Voltage Regulators

COOPER Power Systems

Service Information

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

S225-10-30

Figure 1.
VR-32 Voltage Regulator with Quik-Drive tap-changer and CL-6 control.

Contents

SAFETY FOR LIFE

Cooper Power Systems products meet or exceed all applicable industry standards relating to product safety. 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 Cooper Power Systems 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 flash clothing, safety glasses, face shield, hard hat, rubber gloves, 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 may result in death, severe personal injury, and equipment damage. G102.1

WARNING: Power distribution and transmission equipment must be properly selected for the intended application. It must be installed and serviced by competent personnel who have been trained and understand proper safety procedures. These instructions are written for such personnel and are not a substitute for adequate training and experience in safety procedures. Failure to properly select, install, or maintain power distribution and transmission equipment can result in death, severe personal injury, and equipment damage. G122.3

PRODUCT INFORMATION

Introduction

Service Information S225-10-30 provides the installation, operation, and maintenance instructions for the Cooper Power Systems VR-32 voltage regulator with the Quik-Drive tap-changer. This manual also includes parts replacement information.

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 *S225-11-1 CL-6 Series Control Installation, Operation, and Maintenance Instructions* for information on the CL-6 voltage regulator control.

Additional Information

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

Handling and Storage

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

Unloading

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

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 3. 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

Cooper Power Systems regulators are designed and tested in accordance with the following standards:

IEEE Standard C37.90.1-2002™

IEEE Standard C37.90.2-1995™

IEEE Standard C57.13-1993™

IEEE Standard C57.15-1999™

IEEE Standard C37.91-1995™

IEEE Standard C57.131-1995™

EN 50081-2

EN 61000-4

IEC 60068-2

IEC 60214-1

IEC 610255-5

Quality Standards

ISO 9001:2000 Certified Quality Management System

Description

The Cooper Power Systems VR-32 Voltage Regulator operates to keep voltage levels within programmed limits to improve power quality and is compatible with SCADA and automation distribution systems.

Available in pole-, platform-, and pad-mounted and substation configurations, the Cooper VR-32 is suitable for three- or four-wire overhead and underground systems.

Cooper Power 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 percent 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 (such as 167/187 kVA for a nominal 167 kVA regulator).

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

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

Cooper Power Systems regulators are supplied with the following standard features:

- Dual-rated 55/65 °C 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
- Oil sight gauge
- Upper filter press connection
- Drain valve and oil-sampling device
- CE mark compliant control
- Control cable quick disconnect

Available Options

Available options include:

- Long-length, quick-connect cable (see Figure 2), 10 to 50 feet, 10 foot increments, factory installed

Figure 2.
Quick connect/disconnect cable.

- Armored cable
- Shielded cable
- Adjustable galvanized-steel elevating structure
- Supplemental external fusing to prevent damage from reverse polarity connection to the voltmeter terminals
- Shunt surge arresters
- Oil thermometer with or without alarm contacts
- Oil-level gauge with or without alarm contacts
- Pressure and vacuum gauge
- 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
- Bird guards
- 4-hole NEMA spade bushing connectors

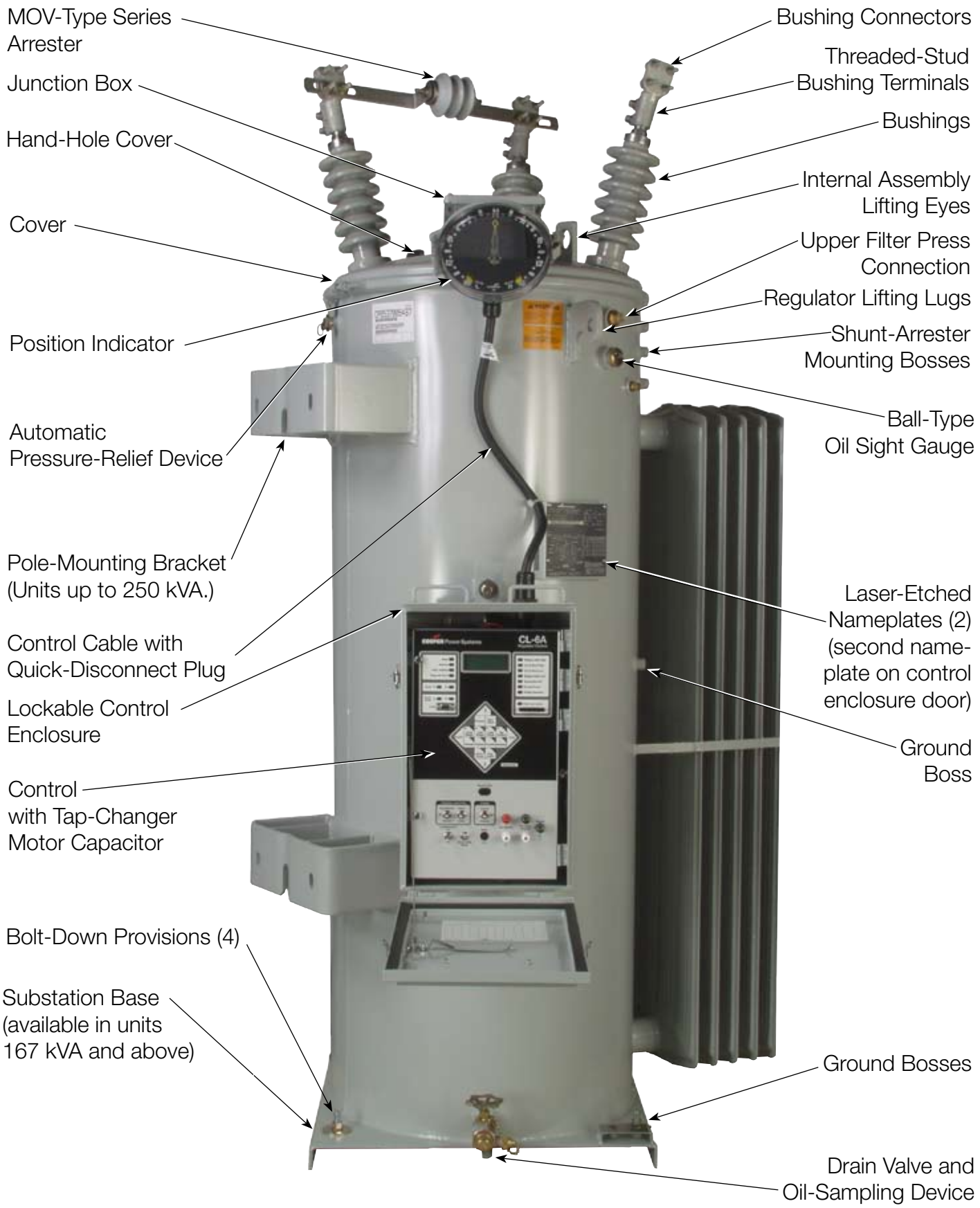


Figure 3.
External features of the VR-32 voltage regulator.

INSTALLATION

Pre-installation Inspection

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

1. Check oil sight gauge. Look for visible signs of oil leakage.
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 oil. If moisture has entered the tank, dry regulator and filter oil before putting unit in service. See Tables 5 and 6 for values that oil should meet. 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 oil according to Tables 5 and 6.
7. Regulator may be energized at rated voltage (with caution) and an operational check can be performed. (This procedure is optional.)
8. A high-potential test may be done to ensure adequate electrical clearances to ground. (This procedure is optional.)

Systems Connections

WARNING: Hazardous Voltage. Connect the "S" bushing to the source, the "L" bushing to the load. For Wye connections, connect the "SL" bushing to neutral. For Delta connections, connect the "SL" bushing to the appropriate phase. Inaccurate connections may cause excessively high or low voltage on the load side of the regulator and can cause death or severe personal injury and equipment damage. 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 Figures 4—8. Refer to the Shunt Arresters section of this manual for information on shunt arrester application.

NOTE: 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.

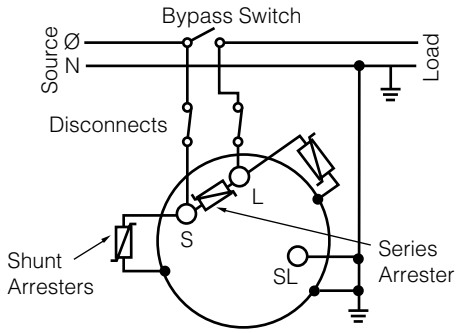


Figure 4.
Regulating a single-phase circuit.

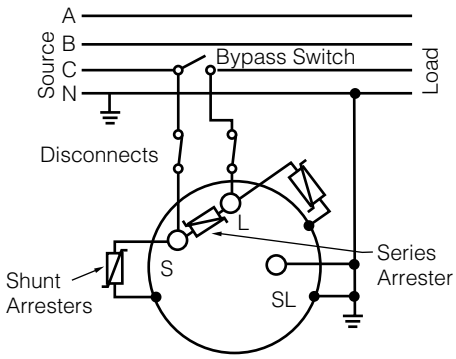


Figure 5.
Regulating one phase of a three-phase, four-wire circuit regulator.

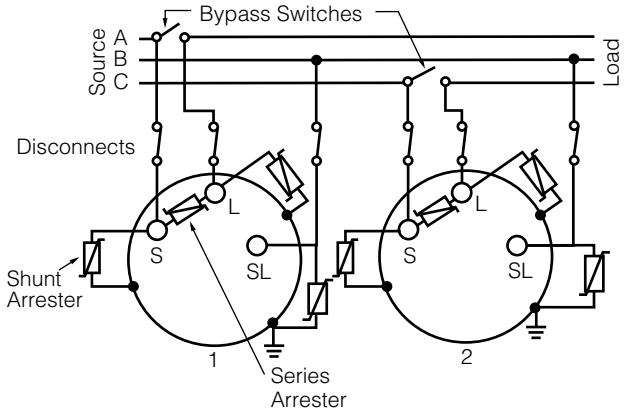


Figure 6.
Regulating a three-phase, three-wire circuit with two regulators (Open Delta).

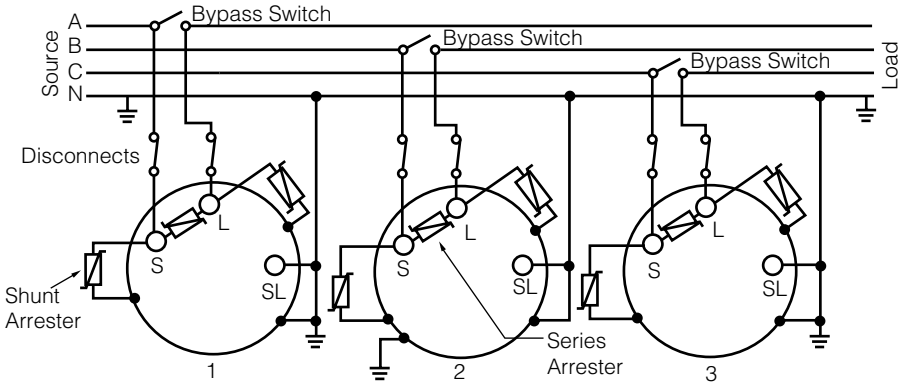


Figure 7.
Regulating a three-phase, four-wire, multi-grounded wye (star) circuit with three regulators (Wye).

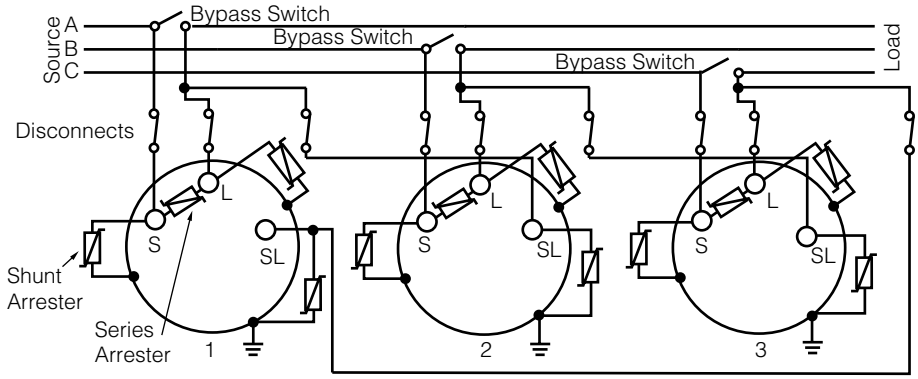


Figure 8.
Regulating a three-phase, three-wire circuit with three regulators (Closed Delta).

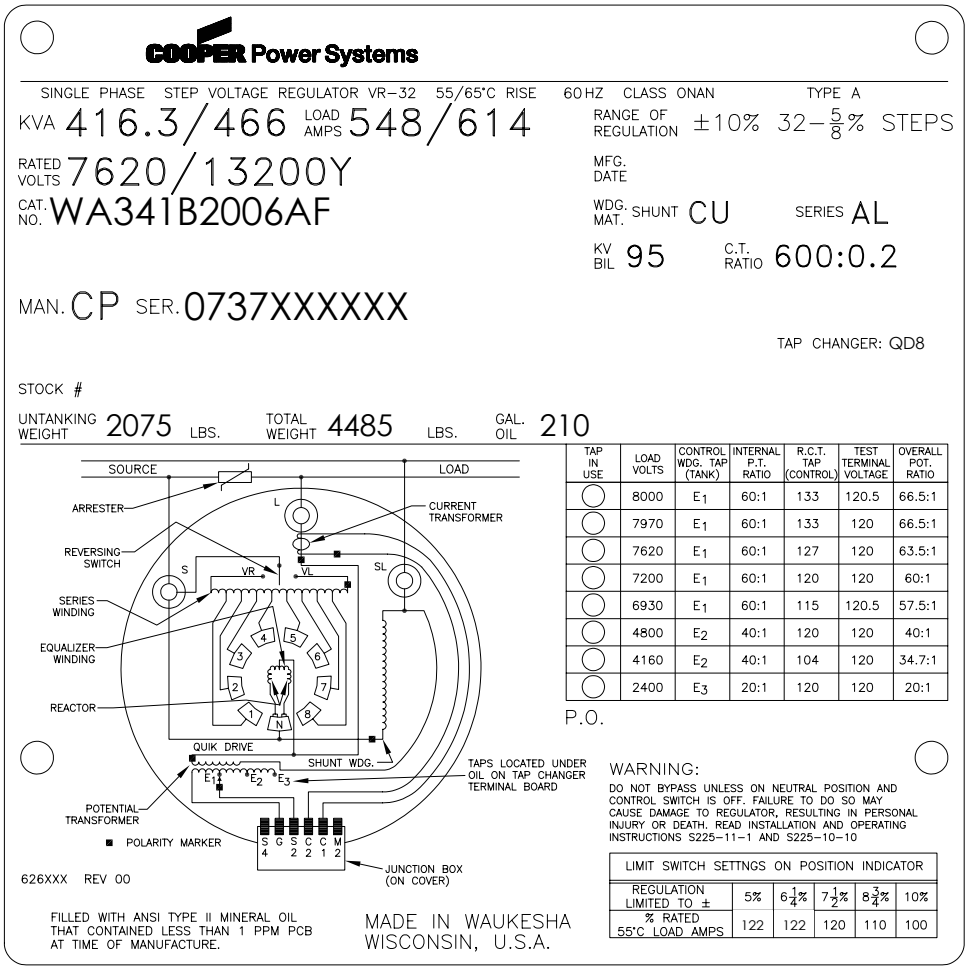
Nameplates

Two anodized aluminum nameplates are provided as standard; refer to Figures 9 and 10. One nameplate is placed on the regulator tank. The other is placed on the control in case the control is removed at a later date. Nameplates provide a substantial amount of 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 and are normally factory pre-programmed into the control. It is recommended that this information be verified prior to placing the control and regulator into service. When calling Cooper Power Systems for service or support-related issues, please obtain the catalog number and serial number found on the nameplate in order for the factory to reference the proper drawings and support information.

Mounting

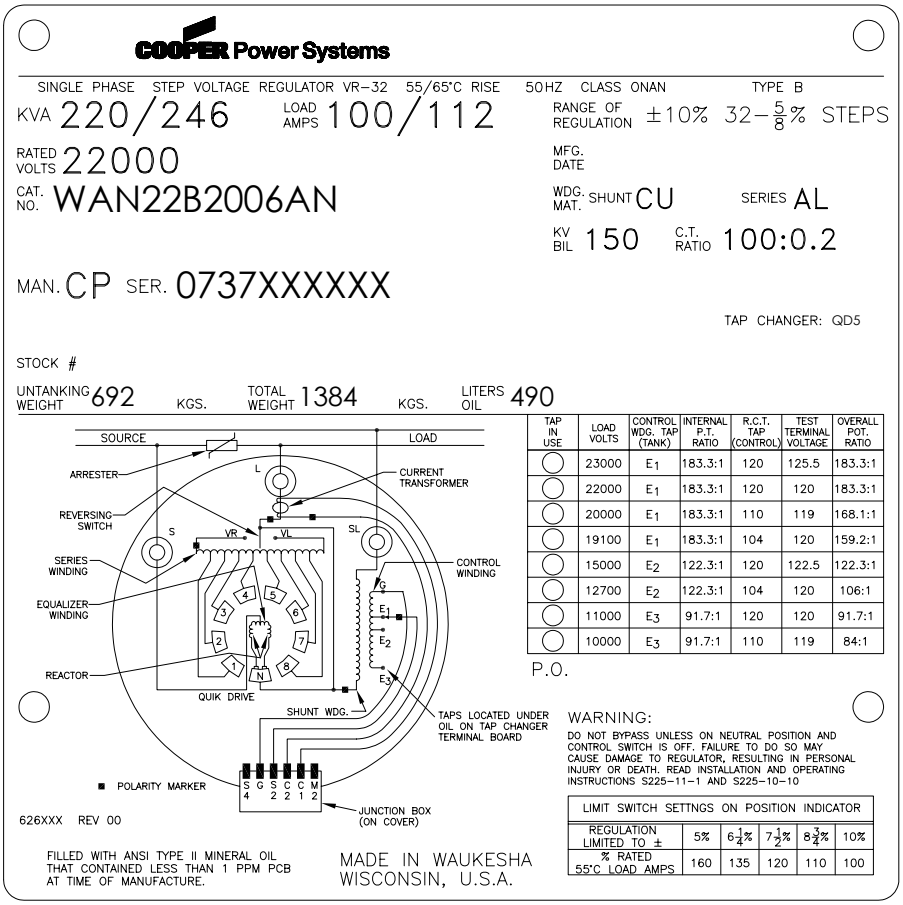
A regulator can be mounted on a pole, a cross-arm platform, or an elevating structure. Regulators are normally provided with either pole-mounting brackets or a substation base according to their rating. An elevating structure can be provided to simplify substation installation of regulators requiring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

The regulator control can be mounted on the regulator tank or at a point remote from the unit. Rubber-covered cable is available in 3.04 m (10 ft) incremental lengths from 3.04 m (10 ft) to 15.20 m (50 ft) for interconnection between the control and the regulator.



TAP IN USE	LOAD VOLTS	CONTROL WDG. TAP (TANK)	INTERNAL P.T. RATIO	R.C.T. TAP (CONTROL)	TEST TERMINAL VOLTAGE	OVERALL POT. RATIO
○	8000	E_1	60:1	133	120.5	66.5:1
○	7970	E_1	60:1	133	120	66.5:1
○	7620	E_1	60:1	127	120	63.5:1
○	7200	E_1	60:1	120	120	60:1
○	6930	E_1	60:1	115	120.5	57.5:1
○	4800	E_2	40:1	120	120	40:1
○	4160	E_2	40:1	104	120	34.7:1
○	2400	E_3	20:1	120	120	20:1

Figure 9.
Typical nameplate, domestic 60 Hz design.



TAP IN USE	LOAD VOLTS	CONTROL WDG. TAP (TANK)	INTERNAL P.T. RATIO	R.C.T. TAP (CONTROL)	TEST TERMINAL VOLTAGE	OVERALL POT. RATIO
○	23000	E_1	183.3:1	120	125.5	183.3:1
○	22000	E_1	183.3:1	120	120	183.3:1
○	20000	E_1	183.3:1	110	119	168.1:1
○	19100	E_1	183.3:1	104	120	159.2:1
○	15000	E_2	122.3:1	120	122.5	122.3:1
○	12700	E_2	122.3:1	104	120	106:1
○	11000	E_3	91.7:1	120	120	91.7:1
○	10000	E_3	91.7:1	110	119	84:1

LIMIT SWITCH SETTNGS ON POSITION INDICATOR					
REGULATION LIMITED TO ±	5%	6 1/4%	7 1/2%	8 3/4%	10%
% RATED 55°C LOAD AMPS	160	135	120	110	100

Figure 10.
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: Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

Refer to *Service Information S225-11-1 Voltage Regulators, CL-6 Series Control Installation, Operation, and Maintenance Instructions* for information on the CL-6 voltage regulator control, including placing the control into service and initial programming. Perform an operational check of the control before installing the regulator. With the control programmed for basic operation, perform an operational check of manual and automatic operation.

Regulators can be placed in service without interrupting load continuity once bypass and disconnect switches are installed.

Procedure A should be followed when one bypass switch and two disconnect switches are used. Procedure B should be followed when a regulator bypass-disconnect switch is used.

A ground pad tapped for 1/2 inch 13 NC thread is provided on the side of the control cabinet.

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

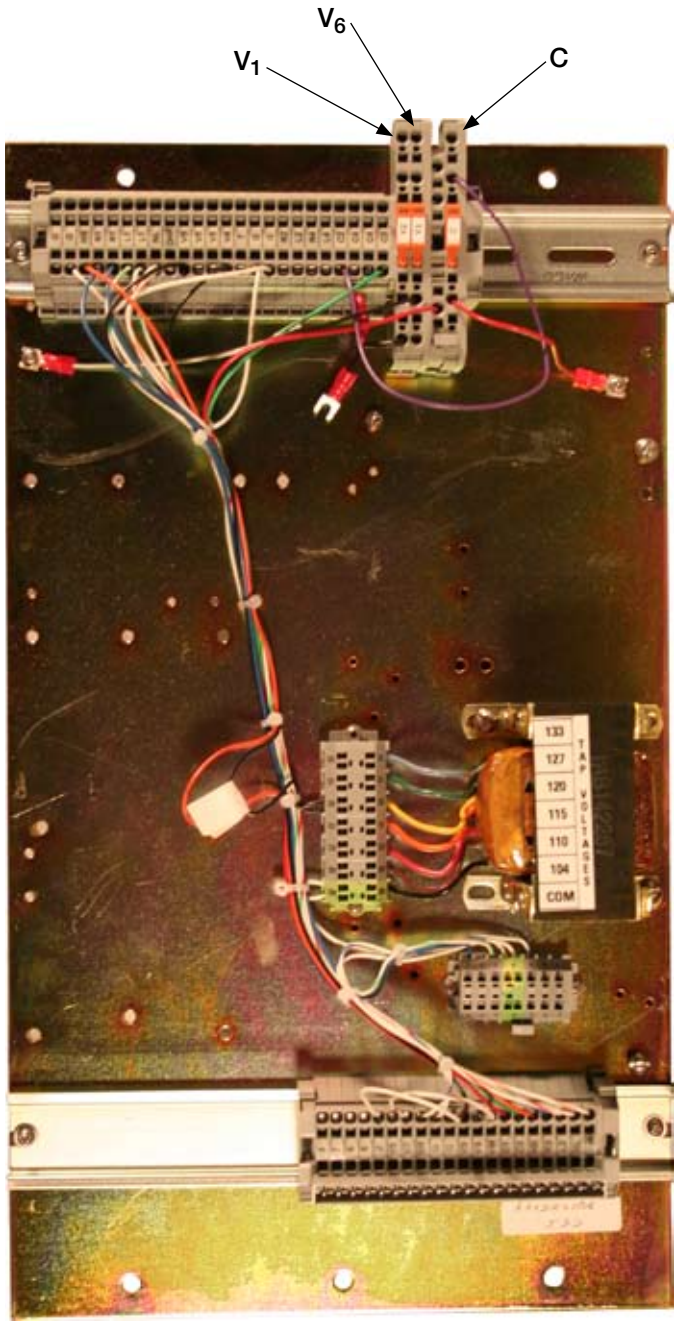


Figure 11.
Control back-panel connections.

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 switch to **OFF**.
3. Knife switches on back panel should be set with $\mathbf{V_1}$ (potential switch) (and $\mathbf{V_6}$ if present) closed (pushed in) and **C** (CT shorting switch) open (pulled out). See Figure 11.
4. Close source-load (SL) disconnect switch if available.
5. Close source (S) disconnect switch.
6. Set power switch to **INTERNAL** and control switch to **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 (Neutral).
8. With regulator in neutral position, set control switch to **OFF**, set power switch to **OFF**, open $\mathbf{V_1}$ knife switch (and $\mathbf{V_6}$ 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 $\mathbf{V_1}$ knife switch, and set power switch to **INTERNAL**.
12. Refer to *Service Information S225-11-1 Voltage Regulators, CL-6 Series Control Installation, Operation, and Maintenance Instructions* for information on the CL-6 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 switch to **MANUAL** and power switch to **EXTERNAL**.
3. Knife switches on back panel should be set with $\mathbf{V_1}$ (potential switch) (and $\mathbf{V_6}$ if present) open (pulled out) and **C** (CT shorting switch) closed (pushed in). See Figure 11.
4. Apply 120 V (or other voltage as indicated by the decal) to external source terminals, if available. If not, proceed to Step 7, below.
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 (Neutral).
6. Remove the voltage from external source terminals.
7. With regulator in the neutral position, set control 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 $\mathbf{V_1}$ knife switch (and $\mathbf{V_6}$ if present), open **C** knife switch, and set power switch to **INTERNAL**.

Setting the Manual (Hard) Limit Switches

Refer to the **CONSTRUCTION AND OPERATION: Position Indicator and ADD-AMP Capability** section of this manual for a complete discussion of these features.

Before setting the manual limit switches, be sure the new settings will not conflict with the present tap-changer position; see Figure 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, follow this procedure:

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

Figure 12.
Position indicator.

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.

Removal from Service

Determining Neutral Position

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: Explosion Hazard. Bypass a regulator with the line energized only if both the position indicator and the neutral light indicate neutral. If both do not indicate neutral, 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. VR-T206.0

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 more than one method to determine the neutral position.

Return the Regulator to Neutral

WARNING: Explosion Hazard. Always use the CONTROL FUNCTION switch (labeled Auto/Remote, Off, Manual and Raise or Lower) to operate the regulator, not the power switch. Failure to comply can result in the tap-changer stepping off of neutral immediately upon being energized, causing personal injury and equipment damage. VR-T207.0

WARNING: Explosion Hazard. To stop the regulator on the neutral position, the CONTROL FUNCTION switch should be returned to Off during the switching operation from positions 1R or 1L to position Neutral. Switching to Off prior to reaching the neutral position prevents overshoot. Failure to comply can result in death or severe personal injury and equipment damage. VR-T208.0

1. Use the **Raise/Lower** switch to bring the regulator to neutral position.
2. When in neutral, the **Neutral Light** will be continuously lit and the position indicator will point to zero (Neutral).
3. Verifying the neutral position of the regulator using 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 illuminated.
   - **B.** Verify the tap position of the control indicates neutral.
   - **C.** Verify that the position indicator on the regulator is in the neutral position.
   - **D.** Using an acceptable method, verify that there is no voltage difference between the source and load bushings.

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. VR-T209.0

4. When the regulator has been placed in the neutral position, but prior to bypassing, additional safety action must be taken to ensure that the tap-changer will not inadvertently switch to an off-neutral position. This can be accomplished by doing the following:
   - **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 $\mathbf{V_1}$ knife switch (and $\mathbf{V_6}$ if present) located on control back panel (see Figure 11).

De-energizing the Regulator

Once it has been established that the regulator is on neutral, immediately proceed with the following steps:

1. Place **CONTROL FUNCTION** switch in the **Off** position.
2. Place control **POWER** switch in the **Off** position.
3. Open $\mathbf{V_1}$ knife switch (and $\mathbf{V_6}$ if present) located on control back panel (see Figure 11).
4. Remove the 6 A motor fuse.
5. Close bypass switch.
6. Open load (L) disconnect switch.
7. Open source (S) disconnect switch.
8. Open source-load (SL) disconnect switch, if available.

NOTE: If a regulator bypass disconnect is used in place of three separate switches, steps 5, 6 and 7 are carried out in one operation.

CONSTRUCTION AND OPERATION

The Cooper Power Systems VR-32 Voltage Regulators are designed, manufactured, and tested in accordance with IEEE Standard C57.15-1999™. 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 Pole-Mounted Regulator External Features

The BIL rating of the bushings is compatible with the BIL of the regulator, and all ratings, 25 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 to 2000 A, each bushing includes a 1.5"-12 UNF-2A stud. Connectors are not integral to the bushing. Refer to Table 1 for standard terminals.

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 stud only
1201-2000	1.5" - 12 UNF-2A stud only

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.

All regulators are provided with an external UltraSIL, Heavy Duty, VariGAP MOV-type 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.

A fluid sight gauge indicates fluid color and level at 25 °C ambient.

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

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

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

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 Tables 11 and 12 (see Appendix).

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.

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.

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.

The sealed-tank construction permits operation at 65 °C rise without increasing the oxidation rate of the oil. A pressure-relief device vents at approximately 5 psig.

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 ANSI C57.12.28 and C57.12.31. 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 during energizing.

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

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.

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 capabilities at reduced regulation, 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, the SOFT-ADD-AMP feature allows adjustment by way of the control 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 Figures 3 and 11) is mounted on a 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 automatically 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 ADD-AMP feature of VR-32 regulators allows increased current capacity by reducing the regulation range. This is accomplished by either setting limit switches in the position indicator or enabling the SOFT-ADD-AMP feature (Function Code 79) to prevent the tap-changer from traveling beyond a set position in either raise or lower directions.

The limit switches have scales graduated in percent regulation and are adjustable to specific values of 5, 6 1/4, 7 1/2, 8 3/4, and 10% regulation to alter the regulation range. These percentages translate to tap position limitations of 8, 10, 12, 14, or 16 raise or lower. The five possible load current ratings associated with the reduced regulation ranges are summarized in Tables 13 and 14 (see Appendix). Higher regulation ranges are realized in closed delta application.

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

NOTE: If 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 ADD-AMP limit. If the unit is switched back to automatic mode, the control will step the regulator back to within the ADD-AMP limits set in the control.

See also the **TROUBLESHOOTING** section of this manual for position indicator replacement instructions.

Surge Protection

Series Arrester

All VR-32 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 3. 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 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*

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

* Contact factory for specific shunt arrestor application ratings.

Internal Construction & 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.) The military specification-style, quick-disconnect circular connector has a solid-state automatic current-transformer shorting device.

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 the **Quik-Drive Tap-Changer** section of this manual for more information.

An electrical feedback circuit, monitoring motor current, is incorporated with the tap-changer motor circuit and control to ensure accurate indication of tap position and number of operations.

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 current rating.

A suitably 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 supplies a voltage for the tap-changer motor and the control sensing circuit. Additional taps are available on them for line voltages lower 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.

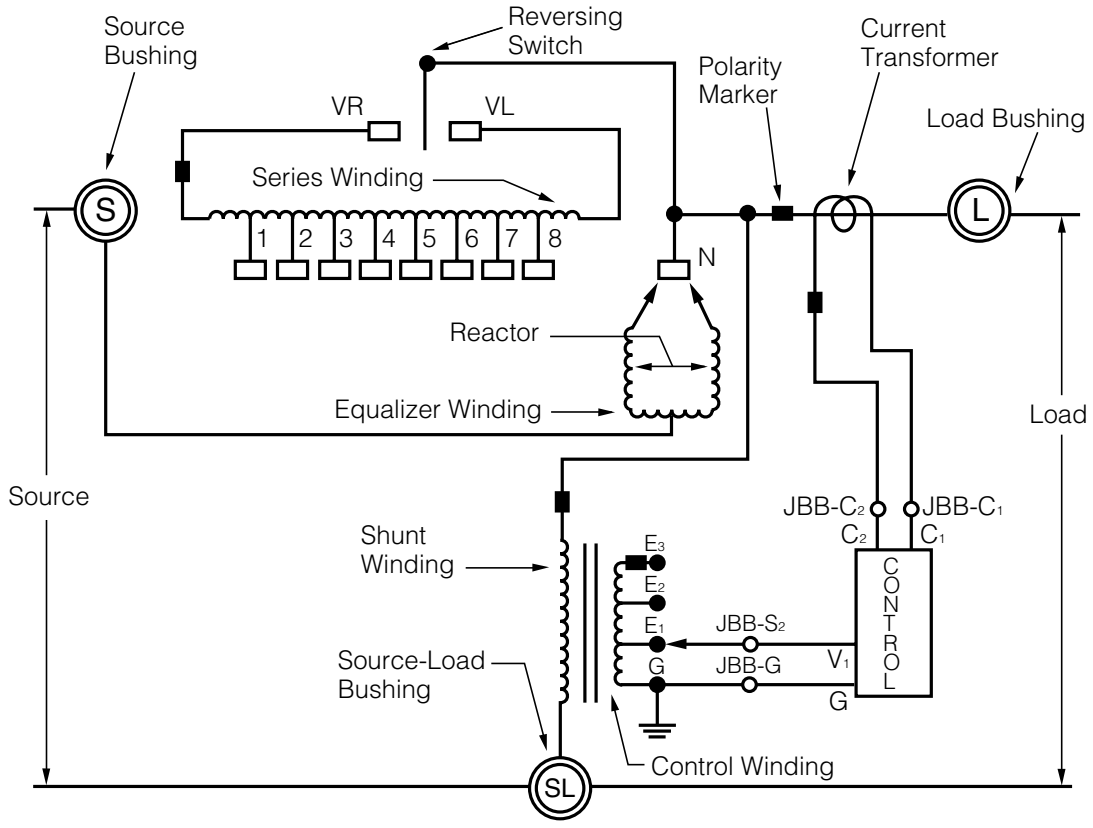


Figure 13.
Power circuit — series winding located on the source-side (ANSI Type B).

This interlacing of the two coils reduces 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. Figures 26 and 27 (see Appendix) illustrate the typical internal wiring schemes. Most of the wiring is on the tap-changer itself. The terminal board inside the junction box on the cover connects the internal tank wiring to the position indicator and control. The junction box wiring is shown in Figure 28 (see Appendix).

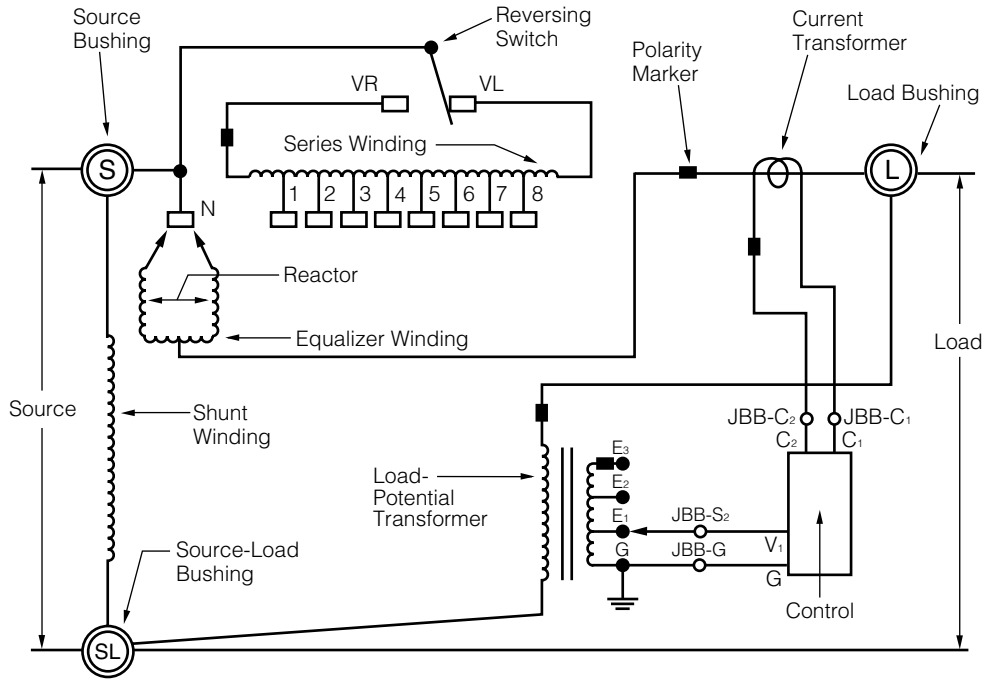


Figure 14.
Power circuit — series winding located on the load-side (ANSI Type A).

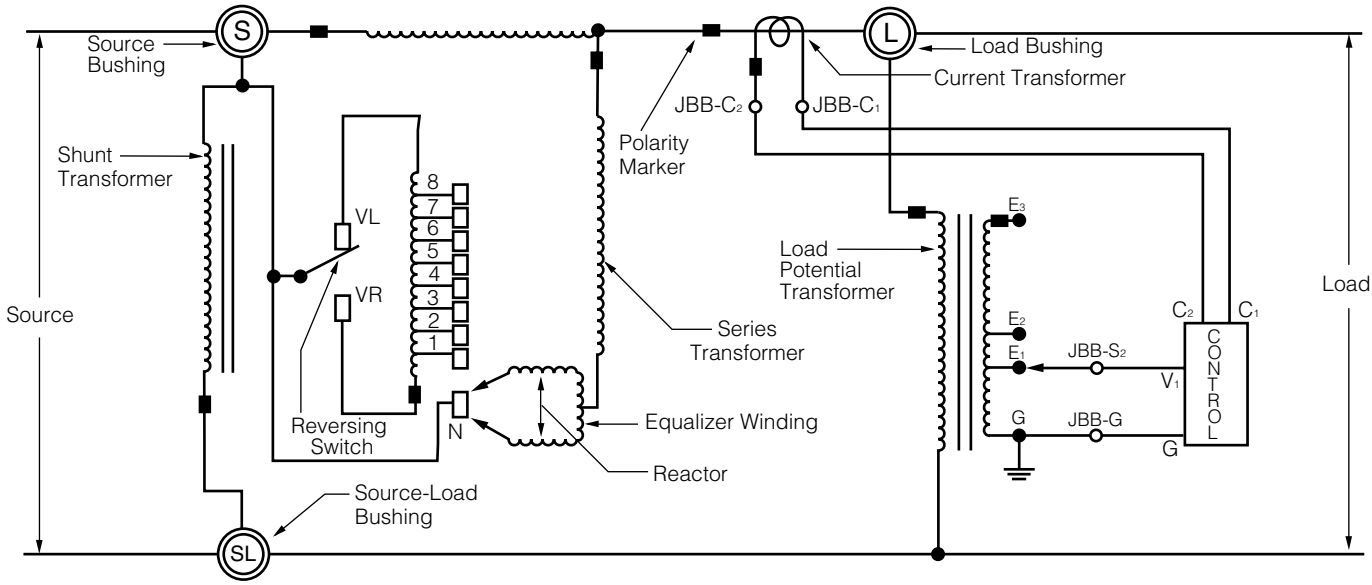


Figure 15.
Power circuit — series transformer (similar characteristics to Type A).

Voltage Circuits

All Cooper Power Systems VR-32 regulators have provisions for operation at system voltages lower than the nameplate rating, as listed in Tables 11 and 12 (see Appendix). 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 oil, and are marked **E_1**, **E_2**, etc. (See Figure 16.) The connections are made with push-on terminals and are easily accessed through the hand hole.

If an additional voltage transformer is required for a Reverse Power Flow application or indication of the unregulated voltage supply, the "**P**" taps are located on the voltage transformer itself or on the tap-changer terminal board.

The tapped potential winding cannot always provide adjustment of the voltage fine enough for control or motor use. A tapped autotransformer is therefore used for fine voltage adjustment. This transformer, the Ratio Correcting Transformer (**RCT_1**), 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. **RCT_1** is located on the control back panel (see Figure 11).

To operate a regulator on a system other than its rating, the appropriate selection must be made for the internal tap and **RCT_1** tap (and **RCT_2** if provided) and the control must be programmed properly at Function Code 43 (System Line Voltage) and Function Code 44 (Overall PT Ratio). The nameplate provides these values for common system voltages (see Figures 9 and 10).

The internal voltage supply is brought from the tap-changer terminal board to the junction box terminal board through the control cable, into the enclosure, terminating at the knife switch labeled **V_1** (and **V_2**, **V_6** 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_1** as previously described. The motor circuit is routed directly to the control front panel and the sensing potential is brought back to the top terminal strip through a series of removable jumpers and then to the front panel. This scheme allows for the complete interchangeability with all the prior CL-series controls and accompanying accessories.

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-6 control has full reverse power capabilities.

Refer to *Service Information S225-11-1 Voltage Regulators, CL-6 Series Control Installation, Operation, and Maintenance Instructions* for more information on the CL-6 control, reverse power operation, and source-side voltage calculation.

On the front panel, the three potentials (**V_S**, sensing voltage; **V_7**, differential voltage; **V_m**, motor voltage) are all brought directly to the power switch. Without an optional source-side supply, the **V_7** terminal is connected to the **V_S** terminal on the control back panel and the control software then recognizes that the **V_7** voltage 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 energizing the high-voltage winding and bushings. The external-source terminals are prominently located adjacent to the voltmeter test terminals.

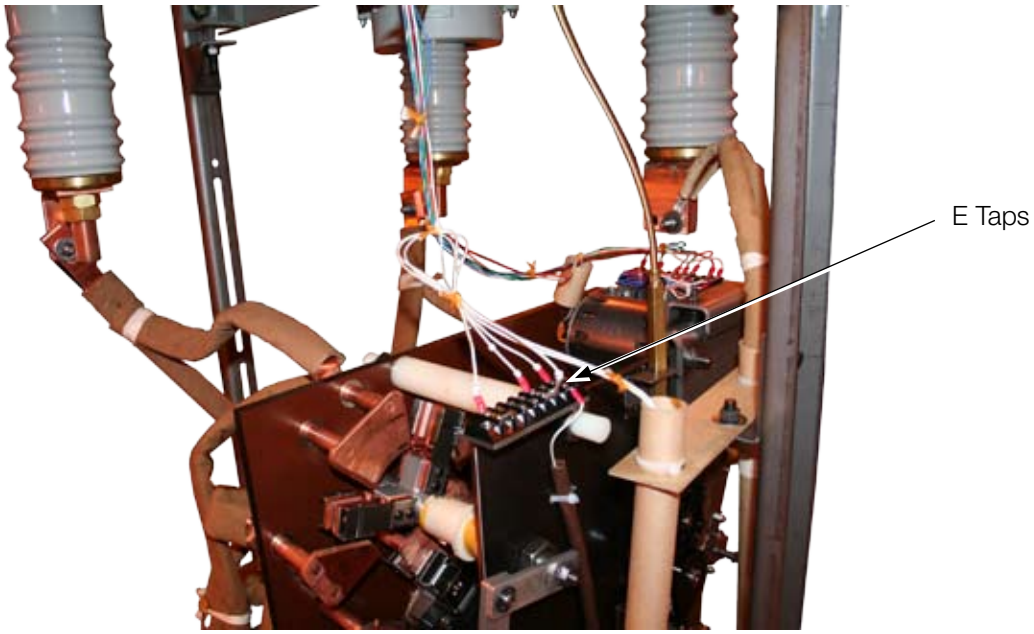


Figure 16.
Internal tap terminals.

The voltmeter terminals allow the monitoring of the voltage that is applied to the circuit board. This is the voltage output from **RCT_1** and the voltage displayed at Function Code 47 (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 auto/manual selector switch, the drag-hand reset solenoid, the neutral light, and the holding switch (alternate motor source) circuits.

Current Circuit

All VR-32 regulators are designed with an internal current transformer (see Figure 17) to provide a current source for the line-drop compensation calculations and for metering functions. Table 4 provides the application information for the various CTs used on the Cooper Power Systems regulators. These CTs provide 200 mA output for the rated CT primary current.

Figure 17.
Internal bushing-mounted current transformer.

TABLE 4
Current Transformer Applications (50 & 60 Hz)

Regulator Current Ratings	CT Primary Current
25	25
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	500
548, 578, 656, 668	600
833, 875, 1000, 1093	1000
1332, 1665	1600

The current developed by the CT is brought to the terminal board inside the junction box, through the control cable, into the enclosure, terminating 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 **V_1** and **V_6** knife switches should also be opened.) For all regulators with the quick-disconnect connector (Figure 3), 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.

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 (auto/manual) 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 circuit board.

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 is a switch or 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 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 S225-11-1 Voltage Regulators, CL-6 Series 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 toggle 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

The present load tap-changer product offering consists of three Quik-Drive tap-changers (see Figures 18—20). 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.
- Position Indicator Drive – A common indexing mechanism is shared between the tap-changers for driving the Position Indicator.
- Safety Switches – In addition to the limit switches in the Position Indicator, microswitches are employed on the tap-changers to interrupt power to the motor so that they cannot be powered beyond the 16 Raise or 16 Lower positions. These Safety Switches are triggered by a cam that is driven from the Main Contact Assembly.
- Logic Switches (Back-Off Switches) – The Logic Switches are used in parallel with the Safety Switches, based on the polarity of the Reversing Switch, to ensure proper operation of the tap-changer.

Quik-Drive Tap-Changer Mechanism

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

Reversing Switch

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

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

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

Quik-Drive Motors Drive Systems

Either AC Synchronous Motors or Induction Motors are used on Quik-Drive tap-changers. The motor uses a Holding Switch Circuit that is activated after the Control signals for a tap change. 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.

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. Induction Motors use a 50 µF capacitor for 50 and 60 Hz operation.

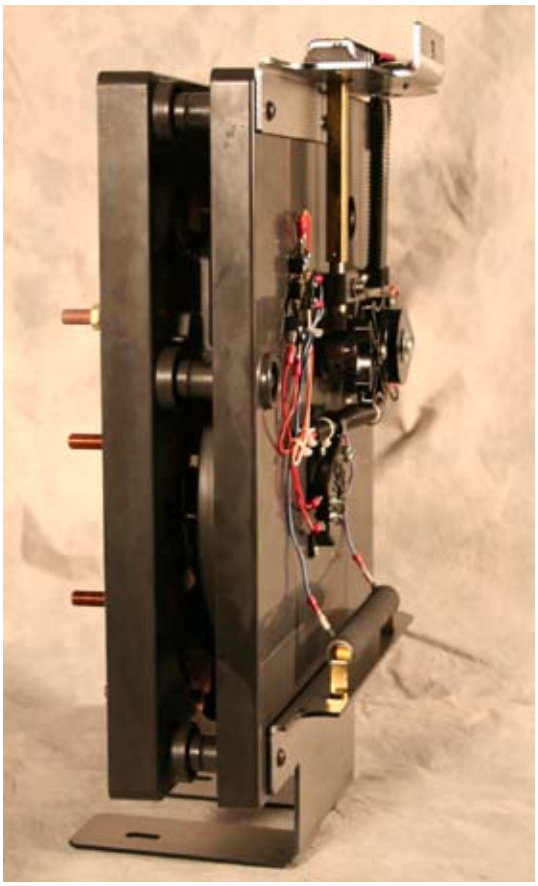


Figure 18.
QD-3 Quik-Drive tap-changer.

Contacts

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

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

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

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

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

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

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

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

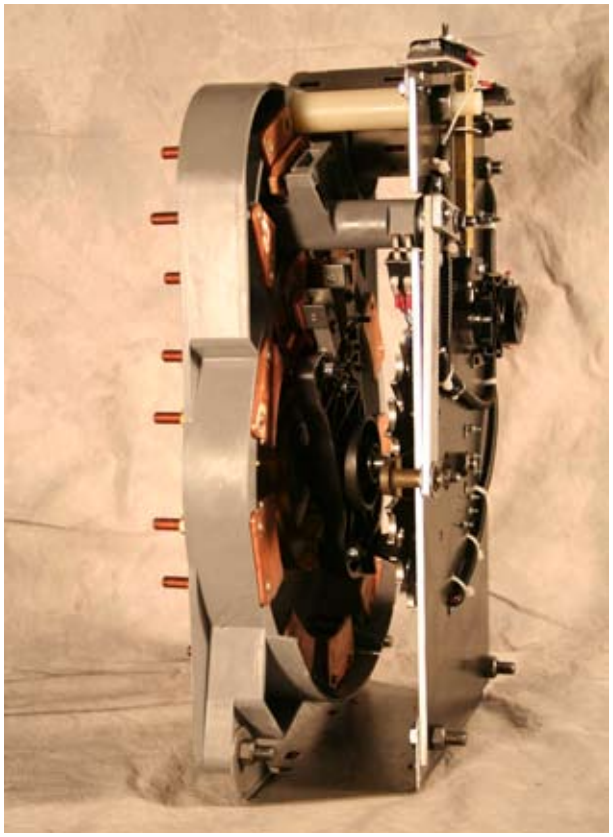


Figure 19.
QD-5 Quik-Drive tap-changer.

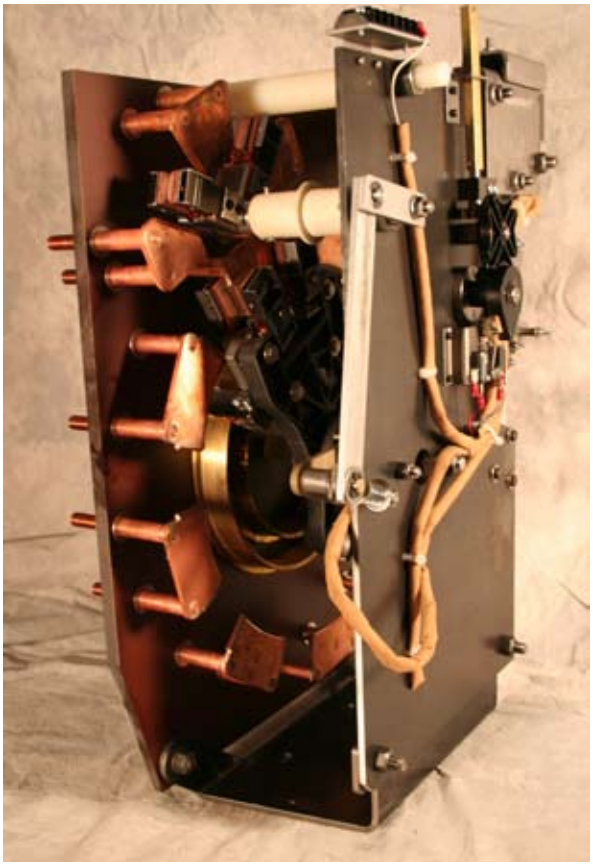


Figure 20.
QD-8 Quik-Drive tap-changer.

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-type voltage regulators are designed to provide many years of trouble-free operation. The usable life of a regulator is affected by its application and periodic inspections are recommended. The schedule for this will vary, based on a specific user's past experience. The Duty Cycle Monitor feature can assist in determining proper maintenance intervals. Additionally, the PMT Preventive Maintenance Tapping feature can automatically perform maintenance tapping. Refer to *Service Information S225-11-1 Voltage Regulators, CL-6 Series Control Installation, Operation, and Maintenance Instructions* for more information on the Duty Cycle Monitor and PMT features.

Proper operation of the regulator can be checked without removing the unit from service. Using the manual mode of operation, run the regulator several steps in the raise direction and then switch the control back to auto. After the time delay (set in Function Code 3) expires, the regulator should return to band edge. When this has been completed, use the manual mode of operation to run the regulator several steps in the lower direction and then switch the control back to auto. After the time delay, the regulator should return to band edge.

If the regulator will not operate properly, a substitute control can be tried before removing the unit from service. Refer to *Service Information S225-11-1 Voltage Regulators, CL-6 Series Control Installation, Operation, and Maintenance Instructions* for proper procedures on removing and replacing the control.

TABLE 5
FR3 Fluid Characteristics (natural ester*)

	New	Used
Dielectric Strength (kV) ASTM D1816 2 mm gap 1 mm gap	 ≥ 45 ≥ 25	 ≥ 40 ≥ 23
Interfacial Tension ASTM D971-91 (mNm)	 —	 —
Water ASTM D1533-88 (ppm maximum)	 ≥ 100	 ≥ 400

*Per IEEE C57.147 (D11)

TABLE 6
Mineral Oil Characteristics (Type II*)

	New	Used
Dielectric Strength (kV) ASTM D1816 2 mm gap 1 mm gap	 ≥ 45 ≥ 25	 ≥ 40 ≥ 23
Interfacial Tension (mNm) ASTM D971	 ≥ 38	 ≥ 25
Water (mg/kg) ASTM D1533	 ≥ 20	 ≥ 15% **

* Per IEEE C57.106

** 15% relative saturation at operating temperature (Table 3 and Table 5 of IEEE Standard C57.106-2002™)

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 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 oil 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 oil when the internal assembly is lifted, causing personal injury.

VR-T222.0

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 (refer to the **INSTALLATION: Removal from Service** section of this manual) and untank the unit to verify contact wear, oil dielectric, etc. The fluid should be checked (a) prior to energizing if the regulator has not been energized for a long time period or (b) at normal maintenance intervals. Table 5 shows the characteristics that FR3 fluid should meet. Table 6 shows the characteristics that mineral oil should meet.

1. Manually run the tap-changer to neutral, if possible. If not, record position indicator reading before proceeding to untank.
2. Disconnect control cable from bottom of junction box (see Figure 2).
3. Remove series arrester.
4. Release internal pressure using pressure relief device on the side of the regulator.
5. Free the cover by removing the clamping ring or the cover bolts.
6. Attach 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 oil (see Figure 21). As a safety precaution, blocking between the cover and the tank lip should be used until inspection of the tap-changer or other maintenance is complete. 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 customer service for availability.

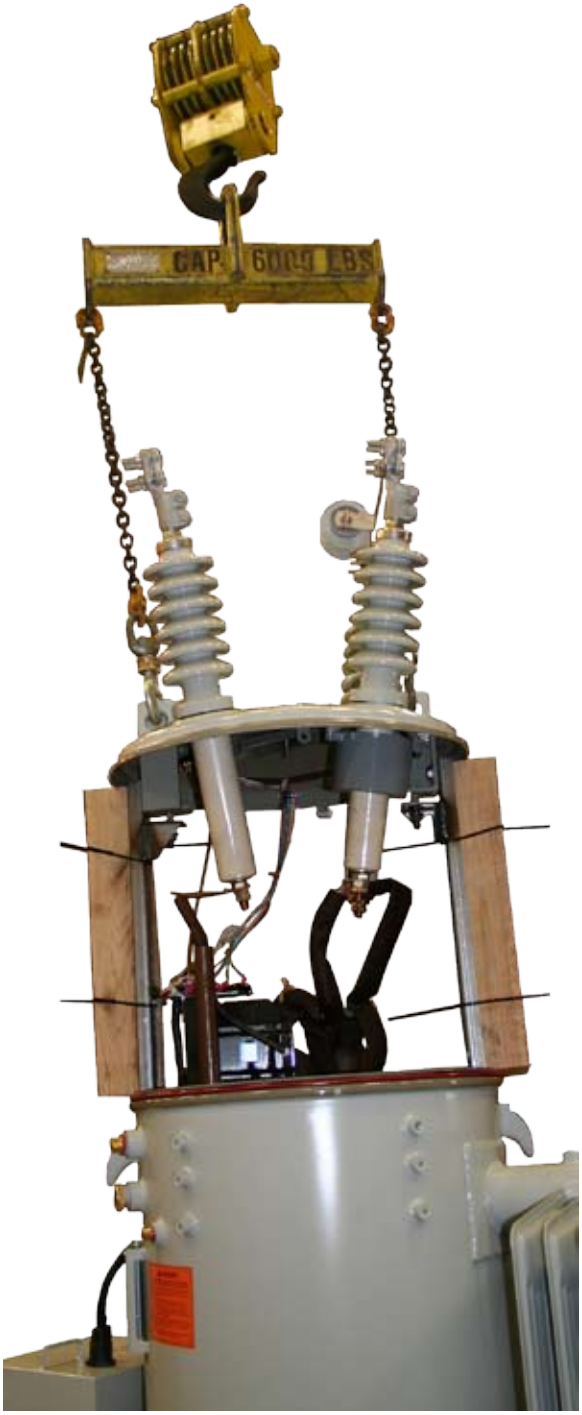


Figure 21.
Untanking the voltage regulator.

Retanking the Regulator

Retank the regulator as follows. Refer to Figure 21.

1. Be sure position indicator shows present position of the tap-changer.

   If not, remove indicator cable in junction box from position indicator shaft after loosening set screw. Rotate indicator shaft until proper position is reached, then tighten set screw. Verify coordination of position indicator with tap-changer in the neutral position (control neutral light on). Refer to the **TROUBLESHOOTING** section of this manual for position indicator replacement.

2. Check gasket seat surfaces on cover and tank, and wipe clean. Wipe gasket and position it on tank lip.
3. Loosen horizontal, side channel bolts to ensure proper seating of regulator in tank and proper cover seal.
4. Raise cover assembly and attached components over tank. Make certain of proper orientation.
5. Lower unit, rotating channels counter-clockwise into tank guides.
6. Seat unit in tank. Tighten cover clamps or bolts.

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

7. Check and retighten the horizontal, side-channel bolts through the hand hole: torque to 68 N•m (50 ft•lbs).
8. Properly reseal hand-hole cover, being careful not to damage cover or insulation on the hand-hole cover.
9. Connect control cable to connector at the bottom of the junction box.

   A. If the unit is out of fluid more than four hours, it must be rebaked at 66 ˚C (150 ˚F). A unit can be rebaked a maximum of two times over its life.

   B. Within four hours after bake, the unit should be retanked and filled with fluid.

   C. Retighten all hardware as needed.

It is recommended that a vacuum be pulled on the unit for at least one hour (2 mm of vacuum or better) after the unit is completely refilled with fluid. 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 Cooper Power Systems VR-32 step-voltage regulator, provide the following information:

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

Refer to Figure 22 for part identification of high-voltage bushings.

Refer to Figure 23 for QD-8 Quik-Drive tap-changer parts.

Refer to Figure 24 for QD-5 Quik-Drive tap-changer parts.

Refer to Figure 25 for QD-3 Quik-Drive tap-changer parts.

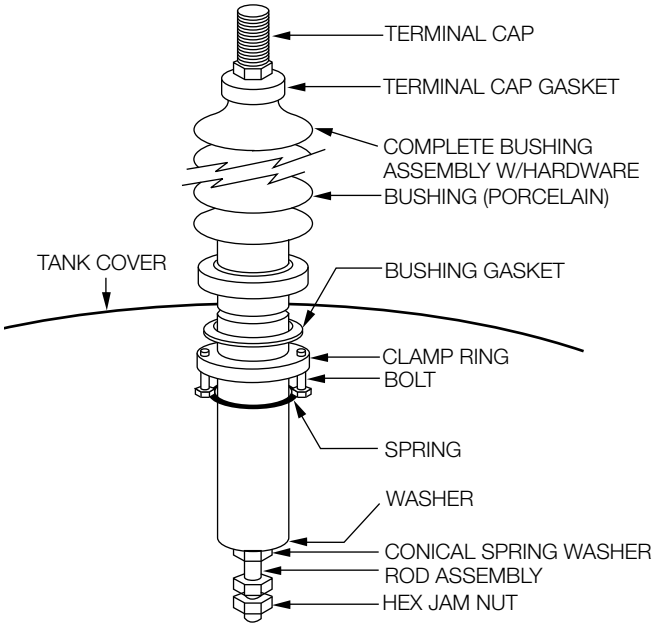
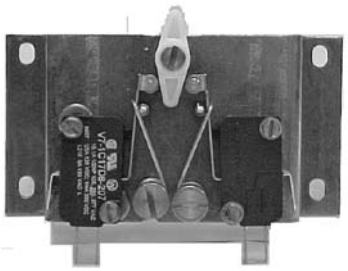


Figure 22.
High-voltage bushing (S, L, and SL).

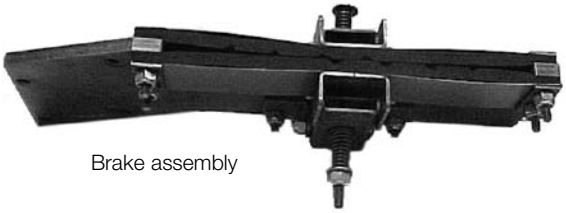


Quik-Drive holding switch assembly

Motor

Chain

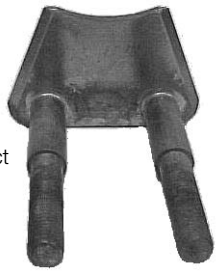
Right-hand reversing stationary contact



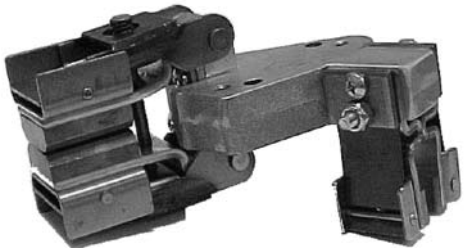
Brake assembly

Left-hand reversing stationary contact

Main stationary contact



Main reversing contact



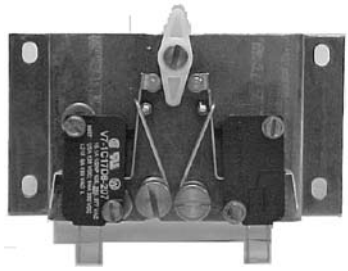
Left-hand movable contact

Reversing movable contacts contact

Right-hand movable contact

Figure 23.
Replacement parts for the Quik-Drive tap-changer QD-8.

Right-hand reversing stationary contact



Quik-Drive holding switch assembly

Reversing movable contact

Left-hand reversing stationary contact

Brake assembly

Main movable contact assembly

Main stationary contact

Neutral stationary contact

Motor

Figure 24.
Replacement parts for the Quik-Drive tap-changer QD-5.

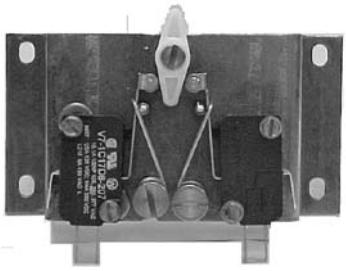
TC-LTC PI drive gear kit

Motor kit

Motor resistor

PI cam

Main stationary contact



Quik-Drive holding switch assembly

Reversing movable contact

Reversing stationary contact

Main movable contact assembly

Figure 25.
Replacement parts for the Quik-Drive tap-changer QD-3.

TROUBLESHOOTING

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

When using the CL-6 Control with a CPS regulator, refer to *Service Information S225-11-1 CL-6 Series Control Installation, Operation, and Maintenance Instructions* for additional information on the CL-6 regulator control.

External Check

Examine the power connections first. For example, verify that the load lead is connected to the load bushing and that the source lead is connected to the source bushing. Check for other potential problems, such as an open ground connection.

Defining the Problem

Determine which of the following categories best describes the malfunction and follow the corresponding steps. Refer to the Appendix, Figures 26 through 28, while diagnosing the problem.

Note: If the tap-changer uses Logic Switches as part of the Safety Switch system and a Logic Switch malfunctions, the tap-changer is likely to only function from 16 Lower to 2 Lower, or from 2 Raise to 16 Raise.

Note: Parameter options, accessed via menu or function code, are shown in **bold**.

Settings of front panel switches are shown in **bold**.

Keypad directions are shown as follows: press keys as shown in **bold**; enter numbers as shown in *italics*.

Tap-Changer Operation Troubleshooting

Regulator Will Not Operate Manually or Automatically

1. Connect a voltmeter between **TB_1-R_1** and **TB_1-G**. Set the **CONTROL FUNCTION** switch on **Manual.**
2. Toggle the **Raise** switch and measure the voltage between terminals **R_1** and **G** on terminal board **TB_1**. The voltage reading should approximate the set voltage setting.
3. Place the voltmeter hot lead on **TB_1-L_1**, then toggle the **Lower** switch.
4. Measure the voltage between terminals **L_1** and **G** on terminal board **TB_1**. The voltage reading should approximate the set voltage value.
5. If correct voltage readings are obtained in Steps 2 and 4, the trouble may be in the position indicator, junction box, control cable, or motor capacitor.
6. If there is no voltage measurement in either Step 2 or 4, make a corresponding measurement (**R_3** to **G** and **L_3** to **G**) on lower terminal board **TB_2**.
7. If the voltages measured in Step 6 are approximately the set voltage value, then the fault is likely a loose connection or a faulty terminal between **TB_1** and **TB_2**.
8. If Steps 2, 4, and 6 do not provide voltage readings, measure the voltage between **VM** and **G** on terminal board **TB_2**. The reading should approximate the set voltage value.
9. If Step 8 does not yield a voltage measurement, check the voltage between **PD_1-1** (**V1**) and ground (**G**) at the voltage disconnect knife switch.

   A. If the set voltage value is approximately obtained, the **V_1** disconnect or the ratio-correcting transformer (**RCT_1**) of the rear-panel signal circuit is probably faulty.

   B. If voltage is not obtained, the trouble is in the control cable, junction box, or regulator tank. If the junction box checks are satisfactory, the trouble is in the regulator tank. See *Service Information S225-10-2* and *S225-10-19* for troubleshooting methods.

Motor Capacitor Problem

A problem with the motor capacitor can prevent a regulator from operating manually or automatically. To check the motor capacitor, use the following steps:

1. Connect a voltmeter from **TB_1-R_1** to **G**.
2. With the control powered up, place the **Auto/ Remote/ Manual** switch on **Manual.**
3. Using the **Raise/Lower** Switch, give a **Raise** signal.
4. The voltmeter reading should approximate the set voltage.
5. With the voltmeter still connected to **TB_1-R_1** to **G**, give a **Lower** signal.
6. The voltmeter should read a capacitive voltage plus run voltage. This voltage could be somewhere between 160 and 190 V ac.
7. A voltage reading on **TB_1-R_1** to **G** of 0 V, or a mV reading, is a sign of a bad capacitor.
8. To double check, place the voltmeter lead on **TB_1-L_1** to **G**.
9. Using the **Raise/Lower** switch, give a **Lower** signal.
10. The voltmeter reading should approximate the set voltage.

11. With the voltmeter still connected to **TB_1-L_1** to **G**, give a **Raise** signal.
12. The voltmeter should read a capacitive voltage plus run voltage. This voltage could be somewhere between 160 and 190 V ac.
13. A voltage reading on **TB_1-L_1** to **G** of 0 V, or a mV reading, is a sign of a bad capacitor.
14. If both the raise and lower circuit reads 0 V or a mV reading, when there should be a capacitive voltage plus run voltage, then the motor capacitor is open. The capacitor will need to be replaced.

Operation Counter Does Not Indicate Tap Change

If the operation counter does not indicate tap changes, check the following:

1. The voltage signal at **TB_2-R_3** and **L_3** should be approximately 120 V when a tap change is made. When this voltage signal is applied, the control panel operation counter will be updated.
2. Measure the voltage at **TB_2-R_3** or **L_3** when the tap-changer is given a command to tap in manual mode by the **Raise/Lower** toggle switch. If the voltage signal is present, the problem is either in the control connector or the control.
3. If the voltage signal is not present at **TB_2-R_3** or **L_3**, the problem could be in the back-panel wiring harness connections at **TB_1-R_1** or **L_1**, the control cable, junction box connections, or the holding switch on the tap-changer.
4. Check the voltage signal at **TB_1-R_1** or **L_1**. If the signal is not present at these points, keep tracing the signal back through the components back into the regulator.

Tap Position Out-of-Sync

If the control (FC 12, Present Tap Position) loses sync with the position indicator, check FC 49, Tap-Changer Type against the nameplate on the regulator. The nameplate indicates what type of tap-changer is on the Cooper Power Systems regulator. FC 49 must be set for the type of tap-changer (Spring Drive, Direct Drive, QD-8, QD-5, or QD-3).

Regulator Will Not Tap Beyond a Certain Tap Position

If the regulator will not tap beyond a certain tap position, check the limit switch settings on the position indicator. If the limits need to be adjusted, adjust upper and lower limits to allow proper regulation.

Regulator Operates Manually but Operates Incorrectly When Set On Automatic

Run the regulator to the neutral position with the control switch. Check for voltage between **V_4** and **G** on **TB_1**. This is the sensing circuit supplying voltage from the output of **RCT_1** on the rear panel. If this voltage is more than 10% above or below the programmed voltage-level setting of the control, then the source is beyond the range of the regulator. An absence of voltage would indicate a wiring problem such as an open somewhere in the control power supply. If these voltage checks are within range, perform the following:

1. Verify that the band edge indicators are functioning. (These are the **Out-of-Band High** and **Out-of-Band Low** indicators located on the front panel.) If they are not functioning, check FC 56, Reverse Sensing Mode. Set it to **Locked Forward** if it is set for another option. Verify the automatic mode of operation.
2. Verify that Function Code 69, Auto Blocking is set to **Norma**l. Verify the automatic mode of operation.
3. Measure the voltage from **V_S** to **G** on lower terminal board **TB_2**.
   - **A.** A measurement of approximately the set voltage value at **V_S** to **G** indicates that the problem is in the control.
   - **B.** If there is no voltage present at **V_S** to **G**, the trouble is in the **V_1** disconnect or the ratio-correcting transformer of the back-panel circuit. Replace them.
4. Check the holding switch circuit.
   - **A.** Verify that the tap-changer will complete a tap change by placing the CONTROL FUNCTION switch to **Manual** and toggling the **Raise/Lower** switch in the desired direction.
   - **B.** If the **Raise/Lower** switch must be held in the **Raise** or **Lower** position to complete a tap change, the problem is in the holding switch circuit. If the holding switch is not working, a Quik-Drive tap-changer will do multiple taps until the control-set time delay expires.
   - **C.** Check for voltage between **TB_2-H_S** and **G** and **TB_1-H_S** and **G**. If voltage is present at **TB_1-H_S** and not on **TB_2-H_S**, the problem is in the back panel wiring harness. Replace the orange **H_S** lead from **TB_1-H_S** to **TB_2-H_S**. If no voltage is present at **TB_1-H_S**, the problem is in the control cable, junction box cover, or the holding switch (located inside the regulator) itself. Check cable continuity up to the junction box. If it appears normal, the problem is the holding switch. Adjust or replace it (see *Service Information S225-10-2* or *S225-10-19*). If all appears to be in order, the problem is most likely in the control, not in the holding switch.

Check Function Code 56, Reverse Sensing Mode

When there is no load current and the regulator will not operate in automatic, check the **C** switch on the back panel. If the **C** switch is closed and FC 56 is set for **Bidirectional**, the regulator will not operate in automatic. The **C** switch should be open for normal operation.

Check Function Code 69, Auto Operation Blocking Status

1. Check the Auto/Remote/Manual switch. The switch should be on **Auto/Remote**.
2. Verify that FC 69 is set to **Normal**. To check the FC 69 setting:

   Function, *69*, **Enter.**
3. If not on **Normal** and resetting is blocked by the security feature, enter the security code via the keypad to change the blocking status:

   A. Function, *99*, **Enter** *32123* (default), **Enter.**

   B. Function, *69*, **Enter.**

   C. Edit/Reset, Scroll to **Normal**, **Enter**.

Check Function Code 170, Tap-to-Neutral

1. Verify that FC 170 is set to **Off**. To check the FC 170 setting:

   Function, *170*, **Enter.**
2. If not on **Normal** and resetting is blocked by the security feature, enter the security code via the keypad to change the blocking status:

   A. Function, *99*, **Enter** *12121* (default), **Enter.**

   B. Function, *170*, **Enter.**

   C. Edit/Reset, Scroll to **Off**, **Enter**.

Testing with the Voltage Limiter ON and a Limit Value Set

CAUTION: Equipment Damage. Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

When testing a regulator with external power, it is recommended that Function Code 80, Voltage Limiter Mode be set to **Off**.

When testing in the Auto mode with the voltage limiter on, there may be problems getting the regulator to operate in either raise or lower direction if the external voltage is greater than the voltage limit settings.

No Band Indicators

If the band indicators are not working when the voltage is out-of-band, check the following:

1. Check FC 56, Reverse Sensing Mode. If FC 56 is set to **Lock Forward** and there is reverse power, the indicator will not display and the voltage will not regulate.
2. Check FC 57, Reverse Current Sense Threshold and ***Load Current** (*Metering PLUS). If the load current is less then the reverse threshold current, the indicators will not work and the regulator will not regulate.
3. Check the polarity of the current transformer. If the polarity is reversed, the band indicators will not display.

Junction Box Troubleshooting

This section is used if the regulator will not operate manually. (Problem was isolated to junction box or regulator tank after checking out control.)

The junction box is composed of a terminal board, the position indicator, and the control box interconnections. Refer to Figure 28.

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 outlined in the **INSTALLATION: Removal from Service** section of this manual.
2. Ground the three high-voltage bushings.
3. Open **V1**, disconnect switch, on rear panel of control cabinet.
4. Remove junction box lid.
5. Check the wiring on the junction box terminal board for **loose connections, burnt wiring, or bad swage joints.**
6. Set the power switch to **EXTERNAL**.
7. Apply a 60/50 Hz, 120 V ac nominal variable source to the external source terminals. Make certain to maintain correct polarity.
8. Set the control function switch on **MANUAL**.
9. Toggle the raise switch. Measure the voltage between terminals **R** and **G** on terminal board. The voltage reading should be approximately 120 V ac.
10. Move the voltmeter leads to **L** and **G**. Toggle the lower switch.
11. Measure the voltage between terminals **L** and **G** on terminal board. The voltage reading should be approximately 120 V ac.

12. If correct voltage readings are obtained in steps 9 and 11 above, the trouble is in the regulator tank. Refer to the **Troubleshooting** section of *Service Information S225-10-2*.
13. If there is no voltage measurement in either step 9 or 11, the problem is in the limit switches inside the position indicator or in the control cable.
14. Check the continuity of the raise and lower limit switches. The switches should be closed on all tap-changer positions except for the set-limit switch positions of the indicator dial. To check the continuity:
    - **A.** Remove position indicator green-black lead from splice terminals.
    - **B.** Place the meter lead on the disconnected lead and the other lead on terminal **L** of the junction box terminal board. Then check continuity.
    - **C.** If a continuity problem occurs, refer to the **Position Indicator Replacement** section.
    - **D.** Remove the position indicator blue lead from the splice terminal.
    - **E.** Place the meter lead on the disconnected lead and the other lead on terminal **R** of the junction box terminal board. Check continuity.
    - **F.** If a continuity problem occurs, refer to the **Position Indicator Replacement** section.
15. Check the reset solenoid of position indicator. Depress the drag-hand reset switch while measuring the voltage between **DHR** and **G** on the terminal board. The voltage reading should be approximately 120 V ac and drag hands will reset.
16. If 120 V is read and drag hand will not reset, refer to the **Position Indicator Replacement** section.
17. If 120 V is not read, refer to the **Control Panel Troubleshooting** section.

Metering Troubleshooting

Load Voltage Secondary (Output Voltage) Does Not Match the Voltmeter Test Terminal Voltage

When the output voltage at FC 6 is several volts different from what the voltmeter test terminals read, check and verify the following function codes and settings for proper setting per the name plate.

1. Verify FC 43, System Line Voltage (Load Voltage) is set per nameplate value.
2. Verify FC 44, Overall PT Ratio is set per nameplate.
3. Verify **RCT** Control Tap located on the back panel of the control assembly is set per the nameplate.
4. Verify Control Winding **E** Tap and Differential Transformer **P** Taps, if present, are set per nameplate. **E** taps are located on the terminal board on the tap-changer inside the tank. **P** taps are located on the terminal board on the top of the tap-changer or on a differential potential transformer located on the side channel inside the regulator tank.

When all the settings are set per the nameplate, the regulator is in neutral, and the system line voltage or load voltage is what is stated on the nameplate, the voltmeter test terminals on the control panel will read the value per the nameplate.

No Load Current

When there is no load current reading at FC 9, Load Current, Primary, or any of the metering components requiring current as part of the calculation, check the **C** switch on the back panel. The switch should be open. If the **C** is closed, the current transformer is shorted and no current reading is available.

Regulator Will Not Tap Beyond a Certain Tap Position

If the regulator will not tap beyond a certain tap position and the position indicator limit switches setting are at 16 raise and 16 lower, check the SOFT-ADD-AMP settings: FC 175, SOFT-ADD-AMP High Limit, and FC 176, SOFT-ADD-AMP Low Limit.

Control Calibration

WARNING: Explosion Hazard. Verify that both the neutral light and the position indicator hand indicate neutral when the tap-changer is physically in the neutral position. Lack of synchronization will cause an indefinite indication of NEUTRAL. Without both indications of neutral, bypassing of the regulator at a later time will not be possible, and the line must be de-energized to avoid shorting part of the series winding. Failure to comply can result in serious personal injury or death and equipment damage. VR-T212.0

CAUTION: Equipment Damage. Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

All controls are factory-calibrated and should not need to be recalibrated by user. However, calibration can be performed for both the voltage and current circuits as follows:

Voltage Calibration

1. Connect an accurate true-RMS-responding voltmeter to the voltmeter terminal. This voltmeter should have a base accuracy of at least 0.1% with calibration traceable to the National Bureau of Standards.
2. Connect a stable 50/60 Hz voltage source (with less than 5% harmonic content) to the External Source terminals.
3. Set the **POWER** switch to **External**.
4. Adjust the voltage source to provide 120.0 V to the control, as read on the reference voltmeter.
5. Before calibration can be performed, Security Level 3 must be activated by entering the proper security code at FC 99, Security Code.

   Function, *99*, **Enter**; *32123* (default), **Enter**.
6. The display will show the voltage applied to the control. This should correspond to the reading on the reference voltmeter. If the control reading is significantly different, the calibration can be altered by pressing **Edit**, keying in the correct voltage as displayed on the reference meter, and pressing **Enter**. The voltage circuit is now calibrated.

Current Calibration

1. Connect an accurate true-RMS-responding ammeter in series with the current source.
2. Connect a stable 60/50 Hz current source (with less than 5% harmonic content) to the reference ammeter and to the current input terminals $\mathbf{C_1}$ and $\mathbf{C_3}$ on fanning strip $\mathbf{TB_2}$ (C_1 is identified by a red wire, and C_3 is identified as the green wire).
3. To power the control, connect a 120 V ac voltage source to the **EXTERNAL SOURCE** terminals.
4. Place the power switch on **External**.
5. Adjust the current source to provide 0.200 A to the control, as read on the reference ammeter.
6. Before calibration can be performed, Security Level 3 must be activated by entering the proper security code at Function Code 99, Security Code.

   Function, 99, **Enter**, 32123 (default), **Enter**

   The proper level is now activated.
7. Access Function Code 48, Current Calibration.

   Function, *48*, **Enter**.
8. The display will show the current applied to the control. This should correspond to the reading on the reference ammeter. If the control reading is significantly different (greater than 0.6 mA error), the calibration can be altered by pressing **Edit**, then entering the correct current as displayed on the reference meter, followed by **Enter**. The current circuit is now calibrated.

CL-6 Control Panel Troubleshooting

No Power

Check the 6 A fuse on the control front panel. Remove the motor fuse from the control and check for continuity across the fuse. Spare fuses are shipped with each control and are located in the control box.

Note: Use only 250 V ac fuses of the proper current rating. Failure to do so may cause unnecessary fuse operation or insufficient protection of the regulator and control.

If the fuse has blown, the tap-changer motor will not run. If the 6 A fuse is okay, set the front-panel power switch to **Internal Power** and check the following :

1. With a voltmeter, check $\mathbf{TB_2}$-$\mathbf{V_S}$ to **G**. The voltage should approximate the set voltage. If the voltage is present at $\mathbf{TB_2}$-$\mathbf{V_S}$, then the problem is in the control. Replace the control.
2. Check the voltage-disconnect knife switch $\mathbf{V_1}$, $\mathbf{V_6}$ (if present), and the current shorting knife switch **C** of the back panel in the control enclosure. Close the $\mathbf{V_1}$ and $\mathbf{V_6}$ voltage switches if open. Open the CT shorting switch if closed.

3. Check the voltage at **V_1** to **G**. If the voltage is present at **V_1** to **G**, then the problem could be in the wiring harness or ratio-correcting transformer. Check for loose connections or burnt wiring. Verify that the ratio-correcting transformer **RCT_1** is on the correct tap for the regulated voltage as shown on the nameplate on the control enclosure door.
4. If voltage is not present, then the problem is either in the control cable, junction box connection, or inside of the regulator.

Self-Diagnostics

The control hardware performs self-diagnostic physical and memory checks. There are two events which force the control into the self-diagnostic routines:

- Power is turned on;
- Operator entry of the self-test mode (FC 91).

The duration of this test sequence is approximately three seconds. At completion, the display will indicate **PASS** or display a message (see **Diagnostic Error Messages**, in this section of this manual), depending on the test results. The **PASS** message will remain in the display until the operator makes an entry through the keypad or, after 30 minutes, the display will automatically be turned off.

The clock will maintain time-keeping for at least 24 hours after loss of ac power to control. The backup power source requires 65 hours operation on ac power to become fully charged.

Note: After the self-diagnostic and the LCD displays **PASS**, press **Escape** for further keypad use.

Note: The word **ERROR** on the LCD indicates a key entry error, not a diagnostic failure. See **Indication Messages** in the **Control Programming** section of *Service Information S225-11-1 CL-6 Series Control Installation, Operation, and Maintenance Instructions*.

Diagnostic Error Messages

If the control indicates a failure on power up, the LCD displays an error message. This message will give information of what was detected. Also, as long as there is a diagnostic error message, the Diagnostic Error LED indicator will be lit. Messages can include **No Neutral Sync Signal**, **Input Voltage Missing, and Configuration Value Required.** For more information, refer to **Power-Up/Reset Conditions** in the **Control Programming** section of *Service Information S225-11-1 CL-6 Series Control Installation, Operation, and Maintenance Instructions*.

No Neutral Sync Signal

CONTROL NOT INSTALLED ON REGULATOR

This most often occurs when powering up a control on a workbench. The **No Neutral Sync Signal** means the control did not have a neutral signal during the self-test during power up. This can occur because there is no 120 V signal present on the neutral light input. To confirm this and clear the error message, perform the following:

1. **Escape.**
2. **Function**, *99*, **Enter**, *32123* (default), **Enter.**
3. **Function**, *12*, **Enter.**
4. **Edit/Reset**, *(some number from one to 16),* **Enter**.
5. Initiate a self-test.

   Function, *91*, **Enter**, **Enter**, **Enter**.

   The **(No Neutral Sync Signal)** message should not reappear.

CONTROL ON REGULATOR

If the control is on a regulator and the **(No Neutral Sync Signal)** message appears during power up or self test, or there is no neutral light, check the input signal at **TB_1-NL** to **G**. If the regulator is in neutral, there should be 120 V at the input. When there is not 120 V at **TB_1-NL** while on neutral, the neutral light on the control panel will be off.

If there is no neutral light and no neutral light signal at **TB_1-NL**, verify that the regulator is in neutral. For the regulator to be in neutral, the position indicator should be on neutral and if the regulator is energized there should not be a differential voltage between the source (S) bushing and the load (L) bushing.

When there is no neutral light and the regulator is powered up either by internal or external power, check these input points as follows:

- **TB_2-NL**, located on the bottom terminal board on the control assembly back panel:

  If there in no voltage and there is voltage at **TB_1-NL**, the problem is in the connections in the wiring harness on the back panel. If there is voltage on **TB_2-NL** and no neutral light, the problem is in the control panel.

- **TB_1-NL**, located on the top terminal board on the control assembly back panel:

  If there is no voltage, the problem can be in the connection at this terminal point, the control cable, the connection in the junction box, or inside the regulator.

- **JBB-NL**, located on the terminal board inside the junction box and **TCB-NL**, located on the tap change:

  If there is no voltage, the problem is inside the regulator, either with connection point **JBB-NL** under the cover assembly, connection **TCB-NL** on the tap-changer, neutral light switch, or the neutral light actuator segments.

No Input Voltage

The **(No Input Voltage)** message occurs when no input voltage was sensed and FC 56, Reverse Sensing Mode is not set for **Locked Forward**. The input voltage is the source voltage from a differential or source potential transformer. This voltage signal can also be calculated by the control if FC 39, Source Voltage Calculation is set to **On** and the regulator type is properly set at FC 140, Regulator Type.

When this message is indicated and the regulator has a differential transformer, check for a voltage at $\mathbf{V_6}$ to **G**, if $\mathbf{V_6}$ is present. This voltage will be 0.0 V when the regulator is in neutral. The voltage will increase as the regulator is tapped up. When the regulator is at 16 raise, the voltage will be 11.5 to 12 V ac. If there is no input voltage shown at FC 7, Source Voltage Secondary, and the regulator has a differential transformer, the problem could be in the control, back-panel connections, control cable, the junction box, the junction box terminal board under the cover, or the differential transformer.

If there is not a differential transformer on the regulator, turn FC 39 to **On** to verify this indicator. This will supply the calculated voltage signal, causing the input voltage diagnostic error message to turn off.

Indication Messages When Using Edit Key

The following indication messages can occur when using the **Edit** key:

- **(Improper Security)** message will display while attempting an edit function when changes are disabled by the security system. To enable, enter a higher security code at FC 99, Security Code:

  Function, *99*, **Enter**, *Security Code*, **Enter**.

  Proceed with function code value and setting changes.

- **(Value Too Low)** means the function value you have entered is below the acceptable limit.

- **(Value Too High)** means the function value you have entered is above the acceptable limit.

For more information, refer to **Indication Messages** in the **Control Programming** section of *Service Information S225-11-1 CL-6 Series Control Installation, Operation, and Maintenance Instructions*.

Position Indicator Replacement

1. Verify that the tap-changer is in neutral via the neutral light of the control and visual inspection of the tap-changer. If the position indicator does not also show neutral, refer to instructions in *Service Information S225-10-2, Regulator Tap-Changer Operation and Maintenance*.

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

2. Remove the unit from service, as outlined in the **INSTALLATION: Removal from Service** section of this manual.
3. Remove the junction box cover.
4. Note the location of the indicating hand for future alignment and disengage the flexible shaft from the position indicator shaft.
5. Disconnect the four leads from the junction box terminal board and open the two splice terminals to the control cable. Refer to Figure 28.
6. Remove the three bolts holding the indicator to the junction box and slide the indicator free.
7. Remove the gasket from the groove on the back of the indicator body.
8. Clean the gasket surface of the junction box and the gasket and groove on the new indicator.
9. Place the gasket in the groove and insert the leads through the junction box wall, align the holes, and install the three bolts; finger tighten.
10. Wrench-tighten the bolts to evenly compress the gasket and bring the indicator body tight against the junction box.
11. Connect the six leads to the terminal board and control cables leads per Figure 28 and secure all connections.
12. Turn the indicator drive shaft to place the hands at the previously noted position.
13. Slide the flexible shaft coupling into the indicator coupling and secure the Allen screws.
14. Position the wires to prevent snagging on the couplings and secure the wires with tie wraps.
15. Connect a 120 V ac external power supply to the external banana jack on the front of the control panel.
16. Run the tap-changer manually to verify the alignment of the position indicator hand and the neutral light. The neutral light should be **ON** with the yellow pointer hand on zero (Neutral).

17. The following steps are instructions for setting the proper alignment to ensure rotational calibration on the position indicator.

A. Align the black scribe line on the position indicator (PI) coupling to the center of the operating band notches on the PI housing. (The notches are located on the back hub of the PI housing.)

Note that the new Cooper Power Systems' PI has a one-piece input shaft/coupling and a raised mark at the 12 o'clock position on the PI housing hub.

Also, note the counterclockwise (ccw) and clockwise (cw) band indicator notches located on the sides of the 12 o'clock mark. Each band indicator notch is 15 degrees in bandwidth.

B. Directly align the scribe line on the coupling and the 12 o'clock housing marks and insert the external flex end into the receiver hole of the coupling and tighten the two set screws to 1.8 N•m (16 in•lbs).

C. Apply power to the control, set the control to manual mode, and proceed to check the proper movement and alignment of the PI.

18. Index the PI to the 2-R position: the scribe line on the coupling should be located ccw of the 12 o'clock mark.

If the scribe line is inside the notch, proceed to step 19.

If the scribe line is outside of the ccw band notch of the PI back hub, loosen the brass coupling set screws and rotate the coupling (while holding the flex shaft) until the scribe line is one line-width inside the band notch. Retighten the setscrews and proceed to step 19.

19. Index the PI to neutral (**0**) position. The scribe line should be located cw of the 12 o'clock mark. If the scribe line is outside the cw band notch, loosen the screws and rotate the coupling until the scribe line is one line-width inside the band notch and retighten the setscrews to 1.8 N•m (16 in•lbs).

20. Index the PI to 2-R and 2-L position several times and each time, the scribe line should stop inside the notched area of the PI housing. If at any time the scribe line falls outside of the notch area after each indexing, try to recalibrate per this procedure one more time or contact the Cooper Service Department for assistance.

21. Repeat step 16.

22. Replace the junction box cover.

Troubleshooting Procedures and Tests

Regulator Control Reverse Power Flow

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

Test

1. Remove the unit from service, as outlined in the **INSTALLATION: Removal from Service** section of this manual.

WARNING: Hazardous Voltage. When troubleshooting energized equipment, protective gear must be worn to avoid personal contact with energized parts. Failure to comply can cause serious injury or death. 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 "S" and the "L" bushings.
5. Install a clamp-on ammeter on the cable between the "S" and the "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 V ac to the control **External Source** terminals.
8. Using the manual **Raise/Lower** switch, place the regulator on the **3 Raise** position.
9. Check control settings and correct if necessary. Ensure that Function Code 56 is set for bidirectional. This will allow the control to function in both the forward and reverse power flow arrangements.

CAUTION: Equipment Damage. Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

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

10. Connect a variable source to the "L" and "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 LCD annunciator does not indicate **REV PWR**, 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 light, indicating the control is in the reverse power flow mode.

VR-32 Voltage Regulator Ratio Test

The ratio test determines:

A. If incorrect series winding tap-changer connections have been made.

B. If an open or short-circuit exists in the series or shunt winding.

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

CAUTION: Equipment Damage. Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

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

2. Ensure that the regulator operates correctly. Connect a 120 V ac external source to the **External Source** terminals on the control front panel. Move the control power switch to the **External** position to operate the tap-changer. Place the **Auto/Remote-Off-Manual** switch to **Manual**. Using the **Raise/Lower** switch, tap the regulator to **16 Raise** and back to **16 Lower**, then return to **Neutral**.

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

3. Connect a voltmeter between the “L” and “SL” bushing terminals.
4. Use a variac to apply 120 V ac between the source (S) and source-load (SL) bushing terminals.
5. Connect a separate 120 V ac to the external source terminals on the control front panel. Move the control power switch to the external position to operate the tap-changer.
6. Increase the voltage on the variac to 120 V ac. This will provide 12 V on the series winding. (120 V ac x 10% regulation = 12 V).
7. Calculate the change in volts per tap change as follows:

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

8. Operate the tap-changer with the control switch through all 32 steps from **16 Raise** to **16 Lower**. Record the voltmeter reading at each tap position. The change in voltage should be almost the same between each step (± 0.10 V). If a substantial difference in any reading exists, then there is a problem with the windings or their connection.

TABLE 7
Typical Meter Readings with 120 V ac for a Type A Regulator

Lower	Raise
16L - 108.0 V	16R - 132.0 V
15L - 108.75 V	15R - 131.25 V
14L - 109.5 V	14R - 130.5 V
13L - 110.25 V	13R - 129.75 V
12L - 111.0 V	12R - 129.0 V
11L - 111.75 V	11R - 128.25 V
10L - 112.5 V	10R - 127.5 V
9L - 113.25 V	9R - 126.75 V
8L - 114.0 V	8R - 126.0 V
7L - 114.75 V	7R - 125.25 V
6L - 115.5 V	6R - 124.5 V
5L - 116.25 V	5R - 123.75 V
4L - 117.0 V	4R - 123.0 V
3L - 117.75 V	3R - 122.25 V
2L - 118.5 V	2R - 121.5 V
1L - 119.25 V	1R - 120.75 V
Neutral 0 - 120 V ac	

Note: The readings will be the same with or without the equalizer winding.

Voltage values for Lower Positions of Type B regulators will be higher than the values shown.

VR-32 Voltage Regulator Potential Transformer Ratio Test

Purpose

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

Required Equipment

- Voltmeter, such as a Fluke 8000 series multimeter
- 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 outlined in the **INSTALLATION: Removal from Service** section of this manual.
2. With the regulator in the neutral position, connect 120 V ac between the source "S" and the source-load "SL" bushings.
3. Open the backpanel knife switch marked $\mathbf{V_1}$. Measure the voltage between the top of the $\mathbf{V_1}$ knife switch and the top terminal strip ground $\mathbf{TB_1}$-**G**.
4. Note the correct PT ratio as given on the nameplate under the Internal PT Column.
5. Verify the internal tap setting of the PT by inspecting the top of the tap-changer board located under the regulator cover hand hole. It will be $\mathbf{E_1}$, $\mathbf{E_2}$, $\mathbf{E_3}$, etc. Use the correct ratio.
6. Using the formula in the example below, determine what the correct output voltage should be and compare it to the actual reading as seen on the voltmeter across the control test terminals.

Example:

If ratio is shown as 60:1, then the $\mathbf{V_1}$ to ground voltage will be:

$$\frac{\text{Input Voltage (120 V ac)}}{\text{PT Ratio}} = \mathbf{V_1} \text{ to ground voltage}$$

(120 V ac)/(60) = 2.0 V

Contact your Cooper Power Systems representative with any questions.

Regulator Dry-Out 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 outlined in the **INSTALLATION: Removal from Service** section of this manual.

WARNING: Hazardous Voltage. The regulator will be energized with load current present for the duration of the procedure. The regulator must be placed in a protected area, preventing anyone from coming in contact with the unit. Failure to do so could result in injury or possible death. VR-T226.0

2. Conduct this test 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.
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.
6. Using a variac apply impedance voltage at 16 raise to the source (S) and load (SL) bushings. Raise the voltage until rated current is read on the ammeter. Impedance voltages may be obtained from the factory. Contact your Cooper Power Systems representative for assistance.
7. Let the regulator set in this condition for approximately 24 hours. This will drive the moisture out of the coil into the oil.
8. De-energize the regulator and drain the oil.
9. Refill with new oil.
10. Perform an insulation power factor test after the regulator temperature has stabilized to the ambient temperature. The reading results should be lower than the original test results.

VR-32 Regulator Current Test

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

WARNING: Hazardous Voltage. When troubleshooting energized equipment, protective gear must be worn to avoid personal contact with energized parts. Failure to comply can cause serious injury or death. VR-T213.0

2. Conduct this test with the regulator located in the maintenance shop or other suitable location.
3. Use the external source terminals and voltage source to move the tap-changer from position to position.
4. Place a jumper, rated for nominal current, between the source (S) and load (L) bushings. Use a clamp-on ammeter to measure the current in the jumper during the test.

WARNING: Hazardous Voltage. The regulator tank must be solidly earth grounded. Failure to comply can cause severe personal injury and equipment damage. VR-T225.0

5. Ground the regulator tank.
6. Close knife switch **C** on the back panel.
7. Remove the metal jumper, $\mathbf{C_3 - C_4}$, on the top terminal board **(TB_1)** of the back panel. Place a milliampere meter between these terminals.

CAUTION: Equipment Damage. Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

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

8. Using a variable voltage source, place approximately 120 V between the “L” and “SL” bushings until a current value is shown on the clamp-on meter.
9. Open the knife switch **C** on the back panel. The milliampere meter should indicate a current value based on the C/T ratio shown on the rating plate.
10. Run the voltage regulator through all of the tap positions to check the continuity and reveal any possible intermittent opens. The current indicated on the clamp-on meter will increase or decrease as the tap-changer moves from **Neutral** to **16 Raise** position. The current will reach its maximum value at a specific position dependent on the type and rating of the regulator. Current reduces to zero when it reaches the neutral position.

Insulation Test

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

Note: Regulator tank must be isolated from ground potential.

CAUTION: Equipment Damage. Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

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 using the external source terminals and voltage source.
4. Place a jumper, rated for nominal current, tying all the bushings together.
5. Close knife switch **C** on the back panel.
6. Using the variac on the tester, bring the voltage up to the desired test level. Refer to the tester manufacturer instructions for guidelines on voltage test levels.
7. Read the test value in mega-ohms.
8. Compare the reading with the baseline reading.

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

Procedure to Free a Stalled Tap-Changer

1. To determine if the tap-changer is stalled between tap positions with the holding switch closed, check the voltage on the **L_1** or **R_1** terminals on the back panel. This is done by touching one lead from an ac voltmeter to ground and the other to either **L_1** or **R_1**. Whichever position reads approximately 120 V is the direction the tap-changer was moving when stalling occurred. Note there will, in all likelihood, be an induced voltage on the opposite end of the motor winding. Record this voltage level. Once it has been determined that the tap-changer is stalled, the following steps can be used to reverse the direction of the tap-changer to free the mechanism.
2. Place the **Auto/Remote-Off-Manual** switch in **OFF** position.
3. Place the **Internal/External** switch in **OFF** position.
4. Close the **C** (CT) shorting switch on the back panel of the control.
5. Open the **V_1** disconnect switch on the back panel of the control, removing power from the control.

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

6. Disconnect the orange wiring harness lead from the **HS** terminal on the bottom of terminal board (**TB_1**) that is located on the back panel of the control, thus removing power from the tap-changer holding switch.
7. Close the **V_1** disconnect switch.
8. Place the **Internal/External** power switch on **Internal**.
9. Place the **Auto/Remote-Off-Manual** switch on **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.
11. Place the **Auto/Remote-Off-Manual** switch on **OFF**.
12. Place the **Internal/External** power switch on **OFF**.
13. Open **V_1** disconnect switch.
14. Reconnect the orange lead to the **HS** terminal restoring power to holding switch.
15. Close the **V_1** disconnect switch.
16. Open the CT shorting switch.
17. Place the **Internal/External** power switch on **Internal**.
18. Turn **Auto/Remote-Off-Manual** control switch to **Manual.**
19. Using the **Raise/Lower** switch step the regulator to the **Neutral** position.
20. Before de-energizing the regulator by bypassing to remove from the system, verify that the regulator is truly in the Neutral Position: the Neutral Light on the control is lit, the Position Indicator is on Zero, and there is no differential voltage between the "S" and "L" bushings.

Tapping to Neutral and Verifying Neutral Tap Position If Front Panel Is Completely Inoperable

On occasions when a regulator has a control that becomes inoperable when the tap-changer is not at the neutral position, it would be desirable to have the ability to operate the tap-changer. This is possible if the identification of the control winding, motor, and neutral light switch wires are known. Refer to schematic diagrams included in the appendix.

Procedure

1. Open knife switch **V_1** (and **V_6**, if present) and close knife switch **C**.
2. Set the control function and power switches (located on the front panel) to **Off** and remove the front panel.
3. Install a jumper from the lower **V_1** knife switch contact to terminal **TB_1-L_1** (lower command) or **TB_1-R_1** (raise command).
4. Momentarily close **V_1** long enough to allow the tap change to complete. Verify that the position indicator pointer moved one tap position in the appropriate direction.
5. Repeat step four until the position indicator shows the unit to be in the neutral position.
6. With **V_1** open, measure the voltages present between **TB_2-HS** and **TB_2-G** (ground) and **TB_2-NL** and **TB_2-G**. These voltages should read approximately zero (this is done to verify that the continuity meter used in the next step will not be damaged).
7. Check continuity between **TB_2-HS** and **TB_2-NL**. Continuity indicates that the **Neutral** switch is closed and the tap-changer is in the neutral position.
8. Use an appropriate method to determine the voltage across the source (S) and load (L) bushings. A unit is in neutral if all three of the following conditions are met:
   - **A.** There is no Differential Voltage present between the "S" and "L" bushings.
   - **B.** The position indicator pointer is at “0”.
   - **C.** There is continuity from terminals **TB_2-HS** to **TB_2-NL.**

Connecting Single-Phase Voltage Regulators for Parallel Operation

In any connection of parallel devices, there is the possibility of circulating currents that may develop. Due to the nature of voltage regulators and the changing voltage at their output terminals, there is a voltage difference between the two units connected in parallel. The method described below is designed to limit the circulating current to avoid overloading of the equipment, voltage regulators and transformers, connected in the circulating loop.

Negative Reactance Method:

The current that will circulate in the loop will be largely reactive current. By using the reactive line-drop compensation circuit of the control, the control will respond to the circulating current to either raise or lower its tap position to limit the circulating current. This method has been described in greater detail in other papers in the industry for many years.

The limitations to this method are that the loop impedance must be relatively high, a minimum of 20%. This loop impedance is the combination of the equipment in the loop, which will likely include two transformers. So if each transformer has impedance of 10%, this method will work properly. Too little impedance will result in higher than acceptable loop current and possibly overload the equipment in the loop. The use of reactors may be used to increase the loop impedance.

Another limitation to this method is that since the line drop compensation is being used to limit the circulating current, only the resistive component is available for the control to maintain correct voltage at the load center. If the resistive component is to be used while the negative reactance method of paralleling is used, the resistive settings of all of the regulators being paralleled should be set to the same value. The advantages to this method are that there is no interconnection between the regulators so they can be located relatively far apart. Also more than two units can be paralleled together, if required, using this method.

To set the current controls offered by Cooper Power Systems, the system connection configuration does not change. So if the units are connected in wye (star), Function Code 41 is set to "0". To configure the control for the negative reactance, set Function Code 5 to some large negative number. The control allows a setting of up to negative 96 V.

External Application of a Motor Start Capacitor on a Single-Phase Voltage Regulator

CAUTION: Equipment Damage. Test the motor capacitor before performing this procedure. Installing another motor capacitor in the circuit with a motor capacitor that is not open will result in double capacitance and double motor current. Failure to comply can result in damage to the control panel. VR-T228.0

Test the motor capacitor before performing this procedure. Refer to the **Motor Capacitor Problem** section of this manual.

Introduction

A step voltage regulator utilizes a capacitor to start the motor of the tap-changer. A number of regulators operating in the field have an internally mounted, under-oil motor start capacitor. The motor start capacitor, if failed, will not allow the tap-changer to operate. In this situation, the motor may be able to be operated by proper application of a capacitor in the control box of the regulator.

Required Items

- Appropriately sized temporary capacitor. If in doubt as to correct capacitor size, contact the Cooper Power Systems Service Department.

  Spring-drive model McGraw Edison regulator tap-changers utilized a 7.5 µF, 440 V, 100 ˚C capacitor.

  Direct-drive model McGraw Edison regulator tap-changers, built 1994 and earlier, utilized a 40 µF, 440 V, 100 ˚C capacitor.

  Direct-drive model McGraw Edison regulator tap-changers, built 1995 and after, utilized a 50 µF, 440 V, 100 ˚C capacitor.

  QD-8 and QD-5 Quik-Drive model Cooper Power Systems regulator tap-changers utilize a 50 µF, 440 V, 100 ˚C capacitor.

  QD-3 Quik-Drive model Cooper Power Systems regulator tap-changers, for domestic use, utilize 12 µF, 440 V, 100 ˚C motor capacitors.

  QD-3 Quik-Drive model Cooper Power Systems regulator tap-changers, for international use on 50 Hz regulators, utilize 15 µF, 440 V, 100 ˚C motor capacitors.

- Temporary capacitor leads.

  Leads should be connected to the temporary capacitor terminals and have terminals on the free lead end that can be attached to a control box terminal screw or wire. Alligator clips work well in most applications.

- Screwdriver.

  As needed to allow capacitor leads to be attached into the control circuit where screw terminals are present.

WARNING: Hazardous Voltage. Residual capacitive voltage may be present in the motor circuit. Remove the power from the control box and follow the appropriate shorting procedure to discharge any residual voltage. Failure to comply can cause serious injury or death. VR-T229.0

Procedure

1. Identify the raise (R) and lower (L) circuits coming into the control box from the regulator.
2. Place a momentary short circuit across the raise and lower leads to discharge any residual capacitive voltage that may be in the motor circuit.
3. Connect temporary capacitor leads. Connect the temporary capacitor leads across the raise (R) and lower (L) circuit lead wires on **TB_1**, located on the top of the control assembly back panel. A capacitor connected in this way electrically replaces the failed internal capacitor.
4. Operate the tap-changer. Energize the control and run the regulator to neutral.
5. Remove the unit from service, as outlined in the **INSTALLATION: Removal from Service** section of this manual.
6. Remove the internal capacitor.
7. Install an external capacitor, located electrically between the position indicators mechanical limit switches and the motor.

Note: The described procedure will work in cases where the limit switches located in the position indicator are closed. Closed switches provide the electrical path necessary for the capacitor to be across the raise and lower motor windings. If either of the limit switches are open, the circuit is interrupted and the motor will not turn. Limit switches are typically open at **16 Raise** or **16 Lower** or at whatever tap position they are set to open. Any permanent placement of a capacitor must be electrically connected between the motor and the limit switches.

Applied Voltage

DANGER: High Voltage. This is a high-voltage test. The high-voltage potentials can arc to a person or to equipment over a short distance. The regulator must be in a test cage or similar protective device. Failure to comply will result in serious injury or death. VR-T230.0

CAUTION: Equipment Damage. Be mindful of polarity when using an external source. Polarity reversal will result in control damage. VR-T201.0

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

1. Apply a source voltage of 120 V (*240 V international) to the control panel external source terminals. Check the polarity of the source leads before connecting to the control external source terminals.

   *International units setup for 240 V may have a 240 V decal at the control panel external source terminals.

   A. Apply the hot lead to the Black terminal on the external source.

   B. Ground to White terminal.

   Note: Failure to connect properly will cause damage to control.

2. Switch the **Internal/ External** switch to **External**.
3. Switch the **Auto/Remote-Off-Manual** switch to **Manual**.
4. Using the **Raise/Lower** switch, lower the tap-changer until the position indicator reads **16 lower**.
5. Switch the **Auto/Remote-Off-Manual** switch to **OFF**.
6. Switch the **Internal/External** Switch to **OFF**.
7. Remove the external source from the external source terminals.
8. Using at least a #14 stranded copper cable, jumper the “S”, “L” and “SL” bushing terminal together.
9. Connect the applied ac voltage potential test lead from the high voltage test transformer to one of the bushing terminals.

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

10. Ground the tank of the of the voltage regulator.
11. Close the **C** knife switch and open all other knife switches, which are located on the back panel inside the control box.

TABLE 8
Applied Potential for New Units

BIL	Applied AC Potential Test Voltage (kV)
30	10
45	15
60	19
75	26
95	34
125	40
150	50
200	70

TABLE 9
Applied Potential for Used Units
(Units that have been energized on a system)

BIL	Applied AC Potential Test Voltage (kV)
30	6
45	9
60	11.5
75	15.5
95	20.5
125	24
150	30
200	42

12. Refer to the regulator nameplate for the BIL and refer to Table 8 or 9 to determine the correct ac potential voltage. Starting at zero volts, increase the voltage to the specified level, within 15 seconds.
13. The potential voltage is to be applied for 60 seconds.

    The following may indicate a failure:

    A. A sudden increase in test circuit current.

    B. An indication of smoke and bubbles.

    C. An audible sound such as a thump.

    D. An appreciable increase in partial discharge (corona) level.

14. Once a failure has been detected, use extreme caution when doing any diagnostic testing.
15. Once the applied voltage test time has been completed and there is no signs of problem lower the potential voltage to zero volts.
16. Return the tap-changer back to neutral by using an external source voltage to the control and by using the **Internal/External** switch, **Auto/Remote-Off-Manual** switch and the **Raise/Lower** switch.
17. Remove the potential lead and jumper from the bushings and disconnect the ground from the tank.

APPENDIX

TABLE 10
VR-32 Tap Connections and Voltage Levels (60 Hz)

Regulator Voltage Rating	Nominal Single Phase Voltage	Ratio-Adjusting Data			Test Terminal Voltage **	Overall Potential Ratio **
		Internal Tap*	PT Ratio	RCT Tap		
1	2	3	4	5	6	7
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
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
	7200	E_3/P_3	60:1	120	120	60:1
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

TABLE 11
VR-32 Tap Connections and Voltage Levels (50 Hz)

Regulator Voltage Rating	Nominal Single Phase Voltage	Ratio-Adjusting Data			Test Terminal Voltage **	Overall Potential Ratio **
		Internal Tap*	PT Ratio	RCT Tap		
1	2	3	4	5	6	7
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	23000	E_1/P_1	183.4:1	120	125.4	183.4:1
	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	34500	E_1/P_1	275.0:1	127	115.1	291.0:1
	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

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

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

TABLE 12
ADD-AMP Capabilities of 60 Hz Ratings

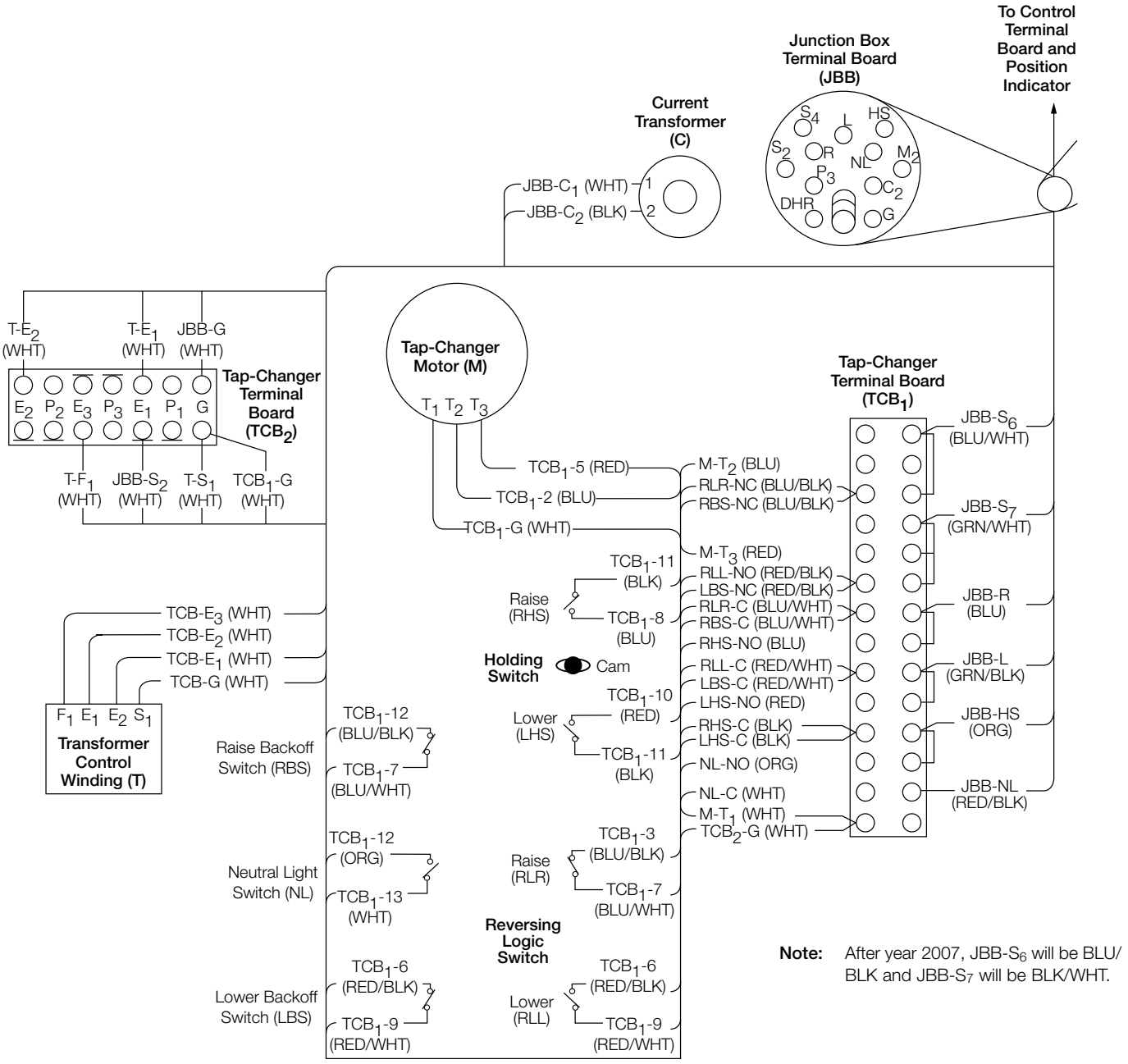
Rated Volts	Rated kVA	†Load Current Ratings (A)				
		Regulation Range (Wye and Open Delta)				
		±10%	±8.75%	±7.5%	±6.25%	±5%
		Regulation Range (Closed Delta)				
		±15%	±13.1%	±11.3%	±9.4%	±7.5%
2500	50	200	220	240	270	320
	75	300	330	360	405	480
	100	400	440	480	540	640
	125	500	550	600	668	668
	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*	38.1	50	55	60	68	80
	57.2	75	83	90	101	120
	76.2	100	110	120	135	160
	114.3	150	165	180	203	240
	167	219	241	263	296	350
	250	328	361	394	443	525
	333	438	482	526	591	668
	416.3	548	603	658	668	668
	500	656	668	668	668	668
	667	875	875	875	875	875
	833	1093	1093	1093	1093	1093
13800	69	50	55	60	68	80
	138	100	110	120	135	160
	207	150	165	180	203	240
	276	200	220	240	270	320
	414	300	330	360	405	480
	500	362	398	434	489	579
	552	400	440	480	540	640
	667	483	531	580	652	668
	833	604	664	68	668	668
14400	72	50	55	60	68	80
	144	100	110	120	135	160
	288	200	220	240	270	320
	333	231	254	277	312	370
	416	289	318	347	390	462
	432	300	330	360	405	480
	500	347	382	416	468	555
	576	400	440	480	540	640
	667	463	509	556	625	668
	720	500	550	600	668	668
	833	578	636	668	668	668
19920	100	50.2	55	60	68	80
	200	100.4	110	120	135	160
	333	167	184	200	225	267
	400	200.8	220	240	270	320
	500	250	275	300	338	400
	667	335	369	402	452	536
	833	418	460	502	564	668
	1000	502	552	602	668	668
34500	172.5	50	55	60	68	80
	345	100	110	120	135	160
	517	150	165	180	203	240
	690	200	220	240	270	320

TABLE 13
ADD-AMP Capabilities of 50 Hz Ratings

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

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

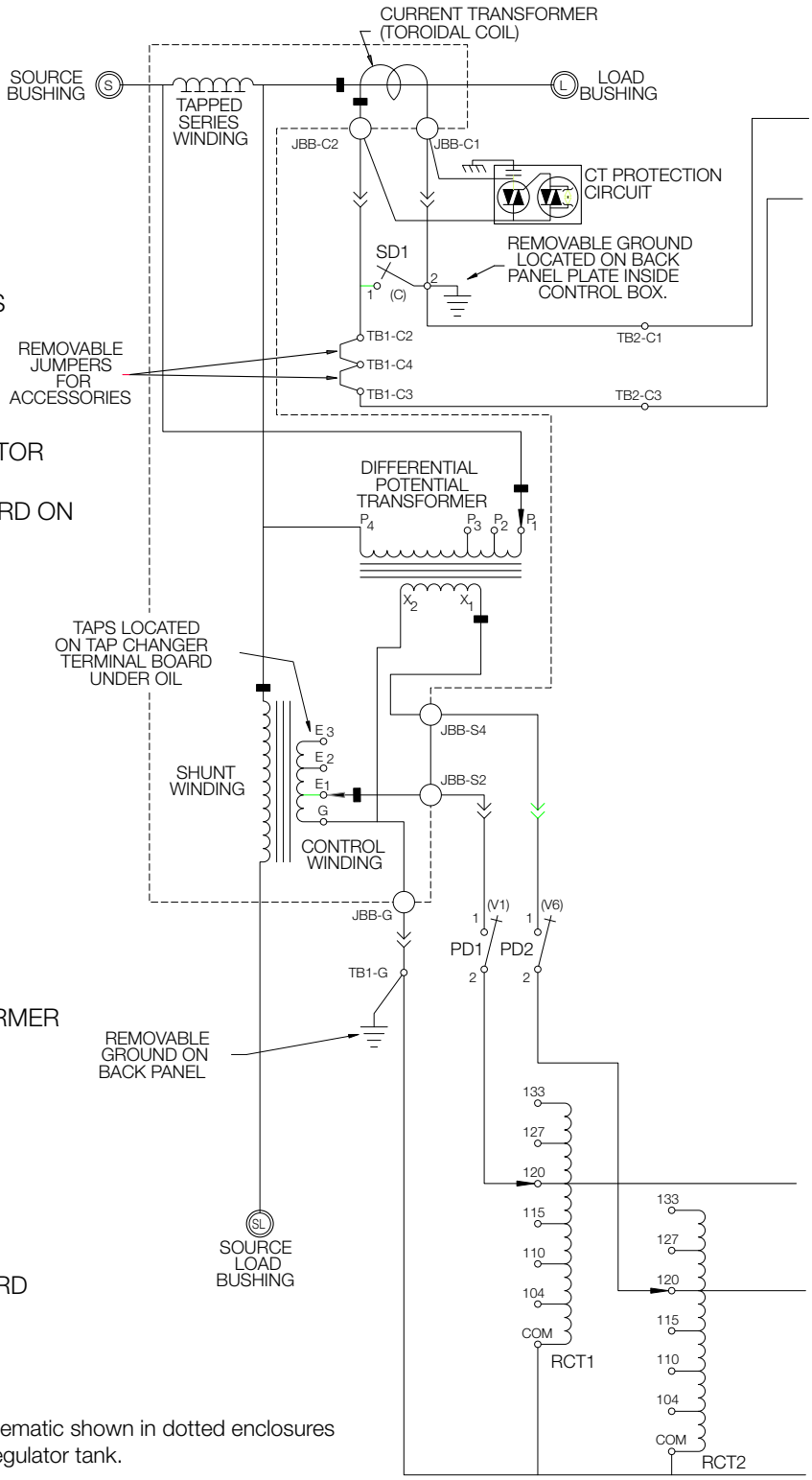
† 55/65 °C rise rating on VR-32 regulators gives an additional 12% increase in capacity if the tap-changer's maximum current rating has not been exceeded. For loading in excess of the above values, please refer to your Cooper Power Systems representative.



Note: After year 2007, JBB-S_6 will be BLU/BLK and JBB-S_7 will be BLK/WHT.

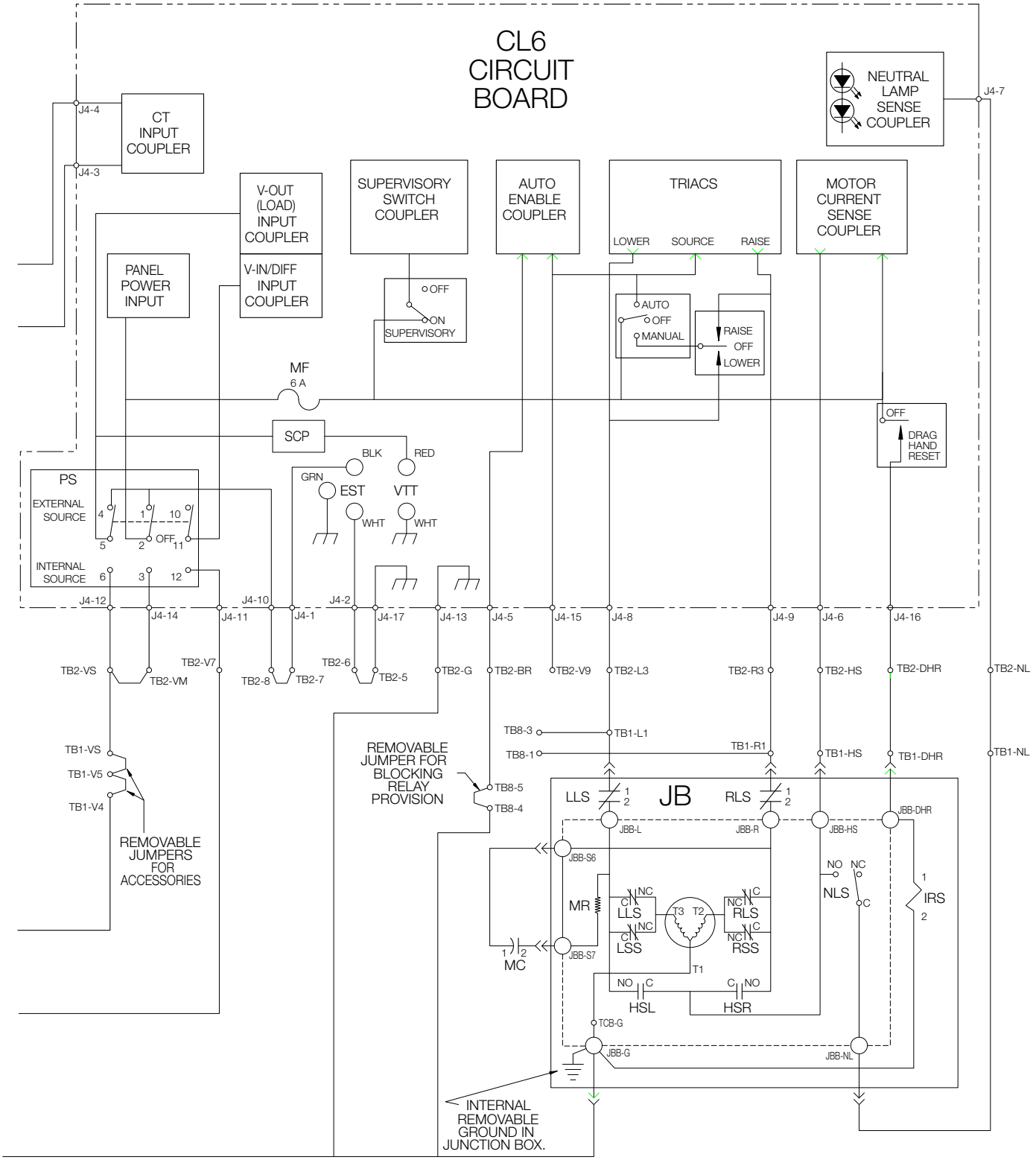
Figure 26.
Typical internal wiring of regulator with Quik-Drive QD-8 tap-changer.

DF - DIFFERENTIAL VOLTAGE FUSE
DHR - DRAG HAND RESET
EST - EXTERNAL SOURCE TERMINALS
HSL - HOLDING SWITCH LOWER
HSR - HOLDING SWITCH RAISE
IRS - INDICATOR RESET SOLENOID (POSITION INDICATOR)
JB - JUNCTION BOX ON THE REGULATOR COVER
JBB - JUNCTION BOX TERMINAL BOARD ON THE COVER
LLS - LOWER LIMIT SWITCH (POSITION INDICATOR)
LLS - LOWER LOGIC SWITCH (TAP CHANGER)
LSS - LOWER SAFETY SWITCH
MC - MOTOR CAPACITOR
MF - MOTOR FUSE
MOV - METAL OXIDE VARISTOR
MR - MOTOR RESISTOR
NL - NEUTRAL LIGHT
NLC - NEUTRAL LIGHT CAPACITOR
NLS - NEUTRAL LIGHT SWITCH
PD - POTENTIAL OPENING DEVICE
PF - PANEL FUSE
PS - POWER SWITCH
RCT - RATIO CORRECTION TRANSFORMER
RLS - RAISE LIMIT SWITCH (POSITION INDICATOR)
RLS - RAISE LOGIC SWITCH (TAP-CHANGER)
RSS - RAISE SAFETY SWITCH
SCP - SHORT CIRCUIT PROTECTION
SD - CURRENT SHORTING DEVICE
TB - CONTROL TERMINAL BOARD
TCB - TAP-CHANGER TERMINAL BOARD
VM - MOTOR VOLTAGE
VS - SENSING VOLTAGE
VTT - VOLTAGE TEST TERMINALS



NOTE: Portion of schematic shown in dotted enclosures is located in regulator tank.

Figure 27.
Wiring diagram for Type B VR-32 regulator and CL-6 control with differential potential transformer.


CL6
CIRCUIT
BOARD
CT
INPUT
COUPLER
J4-4
J4-3
V-OUT
(LOAD)
INPUT
COUPLER
V-IN/DIFF
INPUT
COUPLER
PANEL
POWER
INPUT
SUPERVISORY
SWITCH
COUPLER
OFF
ON
SUPERVISORY
AUTO
ENABLE
COUPLER
TRIACS
LOWER
SOURCE
RAISE
AUTO
OFF
MANUAL
RAISE
OFF
LOWER
MOTOR
CURRENT
SENSE
COUPLER
NEUTRAL
LAMP
SENSE
COUPLER
J4-7
MF
6 A
SCP
BLK
RED
GRN
EST
VTT
WHT
WHT
PS
EXTERNAL
SOURCE
INTERNAL
SOURCE
OFF
DRAG
HAND
RESET
J4-12
J4-14
J4-11
J4-10
J4-1
J4-2
J4-17
J4-13
J4-5
J4-15
J4-8
J4-9
J4-6
J4-16
TB2-VS
TB2-VM
TB2-V7
TB2-8
TB2-7
TB2-6
TB2-5
TB2-G
TB2-BR
TB2-V9
TB2-L3
TB2-R3
TB2-HS
TB2-DHR
TB2-NL
TB8-3
TB8-1
TB1-L1
TB1-R1
TB1-HS
TB1-DHR
TB1-NL
TB1-VS
TB1-V5
TB1-V4
REMOVABLE
JUMPERS
FOR
ACCESSORIES
REMOVABLE
JUMPER FOR
BLOCKING
RELAY
PROVISION
TB8-5
TB8-4
JB
LLS
RLS
JBB-L
JBB-R
JBB-HS
JBB-DHR
JBB-S6
JBB-S7
MR
LLS
LSS
RLS
RSS
T3
T2
T1
NLS
IRS
MC
HSL
HSR
TCB-G
JBB-G
JBB-NL
INTERNAL
REMOVABLE
GROUND IN
JUNCTION BOX.

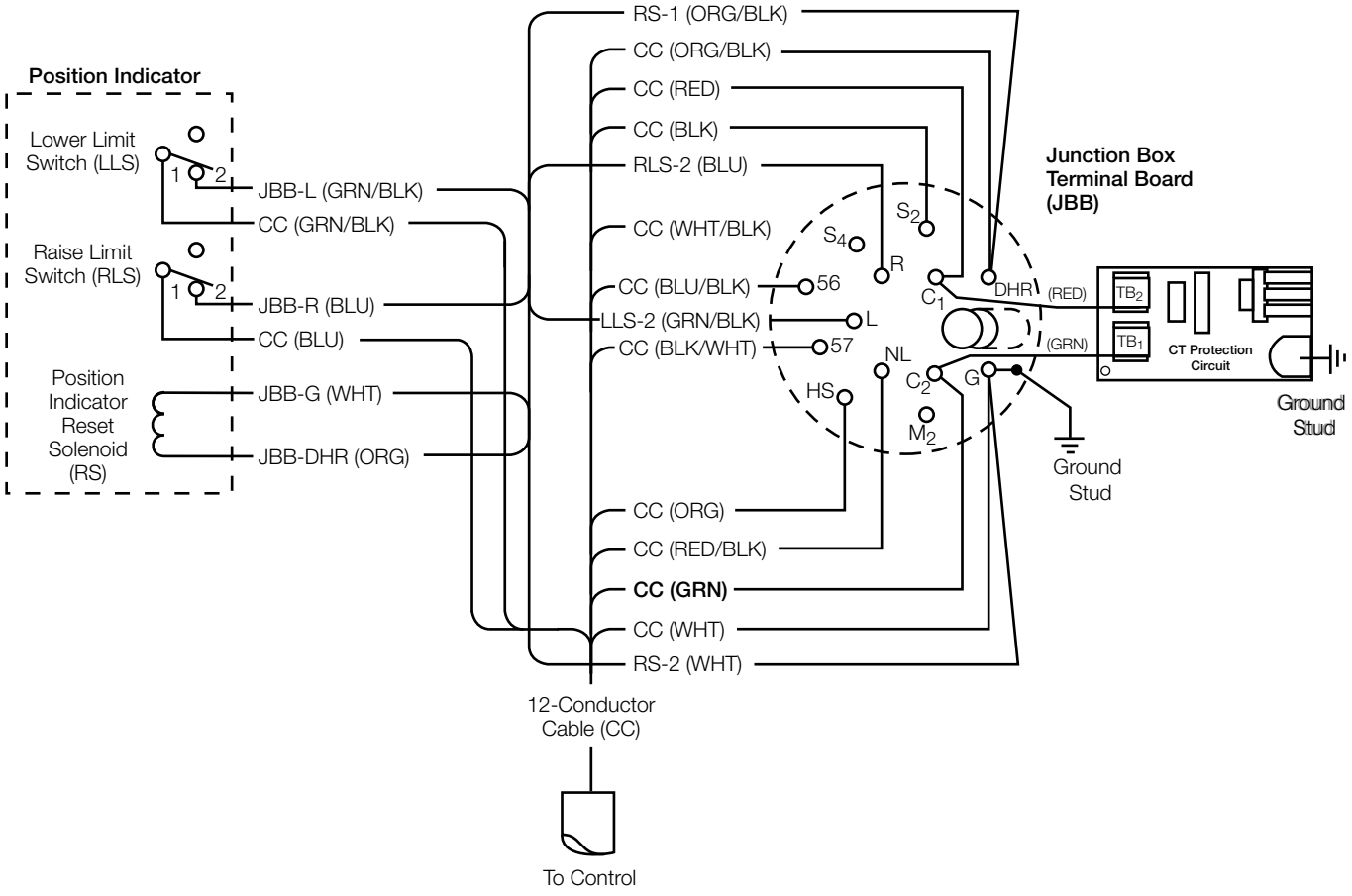


Figure 28.
Junction box wiring diagram.

COOPER Power Systems

1045 Hickory Street
Pewaukee, WI 53072 USA
www.cooperpower.com