Voltage Regulators

COOPER Power Systems

McGraw-Edison® VR-32 Regulator and CL-5 Series Control Installation, Operation and Maintenance Instructions and Parts Replacement Information

Service Information

S225-10-10

Contents

General

McGraw-Edison® 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.

McGraw-Edison regulators are supplied with the following standard features:

- Dual-rated 55/65°C rise
- ADD-AMP™ capability
- Unit construction
- Sealed-tank construction
- Pressure relief device
- 17” minimum creep bushings with clamp-type connectors
- MOV-type external series arrester
- Shunt arrester mounting bosses
- Two laser-etched nameplates
- Oil sight gauge
- Upper filter press connection
- Drain valve and oil-sampling device
- CE mark compliant control
- Control cable quick disconnect

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). All McGraw-Edison regulators are manufactured and tested to ANSI standard C57.15.

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. McGraw-Edison regulators are usually equipped with an equalizer winding. The nameplates located on the tank and control box define the power circuit.

Figure 1.
VR-32 Voltage Regulator with CL-5 Series Control

These instructions do not claim to cover all details or variations in the equipment, procedure, or process described, nor to provide directions for meeting every possible contingency during installation, operation or maintenance. When additional information is desired to satisfy a problem not covered sufficiently for the user’s purpose, please contact your Cooper Power Systems representative.

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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 these 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 voltage lines and equipment.

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

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

WARNING: Power distribution equipment must be 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 this equipment can result in death, severe personal injury, and equipment damage.

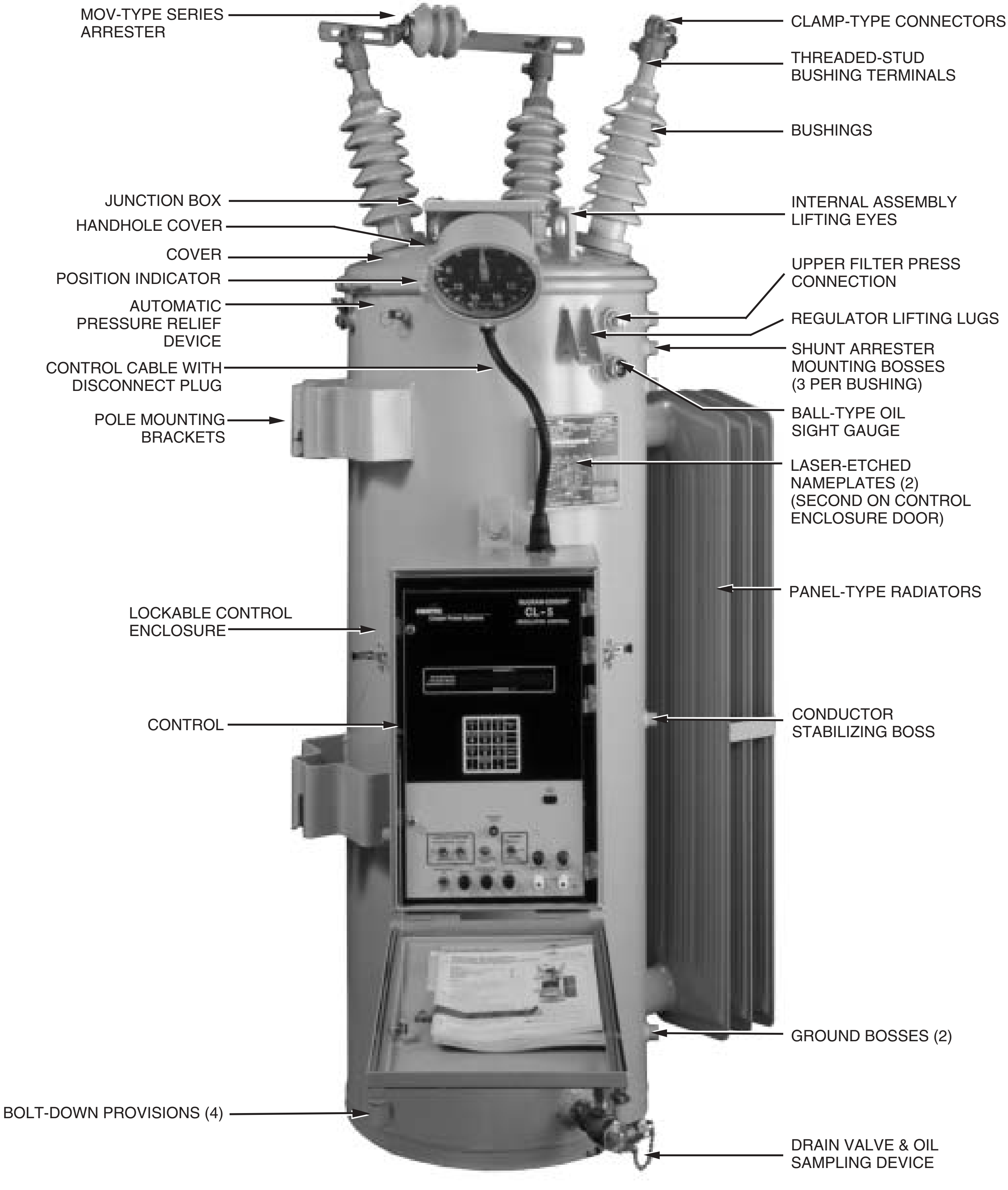


Figure 2.
External Features of the VR-32 Voltage Regulator

Receiving, Installation and Maintenance

Receiving

Inspection

Prior to shipment, the regulator is thoroughly tested and inspected at the factory. Immediately 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 Cooper Power Systems, 2300 Badger Drive, Waukesha, Wisconsin 53188, attention Service Manager.

Unloading

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

> **WARNING:** The cover may fracture if the cover-mounted lifting eyes are used to lift the entire unit. Lift the entire unit only with tank-mounted lifting lugs.

Storing

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.

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. If there is a suspicion that moisture has entered unit, remove handhole cover and inspect for evidence of moisture such as rust or water tracks in oil. If moisture has entered that tank, dry

> **CAUTION:** 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.

regulator and filter oil before putting unit in service. See Table 1-5, page 1-12, for values that oil should meet. Be sure to properly replace handhole cover.

4. Check position indicator for damage. When cleaning the faceplate, do NOT use solvent or fuel.
5. If regulator has been stored for some time, test dielectric strength of oil according to Table 1-5, page 1-12.
6. Regulator may be energized at rated voltage (with caution) and an operational check (see page 1-10) can be performed. (This procedure is optional.)
7. A high-potential test may be done to ensure adequate electrical clearances to ground. (This procedure is optional.)

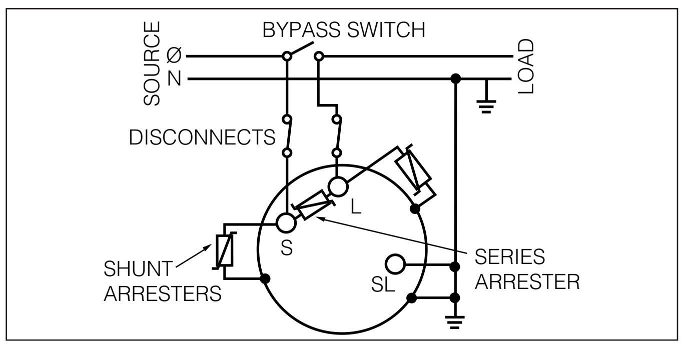


Figure 1-1.
Regulating a single-phase circuit

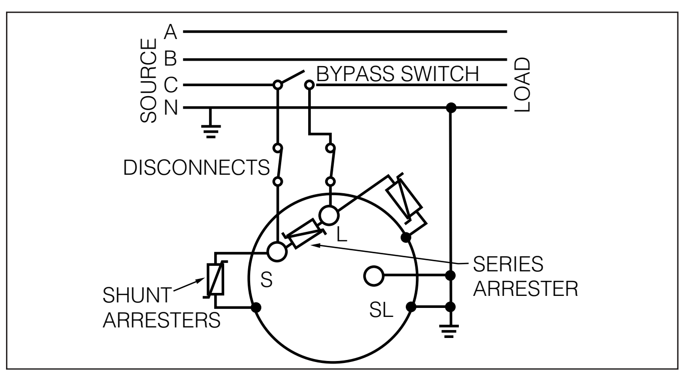


Figure 1-2.
Regulating one phase of a three-phase, four-wire circuit

WARNING: Connect the "S" bushing to the source, the "L" bushing to the load, and the "SL" bushing to neutral. To do otherwise may cause excessively high or low voltage on the load side of the regulator or cause severe damage to the regulator.

Systems Connections

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 1-1 through 1-5.

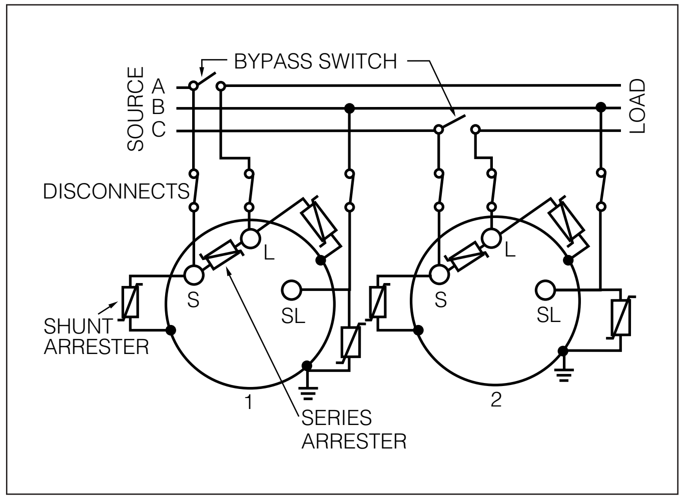


Figure 1-3.
Regulating a three-phase, three-wire circuit with two regulators

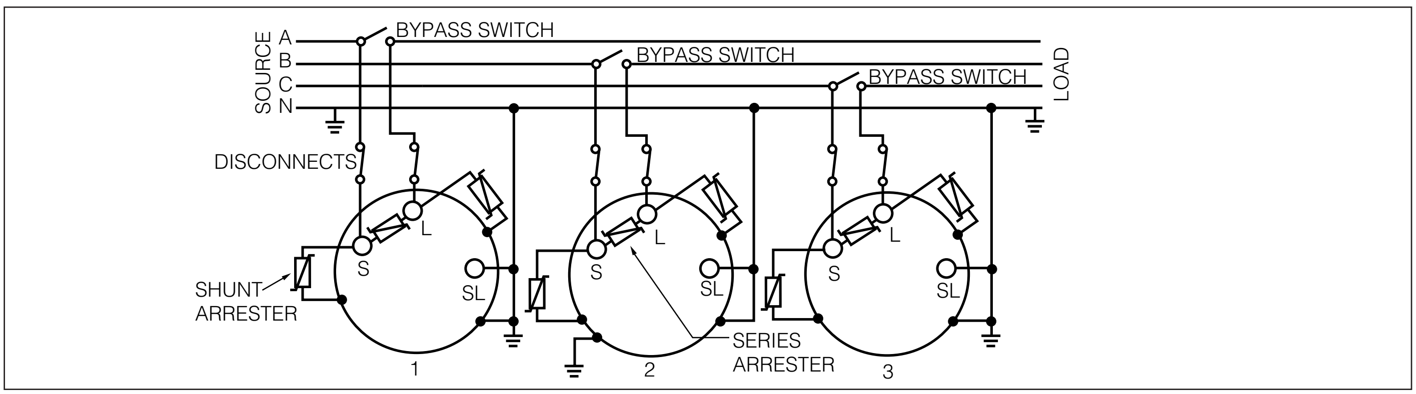


Figure 1-4.
Regulating a three-phase, four-wire, multi-grounded wye (star) circuit with three regulators

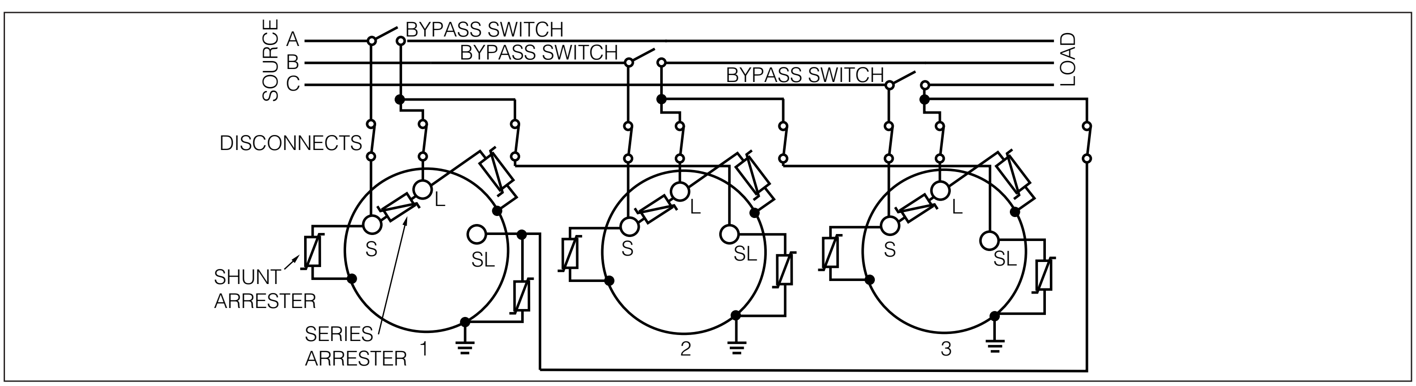


Figure 1-5.
Regulating a three-phase, three-wire circuit with three regulators

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.

Mounting

A regulator can be mounted on a pole, crossarm platform or elevating structure. Regulators are normally provided with either pole mounting brackets or a substation base according to the 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 5 foot (1.52 m) incremental lengths from 15 feet (4.57 m) to 45 feet (13.7 m) for interconnection between the control and the regulator.

Placing a Regulator in Service

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

> **WARNING:** Closing the bypass switch with the tap changer in any position other than neutral will short-circuit part of the series winding. Before closing the bypass switch, the regulator must be in neutral, the control switch set to OFF and the motor circuit fuse removed.

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.

> **WARNING:** For the protection of personnel from surges while operating the control, the following control enclosure grounding procedures should be followed:
> If the enclosure is attached to the regulator tank or is remote from the tank but only accessible with a ladder, then the enclosure should be connected to the regulator-to-ground rod conductor.
> If the enclosure is accessible by personnel standing on the ground, then the enclosure should be directly connected to a ground mat and ground rod.

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

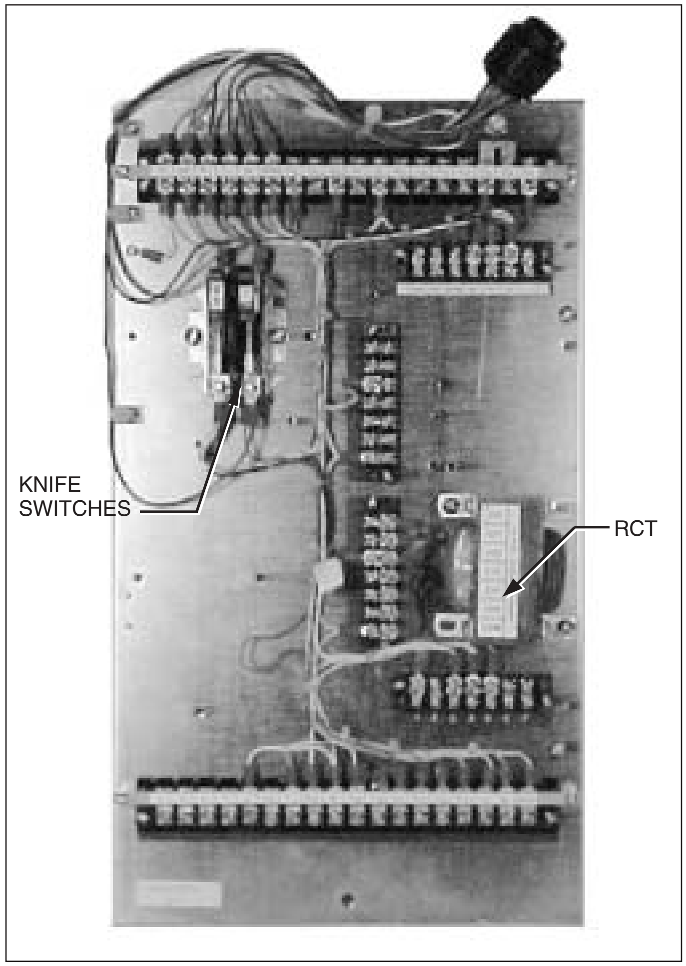


Figure 1-6.
Back panel

> **CAUTION:** Only an ac power supply is to be used to energize the control externally; direct current (dc) to alternating current (ac) inverters are not to be used due to excessive harmonics that can be generated, resulting in damage to the front panel.

> **CAUTION:** Be mindful of polarity when using an external source. Polarity reversal may result in control damage.

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 V_1 (potential switch) (and V_6 if present) closed (pushed in), and C (CT shorting switch) open (pulled out). See Figure 1-6.
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, neutral light will glow continuously and position indicator will point to zero.
8. With regulator in neutral position, set control switch to OFF, set power switch to OFF, open V_1 knife switch (and 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 V_1 knife switch and set power switch to INTERNAL.
12. Go to Setting the Control for Service, following.

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 V_1 (potential switch) (and V_6 if present) open (pulled out), and C (CT shorting switch) closed (pushed in). See Figure 1-6.
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, neutral light will glow continuously and position indicator will point to zero.
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. Close source-load (SL) disconnect switch. (Delta applications only.)
9. Close regulator bypass-disconnect switch. The regulator is now energized.
10. Replace 6 A motor fuse, close V_1 knife switch (and V_6 if present), open C knife switch, and set power switch to INTERNAL.
11. Go to Setting the Control for Service, following.

Setting the Control for Service

There are more than 50 parameters on the control which are user-selectable. Many of these values pertain to the operation of the advanced features that are not needed for normal regulator operations. A full detailed description of each of the features is given in the Control Advanced Features section, along with set-up instructions.

The control must be energized to perform the programming. This can be accomplished by applying 120 V (or other voltage as indicated by the decal) to the external source terminals and placing the power switch in the external position. Alternately, the regulator may be energized at line potential, and the power switch placed in the internal position. When power is applied to the control, all segments of the display will light, followed by a PASS indication. If the FAIL message is encountered, see Diagnostics, on page 2-5.

Accessing the Control

Before gaining access to change the control settings, the proper security level must be activated. This is accomplished by entering a security code at the Function Code 99 location. Depress the following keys on the keypad:

FUNCTION, 99, ENTER
12121, ENTER

The proper level of security to change operational settings has now been activated.

All programming of the control is done through the keypad or communication ports.

For quick set-up of Cooper Power Systems regulators, see Table 1-1, page 1-5. For complete set-up, see Table1-2, page 1-6 for a detailed checklist for control programming. The only two parameters this checklist does not address are voltage and current calibration, Function Codes 47 and 48.

TABLE 1-1
Setting the Controls for Basic Operation

Security System

Keys to Depress	F.C	Display	Description
FUNCTION, 99, ENTER	99	_ _ _ _ _	
12121, ENTER	Func	_ _	The security system is now activated for changing operational settings

Set Voltage
Range: 100.0 - 135.0 (Factory Setting: 120.0)

Keys to Depress	F.C	Display	Description
1	01	120.0	This is the set voltage as shipped from the factory
Change	01	_ _ _._c	Enter the desired value. Example: 122.0
1220, ENTER	01	122.0	The set voltage is now 122.0 volts.

Bandwith
Range: 1.0 - 6.0 (Factory Setting: 2.0)

Keys to Depress	F.C.	Display	Description
2	02	2.0	This is the bandwith as shipped from the factory
Change	02	_._c	Enter the desired value. Example: 3.0
30, ENTER	02	3.0	The bandwidth is now 3.0 volts

Time Delay
Range: 5 - 180 (Factory Setting: 30)

Keys to Depress	F.C.	Display	Description
3	03	30	This is the time delay as shipped from the factory
Change	03	_ _ _c	Enter the desired value. Example: 45
45, ENTER	03	45	The time delay is now 45 seconds

Line Drop Compensation, Resistance
Range: -96.0 - +96.0 (Factory Setting: 0.0)

Keys to Depress	F.C.	Display	Description
4	04	0.0	This is the resistive compensation as shipped from the factory
Change	04	_ _._c	Enter the desired value. Example: 5.0
50, ENTER	04	5.0	The resistive compensation is now 5.0 volts

Line Drop Compensation, Reactance
Range: -96.0 - +96.0 (Factory Setting: 0.0)

Keys to Depress	F.C.	Display	Description
5	05	0.0	This is the reactive compensation as shipped from the factory
Change	05	_ _._c	Enter the desired value. Example: 3.0
30, ENTER	05	3.0	The reactive compensation is now 3.0 volts

Regulator Configuration
Range: 0 - 2 (Factory Setting: 0 [Wye or Star])

Keys to Depress	F.C.	Display	Description
FUNCTION, 41, ENTER	41	0	This is the regulator configuration as shipped from the factory
Change	41	_c	Enter the desired value. Example: 1
1, ENTER	41	1	The regulator configuration is now Delta Lag

Control Operating Modes
Range: 0 - 2 (Factory Setting: 0 [Sequential])

Keys to Depress	F.C.	Display	Description
FUNCTION, 42, ENTER	42	0	This is the control operating mode as shipped from the factory
Change	42	_c	Enter the desired value. Example: 1
1, ENTER	42	1	The control operating mode is now Time Integrating

System Line Voltage
Range: 1200 - 36000 (Factory Setting: Regulator Rated Voltage)

Keys to Depress	F.C.	Display	Description
FUNCTION, 43, ENTER	43	7620	This is the system line voltage for a 7620 volt regulator as shipped from the factory
Change	43	_ _ _ _ _c	Enter the desired value. Example: 7200
7200, ENTER	43	1	The system line voltage is now 7200 volts

Overall Potential Transformer Ratio
Range: 10 - 300 (Factory Setting: PT ratio for Regulator Rated Voltage)

Keys to Depress	F.C.	Display	Description
FUNCTION, 44, ENTER	44	63.5	This is the overall PT ratio for a 7620 volt regulator as shipped from the factory
Change	44	_ _ _._c	Enter the desired value. Example: 60.0
600, ENTER	44	60.0	The system line voltage is now 7200 volts

Calendar Clock
Range: 10 - 300 (Factory Default Setting XX)

Keys to Depress	F.C.	Display	Description
FUNCTION, 50, ENTER	50	1.01	This is the default value for the date.
Scroll up	50	x.xx	This is the present time (hour/minute).
Scroll up	50	1d 90	This is the default value for the year, 1990.
Change	50	1 _ _c	Enter the desired value for Year. Example: 2000
00, ENTER	50	1 0	The Year is now 2000.
Scroll up	50	2 1	This is the default value for the month, January.
Change	50	2 _ _c	Enter the desired value for Month. Example: October
10, ENTER	50	2 10	The month is now October.
Scroll up	50	3 1	This is the default value for the Day 1.
Change	50	3 _ _c	Enter the desired value for the Day. Example 24.
24, ENTER	50	3 24	The Day is now 24.
Scroll up	50	4 xx	This is the present value for the Hour, xx.
Change	50	4 _ _c	Enter the desired value for Hour. Example: 2:00 P.M.
14, ENTER	50	4 14	The Hour is now 14. Military Time.
Scroll up	50	5 xx	This is the present value for the Minutes. Example: xx.
Change	50	5 _ _c	Enter the desired value for Minutes. Example: 30.
30, ENTER	50	5 30	The Minutes is now 30.
Scroll up	50	6 xx	This is the present value for the Seconds, xx.
Change	50	6 _ _c	Enter the desired value for Seconds. Example 45.
45, ENTER	50	6 45	The Seconds is now 45.

TABLE 1-2
CL-5 Series Control Programming Checklist

Step	Activity/Question	Function Code	Factory Set	Owner Set	Check	Next Step
A	Power up control or run Self Test (FC 91).					Pass = B; Fail = Refer to page 2-5
B	Access Security Level 3.	99	32123			C
C	Set the Forward Power Flow Control Settings -- Set Voltage	1	120			
	Bandwidth	2	2			
	Time Delay	3	30			
	LDC Resistance	4	0			
	LDC Reactance	5	0			D
D	Verify position indicator is in sync with tap changer by stepping through the neutral position.					E
E	Is the Control Tap Position in sync with the position indicator?	12P				No = F; Yes = G
F	Set the Control Tap Position.	12P				G
G	Is Source Side Voltage Calculation required?	39	0			No = J; Yes = H
H	Activate Source Side Calculation.	39		1		I
I	Set Type of Regulator. (A and Series Transformer =1; B=2)	39-1		Nameplate value		J
J	Change Control I.D.?	40	Control Serial No.			No = L; Yes = K
K	Set Control I.D.	40				L
L	Is regulator bank configuration closed or open delta?					No = O; Yes = M
M	Refer to Determination of Leading or Lagging, page 1-7.					N
N	Set Regulator Configuration.	41	0			O
O	Change Operating Mode? (Factory set for sequential)	42	0			No = Q; Yes = P
P	Set Operating Mode.	42				Q
Q	Set System Line Voltage.	43	Rated Voltage			R
R	Set Overall P.T. Ratio. (from Nameplate)	44	Rated P.T.Ratio			S
S	Verify C.T. Primary Rating. (from Nameplate)	45	Rated C.T. Primary			T
T	Change Demand Time Interval?	46	15			No = V; Yes = U
U	Set Demand Time Interval.	46				V
V	Change Tap Changer selection?	49	Nameplate value			No = X; Yes = W
W	Set Tap Changer selection.	49		Nameplate value		X
X	Are date and time correct?	50				No = Y; Yes = Z
Y	Set the required date and time by way of subfunctions- Year	50-1				
	Month	50-2				
	Day	50-3				
	Hour	50-4				
	Minute	50-5				
	Second	50-6				Z
Z	Should control be set up to react to a reverse power flow condition?					No = AA; Yes = BA (Table 1-3)
AA	Verify Reverse Sensing Mode is set on Locked Forward (0).	56	0			AB
AB	Verify the baud rate of Local Channel #1 (Data Reader) is set for 4800.	60	4			AC
AC	Set up Remote Communications Channel #2?					No = AE; Yes = AD
AD	Set Remote Communications Function Codes as desired.	64				
		65				
		66				
		67				
		68-1				
		68-2				AE
AE	Verify the Blocking Status is normal.	69	0			AF
AF	Is Voltage Reduction required?	70	0			No = AH; Yes = AG
AG	Set Voltage Reduction Function Codes as desired.	70				
		72				
		73				
		74				
		75				
		76				
		77				AH
AH	Is Soft Add-Amp required?	79*	0			No = AJ; Yes = AI
AI	Activate Soft Add-Amp.	79*		1		
	Set Add-Amp Raise Limit.	79-1*				
	Set Add-Amp Lower Limit.	79-2*				AJ
AJ	Is Voltage Limiter required?	80	0			No = AL; Yes = AK
AK	Set Voltage Limiter Function Codes as desired.	80				
		81				
		82				AL
AL	Set Profile Recorder Parameters.	85*				
		85-1				
		85-2				
		85-3				
		85-4				
		85-5*				AM
AM	Is Security Override required?	92	0			No = AO; Yes = AN
AN	Set Security Override.	92		1		AO
AO	Change Security Codes?					No = AQ; Yes = AP
AP	Set Security Codes as desired.	96	1234			
		97	12121			
		98	32123			AQ
AQ	Reset Metering & Tap Position.	38				AR
AR	Take Data Reader reading (optional).					AS
AS	Press DISPLAY OFF key to return to Base Security Level.					AT
AT	**CONTROL IS NOW FULLY PROGRAMMED.**					

TABLE 1-3
CL-5 Series Control Programming Checklist for Reverse Power Flow Detection and Operation

Step	Activity/Question		Function Code	Factory Set	Owner Set	Check	Next Step
BA	Is voltage regulation required on the source and load side of regulator?						No = BC; Yes = BB
BB	Is dispersed generation available on load side of regulator?						No = BH; Yes = BI
BC	Is voltage regulation required on the source side of regulator during a reversal of power flow?						No = BD; Yes = BJ
BD	Is the load side of regulator dedicated to a Co-generation facility?						No = BE; Yes = BK
BE	Is Tap to Neutral required for excursions below a reverse power threshold?						No = BF; Yes = BL
BF	Set Reverse Sensing Mode to Reverse Idle.		56		2		BG
BG	Is source side metering required during a reversal of power flow?						No = BQ; Yes = BN
BH	Set Reverse Sensing Mode to Bi-directional.		56		3		BM, BN & BO
BI	Set Reverse Sensing Mode to Reactive Bi-directional		56		6		BM, BN & BO
BJ	Set Reverse Sensing Mode to Lock Reverse.		56		1		BM & BO
BK	Set Reverse Sensing Mode to Co-Generation.		56		5		BM, BN & BO
BL	Set Reverse Sensing Mode to Neutral Idle.		56		4		BM & BO
BM	Set the Reverse Power Flow Control Settings -	Set Voltage	51	120			
		Bandwidth	52	2			
		Time Delay	53	30			
		LDC Resistance	54	0			
		LDC Reactance	55	0			BR
BN	Set Reverse Power Threshold (%)		57	2			BR
BO	Does regulator have an internal or external source side sensing voltage?						No = BP; Yes = BR
BP	Activate Source Side Calculation.		39		1		BQ
BQ	Set Type of Regulator. (A and Series Transformer =1; B=2)		39-1		Nameplate value		BR
BR	**REQUIRED REVERSE MODE IS PROGRAMMED.**						See Table 1.2 - AB

Delta-connected (Line-to-line) Regulators

Determination of Leading or Lagging

For a regulator to operate properly when connected phase to phase, it is necessary for the control to be programmed with the correct regulator configuration in Function Code 41. It must be determined whether it is connected “leading” or “lagging”. The control aids the operator in making this determination.

1. Regulator must be installed.
2. Power switch must be set to Internal.
3. V_1 knife switch (and V_6, if present) must be closed.
4. Knife switch C must be open. Current must be flowing.
5. Control (Auto/Remote-Off-Manual) switch may be in any position.
6. For regulator #1, set Function Code 41 to 1 (Delta Lag) and record the Power Factor, Function Code 13.
7. For the same regulator set Function Code 41 to 2 (Delta Lead) and record the Power Factor.
8. Repeat steps 6 and 7 for each regulator in the bank.

For each regulator, one of the two power factor values will be reasonable and the other will be unreasonable. Set the Regulator Configuration (FC 41) to the value which produced the reasonable power factor.

For one regulator: Set Function Code 41 to the value which produced the reasonable power factor.

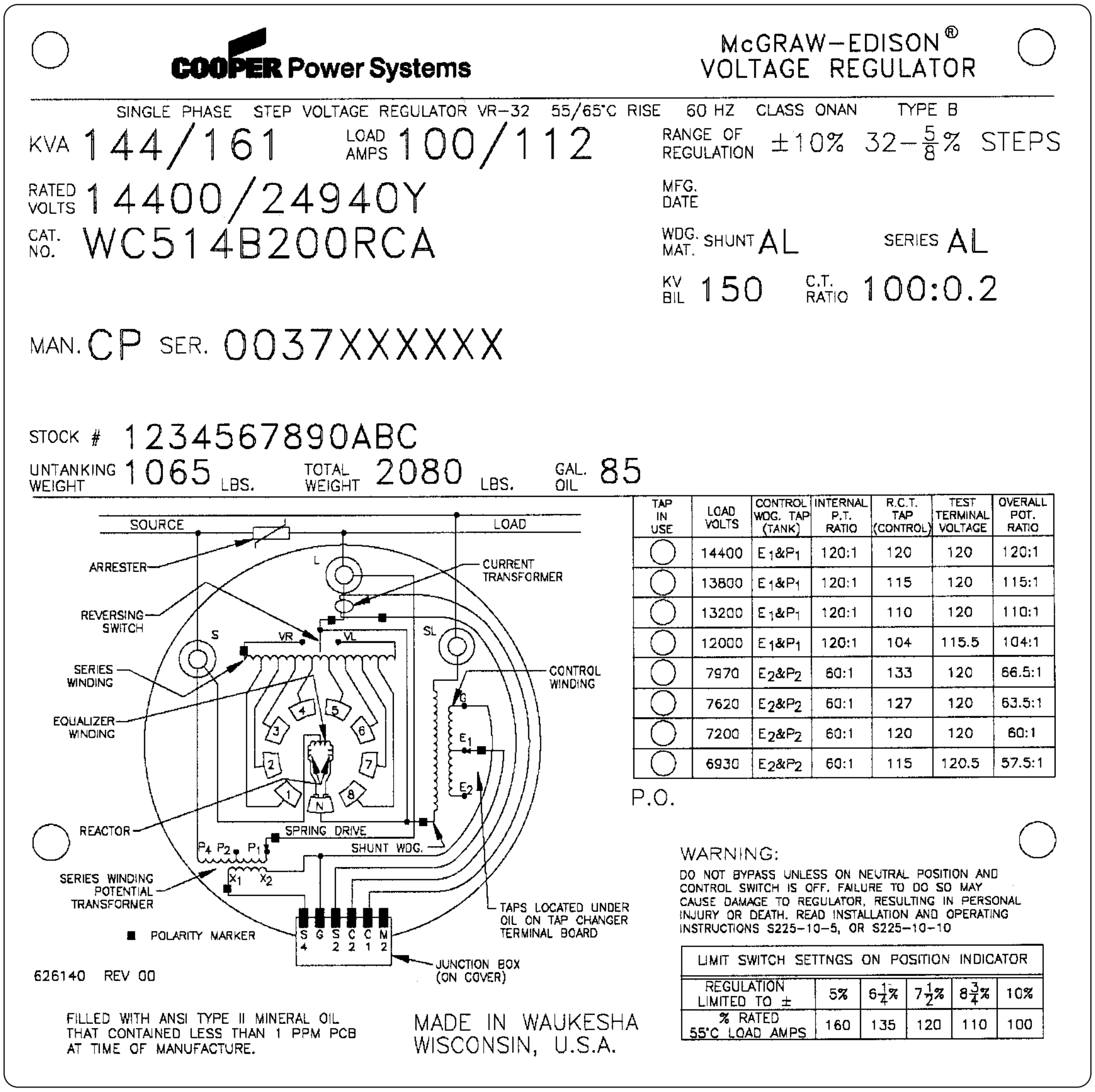
For two regulators in open delta: See the example in Table 1-4. In an open delta connection one of the regulators will always be leading and the other lagging. The reasonable power factor for each regulator should be very close to the typical power factor of the system. In this example, regulator #1 is the lagging unit and regulator #2 is the leading unit.

For three regulators in closed delta: In closed delta, all three regulators are either leading or lagging, depending on how they are connected relative to generator phase rotation.

TABLE 1-4
Sample Power Factor Values for Regulators Connected in Open Delta Configuration

Configuration (FC 41) Set to This Value	Recorded Power Factor (FC 13)	
	Reg. #1	Reg. #2
1 (Delta Lag)	0.94*	-0.77
2 (Delta Lead)	0.17	0.93*

*Reasonable power factor values.



COOPER Power Systems

McGRAW–EDISON®
VOLTAGE REGULATOR

SINGLE PHASE STEP VOLTAGE REGULATOR VR–32 55/65°C RISE 60 HZ CLASS ONAN TYPE B

KVA 144/161 LOAD AMPS 100/112 RANGE OF REGULATION ±10% 32–5/8% STEPS

RATED VOLTS 14400/24940Y MFG. DATE

CAT. NO. WC514B200RCA WDG. MAT. SHUNT AL SERIES AL

KV BIL 150 C.T. RATIO 100:0.2

MAN. CP SER. 0037XXXXXX

STOCK # 1234567890ABC

UNTANKING WEIGHT 1065 LBS. TOTAL WEIGHT 2080 LBS. GAL. OIL 85

TAP IN USE	LOAD VOLTS	CONTROL WDG. TAP (TANK)	INTERNAL P.T. RATIO	R.C.T. TAP (CONTROL)	TEST TERMINAL VOLTAGE	OVERALL POT. RATIO
◯	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	66.5:1
◯	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	115	120.5	57.5:1

P.O.

WARNING:
DO NOT BYPASS UNLESS ON NEUTRAL POSITION AND CONTROL SWITCH IS OFF. FAILURE TO DO SO MAY CAUSE DAMAGE TO REGULATOR, RESULTING IN PERSONAL INJURY OR DEATH. READ INSTALLATION AND OPERATING INSTRUCTIONS S225–10–5, OR S225–10–10

LIMIT SWITCH SETTNGS ON POSITION INDICATOR					
REGULATION LIMITED TO ±	5%	6¼%	7½%	8¾%	10%
% RATED 55°C LOAD AMPS	160	135	120	110	100

626140 REV 00

FILLED WITH ANSI TYPE II MINERAL OIL THAT CONTAINED LESS THAN 1 PPM PCB AT TIME OF MANUFACTURE.

MADE IN WAUKESHA WISCONSIN, U.S.A.

Figure 1-7.
Nameplate of a 60 hertz regulator with an internal series winding P.T.

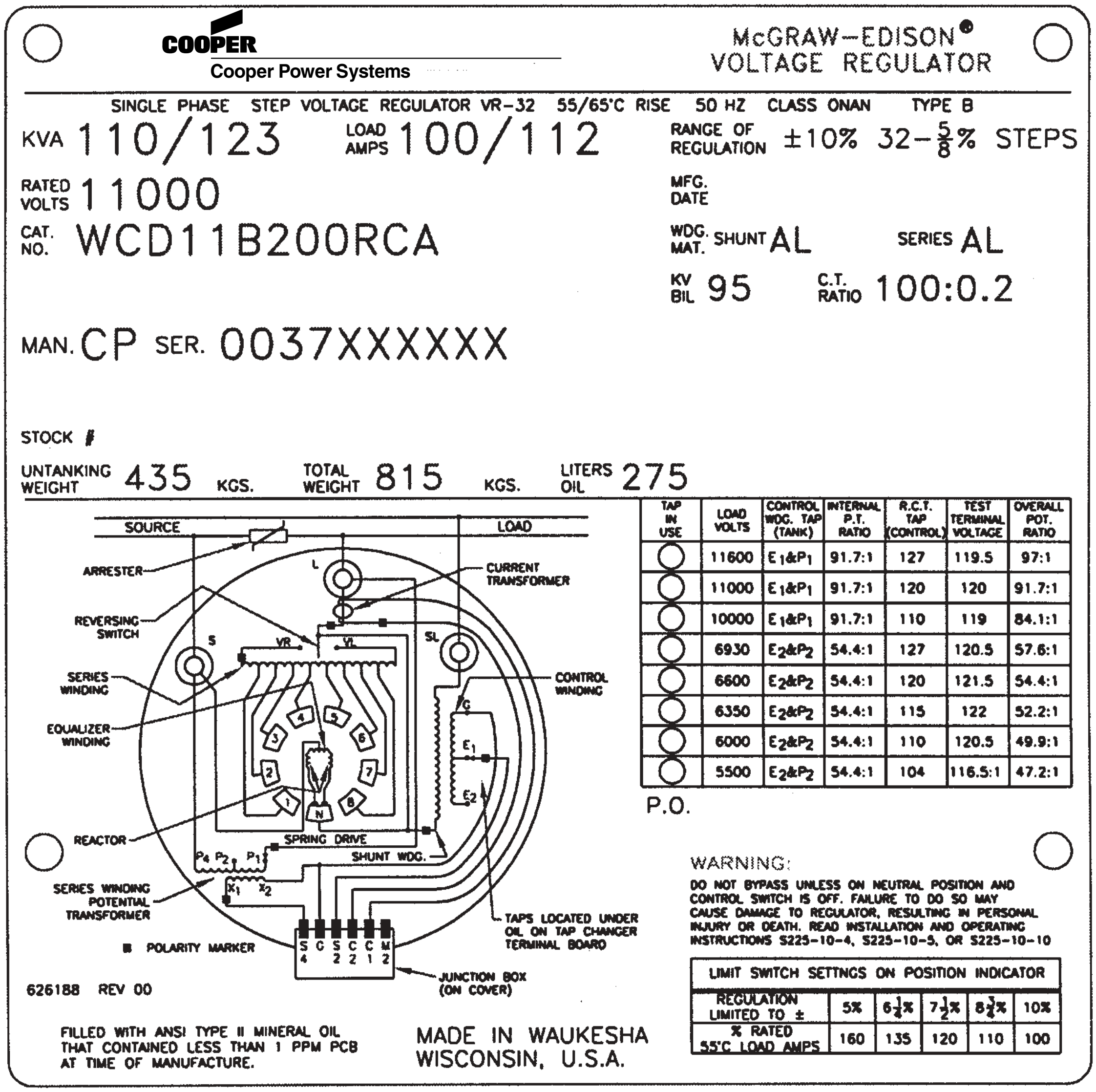


Figure 1-8.
Nameplate of a 50 hertz regulator indicating metric weights and volumes

Operational Check

Pre-Installation Operational Check

The CL-5 Series Control has the facilities for either manual or automatic operation of the tap changer, using either the internal source of power (the regulator), or an external source. To perform an operational check of the control before installing the regulator, follow these steps:

1. Open V_1 (and V_6, if present) knife switch(es) located on control backpanel.
2. Place POWER switch in OFF position, and CONTROL switch in OFF position.
3. Connect a variable 120-volt 50/60 Hz source to EXTERNAL SOURCE terminals. Grounded side of external source must connect to ground (white) terminal on control.
4. Place POWER switch in EXTERNAL position.
5. Move CONTROL switch to MANUAL, and depress and hold RAISE-LOWER momentary toggle switch. Allow tap changer to operate to 8L, the 5% buck position.
6. Hold up on RAISE-LOWER momentary toggle switch. Allow tap changer to operate to 8R, the 5% boost position.
7. Now place Control switch in the AUTO/REMOTE position.
8. Increase variable voltage source so applied voltage is out of band. Note that “HIGH” band annunciator in display will come on. After time delay period, control will issue “LOWER” tap change signals. Check to ensure that operations counter is registering tap changes by pressing “0” key on keypad.
9. Decrease variable voltage source so applied voltage is out of band. Note that “LOW” band annunciator in display will come on. After time delay period, control will issue “RAISE” tap change signals. Check to ensure that operations counter is registering tap changes.
10. Place CONTROL switch in MANUAL position and manually return tap changer to NEUTRAL. When on NEUTRAL, NEUTRAL LAMP will light continuously and position indicator will point to zero.
11. Place CONTROL switch in OFF position.
12. Press down on momentary toggle switch labeled DRAG HAND RESET, and position indicator drag hands will reset around indicating hand.
13. Turn POWER switch to OFF and disconnect power supply from EXTERNAL SOURCE terminals.

In-Service Operational Check

With the control now set for basic operation, an operational check of manual and automatic operation should be performed as follows:

1. Depress “8” key to display compensated voltage.
2. Place control switch in MANUAL position.
3. Lift up on Raise/Lower switch to activate a raise operation.
4. Allow tap changer to operate for enough steps to take voltage out of band.
5. Place control switch in the AUTO position. After time delay period, the control should cause the regulator to step down to the top band edge. (EXAMPLE: 120 V and a 2 V B.W. = 121 V top band edge.) This should be shown in the display.
6. After voltage is brought in-band and tap changing has stopped, move control switch to the MANUAL position.
7. Press down on Raise/Lower switch to activate a lower operation.
8. Allow tap changer to operate for enough steps to take voltage out of band.
9. Place control switch in the AUTO position. After time delay period, the control should cause the regulator to step up to the lower band edge. (EXAMPLE: 120 V and a 2 V B.W. = 119 V lower band edge.) This should be shown in the display.

Field Calibration Check

If the operator also desires to check the calibration of the control, perform the steps listed below.

NOTE: Field calibration checks are only an indication of calibration, and are not nearly as precise as the laboratory procedure described in the Troubleshooting Guide section of this manual.

1. Connect an accurate true-RMS responding voltmeter to the voltmeter terminals.
2. The easiest and most direct way to perform a calibration check is to compare the voltage that the control “sees” to the voltage measured at the test terminals. This is accomplished by accessing the keypad and keying:

   FUNCTION, 47, ENTER.
3. Under ideal conditions, the displayed voltage of the control will match the voltage of the voltmeter. Realistically, the voltages may be slightly different because:

a. The metering and operation is based upon the RMS value of the fundamental power line frequency. Thus, the metered values exclude the influences of harmonic voltages which are probably present on the line. A true-RMS meter however, will include these harmonic voltages in its calculations of the RMS voltage. This does not present a problem with either metering device, since each device uses a different approach to metering.

b. The calibration of the voltmeter being used for measurement is probably not exact. Even a very good meter with a basic accuracy of 0.5% could be in error by as much as 0.6 V (out of 120 V), and still be considered to be "in-calibration." The control is calibrated using a conditioned power supply and reference voltmeters which are periodically calibration-checked, traceable to the National Bureau of Standards.

NOTE: The control is designed to perform ratio correction in software. Through the use of the ratio correcting transformer (RCT) located on the back panel, the voltage brought to the front panel is usually already corrected to the 120 V base voltage. However, there are some ratings in which this voltage is not fully corrected by the RCT. Column 6 in Table 1-10 or 1-11, page 1-21 gives a general indication of these voltages, however, always refer to the nameplate which provides the specific information for the particular regulator.

Whatever voltage results from dividing the nominal system voltage, FC43, by the overall P.T. ratio, FC44, is considered by the control to be the nominal voltage. Therefore, when that voltage appears at the input of the control, 120 volts will be reported as the output voltage, FC6 (whether the nominal is actually 120 or not). Likewise, the compensated voltage, FC8, and input voltage, FC7, will be scaled accordingly. If the regulator is equipped and programmed for reverse power operation, the voltage displayed at Function Code 8 will be correct even during reverse power conditions.

The load voltage, FC10, source voltage, FC11, and calculated parameters such as the kVA, kW and kvar are not scaled similar to FCs 6 and 8. Instead, they reflect the true value of line voltage.

NOTE: The voltage measured at the test terminals during reverse power flow is the new source voltage at the L bushing of the regulator.

Removal From Service

Determining Neutral Position

WARNING: In order to prevent possible damage to equipment and injury to personnel, prior to bypass switching being attempted, the following must be accomplished: 1) The regulator must be placed in the neutral position; 2) action must be taken to prevent tap changer operation while the bypassing is being performed.
If the regulator is in any position other than neutral, part of the series winding will be shorted if bypass switch is closed. This results in high circulating current which can severely damage the regulator. If catastrophic failure occurs, it could pose a threat of injury or death to operating personnel.

Return the regulator to neutral. The regulator can be safely removed from service without interrupting load continuity only in the neutral position. It is recommended to use more than one method to determine whether a regulator is on neutral.

To Return the Regulator to Neutral

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

WARNING: A regulator should be bypassed 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.

WARNING: Always use the control switch (labeled AUTO/REMOTE-OFF-MANUAL) to operate the regulator, not the power switch. Failure to do so may result in the tap changer stepping off of neutral immediately upon being energized.

2. When in neutral, neutral light will light continuously and position indicator will point to zero.

WARNING: To stop the regulator on the neutral position, the control switch should be turned to OFF during the switching operation from positions "1" or "-1" to position zero. Switching to OFF prior to reaching the neutral position prevents overshoot.

3. To increase safety, we recommend verifying that the regulator is in the neutral position using the following three 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 that position indicator is in the neutral position.
   c. Using an acceptable method, verify that there is no voltage difference between the source and load bushings.
4. When the regulator has been placed in the neutral position, and 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 (Auto/Remote-Off-Manual) switch in OFF position.
   b. Remove motor fuse.
   c. Place control power switch in OFF position.
   d. Open V_1 knife switch (and V_6 if present) located on control back panel.

   If the precautions listed above are taken, the likelihood of damaging a regulator or injuring personnel is eliminated.

De-energizing the Regulator

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

1. Place control (Auto/Remote-Off-Manual) switch in OFF position.
2. Place power switch in OFF position.
3. Open V_1 knife switch (and V_6 if present) on back panel (see Figure 1-7, page 1-8).
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.

Maintenance Program

Periodic Inspections

Step-type voltage regulators are designed to provide many years of trouble-free operation. 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, FC3, 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 the following sections for proper procedures on removing and replacing the control.

Since the usable life of a regulator is affected by its application, it may be desirable to periodically remove the regulator from service and untank the unit to verify contact wear, oil dielectric, etc. The time for this will vary, depending on a specific user's past experience.

The oil should be checked (a) prior to energization, if the regulator has not been energized for a long time period, or (b) at normal maintenance intervals. Table 1-5 shows the characteristics that the oil should meet.

TABLE 1-5
Oil Characteristics*

	New	Used
Dielectric Strength (kV minimum)		
ASTM D1816-84 0.08 inch gap	40	34
ASTM D877-87	30	26
Interfacial Tension ASTM D971-91 (mN/m)	35	24
Water ASTM D1533-88 (ppm maximum)	25	35

*Per C57.106.

Removal of Control Front Panel

The front panel may be removed from the regulator with the regulator energized.

To open the front panel, unscrew the captive knurled knobs on the left side of the panel. This allows the control to swing open on its hinges. With the control open, the back panel is readily accessible. The design of the control enclosure, back panel and front panel enable easy replacement of the front panel, leaving the back panel, control enclosure, and cable intact. To remove the front panel, proceed as follows:

> **WARNING:** Push the C shorting switch closed before attempting to remove the fanning strip. Failure to do so may open the regulator CT circuit, producing a flashover in the control.

1. Push closed the current shorting switch, C. This shorts out the secondary of the regulator CT.

NOTE: Regulators shipped with a quick disconnect cable contain a solid-state CT shorting board in the junction box. This device automatically places a burden on the CT anytime the CT circuit is opened. For consistency, it is recommended that the CT shorting switch be used whenever it is present on the back panel.

2. Pull open disconnect switch, V_1, (and V_6 if present). This de-energizes terminal board TB_2.
3. Loosen screws on terminal board TB_2 at the bottom of back panel.
4. Pull fanning strip (a series of terminals, wired to front panel) free from terminal strip.
5. Disconnect front panel ground lead from back panel.

The front panel can now be lifted off its hinges. Care should be taken to prevent damage to a control front panel while in transit and/or storage.

Replacement of Control Front Panel

To replace a front panel in the control enclosure, follow the procedure outlined below:

1. Engage the front panel on enclosure hinges.
2. Connect front panel ground lead to back panel.
3. Insert fanning strip from front panel wiring harness under TB_2 terminal board screws.
4. Tighten screws on interconnecting terminal board.
5. Push closed the disconnect switch, V_1, (and V_6 if present).
6. Pull open the current shorting switch, C.
7. Close panel and tighten panel locking screws.

> **WARNING:** Do not pull open the current shorting switch, C, until the screws have been tightened on the interconnecting terminal block. Failure to do so could open the regulator CT secondary causing a flashover in the control.

Untanking the Regulator

> **WARNING:** 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 should the lifting apparatus fail.

> **CAUTION:** 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/or spillage of oil when the internal assembly is lifted.

> **CAUTION:** Do not suspend the control box using the control cable.

1. Manually run 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 (Figure 1-9).
3. Remove series arrester. Release internal pressure using pressure relief device on side of regulator.
4. Free cover by removing clamping ring or cover bolts.
5. Attach sling or hooks with spreader bar (Figure 1-10) to 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. As a safety precaution, blocking between the cover and 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 connection cable is not long enough. Contact customer service for availability.

Figure 1-9.
Quick Disconnect Cable

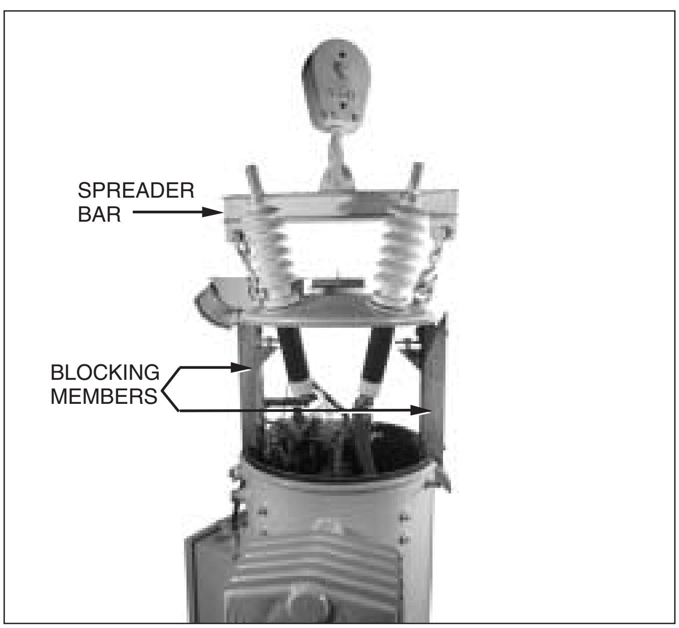


Figure 1-10.
Untanking

Retanking the Regulator

Retank the regulator as follows:

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

NOTE: Tap cover with a rubber hammer around edge to properly seal gasket while tightening cover band.

6. Check and retighten horizontal side channel bolts through handhole, if required.
7. Properly reseal handhole cover, being careful not to damage cover or insulation on the handhole cover bolt.
8. Connect control cable to connector at bottom of junction box.

Maintenance

The following is the recommended maintenance program for a regulator that has been untanked:

1. Check all connections for tightness.
2. Check all contacts for wear (refer to S225-10-2).
3. Avoid removing main core-and-coil assembly from oil, except when a winding failure occurs. Blocking between cover and tank lip should be used to suspend core-and-coil assembly within oil until inspection of tap changer or other maintenance is complete.

   If it is necessary to remove main core-and-coil assembly from oil, the following steps should be followed.

   a. Tap changer must not be subjected to temperatures above 150°F (66°C). It must be removed if the unit is baked at higher temperatures.

b. If unit is out of oil more than four hours, it must be rebaked for a minimum of 24 hours at 100°C (212°F). The maximum number of times a unit should be rebaked is twice over its life.

c. Within four hours after bake, the unit should be retanked and filled with oil.

d. 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 oil. If vacuum processing is not available, allow entire internal assembly to soak in oil for at least five days before energizing.

Construction

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 2, page 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 1-6.

TABLE 1-6
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		

Position Indicator & ADD-AMP Capability

The position indicator (Figure 1-11) 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 to 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 function code 79 (soft ADD-AMP) 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, 6¼, 7½, 8¾, 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 1-7 and 1-8. 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 page 6-3 for position indicator replacement and calibration.

Figure 1-11.
Position Indicator

Setting the Manual (Hard) Limit Switches

Before setting the manual limit switches, be sure the new settings will not conflict with the present tap changer position. 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 two-step procedure:

1. Loosen the captive bezel securing screws and swing the bezel 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.

Internal Construction & Wiring Diagrams

The main core-and-coil assemblies are of the shell-form configuration. The series winding on the input (source) side of the regulator (Figure 1-12) 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 1-13) 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 1-14 shows a typical regulator power circuit with a series transformer. This design is utilized when the load current rating exceeds the tap changer rating. In this type of design, the series transformer winding losses are a function of the load alone and are independent of the tap position. Because of this, limiting the range of voltage regulation does not reduce losses and therefore, the ADD-AMP feature is not applicable.

The bridging reactor is a core-form design, consisting of a coil on each leg of one core. The inside half of one coil is connected to the outside half of the other coil and vice versa, providing equal current in each half of the reactor winding. This interlacing of the two coils 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 6-3 and 6-4 in the Troubleshooting section illustrate **typical** internal wiring schemes of the various types of regulator constructions. Most of the wiring is on the tap changer itself. Application, troubleshooting and operation of the tap changer and related components are covered extensively in Service Manual S225-10-2.

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 6-1, page 6-5.

TABLE 1-7
ADD-AMP Capabilities of 60 Hz Ratings

Rated Volts	Rated kVA	†Load Current Ratings (amperes)				
		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	25	100	110	120	135	160
	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*	219/232	241/255	263/278	296/313	350/370
	250*	328/347	361/382	394/417	443/469	525/556
	333*	438/464	482/510	526/557	591/625	668
	416.3*	548/580	603/638	658/668	668	668
	500*	656/668	668	668	668	668
	667*	875/926	875/926	875/926	875/926	875/926
	833*	1093/1157	1093/1157	1093/1157	1093/1157	1093/1157
13800	69	50	55	60	68	80
	138	100	110	120	135	160
	207	150	165	180	203	240
	276	200	220	240	270	320
	414	300	330	360	405	480
	500	362	398	434	489	579
	552	400	440	480	540	640
	667	483	531	580	652	668
	833	604	664	668	668	668
14400	72	50	55	60	68	80
	144	100	110	120	135	160
	288	200	220	240	270	320
	333	231	254	277	312	370
	416	289	318	347	390	462
	432	300	330	360	405	480
	500	347	382	416	468	555
	576	400	440	480	540	640
	667	463	509	556	625	668
	720	500	550	600	668	668
	833	578	636	668	668	668
19920	50	25.1	28	30	34	40
	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

† 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 customer service.

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

TABLE 1-8
ADD-AMP Capabilities of 50 Hz Ratings

Rated Volts	Rated kVA	†Load Current Ratings (amperes)				
		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
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
33000	165	50	55	60	68	80
	330	100	110	120	135	160
	495	150	165	180	203	240
	660	200	220	240	270	320

† 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 customer service.

TABLE 1-9
Current Transformer Applications (50 & 60 Hz)

Regulator Current Ratings	C.T. 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

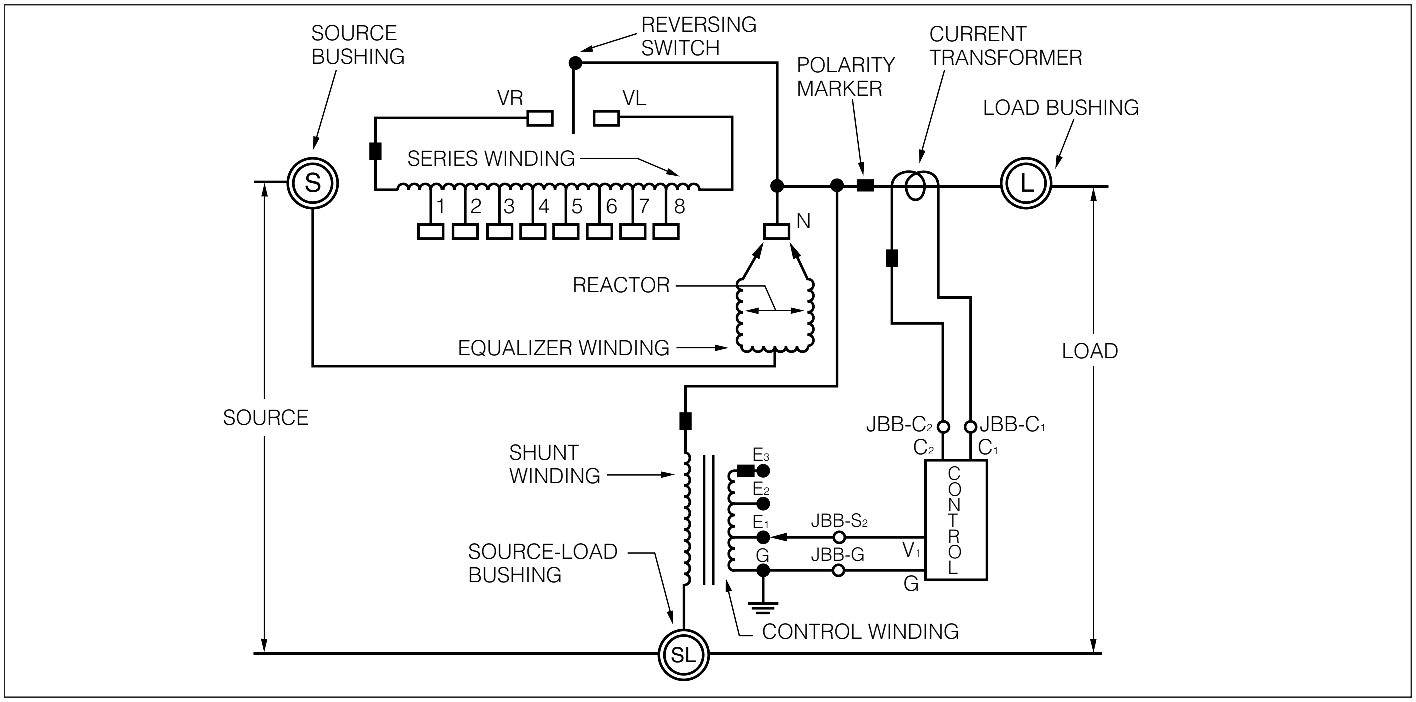


Figure 1-12.
Power circuit — series winding located on the source-side (ANSI Type B)

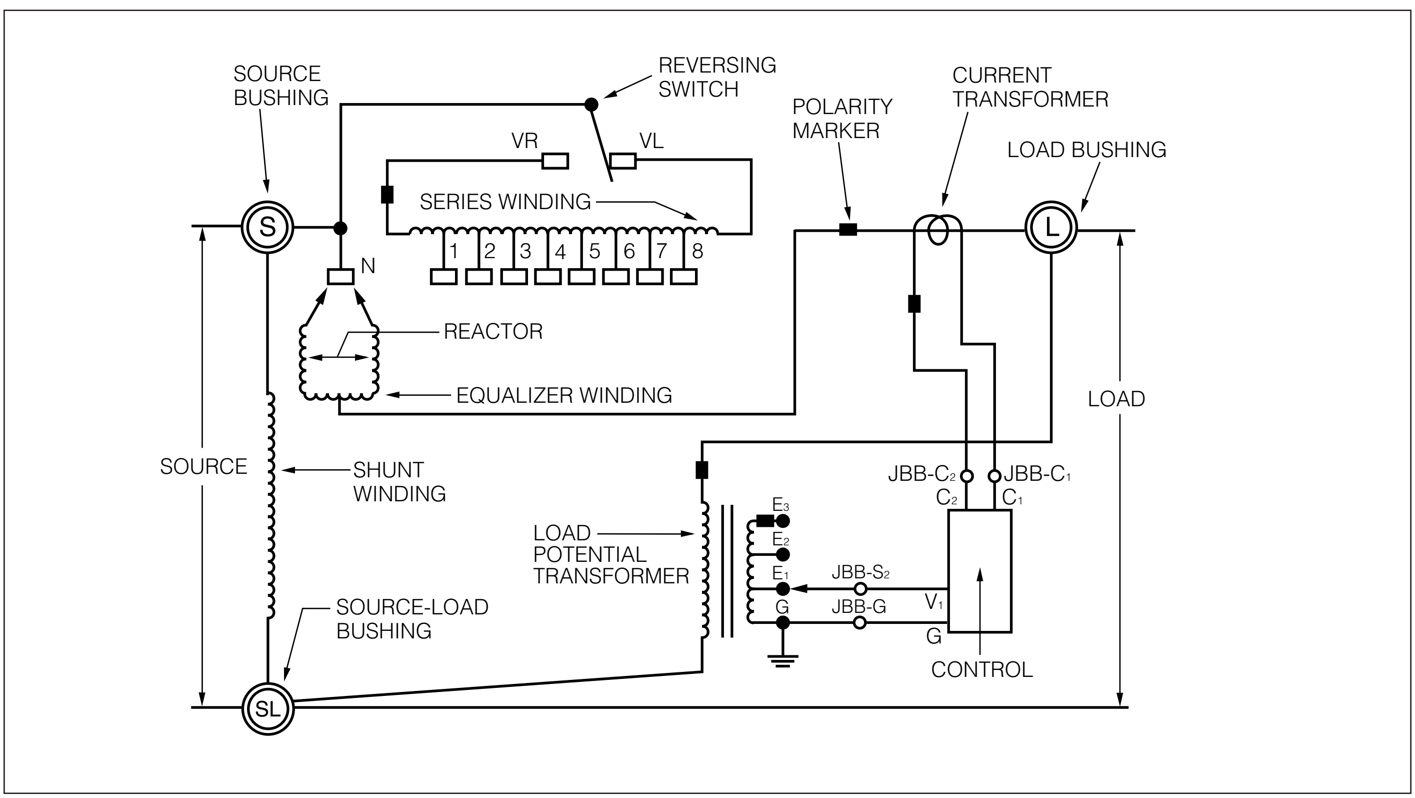


Figure 1-13.
Power circuit — series winding located on the load-side (ANSI Type A)

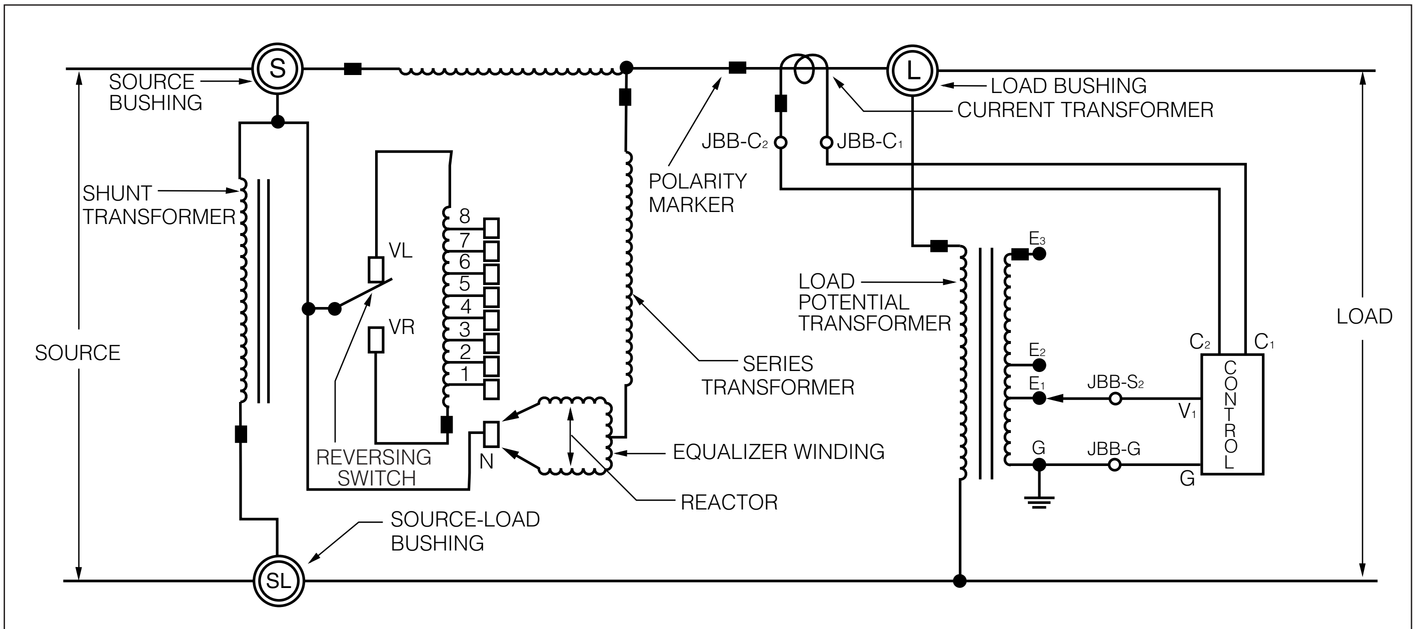


Figure 1-14.
Power circuit — series transformer

Voltage Circuits

All McGraw-Edison VR-32 regulators have provisions for operation at system voltages lower than the nameplate rating, as illustrated in Tables 1-10 and 1-11. This is accomplished by providing taps on the control winding or P.T. 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 1-15.) The connections are made with push-on terminals and are easily accessed through the handhole.

Regulators built prior to 1995 will have all the voltage terminal connections mounted on the top of the tap changer. Since the middle of 1995, the voltage connections will be as shown in figure 1-15.

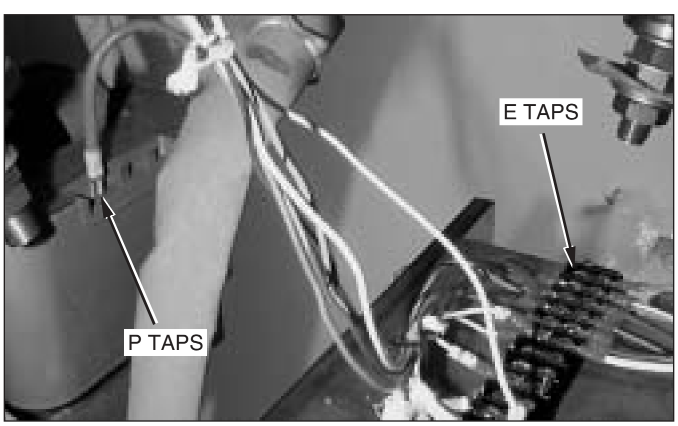


Figure 1-15.
Internal tap terminals

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 1-7, page 1-3). 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 the control must be programmed properly at Function Code 43 (System Line Voltage) and Function Code 44 (Overall P.T. Ratio). The nameplate provides these values for common system voltages (see Figure 1-8 on page 1-9).

This voltage supply is then 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. 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.

If a regulator is purchased with the intent of using it in an area where reverse power flow is likely, the unit may have a second voltage source installed internal to the regulator to develop the source-side voltage supply. (For the CL-5C and subsequent controls, reverse power flow may instead be handled using the source voltage calculator. See page 4-3, Reverse Power Operation.) A series winding (differential) P.T. is utilized for measuring the voltage across the series winding, which is then used, along with the existing control winding or separate control windings, to develop the source-side voltage. The series winding P.T. will have taps similar to the load side supplies. These high-voltage taps (see Figure 1-15) are located on the series winding P.T. and are marked P_1, P_2, etc. The secondary voltage of the series winding P.T. is brought directly to the knife switch labeled V_6, and then passes through RCT_2 for ratio correction (similar to that performed for V_1). The differential V_6 voltage, once corrected by RCT_2, is labeled V_7 and is then routed to the control front panel.

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 a 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.

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. 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 voltage.

The three voltage circuits are routed from the power switch to the respective 6 A motor fuse, 2 A panel fuse, and 2 A differential voltage fuse. The differential voltage fuse is provided to protect the front panel if an external source P.T. is used. 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. The sensing voltage and differential voltage are connected directly to their respective circuit board input terminals.

TABLE 1-10
VR-32 Tap Connections and Voltage Levels (60 Hz)

Regulator Voltage Rating 1	Nominal Single Phase Voltage 2	Ratio Adjusting Data			Test Terminal Voltage ** 6	Overall Potential Ratio ** 7
		Internal Tap* 3	PT Ratio 4	RCT Tap 5		
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	125	99.7:1
	12000	E_1/P_1	115:1	104	120	99.7:1
	7970	E_2/P_2	57.5:1	133	125	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	125	57.5:1
	6930	E_2/P_2	57.5:1	120	120.5	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	66.5:1
	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	115	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	66.5:1
	7620	E_3/P_3	60:1	127	120	63.5:1
	7200	E_3/P_3	60:1	120	120	60:1

* 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 1-11
VR-32 Tap Connections and Voltage Levels (50 Hz)

Regulator Voltage Rating 1	Nominal Single Phase Voltage 2	Ratio Adjusting Data			Test Terminal Voltage ** 6	Overall Potential Ratio ** 7
		Internal Tap* 3	PT Ratio 4	RCT Tap 5		
6600	6930	—	55:1	127	119	58.2:1
	6600	—	55:1	120	120	55:1
	6350	—	55:1	115	120.5	52.7:1
	6000	—	55:1	110	119	50.4:1
	5500	—	55:1	104	115.5	47.7:1
11000	11600	E1/P1	91.7:1	127	119.5	97:1
	11000	E1/P1	91.7:1	120	120	91.7:1
	10000	E1/P1	91.7:1	110	119	84.1:1
	6930	E_2/P_2	55:1	127	119	58.2:1
	6600	E_2/P_2	55:1	120	120	55:1
	6350	E_2/P_2	55:1	115	120	52.7:1
	6000	E_2/P_2	55:1	110	119	50.4:1
	5500	E_2/P_2	55:1	104	115.5	47.7:1
15000	15000	E1/P1	120:1	120	125	120:1
	14400	E1/P1	120:1	120	120	120:1
	13800	E1/P1	120:1	115	120	115:1
	13200	E1/P1	120:1	110	120	110:1
	12000	E1/P1	120:1	104	115.5	104:1
	11000	E_2/P_2	92.3:1	120	119	92.3:1
	10000	E_2/P_2	92.3:1	110	118	84.6:1
	8660	E_3/P_3	72.9:1	120	119	72.9:1
22000	23000	E1/P1	183.3:1	120	125.5	183.3:1
	22000	E1/P1	183.3:1	120	120	183.3:1
	20000	E1/P1	183.3:1	110	119	168:1
	19100	E1/P1	183.3:1	104	120	159.2:1
	15000	E_2/P_2	119.8:1	120	125.5	119.8:1
	12700	E_2/P_2	119.8:1	104	122.5	103.9:1
	11000	E_3/P_3	91.6:1	120	120	91.6:1
	10000	E_3/P_3	91.6:1	110	119	84:1
33000	34500	E1/P1	275:1	127	118	291:1
	33000	E1/P1	275:1	120	120	275:1
	30000	E1/P1	275:1	110	119	252.1:1
	22000	E_2/P_2	183.3:1	120	120	183.3:1
	20000	E_2/P_2	183.3:1	110	119	168:1
	11600	E_3/P_3	91.7:1	127	119.5	97:1
	11000	E_3/P_3	91.7:1	120	120	91.7:1
	10000	E_3/P_3	91.7:1	110	119	84:1

* 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 1-12
RCT Ratios

RCT Input Tap	RCT Ratio
133	1.108
127	1.058
120	1.000
115	0.958
110	0.917
104	0.867

Allowable System Voltages

Calculation of Overall P.T. Ratio

If the system voltage is other than those listed on the nameplate, it can be determined whether there is sufficient ratio correction available from the control winding (internal P.T.) taps and the Ratio Correction Transformer (RCT) taps to allow the CL-5 Series control and motor to function properly. The general guideline is that the overall P.T. ratio is sufficient if the voltage delivered to the control for the nominal voltage conditions is in the range of 115-125 V.

To determine the voltage delivered to the control, use the following procedure:

1. Of the P.T. ratios shown on the nameplate choose the one which provides a voltage closest to 120V at the output of the internal P.T. (The output of the internal P.T. is the input to the RCT).
2. Calculate the voltage at the output of the internal P.T., and compare that to the RCT input taps of 133, 127, 120, 115, 110 and 104.
3. Choose the RCT tap closest to the RCT input voltage.
4. Given the RCT input tap use Table 1-12 to determine the RCT ratio.
5. Use the formula below to calculate the control input voltage.
6. Use the formula below to calculate the overall P.T. Ratio.

Control Input V = Internal P.T. Output V (RCT Ratio)
Overall P.T. Ratio = Internal P.T. Ratio x (RCT Ratio)

EXAMPLE: If a 60Hz, 14400 V regulator is to be used on a system with a nominal voltage of 12700, the following is determined:

1. 12700V / 120V=105.8. Choose 120:1 Control Winding Tap
2. Internal P.T. output voltage = 12700V / 120=105.8V
3. Best RCT input tap is 104
4. RCT ratio is 0.867
5. Control input V = 105.8/0.876 = 122V. This is within allowable range.
6. Overall P.T. ratio = 120 x .867 = 104:1

Changing System Voltage

> ⚠ **WARNING:** Remove regulator from service before performing internal lead connection changes.

To utilize a regulator at a system voltage other than the nominal voltage designated on the nameplate,

1. If required, change control winding tap (E1-E3) on the terminal strip (accessible through the handhole,) to the value indicated on the nameplate.
2. If the regulator contains an internal differential P.T., and if a change to the P.T. settings is required, make the changes on the P.T. (through the handhole.)
3. Move the Control Function switch to OFF.
4. Move the Power switch to OFF.
5. Remove the 6 amp motor fuse.
6. Open the V_1 (and V_6 if present) knife switches, on the control back panel.
7. If required, change the Ratio Correction Transformer tap (on the control back panel) to the value indicated on the nameplate.
8. Close The V_1 (and V_6 if present) knife switches, on the control back panel.
9. Replace the 6 amp motor fuse.
10. Move the Power switch to External or Internal, depending on how regulator control is energized.
11. Change Function Code 44 to the new overall P.T. Ratio.
12. Change Function Code 43 to new system voltage.
13. Move the Control Function switch to AUTO/ REMOTE.

Current Circuit

All VR-32 regulators are designed with an internal current transformer to provide a current source for the line drop compensation calculations and for metering functions. Table 1-9, page 1-17 provides the application information for the various C.T.s used on the McGraw-Edison regulators. These C.T.s provide 200 mA output for the rated C.T. primary current.

The current developed by the C.T. 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 C.T.**, 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 quick disconnect, connector (Figure 1-9), an automatic solid-state C.T. shorting device is located in the junction box. This solid-state device automatically will short the C.T. when the cable is disconnected.

Figure 1-16.
Internal bushing mounted current transformer

At this knife switch, one side of the C.T. 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 drawn through an input on the circuit board which 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, page 2-8.

Two other unassociated circuits which 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.

Control Basics

Introduction

The CL-5 Series Control

The McGraw-Edison CL-5 series control is a full-featured control which incorporates digital logic and microprocessor technology. A keypad is used to simplify the setup of the basic control and its many built-in accessory features. An LCD (liquid crystal display) screen displays the control settings, accessory settings, metering values and annunciator words.

Standard features of the control are:

- Line Drop Compensation
- Voltage Limiting
- Voltage Reduction (Local and Remote)
- Reverse Power Flow Operation
- Metering
- Data Port
- CE Mark Compliant

Advanced features of the control are:

- Source Voltage Calculation (CL-5C and later only)
- Calendar/Clock
- Time-Tagged Min/Max Demand Metering
- Metering Profile Recorder
- Total Harmonic Distortion and odd harmonic voltages and currents up to the 13th
- Tap Position Indication
- Pulse Voltage Reduction Mode
- Security Override
- Supervisory On/Off Switch
- Resident Communications Protocol (DATA 2179)
- Tap to Neutral*
- Enhanced Operation Counter*
- SOFT ADD-AMP Limits*

  * CL-5E only

The demand metering values and control settings are stored in EEPROM memory to prevent their loss during a power outage. Information stored in the EEPROM will be retained indefinitely, with or without power applied.

To fully capitalize on the microprocessor capabilities, a 12-bit analog-to-digital converter is used in the front end of the design to convert the analog voltage and current waveforms into digital signals. A digital signal processing technique, called Discrete Fourier Analysis, is then performed on this data. This permits extremely accurate resolution of both the voltage and current input signals. It is this technique which enables the control to do harmonic analysis (to the 13th harmonic frequency), as well as measurements for metering and control.

TABLE 2-1
Control Specifications

A.	Physical Size	17 1/2” H 10 1/4” W 2 1/2” D (44.5 cm 26.0 cm 6.35 cm)
B.	Weight	11 1/2 lbs. (5.2 kg)
C.	Burden @ 120 V	4 VA
D.	Operating Temperature Range	-40° C to +85° C
E.	Control System Accuracy	±1%
F.	Metering Accuracy Voltage Inputs (2) Output Voltage and Differential/Source Voltage 80-137 V ac, 45 to 65 Hz with error not to exceed 0.5%*† of the reading under all conditions. The control will withstand up to 137 V without damage or loss of calibration. Current Input 0-0.400 A ac 45 to 65 Hz with error not to exceed 0.6% (0.0012 A)* of the nominal full load current (0.200 A), under all conditions. The control will withstand the short-circuit rating of the regulator without damage or loss of calibration. Calculated Values - kVA, kW, kvar 0-9999, with error not to exceed 1%* under all conditions. Harmonic Analysis - Current and Voltage Harmonics 3, 5, 7, 9, 11, 13th harmonic frequencies and THD, with error not to exceed 5%* under all conditions.	

*Basic accuracy of the device, excluding P.T. and C.T. errors
†0.5% on 120 volt base; (0.5%) (120)=0.6 volts

All control setting values, instantaneous and demand metering values, tap position values and diagnostic values can be displayed on the LCD screen. (Some reverse power flow operation modes and metering require source side voltage, from either an optional differential potential transformer or the source voltage calculator in the control [CL5C and later.])

The entire control data base (all Function Codes) may be copied through the control Data Port to an optional McGraw-Edison Data Reader for transfer to a personal computer, or be copied directly to a personal computer.

The control can communicate digitally with a SCADA system.

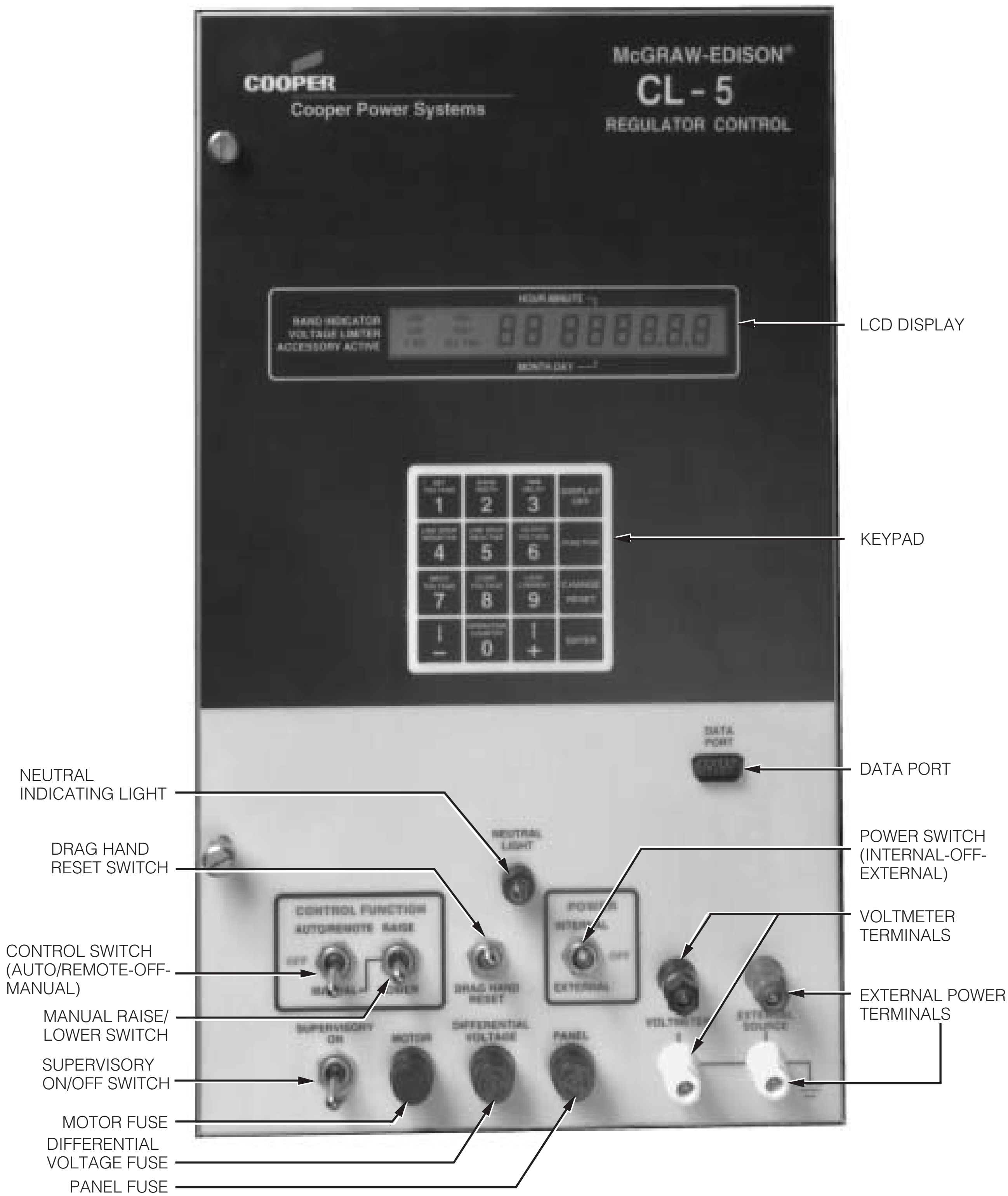


Figure 2-1.
CL-5 series control front panel

Front Panel Components

Lower Section - Grey

The lower section of the control contains components which are similar to the other controls in the McGraw-Edison CL series.

Power Switch

In the external position, the control and tap changer motor are powered from an external 120 V ac source connected to the external source terminals. In the internal position, the control and motor get power from the regulator. In the off position, no power is delivered to either the control or the motor.

External Power Terminals

Providing 120 V ac to these terminals powers the control and tap changer motor. See page 1-3 for cautionary note. Controls wired for an external source of 220-240 V ac have a “240” decal at the terminals.

Control Switch

In the auto/remote position, the tap changer motor can be controlled by either the front panel (auto) or remotely by SCADA. In the off and manual positions, automatic operation and analog-type remote motor control are inhibited. In the manual position, automatic operation and analog-type remote motor control are inhibited and the tap changer may be raised or lowered locally by momentarily depressing the raise/lower switch.

Manual (Raise/Lower) Switch

This switch allows the operator to manually raise or lower the tap changer motor.

Supervisory Switch

This switch is used for digital communications only. When in the on position, SCADA has full capabilities. When in the off position, SCADA may only read the control database. See DIGITAL SCADA, page 4-11.

Draghand Reset Switch

This switch operates a solenoid in the Position Indicator to move the draghands to the present position of the main hand.

Neutral Light

This is the primary indication that the tap changer is in the neutral position. See Determining Neutral Position, page 1-11.

Voltmeter Terminals

These allow the connection of a voltmeter so that the potential sensed by the control (between the load (L) bushing and SL bushing of the regulator) can be measured.

Fuses

The motor fuse is a 6.25 A slow-blow fuse. The 2 A panel fuse protects the control panel circuit. The 2 A differential voltage fuse protects the circuit from mis-wiring of an external PT.

Data Port

This was first introduced on the CL-4 control. It allows the temporary connection of a McGraw-Edison Data Reader or personal computer. See Data Retrieval and Settings Uploading, page 4-12.

Upper Section - Black

The man-machine interface chosen for the CL-5 Series control is a 16-key touchpad and a liquid crystal display (LCD).

The keypad, with a layout similar to a touch-tone telephone, has a snap-action response. (See Figure 2-2.)

The special, low-temperature LCD was chosen to be easily visible in direct sunlight. (See Figure 2-3 for a diagram of the LCD with all of the segments on.)

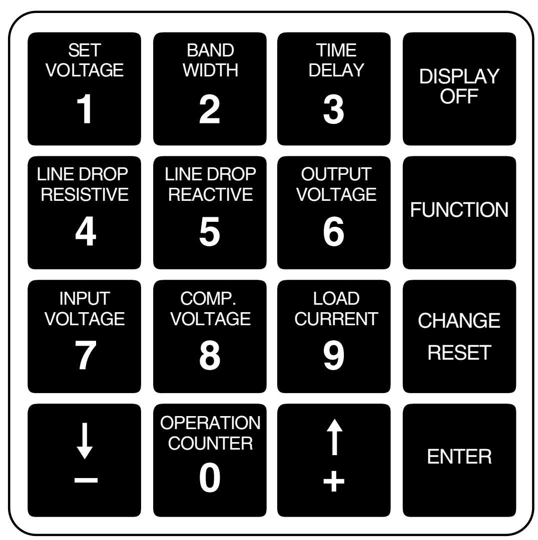


Figure 2-2.
Keypad

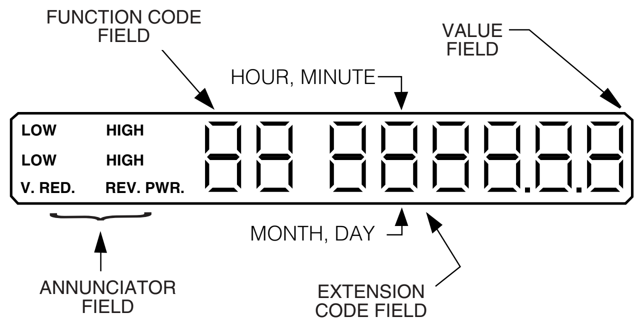


Figure 2-3.
Display fields

Control Operation

In the automatic mode of operation, the power switch will be set on internal, and the control switch will be placed on auto. The regulator is assumed energized from the primary circuit. If the sequential mode of operation is selected (the standard mode), the control response is as follows:

1. As the primary voltage moves to a level which represents an out-of-band condition, the sensing voltage will correspondingly reflect the same results on the 120 V base. Assuming the voltage dropped low, a lower than nominal signal will appear at the printed circuit board input, terminals P_5-4 to P_5-3.
2. The signal is transformed and converted into a digital format for use by the microprocessor.
3. The microprocessor, recognizing the voltage condition as low and out-of-band, issues an output which activates the LOW band indicator in the display, and starts an internal timer which is equivalent to the time delay setting.
4. During the time-out period, the voltage is continually sensed and sampled. Should the voltage momentarily move into band, the low band indicator is deactivated and the timer is reset.
5. At the end of the time delay period, the microprocessor issues an output which causes the RAISE relay coil to be energized.
6. The tap changer motor begins to turn as a result of the relay closure, and a cam on the tap changer closes the RAISE holding switch. This now provides an alternate source for the motor current, which passes through the input terminals P_4-9 and P_4-11 on the circuit board.
7. The microprocessor now recognizes that current is flowing in the holding switch circuit; the operations counter and tap position indication are incremented, and the RAISE relay is de-energized, thus opening its contacts.
8. As a result of the relay contacts opening, the motor current is now carried solely by the holding switch circuit. When the motor rotation is complete, the holding switch opens as a result of the cam action, and the motor stops.
9. The microprocessor recognizes that the tap change is now complete by detecting that motor current is no longer flowing through input terminals P_4-9 and P_4-11. A 2-second pause then occurs, allowing the sensing voltage to stabilize from the motor operation.
10. At the end of this pause, if the voltage is still out-of-band, another output is issued to close the RAISE relay, thus starting another tap change sequence (step 6). If the voltage is in-band, the LOW band indicator is turned off, and the time delay timer is reset. At all times, the microprocessor is sampling the sensing voltage for a change of conditions.

This sequence is altered slightly if the voltage averaging or time integrating mode of operation is selected. These characteristics are described in Control Operating Modes, starting on page 2-8.

Manual Operation

In the manual mode of operation, the power switch can be set on either internal or external and the control switch will be placed on manual. If the external position is chosen, an external source must be applied through the terminals on the front panel. This should be a nominal 120 V ac source (or other ac voltage as indicated by a decal) and should not be a direct current (dc) to alternating current (ac) inverter.

Operation of the momentary toggle raise-lower switch applies power through the position indicator limit switch contacts directly to the tap changer motor. As the tap changer motor cam rotates, the holding switch is closed, as described in the preceding section, step 6. This holding switch current is sensed by the circuit board, and the operations counter and tap position indicator are appropriately incremented (Function Code 0).

Tap changes will continue to occur as long as the raise-lower switch is closed and the ADD-AMP limit switch is not opened.

System Protection

All control inputs (15) are protected with metal oxide varistors (MOVs) and capacitors to prevent damage from line surges and high-frequency transients. This protection concept has proven very effective in the surge tests conducted by Cooper Power Systems. Provisions have also been made in the design to further enhance the control operation under adverse conditions. Orderly operation is ensured by MERTOS4, an operating system developed by Cooper Power Systems for microprocessor-based systems. There are four error detection firmware activities, overseen by MERTOS4, which are an inherent part of the normal operation:

1. The microprocessor architecture includes a COP (Computer Operating Properly) watchdog system to protect against firmware failures. A watchdog reset sequence is executed on a periodic basis so that the watchdog timer is never allowed to time out. Should the firmware malfunction, the reset sequence will not be generated, and the COP will time out, causing the system to enter a diagnostic routine.
2. MERTOS4 continually polls the various firmware tasks to ensure that they are performing correctly. If an abnormality is encountered, MERTOS4 will cause the system to enter a diagnostic routine.
3. Throughout the unused memory space, commands are embedded which generate a system reset if executed. Should an event occur which causes the processor to run errantly into unused memory space, the system will immediately be directed to a diagnostic routine.
4. Settings programmed into the control are stored in non-volatile memory in triplicate. A voting scheme is used as each parameter is accessed. If one of the three values does not match, the "different" value will be corrected to agree with the other two. This will also be counted as an EEPROM correction and the "Number of EEPROM Corrections" (Function Code 93) will be increased by 1.

   If all three values are different, a "default" value (one that is chosen as a representative value programmed into ROM), will be used for that particular parameter. If a setting parameter defaults, the "Number of Defaults" (Function Code 90) will be increased by 1. Additionally, when interrogated, the parameter(s) that defaulted will display a "d" preceding the value to indicate it is a default. The control will continue to operate using the default value(s).

Three parameters cannot default to a predetermined value because no logical choice is possible. The three parameters, regulator configuration (Function Code 41), system line voltage (Function Code 43), and overall P.T. ratio (Function Code 44) will revert to an invalid status and will display dashes preceded by a "d". Anything dependent upon these values will cease to function, and Function 95 will display a "6" to represent invalid critical parameters.

Diagnostics

There are three events which force the control into the self-diagnostic routines: 1) The power is first turned on; 2) operator entry of the self-test mode (Function Code 91); or 3) MERTOS4 detects a firmware problem. Once the diagnostic routines are entered, the first action taken by the control is to light all segments of the LCD display for approximately six seconds. This provides the operator an opportunity to observe the display for defective segments. Activities are performed as follows:

1. Non-volatile memory is checked to ensure all locations can be written to and erased;
2. The frequency detection circuitry is checked to verify a signal frequency between 45 and 65 Hz is being sampled;
3. The interrupt line to the processor is checked to verify that it is functional;
4. The multiplexor and analog-to-digital converter are checked to verify operation;
5. Critical parameters are checked to ensure validity;
6. The input/differential voltage channel is checked for the presence of a signal;
7. The output voltage channel is checked for the presence of a signal.

The duration of this test sequence is approximately three seconds. At completion, the display will indicate PASS or FAIL, depending upon the test results. The PASS message will remain in the display until the operator makes an entry through the keypad, or 30 minutes if no keypad entry is made. After 30 minutes, the display will automatically be turned off. The PASS message will be preceded by dashes (----) if the internal calendar/clock requires resetting. If, after 30 minutes, no keys have been pressed, the display will be formatted showing four dashes (----) only if the calendar/clock requires resetting. The clock will maintain timekeeping for 24 hours after loss of ac power to control. The backup power source requires 65 hours operation on ac power to become fully charged.

"Soft" failures are those listed under Function Code 95, System Status Code. Keypad entry is allowed, but automatic operation is inhibited for the following System Status Codes: 3, 4, 5, 6 and 8. Automatic operation is resumed as soon as the problem condition is removed. If status code is 10, see tap position indication, page 4-3.

For a "hard" failure, such as a RAM malfunction, the control will not operate. For hard failures the FAIL message remains in the display for approximately 15 minutes, then the diagnostic routines are executed again. The control will attempt to overcome the problem

TABLE 2-2
Security Codes

Security Level	Accessible at Function Code	Factory Programmed Code	User Definable Range	Functions Available at the Active Code
0	No Code Required	No Code Required	No Code Required	Read all parameters except security (Function Codes 96, 97, & 98).
1	96	1234	1-9999	Read all parameters as described above, and reset all demand metering and tap position maximum and minimum values and date/times.
2	97	12121	10000-19999	Read all parameters as described above, reset all demand meter and tap position maximum and minimum values and date/times, and change any operational or setup parameter.
3	98	32123	20000-32766	Read, reset or change any parameter.

that disabled it by going through this process continually until it receives operator attention. Keypad entry is denied during a hard failure.

NOTE: The word ERROR on the LCD indicates a key entry error, not a diagnostic failure. See Table 9-2, page 9-2 for a listing of the error codes.

Security System

The security (password) system implemented on the control is structured into four (4) levels. This permits selective access to the various parameters as dictated by the active security level. Most Function Codes may be read (accessed) at level 0, the base (unsecured) level. The security level required to change or reset each parameter is listed in Table 3-1, page 3-1. The security access codes for levels 1, 2 and 3 have been programmed into the control at the factory. These codes may be changed by the user according to Table 2-2. Access into the system is accomplished by entering the appropriate security code at Function Code 99.

The user has the option of overriding (inhibiting) one or more levels of security by choosing the appropriate Security Override Code at Function Code 92. Choices at Function 92 are 0 = standard security mode (no override); 1 = override level 1; 2 = override levels 2 and 1, and 3 = override levels 3, 2 and 1.

The values of the three security codes, Function Codes 96, 97 and 98, may be read only at level 3. If the level 3 code has been changed and forgotten, it may be retrieved with the McGraw-Edison Data Reader or with a personal computer using the Cooper Control Interface (CCI) CL-4/CL-5 Interface program.

Working with the Control

Function Codes

All of the parameters of the control — settings, metering values, etc., have been assigned a number. This number is called the Function Code of the parameter. To read the value of a parameter — that is, to display the parameter on the LCD — the operator accesses the appropriate Function Code. The value appears on the LCD, right-justified, with decimal point shown as necessary. See Table 3-1, page 3-1 for a list of the Function Codes grouped by subject.

Accessing Function Codes

All parameters, except for the Profiler data, can be read at the LCD by accessing its Function Code by one of the following methods:

One-touch Method

Access Function Codes 0-9 directly by pressing keys 0-9. The parameter printed on these keys is the same as the Function Code number. EXAMPLE: Function Code 1 = Set Voltage. Via the one-touch method, the operator may quickly read the Operations Counter (0), the five basic control settings (1-5), and the four most important instantaneous metering values (6-9).

Scroll Method

Use the scrolls keys — the upward- and downward-pointing arrows — to scroll up or down through the Functions Codes. In addition to the main Function Codes, there are Function Code Extensions. For instance, the extensions of Function Code 18, are 3, 5, 7, 9, 11 and 13. When Function Code 18 is accessed the Total Harmonic Distortion (THD) is displayed. When one scrolls up from THD, the extension number 3 is displayed just to the right of the Function Code 18, denoting that the value displayed to the far right is the 3rd harmonic. Function code extensions may only be accessed by scrolling.

Function Key Method

One may scroll to Function Codes numbered higher than 9, but a more convenient method is to do the following: Press the FUNCTION key, key in the Function Code number, and press the ENTER key. EXAMPLE: To access Function Code 18: Press FUNCTION, 1, 8, ENTER. The Function Code and its value will be displayed.

For security, certain parameters may only be accessed by the function key method. They are as follows:

- 38 - Master Metering & Tap Position Reset
- 47 - Voltage Calibration
- 48 - Current Calibration
- 89 - Software Version Number
- 91 - Self Test
- 99 - Enter Security Code

LCD Annunciator

The left third of the LCD is the Annunciator field. The operator is advised of the present status of operations by words which appear in this field. While Function Codes and their values are dropped from the LCD 30 minutes after the last keypad activity, the annunciator field is always active.

On the band indicator line, LOW or HIGH indicate an out-of-band condition. (See Control Operating Modes, page 2-8 for details.) On the voltage limiter line LOW or HIGH indicate that the voltage limiter is operating. (See page 4-8.) On the accessory active line V. RED. indicates that voltage reduction is active. (See page 4-9.) Also on that line, REV. PWR. indicates that the regulator is currently experiencing a reverse power condition, except when Function Code 56 is set to zero, Locked Forward. (See Reverse Power Flow Operation, page 4-3)

To display all of the segments of the LCD; if the control is off, turn on; or if the control is on, access Self Test, Function Code 91.

Basic Control Operations

Set Voltage

The set voltage is the voltage level to which the control will regulate, on the 120 V base. Since the control performs ratio correction in software, this value will normally be set for 120.0 V unless it is desired to operate at a voltage level higher or lower than nominal. For proper operation, the ratio correcting transformer located on the control back panel must also be set for the correct tap as shown by the regulator nameplate.

Bandwidth

The bandwidth is defined as that total voltage range, around the voltage setting, which the control will consider as a satisfied condition. As an example, a 2 V bandwidth on a 120 V setting means the operational timer will not activate until the voltage is below 119 V or above 121 V. When the voltage is in-band, the band edge indicators are off, and the timer (time delay) is off, so no relay closure can occur. Selection of a small bandwidth will cause more tap changes to occur, but will provide a more “tightly” regulated line. Conversely, a larger bandwidth results in fewer tap changes, but at the expense of better regulation. Selection of the bandwidth and time delay settings should be made recognizing the interdependence of these two parameters.

Time Delay

The time delay is the period of time (in seconds) that the control waits, from the time when the voltage first goes out-of-band, to the time when relay closure occurs. If a rapid response is required, a smaller setting should be used. If several devices on the same line are to be coordinated (cascaded), different time delay settings will be required to allow the proper devices to operate in the desired sequence. Proceeding from the source, each device should have a longer time delay than the preceding device. We recommend a minimum 15 second difference between regulators located on the same phase on the same feeder. The delay allows the upstream device to perform its operations prior to the downstream device reacting. The time delay setting of a voltage-minimizing activated capacitor control should be set the same as a regulator control. Alternate time delays are available with the voltage limiting feature, page 4-8.

Line Compensation, Resistance and Reactance Settings

Quite often regulators are installed some distance from the theoretical load center (the location at which the voltage is to be regulated). This means the load will not be served at the desired voltage level due to the losses (voltage drop) on the line between the regulator and the load. Furthermore, as the load increases, line losses also increase, causing the lowest voltage condition to occur during the time of heaviest loading.

To provide the regulator with the capability to regulate at a “projected” load center, manufacturers incorporate line drop compensation elements in the controls. This circuitry usually consists of a current source (C.T.) which produces a current proportional to the load current, and resistive (R) and reactive (X) elements through which this current flows. As the load increases, the resulting C.T. current flowing through these elements produces voltage drops which simulate the voltage drops on the primary line.

For the control, the input current is sampled and is used in a computer algorithm which calculates the respective resistive and reactive voltage drops based upon the line drop compensation values, programmed into the control at Function Codes 4 and 5 (or Function Codes 54 and 55 for reverse power flow conditions). This is by far a more accurate and economical means of developing the compensated voltage.

To select the proper R and X values, the user must know several factors about the line being regulated. See reference document R225-10-1 for assistance in this determination.

Regulator Configuration

The control is designed to operate on wye (star) - connected and delta-connected regulators. Regulators connected line-to-ground (wye) develop potentials and currents suitable for direct implementation in the control. Regulators connected line-to-line (delta) develop a potential-to-current phase shift which is dependent upon whether the regulator is defined as leading or lagging. The phase shift must be known by the control to permit accurate calculations for correct operation. This is accomplished by entering the proper code: 0 = Wye, 1 = Delta Lagging, 2 = Delta Leading.

See page 1-7 for an explanation of how to determine whether the regulator is leading or lagging.

Control Operating Modes

Cooper Power Systems is the only manufacturer that offers a selection of three modes in which the control responds to out-of-band conditions. This permits the user to select the mode that best fits the application. These modes and their corresponding codes are: 0 = Sequential, 1 = Time Integrating, 2 = Voltage Averaging.

Sequential

This is the standard mode of response, incorporated on all McGraw-Edison CL-5 Series regulator controls. When the load voltage goes out-of-band, the time delay circuit is activated. At the end of the time-out, a tap change is initiated. After each tap change, a 2-second pause occurs to permit the control to sample the voltage again. This sequence continues until the voltage is brought into band, at which time the timing circuit is reset. Any time the voltage goes in-band, the timer is reset.

Time Integrating

When the load voltage goes out-of-band, the time delay circuit is activated. At the end of the time-out, a tap change is initiated. After each tap change, a 2-second pause occurs to permit the control to sample the voltage again. If the voltage is still out-of-band, another tap change is performed. This sequence continues until the voltage is brought into band. When the voltage goes in-band, the timer is decremented at the rate of 1.1 seconds for every second elapsed, until it reaches zero.

Voltage Averaging

When the load voltage goes out-of-band, the time delay circuit is activated. During this time delay period, the microprocessor monitors and averages the instantaneous load voltage. It then computes the number of tap changes required to bring the average voltage back to the set voltage level. When the time delay period is complete, the computed number of tap changes are performed without any delay between them, up to a maximum of 5 consecutive tap changes, to avoid an accumulative error. The timer is not reset on voltage excursions in-band unless the voltage stays in-band for at least 10 continuous seconds. An error-averaging characteristic is inherent with the voltage averaging mode.

NOTE: To permit sufficient time for the microprocessor to average the voltage, the time delay period must be 30 seconds or longer. If the time delay is set for less than 30 seconds, the control ignores the setting and uses 30 seconds.

System Line Voltage

The control performs ratio correction in software, and, consequently, the primary voltage must be entered for the control to perform this calculation. This value is simply the nominal single phase voltage supplied across the L and SL terminals. Regulators shipped from the factory are set for the voltage indicated by the pin on the nameplate, and this value is programmed into the control. If the regulator is installed on any other system voltage, this system voltage must be entered for proper operation. See page 1-19, Voltage Circuits, for other changes required.

Potential Transformer Ratio

Since the control performs ratio correction in software, the P.T. ratio for the voltage sensing supply must be entered for the control to perform this calculation. The ratio to be programmed in the control is the OVERALL P.T. RATIO, as shown on the regulator nameplate for every applicable system voltage for the particular regulator. The P.T. ratio which corresponds to the regulator rated voltage is set by the factory. If the regulator is installed on any other system voltage, the corresponding P.T. ratio must also be entered for proper operation. This value includes the correction performed by the ratio correcting transformer (RCT) on the control back panel. The voltage from the RCT is normally corrected to 120 V. However, in the instance in which this voltage is other than 120 V, the control will define the particular input voltage as the 120 V base voltage, and 120 V will be displayed at Function Code 6. The voltage test terminals will continue to show the voltage as applied to the control from the RCT.

Current Transformer Primary Rating

The control is designed for 200 mA (full scale) as the rated C.T. current, and will meter to 400 mA (200% load) with no loss of accuracy. Ratio correction is performed by the software, and consequently, the C.T. primary rating must be entered. The C.T. primary rating is available on the regulator nameplate. EXAMPLE: If a C.T. ratio of 400/0.2 is indicated on the nameplate, then 400 must be entered at Function Code 45. (See Table 1-9, page 1-17 for standard ratings.)

Delta-connected (Line-to-line-connected) Regulators

When a regulator is connected line-to-line, the phase angle of the line current is 30° displaced from the voltage impressed across the regulator. By setting the Regulator Configuration, FC 41, correctly, the correct relationship between the voltage and current is established. (See page 1-7.) By setting the Regulator Configuration to the incorrect delta value (lagging instead of leading, or vice versa), the phase angle will be in error 60°. Below are considerations concerning delta-connected regulators:

1. The basic decision-making of the control when line drop compensation is not used is not affected by the phase angle, therefore operation will be correct even if FC 41 is set to either of the two incorrect values. This is true for forward and reverse operation.
2. If line drop compensation is used, the scaling of the R and X values and the positive/negative sign of these values is controlled by FC 41, therefore, it is important to correctly set FC 41.
3. The following metering parameters will be correct only if the Regulator Configuration is correctly set: power factor, kVA, kW, kvar, demand kVA, demand kW and demand kvar.
4. Note that the kVA, kW, kvar, demand kVA, demand kW and demand kvar use the line-to-line voltage, therefore they display the value at the regulator, not on one feeder. To determine the total three-phase value of any one of these parameters, each regulator value must be divided by 1.732 before adding the three together.

Control Function Codes

TABLE 3-1
CL-5 Series Regulator Control Function Codes

Function Code	Function	Security Level Change/Reset
FORWARD CONTROL SETTINGS		
0	Operation Counter (Q, R_, R¯, 1, 2, 3, 4, 5, 6)*	3*
1	Set Voltage	2
2	Bandwidth, volts	2
3	Time Delay, seconds	2
4	Line Compensation Resistance, volts	2
5	Line Compensation Reactance, volts	2
INSTANTANEOUS METERING		
6	Load Voltage, Secondary	
7	Source Voltage, Secondary	
8	Compensated Voltage, Secondary	
9	Load Current, Primary, amperes	
10	Load Voltage, Primary, kV	
11	Source Voltage, Primary, kV	
12	Tap Position & Percent Regulation (TP, %)	3
13	Power Factor	
14	kVA Load	
15	kW Load	
16	kvar Load	
17	Line Frequency	
18	Voltage Harmonics (THD, 3, 5, 7, 9, 11, 13), percent	
19	Current Harmonics (THD, 3, 5, 7, 9, 11, 13), percent	
FORWARD DEMAND METERING		
20	Load Voltage (H-D, T; L-D, T; P)	1
21	Compensated Voltage (H-D, T; L-D, T, P)	1
22	Load Current (H-D, T; L-D, T; P), amperes	1
23H	Power Factor @ Max kVA Demand	
23L	Power Factor @ Min kVA Demand	
24	kVA Load (H-D, T; L-D, T; P)	1
25	kW Load (H-D, T; L-D, T; P)	1
26	kvar Load (H-D, T; L-D, T; P)	1
27	Max Tap Pos & Max % Boost (TP-D, T; %)	1
28	Min Tap Pos & Max % Buck (TP-D, T; %)	1
29	Source Voltage **(H-D, T; L-D, T; P)	
REVERSE DEMAND METERING		
30	Load Voltage (H-D, T; L-D, T; P)	1
31	Compensated Voltage (H-D, T; L-D, T; P)	1
32	Load Current (H-D, T; L-D, T; P), amperes	1
33H	Power Factor @ Max kVA Demand	
33L	Power Factor @ Min kVA Demand	
34	kVA Load (H-D, T; L-D, T; P)	1
35	kW Load (H-D, T; L-D, T; P)	1
36	kvar Load (H-D, T; L-D, T; P)	1
37	Source Voltage**(H-D, T; L-D, T; P)	
MASTER METERING & TAP POSITION INDICATION RESET		
38	Reset	1
CONFIGURATION		
39	Source Voltage Calculation 0 = Off, 1 = On; 1 = Type A, 2 = Type B	2
40	Regulator Identification	2
41	Regulator Configuration 0 = Wye, 1 = Delta Lag, 2 = Delta Lead	2
42	Control Operating Modes 0 = Sequential, 1 = Time Integrating, 2 = Voltage Averaging	2
43	System Line Voltage, volts	2
44	Overall P.T. Ratio	2
45	C.T. Primary Rating, amps	2

Function Code	Function	Security Level Change/Reset
46	Demand Time Interval, minutes	2
49	Tap Changer Selection 0 = Quik Drive, 1 = Spring/Direct Drive	
CALIBRATION		
47	Voltage Calibration, volts	3
48	Current Calibration, amps	3
CALENDAR/CLOCK		
50	Date & Time Set (D, T, 1, 2, 3, 4, 5, 6) 1 = Year, 2 = Month, 3 = Day, 4 = Hour, 5 = Minute, 6 = Second	3
REVERSE CONTROL SETTINGS		
51	Set Voltage, volts	2
52	Bandwidth, volts	2
53	Time Delay, seconds	2
54	Line Compensation, Resistance, volts	2
55	Line Compensation, Reactance, volts	2
56	Reverse Sensing Mode 0 = Locked Forward, 1 = Locked Reverse 2 = Reverse Idle, 3 = Bi-Directional 4 = Neutral Idle, 5 = Co-Generation 6 = Reactive Bi-directional	2
57	Reverse Threshold %	2
COMMUNICATIONS		
60	Channel 1 (Data Port) Baud Rate	2
61	Control Communication Protocol XX.03 = Data 2179	
62	Channel 1 (Data Port) Status	
63	Channel 2 (Comm Port) Status	
64	Control Communications Address	2
65	Channel 2 (Comm Port) Baud Rate	2
66	Comm Port Handshake Mode	2
67	Comm Port Resynch Time Chars.	2
68	Comm Port Transmit Enable Delay (On, Off)	2
69	Blocking Status 0 = Normal, 1 = Blocked	2
VOLTAGE REDUCTION		
70	Voltage Reduction Mode 0 = Off, 1=Local/Digital Remote, 2 = Analog Remote (Latching), 3 = Pulse 10 = Off, 11 = Local/Digital Remote, 12 = Analog Remote (Latching), 13 = Pulse (Utilizing 10-13 activates tap to neutral)**	2
71	% Voltage Reduction In Effect (Read Only)	
72	Local Reduction %	2
73	Remote #1 %	2
74	Remote #2 %	2
75	Remote #3 %	2
76	# of Pulse Reduction Steps	2
77	% of Voltage Reduction Per Pulse Step	2
79	Soft ADD-AMP limits** 0 = Off, 1 = On; High limit; Low limit;	2
VOLTAGE LIMITER		
80	Voltage Limiting Mode 0 = Off, 1 = High Limit Only 2 = High and Low Limits	2
81	High Voltage Limit, volts	2
82	Low Voltage Limit, volts	2

Notes:
H-D, T = Highest (maximum) value since last reset, date & time
L-D, T = Lowest (minimum) value since last reset, date & time
P = Present value
THD = Total Harmonic Distortion
TPI = Tap position indication

Q = Quantity of operations since last change
R_ = Date of last counter change
R¯ = Time of last counter change
* Change/Reset and Sub-function codes only on CL-5E control
** CL-5E only

See next page for more function codes

Function Code	Function	Security Level Change/Reset
	METERING PROFILE RECORDER	
85	Profile Period (5, 10, 15, 30, 60, 90, 120 min.)** 1 = Parameter 1, 2 = Parameter 2, 3 = Parameter 3, 4 = Parameter 4, 5 = Data Retrieval Mode (0 = Off, 1 = On)	1
	WATCHDOG DIAGNOSTICS	
89	Firmware Version #	
90	Number of Defaults	
91	Self Test	
93	Number of EEPROM Corrections	3
94	Number of Resets	3
95	System Status Code (Read Only) 0 All Systems Good 1 EEPROM Write Failure 2 EEPROM Erase Failure 3 Frequency Detection Failure 4 No Sampling Interrupt-Failure 5 Analog-To-Digital Converter-Failure 6 Invalid Critical Parameters-Failure 7 No Input Voltage Detected-Warning 8 No Output Voltage Detected-Failure 9 No Input & Output V Detected-Failure 10 TPT No Neutral Sync Signal-Warning	
	SECURITY ACCESS	
92	Security Override (1 = Override 1, etc.)	3
96	Level 1 Security Code	3
97	Level 2 Security Code	3
98	Level 3 Security Code	3
99	ENTER SECURITY CODE	

** CL-5E control only.

TABLE 3-2
Function Codes

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level To Read	Security Level To Change	Security Level To Reset	Default Value	Key Entry Limit Low	Key Entry Limit High
00	—	Operation Counter	—	0	NA	NA	NA	NA	NA
	• The operation counter is activated by detecting tap changer motor operation which is determined by sensing current flow in the holding switch circuit. • The operations count is written into non-volatile memory after every ten (10) counts. • In the event of a power outage, the count will round back to the nearest ten (10), and then add five (5) to obtain the restored count when power recovers. EXAMPLE: Count 218; After Power Loss/Recovery = 215								
00*	Q,R_,R⁻,1 2, 3, 4, 5 ,6	Operation Counter	—	0	3	3	NA	NA	NA
	• The operation counter is activated by detecting tap changer motor operation which is determined by sensing current flow in the holding switch circuit. • The main operations count is written into non-volatile memory after every ten (10) counts. The subfunction counts are written to non-volatile memory hourly, or daily, as specified below. • In the event of a power outage, the main operations count will round back to the nearest ten (10), and then add five (5) to obtain the restored count when the power recovers. EXAMPLE: Count 218; After Power Loss/Recovery = 215. Applicable subfunction codes (1, 2, & 3) shall reset to zero in the event of a power outage. • Q, the quantity of operations since last change, is displayed upon entering this function code. Scroll (up or down) to R_, to obtain date, R⁻ for time of the last counter change. This counter may be set to a specific value. • 1-6 are subfunctions of function code 00. They are all resettable. They are defined as follows: • 1 = Operations in the last 24 hours (updated hourly) • 2 = Operations in the last 30 days (updated daily) • 3 = Operations since the beginning of current month (updated daily, and reset if clock's month is changed.) • 4 = Operations last calendar month (if reset, this field will remain zero until the first of the next month.) • 5 = Operations since January 1st of current year (updated daily, and reset if clock's year is changed.) • 6 = Operations in last calendar year (if reset, this field will remain zero until the first of the next year.)								
01	—	Set Voltage (Forward)	V	0	2	NA	120.0	100.0	135.0
	• The set voltage is the voltage level to which the control will regulate, on the 120 V base, during forward power flow.								
02	—	Bandwidth (Forward)	V	0	2	NA	2.0	1.0	6.0
	• The bandwidth is defined as the total voltage range, around the set voltage, which the control will consider as a satisfied (in-band) condition, during forward power flow. EXAMPLE: A bandwidth of 2.0 V and a set voltage of 120 V will establish a low limit of 119.0 V and a high limit of 121.0 V.								
03	—	Time Delay (Forward)	sec.	0	2	NA	30	5	180
	• The time delay is the period of time that the control waits, from when the voltage first goes out-of-band to when a tap change is initiated, during forward power flow. • See Function Code 42, Control Operating Mode.								

* CL-5E control only.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
04	—	Line Compensation, Resistance (Forward)	V	0	2	NA	0.0	–96.0	96.0
	• The resistive line drop compensation value is used to model the resistive line voltage drop between the regulator and the theoretical load center. • The control uses this parameter, in conjunction with the regulator configuration (Function Code 41) and the load current, to calculate and regulate to the compensated voltage (displayed at Function Code 8) during forward power flow.								
05	—	Line Compensation, Reactance (Forward)	V	0	2	NA	0.0	–96.0	96.0
	• The reactive line drop compensation value is used to model the reactive line voltage drop between the regulator and the theoretical load center. • The control uses this parameter, in conjunction with the regulator configuration (Function Code 41) and the load current, to calculate and regulate to the compensated voltage (displayed at Function Code 8) during forward power flow.								
06	—	Load Voltage, Secondary	V	0	NA	NA	NA	NA	NA
	• This is the fundamental RMS voltage, referred to the secondary, which appears at the output (load) terminals of the regulator. • Since ratio correction is performed by the firmware, this parameter is scaled according to the inputs at Function Code 43 (System Line Voltage) and Function Code 44 (overall PT Ratio).								
07	—	Source Voltage, Secondary	V	0	NA	NA	NA	NA	NA
	• This is the fundamental RMS voltage, referred to the secondary, which appears at the input (source) terminals of the regulator. • Since ratio correction is performed by the firmware, this parameter is scaled according to the inputs at Function Code 43 (System Line Voltage) and Function Code 44 (overall PT Ratio). • The control requires source voltage from a differential or source potential transformer or from the source voltage calculator to obtain this parameter. Lack of this voltage will result in the parameter displaying dashes. Refer to page 4-1.								
08	—	Compensated Voltage, Secondary	V	0	NA	NA	NA	NA	NA
	• This is the calculated voltage at the load center, referred to the secondary. • This is based upon the resistive compensation setting (Function Codes 4 or 54), reactive compensation setting (Function Codes 5 or 55), and the load current. • This is the voltage that the regulator is regulating during either forward or reverse power flow.								
09	—	Load Current, Primary	A	0	NA	NA	NA	NA	NA
	• This is the fundamental RMS current flowing in the primary circuit. • This parameter is scaled according to the CT primary rating which is entered at Function Code 45.								
10	—	Load Voltage, Primary kV	kV	0	NA	NA	NA	NA	NA
	• This is the fundamental RMS voltage, referred to the primary, which appears at the output (load) terminals of the regulator. • Since ratio correction is performed by the firmware, this parameter is scaled according to the inputs at Function Code 43 (System Line Voltage) and Function Code 44 (overall PT ratio).								
11	—	Source Voltage, Primary kV	kV	0	NA	NA	NA	NA	NA
	• This is the fundamental RMS voltage, referred to the primary, which appears at the input (source) terminals of the regulator. • Since ratio correction is performed by the firmware, this parameter is scaled according to the inputs at Function Code 43 (System Line Voltage) and Function Code 44 (overall PT ratio). • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in the parameter displaying dashes. Refer to page 4-1.								
12	P	Tap Position Indication	Tap	0	3	NA	NA	–16	16
	• This is the present position of the tap changer. • The tap position indication is reset when in the neutral position, as indicated by the neutral light circuit. Tap positions are displayed from – 16 to 16 corresponding to 16 Lower (regulator bucking) to 16 Raise (regulator boosting), respectively. • Function Code 12P may be changed via the keypad by accessing security level 3. • This is the actual percentage that the regulator is actively boosting (raising) or bucking (lowering) the input (source) voltage. • This parameter is displayed after pressing the scroll-up key after entering function Code 12. • This is calculated as follows: Percent Regulation = ([Output/Input] -1) x 100								

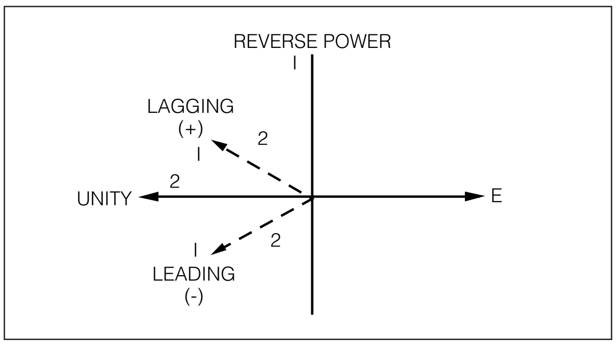
<table>
<tr><th rowspan="2">Function Code</th><th rowspan="2">Function Code Extension</th><th rowspan="2">Parameter</th><th rowspan="2">Unit of Measure</th><th colspan="3">Security Level</th><th rowspan="2">Default Value</th><th colspan="2">Key Entry Limit</th></tr>
<tr><th>To Read</th><th>To Change</th><th>To Reset</th><th>Low</th><th>High</th></tr>
<tr><td>12 (Cont.)</td><td>—</td><td>Percent Regulation</td><td>%</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• When the regulator output voltage is greater than the input voltage (regulator boosting), the sign is implied (+). When the output voltage is lower than the input voltage.
• The control requires an input voltage to obtain this parameter.
Lack of this voltage will result in the parameter displaying dashes. Refer to page 4-1.</td></tr>
<tr><td>13</td><td>—</td><td>Power Factor</td><td>—</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the power factor of the primary circuit, as represented by the phase difference between the line current and voltage.
• Lagging current, or inductive loads, are designated by an implied (+) sign, and leading current, or capacitive loads, are designated by a (-) sign


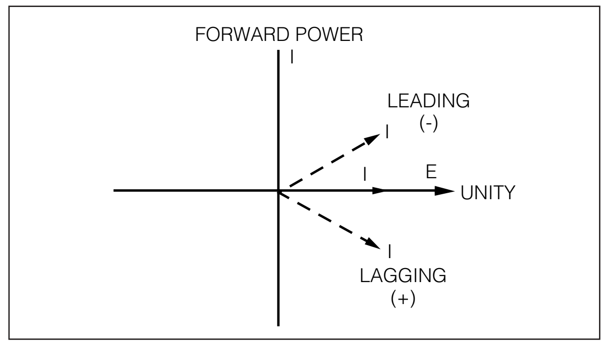
Figure 3-1.
Reverse power vector diagram.


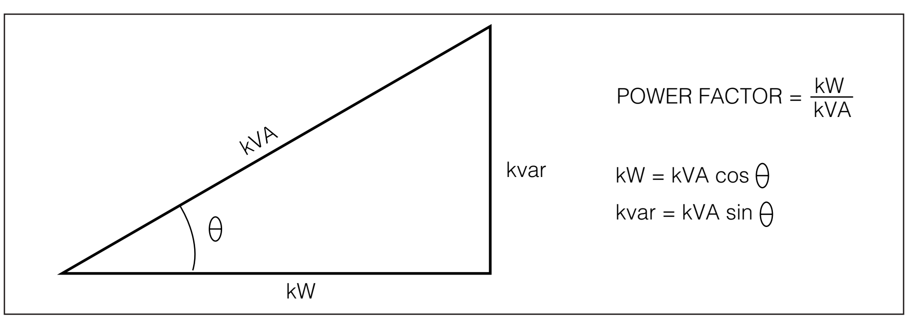
Figure 3-2.
Forward power vector diagram.</td></tr>
<tr><td>14</td><td>—</td><td>kVA Load</td><td>kVA</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the total kilovolt-amperes drawn by the load, as calculated by the product of the primary kV (Function Code 10) times the primary load current (Function Code 9). See Figure 3-3.</td></tr>
<tr><td>15</td><td>—</td><td>kW Load</td><td>kW</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the total kilowatts (true power) consumed by the load.
• This is calculated by the product of the power factor (Function Code 13) times the kVA load (Function Code 14). See Figure 3-3.</td></tr>
<tr><td>16</td><td>—</td><td>kvar Load</td><td>kvar</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the total kilovolt-amperes reactive (reactive power) drawn by the load.
• It is this reactive power which adds to losses on the line, yet does not do any work. See Figure 3-3.


Figure 3-3.
Power Triangle</td></tr>
</table>

<table>
<tr><th rowspan="2">Function Code</th><th rowspan="2">Function Code Extension</th><th rowspan="2">Parameter</th><th rowspan="2">Unit of Measure</th><th colspan="3">Security Level</th><th rowspan="2">Default Value</th><th colspan="2">Key Entry Limit</th></tr>
<tr><th>To Read</th><th>To Change</th><th>To Reset</th><th>Low</th><th>High</th></tr>
<tr><td>17</td><td>—</td><td>Line Frequency</td><td>Hz</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the frequency of the power line, as measured by the control.
• The control is capable of operating on systems from 45 to 65 Hz with no loss of accuracy in its measurements.</td></tr>
<tr><td rowspan="2">18</td><td>—</td><td>Voltage THD</td><td>%</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>3, 5, 7, 9, 11, 13</td><td>Voltage Harmonics</td><td>%</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• The total harmonic distortion (THD) is displayed after entering Function Code 18. The harmonic contents at the 3rd, 5th, 7th, 9th, 11th and 13th harmonic frequencies are displayed by pressing the scroll-up key. “3, 5, 7, 9, 11, and 13” are displayed as a Function Code extension to identify the individual harmonic values.
• The total harmonic distortion is computed as the RSS (square root of the sum of the squares) of the six individual odd harmonic values.
• The value displayed is a percentage of the fundamental RMS voltage. Example: 120.0 V of 60 Hz fundamental (power line frequency), with a reading of 0.5 at the 7th harmonic (420 Hz), is 0.6 V RMS.</td></tr>
<tr><td rowspan="2">19</td><td>—</td><td>Current THD</td><td>%</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>3, 5, 7, 9, 11, 13</td><td>Current Harmonics</td><td>%</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• The total harmonic distortion (THD) is displayed after entering Function Code 19. The harmonic contents at the 3rd, 5th, 7th, 9th, 11th and 13th harmonic frequencies are displayed by pressing the scroll-up key. “3, 5, 7, 9, 11, and 13” are displayed as a Function Code extension to identify the individual harmonic values.
• The total harmonic distortion is computed as the RSS (square root of the sum of the squares) of the six individual odd harmonic values.
• This is displayed as a percentage of the fundamental RMS voltage. Example: 200 A of 60 Hz fundamental (power line frequency), with a reading of 1.9 at the 5th harmonic (300 Hz), is 3.8 A RMS.</td></tr>
<tr><td>20</td><td>H, H_, H¯,
L, L_, L¯, P</td><td>Load Voltage Demand (Forward)</td><td>V</td><td>0</td><td>NA</td><td>0</td><td>Reset**</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the secondary output voltage of the regulator, as a demand value, according to the demand time interval at Function Code 46.
• H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value.</td></tr>
<tr><td>21</td><td>H, H_, H¯,
L, L_, L¯, P</td><td>Compensated Voltage Demand (Forward)</td><td>V</td><td>0</td><td>NA</td><td>1</td><td>Reset**</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the calculated secondary voltage at the load center, as a demand value, according to the demand time interval at Function Code 46.
• The line compensation settings for resistance and reactance (Function Codes 4 and 5) are used in this calculation.
• H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_, to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value.</td></tr>
<tr><td>22</td><td>H, H_, H¯,
L, L_, L¯, P</td><td>Load Current Demand (Forward)</td><td>A</td><td>0</td><td>NA</td><td>1</td><td>Reset**</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the load current, as a demand value, according to the demand time interval at Function Code 46.
• H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value.</td></tr>
<tr><td>23</td><td>H</td><td>Power Factor at Maximum kVA Demand (Forward)</td><td>—</td><td>0</td><td>NA</td><td>[A]</td><td>“----” (invalid)</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is the instantaneous power factor of the load at the first time when the maximum kVA demand occurred, since last reset.
• (A) This parameter is associated with the maximum kVA demand and, therefore, cannot be reset independent of that parameter.</td></tr>
</table>

* CL-5E Control only.

**A default value of “Reset” indicates that the parameter is reset to the present value.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
23	L	Power Factor at Minimum kVA Demand (Forward)	—	0	NA	[A]	"----" (invalid)	NA	NA
	• This is the instantaneous power factor of the load at the first time when the minimum kVA demand occurred, since last reset. • The power factor at maximum kVA demand "H" is displayed when entering Function Code 23, scroll up to the power factor at minimum kVA demand "L" value. • (A) This parameter is associated with the minimum kVA demand and, therefore, cannot be reset independent of that parameter.								
24	H, H_, H¯, L, L_, L¯, P	kVA Load Demand (Forward)	kVA	0	NA	1	Reset**	NA	NA
	• This is the load kVA, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_, to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value.								
25	H, H_, H¯, L, L_, L¯, P	kW Load Demand (Forward)	kW	0	NA	1	Reset**	NA	NA
	• This is the load kW, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value.								
26	H, H_, H¯, L, L_, L¯, P	kvar Load Demand (Forward)	kvar	0	NA	1	Reset**	NA	NA
	• This is the load kvar, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value.								
27	H, H_, H¯	Maximum Tap Position	Tap	0	NA	1	Reset**	NA	NA
	• This is the highest tap position that the regulator has reached since last reset. • H, the highest position since last reset, is displayed after entering this Function Code. Scroll up to H_ for date, and H¯ for time the highest position occurred. • The maximum position and associated date and time can be reset via the reset key or via master reset. Function Code 38. This parameter is not reset by the draghand reset switch.								
	—	Maximum % Boost (Minimum % Buck)	%	0	NA	1	Reset**	NA	NA
	• This is the highest percentage that the regulator has raised the input voltage since last reset. • Scroll up from 27 H¯ to read this parameter. • This parameter is the upper draghand value for the present percent regulation, Function Code 12. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in the parameter displaying dashes. Refer to page 4-1.								
28	L, L_, L¯	Minimum Tap Position	Tap	0	NA	1	Reset**	NA	NA
	• This is the lowest tap position that the regulator has reached since last reset. • L, the lowest position since last reset, is displayed after entering this Function Code. Scroll up to L_, for date, and L¯ for time the lowest position occurred. • The minimum position and associated date and time can be reset via the reset key of via master reset, Function Code 38. This parameter is not reset by the draghand reset switch.								
	—	Maximum % Buck (Minimum % Boost)	%	0	NA	1	Reset**	NA	NA
	• This is the highest percentage that the regulator has lowered the input voltage since last reset. • Scroll up from 28 L¯ to read this parameter. • This parameter is the lower draghand value for the present percent regulation, Function Code 12. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in the parameter displaying dashes. Refer to page 4-1.								

* CL-5E control only.
**A default value of "Reset" indicates that the parameter is reset to the present value.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
29*	H, H_, H¯, L, L_, ,L¯, P	Source Voltage Demand (Forward)	V	0	NA	NA	NA	NA	NA
	• This is the primary input voltage of the regulator, as a demand value, according to the demand time interval at Function Code 46. • H, the maximum source voltage seen, is displayed after this function code is entered. Scroll up to H_ for date, and H¯ for time the maximum source voltage occurred. Continue scrolling up to see L, the lowest source voltage seen, followed by the L_ and L¯, the date and time of its occurrence. Continue to scroll up to P to see the present value.								
30	H, H_, H¯, L, L_, L¯, P	Load Voltage Demand (Reverse)	V	0	NA	1	Reset**	NA	NA
	• This is the secondary output voltage of the regulator during reverse power flow, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1.								
31	H, H_, H¯, L, L_, L¯, P	Compensated Voltage Demand (Reverse)	V	0	NA	1	Reset**	NA	NA
	• This is the calculated secondary voltage at the load center during reverse power flow, as a demand value, according to the demand time interval at Function Code 46. • The line compensation setting for resistance and reactance (Function Codes 54 and 55) are used in this calculation. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1.								
32	H, H_, H¯, L, L_, L¯, P	Load Current Demand (Reverse)	A	0	NA	1	Reset**	NA	NA
	• This is the load current during reverse power flow, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1.								
33	H	Power Factor at Maximum kVA Demand (Reverse)	—	0	NA	[A]	"----" (invalid)	NA	NA
	• This is the instantaneous power factor of the load at the first time the maximum kVA demand occurred during reverse power flow since last reset. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1. • (A) This parameter is associated with the maximum kVA demand and, therefore, cannot be reset independent of that parameter.								
33	L	Power Factor at Minimum kVA Demand (Reverse)	—	0	NA	[A]	"----" (invalid)	NA	NA
	• This is the instantaneous power factor of the load at the first time the minimum kVA demand occurred during reverse power flow since last reset. • The power factor at maximum kVA demand "H" is displayed after entering Function Code 33, scroll up to the power factor at minimum kVA demand "L" value. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1. • (A) This parameter is associated with the minimum kVA demand and, therefore, cannot be reset independent of that parameter.								

* CL-5E control only.
** A default value of "Reset" indicates that the parameter is reset to the present value.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
34	H, H_, H¯, L, L_, L¯, P	kVA Load Demand (Reverse)	kVA	0	NA	1	Reset**	NA	NA
	• This is the load kVA during reverse power flow, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1.								
35	H, H_, H¯, L, L_, L¯, P	kW Load Demand (Reverse)	kW	0	NA	1	Reset**	NA	NA
	• This is the load kW during reverse power flow, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1.								
36	H, H_, H¯, L, L_, L¯, P	kvar Load Demand (Reverse)	kvar	0	NA	1	Reset**	NA	NA
	• This is the load kvar during reverse power flow, as a demand value, according to the demand time interval at Function Code 46. • H, the highest value since last reset, is displayed after entering this Function Code. Scroll up to H_ to obtain date, and H¯ for time the maximum value occurred. Continue to scroll up to L, the lowest value since reset, L_ for date, and L¯ for time the lowest value occurred. Continue to scroll up to P for present value. • The control requires an input voltage from a differential or source potential transformer to obtain this parameter. Lack of this voltage will result in this parameter displaying dashes. Refer to page 4-1.								
37*	H, H_, H¯, L, L_, L¯, P	Source Voltage Demand (Reverse)	V	0	NA	NA	NA	NA	NA
	• This is the primary input voltage of the regulator during reverse power flow, as a demand value, according to the demand time interval at Function Code 46. • H, the maximum source voltage seen, is displayed after this function code is entered. Scroll up to H_ for date, and H¯ for time the maximum source voltage occurred. Continue scrolling up to see L, the lowest source voltage seen, followed by the L_ and L¯, the date and time of its occurrence. Continue to scroll up to P to see the present value.								
38	—	Master Demand Reset & Tap Position Indication Reset	—	NA	NA	1	NA	NA	NA
	• All demand metering and tap position maximum (H) and minimum (L) values will be reset to their corresponding present (P) values when this function code is accessed. Successful master reset is indicated by the word "done" appearing on the display. • All dates and times associated with demand metering and tap position maximum and minimum values will be reset to the present date and time. • If the present demand value or tap position is in an invalid state (dashes), the maximum and minimum values will also become invalid (displaying dashes). • Individual H and L values and their date/time may be reset to the present value by first accessing the appropriate H or L value, or its date or time, and then pressing the reset key. • Scrolling to this parameter is not allowed.								
39	1	Source Voltage Calculation (CL-5C and later only)	—	0	2	NA	0	0	1
	• The source side voltage is calculated based on tap position and the regulator type of A or B (for series transformer, use type A): 0 = source voltage calculator off 1 = source voltage calculator on • Subfunction 1 defines to the control, the regulator type, as defined by ANSI. Regulator type is defined on the nameplate. 1 = A 2 = B • The calculated method provides accuracy to ±1.5% maximum error. • When the calculated values are used, a small "c" is shown on the display following the function code. If the tap position becomes invalid, the calculated values become invalid and if the regulator uses the calculated values, it will idle until conditions are established to valid values for the decision process.								

* Available on CL-5E control when available.
**A default value of "Reset" indicates that the parameter is reset to the present value.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
40	—	Regulator Identification	—	0	2	NA	12345	1	32766
	• Provision is made for entry of a number to uniquely identify each control. • The serial number of the control (as shown on the decal on the back of the front panel) was entered at Function Code 40 at the factory. However, any other number within the limits defined above may be chosen instead. • This permits easy identification when data is collected via the Data Reader or other means.								
41	—	Regulator Configuration	—	0	2	NA	"----" (invalid)	0	2
	• The control is designed to operate on wye-connected or delta-connected three-phase systems. • Regulators connected line-to-ground (wye or star) develop potentials and currents suitable for direct implementation in the control. • Regulators connected line-to-line (delta) develop a potential-to-current phase shift which is dependent upon whether the regulator is defined as leading or lagging. This phase shift must be known by the control to permit accurate calculations for correct operation. This is accomplished by entering the proper code: 0 = Wye (or Star); 1 = Delta Lagging; or 2 = Delta Leading. • See Reference Bulletin R225-10-1 for a discussion of delta connections. See page 1-7 for use of the control to determine whether the regulator is leading or lagging.								
42	—	Control Operating Mode	—	0	2	2	0	0	2
	• The manner in which the control responds to out-of-band conditions is selectable by the user. The appropriate mode is selected by entering one of the corresponding codes: 0 = Sequential (Standard) 1 = Time Integrating 2 = Voltage Averaging • For detailed information, see Control Operating Modes, page 2-8.								
43	—	System Line Voltage	V	0	2	NA	"----" (invalid)	2400	36000
	• The control is designed to operate on primary system voltages from 2400 V to 36000 V. • Ratio correction is performed by the firmware, and consequently, the primary voltage must be entered for this calculation. EXAMPLES: A regulator installed on a 7200 V system (line-to-neutral) would have 7200 entered at Function Code 43. A regulator installed open or closed delta on an 11000 V system (line-to-line) would have 11000 entered at Function Code 43.								
44	—	Overall Potential Transformer Ratio	—	0	2	NA	"----" (invalid)	20.0	300.0
	• The control is designed to operate on primary system voltages from 2400 V to 36000 V. • Ratio correction is performed by the firmware, and consequently, the overall potential transformer (P.T.) ratio must be entered for this calculation. The overall P.T. ratio is available on the regulator nameplate, and is summarized in Tables 1-10 and 1-11 on page 1-20 and 1-21 for most regulator ratings. EXAMPLE: A 13800 V regulator, installed on a 7970 V system, would have 7970 entered at Function Code 43, and 63.7 entered at Function Code 44. The control will then define the 125.1 V (output from the back panel ratio correction transformer) as the 120-base voltage, and 120 V is displayed at Function Code 6.								
45	—	Current Transformer Primary Rating	A	0	2	NA	100	25	2000
	• The control is designed for 200 mA as the rated current transformer (C.T.) output current, and will meter to 400 mA (200% load) with no loss of accuracy. • Ratio correction is performed by the firmware, and consequently the C.T. primary rating must be entered. The C.T. primary rating is available on the regulator nameplate, and is summarized in Table 1-9 on page 1-17 for most regulator ratings. EXAMPLE: A 7620 V, 328 A regulator (250 kVA) would have a C.T. primary rating of 400 A, and therefore, 400 is entered at Function Code 45.								
46	—	Demand Time Interval	min.	0	2	NA	15.0	3.0	60.0
	• This is the time period during which the demand integral is performed for all demand readings, Function Codes 20 through 36. • Demand readings are useful because they represent the values which produce actual heating effects in electrical equipment, and they do not respond to the continuous fluctuations which occur on the line.								
47	—	Voltage Calibration	V	0	3	NA	[B]	110.0	130.0
	• The voltage which the control actually measures is displayed at Function Code 47. In the example given in Function Code 44 description, Function Code 47 would indicate 125.1 V when Function Code 6 indicated 120 V. • Calibration is performed by the factory, and should not be necessary in the field. • To calibrate, this value is compared to a reference voltmeter and, if different, is changed to display the correct value. • Scrolling to this parameter is not allowed. • See Control Calibration, page 6-4.								

[B] Representative calibration "factors" are programmed into ROM for use in the event the working memory experiences a default condition.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
48	—	Current Calibration	mA	0	3	NA	[B]	100.0	400.0
	• The current which the control actually measures, in milli-amps, is displayed at Function Code 48. • The control is designed for 200 mA as the rated C.T. output current, and will meter to 400 mA (200% load) with no loss of accuracy. • Calibration is performed by the factory and should not be necessary in the field. • To calibrate, this value is compared to a reference ammeter and, if different, is changed to display the correct value. • Scrolling to this parameter is not allowed. • See Control Calibration, page 6-4.								
49	—	Tap Changer Selection (CL-5D and Later)	NA	0	2	NA	As Manuf.	0	1
	• This function code identifies the tap changer type (See Chapter 5.) This function code is pre-set at the factory. Changing this function code changes the control's sampling rate. • 0 = Quik Drive 1 = Spring/Direct Drive								
50	[C]	Calendar/Clock	—	0	NA	NA	"----" (invalid)	—	—
	1, 2, 3, 4, 5, 6	Year, Month, Day, Hour,	—	0	3	NA	"----" (invalid)	—	—
	• [C] A segment bar after the Function Code 50 in the LCD moves from bottom of display indicating month.day to the top of LCD display to indicate hour.minute. • The date (month.day) is displayed after entering Function Code 50. The time (hour.minute) is displayed after pressing the scroll up key. These are read-only parameters. • Continued depressions of the scroll-up key display function extensions: 1 = year; 2 = month; 3 = day; 4 = hour; 5 = minute; 6 = seconds. These values may be changed if necessary. • If power is restored after internal backup power is exhausted, the Calendar/Clock starts at January 1, 1990; 00:00:00. • Refer to page 4-1.								
51	—	Set Voltage (Reverse)	V	0	2	NA	120.0	100.0	135.0
	• The set voltage is the voltage level to which the control will regulate, on the 120 V base, during reverse power flow. • See Reverse Power Operation, page 4-3.								
52	—	Bandwidth (Reverse)	V	0	2	NA	2.0	1.0	6.0
	• The bandwidth is defined as that total voltage range, around the set voltage, which the control will consider as a satisfied (in-band) condition, during reverse power flow. EXAMPLE: A bandwidth of 3 V and a set voltage of 120 V will establish a low limit of 118.5 V and a high limit of 121.5 V. • See Reverse Power Operation, page 4-3.								
53	—	Time Delay (Reverse)	sec.	0	2	NA	30	5	180
	• The time delay is the period of time (in seconds) that the control waits, from the time when the voltage first goes out-of-band, to the time when the relay closure occurs, during reverse power flow. • See Reverse Power Operation, page 4-3.								
54	—	Line Compensation, Resistance (Reverse)	V	0	2	NA	0.0	–96.0	96.0
	• The resistive line drop compensation value is used to model the resistive line losses between the regulator and the theoretical load center. • The control uses this parameter, in conjunction with the regular configuration (Function Code 41) and the load current flow, to calculate the compensated voltage (displayed at Function Code 8) during the reverse power flow. • See Reverse Power Operation, page 4-3.								
55	—	Line Compensation, Reactance (Reverse)	V	0	2	NA	0.0	–96.0	96.0
	• The reactive line drop compensation value is used to model the reactive line losses between the regulator and the theoretical load center. • The control uses this parameter, in conjunction with the regular configuration (Function Code 41) and the load current flow, to calculate the compensated voltage (displayed at Function Code 8) during the reverse power flow. • See Reverse Power Operation, page 4-3.								

[B] Representative calibration "factors" are programmed into ROM for use in the event the working memory experiences a default condition.

<table>
<tr><th rowspan="2">Function Code</th><th rowspan="2">Function Code Extension</th><th rowspan="2">Parameter</th><th rowspan="2">Unit of Measure</th><th colspan="3">Security Level</th><th rowspan="2">Default Value</th><th colspan="2">Key Entry Limit</th></tr>
<tr><th>To Read</th><th>To Change</th><th>To Reset</th><th>Low</th><th>High</th></tr>
<tr><td>56</td><td>—</td><td>Reverse Sensing Mode</td><td>—</td><td>0</td><td>2</td><td>NA</td><td>0</td><td>0</td><td>6</td></tr>
<tr><td></td><td colspan="9">• The control offers six different response characteristics for reverse power flow operation, selectable by the user. The six modes, and their corresponding codes are:
0 = Locked Forward
1 = Locked Reverse [D]
2 = Reverse Idle
3 = Bi-directional [D]
4 = Neutral Idle [D]
5 = Co-generation [D]
6 = Reactive bi-directional [D]
• See Reverse Power Operation, page 4-3.</td></tr>
<tr><td>57</td><td>—</td><td>Reverse Threshold</td><td>%</td><td>0</td><td>2</td><td>NA</td><td>2</td><td>1</td><td>5</td></tr>
<tr><td></td><td colspan="9">• This is the current threshold at which the control switches operation, either from forward to reverse, or reverse to forward.
• This threshold is programmable as a percentage of the rated C.T. primary rating. EXAMPLE: A 328 A regulator utilizing a C.T. with a 400 A primary rating, and with a 3% threshold value, would have a threshold of 12 A.
• The metering of the control switches on a fixed 1% threshold, completely independent from Function Code 57.
• See Reverse Power Operation, page 4-3.</td></tr>
<tr><td>60</td><td>—</td><td>Data Port (Channel #1) Baud Rate</td><td>—</td><td>0</td><td>2</td><td>NA</td><td>4</td><td>1</td><td>4</td></tr>
<tr><td></td><td colspan="9">• The control microprocessor has two communications channels, each with selectable baud rates.
• Channel #1 is dedicated to the 9-pin Data Port located on the control front panel. The available baud rates for Channel #1 are: 1 = 300 Baud; 2 = 1200 Baud; 3 = 2400 Baud; and 4 = 4800 Baud.
• To permit communications with the McGraw-Edison Data Reader (data gathering device), the Channel #1 baud rate has been factory set to 4800; i.e., Function Code 60 = 4.</td></tr>
<tr><td>61</td><td>—</td><td>Communications Protocol</td><td>—</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• Communications Channel #2 is dedicated to the real-time digital communications interface. Function 61 indicates the type of protocol installed and its revision. The readout is RR.PP (read only). RR is an internal revision number from 1-99. PP is the protocol: 03 = Cooper Power Systems DATA 2179.
• CL-5 Series Controls are supplied with DATA 2179 protocol installed.
• See Digital SCADA, page 4-11.</td></tr>
<tr><td>62</td><td>—</td><td>Data Port (Channel #1) Status</td><td>—</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• The control microprocessor monitors the communications channels and reports the status of communication channel #1 Data Port sessions at Function 62.
• This is for information only.
• Status codes are listed with Function Code 63.
• The control microprocessor monitors the communications channels and reports the status of channel #2 sessions at Function 63.</td></tr>
<tr><td>63</td><td>—</td><td>Communications Port (Channel #2) Status</td><td>—</td><td>0</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td></td><td colspan="9">• This is for information use only.
• Status codes for both Function Codes 62 and 63 are listed as follows:
0 = Valid message received
1 = Control in local mode
2 = Framing error in the received message
3 = Overrun error in the received message
4 = Noise error in the received message
5 = Parity error in the received message
6 = Check sum error in the received message
7 = Invalid point type requested
8 = Invalid command received
9 = Invalid point number specified
“----” = Channel inactive</td></tr>
</table>

[D] Source-side voltage is required for these modes to be active.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level To Read	Security Level To Change	Security Level To Reset	Default Value	Key Entry Limit Low	Key Entry Limit High
64	—	Control Communications Address (Protocol 2179)	—	0	2	NA	"----" (invalid)	0	2046

- Cooper Power Systems has developed advanced controls for various products utilizing common protocol communications.
- Each control on the system can be uniquely addressed by the SCADA RTU or other communications device.
- The control SCADA address is entered at Function 64 with a factory preset address of 5.
- For protocol DATA-2179, the device addresses and responses are as follows:
  0-2046 = Unique device address range. Controls with addresses in this range uniquely respond when the particular address is sent.
  2047 = Broadcast address. All controls on the system listen and change as commanded, with no response if a message is sent to address 2047.

Function Code	Function Code Extension	Parameter	Unit of Measure	To Read	To Change	To Reset	Default Value	Low	High
65	—	Communications Port (Channel #2) Baud Rate	—	0	2	NA	"----" (invalid)	1	5

- The user may select the baud rate to which the control system interfaces to the SCADA system. The available baud rates are: 1 = 300 Baud; 2 = 1200 Baud; 3 = 2400 Baud; 4 = 4800 Baud; 5 = 9600 Baud.
- The control is factory set for 4800 Baud.

Function Code	Function Code Extension	Parameter	Unit of Measure	To Read	To Change	To Reset	Default Value	Low	High
66	—	Communications Port Handshake Mode	—	0	2	NA	"----" (invalid)	0	2

- The user can select the appropriate method for control-to-SCADA message interaction (handshake mode).
- The transmit/receive handshaking mode allows adaptability to different types of communication system interfaces with the CL-5C control. When using mode 2, the handshake out signal is used as the transmit enable. The handshaking input signal is ignored.
- The available modes are:
  0 = No handshaking. This mode is used for direct communication between the control and a personal computer. It may also be used with an RTU for point-to-point communications.
  1 = Not applicable. For C.P.S. use only.
  2 = Handshaking is active. This mode is used where a transmit enable signal (push-to-talk) is required as part of the handshaking. Transmit enable is also required when the control is connected in a fiber-optic ring.
- See Function Code 68 for the programming of Transmit Enable Delay On and Transmit Enable Delay Off (transmit disable).

Function Code	Function Code Extension	Parameter	Unit of Measure	To Read	To Change	To Reset	Default Value	Low	High
67	—	Communications Port Number of Line Sync Characters	Char.	0	2	NA	"----" (invalid)	0	10

- Defines the period of time the receive must idle to assume the start of a request message. Dead-line sync is used to determine the start of the request message. When used on a ring-configured or broadcast communication system, the control "hears" messages for devices at other nodes on the received data line. By reading the address, the control determines if the message is intended for it and ignores the remaining bytes if it is not. A period of time during which the received data line is inactive, defines the end of the previous message. This inactive time is the dead-line sync period. The control is now synchronized so that the next byte received is considered the beginning of a new message.The value programmed is the equivalent number of characters that the receive line must remain inactive, to be considered the end of a message. The control determines the actual time delay internally, taking into account baud rate and the number of bits in the character.
  For example: Baud = 4800; Dead-line sync character = 5 characters
  Dead time = 5 characters x 10 bits/character* = 50 bits
  50 bits @ 4800 bits/second = 10.4 mS dead-line sync time
  *10 bits/character applies to protocol 2179, 8 data bits, 1 start bit, 1 stop bit.
- See Figures 3-4 and 3-5.

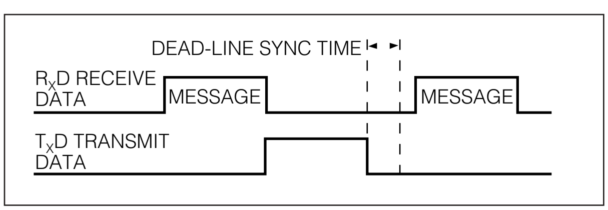


Figure 3-4.
Message received at CL-5 Series control; message is for the CL-5 Series control

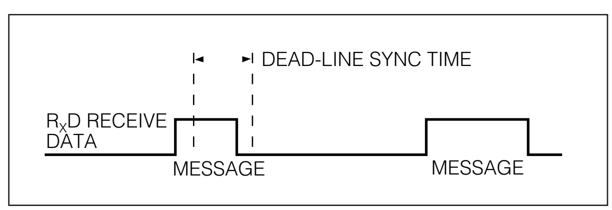


Figure 3-5.
Message received at CL-5 Series control; message is not for the CL-5 Series control

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level To Read	Security Level To Change	Security Level To Reset	Default Value	Key Entry Limit Low	Key Entry Limit High
68	1	Communications Port Transmit Enable Delay - On	msec.	0	2	NA	"----" (invalid)	0	425

- When the control is set for transmit control handshaking (Function Code 66 = 2), the user may require a delay to occur between the time when the transmit enable is enabled to when data is transmitted. As an example, if the transmit enable were used as a keying device for a transmitter or modem, a "warm-up" period may be necessary before data can be transmitted.
- The delay period can be entered at this function code extension and is normally set to 0 for the presently supported communications system. See Figure 3-6.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level To Read	Security Level To Change	Security Level To Reset	Default Value	Key Entry Limit Low	Key Entry Limit High
68	2	Communications Port Transmit Enable Delay - Off	msec.	0	2	NA	"----" (invalid)	0	250

- When the control is set for transmit control handshaking (Function Code 66 = 2), the user may require a delay to occur between the time when the data transmission is terminated and when the transmit enable signal is disabled.
- The delay period can be entered at this function code extension and is normally set to 0 for the presently supported communications system. See Figure 3-6.

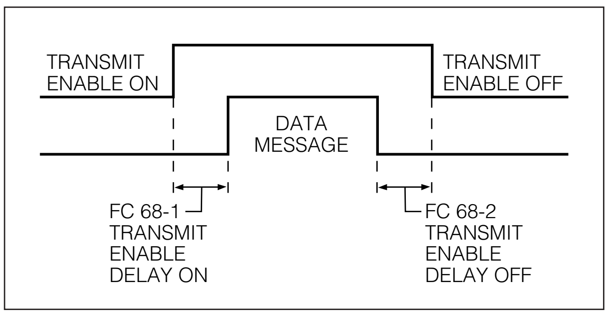


Figure 3-6.
Data transmission from the CL-5 Series control to the communication system for handshaking applications

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level To Read	Security Level To Change	Security Level To Reset	Default Value	Key Entry Limit Low	Key Entry Limit High
69	—	Regulation Blocking Status	—	0	2	NA	NA	0	1

- The control with communications options allows the user to completely control the regulator through the SCADA system. The SCADA system may place the regulator in a "blocked" state, thus inhibiting any further tap changer operation initiated by the control. A practical example might be to perform a certain amount of voltage reduction, and then disable the tap changer (inhibit additional operations) for an indefinite time period.
- Statuses are as follows:
  0 = Normal (normal automatic operation)
  1 = Blocked (automatic operation is inhibited)
- The operator may change the state of this code by entering the level 2 security at the control and pressing the CHANGE/RESET key. If SCADA has the control blocked, the operator may override the SCADA system by changing Function Code 69 from 1 to 0, or if the operator chooses to block automatic operation, Function Code 69 can be changed from 0 to 1.
- Additional information concerning the SCADA interaction with the control is on page 4-9.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level To Read	Security Level To Change	Security Level To Reset	Default Value	Key Entry Limit Low	Key Entry Limit High
70	—	Voltage Reduction Mode	—	0	2	NA	0	0	3

- The control has three voltage reduction modes available for user selection. The appropriate mode is activated by entering the corresponding code:
  0 = Off
  1 = Local/Digital Remote
  2 = Analog Remote - Latching
  3 = Remote - Pulse
- See Voltage Reduction, page 4-8.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
70*	—	Voltage Reduction Mode/ Tap to Neutral	—	0	2	NA	0	0	13
	• The control has three voltage reduction modes available for user selection. The appropriate mode is activated by entering the corresponding code: 0 = Off — 10 = Off, Tap to Neutral Enabled 1 = Local/Digital Remote — 11 = Local/Digital Remote, Tap to Neutral Enabled 2 = Analog Remote (Latching) — 12 = Analog Remote (Latching,) Tap to Neutral Enabled 3 = Pulse — 13 = Pulse, Tap to Neutral Enabled • If enabled, tap-to-neutral is activated by energizing contacts 1 and 2 on TB-2. It is not possible to employ voltage reduction Remote #3 (Function Code 75) if tap-to-neutral is active. • See Voltage Reduction, page 4-8.								
71	—	Percent Voltage Reduction in Effect	%	0	NA	NA	NA	NA	NA
	• This is the actual percentage of voltage reduction presently active. • See Voltage Reduction, page 4-8.								
72	—	Local/Digital Remote Voltage Reduction %	%	0	2	NA	0.0	0.0	10.0
	• The percentage of local voltage reduction to be performed, is entered here. Example: If the regulator is set for 125 V voltage setting and 3.6% voltage reduction is required, 3.6% is entered here (first set Function Code 70 = 1), and the regulator will tap down 4.5 V (3.6% of 125 V) immediately following the time delay period. • When activating voltage reduction via digital SCADA, this is the parameter which is changed to the percent desired. • See Voltage Reduction, page 4-8.								
73	—	Analog Remote Reduction Setting #1	%	0	2	NA	0.0	0.0	10.0
	• Three levels of remotely activated latching voltage reduction are available. • The percentage of voltage reduction to be performed at Removal Level 1 is programmed at the Function Code 73. Remote activation is then accomplished by applying a signal to the appropriate input terminal, when Function Code 70 = 2. • See Remote (Latching) Mode, page 4-9.								
74	—	Analog Remote Reduction Setting #2	%	0	2	NA	0.0	0.0	10.0
	• Three levels of remotely activated latching voltage reduction are available. • The percentage of voltage reduction to be performed at Removal Level 2 is programmed at the Function Code 74. Remote activation is then accomplished by applying a signal to the appropriate input terminal, when Function Code 70 = 2. • See Remote (Latching) Mode, page 4-9.								
75	—	Analog Remote Reduction Setting #3	%	0	2	NA	0.0	0.0	10.0
	• Three levels of remotely activated latching voltage reduction are available. • The percentage of voltage reduction to be performed at Removal Level 3 is programmed at the Function Code 75. Remote activation is then accomplished by applying a signal to two appropriate input terminals, when Function Code 70 = 2. • See Remote (Latching) Mode, page 4-9.								
76	—	Analog Pulsed Voltage Reduction Number of Steps	—	0	2	NA	0	0	10
	• Up to ten steps of voltage reduction are available when pulsed voltage reduction mode is selected. (Function Code 70 = 3.) • Function 76 defines the number of steps selected for pulsed reduction operation. The percentage of voltage reduction of each step is defined at Function Code 77. • See Pulse Mode, page 4-9.								
77	—	Analog Pulsed Voltage Reduction Voltage Reduction Per Step	%	0	2	NA	0.0	0.0	10.0
	• Function Code 77 defines the percentage of voltage reduction which will be applied for each step of pulsed voltage reduction selected at Function Code 76 • See Pulse Mode, page 4-9.								

* CL-5E control only.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
79*	1, 2	Soft Add-Amp Limits	NA	0	2	2	0	NA	NA
	• The control has soft add-amp capabilities. 0 = Off, 1 = On (Default is off) • Subfunction 1 defines the high soft add amp setting. The allowable values are 16, 14, 12, 10, or 8. Default is 16. • Subfunction 2 defines the low soft add amp setting. The allowable values are -16, -14, -12, -10, or -8. Default is -16. • See Add Amp, Page 1-15 and 4-10.								
80	—	Voltage Limiting Mode	—	0	2	NA	0	0	2
	• The control has voltage limiting capabilities for both high-voltage and low-voltage conditions. • The appropriate mode is activated by entering the corresponding code: 0 = Off 1 = High limit active only 2 = High and low limits active • See Voltage Limiting, page 4-8.								
81	—	High Voltage Limit	V	0	2	NA	130.0	120.0	135.0
	• The high-voltage limit is programmed here. • When the voltage limiting function is activated (Function Code 80 = 1 or 2), the control will prevent the output voltage of the regulator from exceeding this value. • See Voltage Limiting, page 4-8.								
82	—	Low Voltage Limit	V	0	2	NA	105.0	105.0	120.0
	• The low-voltage limit is programmed here. • When the voltage limiting function is activated (Function Code 80 = 2), the control will prevent the output voltage of the regulator from dropping below this value. • See Voltage Limiting, page 4-8.								
85	1, 2, 3, 4	Profile Recorder	NA	0	1	NA	9,14,15,16	6	19
	• Function Code 85, with its four extensions, is used to select the parameters to be included in the profile recorder data table. • The profile recorder samples any four instantaneous metering functions (Function Codes 6 thru 19). The sample interval is every 15 minutes for a 30-hour period (120 values). • See Profile Recorder, page 4-2.								
85*	1, 2, 3, 4, 5,	Profile Recorder	NA	0	1	NA	1 9,14,15,16	1 6	7 19
	• Function Code 85 is used to profile any four instantaneous metering functions (Functions Codes 6 through 22, or demand values 24-26, 29-32, or 34-37) and to set a time interval for profiling data collection. • The sample period (time interval) is defined by function code 85, where 1 = 5 minutes, 2 = 10 minutes, 3 = 15 minutes, 4 = 30 minutes, 5 = 60 minutes, 6 = 90 minutes, 7 = 120 minutes. The last 120 values for each function shall be stored in volatile control memory. • The first four subfunctions of function code 85 define the four instantaneous metering functions (Functions Codes 6 through 22, or demand values 24-26, 29-32, or 34-37) to be profiled. • The fifth subfunction of function code 85 reflects the “on/off” state of the profiler feature related to the 2179 protocol, that determines whether the parameters returned in response to a request message are all the values, or only the “new” values since the last read.								
89	—	Device Firmware Version	—	0	NA	NA	NA	NA	NA
	• This parameter takes the form RR.DD, where RR is the revision number and DD is the device number. The control is device 06. • Scrolling to this parameter is not allowed.								
90	—	Number of Defaults	—	0	NA	NA	NA	NA	NA
	• This is a counter for the number of parameters in the control operating system which have defaulted. • During normal operation this will be zero. • If any number other than zero is encountered, all of the control settings must be examined to determine which has defaulted. Then the setting(s) must be changed to the correct value(s). • Defaulted functions will be identified with the letter “d” after the function code number in the LCD display.								

* CL-5E control only.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
91	—	Self Test	—	NA	NA	NA	NA	NA	NA
	• The control will execute a self-diagnostic routine by entry of Function Code 91. • This causes the system to re-boot, or initialize itself, and in so doing to check the various components for failures. • The test initiates by lighting all segments in the display for 3 seconds, and then displays PASS or FAIL, depending upon the test results. • "----" (dashes) preceding the PASS indicates that the clock needs to be set. • Performing the self test will appear as a power interruption to the control demand task, and accordingly, it will cause the present demands to go invalid (dashes) and the max/min demands to cease tracking for one demand interval. • Self test does not set all profiler values to zero. • Scrolling to this parameter is not allowed.								
92	—	Security Override	—	0	3	NA	0	0	3
	• Function Code 92 is the control security override parameter. • Entering the level 3 security code at Function Code 99 will permit the security parameters to be modified, 0 = standard security mode 1 = override security level 1 2 = override security levels 2 and 1; 3 = override security levels 3, 2 and 1; • EXAMPLE: With Function Code 92 = 1, metering and tap position resetting may be done without entering security level 1. • See Tap Position Indication, page 4-3.								
93	—	Number of EEPROM Corrections	—	0	NA	3	0	NA	NA
	• This is a counter for the number of times the control has detected an incorrect value in its non-volatile memory (EEPROM), and has changed it to the correct value. • This is for information only.								
94	—	Number of Resets	—	0	NA	3	0	NA	NA
	• This is a counter for the number of times the control has experienced a transient condition (such as a lightning stroke) which caused it to reset. • The control will recover after a transient condition and will resume normal operations.								
95	—	System Status Code	—	0	NA	NA	NA	NA	NA
	• The control is continually checking itself, and the results of this self-diagnosis are displayed at Function Code 95 via a system status code as follows: 0 = All Systems Good 1 = EEPROM Write Failure 2 = EEPROM Erase Failure 3 = Frequency Detection Failure 4 = No Sampling Interrupt - Failure 5 = Analog-to-Digital Converter Failure 6 = Invalid Critical Parameters - Failure 7 = No Source Voltage Detected - Warning 8 = No Output Voltage Detected - Failure 9 = No Source and Output Voltage Detected - Failure 10=TPI. No Neutral Sync Signal - Warning • If the word ERROR appears on the display this indicates a key entry error, not the system status code. See Table 9-2. • See System Protection, page 2-4 and Diagnostics, page 2-5.								
96	—	Level 1 Security Code	—	3	3	NA	1234	1	9999
	• The number to be used as the level 1 security code is entered here. • The level 1 code assigned at the factory is 1234. • Entry of this number at Function Code 99 permits the user to change/reset only the parameters marked as level 1 security (demand and tap position readings). • Scrolling to this parameter is not allowed. • See Security System, page 2-6.								

* CL-5E control only.

Function Code	Function Code Extension	Parameter	Unit of Measure	Security Level			Default Value	Key Entry Limit	
				To Read	To Change	To Reset		Low	High
97	—	Level 2 Security Code	—	3	3	NA	12121	10000	19999
	• The number to be used as the level 2 security code is entered here. • The level 2 code assigned at the factory is 12121. • Entry of this number at Function Code 99 permits the user to change/reset only the parameters marked as level 2 security (control settings, configuration and clock) and level 1 security. • Scrolling to this parameter is not allowed. • See Security System, page 2-6. • The number to be used as the level 3 security code is entered here.								
98	—	Level 3 Security Code	—	3	3	NA	32123	20000	32766
	• The level 3 code assigned at the factory is 32123. • Entry of this number at Function Code 99 permits the user to change/reset any parameter. • NOTE: If the level 3 code is changed by the user, the new value should be recorded and kept in a safe place. If lost, the security codes cannot be displayed or changed, diagnostic codes cannot be displayed or change, and calibration cannot be performed unless the present code is identified by using the Data Reader and Data Reader software or Communication Interface software available from Cooper Power Systems. • Scrolling to this parameter is not allowed. • See Security System, page 2-6.								
99	—	Enter Security Code	—	NA	0	NA	NA	1	32766
	• This is the function code location where the security codes are entered for access to the system. • Scrolling to this parameter is not allowed. • See Security System, page 2-6.								

Control Advanced Features

Differential Voltage

Unless specifically ordered, or required as a part of the specified operation, most regulator designs will be without the internal source-load differential P.T. Units with the CL-5C or newer controls have source voltage calculation available (FC 39). Without a source voltage input, several functions cannot be obtained, and will indicate dashes when displayed (see Table 4-1). Also, Function Code 95 will display a “7” to indicate no input voltage.

TABLE 4-1
Function Code Dependent Upon Differential Voltage

Function Code	Description
7	Source Voltage, Secondary
11	Source Voltage, Primary
12	Percent Regulation
27	Maximum % Boost/Minimum % Buck
28	Maximum % Buck/Minimum % Boost
30-36	All Reverse Metered Demand Values

If the parameters listed in Table 4-1 are desired and the regulator is not able to determine the source voltage, an external source side potential transformer may be connected to the control. (See Reverse Power Operation, page 4-3.)

Calendar/Clock

Integral to several functions of the control is an internal calendar/clock. The digital clock maintains the year, month, day, hour, minute and seconds, and has resolution of 1 second. Hours are in 24-hour (military) time, that is, 3:15 p.m. is shown as 15:15. The clock does not adjust for Daylight Savings Time. It is powered by ac (60 or 50 Hz) and operates under normal power when the control is powered up. When ac power is off, the clock uses a crystal as a reference and a capacitor as the power source. The back-up power will sustain the clock for a minimum of 24 hours. Sixty-five hours on ac power are required to fully charge the capacitor.

Upon powering up the control, if the clock is invalid due to lack of power, four (4) dashes will appear in the display to the left of the word PASS. In this situation the clock will restart at 1/1/90 00:00:00. Until the clock is reset, four dashes will appear on the right of the display whenever the display would normally be blank.

Metering

The control has extensive metering capabilities, which we categorize as Instantaneous, Demand and Profile.

Instantaneous Metering

Instantaneous metering values are stored in RAM, and are refreshed once per second. They may be read at Function Codes 6 through 19. See the detailed description of these parameters starting on page 3-2.

Demand Metering

The control provides demand metering values for six or eight parameters: load voltage, source voltage* (forward and reverse), compensated voltage, load current, kVA load, kW load, and kvar load. For each of these parameters the present “P” value, the maximum “H” value since last reset, and the minimum “L” value since last reset are recorded, as well as the earliest time and date that the maximum and minimum values occurred. Additionally, the power factor at maximum kVA demand and minimum kVA demand are recorded. All of these values are stored in non-volatile memory separately for forward and reverse power conditions.

Demand values may be read at Function Codes 20 through 37. See the detailed description of these parameters starting on page 3-5, and the discussion concerning metering during reverse power flow, starting on page 4-3.

Demand Task Operation

The demand metering function is based upon a sliding window concept, or moving integral. The algorithm implemented simulates the response of a thermal demand meter which will reach 90% of its final value after one demand interval in response to a step function input. (See Figure 4-1.)

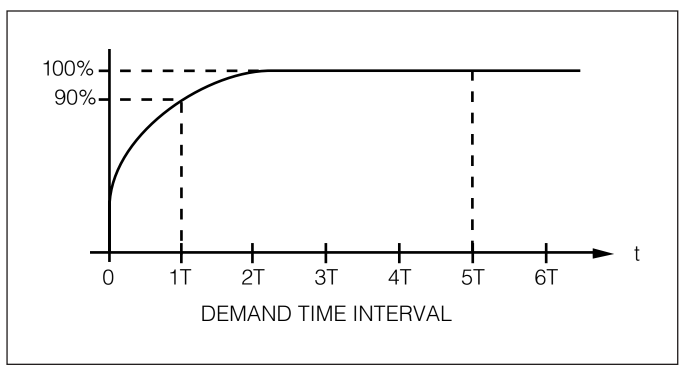


Figure 4-1.
Demand time interval response

* Source voltage: CL-5E only.

The task works like this:

1. For 3 minutes after a power outage or power reversal, no demands are calculated. This allows the utility system to stabilize from the event which created the outage or power reversal.
2. At 3 minutes, the present demands (for the appropriate power direction) are set to their corresponding instantaneous value, and the integration algorithm begins according to the programmed demand interval at Function Code 46.
3. At 15 minutes or at the demand time interval (whichever is longer), the max/min demand values begin to track the present demand, similar to drag hands. All demand values are calculated continuously in the working memory (RAM), and the max/min demands are also stored in the non-volatile memory (EEPROM) every 15 minutes, if a change has occurred. This prevents loss of data during a power interruption or outage.

Notice that the provisions are made to reset any demand value by itself via the change/reset key, or all demands can be reset simultaneously by entering Function Code 38. Maximum (H) and minimum (L) values will be set to their corresponding present (P) demand value and the H and L dates and times will be set to the present date/time. If the present demand is in an invalid state (dashes), the maximum and minimum values will also become invalid, displaying dashes.

Two conditions can cause the present demands to be invalid: The power has just been applied (within the 3 minute freeze period) or the power flow has changed direction. If the control is metering in the forward direction, the reverse present demands will be invalid; and if metering in the reverse direction, the forward present demands will be invalid.

Profile Recorder

Function Code 85.

The CL-5D control has a Profile Recorder (Profiler) function which records any four (4) metering values every 15 minutes for 30 hours (120 time slots). On the CL-5E and newer controls, the time interval is variable, from 5-120 minutes. See Function Code 85 description. To set the Profiler, access security level 1, then enter the parameters of choice at the Function Code extensions 1, 2, 3 and 4. The selectable CL-5D parameters are:

- 6 - Load Voltage, Secondary
- 7 - Source Voltage, Secondary*
- 8 - Compensated Voltage, Secondary
- 9 - Load Current, Primary
- 10 - Load Voltage, Primary
- 11 - Source Voltage, Primary*
- 12 - Present Tap Position
- 13 - Power Factor
- 14 - kVA Load
- 15 - kW Load
- 16 - kvar Load
- 17 - Line Frequency
- 18 - Voltage Total Harmonic Distortion
- 19 - Current Total Harmonic Distortion

*Source voltage required

For the CL-5E, the following parameters are also available for Profiler data collection.

- 20 Forward Load Voltage
- 21 Forward Compensated Voltage
- 22 Forward Load Current
- 24 Forward kVA Load
- 25 Forward kW Load
- 26 Forward kVAR Load
- 29 Forward Source Voltage
- 30 Reverse Load Voltage
- 31 Reverse Compensated Voltage
- 32 Reverse Load Current
- 34 Reverse kVA Load
- 35 Reverse kW Load
- 36 Reverse kVAR Load
- 37 Reverse Source Voltage

TABLE 4-2
Default Values for Profiler Parameters

F.C.	Extension	Value	Parameter
85	1	9	Load Current, Primary
85	2	14	kVA Load
85	3	15	kW Load
85	4	16	kvar Load

EXAMPLE: To record the tap position (FC 12) instead of the load current, do the following:

1. Access security level 2.
2. Press FUNCTION, 8, 5, ENTER.
3. The display will read “85 1 9”, or, if the CL-5E or newer control is installed, the display will read, “85 15”.
4. If the control is a CL-5E or newer, scroll up one value. The control will now read, “85 1 9”.
5. Press CHANGE, 1, 2 ENTER.

The profiler data is stored in working memory (RAM), therefore, if power is lost, all profiler values are lost. Upon return of power, if the clock is still operating on backup power, the profiler will start at the next time interval. If due to lack of power the clock starts with the default hour: minute values of 00:00, the first values will be recorded at 00:15 or at the first time interval, if the CL-5E control is in use.

If a parameter at one of the extensions of Function Code 85 is changed, the entire profiler database will be reset, that is, all values for all four parameters will be set to 0. To reset all profiler values to 0 either turn the power off, or change one of the Function Code 85 extension values.

If the clock is reset, prior values and times in the profiler will be retained, and the newest value will be recorded at the next time interval. It should be noted that the hour and minute are stored on the profiler, not the month and day.

After all 120 time slots are filled, the oldest set of values is deleted when the newest set of values is recorded.

The time-stamped profiler values are not accessible through the keypad and display. To retrieve the values, download the control database through the Data Port with a McGraw-Edison Data Reader or with a PC using CCI CL-4/CL-5 Interface Program or extract the data through the communications channel.

Tap Position Indication

The control has the ability to track the position of the tap changer. The tap position indication (TPI) function senses the status of the motor and neutral light circuits and does not require source (input) voltage. The present tap position is stored at Function Code 12. EXAMPLES: "8" at Function Code 12 indicates 8 raise and "-7" indicates 7 lower.

The TPI function is synchronized to the position of the tap changer by running the regulator to the neutral position. When the tap changer cannot be returned to neutral due to the voltage support which is necessary, the value of the present tap position may be changed to the position shown by the position indicator main hand by doing the following: Access security level 3; access FC 12; use the CHANGE key to change to the desired value.

The maximum tap position since last reset (upper draghand value of the present tap position) and its date and time are stored at Function Code 27. The minimum tap position since last reset (lower draghand value of the present tap position) and its date and time are stored at Function Code 28. The TPI draghand values and dates/times are reset to the present values by the master reset, Function Code 38, or by resetting each of the values individually. The draghand reset switch resets the draghands of the position indicator only, not TPI.

All TPI values are stored in a non-volatile memory. The present tap position value will go to invalid "----" if the following condition is detected. The present tap position is "O" (neutral) but no neutral signal is detected. This condition will occur if a replacement control with present tap position set to "O" is installed on a regulator which is not in the neutral position. If the TPI function detects a successful upward tap and the prior value of FC 12 was "16", or a successful downward tap is detected and the prior value of FC 12 was "–16" the prior value will be maintained. These conditions could occur if the present tap position was manually set incorrectly.

The following relates the action of the diagnostics routine with regard to the Tap Position Indication function only. See page 2-5 for the list of other reasons which would cause diagnostics to report FAIL.

The display will show FAIL upon power-up under these circumstances: 1) the present tap position value prior to power-up is "---" (invalid) and the regulator is not in neutral position. 2) The present tap position prior to power-up is 0 and the regulator is not in the neutral position. This condition will cause the present tap position value to go to invalid ("----"). 3) During automatic or manual operation the present tap position changes to 0, but a neutral signal is not received. In all of these cases, the value at Function Code 95, Systems Status, is set to "10", "TPI - NO NEUTRAL SYNC - WARNING".

The display will show PASS upon power-up under the following circumstances: 1) The present tap position is not 0 and the regulator is not in neutral. 2) The regulator is in neutral.

Reverse Power Operation

Most voltage regulators are installed in circuits with well-defined power flow from source to load. However, some circuits have interconnection 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 control has full reverse power capabilities, but for fully automatic reverse operation the source voltage or source-to-load differential voltage must be supplied to the control in addition to the load voltage. Regulators may be ordered direct from the factory with an internal (source-to-load) series winding P.T., or an external source-side P.T. may be installed in the field. In either case, a second Ratio Correcting Transformer (RCT) on the control back panel is required for proper correction of the source voltage if the external source side P.T. has a voltage other than 120V. Regulators with factory installed series winding P.T.s also have the second RCT installed at the factory.

Some field installations may require that a source voltage P.T. be used instead of the series winding P.T. which is the standard technique used on the McGraw-Edison voltage regulator. The control is designed such that it can be configured for this application also. This reconfiguration is accomplished by removing the back shield and moving a soldered jumper from one set of terminal posts marked V_{diff} to another set of terminals marked $V_{in.}$ The software of the control then recognizes this differential/source voltage as a source voltage, and will function accordingly.

The CL-5C and later generation controls have the ability to calculate the source side voltage without a series winding P.T.. When this feature is turned on, the control will use the load voltage from the main P.T., the regulator type (either straight, also known as ANSI type A, or inverted, also known as ANSI type B), the tap position and the internal impedance of the regulator to calculate the source side voltage. This source voltage is with ±1.5% of actual. With the source voltage P.T. the accuracy improves to ±1%. Only the regulator type needs to be programmed into the control. The other values are already available to the control.

The control offers seven different response characteristics for reverse power detection and operation. These characteristics are user selectable by programming Function Code 56. The seven modes, and their corresponding codes are:

0 = Locked Forward, 1 = Locked Reverse
2 = Reverse Idle, 3 = Bi-directional
4 = Neutral Idle, 5 = Co-generation
6 = Reactive Bi-directional

This section will separately explain each mode of operation. Since the control retains the reverse metered demand values separate from the forward metered values, the metering will also be explained for each mode.

In determining power direction, the control senses the real component of the current (except in reactive bi-directional mode), and then determines the current direction and magnitude in that direction. When the conditions indicate the power is flowing in reverse, the following parameters assume new values and the control operation is affected accordingly:

Load Voltage - Now sensed from what was previously the source voltage supply.

Source Voltage - Now sensed from what was previously the load voltage supply.

Load Current - In the forward direction, the current is used directly as measured. In the reverse direction, the current is scaled to reflect the ratio difference between the source and load side of the regulator, according to this formula:

$$\text{Reverse Load Current} = \frac{(\text{Forward Load Current})(\text{Source Voltage Supply})}{\text{Load Voltage Supply}}$$

where source voltage supply and load voltage supply are in the reverse direction.

kVA, kW, kvar, and % buck/boost are now calculated based upon the new metered reverse values.

Locked Forward Mode

Function Code 56 = 0. No source voltage is required. This mode is not intended to be used in applications where reverse power flow is possible.

METERING: Always operates in the forward direction, regardless of power flow direction. If reverse power occurs, the metering functions remain on the normal load side of the regulator—no reverse demand readings will occur.

OPERATION: (Figure 4-2) Always operates in the forward direction. This allows operation down to zero current conditions since there is no forward threshold involved. A safeguard has been built into the control to prevent misoperation in the event reverse power flow does occur. If more than 2% (.004 A C.T. secondary) reverse current occurs, the control idles on the last tap position held, and the band edge indicators will turn off. As the current flow returns to a level above this reverse threshold, normal forward operation resumes.

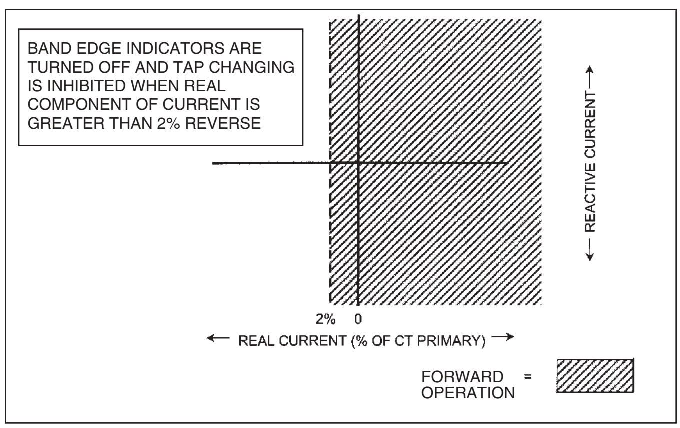


Figure 4-2.
Locked forward mode operation

Locked Reverse Mode

Function Code 56 = 1. Source voltage is required. This mode is not intended to be used in applications where forward power flow is possible.

METERING: Always operates in the reverse direction, regardless of power flow direction. If forward power occurs, the metering functions remain on the source (S bushing) side of the regulator — no forward demand readings will occur.

OPERATION: (Figure 4-3.) Always operates in the reverse direction using the reverse settings at Function Codes 51, 52, 53, 54 and 55. This allows operation down to zero current conditions since there is no reverse threshold involved. A safeguard has been built into the control to prevent misoperation in the event forward power flow does occur. If more than 2% (.004 A C.T. secondary) forward current occurs, the control idles on the last tap position held, and the band edge indicators will turn off. As the current flow returns to a level above this forward threshold, normal reverse operation resumes. (See Figure 4-3.)

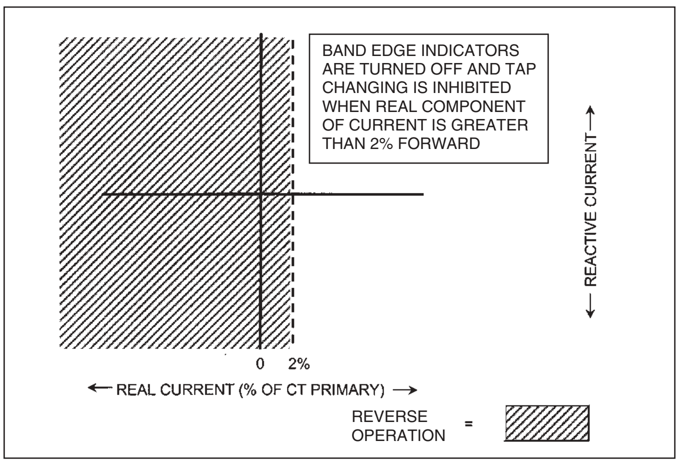


Figure 4-3.
Locked reverse mode operation

Reverse Idle Mode

Function Code 56 = 2. Source voltage required for metering only. This mode is recommended for installation where reverse power flow may occur, but a source voltage is not available.

METERING: (Figure 4-4.) A threshold level of 1% (.002 A) of the full load C.T. secondary current (.200 A) is used in setting the power direction. The metering will be forward until the current exceeds the 1% threshold in the reverse direction. At this time, the various parameters use the reverse settings, and the REV PWR annunciator turns on. The control continues metering in reverse until the current exceeds the 1% threshold in the forward direction, and then the parameter scaling reverts back to normal and the REV PWR annunciator turns off. If the source or differential P.T. is not installed, reverse metering will not be available, but all other metering operations remain the same. If the P.T. is installed, metering will be per Figure 4-6.

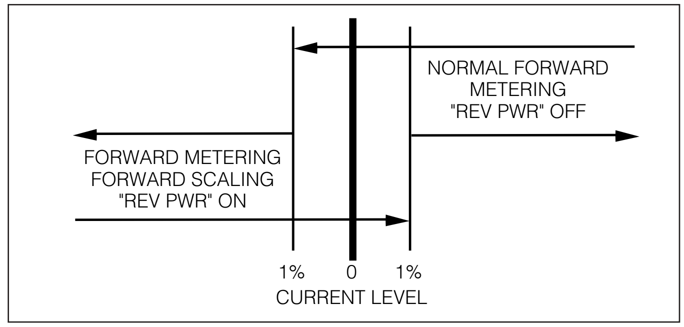


Figure 4-4.
Reverse idle metering without source voltage

OPERATION: (Figure 4-5.) The threshold for which the control switches operation is programmable at Function Code 57 over the range 1 to 5% of the rated C.T. current. When the real component of the current is above this threshold, the control operates in the normal forward direction. When current falls below this threshold, all tap changing is inhibited. The control idles on the last tap position held before the threshold was crossed. The operational timer (time delay) is reset on any excursion below this threshold, and the band edge indicators turn off.

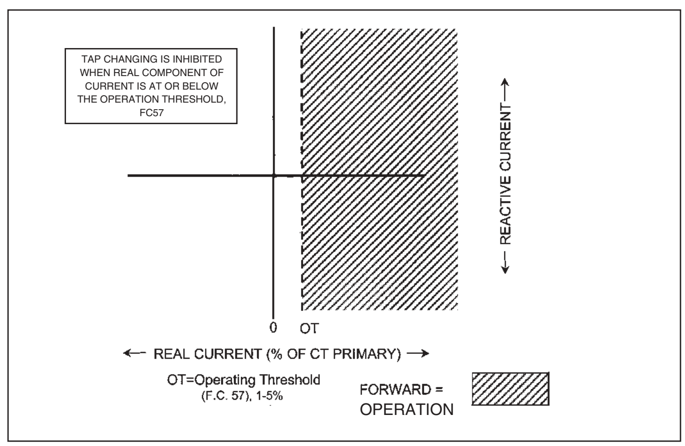


Figure 4-5.
Reverse idle mode operation

*Tap changing is inhibited and band edge indicators are turned off.

Bi-directional Mode

Function Code 56 = 3. Source voltage is required. This mode is recommended for all installations where reverse power flow may occur except where the source of reverse power is a co-generation facility or independent power producer.

METERING: (Figure 4-6.) A threshold level of 1% (.002 A) of the full load C.T. secondary current (.200 A) is used in setting the power direction. The metering will be forward until the current exceeds the 1% threshold in the reverse direction. At this time the various parameters use the reverse settings, and the REV PWR annunciator turns on. The control continues metering in reverse until the current exceeds the 1% threshold in the forward direction, and then the parameter scaling reverts back to normal and the REV PWR annunciator turns off.

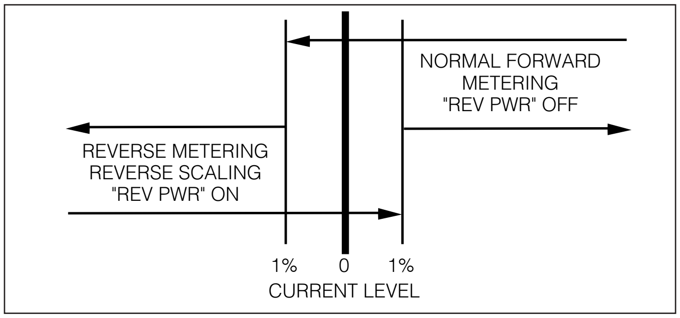


Figure 4-6.
Bi-directional, Neutral Idle and Reactive Bi-directional Metering

OPERATION: (Figure 4-7.)The control operates in the forward direction whenever the real component of the current is above the operator defined forward threshold (Function Code 57). The control operates in the reverse direction, using the reverse settings at Function Codes 51, 52, 53, 54 and 55, whenever the current is above the operator defined reverse threshold (Function Code 57). When the current is in the region between the two thresholds, the control idles on the last tap position held before the current fell below the threshold. The operational timer (time delay) is reset on any excursion below the threshold in either direction, and the band edge indicators turn off.

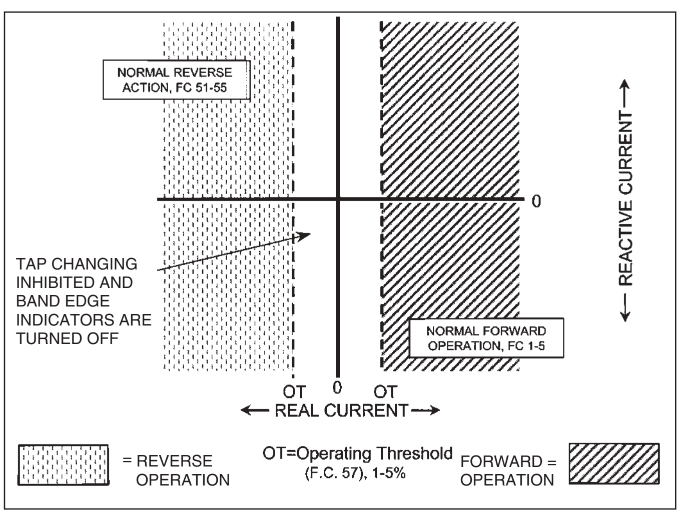


Figure 4-7.
Bi-directional mode operation

Neutral Idle Mode

Function Code 56 = 4. Source voltage is required.

METERING: (Figure 4-6.) A threshold level of 1% (.002 A) of the full load C.T. secondary current (.200 A) is used in setting the power direction. The metering will be forward until the current exceeds the 1% threshold in the reverse direction. At this time, the various parameters use the reverse settings, and the REV PWR annunciator turns on. The control continues metering in reverse until the current exceeds the 1% threshold in the forward direction, and then the parameter scaling reverts back to normal and the REV PWR annunciator turns off.

OPERATION: (Figure 4-8.) The control operates in the forward direction whenever the real component of the current is above the operation defined forward threshold (Function Code 57). When the current exceeds the operator defined reverse threshold (Function Code 57), and is held for 10 continuous seconds, the control will tap to neutral. Neutral position is determined as when the percent buck/boost is within ±.3% of 0. When the current is in the region between the two thresholds, the control idles on the last tap position held before the forward threshold was crossed. While tapping to the neutral position, if the current falls below the reverse threshold, the control continues to tap until neutral position is reached. The operational timer (time delay) is reset on any excursion below the forward threshold and the band edge indicators turn off.

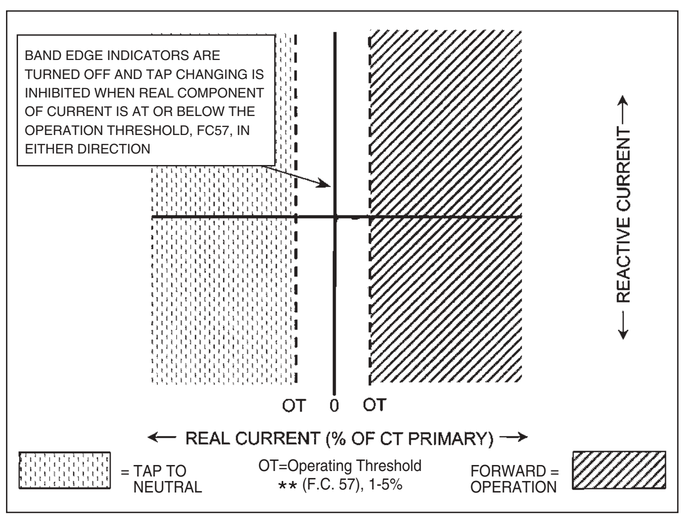


Figure 4-8.
Neutral idle mode operation

** Band edge indicators are turned off.

Co-generation Mode

Function Code 56 = 5. Source voltage is required.

In recent years, there have been a growing number of voltage regulator applications involving co-generation by the utilities' customers. The co-generation mode was developed for the McGraw-Edison control to satisfy the specialized needs of these applications. Normally, the desired operation of a regulator installed on a feeder involving co-generation is to regulate the voltage at the customer substation during times of power flow into the customer site, and to regulate the voltage at the regulator (on the same output side) during power flow into the utility grid. This is accomplished by simply not reversing the control sensing input voltage when reverse power is detected, and by altering the line drop compensation settings to account for this change in power flow direction. (See Figure 4-9.)

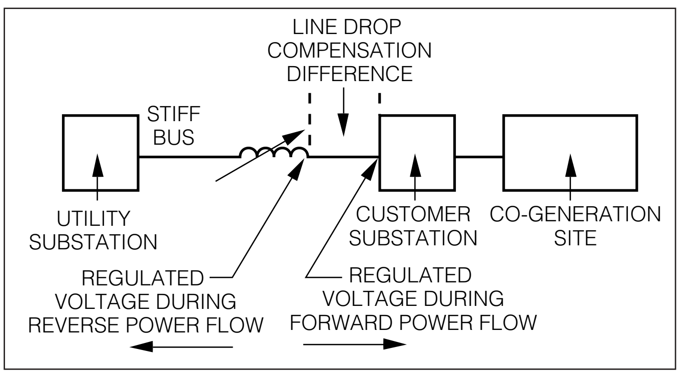


Figure 4-9.
Co-generation regulation points

METERING: (Figure 4-10.) Always operates in the forward direction except that load center voltage is calculated based upon the reverse line drop compensation settings (Function Codes 54 and 55), when the fixed 1% reverse metering threshold is exceeded. The REV PWR annunciator turns on when this reverse threshold is crossed. The forward line drop compensation settings (Function Codes 4 and 5) are used when the current exceeds the fixed 1% forward metering threshold. The demand values acquired during reverse power flow are stored as reverse metered data but the values are not scaled (to reflect the other side of the regulator) since the operating direction of the regulator never truly reverses.

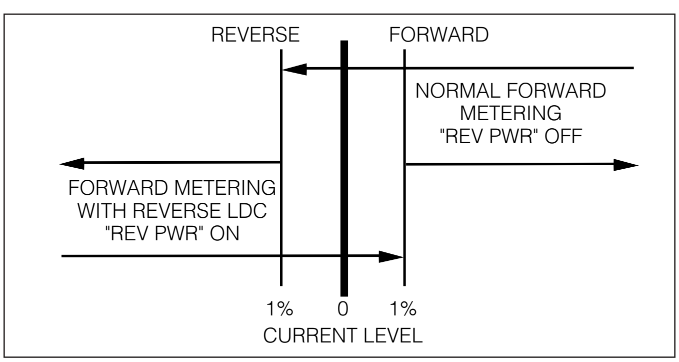


Figure 4-10.
Co-generation metering

OPERATION: (Figure 4-11.) The control always operates in the forward direction. The control will operate in the forward direction, but will use the reverse settings for line drop compensation when the real component of the current is above the fixed 1% reverse metering threshold. The control will continue to use the reverse line drop compensation settings until the real component of the current is above the fixed 1% forward metering threshold. The operational timer (time delay) is not reset on any transitions between the application of forward and reserve line drop compensation settings.

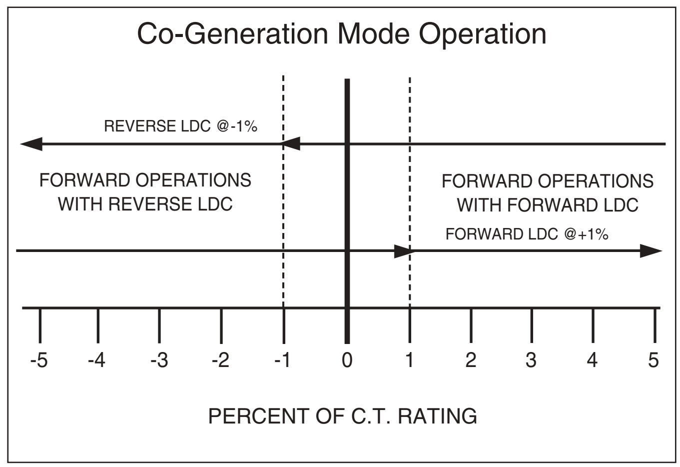


Figure 4-11.
Co-generation mode operation

Reactive Bi-Directional Mode

Function Code 56 = 6. Source voltage is required.

This mode is recommended for installations where reverse power flow may occur and the real component of the current is below the operator defined threshold (Function Code 57), except where the source of reverse power is a co-generation facility or independent power producer.

METERING: (Figure 4-6.) A threshold level of 1% (0.002 A) of the full load C.T. secondary current (0.200 A) is used in setting the power direction. The metering will be forward until the current exceeds the 1% threshold in the reverse direction. At this time, the various parameters use the reverse settings, and the REV PWR annunciator turns on. The control continues metering in reverse until the current exceeds the 1% threshold in the forward direction, and then the parameter scaling reverts back to the normal and REV PWR annunciator turns off.

OPERATION: (Figure 4-12.) The control determines which settings (forward/reverse) to use by sensing the real and reactive components of the current. The control operates in the forward direction whenever the magnitude of the reactive component of the current exceeds the operator defined threshold (Function Code 57) in the negative direction. The control also operates in the forward direction if the magnitude of the real component of the current exceeds the operator defined threshold (Function Code 57) in the positive direction while the magnitude of the reactive component of the current is between the operator-defined thresholds (Function Code 57). The control operates in the reverse direction using the reverse settings at Function Codes 51, 52, 53, 54, and 55, whenever the magnitude of the reactive component of the current exceeds the operator defined threshold (Function Code 57) in the positive direction. The control also operates in the reverse direction if the magnitude of the real component of the current exceeds the operator defined threshold (Function Code 57) in the negative direction while the magnitude of the reactive component of the current is between the operator defined thresholds (Function Code 57).

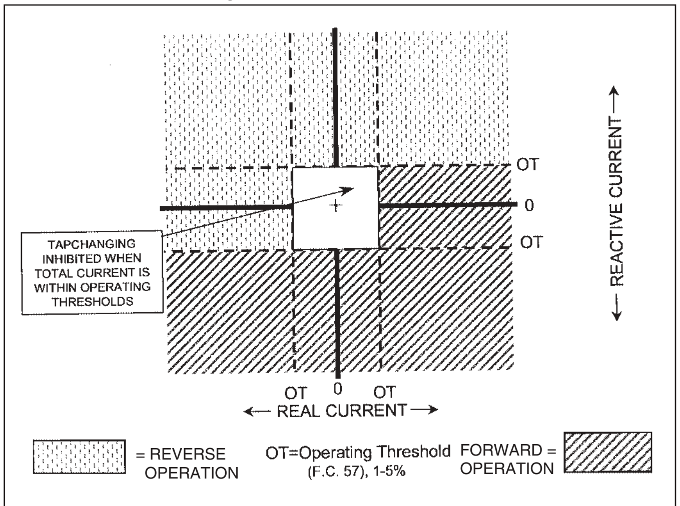


Figure 4-12.
Reactive bi-directional mode operation

Voltage Limiting

The voltage limiting accessory is used to place both a high and low limit on the output voltage of the regulator. When enabled, it operates in either the forward or reverse directions, and has the highest priority of all operating functions. Voltage limiting is overridden only by the operator taking local control, or by an inter-connected SCADA system. The purpose of the voltage limiter is to protect the consumer from abnormally high or low voltages resulting from:

- Large, rapid changes in transmission voltage
- Abnormal loading of the feeder
- Inaccurate regulator control settings (voltage level, bandwidth, and line drop compensation)
- Heavy loading by the first customer while there is a leading power factor on the feeder
- Light loading at the first customer with heavy loading on the feeder at the same time

The appropriate high and low limits for the output voltage can be programmed into the control at Function Codes 81 and 82, respectively. The accessory is then activated by accessing Function Code 80 and entering the appropriate code for the desired operation: 0 = off; 1 = high-voltage limiting only; 2 = both high and low limiting. If low-voltage limiting only is desired, Function Code 80 should be set to 2 to enable this limit, and the value programmed into Function Code 81 for the high limit can be set to some extreme number (such as 135) to prevent the high limit from activating.

The control has two response sensitivities. If the output voltage exceeds either the high or low limit by 3 V or more, the control samples the voltage for two seconds and then taps immediately to bring the voltage to the limit value. If the output voltage exceeds either the high or low limit by less than 3 V, the control samples the voltage for 10 seconds then taps to bring the voltage to the limit value. The 10 second delay is used to prevent false responses to transient conditions. The control uses the sequential method of tapping, a two second pause between taps for voltage sampling, when bringing the voltage back to the limit value. HIGH and LOW annunciators in the display indicate when either limit is active.

To avoid potential cycling of the regulator, set the high- and low-voltage limits at least two volts above and below the upper and lower bandwidth limits. This will establish a “grey zone” between the high-and low-voltage limits and the upper and lower bandwidth limits. When the output voltage is within this “grey zone,” the control will not perform any tap changes that would take the output voltage closer to the limit. If the voltage is directly on the inner edge of the grey zone, the control will allow one tap change to permit the voltage to enter the grey zone by as much as 0.7 V.

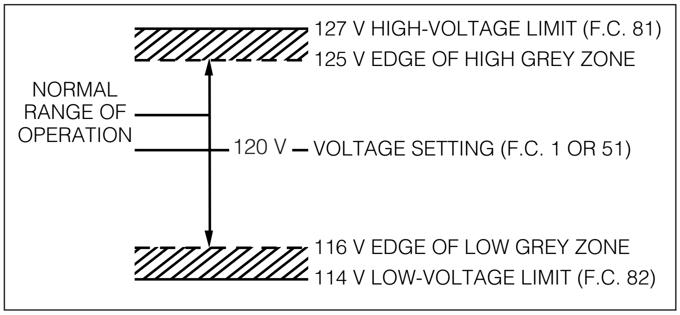


Figure 4-13.
Voltage limiting grey zones

Voltage Reduction

An ideal application for system load management is at the distribution voltage regulator. Voltage reduction capabilities within the regulator control permit it to trigger the regulator to reduce voltage during situations where power demands surpass the available capacity, and where there are extraordinary peak loads. The control offers three modes of voltage reduction: local/digital remote, analog remote, and pulse. All modes operate for forward or reverse power flow conditions.

For the CL-5E control, a tap-to-neutral option has been added to the Voltage Reduction function. This feature may be employed regardless of the voltage reduction mode selected. To activate this feature, it must be enabled via Function Code 70, and 120 V ac must be applied to Terminals 1 and 2 of TB_2. When tap-to-neutral is enabled, the third voltage reduction level of Analog Remote (Latching), (Function Code 75), is disabled. If tap-to-neutral is not used, then Function codes 73, 74, and 75 all work as normal. All voltage reduction modes of the control work by calculating an effective set voltage as follows:

Effective Set Voltage = Set Voltage x (1- (percent reduction))

EXAMPLE: If the set voltage = 123 V and voltage reduction of 4.6% is active, the regulator will regulate the compensated voltage to 117.3 V, that is, tap down 5.7 V.

When any mode of voltage reduction is in effect, the V. RED. annunciator segment is turned on. Voltage reduction occurs after timeout, as established by the time delay, Function Code 3 or 53, and the Control Operating Mode, Function Code 42. The percent reduction in effect is displayed at Function Code 71.

Local/Digital Remote Mode

Function Code 70 = 1 (or 11 for CL-5E).

Voltage reduction can be performed by selecting the Local/Digital Remote mode of operation (Function Code 70 = 1), and then entering into Function Code 72 the amount of reduction required as a percentage of the set voltage. To turn voltage reduction off set function Code 70 to 0.

Remote (Latching) and Pulse Mode

The remote latching and pulse mode of voltage reduction will be discussed in Analog SCADA.

Supervisory Control and Data Acquisition (SCADA)

With its tap changer, potential transformer and current transformer, the regulator is a likely candidate for a Supervisory Control and Data Acquisition system where the utility needs to have centralized voltage control for peak shaving, energy conservation or other purposes. For many years regulators have been connected to analog SCADA systems where the regulator is controlled by contact closure and the feedback is via a voltage transducer connected to the voltage sensing circuit of the regulator control. Regulators are still being installed where the link between the regulator control and the remote terminal unit (RTU) is analog.

The control has a number of features which allow it to function well on these types of systems. For details, see Analog SCADA, following.

With the advent of microprocessor-based controls such as the McGraw-Edison 4 and 5 Series controls, two-way real-time digital communication with the regulator control is now possible. The CL-5C and subsequent controls are specifically designed for this type of system. For details, see Digital SCADA, page 4-11.

The control is also well suited to the user who does not have a SCADA system, but does have a need for detailed information about the bus or feeder loading. See Data Retrieval and Settings Upload, page 4-12.

Analog SCADA

Built-in Voltage Reduction

This is a continuation of the Voltage Reduction discussion. During voltage reduction the control remains in the Automatic mode. See Figure 4-14 which shows the left-most section of TB_2, the bottom terminal board on the back panel. For either of the two modes described next, Remote Latching and Pulse, a nominal 125 V ac needs to be supplied to either or both terminals, 1 and 2. If the user supplies dry contacts, the voltage should be obtained from terminal V_9. V_9 voltage is only available when the control switch is in the auto/remote position. If the user supplies wet contacts, the connections should be as shown in Figure 4-15. Note that J is connected at the factory to the control ground.

Analog Remote (Latching) Mode

Function Code 70 = 2 (or 12 for CL-5E).

Up to three independent values of voltage reduction (VR) are possible. Levels 1, 2 and 3 are programmed at

Function Codes 73, 74 and 75 respectively. As shown in Table 4-3, latching contact 1 activates the VR programmed at Function Code 73, latching contact 2 activates the VR programmed at Function Code 74, and latching both contacts activates the VR programmed at Function Code 75. Each of these function codes may be set from 0.1 to 10.0%.

TABLE 4-3
Voltage Regulator Latching Contacts

Latch Closed at These Contacts	Function Code To Activate Voltage Reduction
1	73
2	74
1 & 2*	75

* Automatic Tap to Neutral for CL-5E, if FC70 is set to values 10, 11, 12 or 13

Pulse Mode

Function Code 70 = 3 (or 13 for CL-5E)

The same terminals and contacts are used for this mode as shown in Figures 4-14 and 4-15, but the contacts are pulsed (momentarily closed) rather than latched closed. Each closure and waiting period between closures is expected to be at least 0.25 seconds in duration.

The number of steps of pulsed reduction, up to 10, is programmed at Function Code 76. The percent reduction per step is programmed at Function Code 77. Starting at zero percent reduction, every time the contact 1 is pulsed, one step of reduction is added to the accumulated total. EXAMPLE: If the number of steps is 3, and the percent per step is 1.5%, four successive pulses of contact 1 will cause the following percentages of reduction: 1.5, 3.0, 4.5, 0. Pulsing to one step higher than the programmed number returns the reduction to zero. Also, any time contact 2 is pulsed the reduction returns to zero.

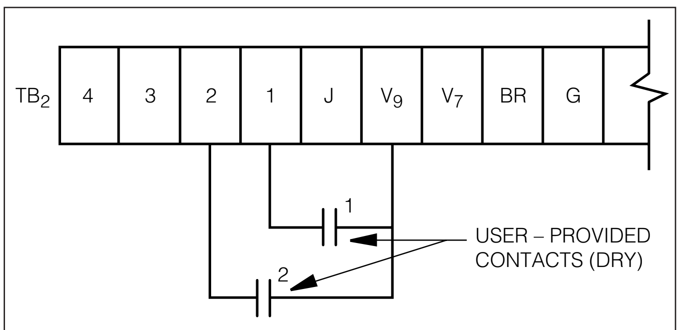


Figure 4-14.
Dry contact connections for Remote Latching and Pulse Modes

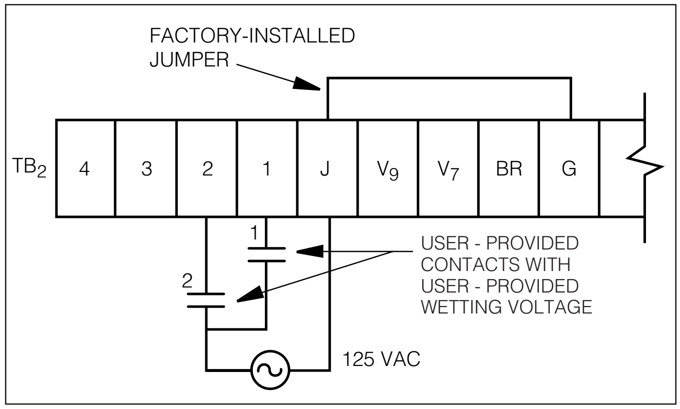


Figure 4-15.
Wet contact connections for Remote Latching and Pulse Modes

SOFT ADD-AMP

This feature (Function Code 79) allows the user to set the regulator for ADD-AMP locally at the control as well as remotely through SCADA. The SOFT ADD-AMP limits can be overridden by a local operator running the tap changer in manual mode of operation. This is not the case for the “hard” ADD-AMP limit switches on the position indicator face.

Remote Motor Control & Auto Inhibit

Terminal board TB_8, located below RCT_1 on the control back panel, is supplied for user connections for Auto Inhibit (blocking) and Motor Control. See Figure 4-16. When the motor is controlled remotely, it is necessary to inhibit automatic operation. To control Auto Inhibit remotely, remove the jumper between terminals 4 and 5 and connect normally-closed contacts. Latching open those contacts inhibits automatic operation.

To remotely raise or lower the tap changer, the appropriate set of contacts is momentarily closed. An optional SCADA relay (current relay) is recommended if there is any chance that the raise and lower contacts may be closed simultaneously. If user-provided interposing relays are used, such that raise and lower contact closure cannot occur simultaneously, then the SCADA relay is not required. If the SCADA relay is not used, then the operator should make a permanent connection from TB_2-V_9 to TB_8-2.

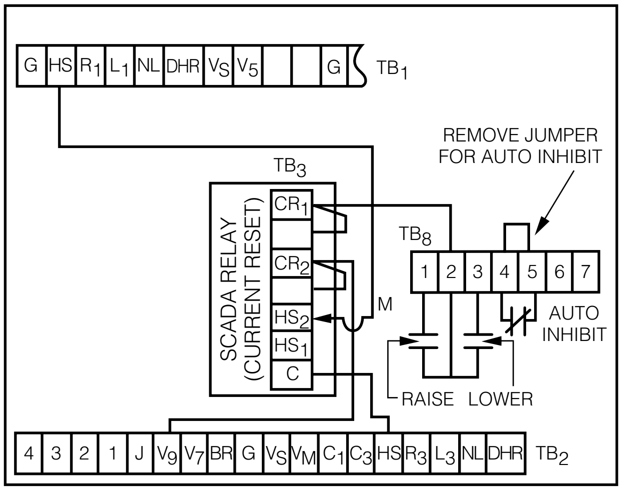


Figure 4-16.
Auto inhibit and remote motor control connections

Transducer Connections

Refer to Figure 6-5, page 6-11 . To monitor the load voltage (forward direction), a transducer, nominal 120 V ac input, may be connected as follows: Connect the transducer hot lead to terminal V_4 on TB_1 and its ground lead to G on TB_1. A current transducer, 200 mA input, may be connected as follows: Close knife switch C. Remove the jumper between C_2 and C_4 on TB_1. Connect the transducer hot lead to C_2 and its ground lead to C_4. Open knife switch C.

Fooler Voltage Scheme

Using this method, the voltage sensed by the control is raised, thereby “fooling” the control into reducing the voltage during its normal automatic operation. This method can be used with all CL-5 Series controls. A VR module, as shown in Figure 4-17, is usually supplied by the Remote Terminal Unit manufacturer. The VR module is usually a tapped auto-transformer with a pulse-activated indexing relay. When connected to the control back panel as shown, the voltage sensed by the control is raised as the module is pulsed to higher taps.

Since this method keeps the control in automatic operation, Auto Inhibiting is not used. An advantage of this method is that it can be applied to many different models of controls from many manufacturers. A disadvantage of this method is that while VR is activated, the measured load voltage is incorrect, as are all other calculated metering values which use the load voltage. To avoid the effects of metering inaccuracy, we recommend that the CL-5 Series Pulse Mode of VR be used.

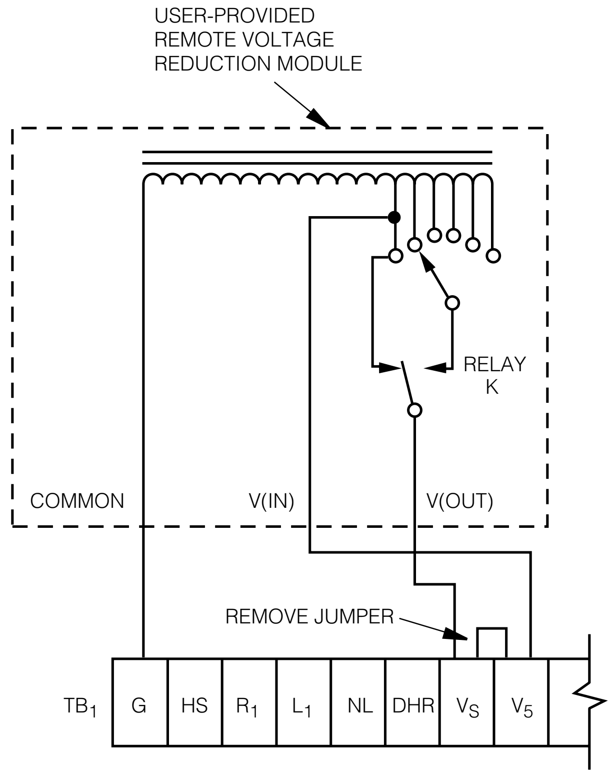


Figure 4-17.
Typical user provided “Fooler Voltage” module

Digital Scada

Communication Protocols

The standard communications protocol used by the CL-5 Series control is C.P.S. DATA 2179. This protocol is resident in the control, therefore a DATA 2179 protocol conversion board is not required by the CL-5 Series control.

Physical Interface

The Communications Channel #2 physical connections are made to an interface board, which is mounted to the control back panel. The interface board can be factory installed or field installed. The board mounts to predrilled holes in the back panel provided on C.P.S. regulator controls since 1989 for the installation of this or other devices. A communications cable connects the interface board to the CL-5 Series communications port.

For connection to an RTU, where the distance between the control and the RTU is typically long, a fiber-optic interface board is recommended for surge isolation. For installations where the interface board is close-coupled to another device, such as a telephone modem or radio, interface boards other than fiber-optic type will be made available.

Local Operator Security

Through the communications channel, the SCADA master may read the CL-5 Series data points, write to certain data points, or reset certain data points. The technique of writing to a data point is used for performing operations such as changing settings like Set Voltage or Reverse Power Mode, or inhibiting automatic operation or controlling the tap changer motor, etc. Following is a discussion of the levels of security used to protect the local operator.

Fiber-optic/RS232 and Fiber-optic/Modem Interface Boards

2197 interface boards can be ordered either 1) equipped for Fiber-optic/RS232 capabilities or 2) equipped for Fiber-optic/Modem capabilities. The interface boards are equipped with provisions for a 3.6 volt lithium cell battery for back-up power. To maximize battery life, no battery is supplied with the unit. If a back-up battery is not installed, loss of power to the interface board will inhibit all SCADA activity with the specific control, and with other controls connected in a loop.

Fiber-optic/RS232 interface boards can communicate via SCADA. The fiber-optic option can be used in a loop or star application. The RS232 option can only be used in a star application.

Fiber-optic/modem interface boards can also communicate via SCADA. The modem option can be used in both loop and star applications. The fiber-optic option is meant to be used only to loop controls.

Supervisory Switch

The CL-5 Series controls are equipped with a Supervisory on/off switch. When this switch is in the on position, SCADA may perform the normal read, write and reset activity. When the switch is in the off position, SCADA may only read the database. This affords protection to the local operator at the front panel, while allowing the system operator to maintain surveillance.

Control Switch

If the local operator switches the control switch (auto/remote-off-manual) to either off or manual, the control internal circuitry prohibits SCADA from controlling the tap changer motor. Resets and other writes are allowed.

Active Control Security Level

If the local operator changes the control active security level to level 1 or above, or security override is set to override 1 or higher, this does not inhibit any SCADA activity. To inhibit SCADA writes and resets the local operator should turn the Supervisory switch to off.

NOTE: A local operator wishing to check automatic operation should check to make sure that the Blocking Status, Function Code 69, is set to normal (0).

NOTE: Changes to any of the communications parameters, Function Codes 60-68 take effect immediately, as compared to the CL-4C which required that the power be turned off, then on, to reset those parameters on the separate protocol communications board.

Data Retrieval and Settings Uploading

The communications #1 channel of the CL-5 Series control is dedicated to the 9-pin D-subminiature connector located on the control front panel, labeled Data Port. The Data Port is designed to interface with the McGraw-Edison Data Reader, a handheld, battery-operated data gathering device. See page 7-1 for details on the Data Reader Kit. With the Data Reader the entire control data base may be downloaded for transfer to a personal computer. Analysis of the "reading" from the control, using the Data Reader Program (included in the Data Reader Kit) allows the user to verify the control settings and analyze the conditions of the feeder as follows:

1) at the moment of the downloading (instantaneous metering), 2) maximum and minimum demand values since last reset (time-tagged demand metering), and 3) the profile of salient parameters (profile recorder).

The Channel #1 baud rate is selectable at 300, 1200, 2400 and 4800 Baud. However, to permit communications with the McGraw-Edison Data Reader, the Channel 1 baud rate is set at the factory to 4800 Baud.

Temporary connection to the Data Port may also be made with an IBM-compatible personal computer. A PC-based program, the CL-5 Interface Program, allows the local operator to 1) download the control data in a similar fashion as the Data Reader, 2) reset all metering and tap position maximum and minimum values, and upload settings which are specific to the control I.D. number. For CL-4 and CL-5 Series control readings which were obtained with the Data Reader or the Interface Program, the Interface Program also allows the user to view the data and to print custom reports.

Tap Changer

Tap Changer Operation

Spring- and Direct-drive Tap Changers

Regulators for low-current applications use stored energy spring-drive tap changers, most commonly on ratings 219 A and below. The tap changer for a specific rating is shown on the rating plate. Figures 5-1 (95 kV BIL and below) and 5-2 (150 kV BIL) illustrate typical spring-drive mechanisms.

Voltage regulators used in medium- and high-current applications employ direct or Quik-drive tap changers. Direct-drive tap changers are commonly applied above 219 A. The model 770B (Figure 5-3), 660C (Figure 5-4), and T875 (Figure 5-5) are rated 150 kV BIL.

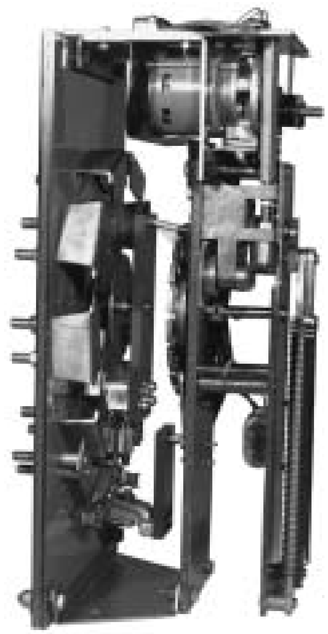


Figure 5-1.
928D Spring-drive Tap Changer

Motor

The motor for the spring-drive and direct-drive tap changer is a capacitor-start, reversing gear-motor suitable for operation at 120 V ac, single-phase, at 50/60 Hz. An integral braking mechanism controls motor coast.

The motor for the Quik-drive tap changers is a capacitor-start, high-torque, reversing, gear-motor rated 120 V ac, single-phase, at 50/60 Hz, with a spring-loaded disc brake mechanism located on the tap changer.

All components are compatible with hot transformer oil and the windings are oil cooled. The motor will carry locked-rotor current for at least 720 hours.

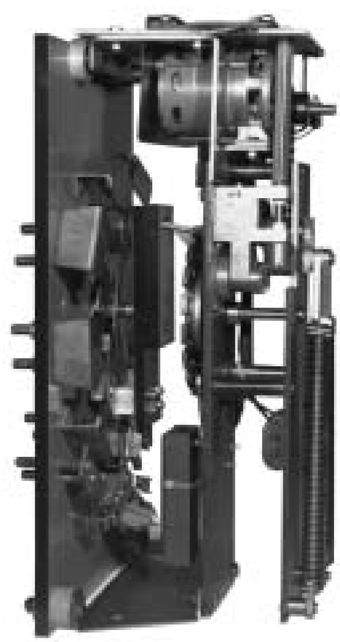


Figure 5-2.
170C Spring-drive Tap Changer

Reversing Switch

The reversing switch function changes the polarity of the tapped winding. When the spring-drive tap changer is in the neutral position, the reversing switch is open. When the direct-drive tap changer is in the neutral position, the reversing movable contact assembly is in contact with the lower reversing stationary contact (V_L).

The load current on all types is carried by the source bushing, the reactor, slip rings, main movable contacts, neutral stationary contact and the load bushing.

The reversing switch motion on the spring-drive tap changer occurs as the main movable contacts enter or leave the neutral position. A pin in the contact drive sprocket assembly engages a slot in the reversing segment when the main switch is in the neutral position. The first tap step in either direction rotates the segment and the reversing switch engages the appropriate reversing stationary.

The drive sprocket pin and reversing segment provide a mechanical stop located approximately 320° on either side of neutral. When the pin engages the end of the segment, the spring-drive mechanism will be loaded and the segment is locked to prevent any further motion in that direction.

The reversing switch motion on the direct-drive tap changers occurs as the main movable contact goes from neutral to the first raise position. On the Model 770B tap changer, a roller on the back side of the rear roller plate engages a slot in the reversing segment on the reversing insulating arm. On the Model 660C tap changer, a pinion, mounted on the same shaft as the rear roller plate, engages a slot in the reversing segment on the reversing insulating arm. As the rear roller plate rotates, the reversing movable contacts are driven from the VL reversing stationary contact to the VR contact.

Spring-drive Mechanism

Two steel extension springs are arranged in a triangular configuration to provide positive spring-over-center action to move the switch contacts. The mechanism is adjusted for smooth make-and-break contact action.

Direct-drive Mechanism

The 770B and 660C tap changers employ drive mechanisms based upon the same design principle, and many components are interchangeable. The motor turns a geneva pinion three complete revolutions per tap change. The motion of the geneva pinion turns a six-tooth geneva gear, a main drive shaft, and a scroll cam 180° per tap change. Each 180° movement of the scroll cam operates one of two roller plates and moves the corresponding main movable contacts 40°. The combination of geneva gearing and scroll cam characteristics results in a three-step, wipe/transfer/wipe contact action.

Attached to the main (geneva gear) drive shaft is a planetary gear-type mechanical stop which prevents contact motion beyond the maximum raise and lower positions.

Quik-drive Mechanism

The T875 tap changer is also a direct drive type. Once a tap change is initiated a holding switch energizes the motor through a separate circuit until the indexing motion is completed. The indexing occurs very fast. The total elapsed time to complete the action is 250 milliseconds from the time the indexing signal is started by the control. The motor turns a geneva gear pinion through a chain drive. Each full turn of the pinion rotates the geneva gear 20 degrees. The moving contacts are mounted on an insulating board that is rotationally attached to the geneva gear. This direct connection achieves accurate indexing of the contacts.

A friction brake arrests the inertia of the system once the tap change is completed. The brake is disengaged

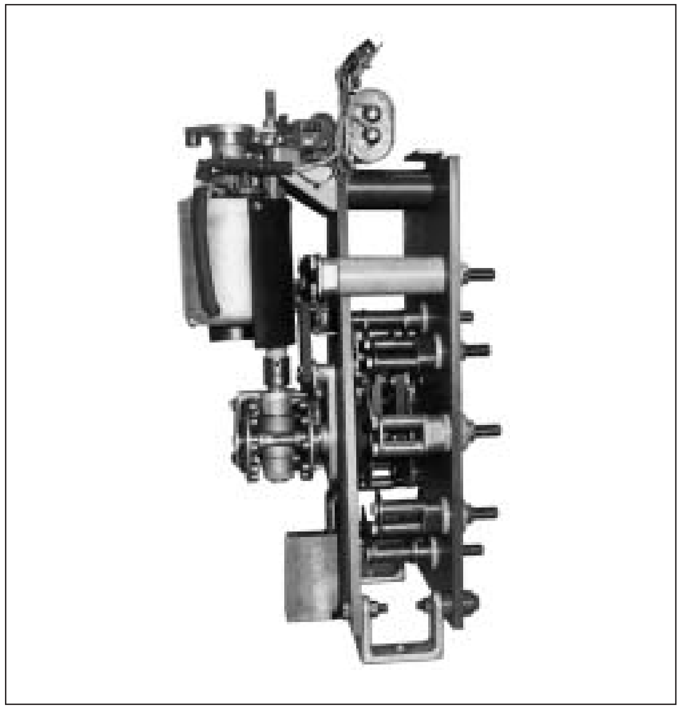


Figure 5-3.
770B Direct-drive Tap Changer

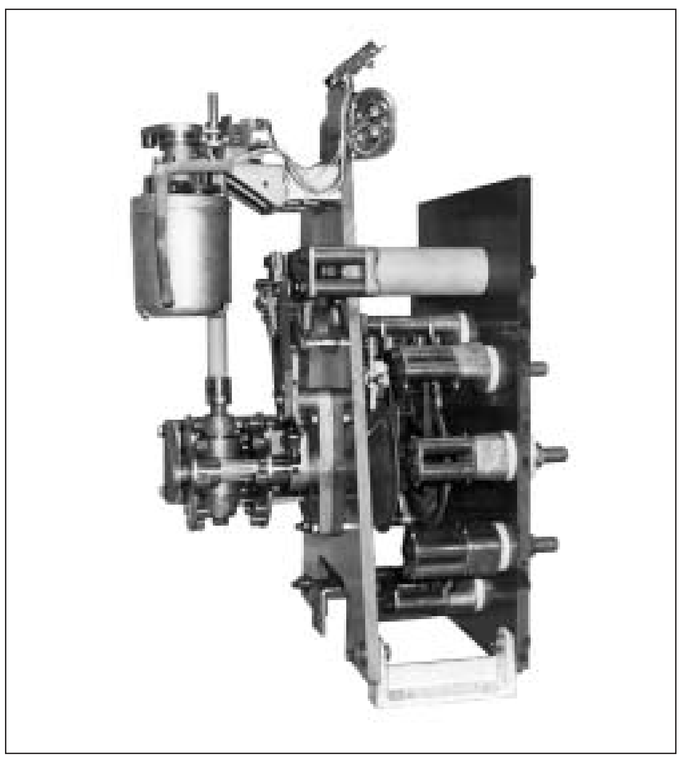


Figure 5-4.
660C Direct-drive Tap Changer

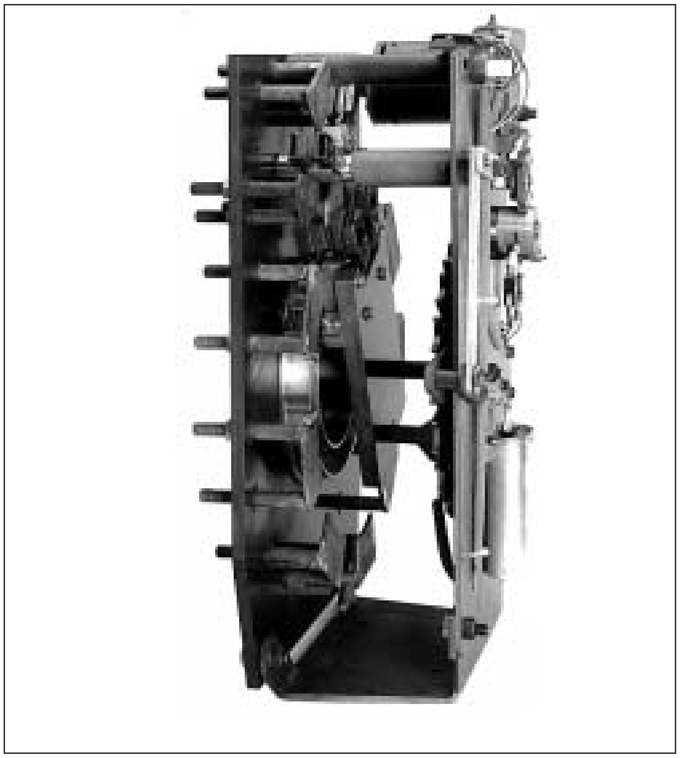


Figure 5-5.
T875 Quik-drive Tap Changer

during the indexing motion. A mechanical stop prevents rotation of the geneva beyond the maximum position.

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 steel leaf springs (in the spring-drive tap changers) or by opposing steel compression springs (in the direct-drive and Quick-drive tap changers). The main movable contact is split to make contact on both surfaces of the slip ring and to resist separation in the event of high-current surges.

There are several types of arcing contacts on a regulator tap changer. They can be divided into two categories, stationary and movable.

1. The main stationary contacts are connected to the series-winding taps. The main movable contacts connect the slip rings to the main stationary contacts.
2. The reversing stationary contacts are connected to opposite ends of the series winding. The reversing movable contacts connect the neutral stationary contacts and load bushing to the reversing stationary contact.

NOTE: The neutral stationary contact in the direct-drive tap changer has both arcing and non-arcing contact conditions.

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.

Silver tungsten is used for movable contacts in high-current applications.

Contact erosion is a function of many variables such as system parameters voltage, load current, power factor, reactor design and main winding design.

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. Refer to S225-10-2 for complete information and typical erosion patterns for the various stages of contact life.

Spring-drive Operating Sequence

When the spring-drive switch is in the neutral position and the control calls for a tap change, the following events occur:

1. Motor brake releases and motor starts.
2. Motor holding switch closes, assuring that one tap change will be completed.
3. The up-slope of sprocket cam engages a lip of the spool. This lifts the pin in the pin cam and frees it from the hole in the actuator.
4. A projection on the sprocket cam contacts a leg on the pin cam, and both turn.
5. Drive shaft, which is attached to the pin cam, begins to turn the crank arm and the springs begin to extend.
6. Pin comes free from the lip on the spool and a spring pushes it against the surface actuator.
7. Down-slope of sprocket cam returns the spool to the start position.

8. Pin drops into the hole in the actuator 180° from the start position.
9. At this point, the crank arm is at top dead-center and the springs are fully loaded. Drive shaft and crank arm, sprocket cam, pin cam and actuator are locked together and connected through the chain to the motor.
10. Motor drives all parts beyond top dead center.
11. Spring unloads, instantaneously pulling pin cam and actuator through 180° at high speed. Pins on the actuator cause the contact drive sprocket to index one tap position.
12. As the contact drive sprocket moves, it imparts motion to the reversing switch segment and main movable contacts. This action closes the reversing movable and reversing stationary contacts and drives the main movable contact onto the adjacent main stationary contact. Also, the neutral light switch opens.
13. Motor continues to turn the sprocket cam until the motor holding switch opens. The gear motor output shaft has completed one revolution.

Should more than one tap change be required, the proceeding sequence will be repeated (except reversing switch portion) until the control is satisfied or the limit switch in the position indicator is reached.

Direct-drive Operating Sequence

When the switch is in neutral and the control calls for a tap change in the raise direction, the following events occur:

1. Motor brake releases and motor starts.
2. Geneva pinion rotates counter-clockwise to engage the geneva gear.
3. Geneva pinion drives the geneva gear, main drive shaft, and scroll cam through 60° and produces initial wipe action at the front main movable contact and reversing movable contacts.
4. Motor holding switch closes, assuring that one tap change will be completed.
5. Geneva pinion completes first revolution and continues to rotate.
6. Geneva pinion drives the geneva gear through 60° and the scroll cam and roller plates transfer the front main movable contacts from the neutral stationary contact N to the stationary contact No. 1. Simultaneously, the reversing movable contact is transferred from the reversing stationary contact (VL) to the stationary contact (VR).
7. Neutral light switch opens.
8. Geneva pinion completes second revolution and continues to rotate.
9. Geneva pinion drives the geneva gear, main drive shaft, and scroll cam through 60° and produces final wipe action at the front main movable and reversing movable contacts.
10. Motor holding switch opens.
11. Motor brake engages.
12. Motor stops.

A tap change from No. 1 raise position to neutral will be accomplished as described, except the geneva pinion will rotate clockwise. The reversing movable contact will be transferred from the reversing stationary contact (VR) to the stationary contact (VL).

Quik-drive 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 begins to turn.
2. The motor sprocket drives the main sprocket through the chain drive.
3. The geneva pinion on the main sprocket enters the geneva slot and begins to index the geneva.
4. The holding switch closes to insure the tap change will go to completion. The control opens the initial circuit. The motor is energized only through the holding switch.
5. The reversing switch pin on the geneva begins to drive the reversing switch indexing 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, driving the reversing switch contacts to pivot, and bridge the neutral contact to a stationary contact connected to one end of the series winding is thus established. No arcing occurs across the reversing switch contacts.
8. The main interrupting contacts slides over and onto the number one stationary contact, making a bridging position from contact N to contact 1 through the reactor.
9. The geneva pinion exits the geneva slot. The geneva stops moving and is rotationally locked.
10. The holding switch opens and de-energizes the motor.

11. The brake engages a disk in the main sprocket and brings it to a stop at mid travel.
12. The motor shaft has completed a 360 degree turn. The elapsed time from step 1 to step 13 is 250 milliseconds.
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.

Troubleshooting Guide

Complete Regulator in Service

WARNING: When troubleshooting energized equipment, protective gear must be worn to avoid personal contact with energized parts. Failure to do so may cause serious injury or death.

External Check

When service personnel arrive at what appears to be a malfunctioning regulator, it is advisable to examine the power connections first. For example, verify that the source lead is connected to the source bushing; that the load lead is connected to the load source bushing; and that the source-load lead is connected to the source-load bushing. Check for other potential problems, such as an open ground connection.

Defining the Problem

Refer to Figure 6-2, page 6-7 while diagnosing the problem.

After the external power connections have been checked, check the voltage-disconnect knife switch (V_1 and V_6 if present) and the current shorting knife switch (C) of the rear panel signal circuit in the control box. Close the voltage disconnects if open. Open the shorting switch, if closed.

Check for loose connections or burnt wiring. Make sure the ratio-correcting transformer RCT_1 is on the correct tap for the regulated voltage shown on the nameplate on the control box door.

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

NOTE: Use only 350 V ac, slow-blow ceramic 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 above checks do not identify the problem, determine which of the following three categories best describes the malfunction, and follow the corresponding diagnostic steps:

The Regulator Will Not Operate Manually or Automatically

Diagnosing Trouble:

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 be approximately the set voltage setting.
3. Place the voltmeter hot lead on TB_1-L_1 and then toggle the lower switch.
4. Measure the voltage between terminals L_1 and G on terminal board TB_1. The voltage reading should be approximately 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 or control cable. Refer to the junction box troubleshooting section on page 6-3.
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 V_M and G on terminal board TB_2. The reading should be approximately the set voltage value.
9. If Step 8 measures correctly, the trouble could be an open motor fuse, power switch or control.
10. If Step 8 does not yield a voltage measurement check the voltage between $PD_1 1$ (V_1) 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. Refer to the junction box troubleshooting section on page 6-3. If the junction box checks are satisfactory, the trouble is in the regulator tank. See S225-10-2 for the troubleshooting method.

The Regulator Will Operate Manually But Not Automatically

Diagnosing Trouble:

1. If the control will not operate automatically, verify that the band edge indicators are functioning. (These are the HIGH and LOW indicators located on the display.) If they are not functioning, check

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Function Code 56, Reverse Sensing Mode. Set it to 0, if it is not there already. Retry the automatic mode of operation.

2. Verify that Function Code 69 (Auto Blocking) is set to 0 (Off). Retry 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 ratio correcting transformer of the rear signal circuit. Replace them.
4. If check "a" indicates that the trouble is in the control, refer to Control Troubleshooting.
5. Check the hold switch circuit.
   a. The tap changer will complete a tap change by placing the control function switch to MANUAL and toggling and holding the raise/lower switch in the desired direction for 2 seconds.
   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 "hold switch" circuit.
   c. Check for voltage between TB_2-HS and G, and TB_1-HS and G. If voltage is present at TB_1-HS and not on TB_2-HS, the problem is in the back panel wiring harness. Replace the orange HS lead from TB_1-HS to TB_2-HS. If no voltage is present at TB_1-HS, the problem is in the control cable, junction box cover or the hold switch (located inside the regulator) itself. Check cable continuity up to the junction box. If it appears normal, the problem is the hold switch. Adjust or replace it (See S225-10-2). If all appears to be in order, the problem is not in the hold switch, but most likely in the control.

The Regulator Operates Manually but Operates Incorrectly When Set On Automatic

Diagnosing Trouble:

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 checks are correct, then the malfunction is probably in the control. Refer to Control Troubleshooting, following.

Control Troubleshooting

At this point, the problem has been determined to be in the control, so the front panel should be taken out of the control cabinet to a service bench for troubleshooting. Figure 6-2, page 6-7 can be used to aid the troubleshooting process. The panel components are checked by using an external voltage of approximately 120 V ac, 60/50 Hz, applied to the external source terminals of the control.

To gain access to the front panel components, first remove the back shield. This is accomplished by removing the cable clamp attached to the shield side, and then removing the four nuts which secure the shield to the front panel.

1. Check the motor and panel fuses to ensure they have not blown.
2. Connect the power source to the external source terminals, **observing the proper polarity**.

> **WARNING:** Correct polarity must be administered to the control. Failure to do so will cause a short circuit of the users' voltage supply and possible damage to the control.

   Place the power switch on the EXTERNAL position.

3. The control display should light. If the display does not light, measure the voltage on the printed circuit board from terminals P_5-4 to P_5-3, expecting to measure approximately 120 V ac.
4. If the display does not light and no voltage is measured from terminals P_5-4 to P_5-3, then the problem is in the power switch. The power (Internal-Off-External) switch can be checked by measuring the voltage from switch terminal PS_2 to ground, switch terminal PS_5 to ground, and switch terminal PS_8 to ground. These measurements should equal the external voltage applied. If not, the power switch is defective.
5. If the display does not light and voltage is measured from terminals P_5-4 to P_5-3, then the circuit board is defective and must be returned to the factory for repair.
6. If the display does light, but reports the FAIL message, then the internal diagnostics have detected a problem. When the word FAIL appears, it does not necessarily indicate the control is malfunctioning.

   Display Function Code 95.

Compare the display number with the System Status Code, page 3-16. If any number other than 0, 6, 7 or 10 is displayed, the control has failed, and in need of repair. Contact Cooper Power Systems for return authorization information. If 10 is displayed, it means there is no neutral light signal and the control has Function Code 12P set to 0 (neutral). Change FC 12P from 0 to 1, then reboot the control. It will now PASS.

The front panel circuits for the drag-hand reset solenoid (DHR) and neutral light (NL) can be checked as follows:

1. Connect the ac voltmeter from G to DHR on fanning strip TB_2 (identified as white wire [G] and white/orange tracer [DHR]).
2. Depress the drag-hand reset toggle switch and observe approximately 120 V on the voltmeter. If no voltage is measured, the switch is probably defective.
3. Connect a 120 V ac source to the fanning strip TB_2-NL (identified as white/red) and fanning strip TB_2-G and TB_2-NL ground (identified as white). The neutral light on the control panel should light. If not, the bulb may be bad.

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, on page 6-1).

The junction box is composed of a terminal board, the position indicator, and the control box interconnections. Refer to Figure 6-1, page 6-5, when the following steps are made:

1. Remove the regulator from service, as stated on page 1-10.
2. Ground the three high-voltage bushings.
3. Open V_1, 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 troubleshooting section of 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 Position Indicator Replacement below.
    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 Position Indicator Replacement below.
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 Position Indicator Replacement, below.
17. If 120 V is not read, refer to Control Troubleshooting, page 6-2.

Position Indicator Replacement

The following instructions apply only to the junction box mounted position indicator construction that was initiated in April, 1980.

To replace a defective position indicator, the unit must be removed from service as outlined in Removal from Service, page 1-11.

WARNING: This procedure must only be performed on a regulator that is out of service.

1. A defect in the position indicator may have caused loss of synchronization between the tap changer and the indicator hand. 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 S225-10-2, Regulator Tap Changer Operation and Maintenance.
2. Remove the junction box cover.
3. Note the location of the indicating hand for future alignment and disengage the flexible shaft from the position indicator shaft. In early 1989 this joint was changed to a setscrew type coupling. Older equipment employed a cotter pin coupling.
4. Disconnect the four leads from the junction box terminal board and open the two splice terminals to the control cable. Refer to Figure 6-1.
5. Remove the three bolts holding the indicator to the junction box and slide the indicator free.
6. Remove the gasket from the groove on the back of the indicator body.
7. Clean the gasket surface of the junction box and the gasket and groove on the new indicator.
8. Place the gasket in the groove and insert the leads through the junction box wall, align the holes and install the three bolts finger tight.
9. Wrench-tighten the bolts to evenly compress the gasket and bring the indicator body tight against the junction box.
10. Connect the six leads to the terminal board and control cables leads per Figure 6-1 and secure all connections.
11. Turn the indicator drive shaft to place the hands at the previously noted position.
12. Slide the flexible shaft coupling into the indicator coupling and secure the allen screws.
13. Position the wires to prevent snagging on the couplings and secure the wires with tie wraps.
14. Connect a 120 V ac external power supply to the external banana jack on the front of the control panel.
15. 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.
16. The following steps are instructions for setting the proper alignment to ensure **rotational calibration on** a new "Cooper " 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 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 2 set screws to 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 as follows:
    d. 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 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 e. If the scribe line is inside the notch, proceed to e.
    e. 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 16 in-lbs.
    f. 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 then proceed to steps 17. If at any time that 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.
17. Replace the junction box cover.

Control Calibration

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

WARNING: It must be verified 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.

Voltage Calibration

1. Connect an accurate true-RMS-responding voltmeter to the voltmeter terminals. 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. Place the power switch on 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. This is accomplished by entering the proper security code at Function Code 99. Depress the following keys on the keypad:

   FUNCTION, 99, ENTER; 32123, ENTER

   The proper level of security is now activated.
6. Access Function Code 47 by keying FUNCTION, 47, ENTER.
7. 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 (see Table 2-1 for allowable tolerances), the calibration can be altered by keying CHANGE, and then entering the correct voltage as displayed on the reference meter, followed by ENTER. The voltage circuit is now calibrated.

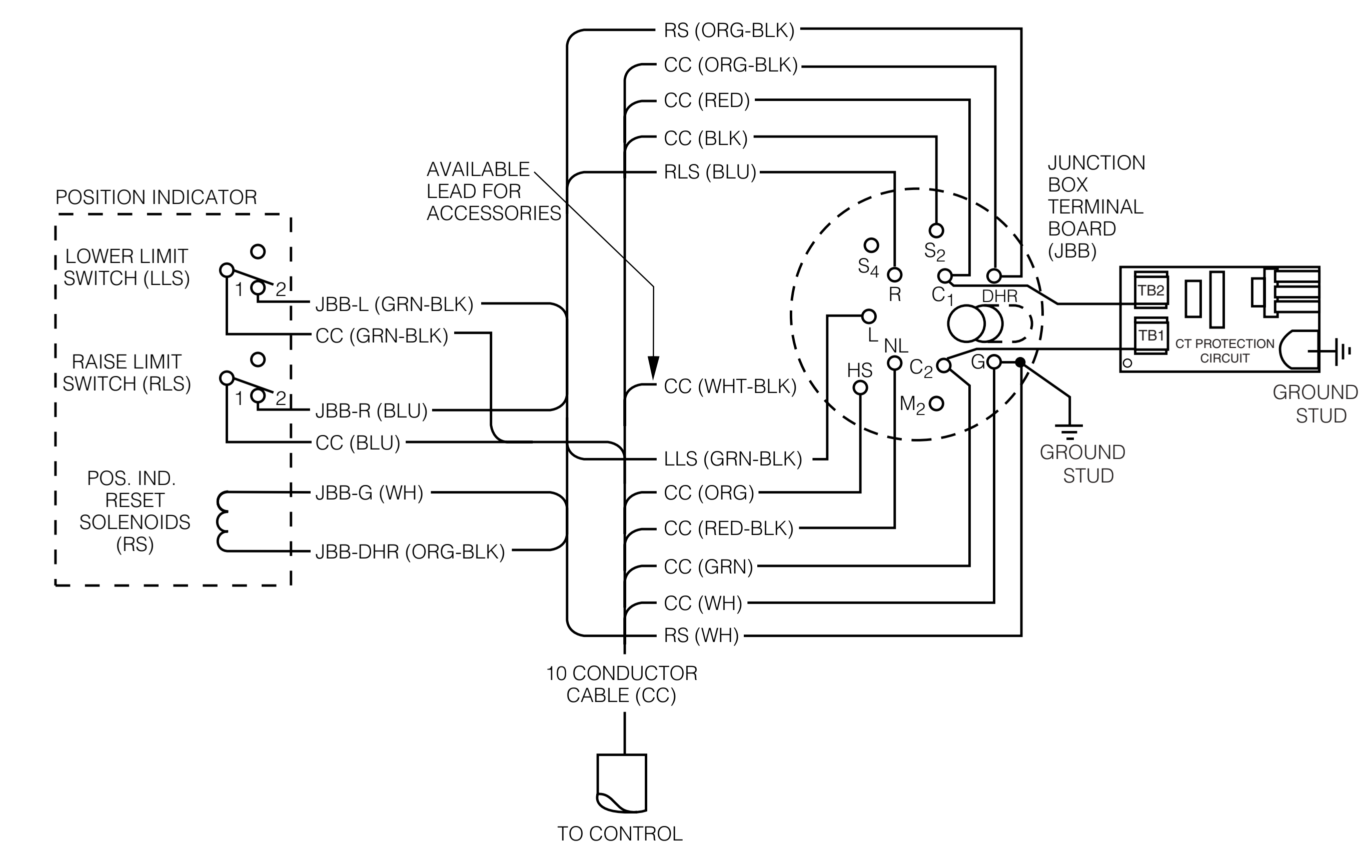


Figure 6-1.
Junction Box Wiring Diagram

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 C_1 and C_3 on fanning strip 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. This is accomplished by entering the proper security code at Function Code 99. Depress the following keys on the keypad:

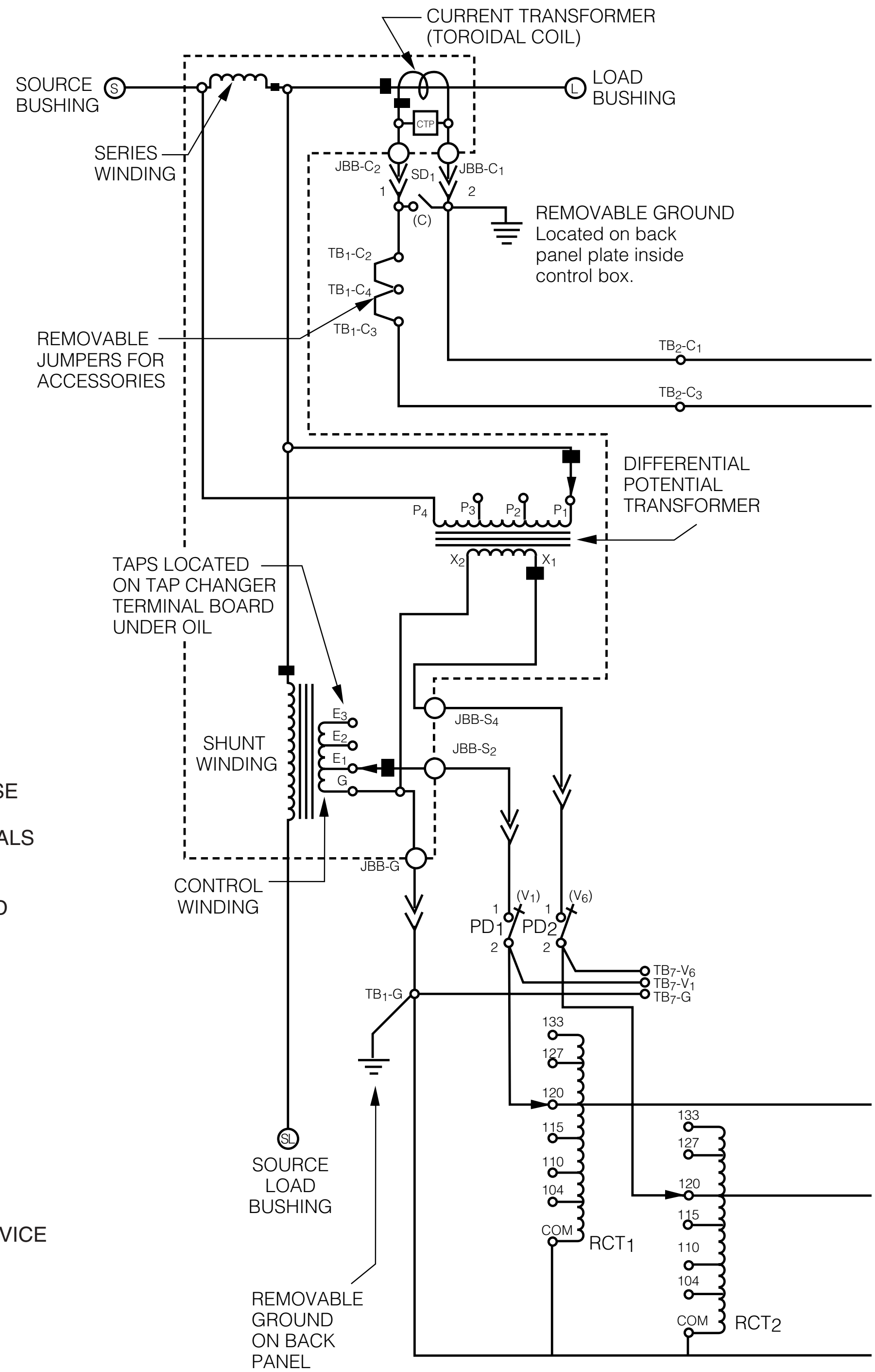
   FUNCTION, 99, ENTER; 32123, ENTER

   The proper level is now activated.
7. Access Function Code 48 by keying 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 milliamperes error), the calibration can be altered by keying CHANGE, and then entering the correct current as displayed on the reference meter, followed by ENTER. The current circuit is now calibrated.

CIRCUIT BOARD CONNECTORS

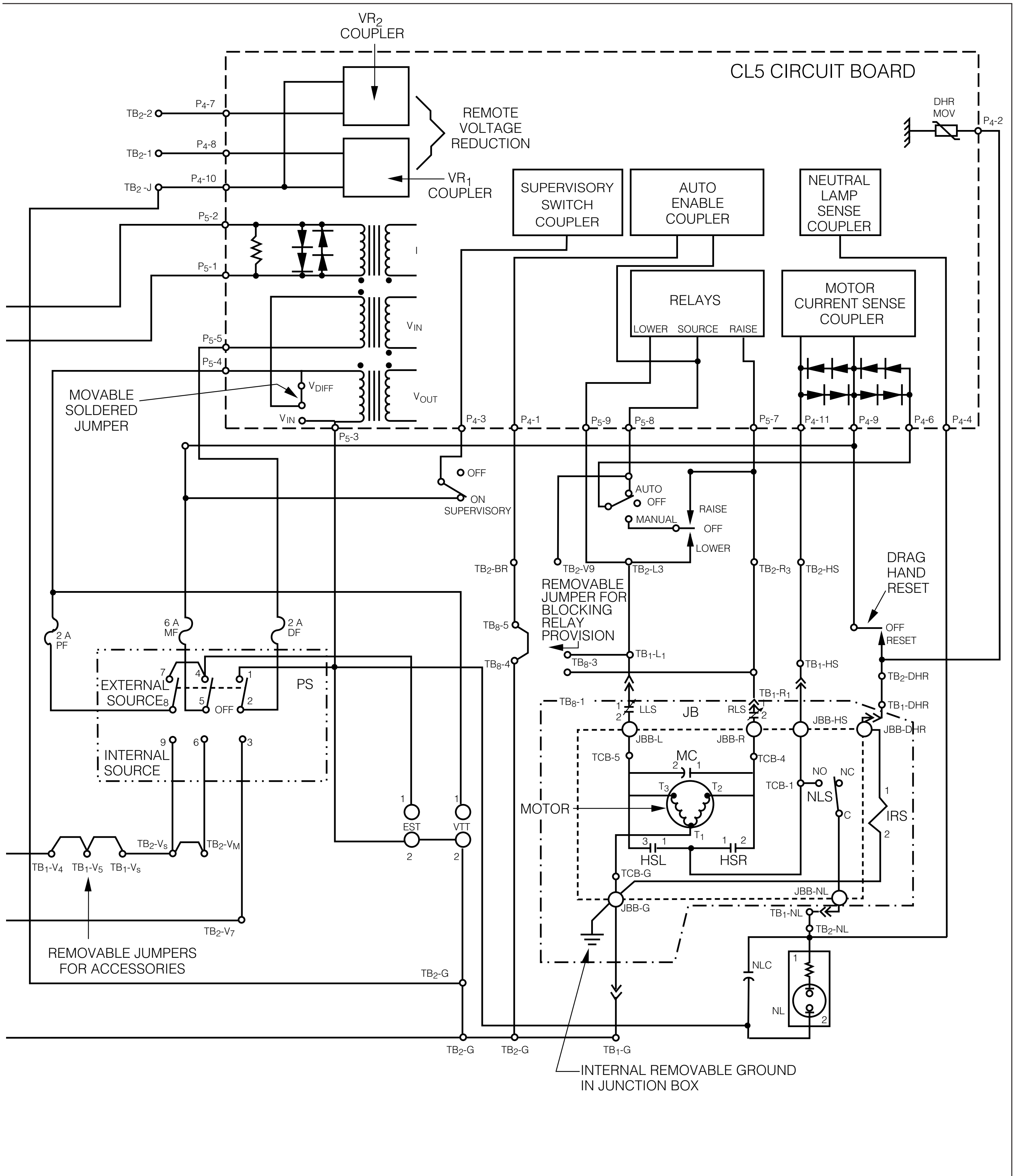
CONNECTOR P4
- 11 ORANGE
- 10 VIOLET
- 9 WHITE
- 8 BROWN
- 7 YELLOW
- 6 WHITE/PURPLE
- 5 (BLANK)
- 4 WHITE/RED
- 3 RED/WHITE
- 2 WHITE/ORANGE
- 1 WHITE/BLUE

CONNECTOR P5
- 9 WHITE/GREEN
- 8 RED/BLACK
- 7 BLUE
- 6 (BLANK)
- 5 WHITE/BROWN
- 4 BLACK
- 3 WHITE
- 2 GREEN
- 1 RED

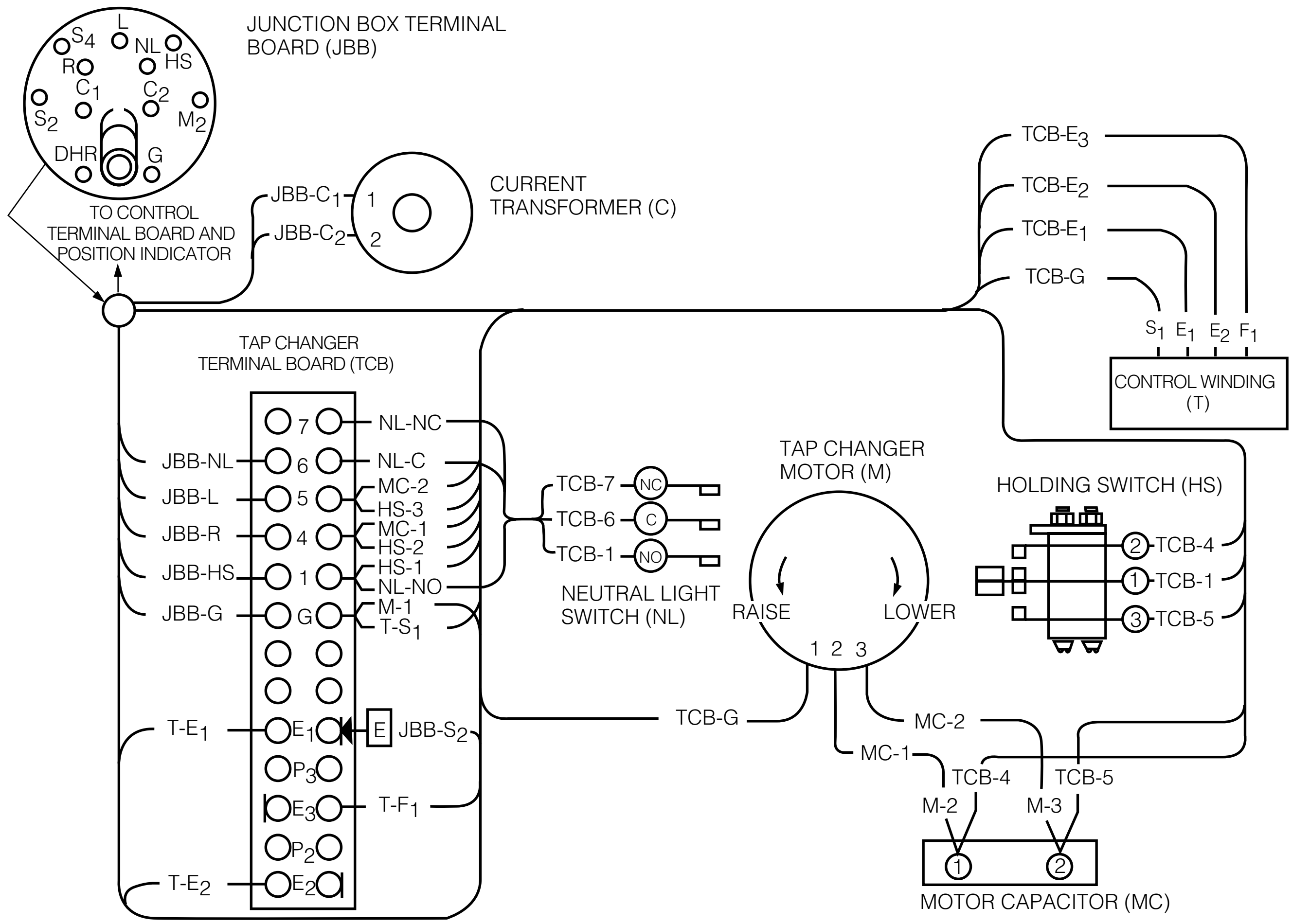


- CTP - CURRENT TRANSFORMER PROTECTOR CIRCUIT
- DF - DIFFERENTIAL VOLTAGE FUSE
- DHR - DRAG HAND RESET
- EST - EXTERNAL SOURCE TERMINALS
- HSL - HOLDING SWITCH LOWER
- HSR - HOLDING SWITCH RAISE
- IRS - INDICATOR RESET SOLENOID (POSITION INDICATOR)
- JB - JUNCTION BOX ON REGULATOR COVER
- JBB - JUNCTION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

Figure 6-2.
Wiring diagram for Type B VR-32 Regulator and control with differential potential transformer



Note: Portions of schematic shown in dotted enclosure (----) are located in regulator tank.
Portions of schematic shown in dashed enclosure (– – – –) are located on the circuit board.
Portions of schematic shown in short-long dashed enclosure (— - —) are located in the junction box near the tank cover.
Portion of schematic shown in short-short-long dashed enclosure (— - - —) is the power switch on the front panel.



HS-1 — BLACK
HS-2 — BLUE
HS-3 — RED
JBB-C_1 — WHITE
JBB-C_2 — BLACK
JBB-G — WHITE
JBB-HS — ORANGE

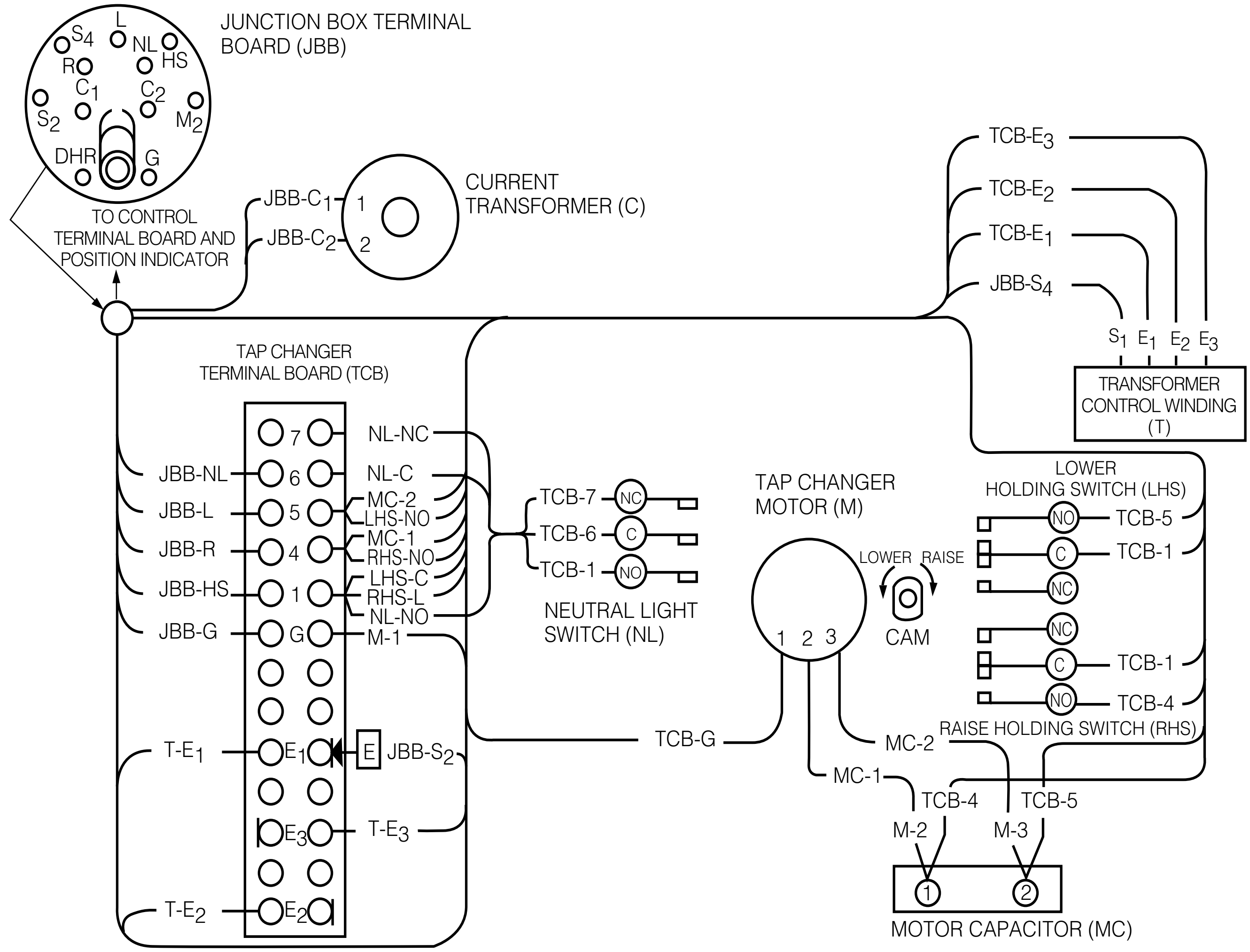
JBB-L — GRN/BLK
JBB-NL — RED/BLK
JBB-R — BLUE
JBB-S_2 — WHITE
M-1 — WHITE
M-2 — BLUE
M-3 — RED

MC-1 — BLUE
MC-2 — RED
NL-C — WHITE
NL-NC — GREEN
NL-NO — ORANGE
T-F_1 — WHITE
T-E_1 — WHITE

T-E_2 — WHITE
T-S_1 — WHITE
TCB-1(HS) — BLACK
TCB-1(NL) — ORANGE
TCB-4 — BLUE
TCB-5 — RED
TCB-6 — WHITE

TCB-7 — GREEN
TCB-E_1 — WHITE
TCB-E_2 — WHITE
TCB-E_3 — WHITE
TCB-G — WHITE

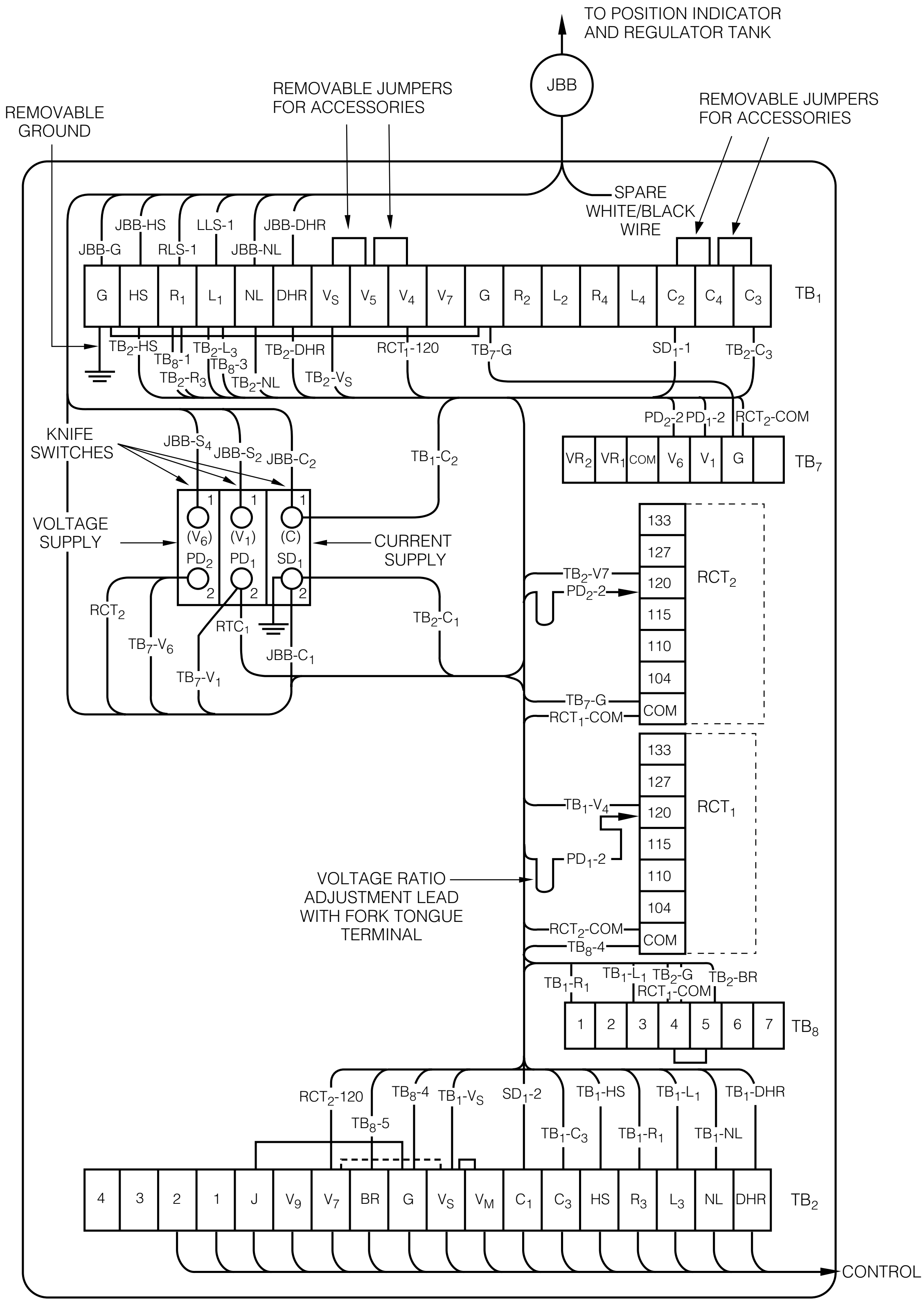
Figure 6-3.
Typical internal wiring of regulator with spring and direct drive tap changer



JBB-S_4 ($SWPT-Y_1$) — BLACK
SWPT-X_1 — BLACK
SWPT-X_2 — WHITE
LHS-NO — BLACK
RHS-NO — BLUE
LHS-C — RED
JBB-C_1 — WHITE
JBB-C_2 — BLACK
RHS-C — BLACK
JBB-G — WHITE
JBB-HS — ORANGE
JBB-L — GRN/BLK
JBB-NL — RED/BLK
JBB-R — BLUE
JBB-S_2 — WHITE
JBB-S_4 (T-S_1)— WHITE
M-1 — WHITE
M-2 — BLUE
M-3 — RED
MC-1 — BLUE
MC-2 — RED
NL-C — WHITE
NL-NC — GREEN
NL-NO — ORANGE
T-E_1 — WHITE
T-E_2 — WHITE
T-E_3 — WHITE
TCB-1(HS) — BLACK
TCB-1(NL) — ORANGE
TCB-4 — BLUE
TCB-5 — RED
TCB-6 — WHITE
TCB-7 — GREEN
TCB-E_1 — WHITE
TCB-E_2 — WHITE
TCB-E_3 — WHITE
TCB-G — WHITE

Figure 6-4.
Typical internal wiring of regulator with Quik-drive tap changer

JBB-G — WHITE
JBB-HS — ORANGE
RLS-1 — BLUE
LLS-1 — GRN/BLK
JBB-NL — RED/BLK
JBB-DHR — ORG/BLK
JBB-S_2 — BLACK
JBB-C_2 — GREEN
JBB-C_1 — RED
TB_2-HS — ORANGE
TB_8-1 — BLUE
TB_2-R_3 — BLUE
TB_2-L_3 — WHT/GRN
TB_8-3 — WHT/GRN
TB_2-NL — WHT/RED
TB_2-DHR — WHT/ORG
TB_2-V_s — BLACK
RCT_1-120 — BLACK
SD_1-1 — VIOLET
TB_2-C_3 — GREEN
RCT_2 — WHT/BRN
RCT_1 — BLACK
TB_7-V_6 — WHT/BRN
TB_7-V_1 — BLACK
PD_2-2 (V_6) — WHT/BRN
PD_1-2 (V_1) — BLACK
RCT_2-COM — WHITE
TB_1-C_2 — VIOLET
TB_2-C_1 — RED
RCT_1-COM — WHITE
TB_7-G — WHITE
TB_1-V_4 — BLACK
TB_8-4 — WHITE
TB_1-R_1 — BLUE
TB_1-L_1 — WHT/GRN
TB_2-G — WHITE
TB_2-BR — WHT/BLUE
TB_8-5 — WHT/BLUE
TB_1-V_S — BLACK
SD_1-2 — RED
TB_1-C_3 — GREEN
TB_1-HS — ORANGE
TB_1-NL — WHT/RED
TB_1-DHR — WHT/ORG
TB_7-G — WHITE
RCT_2-120 — WHT/BRN
JBB-S_4— WHT/BLK
TB_2-V_7 — WHT/BRN



NOTES:

TB_2-V_7 to TB_2-V_s jumper only applies to non-reverse power flow back panel assemblies supplied without RCT_2.

TB_2-V_7 is connected to RCT_2-120 on back panel assemblies set up for reverse power flow supplied with RCT_2.

Figure 6-5.
Back panel signal circuit

Accessories

Heater Assembly

The thermostatically-controlled heater assembly is best used in high-humidity areas.

The thermostat in the heater assembly will turn the heater on when the temperature falls below 85°F (29°C) and off when the temperature exceeds 100°F (38°C). For full details refer to S225-10-1 Supplement 2.

Data Reader

The optional hand-held Data Reader allows the operator to copy all of the function code parameters from the control for transfer to a personal computer. Operation of the control is not affected by the Data Reader.

The Data Reader can store 100 Meter Pac readings, 100 CL-4B/C control readings, 25 CL-5 Series control readings and 20 F4C control readings before the memory must be purged.

Data Reader and Software Kit

The Data Reader and Software Kit includes the Data Reader, the Data Reader-to-control cable, the Data Reader-to-PC cable, the Data Reader windows software and documentation. The non-copy protected software operates on an IBM-compatible personal computer with Windows 3.1 or higher. The software allows the operator to perform the following functions:

1. Upload the data from the Data Reader to the soft - ware database.
2. Erase the Data Reader memory.
3. Scan the data on the monitor.
4. Print reports.
5. Transfer data to another database.

Data Reader Assembly

The Data Reader Assembly consists of the Data Reader and the Data Reader-to-control cable.

Cooper Control Interface Software

The Cooper Control Interface (CCI) is a Windows-based configuration software package for use with the regulator CL-4C and CL-5 Series controls. The CCI allows the users to:

- Create Control Settings
- Upload Settings to the Control
- Download Readings from the Control

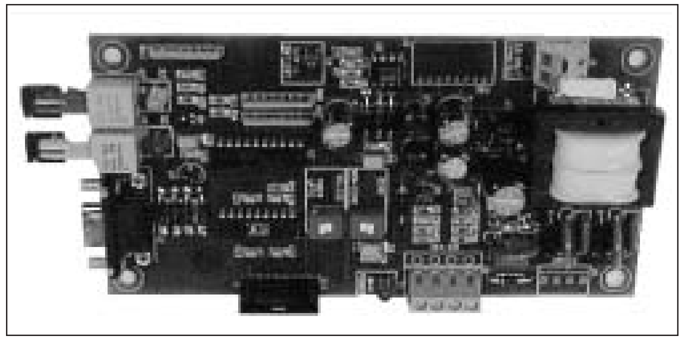


Figure 7-1.
Fiber/RS-232 Board

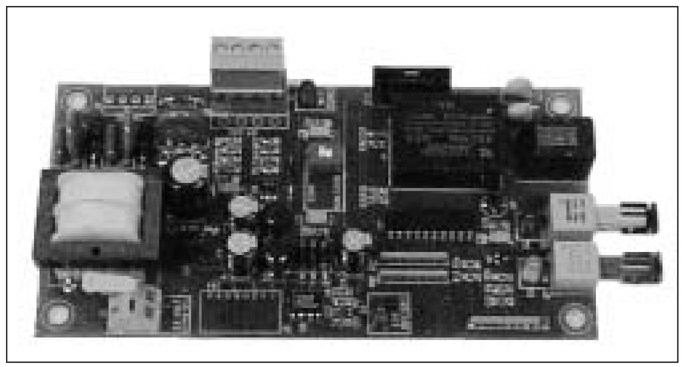


Figure 7-2.
Fiber/Modem Board

- Provide Output of Settings and Readings
- Manage Settings and Readings Effective

This program is fully compatible with Windows 95, Windows 98, Windows 2000, and Windows NT4.0 operating systems. The CCI applications use Dynamic Data Exchange (DDE) technology to connect from hardware to software easily and trouble free.

Both readings and settings are stored as non-proprietary data base formats (.xls) to allow use of the data by other applications without awkward conversions.

Its Graphic User Interface is easy to use and understand. Online help and a complete User Manual make the program easy to learn and generous toolbars make working within the program efficient.

The CCI is designed for front panel configuration with the regulator or recloser control. It also has 2179 protocol for verification with the communication port.

The program includes a file conversion routine to update all of your old files, both settings and readings, to the new file format. This conversion facilitates the transition from the old DOS-based applications to the new applications.

PC to Data Port Cable

For direct connection of a PC to the Data Port of the CL-4 or CL-5 (and also the Form 4C recloser control) a special cable is required. This special cable connects from the computer's RS-232 port to the TTL Data Port. The cable provides the proper voltage and pin configuration.

The Data Port is intended for connection with either the Data Reader black coil cord or the above PC to Data Port cable. A standard RS-232 cable will not work for interfacing from a PC to the Data Port on the CL-4 or CL-5 series controls. Use of a RS-232 may cause damage to the Data Port on the control and future connections to the Data Port may not work properly.

Digital Communications

This feature includes full remote metering and realtime operation capability. Using this feature, all metering and changing of parameters, including all of the options, can be controlled remotely. Additional remote capabilities include the ability to tap up or down a specified number of taps and the ability to determine the status of local activity. Digital communications requires the addition of one interface board to the back panel.

Digital Communication Interface Board

For connection of the CL-5 Series controls to a digital communication system, several interface boards are available.

One option is a board that provides either fiber optic or RS-232 interface with DATA 2179 communication output. A pair of standard ST type fiber optic connectors and an RS-232 port are mounted on the interface board to provide the customer connection to digital SCADA via multi-mode fiber optic cables or a standard 9-pin DB-9 RS-232 cable. Communication settings are easily changed with the use of dip switches. (See Figure 7-1.)

A second option is a board that provides modem/fiber optic interface with DATA 2179 communication output. The modem connection is just like a computer modem at 2400 baud, and is addressed simply by dialing into it via telephone. The modem connection on the board is a standard RJ-11 phone line connection. All communications to and from the digital SCADA system to the regulators utilize the modem connection. A pair of standard ST type fiber optic connectors is mounted on the interface board to provide the customer connection from regulator to regulator in a loop. Therefore, in this application, only one modem interface board is required for the loop of regulators. The standard fiber optic/RS232 boards would be supplied for additional regulators in the loop. (See Figure 7-2.)

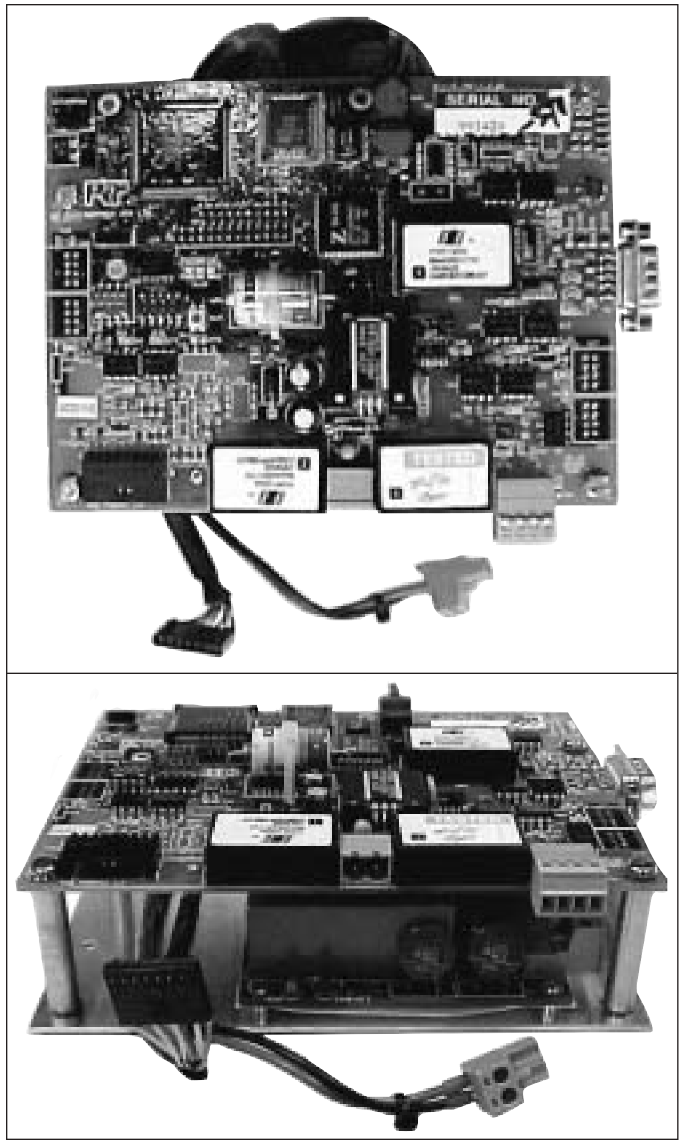


Figure 7-3.
DNP 3.0 Board

Another option is a board that provides either fiber optic or RS-232 interface with DNP 3.0 communication output. This two-layer board consists of a protocol converter interface board (from DATA 2179 to DNP 3.0) and a power supply board. A pair of standard ST type fiber optic connectors and an RS-232 port are mounted on the interface board to provide the customer connection to digital SCADA via fiber optic cables or a standard 9-pin DB-9 RS-232 cable. Communication settings are easily changed with the use of dip switches and rotary switches on the board. (See Figure 7-3.)

The boards are self-powered from the internal regulator potential transformer. A connection from the interface board is made to a port located on the inside of the CL-5 swing panel. The boards can be factory installed or easily installed at the customer's site.

SCADA Relay and Terminal Block

For analog SCADA operation (remote tap changer control), as shown in Figure 4-16, page 4-10, an optional SCADA relay and terminal block assembly is available. (See Figure 7-4.)

Remote Mounting Control Cable

For remote mounting of the control cabinet, extended cable lengths are available in 5 foot (1.5 m) increments from 15 feet (4.6 m) to 45 feet (13.8m).

Fan Cooling Accessory

Voltage regulators 250 kVA and larger can be equipped with fan cooling. Fan cooling increases the load capacity of the regulator by 33%. Special requirements are necessary on regulators using fan cooling. Therefore, the regulator must be ordered with fan cooling or with provisions for adding fan cooling. Mounting cooling fans flush to the plate-type radiator is accomplished by using T-bolts that secure the cooling fan to the bank of radiators.

The automatic operation of the fan is controlled by a thermometer having a thermal switch that will cycle the fan on or off when the top-oil temperature reaches predetermined temperature limits. The thermal switch has an upper limit adjustable from 80°C to 110°C. The differential from make to break is 6°C to 10°C. The thermal switch, when temperature-activated or deactivated, signals a relay which turns the fan on or off.

Figure 7-4.
SCADA relay and terminal block

Spare Parts

Ordering Information

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

1. Regulator serial number (found on nameplate).
2. Regulator catalog number (found on nameplate).
3. Part number (from Parts Manual*).
4. Description of each part.
5. Quantity of each part required.

*A complete list of replacement parts is available. The parts replacement list is most conveniently accessed through the EPIC CD-ROM that requires only a catalog or serial number. This CD-ROM covers parts for VR-32 and Auto-booster regulators built since 1981. Consult your Cooper Power Systems sales representative for information on receiving a CD.

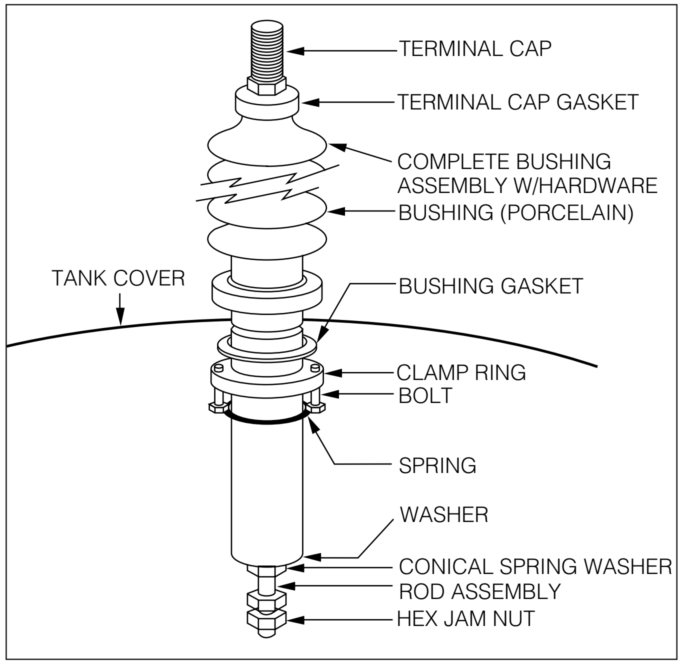


Figure 8-1.
High-voltage bushing

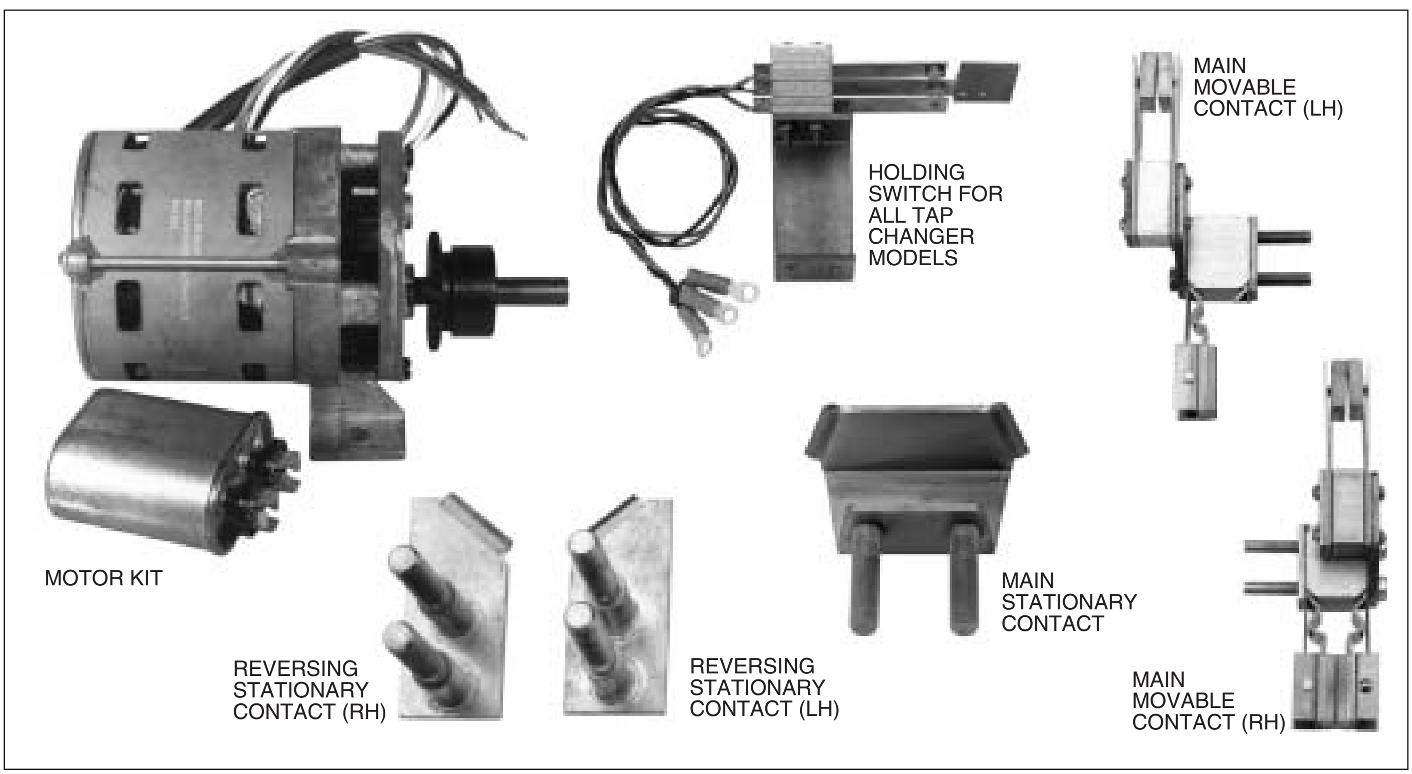


Figure 8-2.
Replacement parts for spring-drive tap changers 928D and 170C

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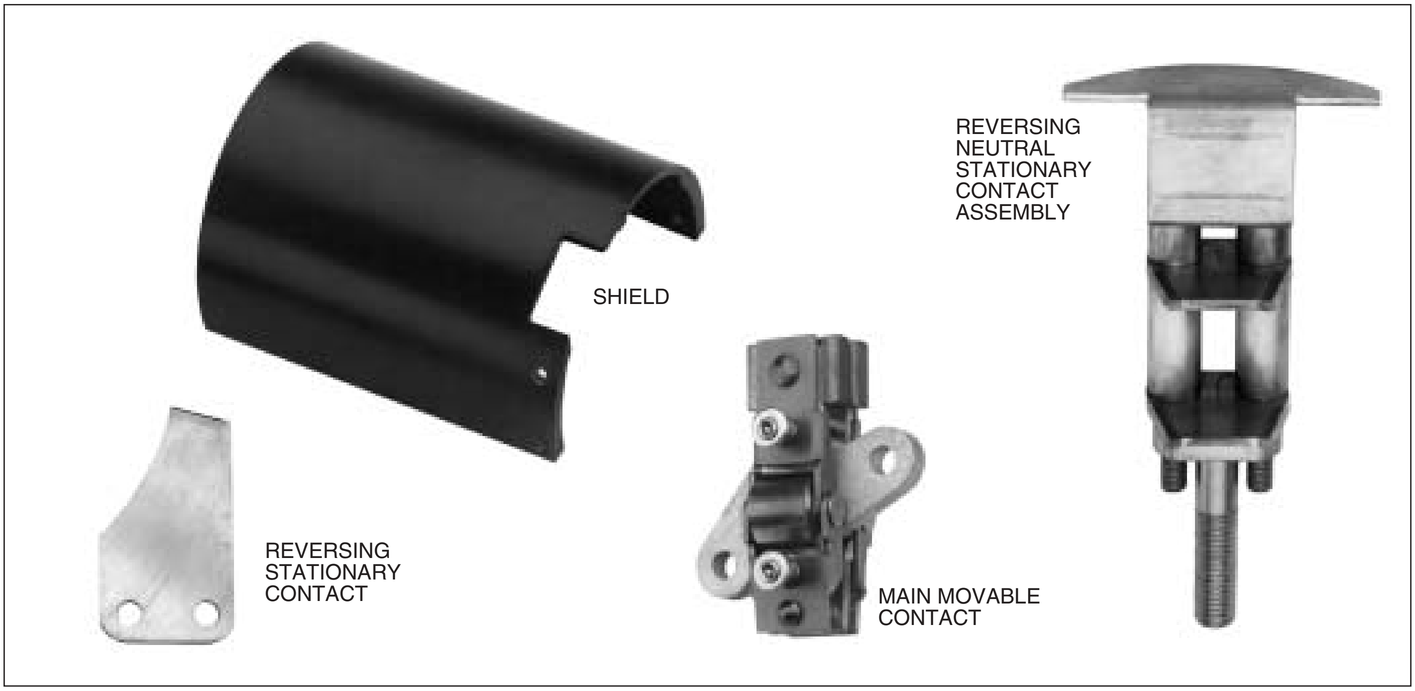

Figure 8-3.
Replacement parts for direct drive tap changer 770B

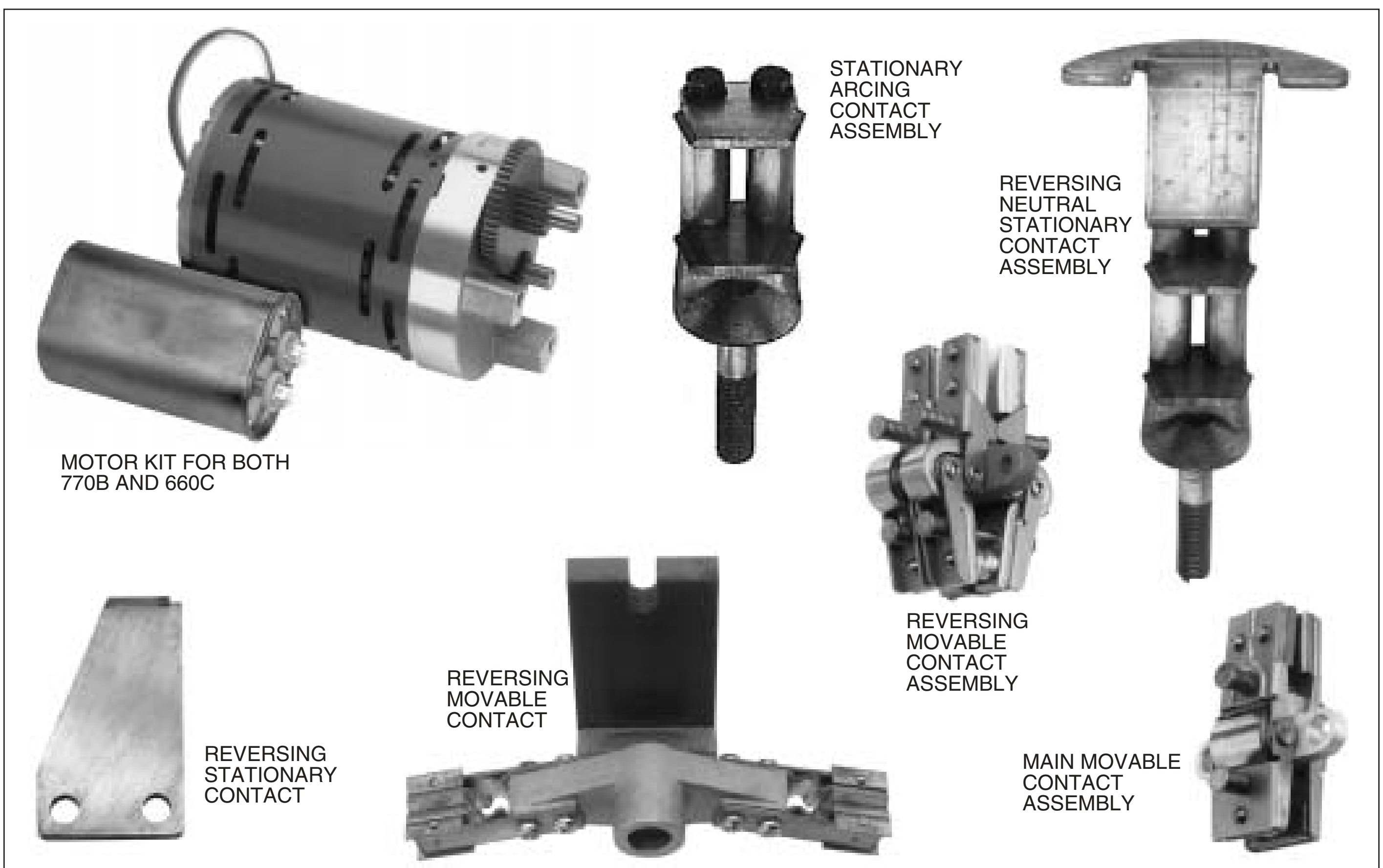

Figure 8-4.
Replacement parts for direct drive tap changer 660C

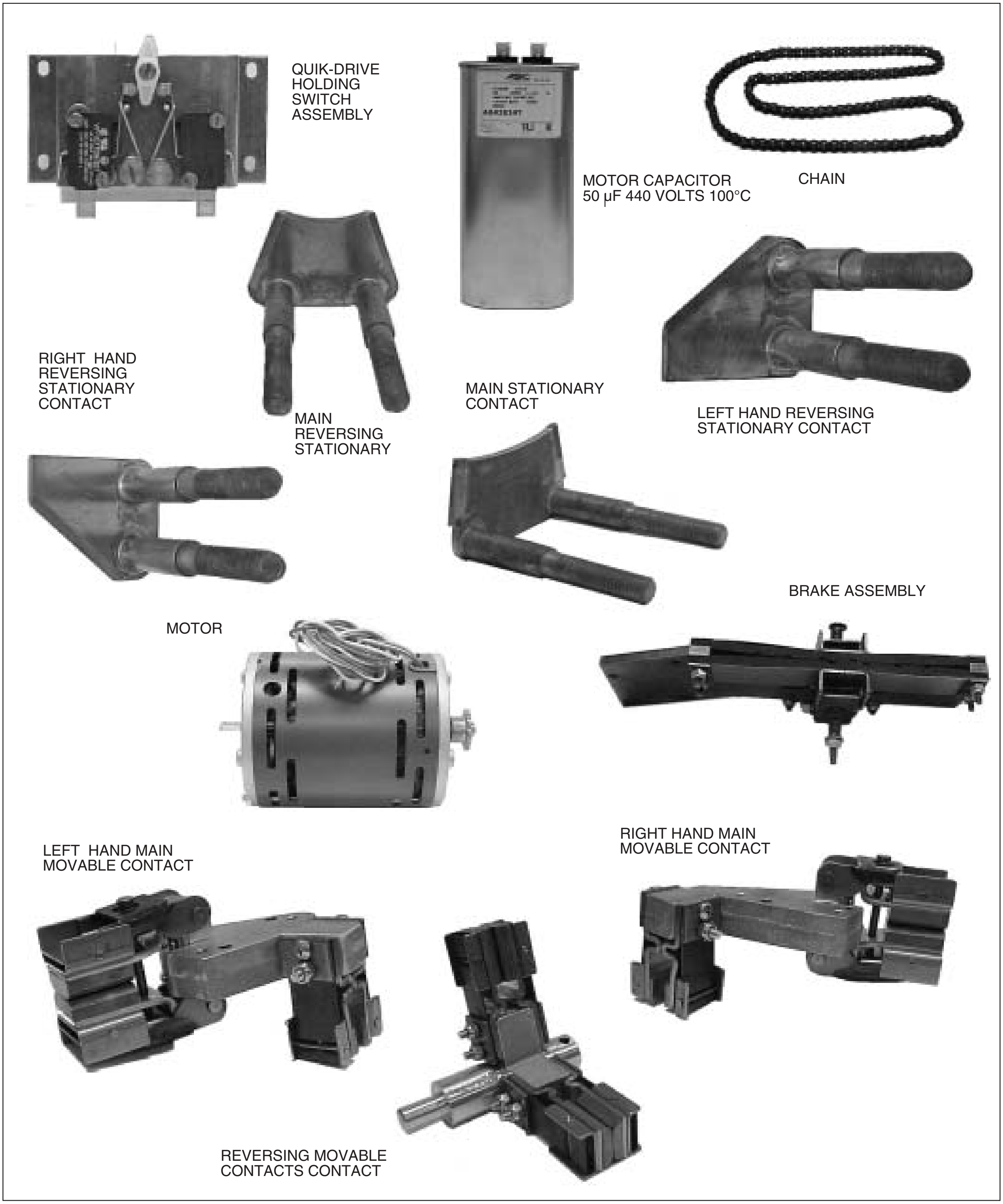

Figure 8-5.
Replacement parts for Quik-drive tap changer T875

Index

TABLE 9-1
Security Codes

Security Level	Factory-set Security Code
0	No Code Required
1	1234
2	12121
3	32123

TABLE 9-2
Error Codes

Error Code	Error Message
XX ERROR 1	Input Value too Low
XX ERROR 2	Input Value too High
XX ERROR 3	Improper Security to Change
XX ERROR 4	Invalid Security Code

Note: XX is the Function Code at which the error was made.

TABLE 9-3
CL-5 Series Regulator Control Function Codes

Function Code	Function	Security Level Change/Reset
FORWARD CONTROL SETTINGS		
0	Operation Counter (Q, R_, R¯, 1, 2, 3, 4, 5, 6)*	3*
1	Set Voltage	2
2	Bandwidth, volts	2
3	Time Delay, seconds	2
4	Line Compensation Resistance, volts	2
5	Line Compensation Reactance, volts	2
INSTANTANEOUS METERING		
6	Load Voltage, Secondary	
7	Source Voltage, Secondary	
8	Compensated Voltage, Secondary	
9	Load Current, Primary, amperes	
10	Load Voltage, Primary, kV	
11	Source Voltage, Primary, kV	
12	Tap Position & Percent Regulation (TP, %)	3
13	Power Factor	
14	kVA Load	
15	kW Load	
16	kvar Load	
17	Line Frequency	
18	Voltage Harmonics (THD, 3, 5, 7, 9, 11, 13), percent	
19	Current Harmonics (THD, 3, 5, 7, 9, 11, 13), percent	
FORWARD DEMAND METERING		
20	Load Voltage (H-D, T; L-D, T; P)	1
21	Compensated Voltage (H-D, T; L-D, T, P)	1
22	Load Current (H-D, T; L-D, T; P), amperes	1
23H	Power Factor @ Max kVA Demand	
23L	Power Factor @ Min kVA Demand	
24	kVA Load (H-D, T; L-D, T; P)	1
25	kW Load (H-D, T; L-D, T; P)	1
26	kvar Load (H-D, T; L-D, T; P)	1
27	Max Tap Pos & Max % Boost (TP-D, T; %)	1
28	Min Tap Pos & Max % Buck (TP-D, T; %)	1
29	Source Voltage **(H-D, T; L-D, T; P)	
REVERSE DEMAND METERING		
30	Load Voltage (H-D, T; L-D, T; P)	1
31	Compensated Voltage (H-D, T; L-D, T; P)	1
32	Load Current (H-D, T; L-D, T; P), amperes	1
33H	Power Factor @ Max kVA Demand	
33L	Power Factor @ Min kVA Demand	
34	kVA Load (H-D, T; L-D, T; P)	1
35	kW Load (H-D, T; L-D, T; P)	1
36	kvar Load (H-D, T; L-D, T; P)	1
37	Source Voltage**(H-D, T; L-D, T; P)	
MASTER METERING & TAP POSITION INDICATION RESET		
38	Reset	1
CONFIGURATION		
39	Source Voltage Calculation 0 = Off, 1 = On; 1 = Type A, 2 = Type B	2
40	Regulator Identification	2
41	Regulator Configuration 0 = Wye, 1 = Delta Lag, 2 = Delta Lead	2
42	Control Operating Modes 0 = Sequential, 1 = Time Integrating, 2 = Voltage Averaging	2
43	System Line Voltage, volts	2
44	Overall P.T. Ratio	2
45	C.T. Primary Rating, amps	2
46	Demand Time Interval, minutes	2
49	Tap Changer Selection 0 = Quik Drive, 1 = Spring/Direct Drive	
CALIBRATION		
47	Voltage Calibration, volts	3
48	Current Calibration, amps	3
CALENDAR/CLOCK		
50	Date & Time Set (D, T, 1, 2, 3, 4, 5, 6) 1 = Year, 2 = Month, 3 = Day, 4 = Hour, 5 = Minute, 6 = Second	3
REVERSE CONTROL SETTINGS		
51	Set Voltage, volts	2
52	Bandwidth, volts	2
53	Time Delay, seconds	2
54	Line Compensation, Resistance, volts	2
55	Line Compensation, Reactance, volts	2
56	Reverse Sensing Mode 0 = Locked Forward, 1 = Locked Reverse 2 = Reverse Idle, 3 = Bi-Directional 4 = Neutral Idle, 5 = Co-Generation 6 = Reactive Bi-directional	2
57	Reverse Threshold %	2
COMMUNICATIONS		
60	Channel 1 (Data Port) Baud Rate	2
61	Control Communication Protocol XX.03 = Data 2179	
62	Channel 1 (Data Port) Status	
63	Channel 2 (Comm Port) Status	
64	Control Communications Address	2
65	Channel 2 (Comm Port) Baud Rate	2
66	Comm Port Handshake Mode	2
67	Comm Port Resynch Time Chars.	2
68	Comm Port Transmit Enable Delay (On, Off)	2
69	Blocking Status 0 = Normal, 1 = Blocked	2
VOLTAGE REDUCTION		
70	Voltage Reduction Mode 0 = Off, 1=Local/Digital Remote, 2 = Analog Remote (Latching), 3 = Pulse 10 = Off, 11 = Local/Digital Remote, 12 = Analog Remote (Latching), 13 = Pulse (Utilizing 10-13 activates tap to neutral)**	2
71	% Voltage Reduction In Effect (Read Only)	
72	Local Reduction %	2
73	Remote #1 %	2
74	Remote #2 %	2
75	Remote #3 %	2
76	# of Pulse Reduction Steps	2
77	% of Voltage Reduction Per Pulse Step	2
79	Soft ADD-AMP limits** 0 = Off, 1 = On; High limit; Low limit;	2
VOLTAGE LIMITER		
80	Voltage Limiting Mode 0 = Off, 1 = High Limit Only 2 = High and Low Limits	2
81	High Voltage Limit, volts	2
82	Low Voltage Limit, volts	

Notes:
H-D, T = Highest (maximum) value since last reset, date & time
L-D, T = Lowest (minimum) value since last reset, date & time
P = Present value
THD = Total Harmonic Distortion
TPI = Tap position indication

Q = Quantity of operations since last change
R_ = Date of last counter change
R¯ = Time of last counter change
* Change/Reset and Sub-function codes only on CL-5E control
** CL-5E only

See next page for more function codes

TABLE 9-3, Continued
CL-5 Series Regulator Control Function Codes

Function Code	Function	Security Level Change/Reset
METERING PROFILE RECORDER		
85	Profile Period (5, 10, 15, 30, 60, 90, 120 min.)** 1 = Parameter 1, 2 = Parameter 2, 3 = Parameter 3, 4 = Parameter 4, 5 = Data Retrieval Mode (0 = Off, 1 = On)	1
WATCHDOG DIAGNOSTICS		
89	Firmware Version #	
90	Number of Defaults	
91	Self Test	
93	Number of EEPROM Corrections	3
94	Number of Resets	3
95	System Status Code (Read Only) 0 All Systems Good 1 EEPROM Write Failure 2 EEPROM Erase Failure 3 Frequency Detection Failure 4 No Sampling Interrupt-Failure 5 Analog-To-Digital Converter-Failure 6 Invalid Critical Parameters-Failure 7 No Input Voltage Detected-Warning 8 No Output Voltage Detected-Failure 9 No Input & Output V Detected-Failure 10 TPT No Neutral Sync Signal-Warning	
SECURITY ACCESS		
92	Security Override (1 = Override 1, etc.)	3
96	Level 1 Security Code	3
97	Level 2 Security Code	3
98	Level 3 Security Code	3
99	ENTER SECURITY CODE	

** CL-5E control only.

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