the core and coil assembly have been out of oil for more than 4 hours, the coil must be dried, as follows:

- a. Bake the unit at 100°C (212°F) for 24 hours.

Note: Units equipped with a phenolic tap-changer must be baked at a maximum temperature of 66°C (150°F). A unit can be rebaked a maximum of two times over its life.

- b. After baking, check all hardware for tightness.
- c. Within four hours after baking, retank the unit and fill it with fluid.

Note: If baking is not possible or practical, see “Regulator dry-out procedure” on page 29 for an alternative to baking.

2. Verify that the position indicator shows the present position of the tap-changer.

Note: If the position indicator is *not* showing the present position of the tap-changer, proceed as follows:

- a. Remove the indicator cable in the junction box from the position indicator shaft after loosening the set screw.
- b. Rotate the indicator shaft until the proper position is reached; then tighten the set screw.
- c. Verify coordination of the position indicator with the tap-changer in the neutral position (control neutral light on).

3. Check the gasket seat surfaces on the cover and tank, and wipe clean. Wipe the gasket and position it on the tank lip.
4. Loosen the horizontal, side channel bolts to ensure proper seating of the regulator in the tank and proper cover seal.
5. Raise the cover assembly and attached components over the tank. Make certain of proper orientation.
6. Lower the unit, rotating the channels counter-clockwise into the tank guides.
7. Seat the unit in the tank. Tighten the cover band or bolts. Torque the cover band to 24.4 – 29.8 Nm (18 – 22 ft-lbs). Make sure the ends of the cover band do not touch when fully tightened. Torque the cover bolts on a square-tanked regulator to 32.5 – 35.6 Nm (24 – 26 ft-lbs).

Note: On round tanks, tap the cover with a rubber hammer around the edge to assist in providing a good seal while tightening the cover band.

8. Check and retighten the horizontal, side-channel bolts through the hand hole; torque to 68 Nm (50 ft-lbs).
9. Properly reseal the hand-hole cover, being careful not to damage the cover or the gasket.
10. Connect the control cable to the connector at the bottom of the junction box.
11. Pull a vacuum on the unit for at least one hour (2 mm of vacuum or better) after the unit is completely refilled with fluid.

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

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 Figure 23 for part identification of high-voltage bushings.

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

- S225-12-1, QD3 Quik-Drive Voltage Regulator Tap-Changer Manual
- S225-12-2, QD5 Quik-Drive Voltage Regulator Tap-Changer Manual
- S225-12-3, QD8 Quik-Drive Voltage Regulator Tap-Changer Manual

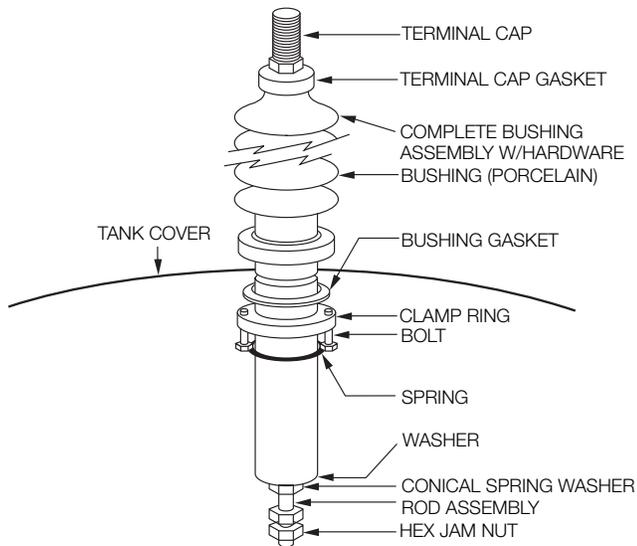


Figure 23. High-voltage bushing (S, L, and SL)

Troubleshooting

For troubleshooting instructions, refer to 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.

Regulator control reverse power flow test

Purpose

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

Required equipment

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

Procedure

WARNING

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

VR-T224.0

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

WARNING

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

VR-T213.0

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.

VR-T225.0

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. VR-T235.0

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. VR-T204.1

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.

VR-32 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. VR-T224.0

1. Remove the unit from service as described in "Removal from service" on page 11.
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. VR-T236.0

4. Connect a separate 120 Vac supply to the external source terminals on the control front panel. Move the control power switch to the external position to operate the tap-changer.

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

⚠ 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.

VR-T237.0

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.

VR-T238.0

5. Increase the voltage on the variac to 120 Vac. This will provide 12 V on the series winding.
120 Vac x 10% regulation = 12 V
6. Calculate the change in volts per tap change as follows:

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

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

Table 7. 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 (± 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.

VR-32 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.

VR-T224.0

 **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.

VR-T213.0

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

Expected Voltage = 120 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.

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

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.

VR-T224.0

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

 **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.

VR-T226.0

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.

 **WARNING**

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

VR-T225.0

5. Ground the regulator tank.

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

- 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.
- Let the regulator set in this condition for approximately 24 hours. This will drive the moisture out of the coil into the insulating fluid.
- De-energize the regulator and drain the insulating fluid.
- Refill with new insulating fluid.
- Check the results of the procedure by performing an insulation power factor test after the regulator temperature has stabilized to the ambient temperature.

VR-32 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

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.

VR-T224.0

- Remove the unit from service as described in "Removal from service" on page 11.

WARNING

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

VR-T213.0

- Conduct this test with the regulator located in the maintenance shop or other suitable location.
- Use the external source terminals and voltage source to power the control and enable tap-changer operation. See Service Information MN225003EN, *CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions*, for detailed information on powering the control externally.

- 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.

VR-T225.0

- Ground the regulator tank.
- 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 24. Place a milli-ampere meter between these terminals. See Figure 25.

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.

VR-T235.0

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.

VR-T204.1

- Using a variable voltage source, place approximately 120 V between the L and Source-Load (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.

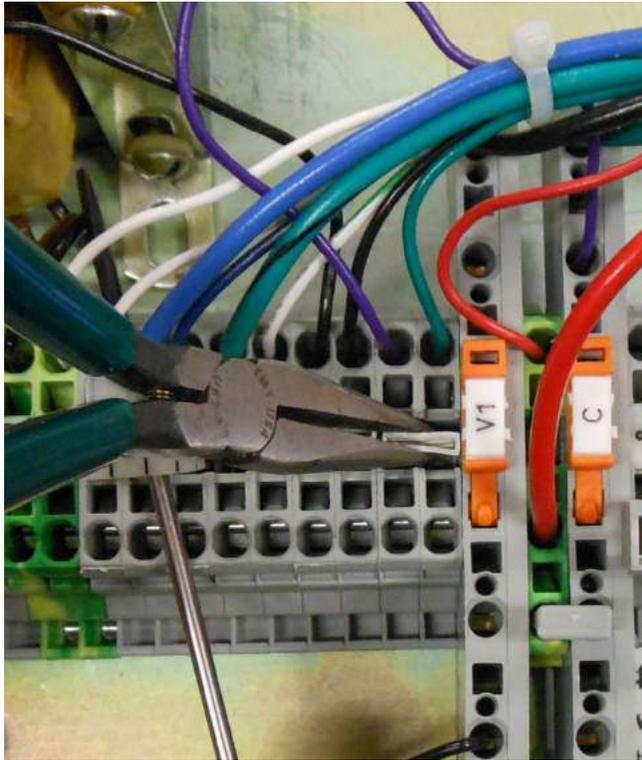


Figure 24. Removing jumper between C2 and C3

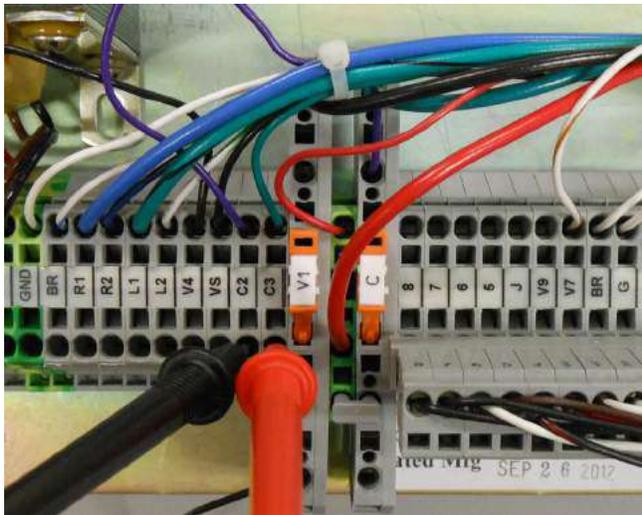


Figure 25. Milli-ammeter connection points

Insulation resistance test

Purpose

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

Required Equipment

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

Procedure

⚠ WARNING

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

VR-T224.0

1. Remove the unit from service as described in “Removal from service” on page 11.
2. Conduct this test with the regulator located in the maintenance shop or other suitable location.

Note: The regulator tank must be isolated from ground potential.

CAUTION

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

VR-T235.0

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.

VR-T204.1

3. Place the regulator in the **16 Lower** position. Power the control using an external power source to enable tap-changer operation. See Service Information MN225003EN, *CL-7 Voltage Regulator Control Installation, Operation, and Maintenance Instructions*, for detailed information on powering the control externally.
4. Place a jumper, rated for nominal current, tying all the bushings together.
5. Close 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.

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

7. Read the test value in mega-ohms; then compare the reading with the baseline reading:
 - If the new reading is **lower than the baseline reading**, further testing and evaluation of the insulation is recommended.
 - If the new reading is the **same as or higher than the baseline reading**, no further testing is indicated.
9. Place the **CONTROL FUNCTION** switch on **LOCAL MANUAL**.
10. Jog the **RAISE/LOWER** switch in the direction the capacitive 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.

Freeing a stalled tap-changer

Purpose

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

Required Equipment

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

Procedure

1. Confirm that a stall has occurred. If the tap-changer is stalled between tap positions with the holding switch closed, a voltmeter placed between terminals **R1** and **G** or **L1** and **G** on the back panel will read approximately 120 Vac. The terminal measuring 120 Vac will be the direction the tap-changer was moving when stalling occurred. There will likely be a floating capacitive voltage in the other direction greater than 120 Vac. After determining the stall direction, the steps of this procedure can be used to reverse the direction of the tap-changer to free the mechanism.
2. Place the **CONTROL FUNCTION** switch in **OFF** position.
3. Place the **POWER** switch in **OFF** position.
4. Close the **C** (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.
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**.
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 you perform a minimum of four checks to confirm that the voltage regulator is in the neutral position:
 - The neutral light remains on continuously.
 - The position indicator points directly at N.
 - The control panel position indication viewed at FC 12 reads zero.
 - A voltage measurement between the S and L bushing measured using voltmeter test equipment indicates no differential voltage.

CAUTION

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.

VR-T227.0

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

Appendix

Connections and voltage levels

Table 8. VR-32 tap connections & voltage levels (60 Hz)

Regulator Voltage Rating	Nominal Single-Phase Voltage	Ratio-Adjusting Data			Test Terminal Voltage ^b	Overall Potential Ratio ^b
		Internal Tap ^a	PT Ratio	RCT Tap		
1	2	3	4	5	6	7
2500	2500	—	20:1	120	125	20:1
	2400	—	20:1	120	120	20:1
5000	5000	E ₁ /P ₁	40:1	120	125	40:1
	4800	E ₁ /P ₁	40:1	120	120	40:1
	4160	E ₁ /P ₁	40:1	104	120	34.7:1
	2400	E ₂ /P ₂	20:1	120	120	20:1
7620	8000	E ₁ /P ₁	60:1	133	120.5	66.5:1
	7970	E ₁ /P ₁	60:1	133	120	66.5:1
	7620	E ₁ /P ₁	60:1	127	120	63.5:1
	7200	E ₁ /P ₁	60:1	120	120	60:1
	6930	E ₁ /P ₁	60:1	115	120.5	57.5:1
	4800	E ₂ /P ₂	40:1	120	120	40:1
	4160	E ₂ /P ₂	40:1	104	120	34.7:1
	2400	E ₃ /P ₃	20:1	120	120	20:1
13800	13800	E ₁ /P ₁	115:1	120	120	115:1
	13200	E ₁ /P ₁	115:1	115	120	110.2:1
	12470	E ₁ /P ₁	115:1	104	120	99.7:1
	12000	E ₁ /P ₁	115:1	104	120	99.7:1
	7970	E ₂ /P ₂	57.5:1	133	120	63.7:1
	7620	E ₂ /P ₂	57.5:1	133	120	63.7:1
	7200	E ₂ /P ₂	57.5:1	120	120	57.5:1
	6930	E ₂ /P ₂	57.5:1	120	120	57.5:1
14400	14400	E ₁ /P ₁	120:1	120	120	120:1
	13800	E ₁ /P ₁	120:1	115	120	115:1
	13200	E ₁ /P ₁	120:1	110	120	110:1
	12000	E ₁ /P ₁	120:1	104	115.5	104:1
	7970	E ₂ /P ₂	60:1	133	120	65.5:1
	7620	E ₂ /P ₂	60:1	127	120	63.5:1
	7200	E ₂ /P ₂	60:1	120	120	60:1
	6930	E ₂ /P ₂	60:1	150	120.5	57.5:1

Table 8. (continued)

Regulator Voltage Rating	Nominal Single-Phase Voltage	Ratio-Adjusting Data			Test Terminal Voltage ^b	Overall Potential Ratio ^b
		Internal Tap ^a	PT Ratio	RCT Tap		
1	2	3	4	5	6	7
19920	19920	E ₁ /P ₁	166:1	120	120	166:1
	17200	E ₁ /P ₁	166:1	104	119.5	143.9:1
	16000	E ₂ /P ₂	120:1	133	120.5	133:1
	15242	E ₂ /P ₂	120:1	127	120	127:1
	14400	E ₂ /P ₂	120:1	120	120	120:1
	7970	E ₃ /P ₃	60:1	133	120	65.5:1
	7620	E ₃ /P ₃	60:1	127	120	63.5:1
34500	34500	E ₁ /P ₁	287.5:1	120	120	287.5:1
	19920	E ₂ /P ₂	165.5:1	120	120.5	165.5:1

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

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

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

Table 9. VR-32 tap connections & voltage levels (50 Hz)

Regulator Voltage Rating	Nominal Single-Phase Voltage	Ratio-Adjusting Data			Test Terminal Voltage ^b	Overall Potential Ratio ^b
		Internal Tap ^a	PT Ratio	RCT Tap		
1	2	3	4	5	6	7
6600	6930	—	54.9:1	127	119.2	58.1:1
	6600	—	54.9:1	120	120.1	54.9:1
	6350	—	54.9:1	115	120.6	52.6:1
	6000	—	54.9:1	110	119.2	50.4:1
	5500	—	54.9:1	104	115.5	47.6:1
11000	11600	E ₁ /P ₁	91.6:1	127	119.7	96.9:1
	11000	E ₁ /P ₁	91.6:1	120	120.1	91.6:1
	10000	E ₁ /P ₁	91.6:1	110	119.1	84.0:1
	6930	E ₂ /P ₂	55.0:1	127	119.1	58.2:1
	6600	E ₂ /P ₂	55.0:1	120	120.1	55.0:1
	6350	E ₂ /P ₂	55.0:1	115	120.6	52.7:1
	6000	E ₂ /P ₂	55.0:1	110	119.1	50.4:1
	5500	E ₂ /P ₂	55.0:1	104	115.5	47.6:1
15000	15000	E ₁ /P ₁	120:1	120	125.0	120.0:1
	14400	E ₁ /P ₁	120:1	120	120.0	120.0:1
	13800	E ₁ /P ₁	120:1	115	120.0	115.0:1
	13200	E ₁ /P ₁	120:1	110	120.0	110.0:1
	12000	E ₁ /P ₁	120:1	104	115.4	104.0:1
	11000	E ₂ /P ₂	91.8:1	120	119.9	91.8:1
	10000	E ₂ /P ₂	91.8:1	110	118.9	84.1:1
	6600	E ₃ /P ₃	53.8:1	120	122.7	53.8:1
22000	22000	E ₁ /P ₁	183.4:1	120	120.0	183.4:1
	20000	E ₁ /P ₁	183.4:1	110	119.0	168.1:1
	19100	E ₁ /P ₁	183.4:1	104	120.2	158.9:1
	15000	E ₂ /P ₂	122.3:1	120	122.7	122.3:1
	12700	E ₂ /P ₂	122.3:1	104	119.9	106.0:1
	11000	E ₃ /P ₃	91.7:1	120	120.0	91.7:1
	10000	E ₃ /P ₃	91.7:1	110	119.0	84.0:1
33000	33000	E ₁ /P ₁	275.0:1	120	120.0	275.0:1
	30000	E ₁ /P ₁	275.0:1	110	119.0	252.1:1
	22000	E ₂ /P ₂	183.3:1	120	120.0	183.3:1
	20000	E ₂ /P ₂	183.3:1	110	119.0	168.1:1
	11600	E ₃ /P ₃	91.7:1	127	119.0	97.0:1
	11000	E ₃ /P ₃	91.7:1	120	120.0	91.7:1
	10000	E ₃ /P ₃	91.7:1	110	119.0	84.0:1

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

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

ADD-AMP capabilities

Table 10. ADD-AMP capabilities of 60 Hz ratings

Rated Volts	Rated kVA	Load Current Ratings (A) ^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%
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 ^b	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
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	

Table 10. (continued)

Rated Volts	Rated kVA	Load Current Ratings (A) ^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%
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
19920	833	578	636	668	668	668
	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
34500	1000	502	552	602	668	668
	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

^a 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.

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

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

Table 11. ADD-AMP capabilities of 50 Hz ratings

Rated Volts	Rated kVA	Load Current Ratings (A) ^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	80
	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
	825	250	275	300	338	372

^a 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.

Wiring diagrams

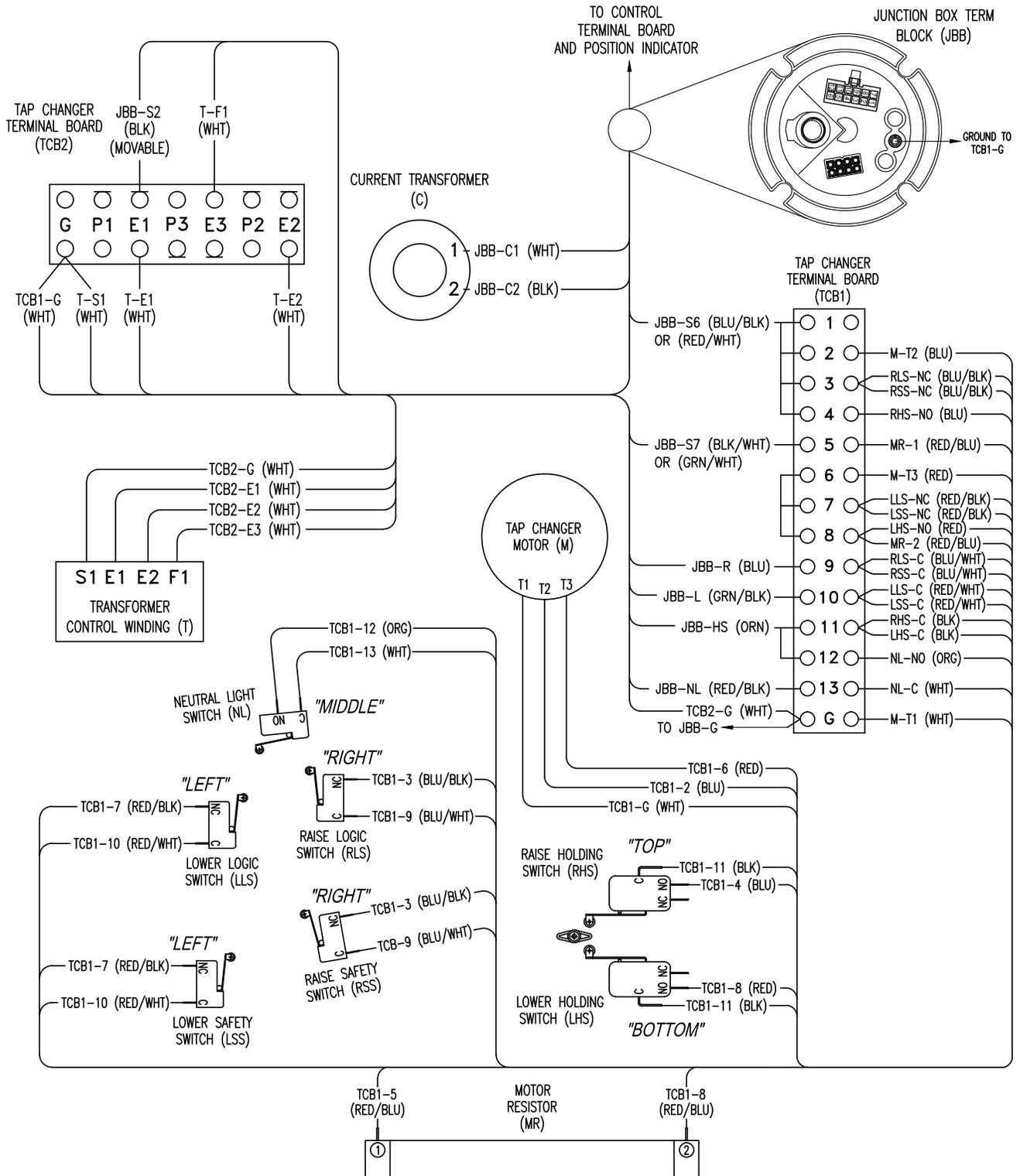


Figure 26. Typical internal wiring of voltage regulators with a QD3 tap-changer

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

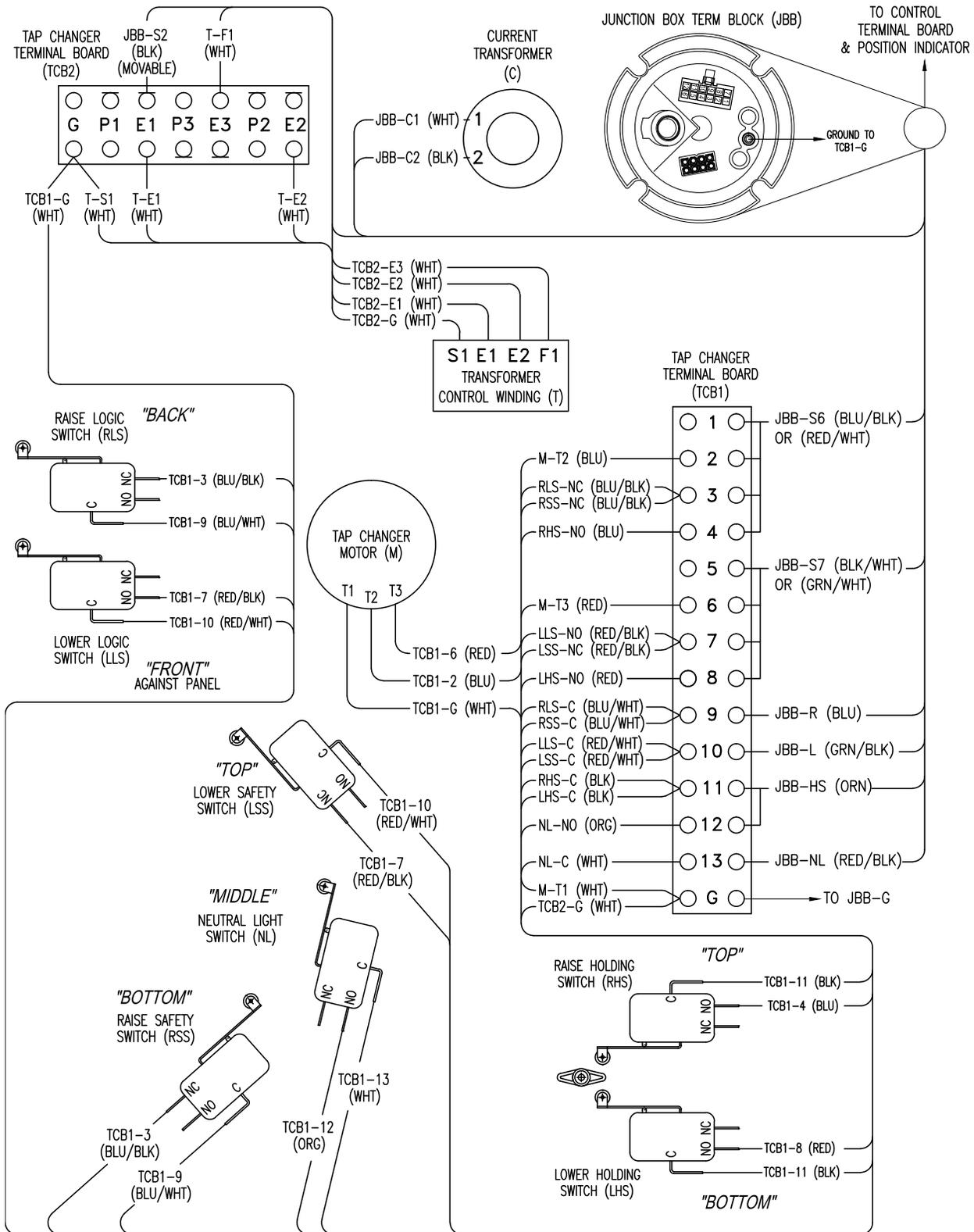


Figure 27. Typical internal wiring of voltage regulators with QD5 and QD8 tap-changers

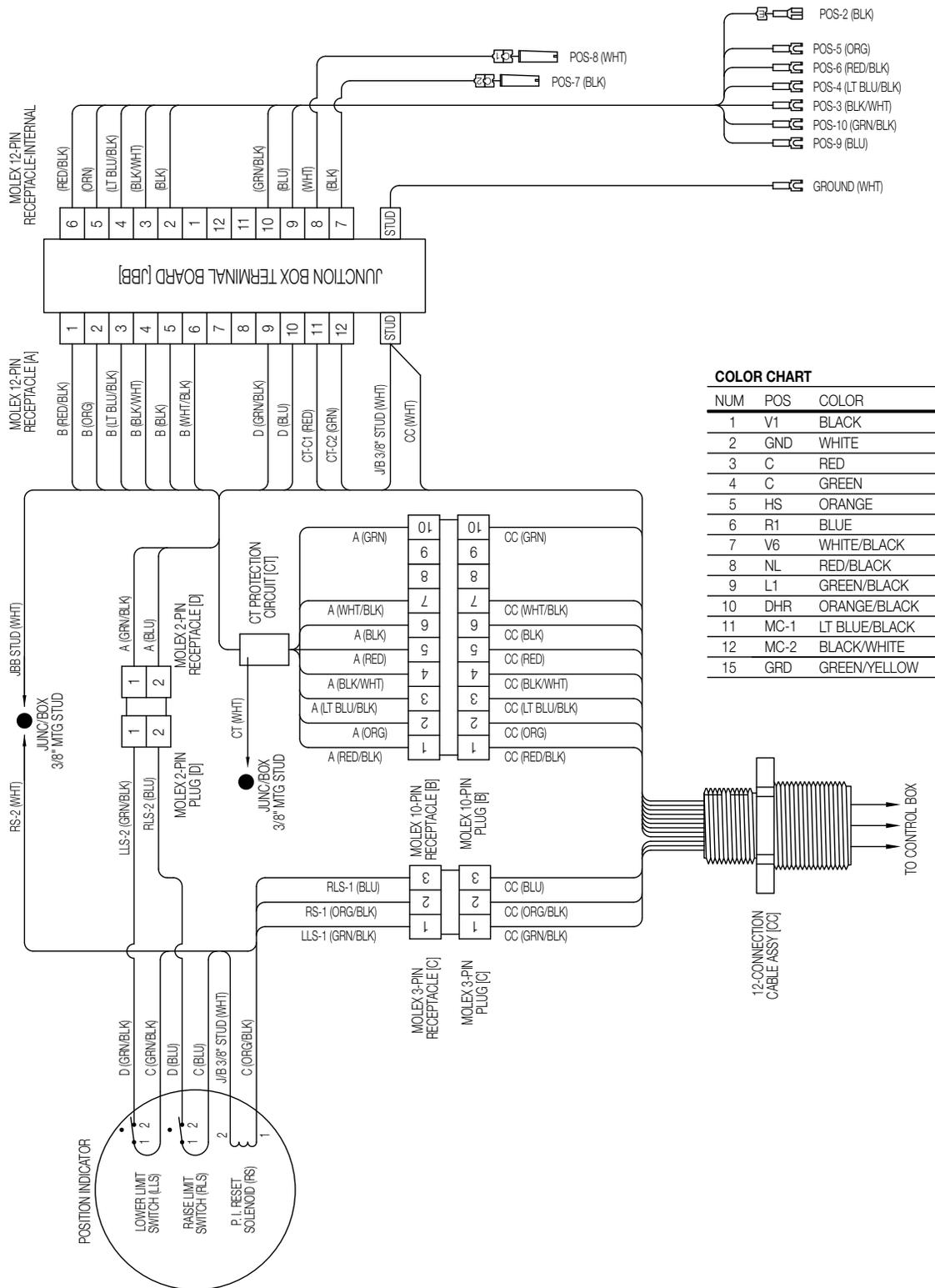


Figure 28. Junction box wiring diagram

VR-32 Voltage Regulator with Quik-Drive™ Tap-Changer

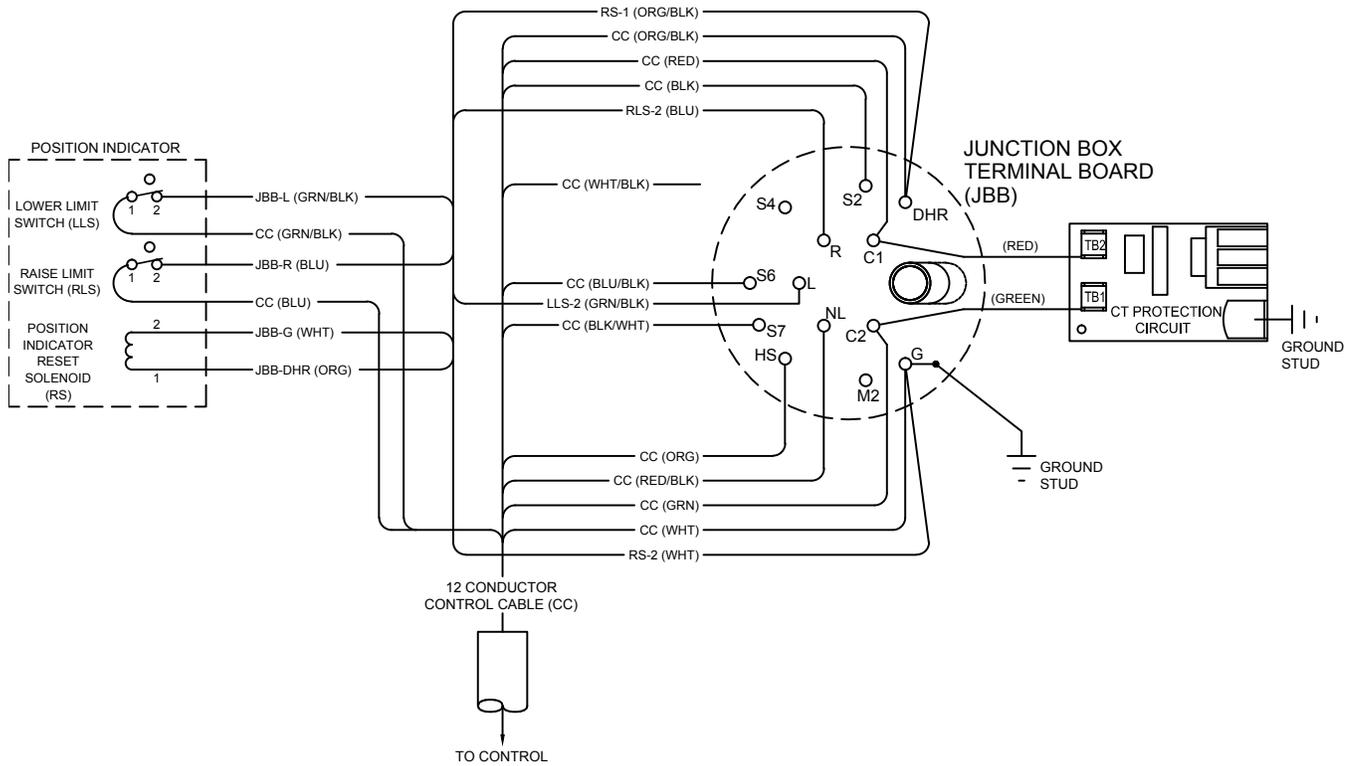


Figure 29. Legacy junction box wiring diagram

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