Voltage Regulators

COOPER
Cooper Power Systems

Service Information

S225-20-1

4-Step Auto-Booster® Line Regulator

CONTENTS

GENERAL

INTRODUCTION

Four-step Auto-Booster™ line regulators can be applied on circuits rated 2400 through 23,000 volts delta and 2400/4160 through 19,920/34,500 volts multi-grounded wye. Units have a continuous-current rating of either 50 or 100 amps.

Auto-Booster line regulators are available in frequency ratings of 50 and 60 Hertz and voltage ratings of 2500, 5000, 6600, 7620, 11,000, 12,000, 14,400, 19,920, and 22,000. Six-percent boost or six-percent buck is provided in four 1-1/2-percent steps, and ten-percent boost or ten-percent buck in four 2-1/2-percent steps. Ten percent 19,920 and 22,000 volt units are available in 50 amp ratings only. "Boost" units are applied primarily to raise voltage on unregulated circuits or on that part of a regulated circuit which is beyond the range of bus regulation. "Buck" units can be used to lower voltage on branch circuits near a substation. Voltage on the balance of the circuit is significantly improved because substation voltage is permitted to increase.

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.

1. Terminals
An eyebolt connector is standard. Special terminals can be furnished to accommodate customer requirements; specify type on inquiry.

2. Series Surge Arrester
MOV-type, 2.2-kV arrester supplied on devices through 14400 volts with 10% regulation range, and 19920-volt devices with 6% regulation range, 4.5-kV arrester supplied on 19920-volt devices with 10% regulation range.

3. Bushings
Wet-process porcelain. Internally clamped. Nitrile-gasketed for oil- and moisture-proof seal.

4. Handhole
Provides convenient access to tank interior.

5. Tank Cover
Nitrile-gasketed and fastened securely by band closure for positive moisture-proof seal. Positively grounded to tank for safety and elimination of radio interference.

6. Automatic Pressure-relief Valve (not visible)
Frees pressure buildup inside the tank. Assures a prompt nominal cracking pressure of 4 psi.

7. Lifting Lugs
Provide adequate strength for lifting the entire regulator.

8. Support Lugs
Jump-proof lip on upper lug for safety.

9. Nameplate
Shows complete rating data. The schematic diagram of connections are given on each nameplate.

10. Drain Valve and Oil-sampling Device

11. Shunt Surge Arrester
MOV-type; direct-connected between Load (L) bushing and ground.

12. Neutral Indicating LED
Lights when tap changer is in the neutral position.

13. Electronic Control
Solid-state components. Senses needs for voltage correction; controls tap-changer motor. Temperature-compensated for use in any climate.

14. Sealed Tank
Welded, heavy-gauge steel, flow-coated with corrosion-resistant finish. The free flow of air through the internal assembly is eliminated, thus minimizing oil sludging and maintaining cooling efficiency.

15. Tap Changer (not visible)
Motor-driven. Operates silently under oil. Provides smooth, positive regulation at controlled speed that minimizes arcing and extends contact life. To minimize operation under transient voltage variations, the first tap change has inherent a 30-second delay; subsequent changes in same direction have 10-second delay.

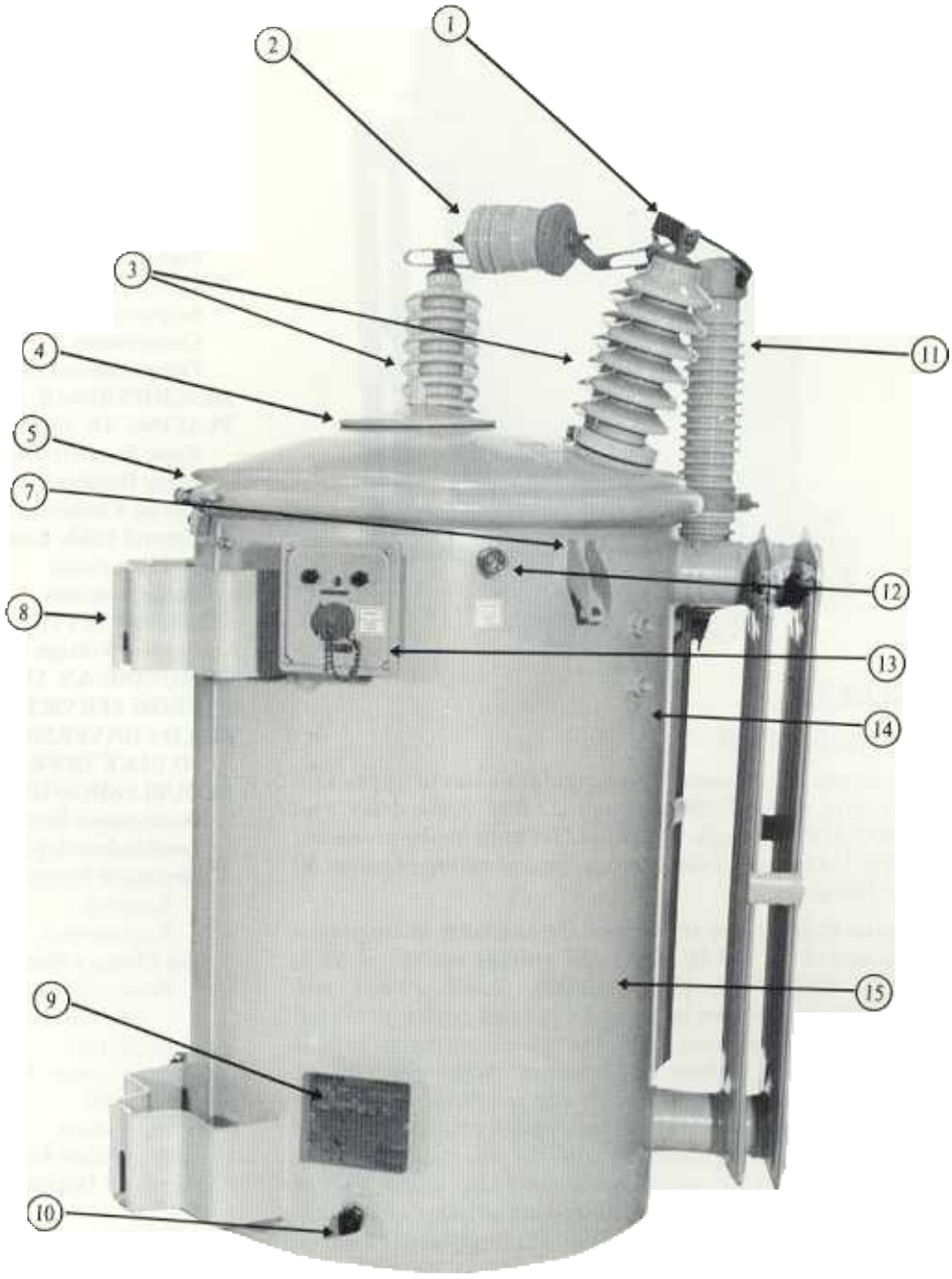


Figure 1
Four-step Auto-Booster line regulator

MULTI-VOLTAGE UNITS

Special multi-voltage Auto-Booster regulators are available for use on 2400, 4160, 4800 and 7200 volt systems. Others are also available for use on 2400, 4800, 7200, 12,000 and 14,400 volt systems. Taps from the potential winding are brought out to a terminal board mounted on the top core clamp. So that the potential tap can be properly reconnected when the regulator is changed from one system voltage to another, taps are clearly identified. Changing the position of a single lead on the terminal board will allow operation at other voltages.

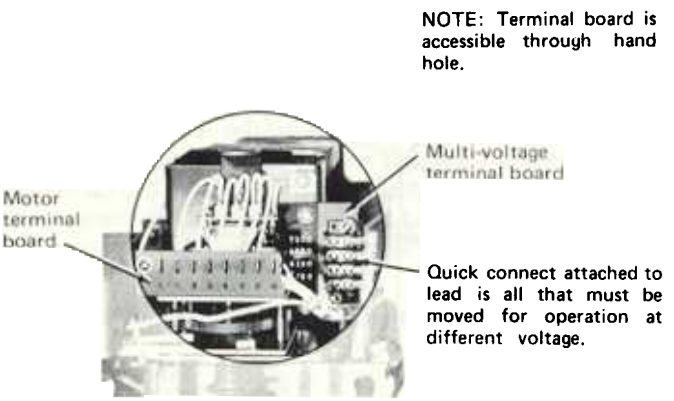


Figure 2
Multi-voltage terminal board

SHIPMENT

McGraw-Edison regulators are completely assembled, tested, and inspected at the factory. When the regulator is accepted by the carrier for shipment it is filled to the correct level with oil, properly calibrated and adjusted, with the tap changer in the neutral position. Immediately upon loading, a thorough inspection, exterior and interior, should be made for damage or evidence of rough handling or shortage.

Should the initial inspection reveal evidence of rough handling or damage in transit and/or shortage, notify – and file a claim with – the carrier at once. Also notify McGraw-Edison Company, Power Systems Division, Zanesville, Ohio 43701, or notify your local McGraw-Edison Company sales representative.

Inspect external areas for signs of leaks. All leaks must be located and repaired before proceeding with the installation of the regulator.

PREPARING REGULATOR FOR STORAGE

If the Auto-Booster regulator is not to be placed in the service-ready condition immediately upon receipt, it is considered to be in storage.

1. Remove all packaging materials that might possibly collect moisture. *Do not remove any bracing or blocking. Maintain bracing and/or blocking intact until the regulator is made ready for service.*
2. Insure that all bushings are clean, dry and in good condition.
3. Locate the unit where the possibility of mechanical damage is minimized; in particular, protect the bushings and control.
4. If the control is stored in its shipping carton, the carton should be protected with a plastic or other weatherproof cover. The control receptacle should be sealed with weatherproof tape.

INSTALLATION

After removing a regulator from storage and before moving it to an installation site, inspect and test the unit as outlined below.

INSPECTION

1. Examine the series arrester to see that it has not been damaged.

   If damaged, install a new arrester, depending upon the voltage rating of the unit. The spun-copper end of the arrester can be connected to the load bushing or source bushing.

2. Inspect the porcelain bushings for damage.

   If a bushing has been damaged, install a new one. A damaged bushing can permit moisture to enter the tank. When this occurs, the regulator must be dried; then using a clean, lint-free cloth, remove the dust and dirt from the tank. The tank should then be refilled with filtered and tested oil before being placed in service.

3. If the regulator has been stored for some time, test the dielectric strength of the oil according to ASTM procedures. A sufficient quantity of oil for testing may be obtained from the sampling plug near the tank bottom.

   The oil must test 28 kv minimum in standard gap (ASTM D-877). If the oil does not test to a minimum strength, filter and retest.

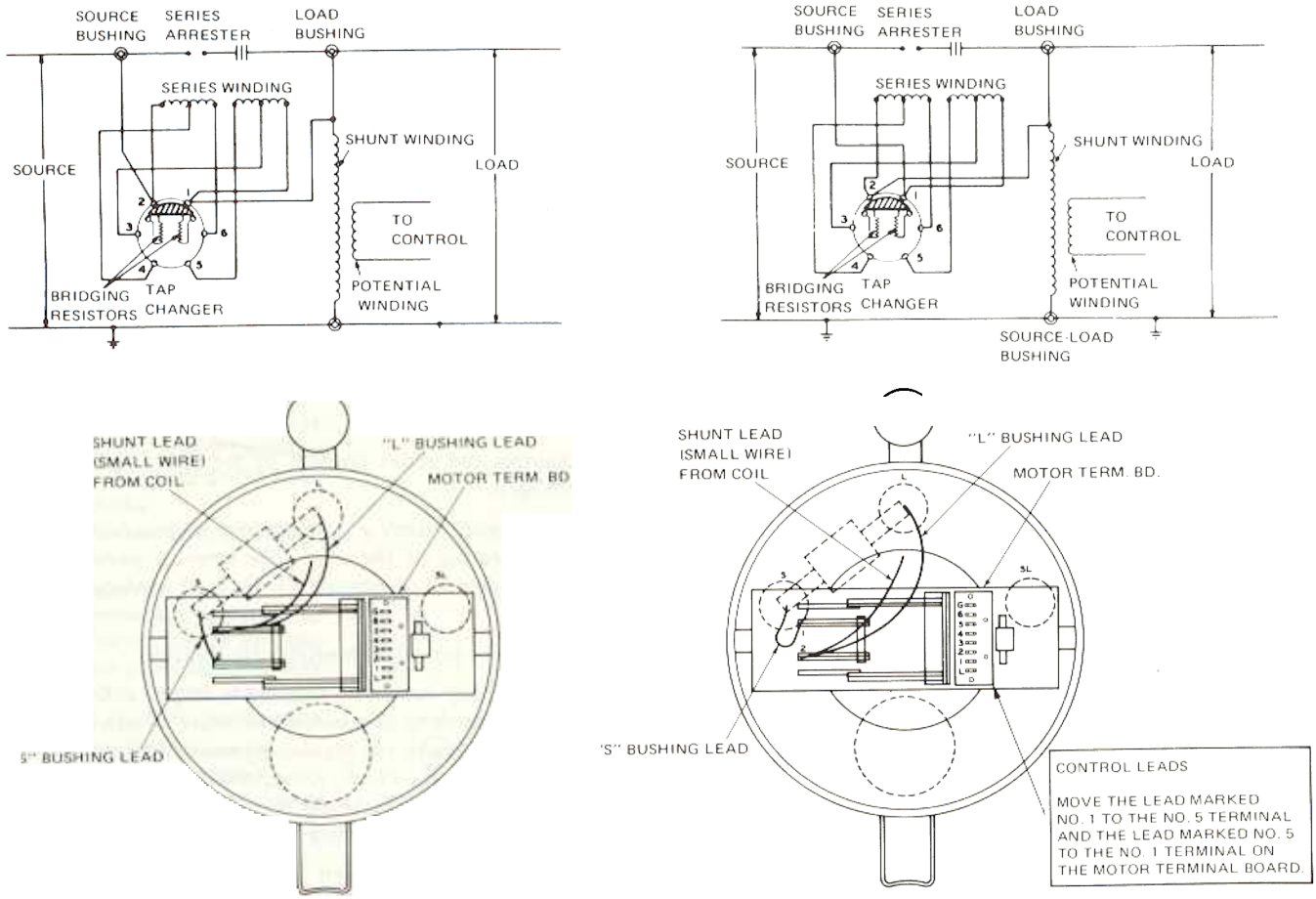
CONNECTIONS

Auto-Booster regulators are manufactured for various voltages through 19.92/34.5 kv GrdY. They have a continuous-current rating of 50 and 100 amps and regulate circuits having kva loads equal to the current rating times the primary voltage in kilovolts. Check the nameplate of this regulator to be sure it is properly applied to your system.

Auto-Booster regulators should be applied on laterals, or circuits, where they are not subject to frequent switching surges. As a general rule, they are not recommended for use in substations. Use on laterals is recommended when 32-step regulators are used on main feeders and no special coordination is required. The life of the tap changer will depend largely on the frequency of switching and the degree of loading. Thus, these regulators should not be applied in locations where there will be frequent switching above rated current.

The Auto-Booster regulator is connected to the PRIMARY line as shown in Figure 3.

There is no bandwidth adjustment to be made on the control. Line voltage is maintained within a preset bandwidth of approximately five volts (using a 120 volt base) for all regulators.



Power circuit schematic for boost connection.

Power circuit schematic for buck connection.

Figure 3

PREOPERATIONAL CHECK

All Auto-Booster regulators are set in the neutral position before shipment. If no operational check is to be made before placing the regulator in the line, a visual check for neutral position should be made through the handhole before installation. In the neutral position the tap-changer rotor bar will be plainly visible connecting the two top stationary contacts to which the "L" and "S" bushings are connected.

If an operational check is made before installation, *return the tap changer to the neutral position before placing the Auto-Booster regulator in the line.* Boost units (connected for raising voltage) will return to neutral when the selector switch on the control is turned to the lower position. Buck units (connected for lowering voltage) will return to neutral when the selector switch is turned to the raise position. In either case the neutral lamp should light approximately five seconds after switching into the neutral position. This operational check can be made on the line by closing the "S" disconnect and leaving the "L" disconnect open so that the regulator is energized but not loaded.

DESCRIPTION OF OPERATION

Auto-Booster regulators provide an inexpensive and effective method of voltage regulation. Auto-Booster regulators are regulating autotransformers. They provide four-step feeder voltage regulation. A solid-state control senses the need for voltage correction and a motor-operated tap changer automatically provides four-step voltage boost or buck (depending on connection) within a six- or ten-percent range of regulation. Each step represents a 1-1/2-percent voltage change for six-percent units, or a 2-1/2-percent change for ten-percent units.

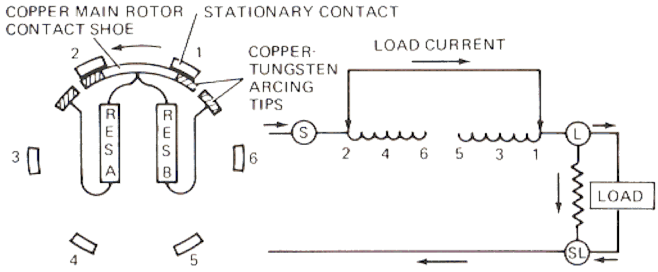
The power circuit schematic for the Auto-Booster regulator (Figure 3) clarifies the operating principles of this regulation tool. As shown, the Auto-Booster regulator basically consists of a series coil, shunt winding, and a control winding. Source voltage is applied across both the series and shunt winding, while the load is across only the shunt winding. The control winding senses the output voltage and provides this intelligence to the control. Voltage correction will be initiated by the control if the ouput voltage does

not stay within the bandwidth of the control setting. In such a case, sections of the series winding will be placed in or taken out of the circuit by the tap changer operation. The winding sections represent either 1-1/2- or 2-1/2-percent rated voltage, depending upon whether the unit has a six- or ten-percent range of regulation.

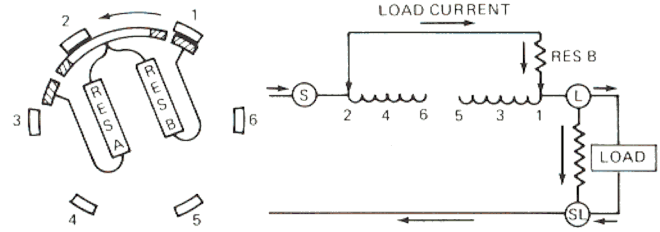
Auto-Booster regulator tap changers have six stationary contacts and a rotor comprised of three separate contacts. Rotor contacts are interconnected electrically with bridging resistors. These resistors allow insertion or removal of tap sections without circuit interruption. This type of switch differs from the one normally used in 32-step regulators in that the bridging resistors cannot carry current continuously. Thus, no bridging positions are possible on the Auto-Booster regulator.

Prevention of the Auto-Booster regulator from switching because of rapid voltage changes is accomplished by an inherent tap-changer time delay. This delay is approximately 30 seconds for the first tap change, and 10 seconds for subsequent tap changes in the same direction. The motor is required to load the spring operator for 30 seconds before the tap change takes place.

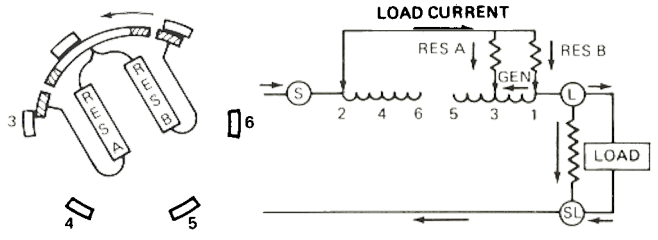
The following details the tap changer operation.



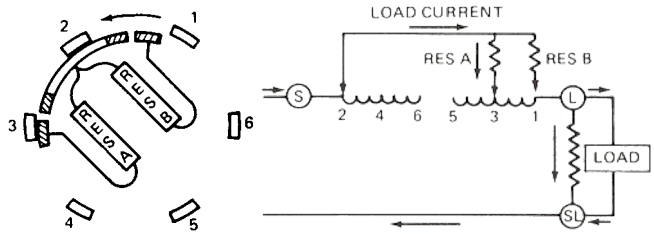
Neutral position of Auto-Booster tap changer.



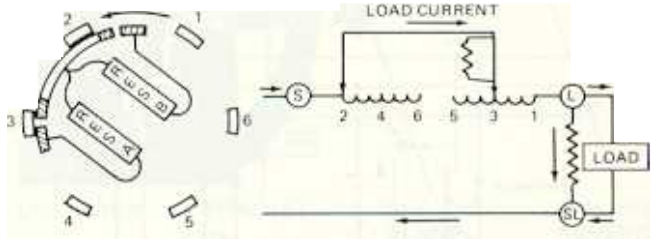
Insertion of resistor B into the circuit is the first phase of a tap change. This prevents possible generation of circulating current, which would cause arcing.



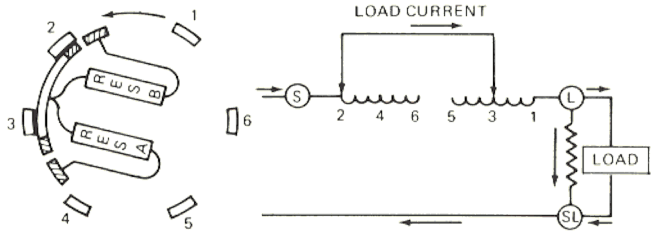
For the second phase of a tap change, both resistors A and B are inserted. This is the first, and only, part of the switching cycle where circulating current is generated in the tap section. Resistors A and B in series limit this generated current.



On removal of resistor B, load current that has not transferred to the winding through resistor A will be present at the break in addition to the induced current. Because of the low value of induced current, a low impedance transfer circuit reduces the current present at the break to a low value.



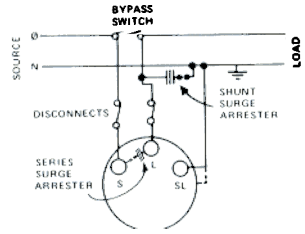
The last step in the switching cycle consists of simply shorting out resistor A and removing it from the circuit.



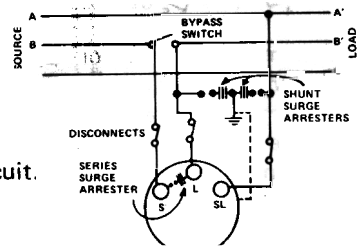
Switch in first boost position.

Auto-Booster regulators use shaded-pole motors to drive the tap changer. This shaded-pole method allows basic single-phase motors to develop starting torque and thus become self-starting. High-resistance shading coils are wound on the stator and induced current flows in the shading coil when it is shorted. The main motor winding has low resistance and high reactance. Thus, the high resistance shading coil will have its magnetic field displaced 30 to 60 degrees from the main motor field. This magnetic field difference provides the starting torque. When neither shading coil is shorted the motor will stall thus preventing a tap change.

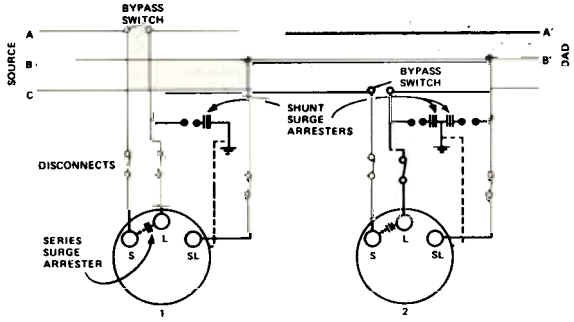
Auto-Booster regulators use a solid-state control (Figure 7). The main functions of the control are to sense the output voltage, and if it is outside the bandwidth for the voltage setting, the control will short the appropriate shading coil causing the tap-changer motor to run in the proper direction to correct the voltage.



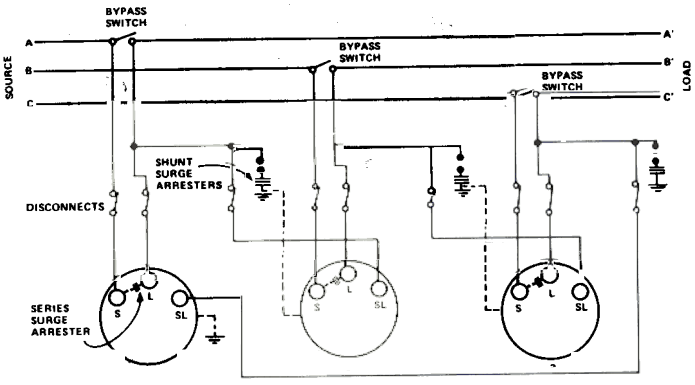
Regulating a single-phase circuit.



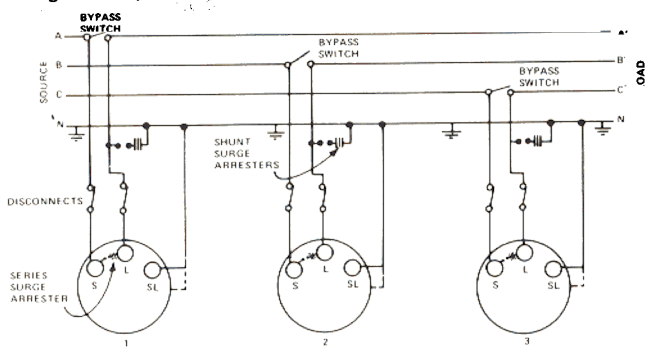
Regulating one phase of a three-phase, three-wire circuit.



Regulating a three-phase, three-wire wye or delta circuit with two regulators.



Regulating a three-phase, three-wire wye or delta circuit with three regulators. (In this case, 6% regulators provide 9% regulation, and 10% units provide 15% regulation.)



Regulating a three-phase, four-wire multi-grounded wye circuit with three regulators.

Figure 4
Auto-Booster line regulator—circuit connections.

PLACING AN AUTO-BOOSTER IN SERVICE

USING SEPARATE DISCONNECT SWITCHES

CAUTION

When separate disconnect switches are used for bypassing as well as connections to the "S" and "L" bushings, it is possible for the regulator to move from the neutral position during installation. To prevent shorting a portion of the series winding, always insure that the regulator is in the neutral position before performing the following installation procedures:

1. Always install the control with the selector switch set to the OFF position.
2. With the "S" and "L" switches open and the bypass switch closed, install the Auto-Booster regulator.
3. Close "S" and "L" disconnect switches and open the bypass switch. The regulator may now be operated manually or automatically as desired, by means of the selector switch on the control.

NOTE: The neutral lamp will not necessarily light during installation since the motor stop arm will not be driven against the lamp switch.

USING REGULATOR BYPASS DISCONNECT SWITCH

Insure that the Auto-Booster regulator is in the neutral position and then perform the following installation procedures:

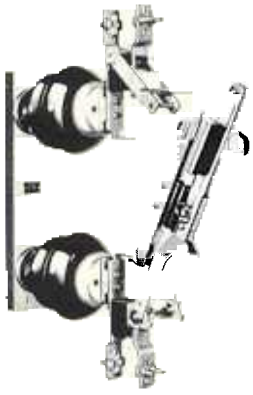
Always install the control with selector switch set to the OFF position.

2. Open the bypass disconnect switch and install the Auto-Booster regulator.
3. Close the bypass disconnect switch. The regulator may now be operated manually or automatically as desired, by means of the selector switch on the control.

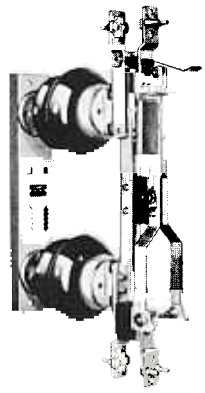
McGraw-Edison's Type B bypass-disconnect switch is a convenient, economical device for installation with Auto-Booster regulators. This switch provides simultaneous closing or opening of source and load contacts as the main feeder contact opens or closes, respectively. Thus, this switch replaces a bypass and two disconnect switches.

Type B switches afford savings in the cost of accessory equipments, decreased installation time, shortened conductor requirements, and reduced total labor and material costs. See Section 250-20 for catalog numbers and ordering information.

NOTE: Individual switches are shown for the bypass and disconnect functions. However, a McGraw-Edison regulator-bypass-disconnect switch can be used in each phase to perform the bypassing and disconnecting operations in proper sequence. Each of these switches replaces one bypass and two disconnect switches shown in the diagrams.



SWITCH OPENED, REGULATOR BYPASSED AND DISCONNECTED.



SWITCH CLOSED, REGULATOR IN SERVICE.

Figure 5
McGraw-Edison Type B bypass-disconnect switch

CIRCUIT CONNECTIONS

An Auto-Booster regulator can regulate a single-phase circuit or one phase of a three-phase wye or delta circuit. Two regulators, connected open-delta, can regulate a three-phase, three-wire wye or delta circuit. Three regulators connected in delta can regulate a three-phase, three-wire circuit, and when connected in wye can regulate a three-phase, four-wire, multi-grounded wye circuit. Three regulators cannot be connected in wye on three-phase, three-wire circuits because of possible neutral shift. Typical connection diagrams are shown in Figure 4.

CONTROL CABLE EXTENSION KIT

The control cable extension kit illustrated in Figure 6, allows an Auto-Booster regulator's solid-state electronic control to be mounted remote from the unit. Included in the kit are a 6-conductor neoprene-covered cable and pole-mounting bracket. Control cable length can be 3, 9, 12, 15, 20, or 30 feet.

NOTE: Disconnecting the control from an Auto-Booster regulator in service has no effect on the unit or system voltage. The regulator will simply serve as a fixed-ratio autotransformer. Reconnecting the control will have no effect on operation of the unit unless voltage has moved outside the bandwidth. The control will then take corrective action to return line voltage on the load-side within the bandwidth.

Instructions:

1. Attach bracket with control cable assembly to pole with two lag screws at desired height.
2. Interconnect the control bracket ground with the tank and ground rod as close to the bracket as possible using a minimum of No. 8 copper wire.
3. Remove solid-state control from Auto-Booster regulator by unscrewing coupling.
4. Reinstall solid-state control on bracket. Tighten coupling to secure control plug in receptacle.
5. To complete installation, connect free end of control cable to receptacle on Auto-Booster regulator tank wall.

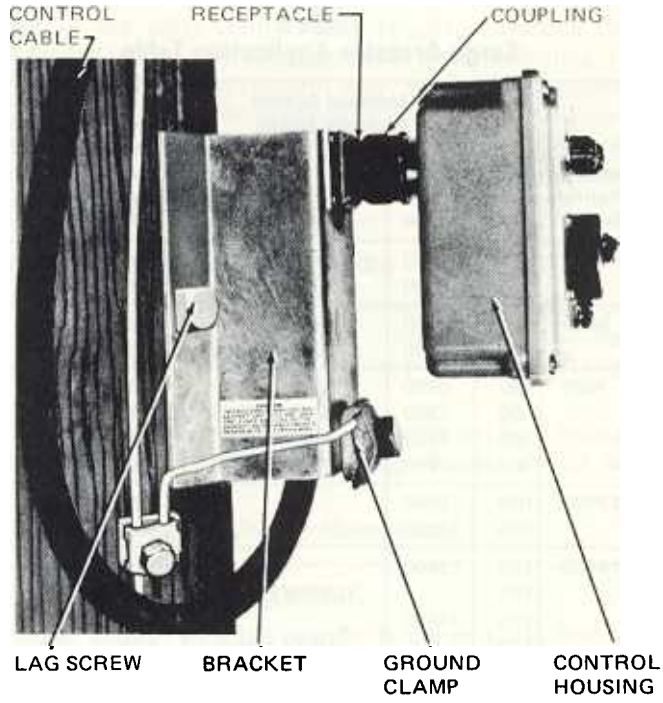


Figure 6
Control cable extension kit.

Table 1 lists control cable extension kit assemblies and their catalog numbers. See your McGraw-Edison Company sales representative for prices and ordering information.

Table 1
Control Cable Extension Kit Assemblies

Description	Catalog Number
Control cable assembly, 3 foot	TAC14221200A
Control cable assembly, 9 foot	TAC14221200B
Control cable assembly, 12 foot	TAC14221200C
Control cable assembly, 15 foot	TAC14221200D
Control cable assembly, 20 foot	TAC14221200E
Control cable assembly, 30 foot	TAC14221200F

SURGE ARRESTERS

Because the series winding of each regulator is connected directly in the line, it is subject to abnormal voltage stresses which may be produced by lightning surges or switching transients. Series winding protection is furnished by a 1-1/2 kv, valve-type arrester on all regulators through 14,400 volts having a ten-percent range of regulation, and on 19,920 volt units having a six-percent range of regulation. 19,920 volt units with a ten-percent range of regulation have a 3 kv arrester.

Shunt winding protection is provided by supplying one direct-connected Type E7M arrester mounted on the regulator tank and connected between the "L" bushing and ground. Two arresters are generally used on each regulator in any three-phase, three-wire circuit. Only one arrester is considered necessary for each regulator connected in a single- or three-phase multi-grounded wye circuit. The application table (Table 2) lists arresters to be used with various system voltages.

Table 2
Surge Arrester Application Table

Regulator Rating (volts)	PT Ratio (N:1)	Nominal System Voltages (volts)		Control Voltage Level Setting (volts)	Recommended Shunt Arrester Rating (kv)
		Delta or Single-Phase	Multi-Grounded Wye		
2500	20	2400	2400/4160	120	3
	20	2500	2500/4330	125	3
5000	40	4800	4800/8320	120	6
	40	5000	5000/8660	125	6
7620	60	6900	6900/11940	115	10
	60	7200	7200/12470	120	10
	60	7620	7620/13200	127	10
	60	7960	7960/13800	133	10
12000	100	12000		120	15
	100	13200		132	15
14400	120	13800		115	15
	120		13800/22900	115	18
	120	14400		120	15
	120		14400/24940	120	18
19920	166	19920	19920/34500 Grd Y	120	27
*Multi-Voltage Units: (2400, 4160, 4800, 7200 12000 14400)	20	2400	2400/4160	120	3
	20	2500	2500/4660	125	3
	34.7	4160	4160/7200	120	6
	40	4800	4800/8320	120	6
	40	5000	5000/8660	125	6
	60	6900	6900/11940	115	10
	60	7200	7200/12470	120	10
	60	7620	7620/13200	127	10
	100	12000		120	15
	120	14400		120	15
	120		14400/24900	120	18

*Ratio's on multi-tap units may vary slightly. See rating plate for exact control voltage.

CONTROL SETTINGS

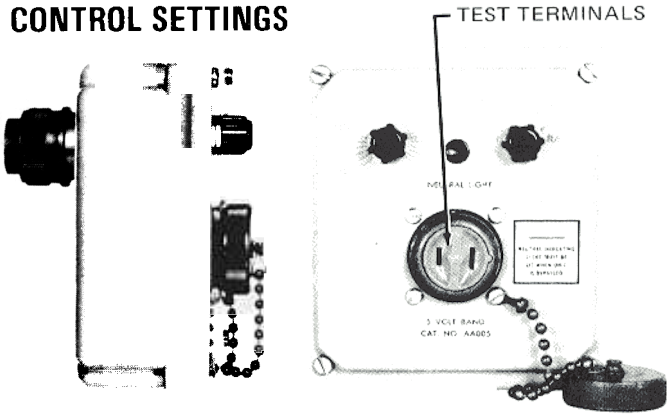


Figure 7
Electronic control for Auto-Booster line regulators.

Auto-Booster regulators use an electronic control to sense the need for voltage correction and control the tap changer motor. Transistors, silicon-controlled rectifiers, diodes, capacitors, and resistors are used in the control circuit design. The solid-state circuit has no moving parts and does not require periodic maintenance. A voltage level control simplifies adjustment to a particular system voltage, and a selector switch allows manual or automatic operation.

CONTROL VOLTAGE LEVEL

The control voltage level must be properly set to obtain the desired line voltage. The voltage level setting is obtained by dividing the desired load voltage by the ratio of rated volts to control volts as shown on the nameplate.

To set the control voltage level:

1. Remove weatherproof cap.
2. Insert small screwdriver in calibrating shaft slot.
3. Rotate shaft until red slot aligns with desired setting.
4. Replace weatherproof cap.

The voltage test terminals are connected in parallel with the input to the control. They may be used with either an indicating or recording voltmeter. Meter should have a minimum impedance of 5000 ohms per volt.

CAUTION

Test terminals are for voltmeter only. Control will be damaged if heavier loads are connected.

Because the Auto-Booster regulator is connected in the primary circuit, *it must always be on neutral position before being bypassed.* Each unit is shipped from the factory with the tap changer set on neutral and ready for installation. However, if the regulator has been energized and is not on neutral, it must be run to neutral before it is inserted into the line. To do so, ground the source-load bushing, connect the source bushing to the line, and turn the five-position selector switch to lower (when unit is connected for boost) or raise (when unit is connected for buck).

To run to neutral in a three-phase, three-wire system, connect the source bushing to one phase line and the source-load bushing to the other phase line and run to neutral as described above.

CAUTION

Neutral indicating light indicates neutral position. It will be lit only when motor is driving against the stop in the neutral direction.

REMOVING AUTO-BOOSTER REGULATOR FROM SERVICE

1. Return the tap changer to its neutral position. If boost unit (connected for raising voltage), turn the selector switch to lower position. If buck unit (connected for lowering voltage), turn the selector switch to raise position. Neutral lamp will light within five seconds after the tap changer switches to the neutral position. If the neutral lamp fails to light, drop the load and disconnect the regulator from the line without bypassing.
2. The neutral light will remain lit if the selector switch is left in the above position while bypassing and removing from the line.

3. Older type controls, having no selector switch, require the removal of the control and the insertion of the shorting plug into the control receptacle (Figure 12). If boost unit, insert receptacle key in "1" or "L" slot, and if buck unit, insert key in "2" or "R" slot. The neutral light will come on indicating neutral position.

FIELD CONVERSION FROM BOOST TO BUCK OPERATION

Auto-Booster regulators are shipped connected for boost operation unless otherwise specified. To connect for buck operation, proceed as follows:

1. Reconnect internal "S" bushing lead, "L" bushing lead, and shunt lead for buck connection as shown in power circuit schematic, Figure 3.
2. Move the control lead marked No. 1 to the No. 5 terminal on the motor terminal board.
3. Move the control lead marked No. 5 to the No. 1 terminal on the motor terminal board.

In the event it is desired to again use a unit that has been connected for buck operation for boost operation the foregoing procedure should be reversed.

TROUBLESHOOTING AND MAINTENANCE

MAINTENANCE RECOMMENDATIONS

It is recommended that all Auto-Boosters, both 50 amp and 100 amp, that have been in service for four years, be removed from service and a maintenance inspection performed.

This maintenance inspection should involve the removing and checking of contacts and resistors. If erosion is noted, a new rotor assembly should be installed.

For the 50 amp Auto-Booster, the rotor assembly part number is TAB14900200A, and the 100 amp Auto-Booster rotor assembly part number is TAB15900100A. Giving your McGraw-Edison representative the catalog number and serial number of your Auto-Booster regulator will enable him to supply you with specific ordering information, prices and installation instructions.

The expected life of the tap changers in all Auto-Boosters is as follows:

Average % of Rated Load Amps	Minimum Expected Life
100	25,000 operations
50	50,000 operations
25	100,000 operations

The average number of operations per year with a five volt bandwidth is of the order of 2500.

To insure that a tap changer is able to perform as indicated above, the oil should be filtered or replaced when the dielectric strength tests below 24 kv, according to ASTM procedures, in the standard test cup (ASTM D-877).

It is also recommended that all controls be returned to a service center for complete testing to improve reliability and to reduce unnecessary and undesirable stepping of the tap changer.

Some of the older controls may require converting the bandwidth to five volts to reduce unnecessary switching. In some cases, the entire control may require replacement. Tables 3 and 4 provide application data on Auto-Booster regulator controls. Your McGraw-Edison representative will provide you with prices, ordering information and guidance relating to your control needs.

TROUBLESHOOTING PROCEDURE

1. Turn the five-position selector switch to either the raise or lower position to initiate operation of the tap changer. Wait for it to stop before proceeding with step 2.
2. Turn the selector switch to the position not used in step 1. Four distinct clicks of the tap changer should be heard.

   If not, refer to Tap Changer Maintenance.

> **WARNING**
>
> Avoid contact with the primary bushings during this test. They will be at full line potential.

3. Connect a vacuum-tube voltmeter or a voltmeter with a sensitivity of at least 5000 ohms per volt to the test receptacle on the electronic control case.
4. Apply rated voltage to the regulator primary bushings.
5. Vary the control setting and observe the voltage at each tap change. The voltage should change approximately three-volts for each step of the tap changer for a ten-percent unit, and 1.8 volts for each step of the tap changer for a six-percent unit.

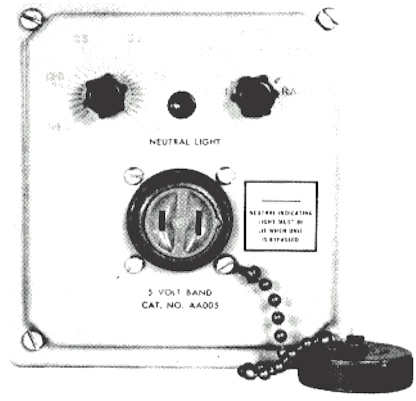


Figure 8
Electronic sensing control

ELECTRONIC SENSING CONTROL

Control malfunction can be identified with the aid of the five-position selector switch on the control. If the regulator will operate throughout its complete range with the selector switch on raise or lower, but does not operate correctly with the selector switch on auto, the control should be replaced. Best results will be achieved by replacing faulty controls. Field repairs cannot be successfully or properly made.

Removal

To remove the electronic control from the regulator, unscrew the coupling on the control plug and remove the control from the tank. If the control is not going to be replaced on the transformer tank immediately, tape should be placed over the connector on the tank.

The regulator can function as a fixed ratio transformer with the control removed. Refer to Operation Without Electronic Control.

Replacement

There are six different controls available to meet the needs of old and new regulators. Regulators of present manufacture are equipped with a light emitting diode (LED) in the control box, plus the required internal circuitry within the regulator to activate it.

All controls listed in Table 3 can be used on all *comparable* Auto-Booster line regulators regardless of the date of manufacture.

When ordering a control from Table 3, be sure that the bandwidth matches the bandwidth of the Auto-Booster regulator. Also determine if a light emitting diode is in the control being replaced, then select the proper control from Table 3. If there is doubt concerning the proper replacement control to specify, provide you McGraw-Edison representative with the catalog number and the serial number of the Auto-Booster. Your representative will obtain the replacement control number for you. To facilitate control replacement, the nameplates on Auto-Boosters of present manufacture have the control number stamped on the lower portion of the nameplate.

NOTE: When reinstalling the electronic control, be sure to insert it firmly into the connector on the tank.

Table 3
Auto-Booster Regulator
Control Application Chart

Control	Application
AA003	Three volt bandwidth with LED
AA013	Three volt bandwidth without LED
AA004	Four volt bandwidth with LED
AA014	Four volt bandwidth without LED
AA005	Five volt bandwidth with LED
AA015	Five volt bandwidth without LED
AA006	Six volt bandwidth with LED
AA016	Six volt bandwidth Without LED

For those users of these controls who are properly equipped and desire to service them, the following information is provided. Figure 9 is a wiring diagram of the electronic sensing control. Figure 10 is a schematic diagram of the voltage-sensing circuit, and Figure 11 lists and locates the circuit board components.

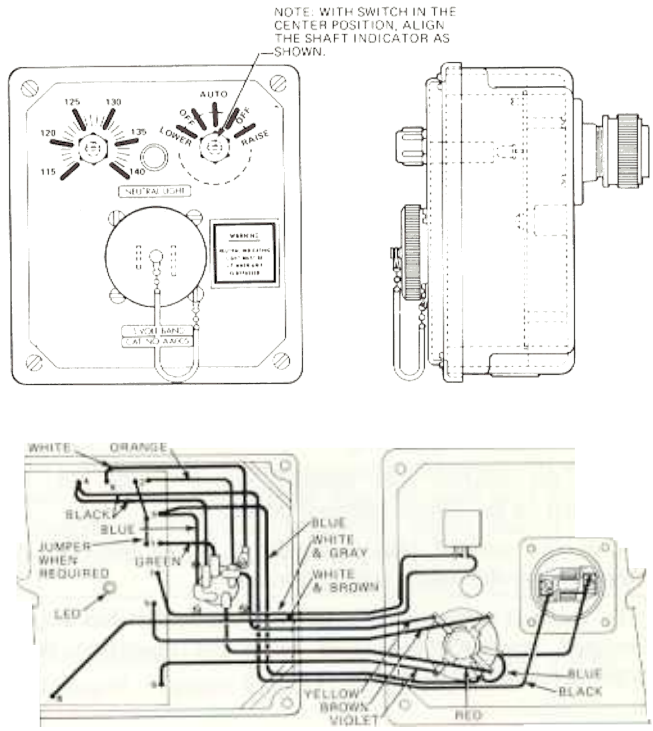


Figure 9
Electronic sensing control wiring diagram.

Controls without the light emitting diode have a jumper between E1J, E2J, and E3J. To convert controls AA013, AA014, AA015 and AA016 to AA003, AA004, AA005 and AA006 respectively, clip the jumpers between E1J, E2J and E3J (Figures 10 and 11).

The bandwidth is determined by the value of resistor R4. Select the value of R4 for the bandwidth required.

Auto-Booster regulators that were originally designed for a control without a light emitting diode can be converted to

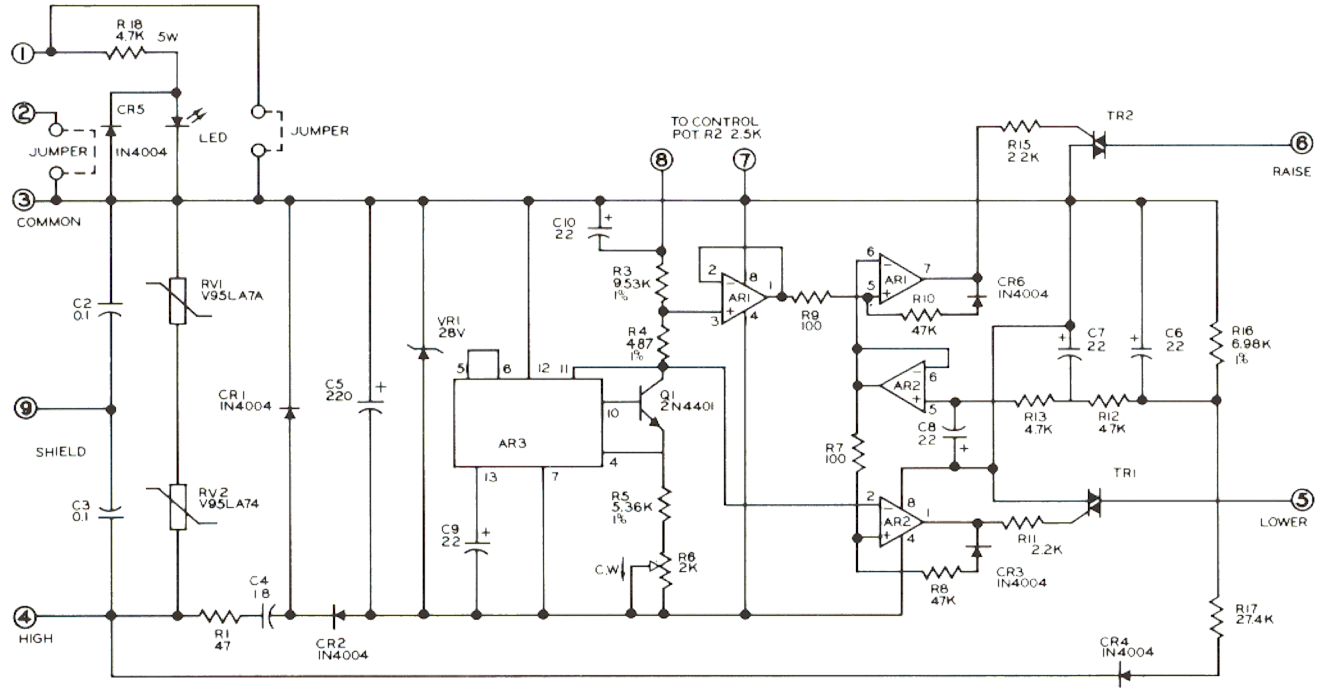
Table 4
Obsolete Auto-Booster Regulator
Control Application Chart

Control	Application
TCA628C3	Three volt bandwidth. Limited to 50 amps and six-percent regulation. Recommend rework to wider bandwidth. Discontinued.
TCA628C4	Four volt bandwidth. Limited to 50 amps and six-percent regulation. Discontinued.
TCA640C1	Four volt bandwidth. 100 amp capacity. Use on 50 and 100 amp units having six-percent regulation only. For ten-percent regulation units, rework to wider band.
TCA640C3*	Five volt bandwidth. 100 amp capacity. Use on 50 or 100 amp units having six-percent or ten-percent regulation.
TCA640C4	Six volt bandwidth. Special for export. 100 amp capacity. Use on 50 or 100 amp six-percent or ten-percent regulation.
TCA640C6	Three volt bandwidth. For special application on 50 or 100 amp six-percent regulation units. Not available for general use.

*Note: This control can be use on all Auto-Booster line regulators.

operate a light emitting diode only after several internal wiring changes and part additions and replacements are made. These are best done in an inside service area.

Table 4 lists obsolete controls that were manufactured prior to the series of controls that are listed in Table 3. Controls selected from Table 4 should only be used as direct replacements for controls having identical control numbers. Do not attempt to use a control from Table 4 as a replacement for a control from Table 3. Serious damage to the control could result.



Reference	Part Number	Qty	Description	Source
AR3	MC 1723 L	1	Voltage Regulator MIL Tmp	Mot/Natl/Fchld
CR1-6	1N4004	6	Diode	GI/Mot
VR1	2VR28	1	Zener Diode 2W-28V	Sarkes Tarsian
Q1	2N 4401	1	Transistor	Mot/etc
C5	50U220	1	Capacitor 220Mf 50V	Nichicon/America
C4	232A1E185M	1	Capacitor 1.8Mf 400V	Electrocube
C2-C3	232A1E104M	2	Capacitor .1Mf 400V	Electrocube
C6-C10	DTSA2502-226M	6	Capacitor 22Mf 25V	Matsuo E of Am
RV1-2	V95LA7A	2	Varistor	General Elect
DS1	CM4-482B	1	Light Emitting Diode	Chic Min etc.
R6	76PR2K	1	Trimpot 2K Ohms	Helitrim Beckmn
TR1-2	L4001L3	2	Triac	Teccor
AR1-2	MC 1458 L	2	Dual Op Amp MIL TEMP	Raytheon/Mot
R18	VC5E / 4641	1	Resistor 4.7K-5Watt	Clarostat/Ohmite
R17	RN55D2742F	1	Resistor 1% 27.4K Ohm	Corning/etc
R16	RN55D6981F	1	Resistor 1% 6.98K Ohm	Corning/etc
R5	RN55D5361F	1	Resistor 1% 5.36K Ohm	Corning/etc
R4	RN55D2940F	1	Resistor 1% 294 Ohm (3 volt bandwidth)	Corning/etc
R4	RN55D4120F	1	Resistor 1% 412 Ohm (4 volt bandwidth)	Corning/etc
R4	RN55D4870F	1	Resistor 1% 487 Ohm (5 volt bandwidth)	Corning/etc
R4	RN55D5900F	1	Resistor 1% 590 Ohm (6 volt bandwidth)	Corning/etc
R3	RN55D9531F	1	Resistor 1% 9.53K Ohm	Corning/etc
R8-R10	47K Ohm 1/2W	2	Resistor 5% Carb Comp	Allen Bradley
R12-13	4.7 K Ohm 1/2W	2	Resistor 5% Carb Comp	Allen Bradley
R11-R15	2.2K Ohm 1/2W	2	Resistor 10% Carb Comp	Allen Bradley
R7-R9	100 Ohm 1/2W	2	Resistor 10% Carb Comp	Allen Bradley
R1	47 Ohm 1/2W	1	Resistor 10% Carb Comp	Allen Bradley
--	C10100A	1	P.C. Board G-10/ 1/16	!CMI
E1-14	10-412-2	14	Bifurcated Terminals	Concord/PMP
--	1B31	AR	Conformal Coating	Humiseal
--	SN 60	AR	Solder per QQs-571	Kester/Alpha
--	4-40 X 1/4 Ing	2	Brass/Phillips Hd Screws	Amfast

Figure 10
Voltage sensing circuit schematic diagram.

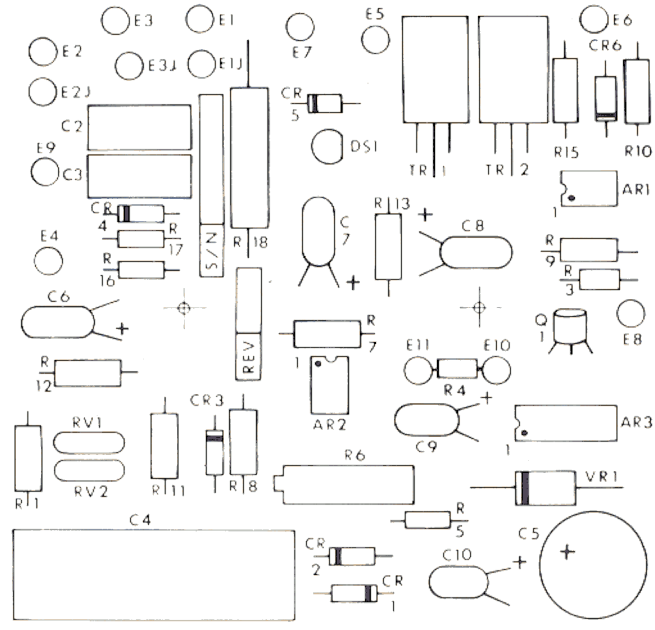


Figure 11
Circuit board parts list.

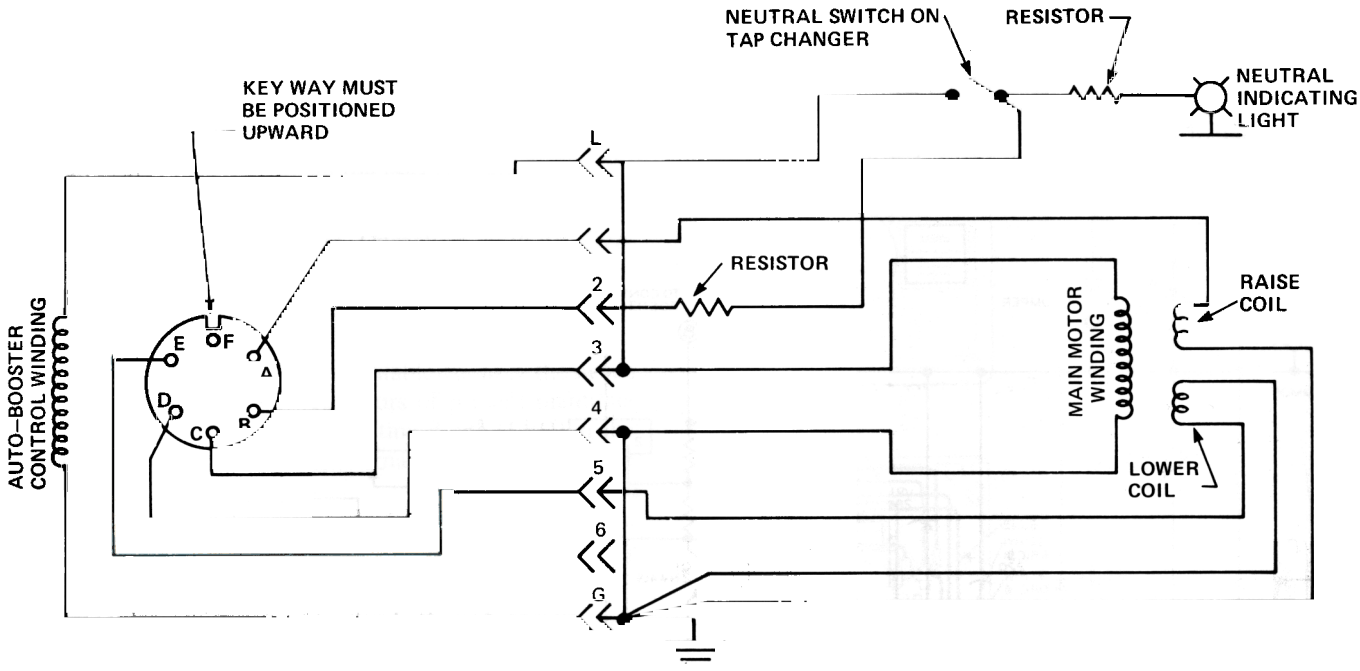


Figure 12
Schematic diagram of tap changer motor circuit.

TAP CHANGER MAINTENANCE

Normal operation of the tap changer is indicated when four distinct clicks can be heard from neutral to full range when the electronic control selector switch is turned to either the raise or lower position to initiate operation of the tap changer. If four clicks are not heard, the tap changer and shaded-pole motor combinations, its leads or the lead connections as shown in Figure 12 must be considered faulty.

Removal or replacement of a tap changer will require that the regulator be removed from the line and moved to a suitable repair location. It must be placed in the *neutral* position before disconnecting, as follows:

Returning Tap Changer To Neutral Position (With Regulator Energized)

When connected for boost–

1. Turn the five-position selector switch to the "Lower" position.
2. Wait for the tap changer to stop operating (maximum of 80 seconds depending on original position of tap changer). The regulator is on neutral and the neutral light will come on. See Warning note below.

When connected for buck–

1. Turn the five-position selector switch to the "Raise" position.
2. Wait for the tap changer to stop operating (maximum of 80 seconds depending on original position of tap changer). The regulator is on neutral and the neutral light will come on. See Warning note below.

WARNING

If at any time the neutral light does not come on, it should IMMEDIATELY be assumed that the regulator is NOT on neutral. Although it is unlikely that the neon light bulb will be defective, a new bulb (No. NE-51H or equivalent) can be inserted if desired, to verify this. To avoid the hazard associated with disconnecting a regulator that is not on neutral, operating personnel should always deenergize the line before switching the regulator off the line.

Inspection

To avoid unnecessary disassembly, the following steps should be followed:

1. Remove the handhole cover and visually inspect the control wiring. Check for broken wires or connections and also for accidental grounds which might occur because of wear and abrasion during shipping or handling. Make any wiring repairs and proceed to the "TESTING" Section.
2. If visual inspection in step 1 does not reveal the cause of the malfunction, it is recommended that the regulator be partially untanked, or the oil partially syphoned out, before proceeding with the other tests. This will provide easier access to the tap changer. If the unit is to be partially untanked, it should be done as follows:
   A. For Auto-Boosters with voltage ratings of 12,000 volts and below, remove terminal caps from cover bushings by loosening setscrew and turning terminal counterclockwise (Figure 13).

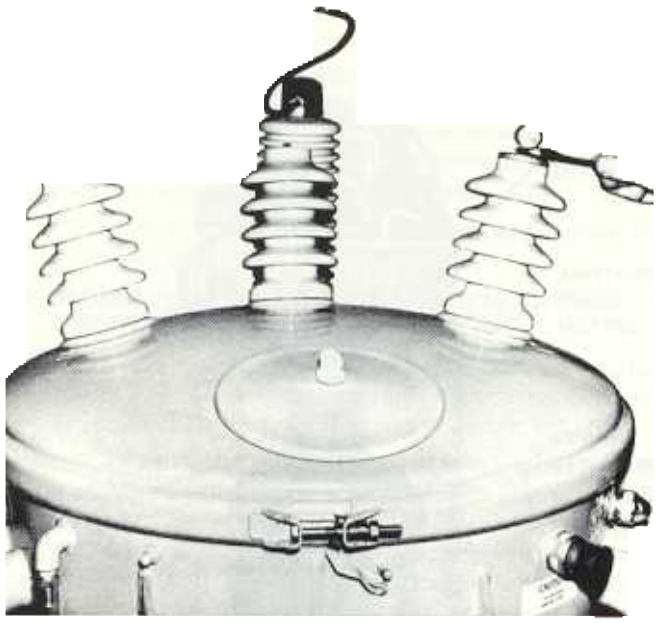


Figure 13
Bushing terminal cap removal.

B. Tap bushing leads "S", "L" and "SL" to loosen.

C. Remove cover.

D. All Auto-Boosters with voltage ratings above 12,000 volts have oil-filled bushings. These bushings *must be* disconnected on the inside of the Auto-Booster. Do not remove the bushing terminal caps or disassemble the bushings in any way or the oil will be lost. The bushings can be disconnected by first removing the cover band and carefully sliding the cover to one side to gain access to the lower terminals.

E. Remove the 9/16-inch hexhead bolts which anchor the core-and-coil assembly (Figure 14).

F. Lifting holes for the 50 amp Auto-Booster regulator are located on diagonal corners of the core clamps. Lifting straps are provided on the 100 amp unit.

NOTE: Partial untanking to allow access to the tap changer is preferred to complete untanking. If complete untanking is necessary, repair should be accomplished as rapidly as possible to prevent oil from draining completely out of the core-and-coil assembly. This will minimize the number of air voids that form in the core-and-coil assembly.

3. Hidden defects in the motor or wiring harness may be detected by applying 120 volts a-c to the control circuit, and checking at the receptacle on the control case as described below.

   A. To eliminate any possibility of backfeeding line voltage to the regulator bushing leads, remove and ground the control winding leads at terminal "G" and ground all three high-voltage bushing leads. On certain older tap changers there is no "G" terminal. The control winding leads are terminated at the No. 2 motor terminals.

   B. The 120 volts a-c test voltage may now be applied at terminals "L" and "G", directly to the motor main coil, or pin C-D on receptacle. The following voltages should appear between the pairs of leads on the control receptacle:

A–D	12 to 46 volts
C–D	120 volts
E–D	12 to 46 volts
B–D	120 volts (when neutral light is on)

   C. Some older model regulators do not have terminals "L" and "G" on the terminal board; but instead have the main motor-coil terminals connected directly to the control winding leads by quick disconnects, as shown on Figure 19. On these units, the control winding leads should be disconnected and grounded, and 120 volts a-c applied as described in step 3B.

4. Absence of proper voltage at any pair of leads may be caused by broken wires, open motor coils, or poorly soldered connections. Broken wires sometimes can be repaired in place. Repair of soldered connections must be made out of oil.

   When soldering to terminal posts, be sure good contact is made with the terminal post itself and not with the hollow rivet that holds the terminal post in place.

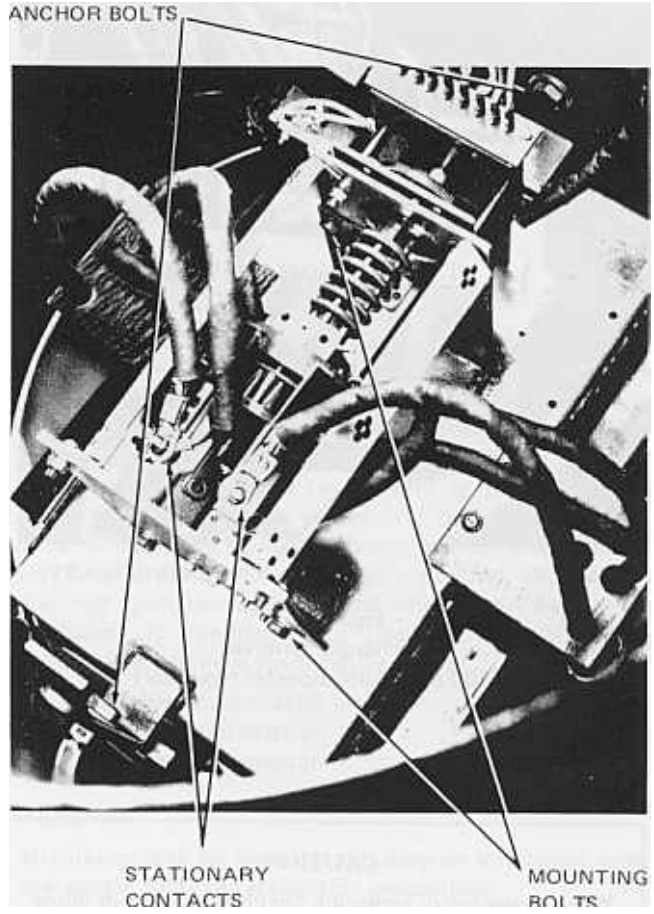


Figure 14
Tap changer removal.
(50 amp Auto-Booster regulator)

Tap Changer Replacement

Open motor coils require replacement of the motor. To insure a proper match, tap changers are furnished as complete units. On older regulators that do not have the neutral indicating light, the complete motor, gear and tap changer assembly should be replaced to insure having the following design improvements:

1. Larger, more powerful motors.
2. Machined steel gears.
3. High capacity carborundum resistors.
4. Reinforced tap changer stops and stronger tap changer bodies with increased fiberglass content.
5. Neutral indicating lights.

Figures 16, 17, and 18 pictorially represent the tap changers utilized in Auto-Booster regulators of current production.

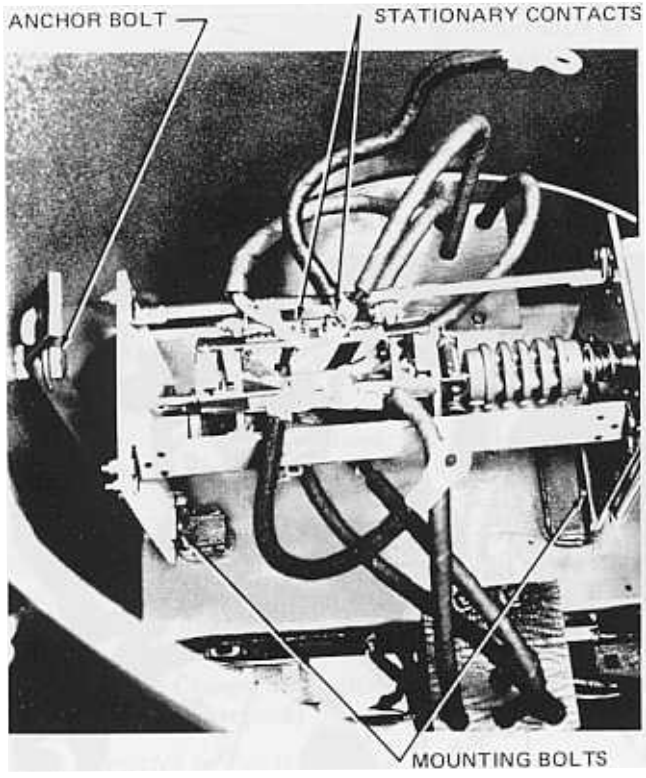


Figure 15
Tap changer removal.
(100 amp Auto-Booster regulator)

Removal

> **CAUTION**
>
> When removing or replacing tap changer, do not allow anything to fall into regulator tank.

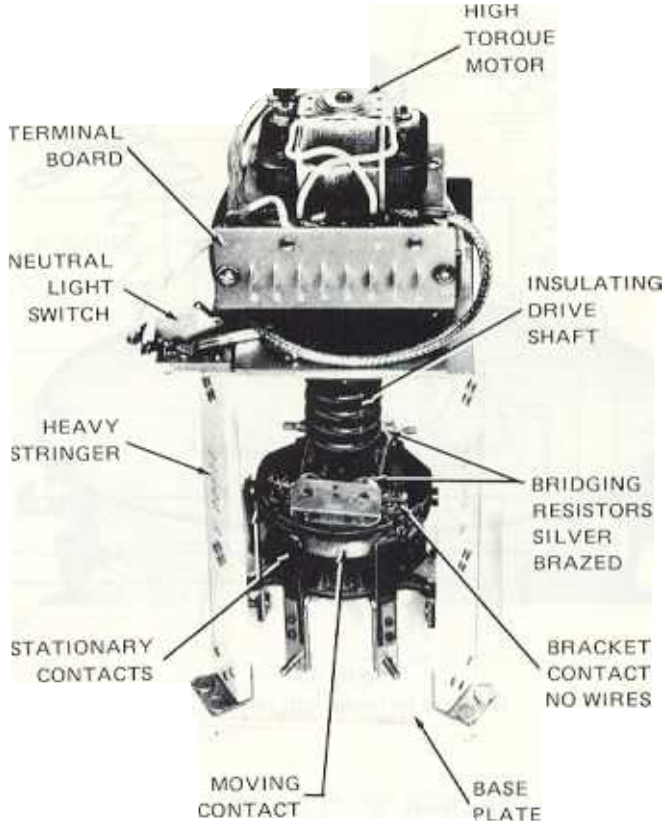


Figure 16
50 amp Auto-Booster regulator tap changer switch through 7620 volts, 10% range of regulation and 12,000 volts, 6% range of regulation.

1. Tag leads from the regulator coil to stationary contacts of tap changer. Terminals on the tap changer are numbered 1 through 6 in a counterclockwise direction (Figure 15). Facing motor end of tap changer, Number 1 terminal is on top right side.
2. Remove all leads from the tap changer stationary contacts.
3. Disconnect the control receptacle leads from motor-terminal board. These are numbered and use quick disconnects.
4. Disconnect the control winding leads from the terminal board. On older models, that have control winding leads connected directly to the tap changer motor through quick disconnects in the leads, pull these disconnects apart (Figure 19).
5. Disconnect the lead from neutral indicator lamp base.
6. Disconnect the ground lead from the core clamp. (Some older models do not have a ground lead attached to the core clamp.)
7. Remove the bolts in the vertical mounting plate holding the tap changer assembly to the core clamp (Figure 15). The tap changer assembly can now be removed.

Installation

All new tap changers are equipped with a lamp and lamp lead. Some older model regulators do not have a neutral indicating lamp and installing one is recommended. To install, drill a 7/8-inch diameter hole through the tank wall as shown in Figure 20 and install the lamp.

1. Place the new tap changer in position and replace the mounting bolts.
2. Reconnect the leads to the tap changer contacts as tagged in step 1 under Removal.
3. Reconnect the control receptacle leads and control winding leads to terminal board. Make sure the quick disconnects are pushed fully onto terminals.

NOTE: Older model regulators, which have control winding leads connected directly to the tap changer motor, must be converted to accommodate the new tap changers equipped with a terminal board to accept the control winding leads and ground lead. Two control winding leads and a ground lead are furnished. Leads from the winding should be pushed onto the leads furnished and attached to the terminals marked "L" and "G". The ground lead from the terminal board should be attached to the core clamp at a convenient location. A hole to receive a self-tapping screw for securing the ground lead should be drilled into the core clamp taking great care to prevent metal bits from falling into the coils.

4. Reconnect lead to indicating lamp base and to ground position on core clamp.
5. Check to make sure all connections are correct and tight.

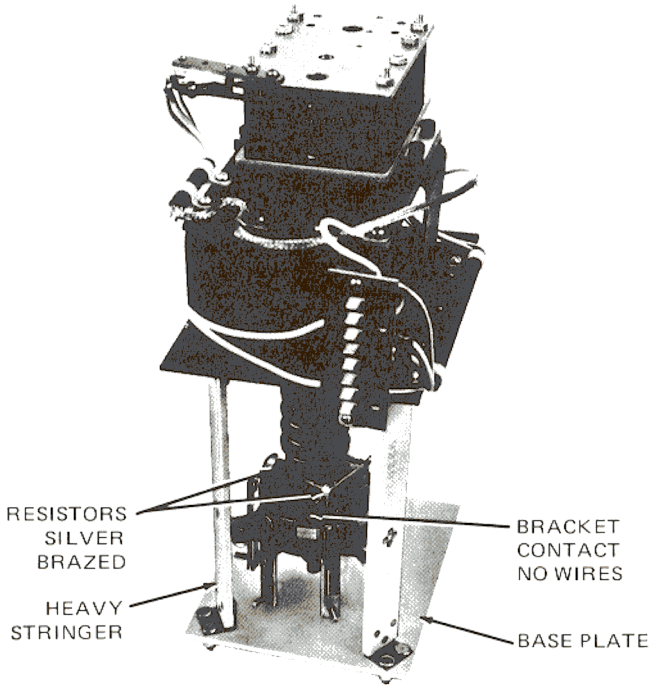


Figure 17

50 amp Auto-Booster regulator tap changer for use on 12,000 volts, 10% range of regulation and 14,000 volts, 6% and 10% range of regulation (uses 100 amp switch parts).

6. Place cover on regulator. Bushing leads on 12,000 volt and below Auto-Booster regulators should be run into proper bushing as cover is being lowered. Screw terminal caps onto bushing lead studs and tighten setscrew into groove on bushing. For Auto-Boosters rated above 12,000 volts, the cover should be moved to one side to allow the bushing leads to be connected to the lower bushing terminals. Carefully position these leads so that adequate clearance will be maintained to grounded parts when the cover is moved back into position. Lead clearances can be checked through the handhole.
7. Test as described under TESTING.

CORE-AND-COIL ASSEMBLY

Damaged core-and-coil assemblies will usually show obvious signs such as discolored tanks, distinctive odor, and heavy carbon. Units suffering from such extensive damage should be repaired by trained personnel. Contact your local McGraw-Edison Company sales representative to make arrangements to return the units to the factory or to a nearby authorized repair shop.

Field experience indicates that considerable reductions in these types of problems can be made by:

1. Insuring adequate surge protection with proper arresters (normally included with the regulators) and correct installation including adequate grounds.
2. Careful attention to bypassing and disconnecting procedures including complete control removal to insure that tap changer remains on neutral.
3. Proper application with respect to voltage and current.
4. Reasonable care during trucking, handling, and installation.

REGULATOR OPERATION WITHOUT ELECTRONIC CONTROL

The regulator functions as a fixed-ratio transformer when the control is removed. Taps can be set in any of the four positions by setting the selector switch in the manual raise or lower position, counting the number of tap changing clicks, and turning the selector switch to the off position. The control may be left on the unit or removed. If it is removed, tape should be placed over the connector on the tank. The amount of voltage boost or buck will be 25, 50, 75, or 100 percent of full range regulation, depending on the tap position selected and the connection of the regulator. If operated as a fixed autotransformer the following continuous loads can be carried:

2nd step from neutral	160-percent
3rd step from neutral	120-percent
4th step from neutral	100-percent

TESTING

Regulators may be tested at the shop or warehouse with a few simple tools and reasonable precautions.

> WARNING
>
> Avoid contact with the primary bushings during tests. They will be at full line potential.

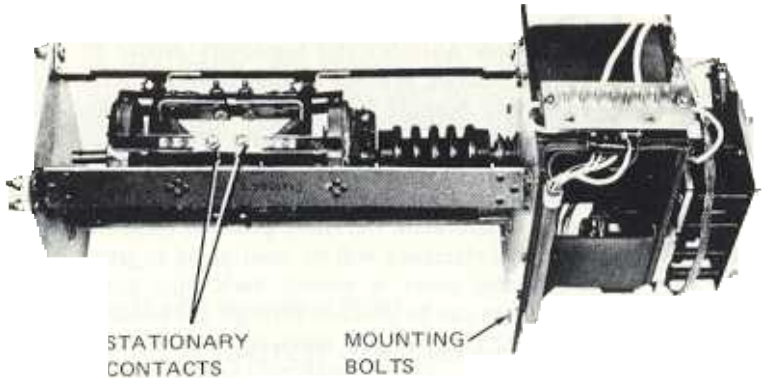


Figure 18
100 amp Auto-Booster regulator tap changer for use on all 100 amp units through 14,400 volts, 6% and 10% range of regulation, and 19,920 volts, 100 amp, 6% range of regulation. Also used on 19,920 volts, 50 amp, 6% and 10% range of regulation.

Tap Changer Operation

1. Apply 120 volts to terminals "L" and "G" of the motor terminal board or receptacle pins C-D. Connect the grounded side of the 120 volt supply to terminal "G" or pin "D" to avoid energizing the tank at 120 volts.
2. Operate tap changer by turning the selector switch to either the raise or lower position.

Regulator Operation and Voltage Regulation

1. Apply rated voltage to the regulator "S" and "SL" terminals from a test source.
2. The tap changer may then be tested by varying the control setting or operating the selector switch.
3. For the voltage regulation test, connect a voltmeter to the test receptacle on the electronic control case.
4. Vary the control setting and observe the voltage at each tap change. For regulators with a six-percent range of regulation, each tap change should change voltage approximately 1.8 volts on a 120 volt base. A change of approximately three volts for each tap changer will be observed on ten-percent range of regulation.

REPLACEMENT PARTS

To insure receiving the correct parts of the latest design, catalog numbers and serial numbers of the Auto-Booster regulator should be included on all orders. This information is shown on the nameplate of all units.

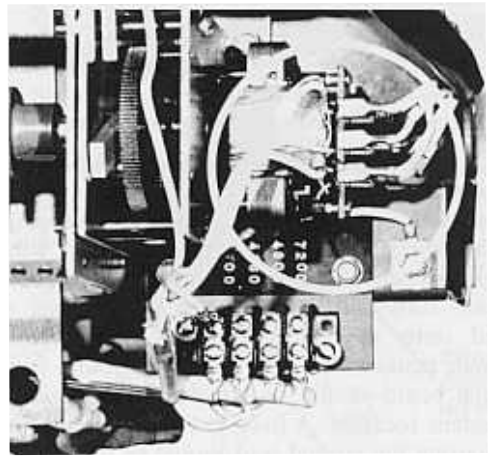


Figure 19
Older model with quick-disconnect control leads.

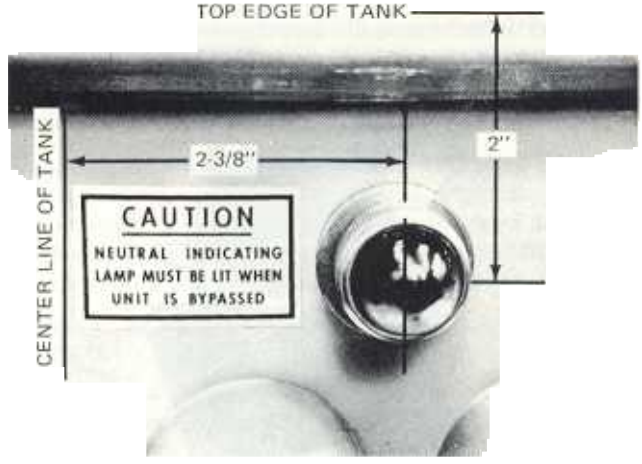


Figure 20
Location of neutral indicating light.

COOPER
Cooper Power Systems

P.O. Box 2850, Pittsburgh, PA 15230