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CENG
a joint venture of
Constellation Energy
eDF

CALVERT CLIFFS
NUCLEAR POWER PLANT

July 12, 2013

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 and 2; Docket Nos. 50-317 and 50-318
Response to Request for Additional Information Regarding Enhancements to Diesel Generator License Amendment Request

REFERENCES:

(a) Letter from Mr. G. H. Gellrich (CCNPP) to Document Control Desk (NRC), dated October 16, 2012, License Amendment Request re: Enhancements to Diesel Generator Surveillance Requirements

(b) Letter from Ms. N. S. Morgan (NRC) to Mr. G. H. Gellrich (CCNPP), dated June 12, 2013, Request for Additional Information Regarding Enhancements to Diesel Generator Surveillance Requirements License Amendment (TAC No. ME9832 and ME9833)

In Reference (a), Calvert Cliffs Nuclear Power Plant, LLC submitted a license amendment request to revise Surveillance Requirements 3.8.1.8, 3.8.1.11, and 3.8.2.1, and add Surveillance Requirement 3.8.1.17 to Technical Specification 3.8.1, "AC Sources-Operating." In Reference (b), the Nuclear Regulatory Commission requested additional information to support their review of Reference (a). Attachment (1) and Enclosures provide the responses to the Nuclear Regulatory Commission's request for additional information contained in Reference (b).

These responses do not change the No Significant Hazards Determination provided in Reference (a). No regulatory commitments are contained in this letter.

A001
NRR

Should you have questions regarding this matter, please contact Mr. Douglas E. Lauver, Director-Licensing, at (410) 495-5219.

I declare under penalty of perjury that the foregoing is true and correct. Executed on July 12, 2013.

Very truly yours,

GHG/PSF/bjd

Attachment: (1) Response to Request for Additional Information Regarding Enhancements to Diesel Generator License Amendment Request
Enclosures: 1 Engineered Safety Features Actuation System Logic Diagram
2 Transformer and Tap Changer Information

cc: CCNPP Project Manager, NRC
Region 1 Administrator, NRC
CCNPP Resident Inspector, NRC
S. Gray, DNR

ATTACHMENT (1)

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING ENHANCEMENTS TO DIESEL GENERATOR LICENSE AMENDMENT REQUEST

RAI 1:

On Page 2 of Attachment 1 of the LAR, in regards to SR 3.8.1.8, the licensee stated that the loads under accident and loss of offsite power (LOOP) conditions are sequentially connected to the bus by automatic load sequencers.

Provide a description of the automatic load sequencers with details such as, the number of sequencers provided per diesel generator (DG) or per safety-related bus and logic diagrams of the sequencers. Also, provide a table of load sequencing for the LOOP conditions for each DG (similar to Table 8-7 for accident conditions in the Calvert Cliffs Updated Final Safety Analysis Report).

CCNPP Response 1:

There is one load sequencer per safety-related bus. The logic diagram for the Engineered Safety Features Actuation System is contained in Enclosure 1. This logic diagram includes the logic details for the accident (loss-of-coolant incident, called the LOCI sequencer) and shutdown sequencer. The accident and shutdown sequencers are one module. Different inputs will actuate different portions of the module. If a Safety Injection Actuation Signal is present with an Undervoltage signal, then the accident function is actuated (six steps). If only an Undervoltage signal is present, then the shutdown function is actuated (three steps).

The table below shows information for the shutdown sequencer similar to the information contained on Table 8-7 in the Updated Final Safety Analysis Report for the accident sequencer.

SEQUENCER STEP NO.	TIME (SECONDS)	SERVICE	1ZA (BUS 11)	1ZB (BUS 14)	2ZA (BUS 21)	2ZB (BUS 24)
0	0[(1)(3)]	Reactor Motor Control Centers	114	104	214	204
		Turbine Bearing Oil Pump*[(2)]			21	
		1E Battery Chargers	11&14	12&13	22&23	21&24
		Transformer for 208/120 Volt Instrumentation Busses	11	12	21	22
		Diesel Generator Room Exhaust Fan		1B	2A	2B
		Control Room HVAC Fans	11			12
		Control Room Air Conditioning Condenser Fans*	11			12
		Emergency Core Cooling System Pump Room Air Coolers	11	12	21	22
		Emergency Core Cooling System Pump Room Exhaust Fans	11	12	21	22
		Boric Acid Storage Tank Heaters*	Two	Two	Two	Two
		Heat Tracing System*	11	12	21	22
		Diesel Building 1A and Auxiliaries	1A			
		Switchgear Room HVAC Fans	11	12	21	22
		1E Battery Room Fans	One exhaust fan and one redundant supply fan			
		Service Water Pump, if previously operating	11	12	21	22
1	5	Service water pump if not previously operating	11	12	21	22

SEQUENCER STEP NO.	TIME (SECONDS)	SERVICE	1ZA (BUS 11)	1ZB (BUS 14)	2ZA (BUS 21)	2ZB (BUS 24)
2	10	Saltwater pumps	11	12	21	22
		Switchgear Room Air Conditioner*				22
2A	20	Computer Room HVAC*		11	12	
3	15	Switchgear Room Air Conditioner*	11	12	21	
		Instrument Air Compressor	11	12	21	22
		Control Room HVAC*	11			12
3A	30	AFW Pump	13			23

(1) At time 0 seconds, the generator breaker is closed and the loads listed for the 0-second time step are energized independent of sequencer action.

(2) The loads identified with * are process controlled. The load feeder breaker will be closed at the time listed but the equipment will not run until called for by the process signal.

(3) There are additional minor loads energized at time 0 not shown in table.

RAI 2:

In regards to SR 3.8.1.8, provide details of any load sequence times outside of the 10% time interval tolerance, which might have occurred during last five years.

CCNPP Response 2:

We have reviewed the Condition Reports for the load sequencers written in the last five years. There were two Condition Reports that documented a failure of a load sequencer time step outside of the 10% time interval tolerance in the last five years. An installed load sequencer was tested on June 23, 2013. One of the six steps (step 2) failed to meet the acceptance criteria of 5 seconds + 10%. A replacement sequencer module was installed on June 24, 2013. One of the six steps (step 6) failed to meet the acceptance criteria of 5 seconds + 10%. A second sequencer module was installed on June 25, 2013. This sequencer module met all of the acceptance criteria. No other failure of sequencer modules to meet the acceptance criteria has been identified in the last five years.

RAI 3:

On page 3 of Attachment 1 of the LAR, in regards to SR 3.8.1.11, the licensee stated, "To perform this surveillance test at the most limiting power factor, the voltage regulators must be placed in the manual mode of operation. This operational mode means that the safety bus voltage now tracks with the grid voltage swings. This places equipment at greater risk for being impacted by degraded grid voltage for the duration of the surveillance test. Currently, the surveillance test is one hour in duration and the exposure time with the voltage regulators in manual is minimal. With the change to a 24 hour surveillance test, the exposure time with the voltage regulators in manual is significant. The probability of a grid voltage swing is increased in a 24 hour period. It is not an optimum testing practice. Therefore, we propose to change the SR by removing the power factor numbers and the associated Note 2. The surveillance testing will be conducted at the required loads for a total of 24 hours at the worst case power factor achievable with the voltage regulators in automatic mode. The achievable power factor will depend on the grid conditions during the surveillance test but is expected to be approximately 0.9."

Regarding the above statements, please provide the following information:

a. *Explain why the voltage regulator needs to be in the manual mode in order to reduce the equipment risk during the surveillance test. Provide catalog cut/operational details of the voltage regulator.*

b. *Explain whether the surveillance test can be performed at the power factor limits during the 2-hour period by keeping the voltage regulators in manual mode of operation, so as to limit the equipment risk to any degraded grid voltage. If yes, provide details of power factor test limits corresponding to the kilo-watts (kW) loading during the 2-hour test period.*

CCNPP Response 3:

3a – As described below, the 13.8 kV voltage regulators need to be in the automatic mode of operation to reduce risk to safety-related equipment during Unit operation. The only way to reach the reduced power factor required by the current Technical Specification under all conditions is to place the 13.8 kV voltage regulators in manual mode, which increases risk to the associated safety-related equipment.

Calvert Cliffs' electrical distribution design includes 13.8 kV voltage regulators which control voltage on the 4 kV safety-related buses. These voltage regulators can adjust voltage, as necessary, for changes in grid voltage. Therefore, the 13.8 kV voltage regulators ensure the 4 kV safety-related bus voltages remain within acceptable values for various grid voltages. When the 13.8 kV voltage regulators are in the manual mode, the 13.8 kV voltage regulators cannot automatically correct for changes in grid voltage. Therefore, a 4 kV safety-related bus voltage and its associated electrical distribution system can be adversely affected by grid voltage changes when its associated 13.8 kV voltage regulator is in manual.

When paralleling a DG to the grid, the DG power factor can be adjusted by either changing the DG generator voltage or the 4 kV bus voltage. To increase the DG VARs (i.e., decrease the DG power factor) the DG voltage can be increased or the 4 kV bus voltage can be decreased. Depending on the 4 kV bus voltage at the time of the test, the DG voltage regulator range may not be sufficient to achieve the required power factor. To further increase the DG VARs and decrease DG power factor, the 4 kV bus voltage could be decreased. This can be accomplished by placing the associated 13.8 kV voltage regulator in manual and "stepping" the 13.8 kV voltage regulator down one step. This decreases the 4 kV bus voltage, increases DG VARs, and decreases DG power factor. However, with the 13.8 kV voltage regulator in manual, the 4 kV bus and associated electrical distribution system can be adversely affected by changes in grid voltages.

Therefore, in order to obtain the required DG power factor, plant conditions (bus voltages, DG voltage regulator performance) may require reducing the 4 kV bus voltage. This requires placing the 13.8 kV voltage regulator in manual, which removes the automatic voltage protection to plant electrical distribution systems from grid voltage changes. As requested catalog and operational details of the transformers and tap changers are contained in Enclosure 2.

3b - The main difference between the current one hour endurance test [Surveillance Requirement (SR) 3.8.1.11] and the proposed 24 hour endurance test is when the test is performed. The one hour endurance test is performed during a refueling outage, during a DG testing window. The associated 4 kV bus is inoperable during this time and placing the voltage regulators in a manual mode has less impact than when the 4 kV bus is operable. The 24 hour endurance test is performed when the Unit is operating. The associated 4 kV bus remains operable during the test and the impact to the stability of the operable 4 kV bus is increased when the voltage regulator is in the manual mode. The voltage regulators in automatic mode support the operation of safety-related equipment under degraded voltage conditions. Even for a two hour period, this exposure to grid voltage changes is not acceptable.

Therefore, we are not able to guarantee that the power factor limits will be achieved during the 24 hour endurance test.

RAI 4:

On page 3 of Attachment 1 of the LAR, the licensee described the kW loading requirements for the DG for SR 3.8.1.11. Provide a summary of the loading calculations for each DG for both accident and LOOP conditions.

CCNPP Response 4:

The table below provides the loading for each DG during accident conditions. The accidents considered were a main steam line break, a large break loss-of-coolant accident (LB LOCA) and a small break loss-of-coolant accident. For each DG, the LB LOCA was the limiting accident for DG loading. The highest loading for each DG is in bold.

Diesel Generator	Accident	1st Minute	Pre-RAS	Post-RAS	On SDC
1A DG	LB LOCA	3088.0	3205.9	**3275.3**	3184.2
1B DG	LB LOCA	2309.8	2280.3	2350.6	**2564.4**
2A DG	LB LOCA	2310.0	2357.3	2425.3	**2591.3**
2B DG	LB LOCA	2841.3	2831.1	**2902.1**	2699.6

RAS – Recirculation Actuation Signal. For a LB LOCA, this is assumed to occur at 30 minutes into the accident.

The table below provides the loading for each DG during loss of offsite power (LOOP) conditions. The highest loading for each DG is in bold.

Diesel Generator	Accident	1st Minute	1-10 Minutes	10-75 Minutes	75 Minutes-4 Hours	On SDC
1A DG	LOOP	2058.7	2799.6	**3495.9**	3148.9	3027.7
1B DG	LOOP	1282.6	1983.2	2359.3	2140.4	**2388.1**
2A DG	LOOP	1310.5	2054.9	2296.4	2076.8	**2427.4**
2B DG	LOOP	1830.2	2450.4	**2771.8**	2539.5	2474.5

RAI 5:

The proposed changes to SR 3.8.1.11 relating to the 2-hour and 22-hour tests, states that, "These test phases may be performed in either order."

Explain how performing the 2-hour test after the 22-hour test demonstrates the capability of the DG to perform its design function.

CCNPP Response 5:

As can be seen in the response to RAI 4, sometimes the DG loading is higher at the end of an event rather than the beginning of an event. Therefore, a higher test load at the end of an endurance run can more closely model the bus loading that could be experienced.

Additionally, DG loading includes a prelubricating and warm-up period and a gradual loading period as described in the Technical Specification Bases. It takes approximately 15 to 30 minutes to load a DG to its test band. During the test, no adjustments are made at the lower load which would affect the ability of the DG to operate at the higher load. Therefore, since time to load is not critical, and the ability to increase to the higher load later is not affected, operating at the lower load first does not affect the higher load test. Also note that wear and tear on the DG may be reduced if operated at the lower load first, thereby reducing the need for tear-down maintenance of the DG.

RAI 6:

Provide the operating modes of the plant that the newly proposed SR 3.8.1.17 will be permitted to be performed.

CCNPP Response 6:

New SR 3.8.1.17 will be performed in Modes 5, 6, and defueled.

RAI 7:

According to the Standard Technical Specification (STS), NUREG-1432, Revision 4, in Section 3.8.2, "AC Sources – Shutdown," SR 3.8.2.1; SR 3.8.1.11 (equivalent to the newly proposed SR 3.8.1.17) is not in the list of SRs which are not applicable, but rather is in the list of SRs in the "NOTE", which are not required to be performed. The NRC staff finds that the exemption for not performing the newly proposed SR 3.8.1.17 should be covered in the "NOTE".

Please explain the deviation from the STS.

CCNPP Response 7:

This deviation from the Improved Technical Specifications is based on plant specific criteria approved during the Improved Technical Specifications conversion. Specifically, the new SR 3.8.17 tests the DG automatic start in response to an undervoltage signal [provided by Diesel Generator (DG)-Loss of Voltage Start (LOVS), Technical Specification 3.3.6]. The DG-LOVS is not required to be Operable in Modes 5 and 6, or during movement of irradiated fuel assemblies. As described in Reference 1, the undervoltage instrumentation is only required in Modes 1 through 3. This is consistent with the discussion provided in our application for a license amendment (Reference 2). That letter states that a DG is required during shutdown and refueling to ensure adequate AC electrical power is available to mitigate events such as a fuel handling incident or a loss of shutdown cooling. Due to the reduced pressure and temperature conditions of the Reactor Coolant System during shutdown conditions, these events develop more slowly and the results are less severe than the events which occur at full power. Thus, additional time is available for the operator to evaluate plant conditions and respond by manually operating the engineered safety feature components (including a DG) as required to successfully mitigate the consequences of the event. These discussions support the exclusion of undervoltage signals in Modes 5 and 6, and during movement of irradiated fuel assemblies.

Technical Specification SR 3.0.1 requires that SRs be met during the Modes or other specified conditions in the Applicability, unless otherwise stated. Failure to meet a SR, whether the failure is experienced during the performance of the SR or between performances of the SR, is a failure to meet the Limiting Condition for Operation. New SR 3.8.1.17 includes the requirement to auto start the DG from a standby condition on a loss of offsite power signal. This requires that the DG-LOVS system be Operable. The DG-LOVS system operability is contained in Technical Specification 3.3.6. The Applicability of Technical Specification 3.3.6 is Modes 1 through 4. The DG-LOVS system is not required to be Operable in Modes 5, 6 or during movement of irradiated fuel assemblies. Therefore, it can be taken out of service in these Modes. When it is taken out of service, the requirements of SR 3.8.1.17 are not met, and the Limiting Condition for Operation is not met. This leads to the need to exempt SR 3.8.1.17 from the list of SRs requirements.

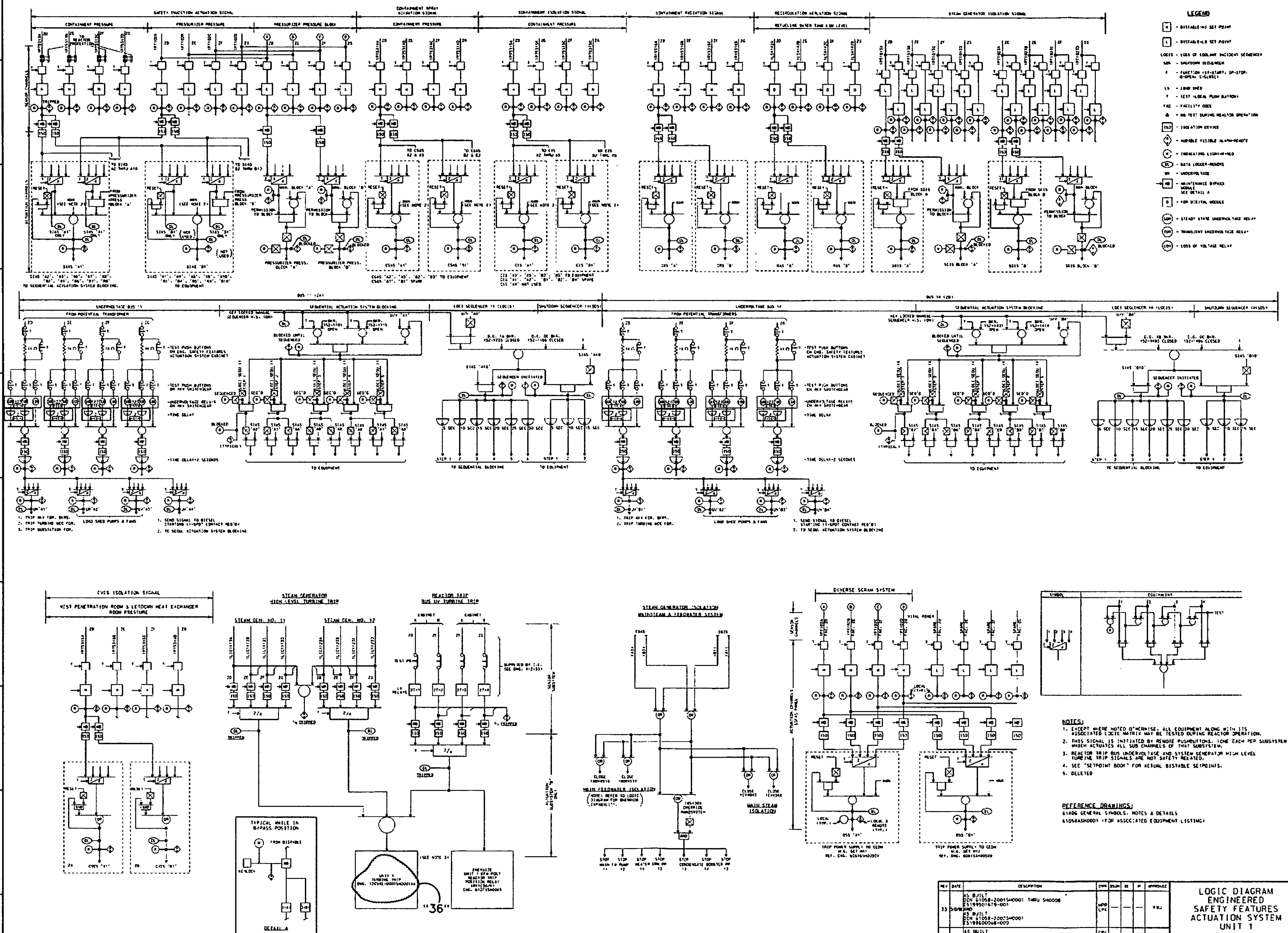
This position is consistent with the current list of SRs exempt in SR 3.8.2.1.

REFERENCES

1. Letter from D. G. McDonald (NRC) to R. E. Denton (CCNPP), dated September 27, 1994, Issuance of Amendments for Calvert Cliffs Nuclear Power Plant, Unit No. 1 (TAC No. M88168) and Unit No. 2 (TAC No. M88169)
2. Letter from R. E. Denton (CCNPP) to Document Control Desk (NRC), dated November 2, 1993, License Amendment Request: Emergency Diesel Generator Testing

ENCLOSURE 1

ENGINEERED SAFETY FEATURES ACTUATION SYSTEM LOGIC DIAGRAM



NOTES:
1. EXCEPT WHERE NOTED OTHERWISE, ALL EQUIPMENT ALONG WITH ITS ASSOCIATED LOGIC MATRIX MAY BE TESTED DURING REACTOR OPERATION.
2. THIS SIGNAL IS INITIATED BY REMOTE PUSHBUTTONS, (ONE EACH PER SUBSYSTEM) WHICH ACTUATES ALL SUB CHANNELS OF THAT SUBSYSTEM.
3. REACTOR TRIP BUS UNDERVOLTAGE AND SYSTEM GENERATOR HIGH LEVEL TURBINE TRIP SIGNALS ARE NOT SAFETY RELATED.
4. SEE "SETPOINT BOOK" FOR ACTUAL BISTABLE SETPOINTS.
5. DELETED

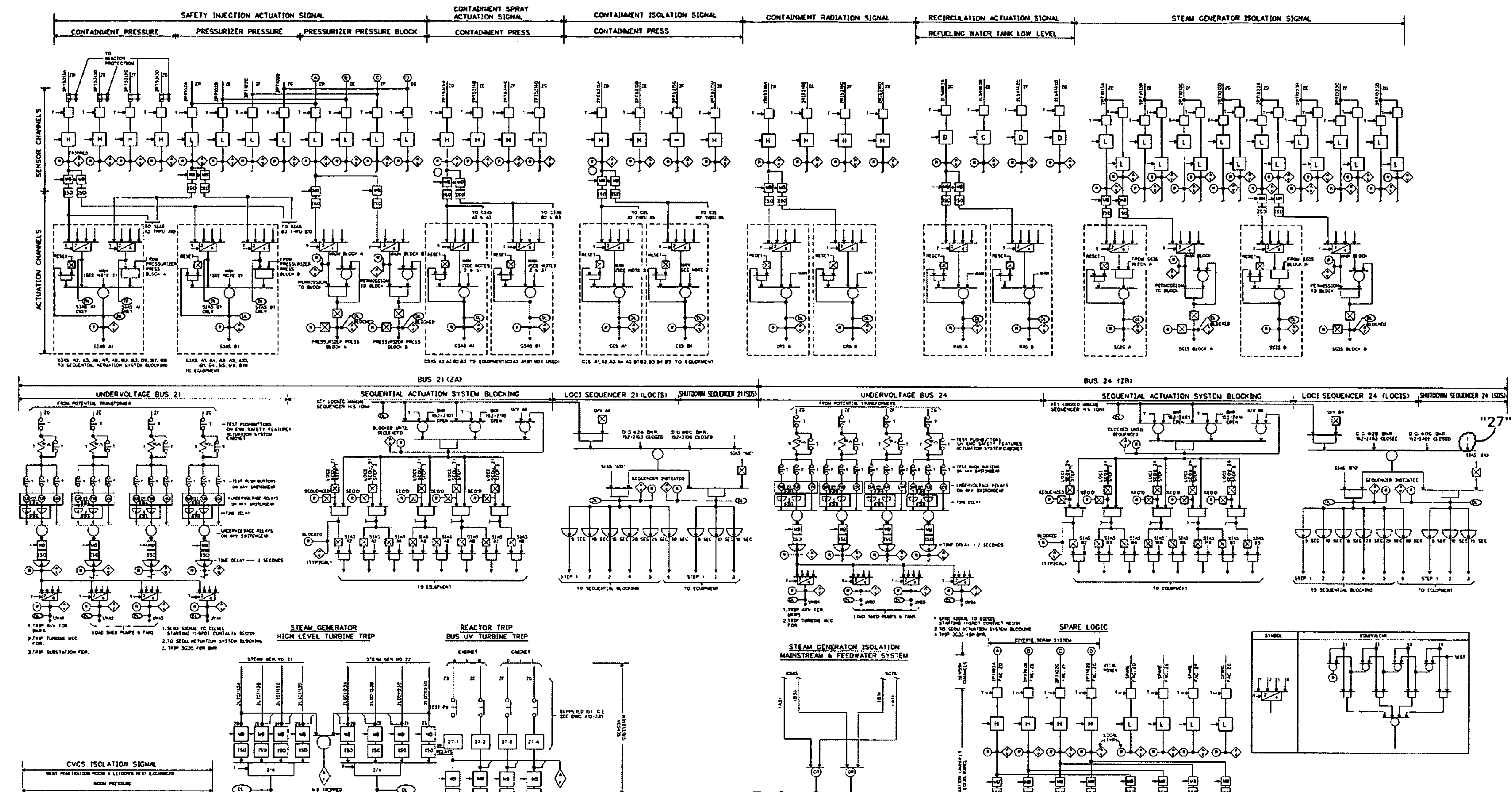
REFERENCE DRAWINGS:
61406 GENERAL SYMBOLS, NOTES & DETAILS
61058ASH0001 (FOR ASSOCIATED EQUIPMENT LISTING)

REV	DATE	DESCRIPTION	DWN	DSGN	ES	IP	APPROVED
33	[illegible]	AS BUILT DCN 61058-2001SH0001 THRU SH0006 ES199501679-001 AND AS BUILT DCN 61058-2002SH0001 ES199600068-003	MPR LPK	—	—	—	KWJ
34	[illegible]	AS BUILT DCN 61058-2003SH0001 ES199600827-002	CPK MPR	—	—	—	KWJ
35	[illegible]	AS BUILT INFO ONLY ES200100722-000	GPK MPR	—	—	—	KWJ
36	[illegible]	AS BUILT DCN 61058-2004SH0001 ES200300470-001	EAM CPM	—	—	—	CPM

LOGIC DIAGRAM
ENGINEERED
SAFETY FEATURES
ACTUATION SYSTEM
UNIT 1

CALVERT CLIFFS NUCLEAR POWER PLANT
ENGINEERING SERVICES DEPARTMENT
CALVERT CLIFFS UNIT 1 — SIZE E — CAT C
SCALE: NONE — VENDOR DWG NO. 1-LD-058 — REV. 36
DWG. NO. 61058

STOP, THINK, ACT AND REVIEW



LEGEND

- H - BISTABLE-HI SET POINT
- L - BISTABLE-LO SET POINT
- LOCIS - LOSS OF COOLANT INCIDENT SEQUENCER
- SDS - SHUTDOWN SEQUENCER
- F - FUNCTION (ST-START, SP-STOP, O-OPEN, C-CLOSE)
- LS - LOAD SHED
- T - TEST (LOCAL PUSHBUTTON)
- FAC. - FACILITY CODE
- D - FOP DIGITAL MODULE
- ✳ - NO TEST DURING REACTOR OPERATION
- ISO - ISOLATION DEVICE
- ◇ - AUDIBLE VISIBLE ALARM REMOTE
- R - INDICATING LIGHT R-RED
- DL - DATA LOGGER-REMOTE
- UV - UNDERVOLTAGE
- MB - MAINTENANCE BYPASS MODULE SEE DETAIL A
- SUR STEADY START UNDERVOLTAGE RELAY
- TUR TRANSIENT UNDERVOLTAGE RELAY
- LOV LOSS OF VOLTAGE RELAY

NOTES:

1. EXCEPT WHERE NOTED OTHERWISE, ALL EQUIPMENT ALONG WITH ITS ASSOCIATED LOGIC MATRIX MAY BE TESTED DURING REACTOR OPERATION
2. THIS SIGNAL IS INITIATED BY REMOTE PUSHBUTTONS (ONE EACH PER SUBSYSTEM) WHICH ACTUATES ALL SUB CHANNELS OF THAT SUBSYSTEM.
3. REACTOR TRIP BUS UNDERVOLTAGE AND STEAM GENERATOR HIGH LEVEL TURBINE TRIP SIGNALS ARE NOT SAFETY RELATED
4. SEE SETPOINT BOOK FOR ACTUAL BISTABLE SETPOINTS

REFERENCE DRAWINGS:

61406 GENERAL SYMBOLS, NOTES & DETAILS
63058A (FOR ASSOCIATED EQUIPMENT LISTINGS)
VENDOR DWG 6750-M-18-402

REV	DATE	DESCRIPTION	DWN	DSGN	CE	QA	APPROVED
24	[illegible]	AS BUILT DCN 63058-1012SH0001 FCR 89-C079-00	BGB CPM	—	—	—	KWJ
25	[illegible]	AS BUILT DCN 63058-2001SH0005,6,7&8 ES199501679-C01	BGB CPM	—	—	—	KWJ
26	[illegible]	AS BUILT DCN 63058SH0001-2002SH0001 ES199803C068-002	BGB KWJ	—	—	—	KWJ
27	[illegible]	AS BUILT DCN 63058SH0001-2003SH0001 ES200330C307-000	EAM CPM	—	—	—	CPM

LOGIC DIAGRAM ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

CALVERT CLIFFS NUCLEAR POWER PLANT
ENGINEERING SERVICES DEPARTMENT
CALVERT CLIFFS UNIT 2 — SIZE E — CAT C
SCALE: NONE — VENDOR DWG NO 2-LD-058SH0001 — REV.
DWG NO 63058SH0001 — 27

ENCLOSURE 2

TRANSFORMER AND TAP CHANGER INFORMATION

15715-012-1023

Service Information

COOPER POWER SYSTEMS

Power Transformers

Load Tap Changing Equipment – Installation, Operation, and Maintenance

S210-40-3

Applicable to Type 550C and in particular to Type 550CS Load Tap Changers.

CONTENTS

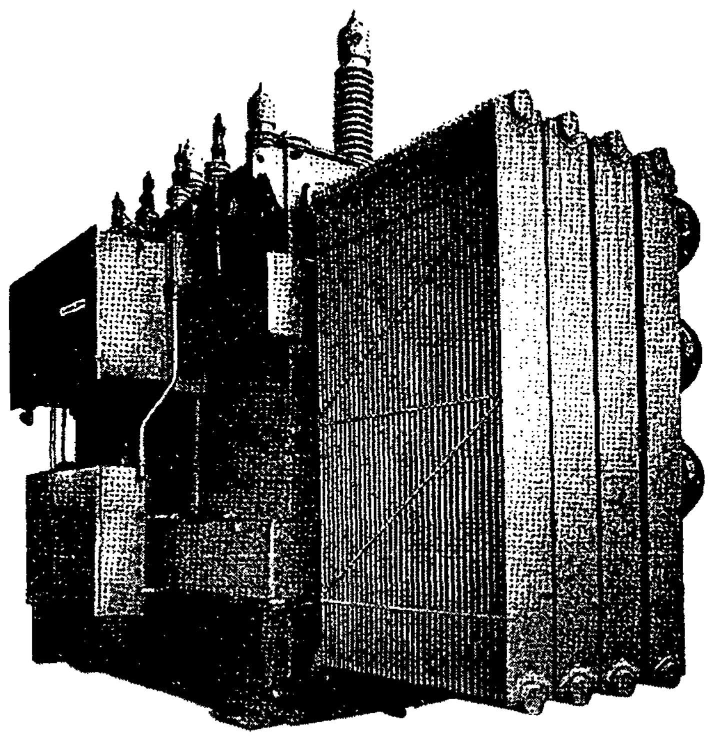


Figure 1.
Typical McGraw-Edison transformer with LTC equipment.

GENERAL

The Type 550CS is an improved version of the original Type 550C load-tap-changing arcing-tap-selector switch first introduced in 1964 for medium-size transformers.

It offers dependable, quiet operation through a normal voltage-regulation range of plus ten percent and minus ten percent in thirty-two ⅝-percent steps; other regulation ranges are also available. They meet appropriate national standards.

Load-tap-changing arcing-tap-selector switches are designed to be operated. Occasionally LTC transformers are used in applications where the LTC is not required and does not operate for extended periods of time. In these situations, it is good operating practice to by-pass the LTC. Refer inquiries concerning by-pass arrangements to the Service Department, McGraw-Edison Power Products, Canonsburg, PA 15317.

The LTC mechanism consists of three major components: the tap selector, the drive, and the controls. The tap selector is located in an oil-filled compartment welded to the upper section of the transformer tank. This compartment has an oil-tight Pennsylite® panel isolating the tap selector from the transformer. The drive and the controls are in an air-filled weatherproof compartment located directly beneath the tap-selector compartment. Part of the drive is contained in a cast-aluminum housing within the compartment. A universal driveshaft connects the drive with the tap selector through a self-compensating spring-loaded stuffing box in the selector compartment.

This Service Information bulletin covers in detail the tap selector and the drive unit; the controls are covered in *S210-40-14, Controls for Power-Type Load Tap Changing Equipment.*

SHIPPING

The tap-selector compartment is shipped filled with either oil, dry nitrogen gas, or dry air. It is standard practice for McGraw-Edison to ship the LTC switch under the same conditions as the main transformer. To determine the conditions under which the LTC switch has been shipped, refer to the detailed outline drawings supplied with the equipment.

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 sales engineer.

INITIAL INSPECTION

Immediately upon receipt of an LTC transformer—preferably before unloading—thoroughly inspect the exterior and the interior of the LTC and the transformer for damage, rough handling in transit, and shortage.

If initial inspection reveals evidence of damage, rough handling in transit, and/or shortage, notify—and file a claim with—the carrier at once. Also notify McGraw-Edison Company, Power Systems Division, Post Office Box 440, Canonsburg, PA 15317.

All leaks must be located and repaired before proceeding with the installation or storage.

STORAGE

If, after initial inspection, a transformer is not to be placed in the service-ready condition immediately, it is considered to be in storage.

Refer to Service Information S210-05-5, Liquid-Immersed Units—Installation and Maintenance Instructions.

PRELIMINARY PREPARATIONS

Refer to the PRELIMINARY PREPARATIONS PRIOR TO FILLING Section in Service Information S210-10-1, Vacuum Filling Oil-Immersed Power Transformers.

> **⚠ WARNING**
> Before performing any work on the LTC arcing tap selector switch, drive or controls, observe the warnings and cautions appearing in *Service Information S210-40-14 and S210-40-18*

1. Vent nitrogen gas or drain oil from the tap-selector compartment.
   A. Remove the 1-in. pipe plug from the drain-and-sampling valve; drain the oil from the compartment.
2. Open the tap-selector compartment door.
3. Inspect the tap selector for physical damage.
4. Inspect the tap-selector compartment for evidence of moisture.
   A. If there is any sign of moisture inside the compartment, determine the extent and the manner by which the moisture entered and correct the condition.
   B. Any moisture detected in the tap-selector compartment must be removed using clean, dry cloths.

INSTALLATION

1. Install the open-breather system on the tap-selector compartment (Figure 2).
   A. Carefully remove the pipe cap from the inlet breather pipe protruding from the bottom of the compartment. *The pipe may contain a small amount of oil that splashed in during manufacturing or shipping.*

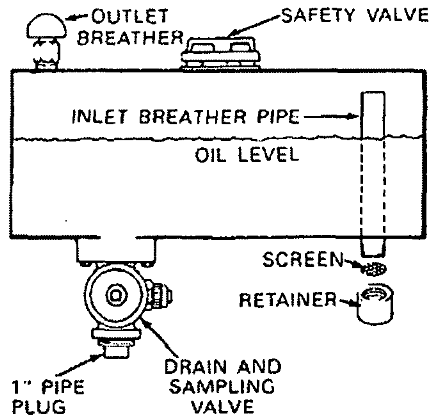


Figure 2.
Installation of open-breather components.

   B. Install the screen and retainer on the inlet breather pipe.
   C. Remove the 1-in. pipe plug from the top of the tap-selector compartment.
   D. Install the outlet breather, using a suitable thread-sealing compound (GE Glyptol 1201 or its equivalent).
   Note: Switches shipped prior to 1970 utilized a sealed compartment equipped with a 4 psi positive pressure relief device. McGraw-Edison's recommendation is the open-breathing system. It is possible to modify the switch compartments in the field to incorporate the open breathing arrangement. Contact Service Department, McGraw-Edison Power Systems Division, Box 440, Canonsburg, PA 15317.
2. Check the tap selector, drive shaft, and drive box (Figure 3) to make sure they are free from foreign objects that could interfere with proper operation.
3. Remove all the blocking from the automatic control panel.
4. Check the tap selector and the drive box for proper neutral-position relationship. *Refer to the NEUTRAL-POSITION RELATIONSHIP Section.*
   If the proper neutral-position relationship is not present, notify McGraw-Edison Company, Power Systems Division, Post Office Box 440, Canonsburg, PA 15317.
5. Place the handcrank on the handcrank shaft in the drive box (Figure 4).
6. Handcrank the LTC through its entire range to make sure there is no mechanical interference and operation is satisfactory.
   Refer to Operation by Handcrank in the PRINCIPLES OF OPERATION Section.
   It is normal for the greatest increase in force required to move the switch to occur in moving the switch from neutral to Position 1 raise or from Position 1 raise to neutral. It is at these positions that the additional load of operating the reversing switch is picked up. Movement of the reversing switch also comes into play in moving the switch from Position 2 raise to Position 3 raise and Position 1 lower to Position 2 lower. In these positions, the reversing switch contacts are moved from a first position to a second position on the stationary contact.

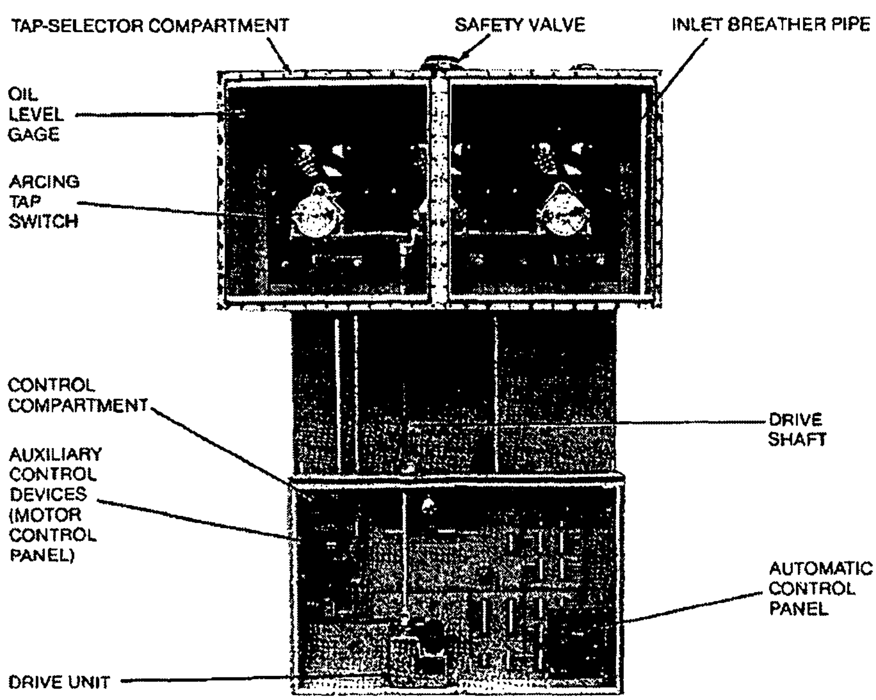


Figure 3.
Components of LTC mechanism.

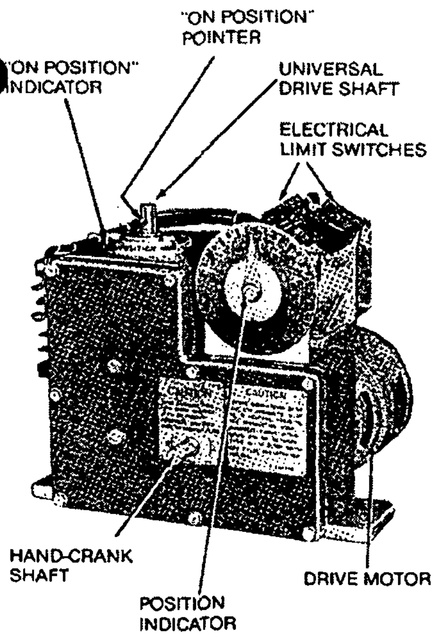


Figure 4.
LTC drive unit.

7. Remove the handcrank from the handcrank shaft; return the crank to its holder.

> ⚠ **WARNING**
> Before performing any work on the LTC arcing-tap-selector switch, drive or controls, observe the warnings and cautions appearing in *Service Information S210-40-14 and S210-40-18*

8. Energize the motor control panel (Figure 3).
9. Using the manual control switch, operate the LTC electrically step-by-step through its entire range.
   Refer to Operation by Electrical Hand Control in the PRINCIPLES OF OPERATION Section.
   A. Make sure the drive unit and the tap selector are stopping properly in position and the ON-POSITION POINTER is centered on the ON-POSITION INDICATOR PLATE.
   If not, refer to the TROUBLE-SHOOTING GUIDE.
   B. Make sure the operation counter is functioning properly.
   If not, refer to the TROUBLE-SHOOTING GUIDE.
   C. Check the limit-switch settings (Figure 4) by attempting to operate the control beyond the limit position. (The motor should not operate.)
   If the motor operates, refer to the TROUBLESHOOTING GUIDE.
   D. Check the handcrank switch by removing the crank from its holder and operating the control switch. (The motor should not operate.)
   If the motor operates, refer to the TROUBLESHOOTING GUIDE.
10. Test the dielectric strength and moisture content of the new oil before filling the compartment.
    Refer to Service Information S210-05-3. The new oil must test at 15 ppm (wt) moisture content and 30 kV minimum in standard gap (ASTM D 877) or 18 kV minimum in 0.040 gap (ASTM D 1816).
11. Close the drain-and-sampling valve, replacing the 1-in. pipe plug.
12. Refill the tap-selector compartment with oil to the 25 C level marked on the oil-level gage.
13. Pressure test the tap-selector compartment.
    Refer to the TESTING FOR LEAKS (PRESSURE TESTING) Section for recommended test procedures.
14. Operate the LTC approximately 30 operations to eliminate any air pockets that may have developed during refilling.
    Refer to the Arcing-Tap Switch-Type Load Tap Changer Section in Service Information S210-10-1, Vacuum Filling Oil-Immersed Power Transformers. If the transformer has been in storage for more than three months, operate the LTC for 10 minutes (approximately 800 operations) to re-seat the contacts and eliminate any air pockets resulting from refilling.

> ⚠ **CAUTION**
> The drive motor is designed for intermittent duty. If the motor is to be operated longer than 10 minutes continuously, it must be fan-cooled.

15. Energize the transformer.

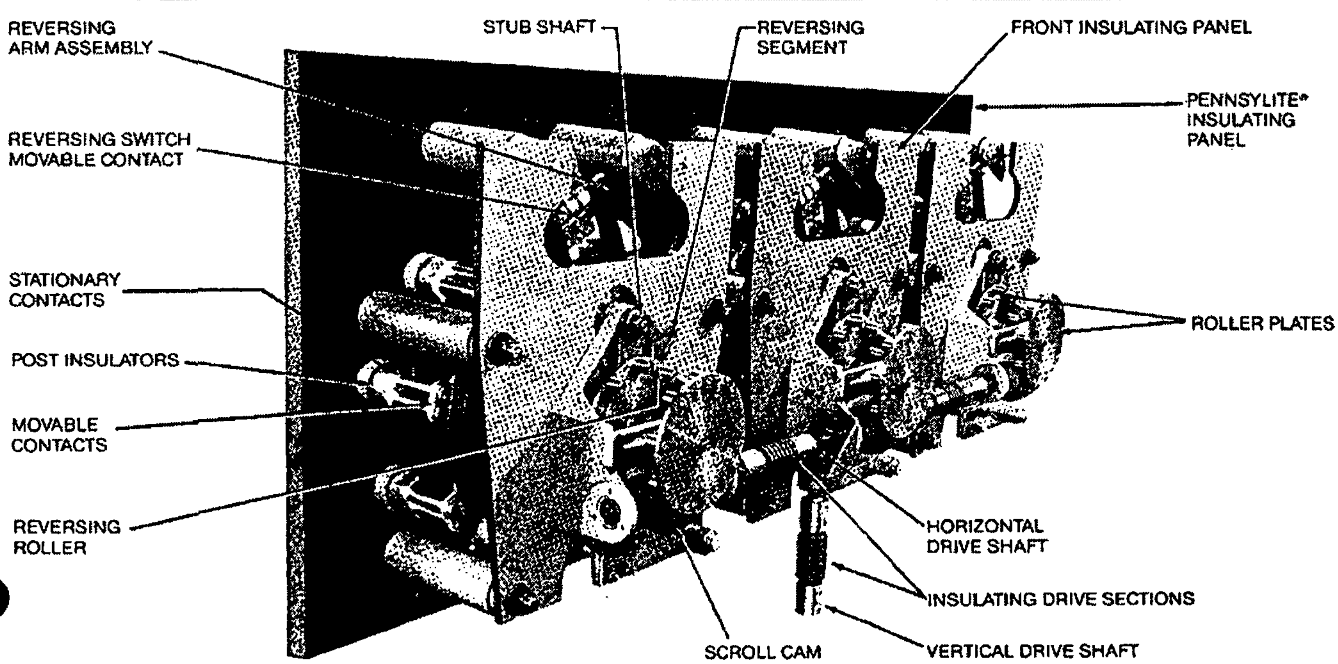


Figure 5.
Tap-selector assembly. (Shown in neutral position.)

PRINCIPLES OF OPERATION

Drive Mechanism

The drive with its associated motor-control panel is mounted in the control compartment located below the tap-selector compartment. Mechanical features of the drive unit are shown in Figure 4.

The drive, enclosed in an air-filled, cast-aluminum housing, is equipped with self-lubricating bearings; the gearing is coated with silicone grease during assembly to protect against rust. The limit switches and seal-in switch are mounted on the drive box.

A mechanical stop located inside the drive housing prevents operation of the tap selector beyond the limit positions when hand cranking, or in the event of electrical limit-switch failure.

The LTC is driven by a 115-Vac, 60-Hz, single-phase, capacitor-start, capacitor-run motor with positive stopping of the drive being achieved by dc braking of the motor. It is important that the motor has a well-regulated voltage supply (measured at the motor).

> **⚠ CAUTION**
> The drive motor is designed for intermittent duty. If the motor is to be operated longer than ten minutes continuously, it must be fan cooled.

Numerals in parentheses in the following discussion refer to Figure 6.

The motor (75), through a spur gear reduction (101 and 99), drives the spur gears (103 and 109). The hand-crank shaft (100) is attached to spur gear (103). Spur gear (92) drives the universal shaft (38) through a pair of miter gears (91 and 47). Shaft (81) extends through the rear of the drive housing and has mounted on it the seal-in switch operating cam (78). The motion of this shaft is transmitted through a pair of miter gears (78 and 77) and worm-gear assembly (49 and 69) to the position indicator and limit-switch arm (58).

Upon energization of the motor, the approximate time required to complete one tap change for a 32-step switch is one second. For a 16-step switch the time of the change is approximately doubled.

Located on the universal driveshaft coupling (36) at the top of the drive housing (43) is an ON-POSITION pointer. Normally, at the completion of each tap change this pointer should be centered on the ON-POSITION plate which is attached to the drive housing (see Checks and Adjustments Nos. 1 and 2 in the *TROUBLESHOOTING GUIDE Section)*. The pointer being anywhere between the indicating ends of the ON POSITION plate indicates that the tap-selector contacts are fully in contact.

> **⚠ CAUTION**
> Before dismantling the drive box, the LTC mechanism must be in the neutral position (see Neutral-Position Relationship in *TROUBLESHOOTING GUIDE Section)*. Incorrect timing within the drive box or between drive and tap selector can cause transformer failure.

If trouble is suspected within the drive housing, the McGraw-Edison Power Systems Division transformer service section should be consulted before repair or adjustment is attempted.

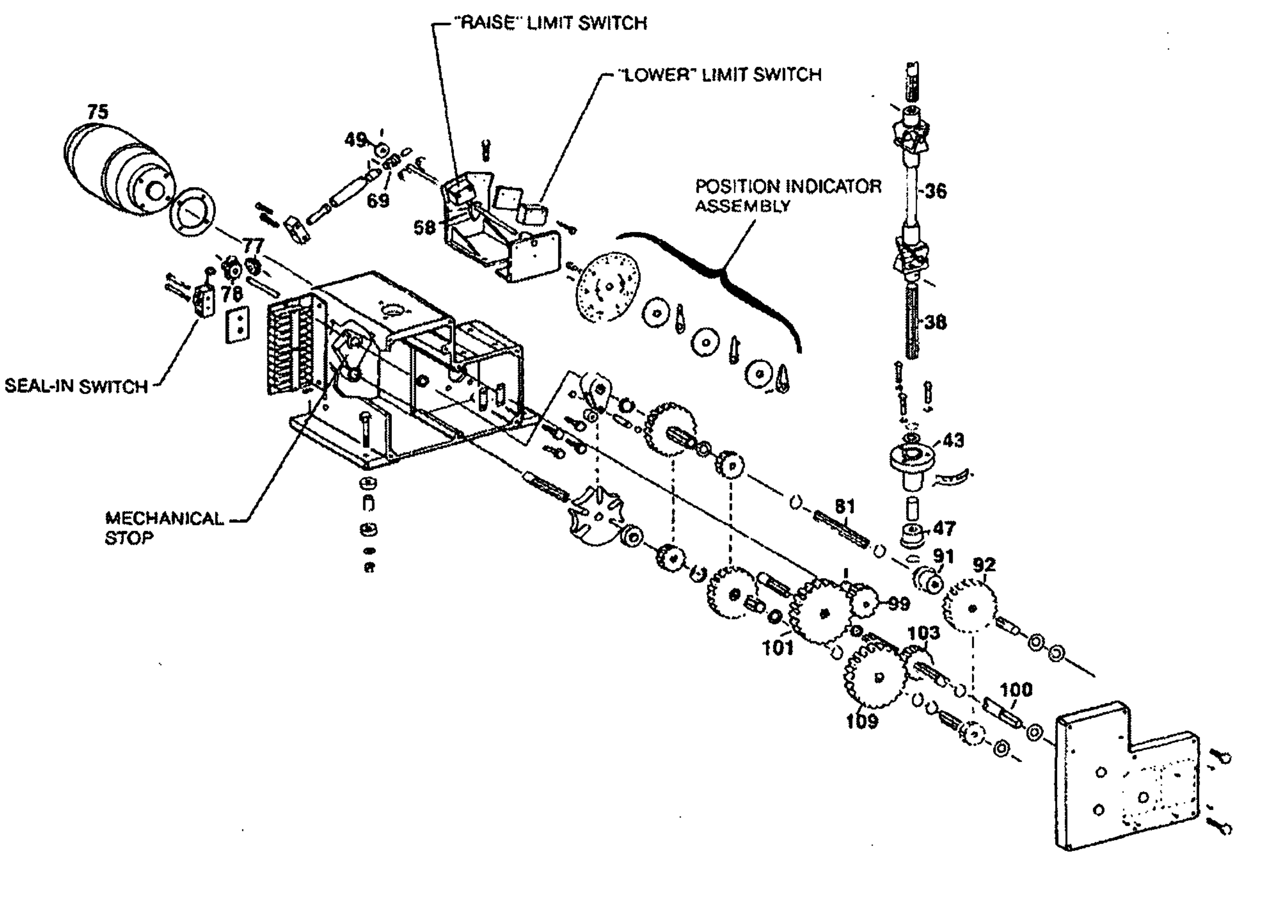


Figure 6.
Exploded view of LTC drive unit. (For complete parts list, refer to Figure 17 and accompanying table.)

Tap Selector

The tap selector is an arcing-tap-switch type load tap changer. The selector is mounted on a Pennsylite insulating panel which is oil-tight and isolates the main transformer compartment from the tap-selector compartment. The insulating panel will withstand full vacuum and serves as the terminal board for the taps from the transformer winding and the leads from the preventive-autotransformer.

> ⚠ **CAUTION**
> Do not operate the LTC switch when the transformer is under full vacuum condition.

The tap-selector compartment is open-breathing. The purpose of an open-breathing system is to exhaust the gases formed by breakdown of the oil by contact arcing. These gases can have a plating effect on copper and copper alloy surfaces which increases contact resistance. The compartment is also equipped with a safety valve (Figure 2) to exhaust any excessive pressure build up.

Note: Switches shipped prior to 1970 utilized a sealed compartment equipped with a 4 psi positive pressure relief device. Experience and verifying tests revealed that a hard black resistive coating could form on copper and copper-bearing alloy surfaces from polymerization of acetylene. Acetylene is always produced with arcing in oil. McGraw-Edison's recommendation is the open-breather system to eliminate as much of the acetylene as possible. It is possible to modify the switch compartments in the field to incorporate the open breathing arrangement.

Contact the Service Department, McGraw-Edison Power Systems Division, Canonsburg, Pennsylvania 15317.

Numerals in parentheses in the following discussion refer to Figure 7.

The universal driveshaft enters the tap-selector compartment through a self-compensating, spring-loaded stuffing box. The motion of the universal driveshaft is transmitted through an insulating coupling (5) to the center phase of the tap selector through a pair of miter gears (21), one of which is attached to the scroll-cam shaft. Motion is transmitted to the two end phases through horizontal insulating shafts (5 and 20). Operation of the end phases is identical to that of the center phase described below.

The motion of the universal driveshaft transmitted to the scroll-cam shaft causes the scroll cam (16) to rotate 180 degrees in the case of a 32-step switch, and 360 degrees in the case of 16-step switch. Every 180-degree movement of the scroll cam operates one of two roller plates (57 and 62) which are located on opposite sides of the scroll cam. Attached to each roller plate and operating concentrically are the movable-arcing-contact shafts (39 and 37), with movable-arcing-contact assemblies attached to insulating supports.

The movable arcing contacts (36) operate in different planes. The scroll cam, in moving 180 degrees, moves one or the other roller plate, causing the movable arcing contact to be moved from one stationary arcing contact (25) to the one adjacent. At the end of this movement, the dwell section of the scroll cam is positioned between two adjacent rollers of each roller plate and, because the arcing contact shafts are attached to the roller plates, they are thus locked in position.

In the case of a 32-step switch, the movable arcing contacts are positioned on the same stationary contact or adjacent stationery contacts for each tap change. In a 16-step switch, the movable arcing contacts are both positioned on the same stationary contact for each tap change.

The reversing switch changes winding connections for raise or lower regulation. The reversing switch for each phase, operated as the selector switches pass through neutral position, is actuated by a roller projecting from the face of the rear roller plate.

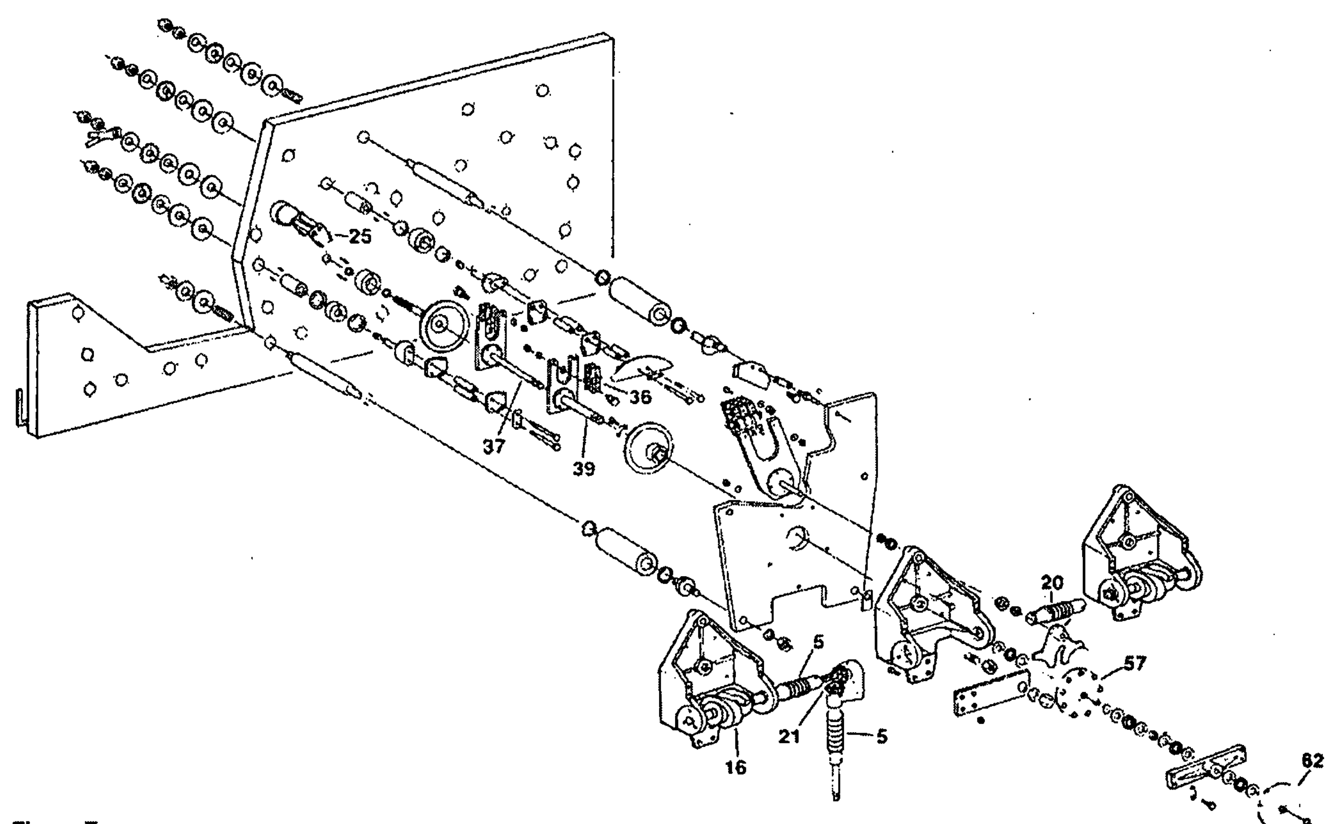


Figure 7.
Exploded view of tap-selector unit. (For complete parts list refer to Figure 18 and accompanying table.)

Automatic Operation by Voltage-Regulating Relay

> ⚠ **WARNING**
> Before performing any work on the LTC arcing-tap-selector switch, drive, or controls, observe the warnings and cautions appearing in *Service Information S210-40-14 and S210-40-18.*

For automatic operation of the mechanism, the control instruments, voltage-regulating relay, and line-drop compensator must be adjusted for the specific requirements of the system. Refer to ADJUSTMENTS Section in *S210-40-14, Controls for Power-Type Load-Tap-Changing Equipment.*

With all controls properly set, the load-tap-changing mechanism will operate automatically, giving the proper correction in secondary voltage as required by the setting of the voltage-regulating relay and line-drop compensator.

Operation by Electrical Hand Control

For operation of the mechanism by hand control, refer to *S210-40-14, "Controls for Power-Type Load-Tap-Changing Equipment."* With the controls properly set, operate the control switch to either RAISE or LOWER as desired.

Operation by Handcrank

> ⚠ **WARNING**
> McGraw-Edison DOES NOT recommend hand cranking the LTC mechanism while the transformer is energized. However, if *IN AN EMERGENCY SITUATION* you choose to hand crank the LTC mechanism while the transformer is ENERGIZED, the following procedure MUST be adhered to, otherwise transformer failure can occur:

1. Place the LTC motor breaker, located on the motor control panel, and the relay breaker, located on the automatic control panel, in the OFF positions.
2. Remove the handcrank. The removal of the handcrank opens the handcrank switch in the motor circuit and de-energizes the motor.
   NOTE: A handcrank stop prevents the operator from hand cranking the tap changer through a limit.
3. For each tap change, in the case of a 32-step switch, three revolutions of the handcrank are required. Crank clockwise to lower and counterclockwise to raise voltage.

> ⚠ **WARNING**
> The three revolutions of the hand-crank *MUST* be accomplished in 3 seconds and the switch MUST be hand cranked steadily *IN ONE DIRECTION ONLY* until the ON-POSITION POINTER is centered over the ON-POSITION plate. If the above instructions are not followed, transformer failure can occur.

4. For each tap change, in the case of a 16-step switch, six revolutions of the handcrank are required. Crank clockwise to lower and counterclockwise to raise voltage.

> ⚠ **WARNING**
> The six revolutions of the handcrank *MUST* be accomplished in 6 seconds and the swich *MUST* be hand cranked steadily *IN ONE DIRECTION ONLY* until the on-position pointer is centered over the ON-POSITION plate. If the above instructions are not followed, transformer failure can occur.

5. After the tap change is complete, remove and replace the handcrank in its holder thus closing the handcrank switch.
6. Place the LTC motor breaker and relay breaker back in the ON position enabling the LTC switch to be operated electrically.

When it is desired to operate the LTC mechanism by handcrank for preventive maintenance *with the transformer DEENERGIZED,* the procedure is identical to that described for "operation by handcrank while the transformer is energized" EXCEPT for the following:

1. The time required to complete a tap change is not limited.
2. The restriction for hand cranking in one direction only no longer applies.

MAINTENANCE

Periodic preventive maintenance inspection of the LTC mechanism is required. Generally, the interval between inspections is determined by the amount of contact erosion based on the number of tap changes as shown on the operation counter. The interval between inspections of like LTC mechanisms will vary considerably depending on individual conditions. For normal utility systems it is recommended that a thorough inspection of the mechanism be made at the end of the first year of operation and that subsequent inspections be based on the amount of contact erosion and number of tap changes noted at the end of the first year.

1. Deenergize the transformer.

> ⚠ **WARNING**
> The transformer must be deenergized before performing any maintenance inspection or work on an LTC. Inspecting or working on an LTC mechanism while the transformer is energized may result in bodily injury.

2. Energize the control circuit and operate the mechanism by electrical hand control step by step through the entire range.
   A. Observing the position indicator and ON-POSITION pointer, make sure the drive unit is stopping properly on position.
   If not, refer to Checks and Adjustments Nos. 1 and 2 in the TROUBLESHOOTING GUIDE Section.
   B. Check that the operation counter is functioning.
   If not, refer to the TROUBLESHOOTING GUIDE Section.
   C. Check the limit-switch settings by attempting to operate the control beyond the limit position. The motor should not operate.
   If the motor operates, refer to the TROUBLESHOOTING GUIDE Section.
   D. Check the handcrank switch by removing the handcrank from its holder and operating the control switch. The motor should not operate.
   If the motor operates, refer to Checks and Adjustments No. 5 in the TROUBLESHOOTING GUIDE Section.
3. Set the LTC mechanism in the neutral position by operating by electrical hand control until the position indicator on the drive unit indicates neutral (N). See Neutral-Position Relationship Section.
4. Remove the 1-in. pipe plug from the drain-and-sampling valve.
5. Open the drain-and-sampling valve; drain the oil from the tap-selector compartment.
   Refer to S210-10-1, Vacuum Filling Oil Immersed Power Transformers.
6. Open the tap-selector compartment door.
7. Inspect the tap selector for physical damage or evidence of moisture.
   A. If there is any sign of moisture inside the tap-selector compartment, determine the extent and the manner by which the moisture entered.
   Refer to the TESTING FOR LEAKS (PRESSURE TESTING) Section.
   B. Any moisture detected in the tap-selector compartment must be removed using clean, dry cloths.

8. Inspect stuffing box (Figure 17, Item 27) for evidence of oil leakage.

A. If there is any sign of oil leakage, determine the extent and the cause and correct.

Refer to the TROUBLESHOOTING GUIDE Section.

9. Check external shaft assembly (Figure 17, Item 25) for freedom of movement by sliding the shaft up and down slightly to make sure there is no binding in stuffing box (27).

If there is binding in the stuffing box, refer to the TROUBLESHOOTING GUIDE Section.

10. Thoroughly flush and, using clean, dry cloths, remove all carbonization which may be deposited on insulating surfaces. We recommend flushing with transformer oil but do not object to the use of *oil-base* solvents.

11. Close the drain-and-sampling valve, replacing the 1-in. pipe plug.

12. Place the LTC motor breaker (on the motor control panel) and the relay breaker (on the automatic control panel) in the OFF position.

13. Remove the handcrank from its holder. Removal of the handcrank opens the handcrank switch in the motor circuit and deenergizes the motor. A handcrank stop prevents the operator from handcranking the tap selector through a limit.

14. Place the handcrank on the handcrank shaft in the drive box.

15. Inspect the arcing contacts (Figure 12 and 13) for arc erosion.

In an arcing-tap-switch-type LTC mechanism, the tap selector performs a dual function: Tap selection and preventive-auto (switching-reactor) switching. Since the tap-selector also switches the preventive auto, the tap selector contacts are subject to arc erosion. Arc-resistant materials are used in both the movable and the stationary contacts. Erosion rates and patterns are functions of the tap voltage, the load current, and the preventive-auto design.

Figure 14 shows typical contact erosion patterns. The stationary arcing contacts normally erode more slowly than the movable arcing contacts because many tap positions (stationary arcing contacts) are encountered by the movable arcing contacts during their service life.

A. Inspect the movable arcing contacts (Figure 12) for arc erosion.

The point of replacement of movable arcing contacts is shown on the left in Figure 14.

If contacts are not replaced at this point, thermal instability at the contact interface will result, followed by thermal failure of the contact.

Contact assemblies are factory-set and designed to produce a 10-12 lb force per contact point.

To replace the movable arcing contacts:

(1) Handcrank the movable contacts to a convenient position between the stationary arcing contacts or remove the stationary arcing contacts on one tap position and handcrank the movable contacts to that position.

(2) Remove the eroded main movable arcing contacts.

(3) Install the new movable arcing contacts, using flatwashers, locknuts, and *shouldered* mounting bolts, positioning the bolt heads next to the thrust piece as shown in Figure 15.

> **⚠ CAUTION**
> When installing main movable arcing contacts, it is essential that zero pressure be maintained in the main transformer tank to establish proper alignment with the main stationary arcing contacts.
> **Do not overtighten the mounting bolts. Overtightening these bolts will crack the main insulating arm in the area of the bolt holes.**

NOTE: Mounting bolts are shouldered, so that, when properly assembled as shown in Figure 15, the thrust piece will move between the bolt heads and the main insulating arm to compensate for misalignment of the stationary and the movable arcing contacts.

(4) Handcrank the LTC slowly through its entire *range* around the dial to make sure there is clearance between the lower spring pins and the slipring and the upper spring pin and the stationary contact while on contact and while sweeping to adjacent contacts.

(5) Return the LTC to the neutral *position.*

Refer to the NEUTRAL-POSITION RELATIONSHIP Section.

B. Inspect the stationary arcing contacts (Figure 13) for arc erosion, using a small inspection mirror to thoroughly examine the backs of the contacts.

The point of replacement of stationary arcing contacts is shown on the right in Figure 14.

Stationary arcing contacts are silver plated to reduce the possibility of high-resistance oxidation which impedes current flow, adding to thermal instability at the point of contact. When the arcing tips erode to the point where burning on the silver plating can occur, the stationary contacts must be replaced.

NOTE: The silver-plated main dial stationary arcing contacts are directly interchangeable with all previous model 550C.

To replace the stationary arcing contacts:

(1) Remove the eroded contacts.

(2) Thoroughly clean all oxidation from the ends of the stationary contact spacer tubes and mounting supports.

Scotch-Brite No. 447 or No. 448 is recommended for cleaning copper surfaces.

(3) Install the new stationary arcing contacts, holding them against the mounting bolts toward the outside of the stationary contact bolt circle to establish proper alignment. See Figure 16.

16. Inspect the non-arcing reversing movable contacts (Figure 16) for mechanical wear.

NOTE: Earlier models shipped prior to February 1975 utilized a reversing switch design which because of the timing with the main dial would have arcing occurring on reversing stationary contact No. 1. At that time the reversing stationary contacts were tipped with a copper tungsten material to withstand the effects of arcing. The movable contact tips which engage the stationary contacts were also of a copper tungsten or silver tungsten material. The slot in the reversing segment was a straight slot as shown in Figure 16.

In 1975 we began using a reversing segment as shown in Figure 16 with an offset slot to delay the reversing movable contact coming off the stationary contact allowing the main dial contacts to interrupt the current eliminating the arcing on reversing stationary contact No. 1. This permitted the use of silverplated stationary contacts and coin silver movable contacts. When updating the reversing switches of older units you must replace the reversing stationary contacts, reversing neutral stationary contact, movable contact assembly and reversing insulating arm assembly. See Figure 5.

The reversing movable contacts are subject to mechanical wear, not arc erosion. When the initial gap between the movable contacts wears to $^{9}/_{32}$ in., the contacts should be replaced. The contact assemblies are factory-set and designed to produce a 10-12 lb force per contact point.

To replace the reversing movable contacts:

A. Handcrank the LTC so that the reversing movable contacts are midway between the reversing stationary contacts.

B. Remove the worn reversing movable contacts.

C. Install the new reversing movable contacts.

> **⚠ CAUTION**
> When installing reversing movable contacts, it is essential that zero pressure be maintained in the main transformer tank to establish proper alignment with the stationary contacts.

(1) Make sure the centerlines of the reversing stationary contact, the reversing movable contact assembly (thrust piece), and the reversing neutral stationary contact coincide (Figure 16).

(2) Handcrank the LTC slowly through at least three positions on either side of neutral to make sure there is clearance between the lower spring pins of the movable contact assembly and the reversing neutral stationary contact and the upper spring pins of the movable contact assembly and the stationary contacts.
Make sure that the reversing insulating arm is not rubbing on the face of the reversing neutral stationary contact.

(3) Return the LTC to the neutral position.
Refer to the NEUTRAL-POSITION RELATIONSHIP Section.

17. Inspect the non-arcing reversing stationary contacts (Figure 16) for mechanical wear.
The reversing stationary contacts are silverplated to reduce the possibility of high-resistance oxidation which impedes current flow, adding to thermal instability at the point of contact.
The reversing stationary contacts are subject to mechanical wear, not arc erosion. When the silver plating has worn off in the path of the reversing movable contacts, the stationary contacts should be replaced.
To replace the reversing stationary contacts:
A. Handcrank the LTC so that the reversing movable contacts are midway between the stationary contacts.
B. Remove the worn reversing stationary contacts.
C. Install the new reversing stationary contacts.

> **⚠ CAUTION**
> When installing reversing stationary contacts, it is essential that zero pressure be maintained in the main transformer tank to establish proper alignment with the reversing movable contacts.

D. Handcrank the LTC slowly through at least two positions on either side of neutral to make sure there is clearance between the reversing stationary contacts and the upper spring pin of the reversing movable contacts.
E. Return the LTC to the neutral position.
Refer to the NEUTRAL-POSITION RELATIONSHIP Section.

18. Make sure all fasteners, lockstrips, and electrical connections are tight and secure.
19. Handcrank the LTC step-by-step through its entire range to make sure there is no mechanical interference and that all the new contacts have been properly installed.
20. Return the LTC to the neutral position.
Refer to the NEUTRAL-POSITION RELATIONSHIP Section.
21. If the same oil is to be returned to the tap-selector compartment, filter and test the oil.
The oil must test 26 kV minimum in standard gap (ASTM D 877) and 25 ppm (wt) maximum moisture content.
22. Close the tap-selector compartment door.
23. Refill the tap-selector compartment with oil to the 25 C level marked on the oil-level gage.
Refer to S210-10-1, Vacuum Filling Oil-Immersed Power Transformers.
24. Pressure test the tap selector compartment.
Although each LTC mechanism is subjected to pressure tests for leaks before leaving the factory and pressure testing is recommended again before the open-breathing system is installed and prior to placing the unit in service for the first time, another pressure test is recommended prior to placing the unit in service after performing maintenance.
Refer to the TESTING FOR LEAKS (PRESSURE TESTING) Section for recommended test procedures.
25. Operate the LTC for 10 minutes (approximately 800 operations) to seat the contacts and eliminate any air pockets resulting from the oil filling.
Refer to the Arcing-Tap-Switch-Type Load Tap Changer Section in Service Information S210-10-1, Vacuum Filling Oil-Immersed Power Transformers.

> **⚠ CAUTION**
> The drive motor is designed for intermittent duty. If the motor is to be operated longer than 10 minutes continuously, it must be fan-cooled.

26. Energize the transformer.

Testing for Leaks
(Pressure Testing)

A pressure test of the tap selector compartment is recommended any time a gasketed device is removed or replaced which may leak oil out of or moisture into the switch compartment. Either one of the following methods is recommended:

Method 1

With the transformer deenergized, the tap selector compartment door sealed and the inlet and outlet of the open breather system sealed:

1. Fill the tap-selector compartment with oil.
2. Hold the oil under 5 psi max pressure for several hours.
Monitor the pressure closely because a change in ambient temperature can easily cause a drastic change in pressure.
3. Dust blue chalk powder on areas of suspected leakage.
The chalk will turn dark when wet with oil.

Method 2

With the transformer deenergized, the tap selector compartment door sealed, and the inlet and outlet of the open breather system sealed:

1. Maintain a nitrogen pressure of approximately 4 psi.
2. Paint a soap-bubble solution such as glycerine and liquid soap on the welded and gasketed joints to disclose leaks.
Alternative to painting with a soap-bubble solution. Seal the unit under the gas test pressure for a period of hours while monitoring for loss of pressure.

PRESSURE TEST OF TAP SELECTOR PANEL

A pressure test of the tap selector panel to check the integrity of all the gaskets forming seals between the tap selector compartment and the transformer is recommended any time a gasket is replaced or the oil level in the LTC compartment increases with no apparent reason.

With the transformer de-energized and the selector compartment drained and opened:

1. Wipe down selector panel with clean dry cloths.
2. Apply 3 psi min., 5 psi max. pressure to the transformer tank.
3. Check for oil seepage at gasketed points.

Neutral-Position Relationship

Whenever any component of the LTC mechanism is disassembled or re-assembled, the mechanism must be in the correct neutral-position relationship.

Before removing any component, match mark the component and its mating part so that they can be re-assembled in proper alignment.

> ⚠ **CAUTION**
> Incorrect timing within the drive box or between drive and tap selector can cause transformer failure.

This neutral-position relationship is established when the position indicator is on N (neutral) and the ON-POSITION POINTER of the drive mechanism is centered on the ON POSITION plate. Refer to Figure 8. The following other neutral-position relationships are established. The main movable arcing contacts of the selector switch are centered on stationary contact N and the reversing switch movable contacts are on stationary contact 10. The reversing roller must be in the slot of the segment and set 20 degrees to the right of the vertical centerline as viewed facing the front of the arcing tap switch.

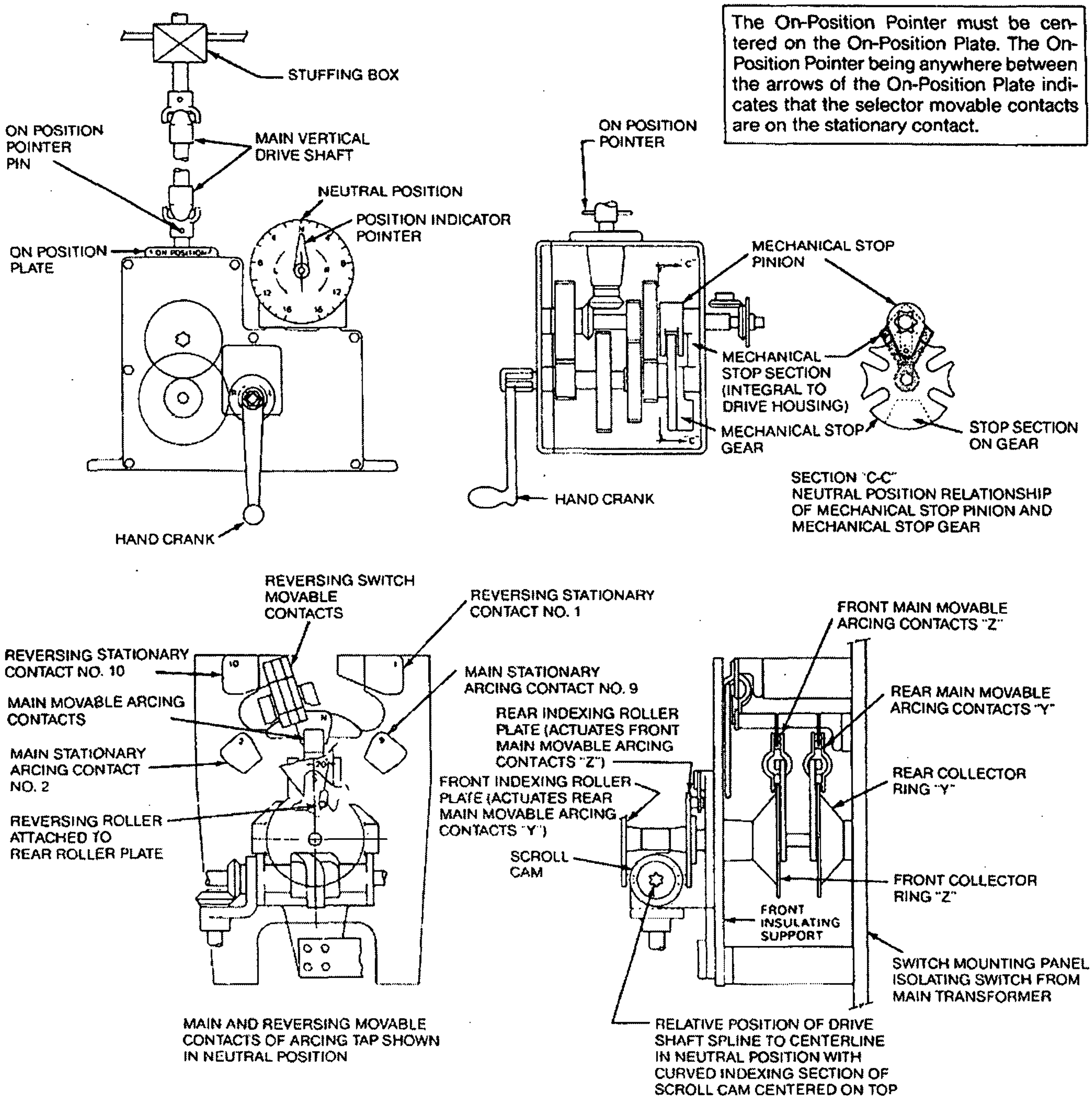


Figure 8.
Neutral-position relationship of tap selector and drive unit.

Maximum Raise and Lower Positions

There are 48 full turns of the handcrank from the neutral position to either maximum position. In the maximum position, the limit switch and seal-in switch open; the limit switch slightly before the seal-in switch (see switch-sequencing charts; Figure 10 for 16-step switch, Figure 11 for 32-step switch). The mechanical stop will become engaged during the 49th turn of the handcrank; however, there will be no change in the position of the movable arcing contacts. Refer to Figure 9.

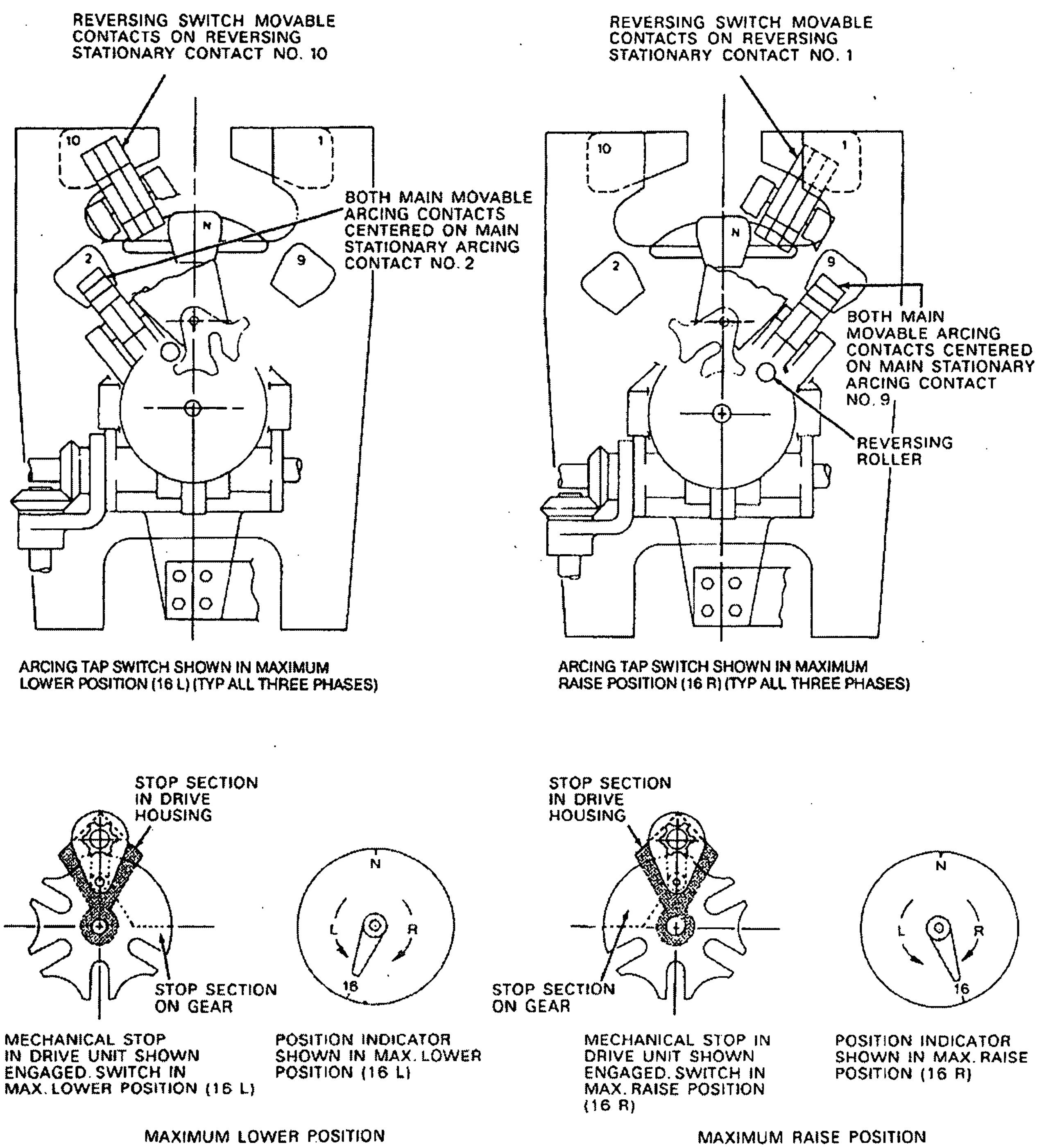
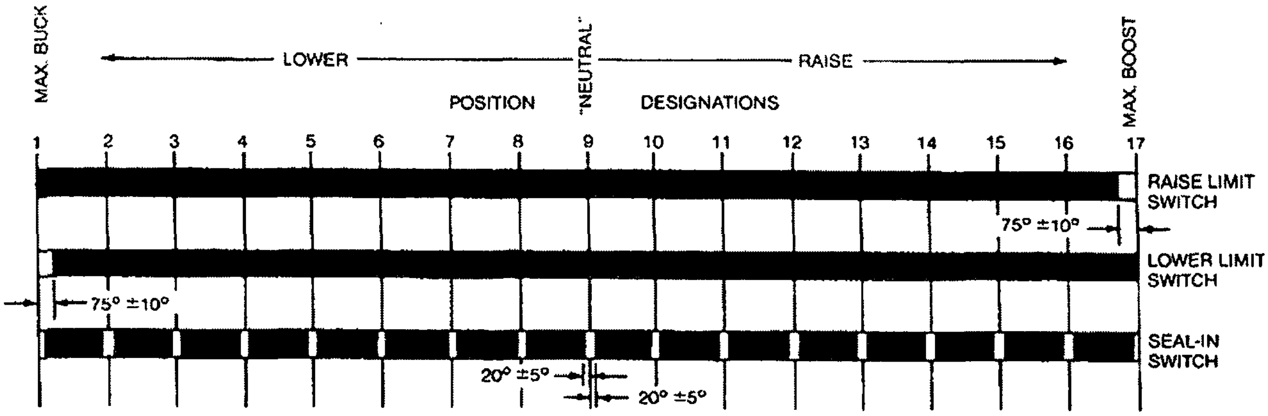


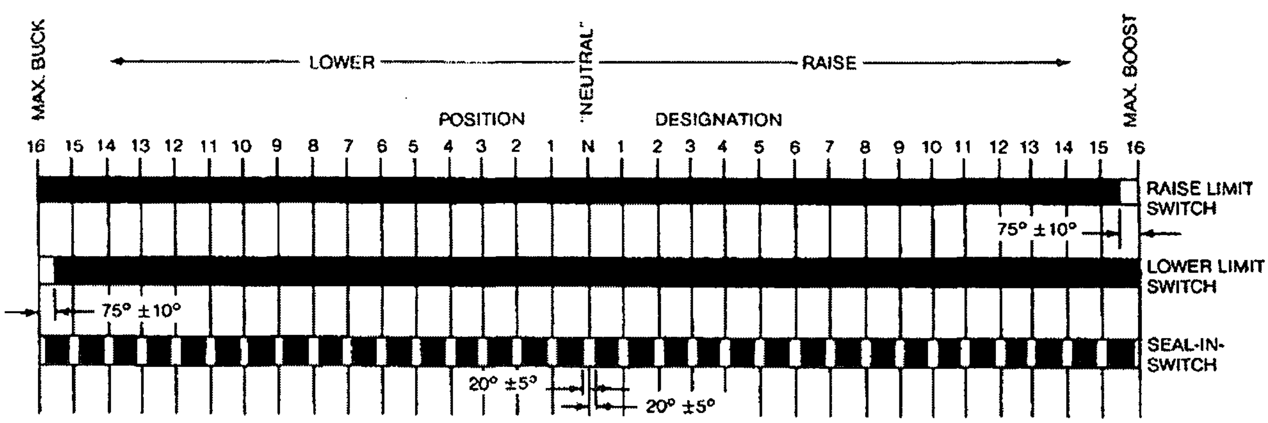
Figure 9.
Maximum-position relationship.



NOTES:

1. Sequence expressed in degrees rotation of main drive shaft.
2. 360° rotation of main drive shaft is required for one tap change.
3. One complete turn of handcrank rotates main drive shaft 60°.
4. Solid lines indicate span of contact closure, contacts are open at other positions.

Figure 10.
Switch sequencing chart for 16-step switch.



NOTES:

1. Sequence expressed in degrees rotation of main drive shaft.
2. 180° rotation of main drive shaft is required for one tap change.
3. One complete turn of hand crank rotates main drive shaft 60°.
4. Solid lines indicate span of contact closure, contacts are open at other positions.

Figure 11.
Switch sequencing chart for 32-step switch.

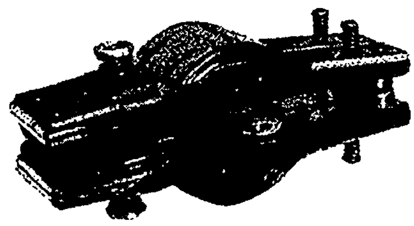


Figure 12.
Movable arcing contact.

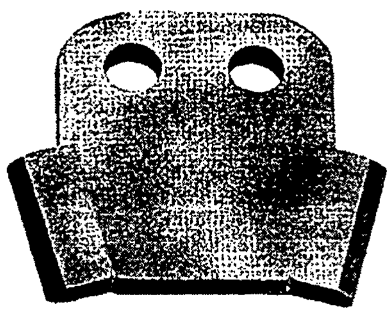


Figure 13.
Stationary arcing contact.

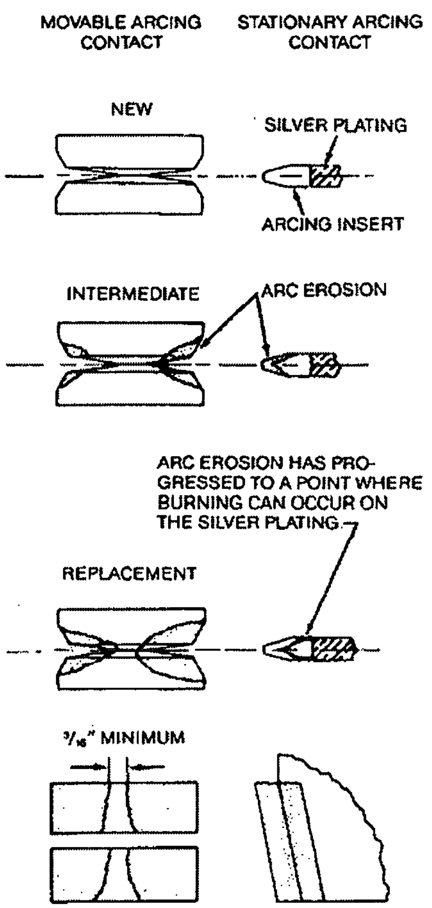


Figure 14.
Typical 550CS
contact erosion patterns.

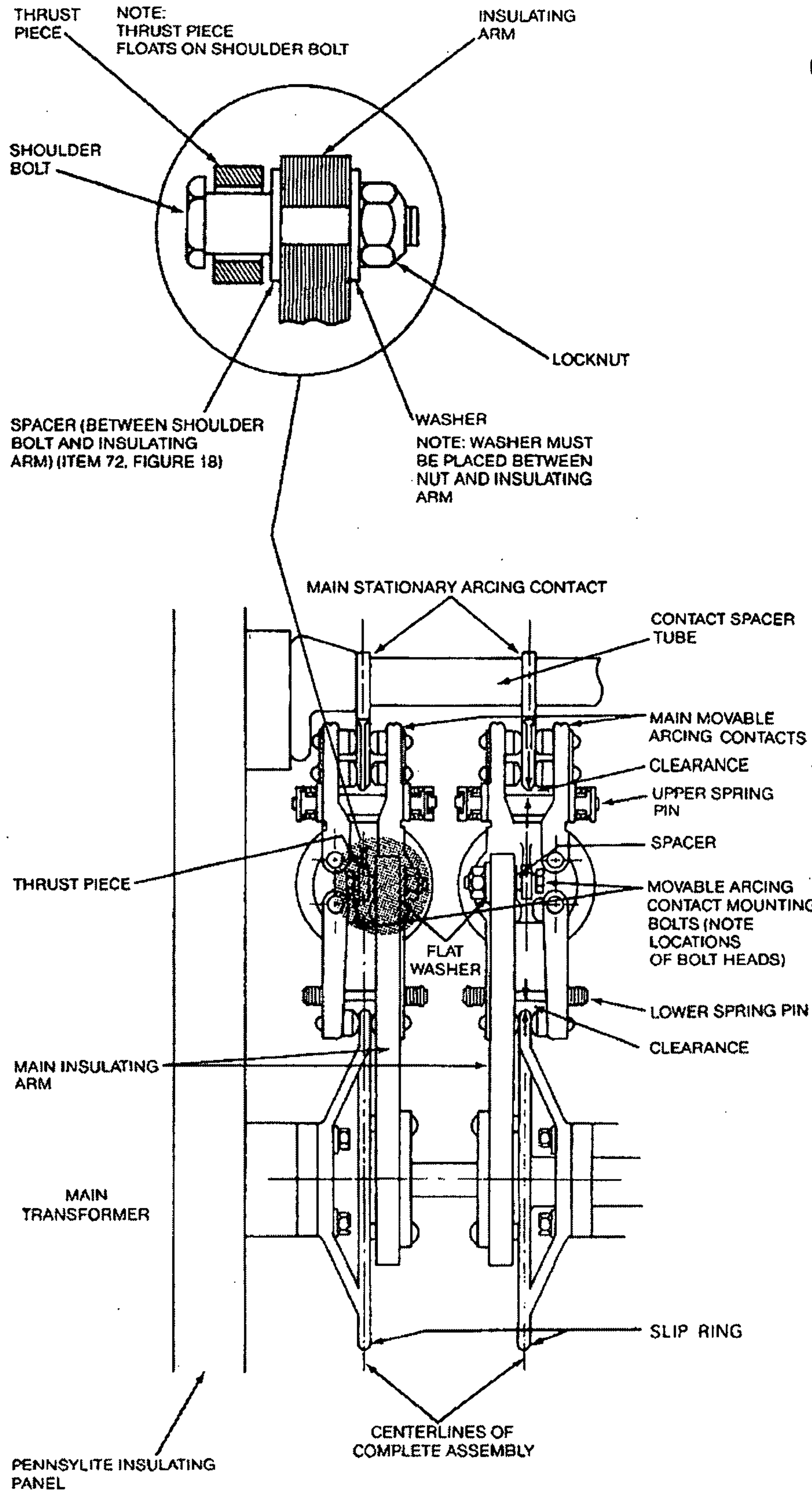
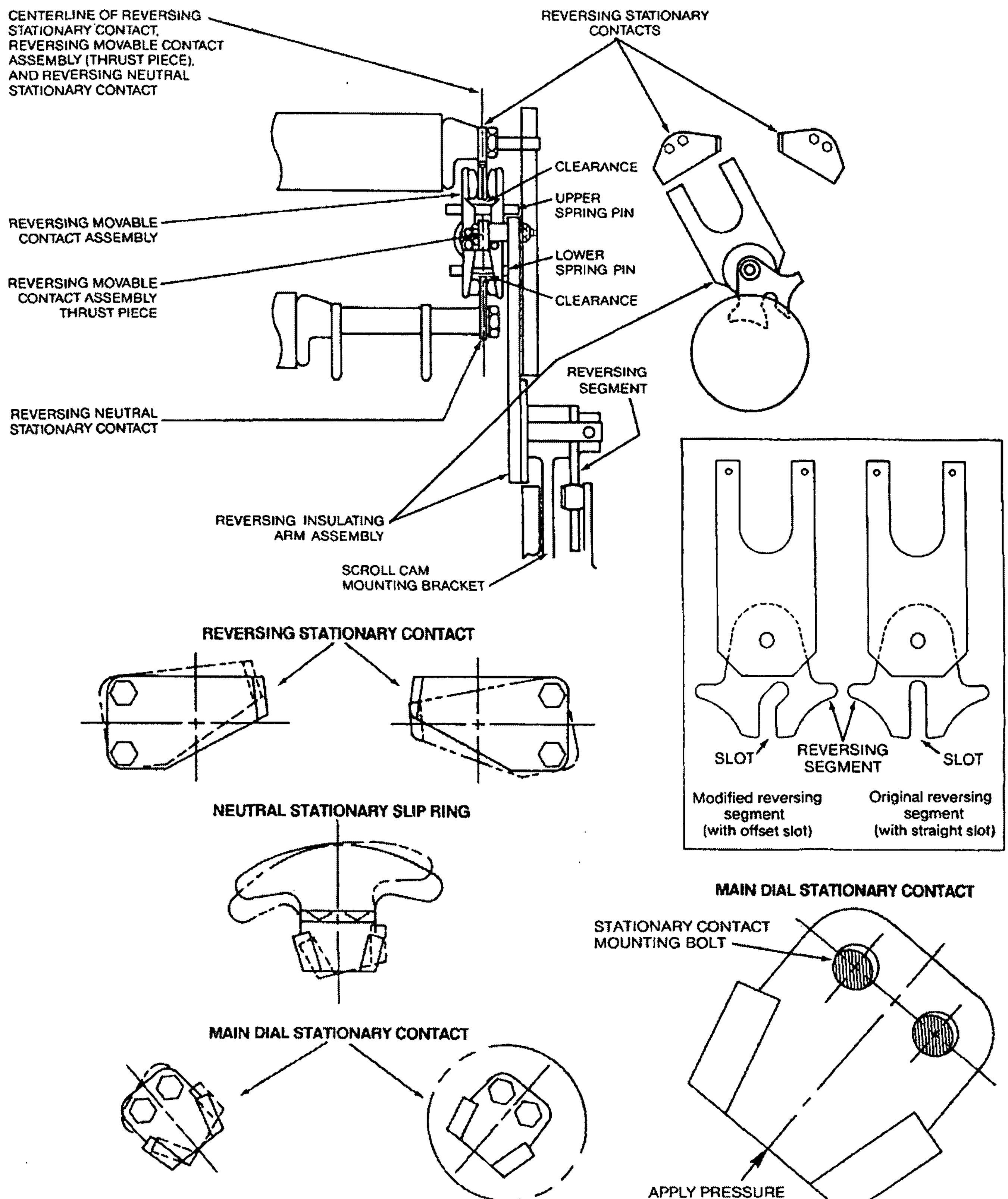


Figure 15.
Movable arcing, stationary arcing, and slip ring assembly.



NOTE: TWISTED CONTACTS CAN INTERFERE WITH THE MOVABLE CONTACT SPRING PINS.

NOTE: WHEN ASSEMBLING MAIN DIAL STATIONARY CONTACTS MAINTAIN PRESSURE AGAINST THE CONTACT MOUNTING BOLTS TO ESTABLISH PROPER CONTACT ALIGNMENT.

Figure 16.
Reversing movable and reversing stationary contact assembly.

TROUBLESHOOTING GUIDE

If any difficulty is experienced with the operation of the LTC switch, it is important to note and record the following information for reference.

1. The position of the switch at time of incident.
   A. By position indicator.
   B. By ON-POSITION pointer (see Figure 8). Normally the ON-POSITION pointer is centered on the ON-POSITION plate at the completion of a tap change.
2. The direction the switch was moving at time of incident.
3. Was switch on automatic or manual control?
4. Check the motor supply voltage. The voltage should be 115 volts, measured at terminals 55 and 57 or 56 and 57 at the terminal block mounted on the side of the drive box. (See Figure 17).
5. The transformer serial number from the transformer nameplate.

⚠ WARNING
Before performing any work on the LTC arcing tap selector switch, drive, or controls, observe the warnings and cautions appearing in *Service Information S210-40-14 and S210-40-18.*

TROUBLESHOOTING GUIDE

Problem	Condition	Solution
Improper manual operation of LTC.	Tap changer does not respond to Raise-Lower switch. Tap changer operates in one direction only or operates erratically. Tap changer makes more than one step at a time.	Refer to the Troubleshooting Guide in *Service Information S210-40-14 Load-Tap-Changing Controls.*
Improper automatic operation of LTC.	Tap changer runs to full boost position, but operates properly manually. Tap changer runs to full buck position, but operates properly manually. Tap changer overruns position and/or hunts.	Refer to the Troubleshooting Guide in *Service Information S210-40-18 Load-Tap-Changing Controls*
Switch failure to complete a tap change. (continued next page)	Motor breaker did not trip. (continued next page)	1. Check for loss of control power. 2. Check for improper operation of seal-in switch. Refer to LTC tap sequencing chart Figure 10 for 16-step unit and Figure 11 for 32-step unit. 3. Check for incorrect or defective motor breaker. Refer to chart. 4. Check controls—refer to *Service Information S210-40-18.*

TROUBLESHOOTING GUIDE (Continued)

Problem	Condition	Solution
Switch failure to complete a tap change. (continued)	Motor breaker did not trip. (continued)	**5.** Check relays a. For freedom of operation. b. For loose screws fastening relay components. If loose screws are found, remove screws one at a time and reinstall with loctite. c. For foreign material lodged in contacts. d. For deteriorated contacts—consider length of service and effect of environment. e. Check motor windings and capacitors—refer to chart (Figure 17).
Switch failure to complete a tap change. (continued next page)	Motor breaker did trip. (continued next page)	**1.** Check time of operation of the motor. The motor is designed for intermittent duty, and should not be operated in excess of ten minutes without forced cooling. **2.** Check for switch binding • Check the main drive shaft at the point it exits the drive control compartment to be certain there is no interference between the main drive shaft rain shield and the compartment. If there is interference move the drive box assembly. **3.** Check motor, windings, capacitor and breaker. Refer to chart Figure 17. **4.** If binding or jamming is suspected in the tap selector switch, deenergize the transformer, drain and open the switch compartment to inspect the switch. **5.** Check the movable contacts for jamming. a. Check that the movable contact spring pins, both main dial and reversing switches are not rubbing on the stationary contacts or slip rings. It is suggested that an inspection mirror be used. NOTE: The switch must be operated to position 3 raise and 2 lower to properly check the reversing switch. b. Check that all stationary contacts, both main dial and reversing switch are properly positioned relative to the center of the contact circle. (Refer to Figure 16). NOTE: This condition can occur at the time the tap leads are connected to the contact studs on the transformer side, twisting the entire contact assembly if the contact assembly is not properly supported on the switch side. A similar condition can also occur at the time replacement stationary contacts are installed if they are not held against the outside of the stationary contact bolt circle to establish proper alignment. Refer to Figure 16.

TROUBLESHOOTING GUIDE (Continued)

Problem	Condition	Solution
Switch failure to complete a tap change. (continued) (continued next page)	Motor breaker did trip. (continued) (continued next page)	c. Check that the main dial and reversing switch movable contacts are in alignment with the stationary contacts. Hand crank the switch while observing the contact alignment with an inspection mirror. d. Check the reversing switch for tightness at the reversing pivot shaft. NOTE: Units shipped prior to August, 1982 do not have tapered roller bearings supporting the reversing pivot shaft. In particular, these units should be checked to ensure there is no galling of metal between the reversing segment and scroll cam mounting bracket casting. Also check for galling between the reversing arm assembly and scroll cam mounting bracket casting. If it is necessary to remove the reversing segment to verify a galling condition or to correct the condition by polishing, be sure to mark the reversing segment and pivot shaft so they can be reassembled exactly as removed. e. Check the main dial contacts, both stationary and movable for any unusual or blunt erosion pattern that could make it difficult for the movable contact to slide onto the stationary contact. Replace the contacts. NOTE: This type of blunt erosion pattern results when the movable contact stops off the stationary contact but close enough to arc. f. Check the clearance between the rear insulating arm and rear slip ring. With zero pressure maintained in the transformer tank and only the head of oil acting on the insulating panel, the clearance should be approximately ⅛ inch. NOTE: For procedure to obtain this dimension contact McGraw-Edison Co. Service Department, P.O. Box 440, Canonsburg, Pa. 15317. g. Check the main drive shaft through the stuffing box for binding by sliding the drive shaft up and down slightly. If there is binding of the shaft or oil leakage in the stuffing box use following procedure. Numerals in parentheses refer to Figure 17. 1. Remove input shaft assembly (5): a. Disengage snapring (1) from external shaft assembly (25), mark the snapring groove on shaft (25), and slide the snapring toward the coupling ball. b. Remove rollpin (26) from driveshaft subassembly (36). c. Slide external shaft (25) down toward drive box (82) until input shaft (25) can be removed.

TROUBLESHOOTING GUIDE (Continued)

Problem	Condition	Solution
Switch failure to complete a tap change. (continued) (continued next page)	Motor breaker did trip. (continued) (continued next page)	2. Match-mark the components of the upper universal coupling end of drive-shaft subassembly (36) and the shaft so that components can be reassembled in exactly the same place if they come apart. 3. Match-mark components of follower assembly (33) and stuffing box (27) so that components can be reassembled in exactly the same place. 4. Loosen bolts (35) securing follower assembly (33) to stuffing box (27). 5. Remove external shaft assembly (25) and washer (14). 6. Remove bolts (35) and lockwashers (34) that secure follower assembly (33) to stuffing box (27). 7. Using a blunt instrument, carefully (to avoid damaging the packing) remove the stuffing box components. a. Female packing (32). b. V packing (31). c. Male packing (30). d. Washers (14). e. Spring washers (29). 8. Polish external shaft assembly (25) to remove any burrs or sharp edges. 9. Check the inside of stuffing box (27) for burrs and sharp edges, polish to remove any found. 10. Be certain that the bearing in the stuffing box is not extending into the stuffing box. Ream the bearing with with a 0.877 dia straight reamer. 11. Lightly lubricate external shaft assembly (25), male packing (30), V packing (31), and female packing (32) with petrolatum (vaseline). 12. Place washer (14) on external shaft assembly (25). 13. Reinstall external shaft assembly (25) in stuffing box (27). 14. Reinstall spring washers (29), washers (14), male packing (30), V packing (31), and female packing (32) on external shaft assembly (25) in the sequence shown in Figure 17. ⚠ **CAUTION** When placing packing on the external shaft assembly, handle the packing with extreme care to avoid damaging the packing.

TROUBLESHOOTING GUIDE (Continued)

Problem	Condition	Solution
Switch failure to complete a tap change. (continued)	Motor breaker did trip. (continued)	**15.** Reinstall follower assembly (33), using bolts (35) and lockwashers (34), but do not tighten the bolts. **16.** Align follower assembly (33) and stuffing box (27), matching the marks made when disassembling. **17.** Tighten bolts (35) securing follower assembly (33) to stuffing box (27). ⚠ **CAUTION** While tightening the bolts, rotate and move external shaft assembly (24) up and down to prevent binding when the bolts are secured. **18.** Slide external shaft assembly (25) into driveshaft subassembly (36) until input shaft assembly (5) can be reinstalled. **19.** Reinstall input shaft assembly (5). **20.** Align the holes in external shaft assembly (25) and drive shaft subassembly (36) and reinstall rollpin (26). **21.** Reengage snapring (1) in the same groove on external shaft assembly (25) from which it was removed. **22.** Make sure all fasteners, lockstrips, and electrical connections are tight and secure.
Operation counter.	Operation counter not functioning properly.	Check the counter terminations and associated circuitry
Drive runs into mechanical stop.	Motor operates beyond maximum position.	Make sure the maximum position limit switch is open just prior to the LTC reaching the maximum position. a. Check for a faulty limit switch b. Using an Allen wrench, adjust the switch internally for proper operation.
Handcrank switch.	Motor operates when the handcrank is removed from its holder.	Make sure the handcrank switch opens when the crank is removed from the holder. a. Check for a faulty handcrank switch. b. Check the switch for sticking or mechanical obstruction.
Seal-in switch.	Drive box pointer is not centered on ON-POSITION plate.	1. Check for a faulty seal-in switch. 2. Loosen the two mounting bolts and realign the seal-in switch. NOTE: For setting seal-in switch refer to LTC tap sequencing chart—Figure 10 for 16-step switch and Figure 11 for 32-step switch.

REPLACEMENT PARTS
(Refer to Figures 17 and 18.)

Few spare parts are required for the LTC mechanism; however, it is recommended that a few select parts be kept on hand for prompt replacement if needed. The parts recommended for spares are indicated in the replacement parts list.

Each replacement parts list is keyed to the related exploded view drawing and the item numbers correspond to the exploded view callout numbers.

To ensure prompt receipt of the correct part the following informaton must be supplied to McGraw-Edison when ordering.

1. The transformer serial number and the type of LTC switch. This information is specified on the transformer nameplate.
   NOTE: Specification of type of LTC switch on the transformer nameplate began in 1972.
2. Specify the bulletin number and date, figure, item number, description, and quantity required.
   Example:
   To order item 54 on the Drive unit.
   Transformer Serial #C- -5-
   Type 550CS LTC
   S210-40-3, September 1982
   Figure 17
   Item 54—Limit Switch—2 each.

Limited Parts Warranty

McGraw-Edison warrants to the original purchaser that type 550CS load tap changers shipped after August 1, 1982 are free of defective workmanship and materials. This warranty commences on the date of arrival at destination and covers any defects and malfunctions of the load tap changer except those caused by improper installation, improper maintenance, improper operation, customer-furnished materials, alterations executed by customer or vandalism.

Type 550CS LTC parts are warranted as follows:

Silver Contacts—five years or 75,000 operations, point of replacement as described in figure 14 *S210-40-3;* cost prorated per % of time or operation.

Mechanism—500,000 operations.

Control—five years.

This drive mechanism for the types 550C and 550CS are identical. However, motor, capacitor and motor-breaker packages have changed as shown in the following table.

Year	Motor Supplier and Model Number	Capacitor Size (mfd)	Motor-Breaker Size (amps)	Braking Fuse (amps)	Motor Winding Resistance (ohms ± 10%)	Motor Drawing Number
1967	Ohio Motor Model 915-23X-4909	100	6	See Schematic Drawing For Particular Unit	2.5	B219444
1982(2)	Custom Motor Design Model 615-01-0602	100	6		2.8	SLB00012A
1983(2)	Custom Motor Design Model 700-01-0606	100	7		2.6	SLB00028A
1988(2)	Century Elec 8-168935-01	175	7		0.9	SLB00281A

(1) Supplier discontinued manufacture of these models.

(2) This motor, capacitor and breaker package can replace all preceding packages providing proper modification is made to the motor control circuitry.

If a change in motor package is deemed necessary be sure to furnish the transformer serial number (see transformer namėplate) to the Service Department, McGraw-Edison Power Products, Canonsburg, PA 15317.

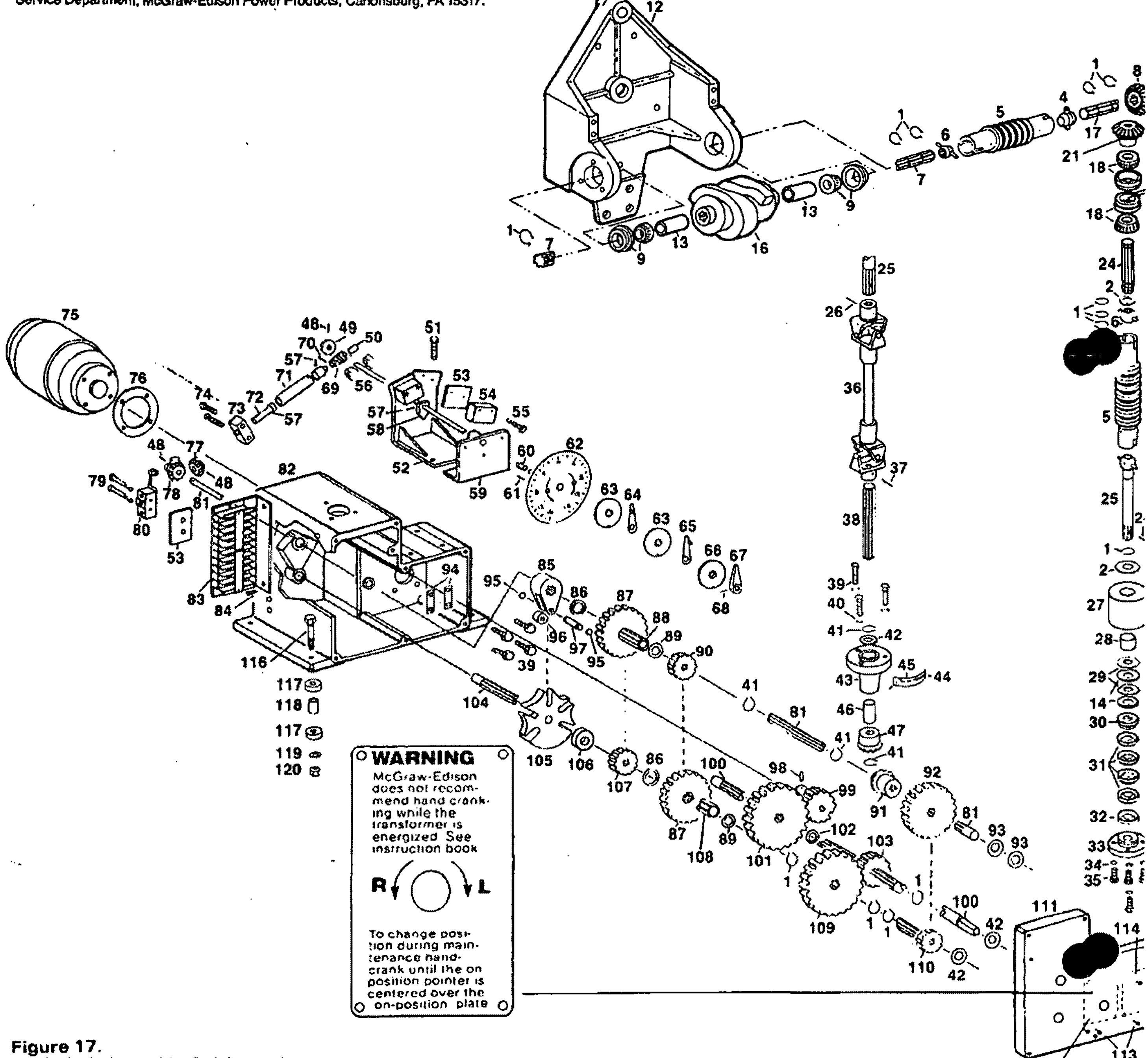
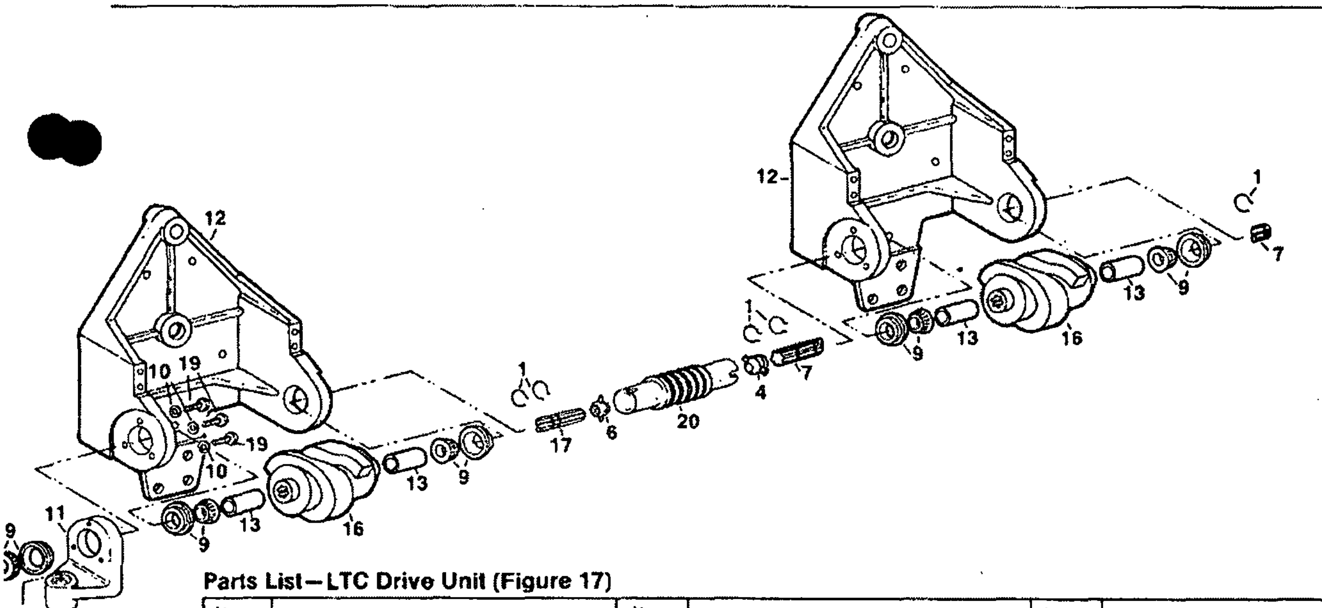
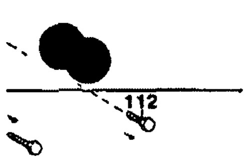


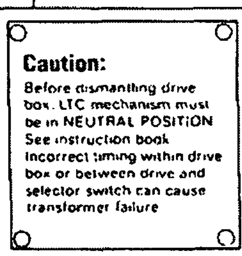
Figure 17.
Exploded view of LTC drive unit.



Parts List—LTC Drive Unit (Figure 17)

Item No.	Description	Item No.	Description	Item No.	Description
1	Snap Ring	37	Roll Pin	79	Screw
2	Washer	38	Drive Shaft	80	Seal-In Switch (1 req'd)
3	Drive Shaft	39	Bolt	81	Spur Gear Shaft
4	Coupling	40	Lockwasher	82	Drive Box
5	Insulating Drive Shaft Assy.	41	Snap Ring	83	Terminal Block
6	Coupling	42	Washer	84	Screw
7	Drive Shaft	43	Drive Shaft Support	85	Geneva Pinion
8	Gear	44	Screw	86	Spacer
9	Bearing Assy. (X)	45	"On Position" Plate	87	Spur Gear
10	Lockwasher	46	Spline Tube	88	Spline Tube Assy.
11	Gear Support	47	Drive Gear	89	Washer
12	Cam Mounting Brkt.	48	Roll Pin	90	Spur Gear
13	Cam Spacer	49	Gear	91	Drive Gear
14	Washers	50	Worm Shaft	92	Spur Gear
15		51	Bolt	93	Washer
16	Cam	52	Mounting Bracket	94	Lock Strip
17	Drive Shaft	53	Spacer	95	Snap Ring
18	Bearing Assy. (X)	54	Limit Switch (2 req'd)	96	Roller Assy.
19	Bolt	55	Screw	97	Pin
20	Insulating Drive Shaft Assy.	56	Worm Gear Shaft	98	Roll Pin
21	Gear	57	Roll Pin	99	Motor Pinion
22	Inner Race & Needle Bearing	58	Limit Switch Cam	100	Spur Gear Shaft
23	Washer	59	Indicator Mounting Bracket	101	Spur Gear
24	Input Shaft	60	Spring	102	Washer
25	Input Shaft	61	Roll Pin	103	Spur Gear
26	Roll Pin	62	Dial Plate	104	Spur Gear Shaft
27	Stuffing Box	63	Spacer	105	Geneva Segment
28	Bearing	64	Pointer	106	Spacer
29	Wave Washer	65	Pointer	107	Spur Gear
30	Male Adapter	66	Spacer	108	Spline Tube
31	Packing	67	Pointer	109	Spur Gear
32	Female Adapter	68	Roll Pin	110	Spur Gear
33	Follower Assy.	69	Worm	111	Drive Box Cover
34	Lockwasher	70	Roll Pin	112	Bolt
35	Bolt	71	Brass Tube	113	Screw
36	Drive Shaft Assy.	72	Gear Shaft	114	Caution Plate
		73	Shaft Support	115	Caution Plate
		74	Bolt	116	Bolt
		75	Motor	117	Rubber Washer
		76	Gasket	118	Rubber Washer
		77	Miter Gear	119	Washer
		78	Seal-In Cam Assy.	120	Locknut





(X) Tap selectors shipped after August 1 1982 are provided with bearing assemblies items 9 and 18.

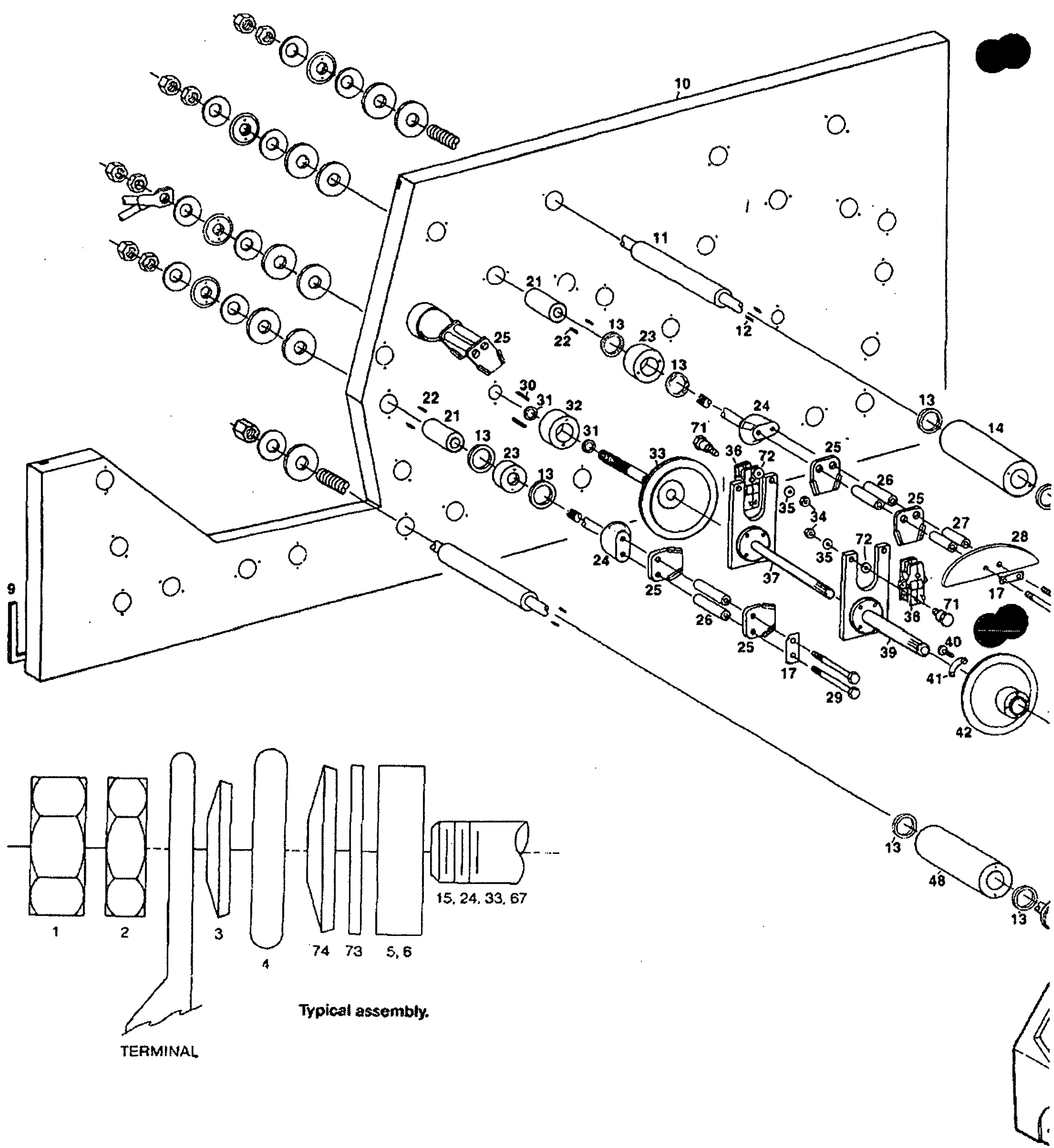


Figure 18.
Exploded view of tap selector.

Parts List—Tap Selector (Figure 18)

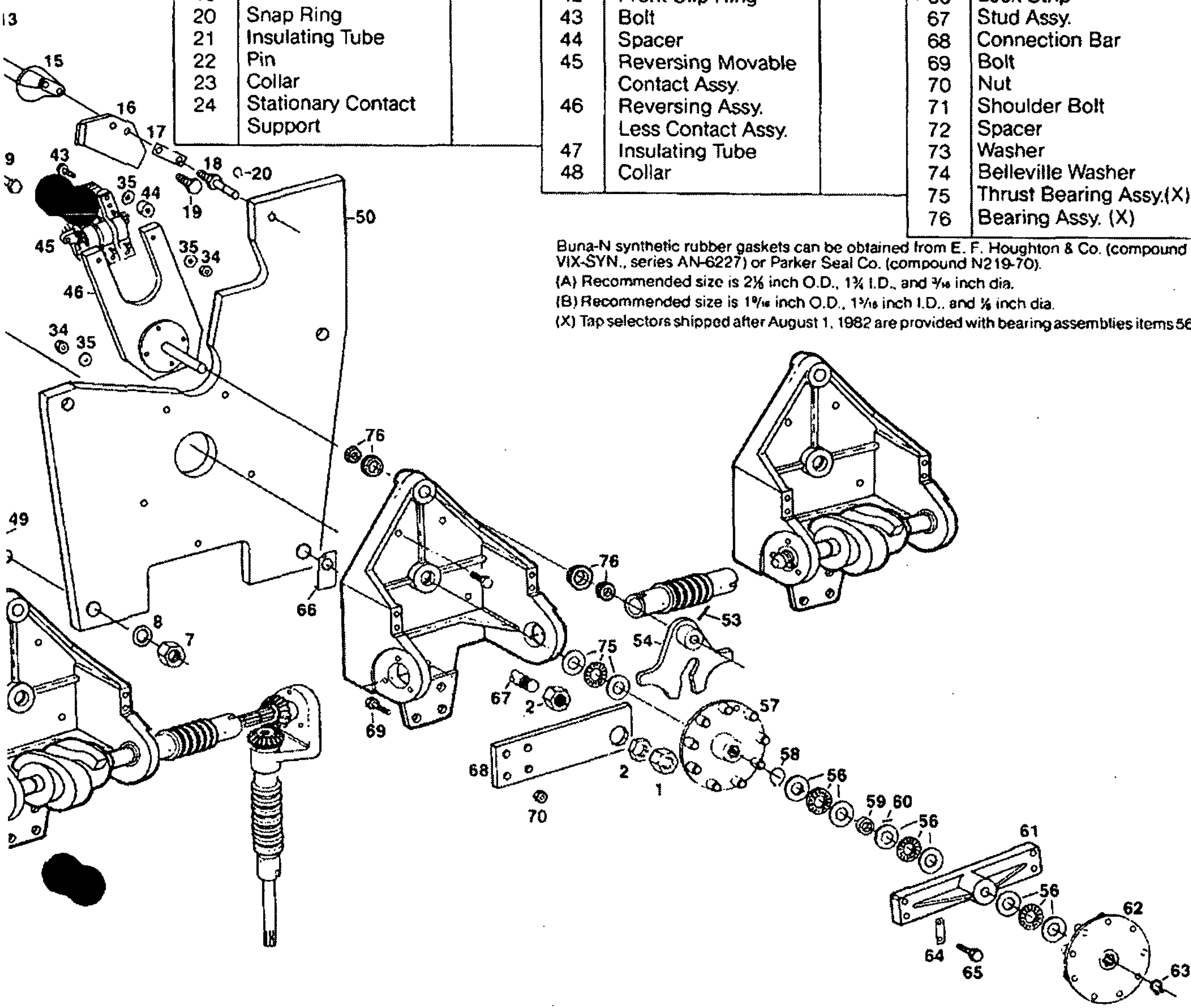
Item No.	Description	Recommended Stock
1	Nut	
2	Jam Nut	
3	Belleville Washer	
4	Spanner Nut	
5	Collar	
6	Collar	
7	Locknut	
8	Washer	
9	Gasket	
10	Panel	
11	Insulating Tube	
12	Pins	
13	Gasket (A)	
14	Collar	
15	Stationary Contact Support	
16	Reversing Stationary Contact	6
17	Lock Strip	
18	Shoulder Stud	
19	Bolt	
20	Snap Ring	
21	Insulating Tube	
22	Pin	
23	Collar	
24	Stationary Contact Support	
25	Stationary Contact	54
26	Spacer	
27	Spacer	
28	Reversing Slip Ring	
29	Bolt	
30	Pin	
31	Gasket (B)	
32	Collar	
33	Rear Slip Ring	
34	Nut	
35	Washer	
36	Main Movable Contact Assy.	
37	Rear Shaft Assy. Less Contact Assy.	
38	Bolt	
39	Front Shaft Assy. Less Contact Assy.	
40	Bolt	
41	Lock Strip	
42	Front Slip Ring	
43	Bolt	
44	Spacer	
45	Reversing Movable Contact Assy.	
46	Reversing Assy. Less Contact Assy.	
47	Insulating Tube	
48	Collar	
49	Support Stud	
50	Front Insulating Panel	
51		
52	Scroll Cam Mounting Bracket	
53	Roll Pin	
54	Reversing Segment	
55	Bolt	
56	Thrust Bearing Assy.(X)	
57	Rear Roller Plate Assy.	
58	Snap Ring	
59	Collar	
60	Roll Pin	
61	Shaft Support	
62	Front Roller Plate Assy.	
63	Snap Ring	
64	Lock Strip	
65	Bolt	
66	Lock Strip	
67	Stud Assy.	
68	Connection Bar	
69	Bolt	
70	Nut	
71	Shoulder Bolt	
72	Spacer	
73	Washer	
74	Belleville Washer	
75	Thrust Bearing Assy.(X)	
76	Bearing Assy. (X)	

Buna-N synthetic rubber gaskets can be obtained from E. F. Houghton & Co. (compound 10V70-VIX-SYN., series AN-6227) or Parker Seal Co. (compound N219-70).

(A) Recommended size is 2⅞ inch O.D., 1¾ I.D., and ³⁄₁₆ inch dia.

(B) Recommended size is 1⁹⁄₁₆ inch O.D., 1⁵⁄₁₆ inch I.D., and ⅛ inch dia.

(X) Tap selectors shipped after August 1, 1982 are provided with bearing assemblies items 56, 75, and 76.



Power Transformers

COOPER POWER SYSTEMS

Load-Tap-Changing Automatic Controls

S210-40-14

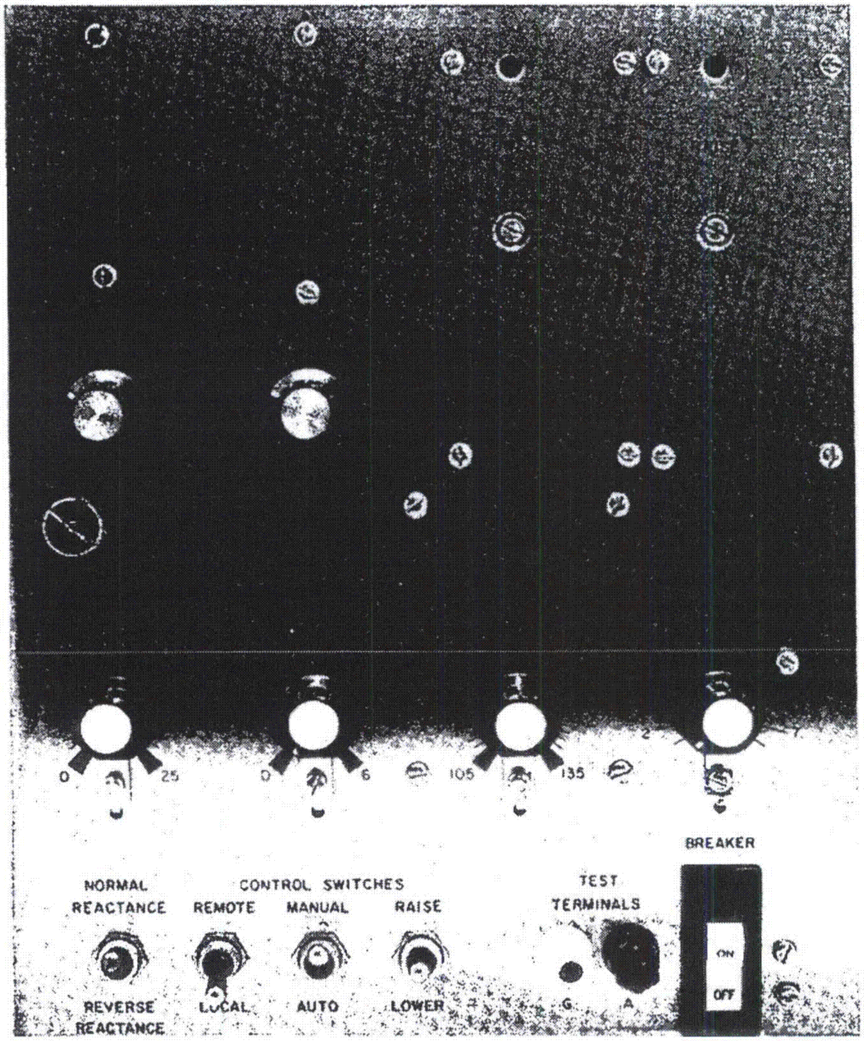


Figure 1.
Automatic control panel.

CONTENTS

GENERAL

The LTC control is divided into two basic components–the automatic control described in Service Information S210-40-14 and the tap changer motor control described in S210-40-18.

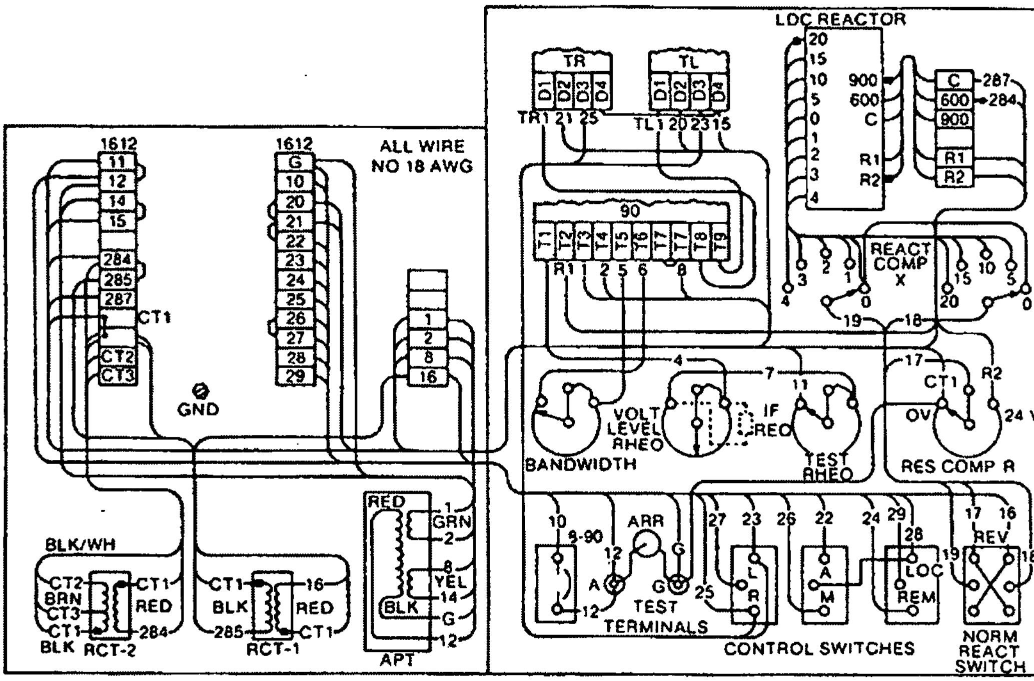
The automatic control panel is shown in Figure 1. Service Information S210-40-14 and S210-40-18 describes the standard features for automatic control of Mcgraw Edison load tap changing transformers.

To operate the load tap changer, the wiring schematics that accompany each transformer must be consulted before making the power supply connections.

> **⚠ CAUTION**
> Incorrect supply voltage could damage drive; motor or controls. Refer to wiring schematics which accompany each transformer.

To operate the load tap changer in the automatic mode, it is necessary to connect a potential transformer between the regulated line and the automatic voltage sensing circuit. The potential transformer (normally supplied by the user) must have a secondary which operates in the 110–130-volt range. Proper polarity relationship must be maintained between the potential transformer and the internal, load-sensitive, line-drop compensator current transformer. Refer to the schematic drawings that accompany the transformer before connecting the potential source to the input connections. To energize the voltage sensing circuit, place the CONTROL CIRCUIT BREAKER in the ON position.

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 sales engineer.



CHASSIS—FRONT VIEW

CONTROL PANEL—REAR VIEW

Figure 2.
Typical automatic control panel wiring.

AUTOMATIC CONTROL PANEL

The automatic control panel includes solid-state voltage sensing and timing devices used in conjunction with mechanical output relays to initiate the operation of the tap changer motor operating panel. The voltage sensing device is factory calibrated. The specific voltage level and bandwidth adjustments are obtainable by using calibrated control knobs which can be locked in place. Unless otherwise specified, the controls are designed for 60-Hz, ac operation with an accuracy class of better than Class 1. Except for the motor breaker, all of the controls for both manual and automatic operations are mounted on the front of the automatic control panel. The motor breaker is located on the motor operating panel.

Manual Operation

The bottom section of the automatic control panel contains four toggle switches, three of which are used to select and direct manual or automatic control of the load tap changer (Figures 1 and 2). With the REMOTE-LOCAL switch in the LOCAL position and the MANUAL-AUTO switch in the MANUAL position, the load tap changer can be operated in the manual mode by actuating the momentary RAISE-LOWER switch in the desired direction.

When more than one tap change is necessary, holding the RAISE-LOWER switch in the appropriate position until just before the tap changer reaches the desired tap position causes the tap changer to operate in a sequential mode. Releasing the RAISE-LOWER switch and allowing it to return to the OFF (center) position permits a short time delay and enforces motor brake operation.

NOTE: The manual operation of the load tap changer is not affected by or related to any of the other components on the automatic control panel.

Automatic Operation

Before attempting to place the load tap changer in the automatic mode of operation, the motor control power and the automatic voltage sensor potential source must be connected and energized. (Refer to the wiring schematic for each specific transformer).

To place the load-tap-changing equipment in the automatic mode, all related control settings must be predetermined and selected.

Individual circuits and controls relating to the automatic operation are covered in the COMPONENTS for automatic control panel section. To clarify the automatic operating procedure, a control setting checklist follows:

1. Place the CONTROL CIRCUIT BREAKER (8-90) Figure 2 in the OFF position.
2. Loosen the four locking screws on the knobs above the control switches.
3. Place the AUTO-MANUAL switch in the MANUAL position and the REMOTE-LOCAL switch in the LOCAL position.
4. Set the TEST RHEOSTAT control at zero (0).
5. Set the VOLTAGE LEVEL control to the desired voltage.
6. Set the BANDWIDTH control to the preselected value.
7. Set the LINE-DROP COMPENSATOR (LDC on control panel), REACTANCE and RESISTANCE controls at zero (0). (After the calibration check, these controls should be set at the calculated levels.)
8. Place the MOTOR BREAKER on the motor operating panel in the ON position. See S210-40-18.
9. If the voltage level and bandwidth are to be checked with a voltmeter, connect the meter to TEST TERMINALS G and A.
10. Place the CONTROL CIRCUIT BREAKER in the ON position. *Wait approximately 15 minutes before proceeding, to allow warm-up.*
    - If the voltage level and bandwidth are not going to be checked with a voltmeter, operate the load tap changer in the manual mode until the LOWER test light in energized—then proceed to checking the bandwidth as outlined in 11 E.

11. If the voltage level and bandwidth are going to be checked with a voltmeter, the TEST RHEOSTAT control can be used to advantage:
 A. Operate the load tap changer in the manual mode until the voltmeter reads as close as possible to the desired band center + 3 volts.
 B. Place the MOTOR BREAKER in the OFF position and pull the dual fuse holder (located on the motor operating panel) out of its retaining block. See S210-40-18.
 C. Set the TEST RHEOSTAT control to a value which equals the voltage increment above the desired band center obtained in Step 11 A.

Example:
To obtain a desired band center of 120 volts:
 (1) Operate the load tap changer in the manual mode until the voltmeter reads as close as possible to the desired band center +3 volts.
  a. Nearest voltage obtainable is 123.5 volts.
  b. Therefore, 123.5 - 120 = 3.5 volts.
 (2) Place the MOTOR BREAKER in the OFF position and pull the dual fuse holder out of its retaining block.
 (3) Set TEST RHEOSTAT control for 3.5 volts.

 D. If necessary, adjust the VOLTAGE LEVEL control until neither the RAISE nor the LOWER test light is lit. For the most accurate setting, center the control between the two points where the RAISE and LOWER test lights are lit.

NOTE: At the time the band level and the bandwidth are being adjusted, the make and break points of both the raise and the lower circuits differ by approximately 0.5 volt. This differential is a seal-in feature furnished to assure the positive making of the contacts at the extremities of the bandwidth.

 E. Check the bandwidth by rotating the TEST RHEOSTAT control in both directions and observing the dial voltage differential between the points where the RAISE and LOWER test lights come on.

 Example (continued from 11C):
 - Assume BANDWIDTH control has been preset to 3 volts.
 - Voltmeter (if used) reads 123.5 volts.
 - TEST RHEOSTAT control set at 3.5 volts.
 - BAND LEVEL control set at 120 volts.
 - Rotate TEST RHEOSTAT control in both directions: LOWER test light comes on at two volts: RAISE test light comes on at five volts.
 - Therefore, 5 - 2 = 3 volts bandwidth.

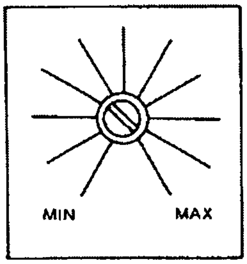
 F. Secure BAND LEVEL and BANDWIDTH controls by tightening their locking screws.
 G. Check operation of time-delay relays by rotating the TEST RHEOSTAT control and noting the time differential between the test light ignition and dimming. (Output relay closure causes test light to attenuate.) Each time-delay relay is factory set for a 30-second time delay. *See instructions for time-delay relays under COMPONENTS for automatic control panel before changing the setting.*
 H. Return the TEST RHEOSTAT control to zero (0) and secure its locking screw.
 I. Set the appropriate LINE-DROP COMPENSATOR setting. (See Step 5 and instructions under Line-Drop Compensator.) Secure the LDC RESISTANCE knob locking screw.
 J. Replace the dual fuse holder and move the MOTOR BREAKER to the ON position.
 K. After completing the preceeding steps, move the AUTO-MANUAL switch to the AUTO position and the load tap changer will respond to the automatic control mode.

Components

1. CONTROL CIRCUIT BREAKER. A single-pole, trip-free breaker provides ON-OFF, short-circuit and overload protection for the control panel.
2. TEST TERMINALS. Two test terminals facilitate connecting a voltmeter during calibration tests.
3. VOLTAGE-REGULATING RELAY. A solid-state, adjustable voltage sensor permits the selection of a band level between 105 and 135 volts. The BANDWIDTH control permits the selection of a bandwidth of from 1.5 to 7.5 volts.
4. TEST LIGHTS. Two test lights incorporated in the time-delay circuits provide a visual indication of the conduction occurring within the voltage regulating relay.
5. LINE-DROP COMPENSATOR. The line-drop compensator, complete with reverse-reactance switch, variable-reactance and variable-resistance controls, facilitates the regulation of the feeder at a point remote from the transformer and provides for reverse reactance paralleling.
6. TEST RHEOSTAT. The fine-adjustment test rheostat facilitates the determination of the bandwidth even though a variable external power source may not be available.
7. CONTROL SWITCHES. Three control switches mounted in the lower section of the automatic control panel provide a selection of the following operations and modes of the load tap changer: remote, local, automatic, manual, raise, off, and lower.
 A. To operate the load tap changer from within the cabinet in either the automatic or manual mode, the REMOTE-LOCAL switch must be in the LOCAL position. To operate the load tap changer from a remote point, the REMOTE-LOCAL switch must be in the REMOTE position. Auxiliary auto-manual and raise-lower switches must be supplied by the user when operating from a remote point.
 B. To operate the load tap changer from within the cabinet in the manual mode or to deactivate local automatic operation, place the AUTO-MANUAL switch in the MANUAL position. To operate the load tap changer in the local automatic mode, place the AUTO-MANUAL switch in the AUTO position.
 C. The RAISE-LOWER switch is used to operate the load tap changer in the local manual mode. The switch is equipped with a center OFF and two momentary ON positions. Making momentary contact in the up direction for RAISE or down for LOWER will cause the load tap changer to move one step at a time. If more than one tap change is required, holding the momentary contact in the desired direction will permit sequential operation.
8. TIME-DELAY RELAYS. Two adjustable time-delay relays (one for RAISE, one for LOWER) are in the circuit between the voltage-regulating relay and the tap changer motor control. These relays provide a selection of time delays from 10 to 90 seconds. *Unless otherwise specified, the relays are factory-set for 30 seconds.*

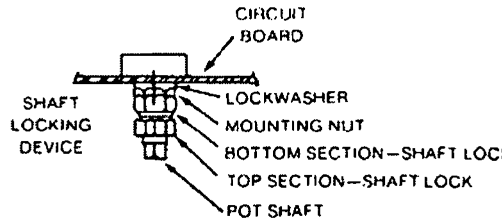
To change the setting, insert a small screwdriver (preferably a ¼-in.-diameter handle) in the potentiometer screwdriver slot and rotate clockwise to increase or counterclockwise to decrease the time delay. Changing of potentiometer settings will show resistance to movement because of a mechanical drag which has been placed on the shaft to prevent accidental movement. Total rotation is about 300 degrees and can be observed by relating the slot position relative to the graduations surrounding the shaft (Figure 3).

⚠ CAUTION
To prevent potentiometer damage, do not use a large screwdriver or force the settings at the extreme ends of the range.

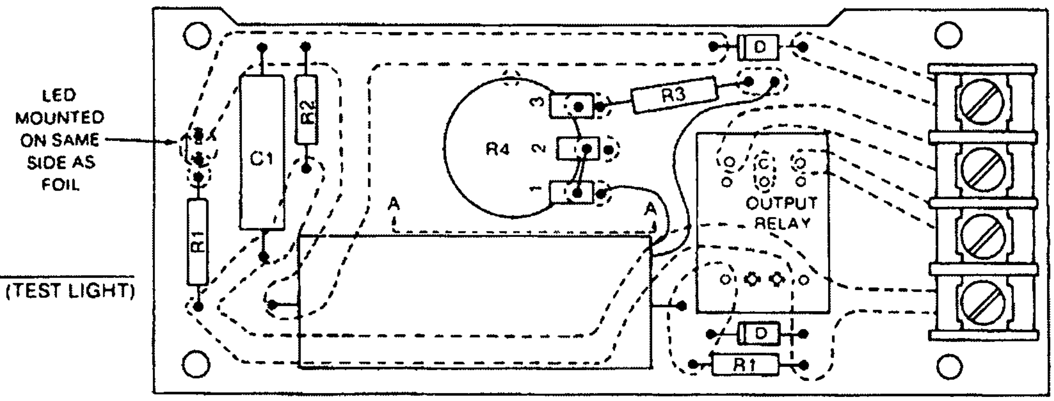


TIME DELAY

NOTE: Potentiometer must be securely mounted. Hold potentiometer while tightening mounting nut. Bottom section of shaft lock must be locked against potentiometer mounting nut. Top section of shaft lock is to be pulled snug enough to make it necessary to use a small screwdriver to adjust the potentiometer. (Screwdriver—Stanley 1010 or equivalent).



VIEW A-A



CIRCUIT BOARD

Legend

LED	Light emitting diode (TEST LIGHT)
R1	560Ω, 1/2 W
R2	1.5KΩ, 1/2 W
R3	100KΩ, 1/2 W
R4	Pot, 2.5MΩ
C1	100 MFD, 25V
D	400V, 1A

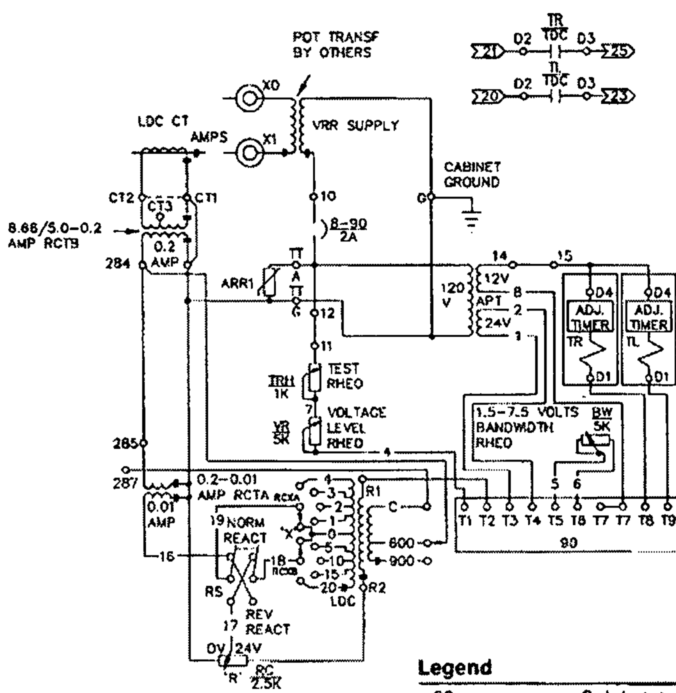
Figure 3.
Physical representation of time-delay relay circuit board.

Time-delay settings can be measured without operating the tap changer. Put the auto-manual switch in the MANUAL position and observe the time interval between the light ignition and the point when the light goes dim due to the closing of the output relay.

Setting

When setting from an independent source, the automatic control panel should be energized by a variable source connected to Terminals 10 and G, Figures 2 and 4.

> **⚠ CAUTION**
> Make sure that the normal potential source is not connected to 10-G before connecting an external source. If the external power source is grounded, the source and ground terminals on the panel must be phased out or the internal ground on the control panel must be removed. (Refer to wiring diagram for ground connections.) Before energizing the independent power source, pull the dual fuse holder on the motor operating panel and make sure that both the CONTROL and MOTOR BREAKERS are in the OFF position.



Legend

90	Solid-state voltage sensor
TR	Time-delay RAISE
TL	Time-delay LOWER
8-90	Control breaker
RCTB	8.66/5—0.2-amp CT
RCTA	0.2—0.01-amp CT
APT	Aux pwr transformer
ARR	Arrester

Figure 4.
Automatic voltage regulation scheme.

1. Connect an ac voltmeter to TEST TERMINALS G and A.
2. Loosen the four locking screws on the knobs above the control switches.
3. Place the AUTO-MANUAL switch in the MANUAL position and the REMOTE-LOCAL switch in the LOCAL position.
4. Set the TEST RHEOSTAT control at zero (0).
5. Set the VOLTAGE LEVEL control for the desired level.
6. Set the BANDWIDTH control for the total desired bandwidth.
7. Set all three LINE-DROP COMPENSATOR controls at zero (0).
8. Place the CONTROL CIRCUIT BREAKER in the ON position.
9. Adjust the source voltage until neither test light is energized. *Wait approximately 15 minutes before proceeding.*
10. To check band level and bandwidth, adjust the source voltage and record the voltmeter readings at the levels where the raise-lower test lights are energized. If required, the VOLTAGE LEVEL and BANDWIDTH controls can be adjusted slightly to obtain the exact bandwidth and level desired.

    NOTE: At the time the band level and the bandwidth are being adjusted, the make and break points of both the RAISE and the LOWER circuits differ by approximately 0.5 volt. This differential produces a seal-in feature to assure the positive making of the contacts at the extremities of the bandwidth.
11. After having obtained the exact band level and bandwidth required, secure the TEST RHEOSTAT, BAND LEVEL, and BANDWIDTH control knobs by tightening the locking screws.
12. Check TIME-DELAY relay settings by adjusting the source voltage and recording the time differential between test light ignition and dimming. (Output relay closure causes test light to attenuate.) *Each time-delay relay is factory set for 30-second time-delay. See instructions for time-delay relays under COMPONENTS on automatic control panel before changing settings.*
13. Set the LDC REACTANCE and RESISTANCE controls for the calculated values. (See Line-Drop Compensator section for calculating procedures.) Secure the LDC RESISTANCE control knob locking screw.

Line-Drop Compensator

The line-drop compensator is supplied with one resistance control and two reactance controls, furnishing resistance and reactance compensation up to 24 volts in either, or both, elements. The resistance compensation is continuously variable from 0 to 24 volts; the reactance compensation is variable in both 1- and 5-volt steps to a total of 24 volts.

If reverse reactance compensation is required, move the NORMAL REACTANCE—REVERSE REACTANCE switch on the front panel to the REVERSE REACTANCE position.

To determine proper settings required for the line-drop compensator, it is necessary to understand the principle of line-drop compensation. The principle involved consists of connecting a resistance-reactance network in series with the voltage-regulating relay input. Current from an internal current transformer is passed through the compensator, producing a voltage drop which is opposed to the applied potential.

Since the current is proportional to the feeder current and, if the resistance and the reactance of the compensator are proportional to those of the feeder from the transformer to the desired point, the voltage at the voltage-regulating relay input will drop by an amount proportional to the feeder voltage drop to that point. This will cause the load tap changing mechanism to adjust its voltage to maintain a constant, selected voltage at the predetermined point.

The remote point, often called the load center, should be selected with great care. It may be an actual point on the feeder where the main trunk branches out in a star-shaped pattern in the center of the feeder's territory. It may also be a fictitious point recurrent about the middle of each feeder branch so that it represents an average condition existing over a wide area.

The line-drop compensator circuit employed by McGraw-Edison is designed to operate at 10 ma and has been equipped with an intermediate current step of 0.2 amp to accommodate provisions for the circulating current method of paralleling with existing load tap changing equipment.

To determine the settings for the line-drop compensator:

1. Determine the feeder line current that will provide 10 ma to flow in the line-drop compensator circuit. For the various winding outputs described below, see the connection diagram nameplate
   - A. For wye-connected output windings with one current transformer for line-drop compensation, this value will be the primary current rating of the current transformer for line-drop compensation.
   - B. For delta-connected output windings, this value will be $\sqrt{3}$ times the primary rated current of the current transformer for line-drop compensation.
   - C. For wye-connected output windings with two current transformers for line-drop compensation (each having a secondary rating of 5.0 amps), the feeder line current will be equal to the primary current rating of either current transformer. The secondaries are so interconnected that, with rated current flowing in each primary, 10 ma will flow in the line-drop compensator circuit. This 10-ma current will be properly phased for use of a line-to-line potential transformer which is connected as shown on the load tap changing schematic diagram.
2. Calculate line resistance and reactance.
3. Calculate line-drop in resistance volts and reactance volts as the products of Step 1 times Step 2.
4. Divide the values obtained in Step 3 by the potential transformer ratio.
5. Set the dials of the line-drop compensator equal to the values obtained in Step 4. The dials, calibrated in volts, are labeled RESISTANCE and REACTANCE VOLTS.

   Example: Consider a delta-connected transformer supplying one mile of feeder to a point for which resistance and reactance compensation are required. The line is a 2/0, 20-in. equivalent spacing line which has a resistance of 0.41 ohm and a reactance of 0.60 ohm per mile.

   If the current transformer for the line-drop compensator has a primary rating of 300 amps, the feeder line current will be $\sqrt{3}$ times 300 or 520 amps.

   The line drop will be 520 times 0.41 or 213 volts resistance and 520 times 0.60 or 312 volts reactance.

   If a 20:1 potential transformer is used to step the output voltage down for use with the voltage-regulating relay, the line-drop compensator settings would be 213 divided by 20 or 10.7 volts resistance and 312 divided by 20 or 15.6 volts reactance. The nearest dial settings on the line-drop compensator would be 11 resistance and 16 reactance. Generally, it is desirable to compensate for the drop in distribution transformers and secondary service. Increase these calculated values accordingly to compensate for this additional drop.

⚠ WARNING

If any work is to be done on the line-drop compensator portion of the control circuit while the transformer is energized, care must be exercised so that the secondary circuits of the current transformers are not accidentally opened. The current transformers must be short-circuited at the short-circuiting device in the drive-and-control compartment before any work begins.

Accidental opening of the current transformer circuits will cause a dangerously high voltage to appear across the opened circuit.

Voltage Sensor

The solid-state voltage sensing relay incorporated in this automatic control circuit utilizes a temperature-compensated, cascaded Zener diode reference voltage (E across Z3) compared to a portion of the input voltage (E across R8) to furnish the intelligence required to select one of three possible relay output modes.

Conduction through silicon-controlled Rectifier #1 (SCR1) indicates that the input voltage T1—T2 is not of sufficient magnitude to provide a voltage across R8 which equals the reference voltage across Z3. Conduction through silicon-controlled Rectifier #2 (SCR2) indicates that input voltage T1—T2 exceeds the magnitude required to produce a voltage across R8 which equals the Z3 reference voltage. A lack of conduction through either SCR1 or SCR2 indicates that the input voltage T1—T2 is at the proper level to produce a match between the voltages across R8 and Z3.

Operational amplifier OP1 compares the voltages across R8 and Z3. If the Z3 voltage exceeds the R8 voltage, OP1 output swings positive causing the OP2 output to go positive and furnish the *turn on* gate voltage for SCR1. If the R8 voltage exceeds the Z3 voltage, OP1 output swings negative causing the OP3 output to go positive and furnish the gate voltage for SCR2. A rheostat (bandwidth control) connected between T5 and T6 desensitizes OP1 input, thereby providing a variable band between the voltage level inputs which cause OP1 output to change. Resistor R11 fixes the minimum bandwidth obtainable. Resistors R17 and R22 furnish a small feedback voltage to OP2 and OP3 after their output swings to provide a hysteresis action (seal-in feature) to the output circuits. Resistor R29 is a shunt resistor selected to bring the sensing-circuit input current to a value which permits the use of a standard rheostat for the voltage level control. Trimming (calibrating) resistor R30 is used to match individual voltage sensors to the preselected voltage levels for which the band-level control has been calibrated. Compensating resistor R9 is a factory-set potentiometer used to compensate for small value changes in Z3, R5, R6, R7, and R8 and still permit setting the sensor null input voltage within the permissible range. A 24-volt input to Terminals T3 and T4 furnishes the power supply for the OP amps and the regulated reference voltage.

The schematic diagram, parts layout, and component identification are shown in Figures 5 and 6.

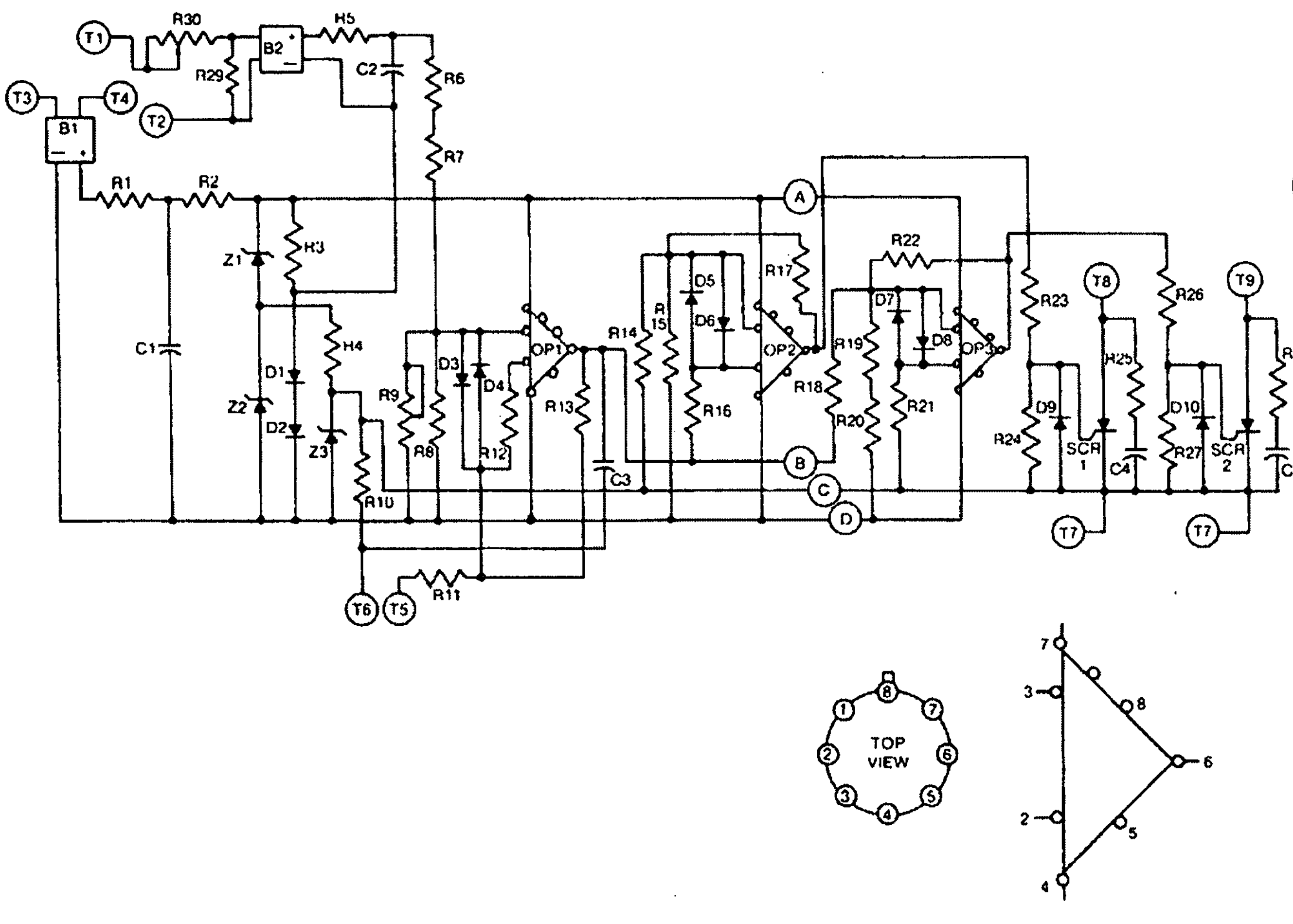
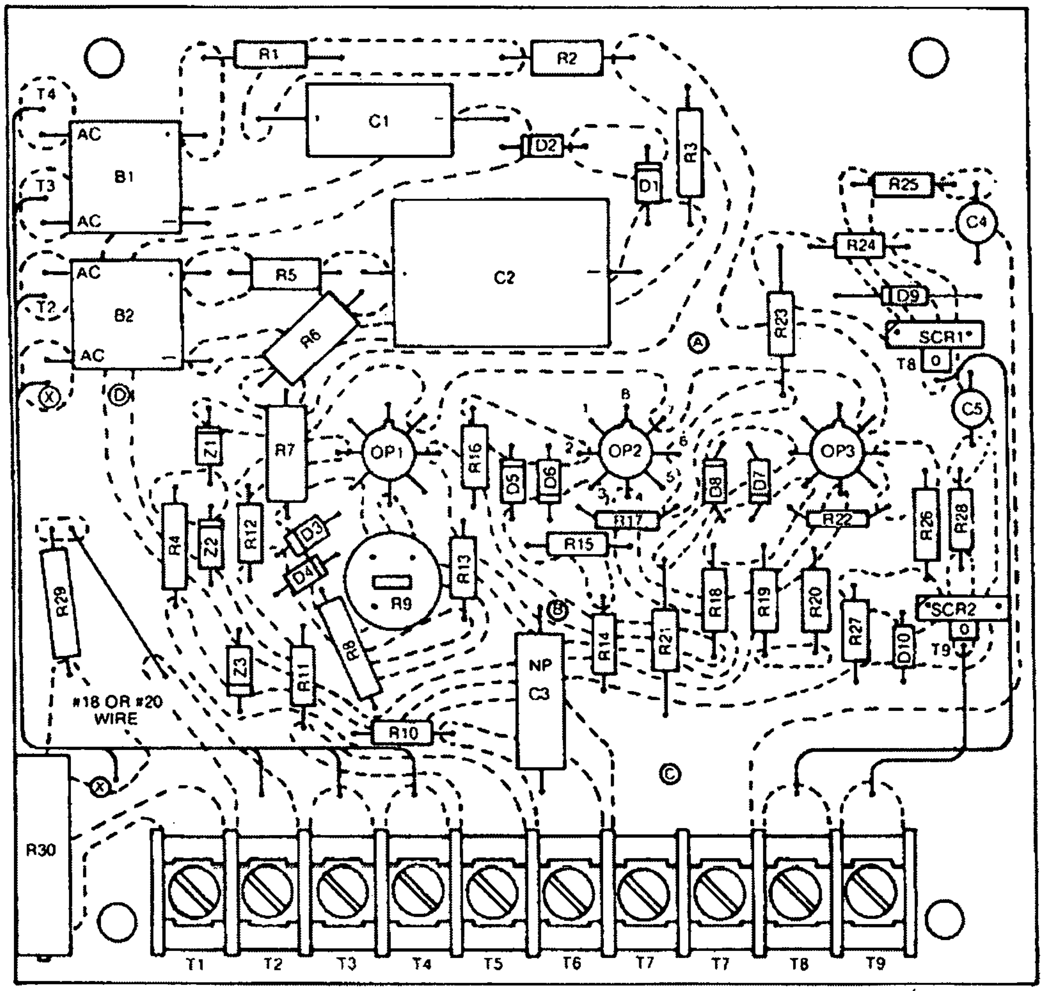


Figure 5.
Schematic of voltage sensor.



Item	Value
B1, B2	Bridge rectifier
R1	10Ω, ½W
R2	200Ω, 2.5W
R3	2KΩ, 1.5W
R4	330Ω, 1.5W
R5, R10, R25, R28	47Ω, ½W
R6, R7	13KΩ, 3W
R8	4.7KΩ, 3W
R9	Pot, 10KΩ
R11	500Ω, ½W
R12	120Ω, ½W
R13, R17	82KΩ, ½W
R14, R15, R18, R19, R20, R23, R26	10KΩ, ¼W
R16, R21, R24, R27	4.7KΩ, 1W
R22	39KΩ, ½W
R29	33K—50K (selected)
R30	Pot, 5KΩ
C1	20 MFD, 75V
C2	20 MFD, 250V
C3	5 MFD, NP, 25V
C4, C5	0.1 MFD, 200V
D1 through D10	400V, 1A
Z1, Z2	12V, 1W
Z3	8.4V (temperature compensated)
OP1, OP2, OP3	OP amps
SCR1, SCR2	Silicon controlled rectifier

Figure 6.
Physical representation of voltage sensor circuit board.

TROUBLESHOOTING GUIDE
For Equipment Built After 1/1/82

AUTOMATIC OPERATION OF LOAD TAP CHANGER

Trouble	Solution
Tap changer runs to full boost position, but operates properly manually. Refer to Service Information S210-40-18.	1. Check for open circuit in VOLTAGE SENSOR circuit by checking voltage between terminals T1 & T2 on voltage sensor card. Should be approximately 80 Vac. *(See VOLTAGE SENSOR TROUBLESHOOTING GUIDE).* 2. Check for open circuit in TEST RHEOSTAT, VOLTAGE LEVEL, LDC resistance controls, R1-R2 winding on LDC reactor, etc. 3. Check for defective voltage sensor. *(See VOLTAGE SENSOR TROUBLESHOOTING GUIDE).* 4. Check for sticking relay on RAISE time-delay relay circuit board.
Tap changer runs to full buck position but operates properly manually. Refer to Service Information S210-40-18.	1. Check for high input voltage by checking voltage at the test terminals. 2. Check for defective voltage sensor. *(See VOLTAGE SENSOR TROUBLESHOOTING GUIDE).* 3. Check for sticking relay on LOWER time-delay relay circuit board.
Tap changer overruns position and/or hunts. Refer to Service Information S210-40-18.	1. Check manual operation for overrun. If LTC overruns, see section covering manual operation. 2. Check time-delay relay dropout time. *Relays should drop out within one second after test light goes out.* 3. Check BANDWIDTH. Should be at least 1.25+ volts for 32 step operation and 2.5+ volts for 16 step operation when connected for independent operation. Add minimum of .25 to .5 volts respectively for current balance parallel operation. 4. If using current balance type paralleling check connections for crossed wires and proper polarity. 5. If using current balance type paralleling, check sensitivity of setting. The LDC reactor provides 3 levels of sensitivity. Use 300 turn connections (600-900 terminals) for narrow bandwidth, 600 turn connections (0-600 terminals) for medium bandwidth or 900 turn connection (0-900 terminals) for wide bandwidth setting.
Tap changer operates properly manually but will not operate automatically. Refer to Service Information S210-40-18.	1. Check positions and integrity of automatic control panel CONTROL SWITCHES and CONTROL CIRCUIT BREAKER. 2. Check potential source of terminals 10 & G (See Figure 2). 3. Check for open circuit in sensor auxiliary power source by checking voltage between terminals T_3 and T_4 on voltage sensor card. Should be approximately 24 Vac. If "0" volts check 11 to G and 12 to G. Should be approximately 120 Vac (See Figure 2). 4. Check for open circuit in time delay relay source by checking voltage between terminal D4 on the delay relay cards and T7 on the voltage sensor card. Should be approximately 12 Vac. If no voltage appears check voltages from 14 and 15 to 8 at terminal strip on cabinet backwall. Should be 12 Vac. (See Figure 2). 5. Check for open circuit in BANDWIDTH CONTROL and associated wiring. (See Figure 2). 6. Check for defective VOLTAGE SENSOR. *(See VOLTAGE SENSOR TROUBLESHOOTING GUIDE).*

LINE DROP COMPENSATOR

Trouble	Solution
Both reactance and resistance compensation work backwards.	1. Check external current transformer and potential transformer wiring. (Polarity must be as shown on wiring diagrams which were furnished with the transformer.) 2. Check auxiliary current transformer wiring. (RCT-A and RCT-B located on LTC control box back wall.) (Polarity must be as shown on wiring diagrams furnished with the transformer.)
Resistance compensation works properly; reactance compensation works backwards.	1. Check load power factor. If load power factor is leading, increase in load should cause negative reactance action. 2. Check wiring of R1 and R2 leads on LDC reactor and wiring of REVERSE REACTANCE switch. (Polarity must be as shown on wiring diagrams furnished with transformer.)

TROUBLESHOOTING GUIDE (Continued)
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VOLTAGE SENSOR

Make certain that the theory of voltage sensor and automatic operation is understood. Read voltage sensor operation, page 6, and automatic operation, page 2.

Trouble	Solution
RAISE test light energized all of the time; LOWER test light will not light	1. Check for open R30, R5, R6, R7, B2, D1, D2, and/or Z3. 2. Check for defective OP1. 3. Check C2 and/or B2 for short.
LOWER test light energized all of the time; RAISE test light will not light.	1. Check for open R8, R9, R29, and/or Z1. 2. Check for defective OP1. 3. Check Z2 and/or Z3 for short.
Neither test light can be energized.	1. Check for defective auxiliary power transformer. 2. Check for open B1, R1, and/or R2. 3. Check B1 and/or C1 for short. 4. Check for defective OP1. 5. Check for open BANDWIDTH control.
Both tests lights energized.	1. Usually due to a failure in either the RAISE or the LOWER side of the circuit board when the input is calling for the opposite mode of operation. (See the RAISE and LOWER troubleshooting solutions above.) 2. If the recheck of the RAISE and LOWER troubleshooting solutions indicates that both RAISE and LOWER circuits are defective, check for multiple failures of SCR1 and SCR2, OP2 and OP3, or a combination of the two failures.

VOLTAGE SENSOR VOLTAGE READINGS

The following readings are given as a guide to use when troubleshooting a voltage sensor. All readings are taken using a high-impedance voltmeter (preferably digital) with the voltage sensor mounted in the control panel under conditions specified. All readings are dc unless otherwise specified. Top and bottom voltage references relate to the physical locations on the voltage sensor circuit board.

NOTE: With the transformer energized and the normal potential transformer connected to Terminals 10 and G in the LTC control box.

1. Place the AUTO-MANUAL control switch in the MANUAL position.
2. Place the LOCAL-REMOTE control switch in the LOCAL position.
3. Set the TEST RHEOSTAT and BANDWITH controls at zero (0).
4. Set all three LDC controls at zero (0).
5. Connect a voltmeter to TEST TERMINALS G and A.
6. Place the CONTROLCIRCUIT BREAKER in the ON position.
7. Using the RAISE-LOWER control, run the LTC to the position that gives a reading as close to 120 Vac as system conditions permit.

   NOTE: If it is necessary to use an outside source, connect a variable 120 Vac, 60-Hz, sinusoidal waveform power source to LTC control box Terminals 10 and G. Set the source level at 120 Vac.

> **⚠ CAUTION**
> If an external source is used, disconnect the normal source and make certain that the source ground lead is connected to G.

8. Set the VOLTAGE LEVEL control at a point where both test lights are deenergized. If this is not possible or, if the VOLTAGE LEVEL control setting is more than 5 volts different than the voltmeter reading, set the VOLTAGE LEVEL control at the voltmeter reading.

The Voltage Chart readings should appear on the voltage sensor circuit board with a sinusoidal power source of 120 Vac, 60 Hz, applied to terminals 10 and G, the BANDWIDTH, TEST RHEOSTAT, and L.D.C. control knobs in their fully counterclockwise positions, and with the VOLTAGE LEVEL control set in a position where both test lights are deenergized (120 Vac).

VOLTAGE CHART

Terminal 1 to Terminal 2	80 Vac ±1
Terminal 3 to Terminal 4	24 Vac ±1
Line A (+) to Line D (-)	24 volts ±10%
Bottom (+) Z3 to Top (-) Z3	8.4 volts ±5%
Top (+) R8 to Bottom (-) R8	Z3 Reading ±.2
Top (+) R13 to Bottom (-) R8	11 volts ±1
Bottom (+) R23 to Bottom (-) R21	1 volt ±1.5
Top (+) R26 to Bottom (-) R21	1 volt ±1.5
Increase VOLTAGE LEVEL control setting by 5 volts (RAISE test light energized)	
Top (+) R13 to Bottom (-) R8	1 volt ±1.5
Bottom (+) R23 to Bottom (-) R21	22 volts ±2
Top (+) R26 to Bottom (-) R21	1 volt ±1.5
Decrease VOLTAGE LEVEL control setting by 10 volts (LOWER test light energized)	
Top (+) R13 to Bottom (-) R8	22 volts ±2
Bottom (+) R23 to Bottom (-) R21	1 volt ±1.5
Top (+) R26 to Bottom (-) R21	22 volts ±2

TROUBLESHOOTING GUIDE (Continued)
For Equipment Built After 1/1/82

VOLTAGE READINGS

Condition	Voltmeter Readings and Troubleshooting Procedure
Neither test light can be energized.	1. Check the voltage from Terminal 3 to Terminal 4 on the voltage sensor. *Voltage should be 24 Vac ±5%.* A. If the voltage from Terminal 3 to Terminal 4 is 0, check the auxiliary power transformer and connections. B. If the voltage from Terminal 3 to Terminal 4 is very low, check B1 and C1 for a short. C. If the voltage from Terminal 3 to Terminal 4 is 24 Vac ±5%, check the voltage from the top (+) of Z1 to the bottom (-) of Z2. *Voltage should be 24 volts ± 10%.* • If the voltage from Z1 to Z2 is 0 or low, check R1, R2, and B1 for an open circuit and check C1 and Z2 for a short.
RAISE test light energized all of the time—LOWER test light operates properly.	1. With the LOWER test light energized, check the voltage from bottom (+) of R23 to top (-) of R20. A. If the voltage is 1 to 3 volts, check SCR1 and C4 for a short. B. If the voltage is high, check OP2.
RAISE test light energized all of the time—LOWER test light will not operate.	1. Check the voltage from the bottom (+) of Z3 to the top (-) of Z3. *Voltage should be 8.4 volts ±5%.* • If the voltage is high, check for an open Z3. 2. Check the voltage from the top (+) of R8 to the bottom (-) of R8. *Voltage should be approximately equal to Z3 voltage.* A. When R8 voltage equals Z3 voltage, check the voltage from top (+) of R13 to bottom (-) of R8. *Voltage should be 11 to 12 volts.* • If the voltage stays low regardless of the change in differential between R8 and Z3 voltage, replace OP1. B. If R8 voltage is 0, check for an open R30, R5, R6, R7, D1, D2 or B2 and check B2, C2, and R9 for a short. C. Check combined resistance of R8 and R9. *Combined resistance should be 2400 to 3000 ohms.* *NOTE: The resistance of R9 is factory set. Do not change this setting. See BIAS POTENTIOMETER SETTING section, page 16.* *(1) If the resistance is low, check for a shorted R8 and/or R9.*
LOWER test light energized all of the time—RAISE test light operates properly.	*1. With the RAISE light energized, check the voltage from the top (+) of* R26 to the top (-) of R20. A. If 1 to 3 volts, check SCR2 and C5 for shorts. B. If the voltage is high, check OP3.
LOWER test light energized all of the time—RAISE test light will not operate.	1. Check the voltage from the bottom (+) of Z3 to the top (-) of Z3. *Voltage should be 8.4 volts ±5%.* • If the voltage is low, check for an open Z1 or R4 and shorted Z2 or Z3. 2. Check the voltage from top (+) of R8 to the bottom (-) of R8. *Voltage should be approximately equal to Z3 voltage.* A. When R8 voltage equals Z3 voltage, check voltage from top (+) of R13 to bottom (-) of R8. *Voltage should be 11 to 12 volts.* • If voltage stays high regardless of change in differential between R8 and Z3 voltage, replace OP1. B. If voltage is high, check combined resistance of R8 and R9. *Combined resistance should be 2400 to 3000 ohms.* NOTE: The resistance of R9 is factory set. Do not change this setting: see BIAS POTENTIOMETER SETTING section, page 16. (1) If resistance is high, check for an open R8 or R9. (2) If R8 and R9 resistance is correct, check for an open R29.
Both test lights energized all of the time.	1. Check for any combination: Defective OP2, OP3, shorted SCR1, SCR2, C4, C5.
Voltage sensor operates test light properly, but voltage level setting drifts and/or is off by more than two volts.	1. Check for poor contact in R9 and/or R30. NOTE: Do not change these settings before reading sections covering BIAS POTENTIOMETER and CALIBRATION POTENTIOMETER settings. 2. Check for open R29, R8, and/or R9. 3. Check for defective Z3, and/or OP1. 4. Check for poor contact in the VOLTAGE LEVEL, TEST RHEOSTAT, and/or BANDWIDTH controls.

TROUBLESHOOTING GUIDE (Continued)
For Equipment Built After 1/1/82

BIAS POTENTIOMETER SETTING

Bias potentiometer R9 has been factory set and sealed. It should not be necessary to change its setting unless it becomes defective or it is necessary to replace R6, R7, R8, or Z3. To reset R9:

1. Set all control knobs except the VOLTAGE LEVEL control at their fully counterclockwise positions.
2. Set VOLTAGE LEVEL control at 120 volts.
3. Turn calibration potentiometer R30 (on the lefthand edge of the voltage sensor circuit board) to its fully counterclockwise position.
4. Place bias potentiometer R9 in its fully clockwise position.
5. Connect a high-impedance voltmeter (preferably digital) to voltage sensor Terminals 1 and 2.
6. Connect a 114-volt ±1 Vac, 60-Hz, sinusoidal waveform voltage source to LTC control box Terminals 10 and G.

   NOTE: This can be done from the normal power source with the transformer energized or from an external source.

> ⚠ **CAUTION**
> If an external source is used, disconnect the normal source and make certain that the source ground lead is connected to G.

7. Energize the power source and, if necessary, adjust the VOLTAGE LEVEL control until the voltmeter reads 75 Vac ±0.2 volts.
8. Slowly turn R9 counterclockwise until the RAISE test light is *just* energized.
9. Seal the bias potentiometer setting with a hot iron or cement.
10. Reset calibration resistor R30 in accordance with the instructions in the CALIBRATION RESISTOR SETTING section.

CALIBRATION RESISTOR SETTING

If necessary to reset calibration resistor R30:

1. Set all controls except the BAND LEVEL control in their fully counterclockwise positions.
2. Connect a high-impedance voltmeter (preferably digital) to TEST TERMINALS A and G.
3. Connect a 120-volt, ±1 Vac, 60-Hz sinusoidal waveform voltage source to LTC control box Terminals 10 and G.

   NOTE: This can be done from the normal source with the transformer energized or from an external source.

> ⚠ **CAUTION**
> If an external source is used, disconnect the normal source and make certain that the source ground lead is connected to G.

4. Energize the power source and set the VOLTAGE LEVEL control to the setting that corresponds to the voltmeter reading + 0.6 volts.

   Example: Voltmeter reading is 119.5 volts + 0.6 = 120.1 Vac; therefore, the VOLTAGE LEVEL control should be set at 120.1 volts.
5. If the LOWER test light is energized, slowly turn calibration resistor R30 clockwise until the LOWER test light goes out and the RAISE test light *just* comes on.
6. If the RAISE test light is energized, slowly turn calibration resistor R30 counterclockwise until the RAISE test light goes out and then clockwise until the RAISE light *just* comes on.

LIMITED PARTS WARRANTY

McGraw-Edison warrants to the original purchaser that load tap changing equipment controls shipped after August 1, 1982 are free of defective workmanship and materials for a period of five years. This limited parts warranty commences on the date of arrival at destination and covers any defects and malfunctions of the load tap changer controls except those caused by improper installation, improper maintenance, improper operation, customer furnished materials, alterations executed by customer or vandalism.

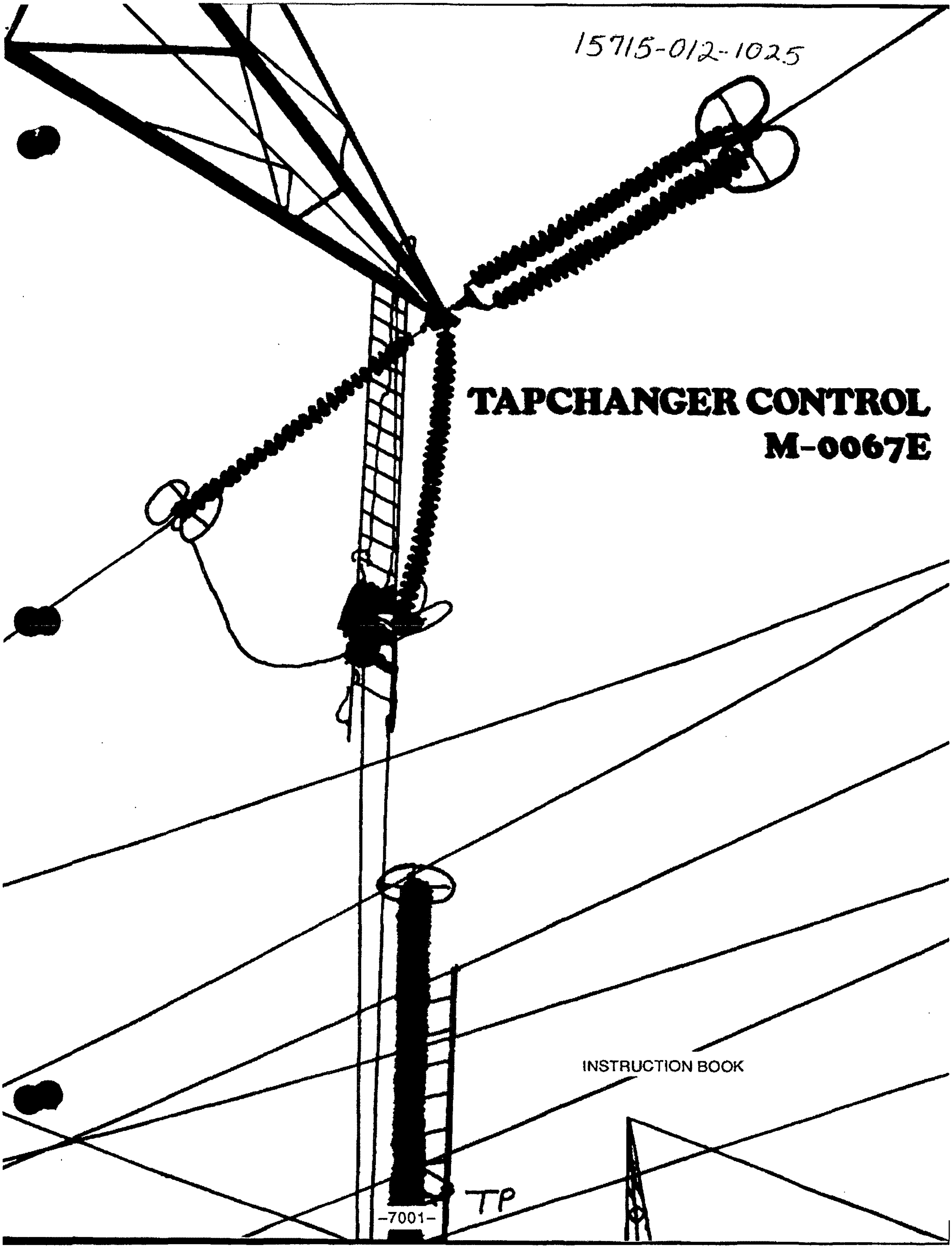
COOPER INDUSTRIES

COOPER POWER SYSTEMS

P.O. Box 440, Canonsburg, PA 153

15715-012-1025

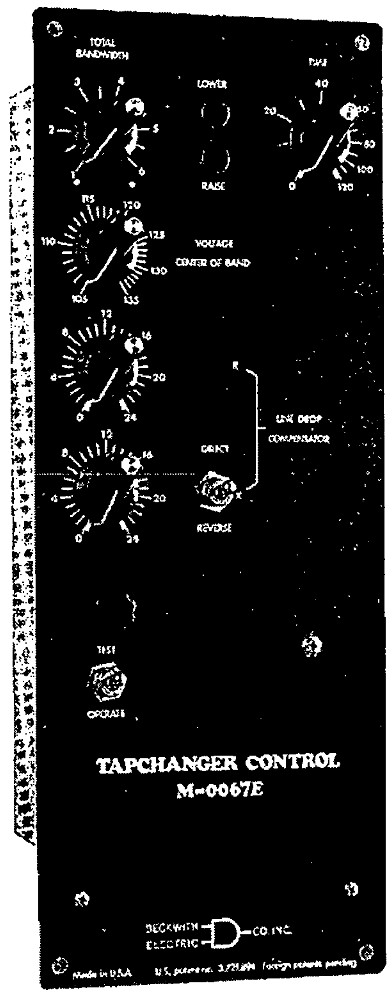
TAPCHANGER CONTROL
M-0067E



INSTRUCTION BOOK

BECKWITH ELECTRIC CO. INC.

Tapchanger Control M-0067E



- Adaptable to any LTC Transformer—Old or New
- Meets ANSI Class 1 (1%) Accuracy Requirement
- Fully Transient Protected
- Now in Use by Leading Manufacturers as Standard Equipment

INPUTS

Power: A two wire input, requiring less than 3 W at 90 to 140 V ac, provides all power requirements. The unit should be powered from a potential transformer or from the voltage to be controlled.

Line Current: Line drop compensation is provided by a C.T. input with a 0.2 A nominal full scale rating. The burden imposed by this input on the current source is 0.03 VA. A Beckwith Electric model M-0121 (5 A to 0.2 A) or M-0169 (5 A or 8.66 A to 0.2 A) Auxiliary Current Transformer is available when required.

Circulating Current: Parallel operation of transformers is provided by a second C.T. input with a 0.2 A nominal full scale rating. The burden imposed by this input on the current source is 0.005 VA. A paralleling input with a 0.2 A full scale rating gives approximately 24 V correction at approximately 90° for parallel operation with other transformers.

OUTPUTS

Two outputs drive a raise and lower motor starter relay. The starters may be any voltage up to 240 V ac. The output contacts are rated at 2.5 A inrush current and will handle a NEMA size 1 starter or smaller.

CONTROLS

VOLTAGE CENTER OF BAND: The center of the control band may be set to any voltage from 105 to 135 V ac. The scale calibration accuracy is ±0.5 V at 120 V ac.

TOTAL BANDWIDTH: The bandwidth control can be adjusted from 1.0 to 6.0 V. The scale calibration accuracy is ±0.3 V.

TIME: The timer is adjustable from 0 to 120 sec. with a scale calibration accuracy of ±10% of setting or ±2 sec., whichever is greater. The timer starts when the voltage goes outside the band and resets within a few milliseconds upon return to the band or when reset by an external contact in the Non-Sequential mode.

LINE DROP COMPENSATOR: The resistance compensation provides 24 V compensation for 0.2 A input in phase with the input voltage. The reactance compensation provides 24 V compensation for 0.2 amps input at a phase angle of ±90° as chosen by the **DIRECT/REVERSE** switch. The magnitude and angle of each circuit is individually set by a pair of trimpots to any accuracy limited only by the instruments used in setting. The factory setting of magnitude will be within ±5% and the phase angles within ±2%. The voltage and two current circuits are isolated from each other and do not interact.

TEST/OPERATE: When this switch is in the **TEST** position, the Line Drop Compensator is deactivated and the voltage may be raised and lowered by means of an uncalibrated voltage control. An external voltmeter with a burden of 500 Ω per V or higher can be connected to test the band limits by observing when the **RAISE** and **LOWER** LEDs light. No special test voltage source required.

LED INDICATORS

The **RAISE** and **LOWER** LEDs light to indicate a voltage outside the band and a forthcoming tapchanger operation as soon as the timer times out. With a slowly varying input, operation of the LEDs and initiation of timing is very sharp with 0.2 V hysteresis. The LEDs have an expected life of 25 years.

MODES OF OPERATION

Either of the following modes are available as determined by presence or absence of a cam switch which is closed while the LTC is in transition.

Non-Sequential Mode: The timer resets after a tapchange, regardless of voltage.

Sequential Mode: The timer resets only after the sensed voltage is back within the control band.

LOW VOLTAGE PROTECTION

Outputs are blocked from operating at input voltages below approximately 60 V ac. A proper raise output will be obtained down to this threshold.

RESPONSE

The M-0067E will respond to 5/8% voltage change in 0.2 sec. ensuring freedom from hunting on minimum bandwidth.

STANDARDS

The unit meets the requirements of accuracy class 1 as defined in ANSI standards C57.12.30-1977 paragraph 9.3 and C57.15-4.2 when tested according to C57.15-1986 paragraph 9.4.1.

OPTIONS

Voltage Setpoint

1. Single-step voltage reduction: The addition of an external resistor lowers the voltage setpoint.
2. Voltage reduction resistors: Resistors for a maximum of two preselected steps of voltage reduction will be mounted on the printed circuit board at the factory.
3. Instantaneous (non-time delayed) voltage reduction: Circuitry is added at the factory.

50 Hz Operating Frequency

This option is available for use in countries outside the continental United States and Canada. The unit will be shipped with the standard 60 Hz operating frequency unless otherwise specified.

TRANSIENT PROTECTION

Input and output circuits are protected against system transients. The M-0067E will pass all requirements of ANSI/IEEE C37.90.1-1989 defining oscillatory surge withstand capability. All inputs and outputs will withstand 1500 V ac to chassis or instrument ground for one minute. Voltage inputs are electrically isolated from each other, from other circuits, and from ground.

MOUNTING

1. Standard vertical
2. Horizontal
3. 19" rack mount

ENVIRONMENTAL

Temperature: The voltage band limits will vary no more than 0.5 V from -50° to +80° C. The timer will vary no more than ±10% of setting or ±2 sec., whichever is greater.
Humidity: Stated accuracies are maintained at up to 95% relative humidity (non-condensing).
Fungus Resistance: A conformal printed circuit board coating inhibits fungus growth.

PHYSICAL

Size and Mounting: Overall dimensions are 6-3/8" x 16-1/2" (16.2 cm x 41.9 cm); requires a panel cutout of 5-7/8" x 15-1/8" (14.9 cm x 38.4 cm).
Approximate Weight: 6 lbs (2.7 kg).
Approximate Shipping Weight: 9 lb (4.1 kg).

PATENTS

U.S. Patent 3,721,894; Canadian Patent 985,368; British Patent 1,432,607; Swedish Patent 7,301,667-7; and other foreign patents applied for.

WARRANTY

The M-0067E Tapchanger Control is covered by a two year warranty from date of shipment.

NOTICE

Any illustrations and descriptions by Beckwith Electric Co., Inc. are for the sole purpose of identification.

THE DRAWINGS AND/OR SPECIFICATIONS ENCLOSED HEREIN ARE THE PROPRIETARY PROPERTY OF BECKWITH ELECTRIC CO., INC. AND ARE ISSUED IN STRICT CONFIDENCE; THEREFORE, SHALL NOT BE USED AS A BASIS OF REPRODUCTION OF THE APPARATUS DESCRIBED THEREIN WITHOUT PRIOR WRITTEN PERMISSION OF BECKWITH ELECTRIC CO., INC.

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THERE SHALL BE NO WARRANTIES WHICH EXTEND BEYOND THOSE CONTAINED IN THE BECKWITH ELECTRIC CO., INC. TERMS OF SALE.

WARNING

DANGEROUS VOLTAGES, CAPABLE OF CAUSING DEATH OR SERIOUS INJURY, ARE PRESENT ON THE EXTERNAL TERMINALS AND INSIDE THIS EQUIPMENT. USE EXTREME CAUTION AND FOLLOW ALL SAFETY RULES WHEN HANDLING, TESTING OR ADJUSTING THE EQUIPMENT. HOWEVER, THESE INTERNAL VOLTAGE LEVELS ARE NO GREATER THAN THE VOLTAGES APPLIED TO THE EXTERNAL TERMINALS.

PERSONNEL SAFETY PRECAUTIONS

The following general rules and other specific warnings throughout the manual must be followed during application, test or repair of this equipment. Failure to do so will violate standards for safety in the design, manufacture and intended use of the product. Qualified personnel should be the only ones who operate and maintain this equipment. Beckwith Electric Co., Inc. assumes no liability for the customer's failure to comply with these requirements.

ALWAYS GROUND THE EQUIPMENT

To avoid possible shock hazard, the chassis must be connected to an electrical ground. When servicing equipment in a test area, the chassis must be attached to a separate ground since it is not grounded by external connections.

DO NOT OPERATE IN AN EXPLOSIVE ENVIRONMENT

Do not operate this equipment in the presence of flammable or explosive gases or fumes. To do so would risk a possible fire or explosion.

KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove the cover or expose the printed circuit board while power is applied. In no case may components be replaced with power applied. In some instances, dangerous voltages may exist even when power is disconnected. To avoid electrical shock, always disconnect power and discharge circuits before working on the unit.

EXERCISE CARE DURING INSTALLATION, OPERATION AND MAINTENANCE PROCEDURES

The equipment described in this manual contains voltages high enough to cause serious injury or death. Only qualified personnel should install, operate, test and maintain this equipment. Be sure that all personnel safety procedures are carefully followed. Exercise due care when operating or servicing alone.

DO NOT MODIFY EQUIPMENT

Do not perform any unauthorized modifications on this instrument. Return of the unit to a Beckwith Electric repair facility is preferred. If authorized modifications are to be attempted, be sure to follow replacement procedures carefully to assure that safety features are maintained.

▲ PRODUCT CAUTIONS

Before attempting any test, calibration or maintenance procedure, personnel must be completely familiar with the particular circuitry of this unit and have an adequate understanding of field effect devices. If a component is found to be defective, always follow replacement procedures carefully to assure safety features are maintained. Always replace components with those of equal or better quality as shown in the Parts List of the Instruction Book.

AVOID STATIC CHARGE

If this unit contains MOS circuitry, it can be damaged by improper test or rework procedures. Care should be taken to avoid static charge on work surfaces and service personnel.

USE CAUTION WHEN MEASURING RESISTANCES

Any attempt to measure resistances between points on the printed circuit board, unless otherwise noted in the Instruction Book, is likely to cause damage to the unit.

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TABLE OF CONTENTS

M–0067E TAPCHANGER CONTROL
Instruction Book

In our efforts to provide accurate and informative technical literature, suggestions to improve the clarity or to correct errors will receive immediate attention. Please contact the Marketing Services Department, specifying the publication and page number.

INTRODUCTION

The M–0067 is a solid-state control that makes novel use of the latest electronic techniques to achieve a highly stable and reliable transformer or regulator control. The Block Diagram is shown in Figure 1. The M–0067 control is suitable for use on existing LTC transformers, single-phase regulators or induction voltage regulators, as well as new transformers.

All components are mounted on a single printed circuit board which in turn is mounted on a metal panel. The panel can be easily removed, leaving a completely functional circuit board with both sides exposed for ease in servicing. The panel mounting space is consistent with a three-unit drawout case.

A self-checking feature permits checking calibration with only an accurate ac voltmeter.

All dials are accurately calibrated with only one knob used for each function. Calibration of each function is independent of all others.

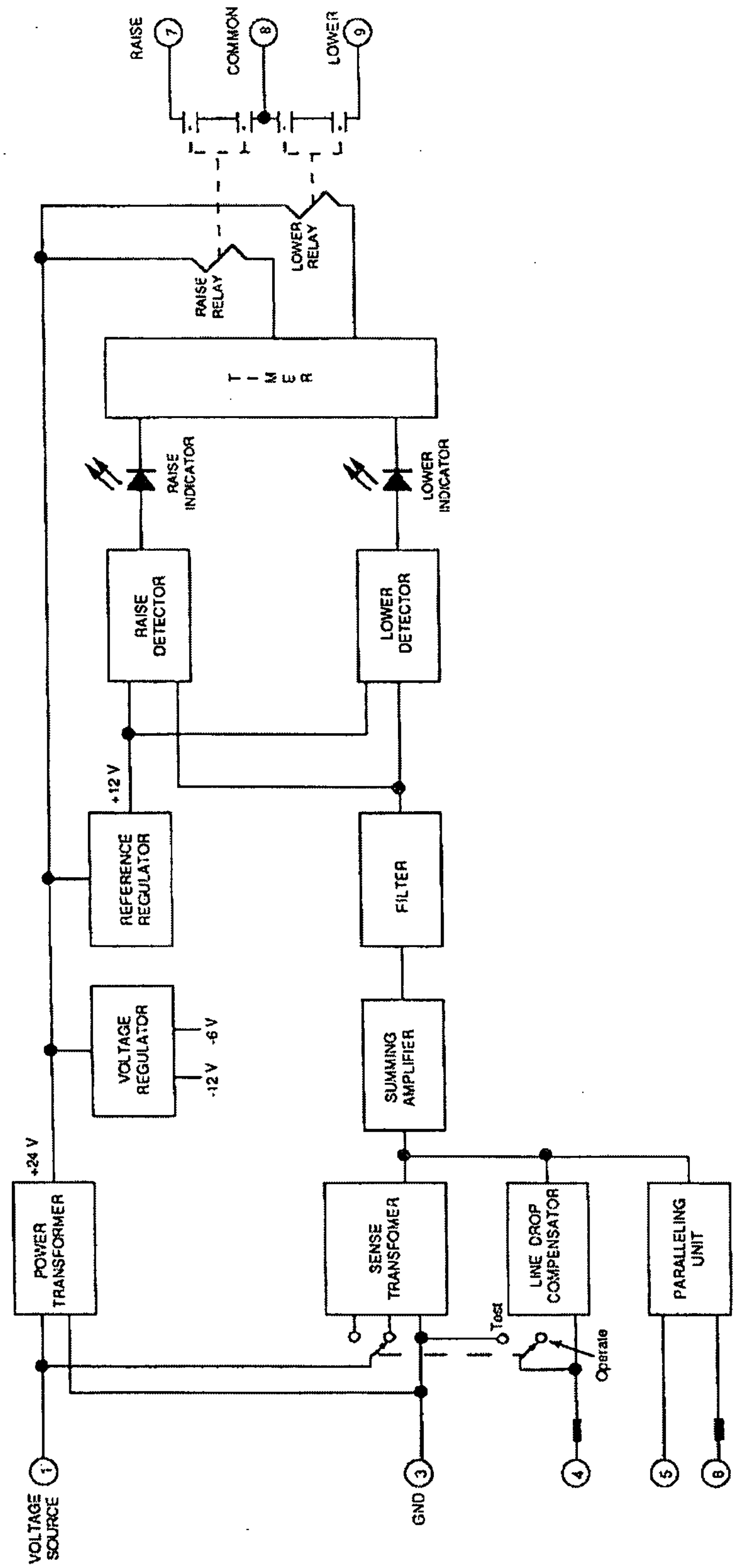


FIGURE 1 Block Diagram

PRINCIPLES OF OPERATION

■ NOTE: It will help in following the Schematic shown in Figure 4 to know that generally dc voltages are positive at the top and negative at the bottom. Information generally flows from left to right.

LINE DROP COMPENSATION

This uses a number of unique circuits to give improved performance at lower cost and with almost no heat rise.

The voltage is scaled down 10:1 by T4 so that 12 V ac on the secondary represents 120 V ac. By bringing the P.T. voltage to a 95% tap for test, both a raised and lowered voltage can be produced across the entire primary by adjustment of R3. This permits checking both band limits without using a separate test voltage source.

Transformer T1 and associated network produces a voltage across R5 of 2.4 V ac for 0.2 A in its primary. Capacitor C19 corrects for transformer inductance causing the voltage across R5 to be exactly in phase with the current. Resistor R2 is the main burden, and trimmer R4 adjusts the half-scale point of the resistance control R5 to be exactly correct.

Transformer T2 and associated network produces a voltage across R9 of 2.4 V ac for 0.2 A in its primary. Switch S2 provides direct or reversed polarity for this reactance compensation voltage.

The pi network consisting of C2, R7 and C5 provides exactly 90° phase shift, including effects of transformer inductance. Trimmer R7, therefore, adjusts the angle of the voltage across R9 to be exactly 90° out of phase with T2 primary current. Trimmer R8 adjusts the magnitude to the correct value at half scale on reactance control R9.

Capacitors are used in the reactance network since they provide nearly perfect linearity with current level and at lower cost than inductances. A reversal of T2 polarity brings the phasing to the correct point, making the capacitive burden look like an inductive burden.

Transformer T3 with C3 and C4 produce a secondary voltage, approximately 90° out of phase with the primary current, for use in parallel operation of transformers. This angle is actually 84° and is not compensated to precisely 90° since this is not required for proper paralleling. Again, reversal of polarity through T3 makes its capacitive burden look like an inductive burden.

Summing amplifier Q1 has a current summing input at pin 2 (-). Current is fed to this point through resistors R13, R10, R11 and R12. It is the nature of Q1 that current cannot enter the device but that, instead, the Q1 output will serve itself so that the sum of the four currents flows through R16. When the sum of the input voltages is positive, Q1 output will be a negative voltage in precise proportion to the sum (at the juncture of D4, R18 and feedback resistor R16). When the sum of the input is negative, the feedback is blocked by D4 so that the summing input actually moves negative and Q1 switches positive to saturation. This forms an effective half-wave rectifier yet without the temperature-sensitive drop of D4 giving an error.

The resistor capacitance network following Q1 gives a dc voltage proportional to the sum. Components R17, R18 and C6 are chosen to make this dc voltage proportional to the rms content of the input regardless of considerable distortion. This provides proper compensation when very nonlinear loads such as arc furnaces distort the current waveshape.

Resistors R20, R66 and R67 together with capacitors C8, C17 and C18 form a twin T-filter which removes the ripple voltage without introducing a time delay which could cause the transformer to hunt when set for a narrow bandwidth. When the bandwidth is so narrow that it can be matched by only one tap position, it is essential to detect the voltage in time to stop the tapchanger on that one tap; otherwise the operation will oscillate continuously, never stopping within the band.

VOLTAGE SENSING

Power transformer T5 and full-wave rectifiers D5 and D6 provide an unregulated 24 V for noncritical circuits and as relay potential.

Integrated circuit regulator Q2 provides a very stable dc reference source for voltage determination and timing.

Full-wave rectifiers D13, D18 and associated network provides negative voltages regulated by zener diodes D14 and D15.

Integrated operational amplifier circuits Q3 and Q4 are used as threshold detectors. Their outputs switch as the dc voltage "E," proportional to the compensated ac input, goes outside a band of reference voltages.

Zener diode D7 maintains a constant voltage across the bandwidth determining circuit so that the bandwidth is independent of voltage control R26. The zener diode D7, and the fact that R27 equals R30, assures that the bandwidth will vary around a bandcenter value determined by R26 alone.

Resistors R34 and R35 provide approximately 0.2 V hysteresis at the band edges. This results in very sharp band edge operation, energizing the motor starter without chattering.

TIMER AND OUTPUT

A precise and stable timer is formed by charging C12 through R43 to a point where operational-amplifier Q6 switches. The second input to Q6 is by timing control R40. Resistor R45 provides a snap action when the threshold is reached.

RAISE and **LOWER** LEDs I1 and I2 operate when either threshold detector Q3 or Q4 operate. Until the timer times out, the LED current is shunted to -6 V by diodes D11 and D12. When the timer does time out, the current from either I1 or I2 is passed to the base of Q9 or Q7, thereby turning it on. This transistor operates relay K1 or K2 which causes a raise or lower operation.

Transistor Q5 shorts the timing capacitor, thereby cutting off either relay whenever the voltage goes back within the band. This occurs in 1/2 cycle or less, assuring that the tapchanger will stop in the band whenever minimum bandwidth is being used.

The timing capacitor can also be discharged by closing a contact from terminals 3 to 10. If tied to a cam switch, closed off normal, non-sequential operation is obtained where the timer starts following each tapchanger step regardless of the voltage.

STABILITY

Excellent stability is achieved from -50° to +80° C (-58° to 176° F). This is accomplished by using circuits and components each having inherent stability. In units with serial numbers up to 5000, it was necessary to include a varistor to correct for a final ±1/2% of temperature drift. Units serial 5000 and greater have this temperature correction eliminated.

This excellent stability is essential when transformers are used in parallel with very narrow bandwidth. If the controls were to drift apart in voltage setting, first one transformer would operate to bring the voltage within its band and then the other. This would occur after each timer times out and would continue until the circulating current stopped the action. Minimum circulating current is thus not obtained.

The design uses operational amplifier integrated circuits which have variations in manufacture, temperature and life measured in terms of less than 10 mV. These are used with voltages in the order of 10 V, well within their rating but far above the levels of undesired variations. In addition, an integrated circuit voltage regulator establishes a highly stable reference to compare with the rectified ac voltage.

Highly stable metal film resistors and wirewound potentiometers are used throughout the design. These are used as voltage dividers in such a way that the essential divided voltage is independent of the small variation of resistance with temperature.

Light emitting diodes assure trouble-free, long life with little deterioration due to age and no effect from vibration.

All active semiconductors are hermetically sealed so that moisture cannot change their characteristics.

The circuit involving Q1 is a novel combination of summing amplifier and compensated half-wave rectifier. This eliminates all interaction between the several inputs to the compensator. It also includes half-wave rectifier D4 inside a high gain feed-back path to eliminate the effect of the voltage drop across D4 which varies with temperature.

The ac voltage and current compensation voltages are scaled down 10:1 to values more appropriate for use with integrated circuits. This and other techniques reduce the power input within the band to about 1 W which reduces warmup drift to a minimum by the simple fact that the temperature rise due to operation is very small.

Accurate timing is achieved by use of a stable resistor and capacitor, and by measuring the charging time to a stable dc voltage using an operational amplifier to compare these voltages to within a few millivolts. Through use of simple logic circuits, a single timer is used for either raise or lower.

High temperature, low leakage electrolytic capacitors are used where necessary to minimize total drift with usage and variations in ambient temperature.

APPLICATION

GENERAL

External connections are shown in Figure 2. Both power (1 to 3 W) and voltage sensing are obtained from a potential device having a nominal 120 V ac output. Normally, this is line-to-neutral potential although line-to-line potential can also be used if special attention is paid when using line drop compensation. Load current must be reduced by suitable auxiliary current transformers to 0.2 A full scale before connecting to the M-0067 input. The Beckwith Electric M-0121 Current Transformer (5A to 0.2 A) can be used with the M–0067 when there is no additional burden present. The M–0169 Current Transformer (8.66 A or 5 A to 0.2 A) is for use in high burden current circuits, such as are found in paralleling schemes. Outputs are protected against overvoltage.

In general, the tapchanger motor must be operated from a different transformer than that used to measure potential. If this is not done, hunting at the upper band edge may result. As soon as the motor starts and before it is sealed in, the motor current can drop the voltage within the band and reset the control. Some motor seal-in schemes are fast enough to prevent this but others are not.

PARALLEL OPERATION

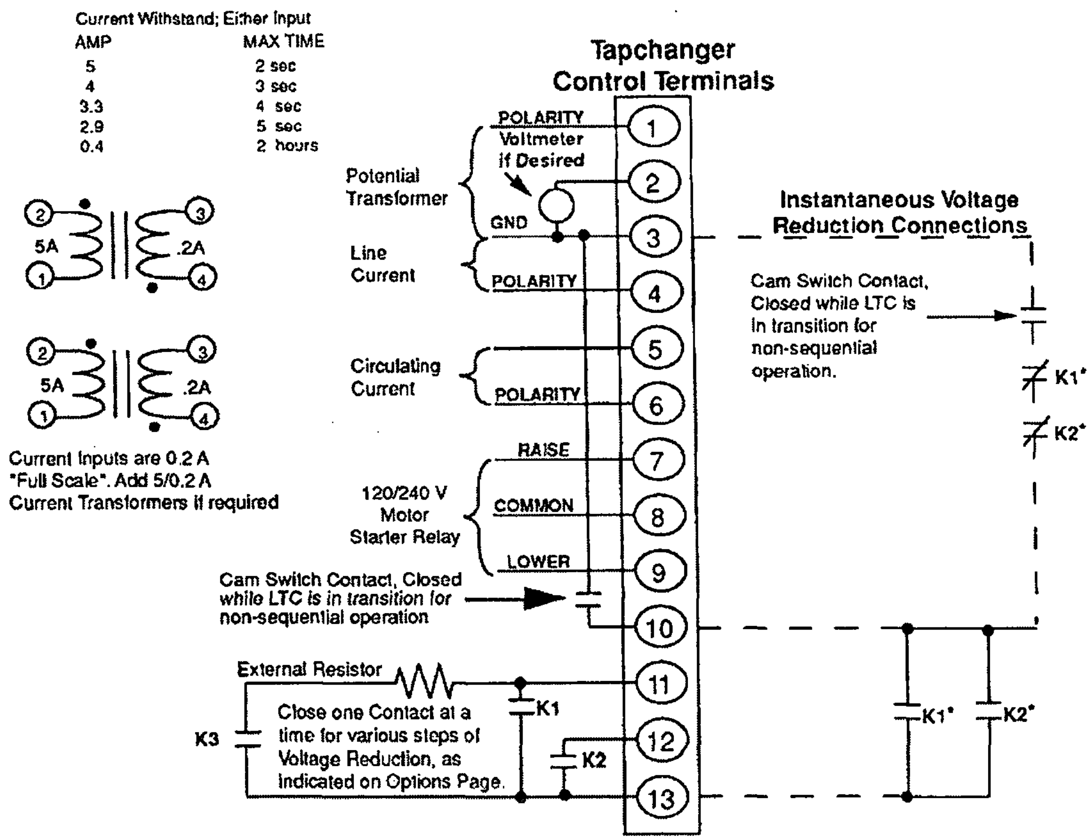
A number of problems of distinct origin may be hard to distinguish because they all result in hunting of transformers in parallel. The net result is excessive operations as noted on the counter. In order to prevent these operations, it is essential that the various causes be carefully distinguished and eliminated to the extent provided by adherence to ANSI Class 1 standards.

Due to the necessity of tapping the transformer winding to the nearest turn, a change may be as much as 3/4% or 1 V. The tapchanger will have only one chance to stop within a 1 V band, and the control timer must reset before a second change is initiated. If not, the tapchanger will move up two steps, reset, time out, move down two steps, time out and continue this indefinitely. The M-0067 has been designed with a sufficiently fast response to avoid this problem.

Another problem is that the industry standard for 1% accuracy may typically be fulfilled by ±1/2% temperature variation and ±1/2% due to other errors. It is quite possible for one control to drift +1/2% and another -1/2% with temperature. This means the minimum practical bandwidth for parallel operation is 2% or 2.4 V, assuming no error was made in setting the controls.

The adjustment error can be reduced by using the same voltmeter with great precision in setting the voltage at center of band of units being paralleled. If the Beckwith control is used with a control of poor stability, even wider bandwidth must be used to compensate for the poor stability of the other control.

A further problem in paralleling can arise if one control is of a different design and if line drop compensation is used. The line drop compensator of the M–0067 has rather exact 0° resistance compensation and 90° reactance compensation. Other controls of older vintage have been found to have reactance compensation of 60° to 70°, rather than 90° as it should be. Due to these imperfections, the line drop compensator of other controls may not track the rather exact line drop compensator of the M–0067. This may cause hunting to occur at load levels different than those existing when the controls were initially adjusted.



*■ NOTE: For Instantaneous Voltage Reduction, use additional contact from the K1 and K2 relays.

● WARNING: Open C.T. secondary will result in high voltage at C.T. terminals.

Death, severe injury or damage to equipment can occur.

Do not operate with C.T. secondary open. Short circuit or apply burden at C.T. secondary during operation.

FIGURE 2 External Connections

An additional problem in paralleling may occur if the transformers themselves have widely different impedances. This will cause current in the circulating current circuit, even with transformers on the same tap. In order to eliminate hunting, it is now necessary to desensitize the circulating current circuit so that no tapchange results from this minimal circulating current.

This can be accomplished by changing R12 (normally 270 K). The sensitivity is inversely proportional to the size of R12, i.e., inserting R12 equal to 540 K would give a sensitivity of 12 V/0.2 A rather than the standard 24 V/0.2 A. This resistor is mounted on turrets to permit unsoldering without removing the panel.

> ▲ CAUTION: **Use a small iron and minimal heat in changing this component. Refer to the TEST PROCEDURE section for the proper equipment required.**

The need to change R12 is eliminated if the Beckwith Electric M-0115 Parallel Balancing Module is used since it contains a sensitivity control. Refer to the Instruction Book on the M-0115 for details.

In another case, the standard sensitivity may not be sufficient. This is the case where the impedance of an overcurrent relay in the circulating current circuit is so high as to reduce the current from the C.T. below the value which should flow. Here a lower than normal R12 value can be used to increase the sensitivity and compensate for the high relay impedance.

This problem is best avoided by using a Beckwith Electric M-0127 10-100 mA ac Overcurrent Relay. The input impedance of approximately 100 Ω avoids saturation of the source current transformer.

These difficulties have led some utilities to decide against using the circulating current method of paralleling. Field experience with the Beckwith Electric controls proves that the operation will be stable over long periods and with no readjustment if the above points are carefully considered.

OPTIONS

VOLTAGE REDUCTION

The voltage setpoint may be reduced by closing the external dry contacts one at a time from terminal 11 or 12 to 13. These contact closures may typically be remotely-controlled by supervisory control.

> ▲ CAUTION: **Leads between contacts and the M-0067 terminals must be kept short and within the control cabinet in order to avoid circuit damage or misoperation.**

Approximate values of resistance for various amounts of voltage reduction may be obtained from Figure 3. The resistors for two preselected steps of voltage reduction will be mounted on the printed circuit board. Please indicate the desired percentage(s) of voltage reduction (based on 120 V) on the **OPTIONS** page when ordering the unit. Resistors R74 and R75 will be factory selected and installed to provide the desired voltage reduction. If no voltage reduction is specified on the option sheet, R74 and R75 will not be installed at the factory. If more than two steps of voltage reduction are required, additional voltage reduction resistors may be added externally to the unit in series with terminals 11 and 12.

INSTANTANEOUS (NON-TIME DELAYED) VOLTAGE REDUCTION

To implement this option, a 2.2 K ±10%, 1/2 W carbon resistor is substituted at the factory for R37. When ordering the M-0067, please indicate if this option is desired by checking the appropriate entry on the **OPTIONS** page.

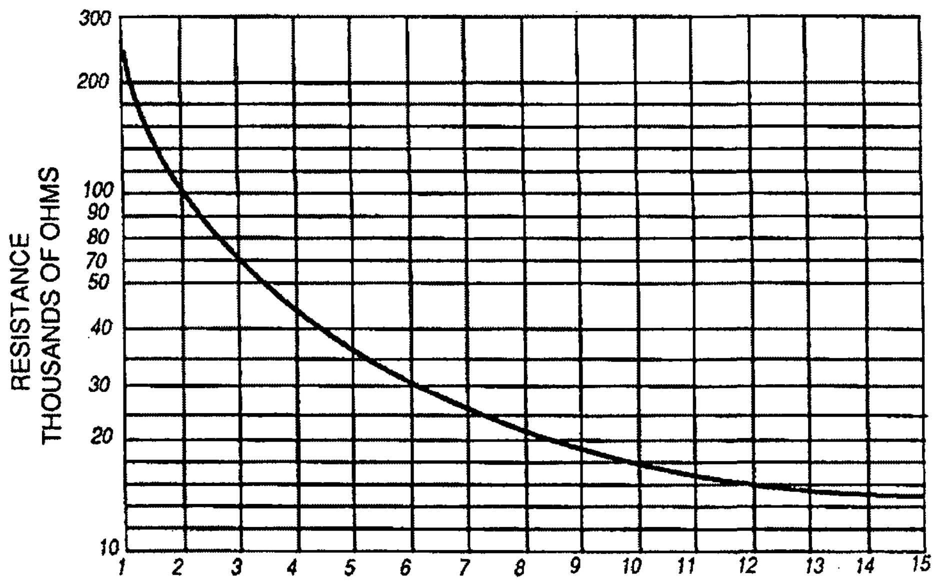


FIGURE 3 Voltage Reduction

The external circuitry required is shown in Figure 2. When voltage reduction is required, the contacts from terminal 10 to terminal 13 close, forcing the timer to instantaneously time out. Subsequent tap changes will occur with no time delay. Meanwhile, the normally closed contacts will open to keep the cam switch from resetting the timer if the control has been wired for nonsequential operation. If the control is being used in the sequential mode of operation, these normally closed contacts are unnecessary.

▲ CAUTION: Leads between contacts and the M-0067 terminals must be kept short and within the control cabinet in order to avoid circuit damage or misoperation.

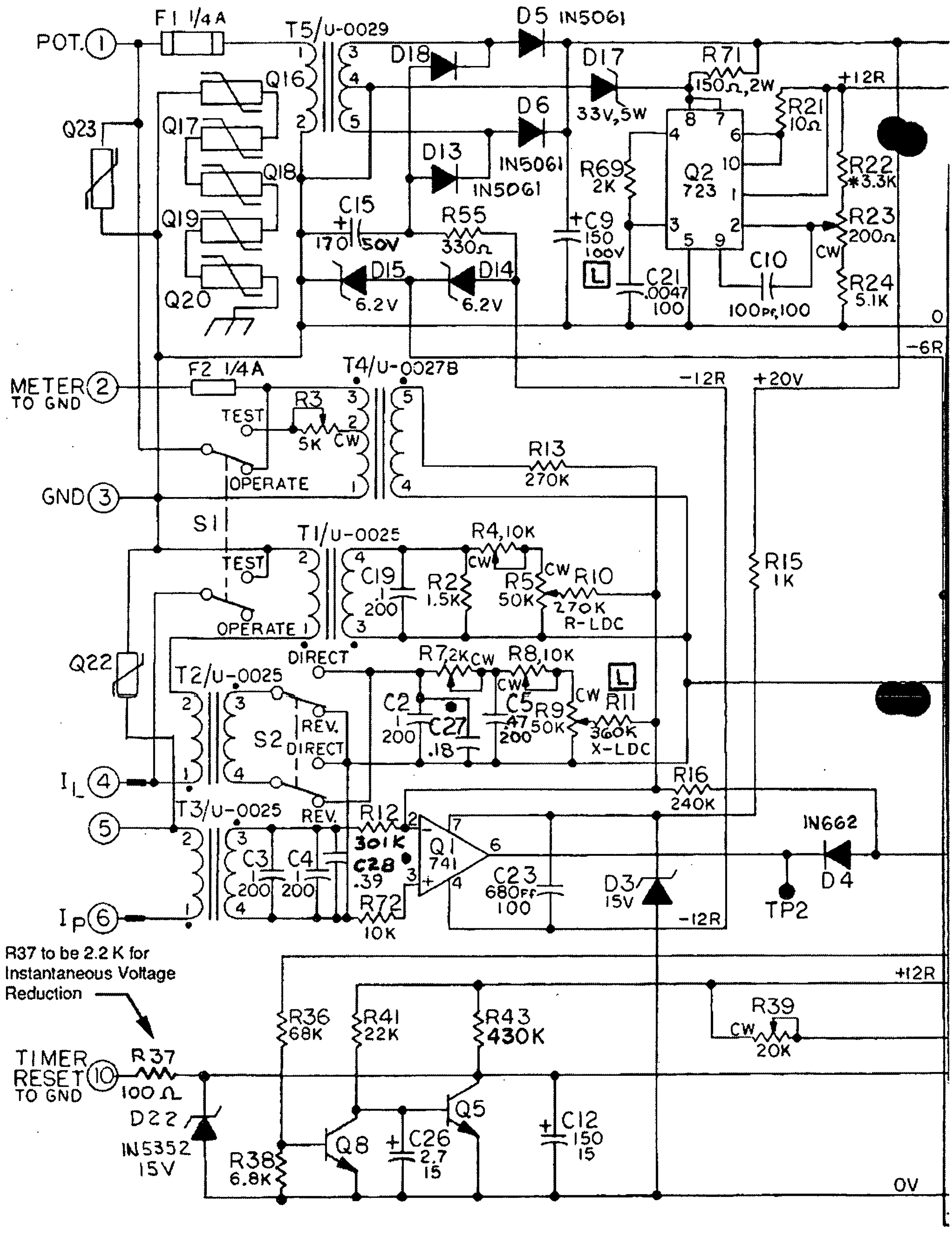
USE OF THE M-0329 LTC BACKUP CONTROL WITH THE M-0067 TAPCHANGER CONTROL

The M-0329 is a single-phase, solid-state backup control that has three main functions:

1. Prevent a defective tapchanger control from running the voltage outside the upper and lower limits.
2. Prevent the line drop compensator from raising the voltage too high under full load or overload conditions.
3. Lower the voltage if the regulated voltage goes above the Block Raise setpoint by a fixed bandwidth.

The Block Raise and Block Lower voltage levels are set by accurately calibrated dials; four per-unit values are available for the fixed bandwidth.

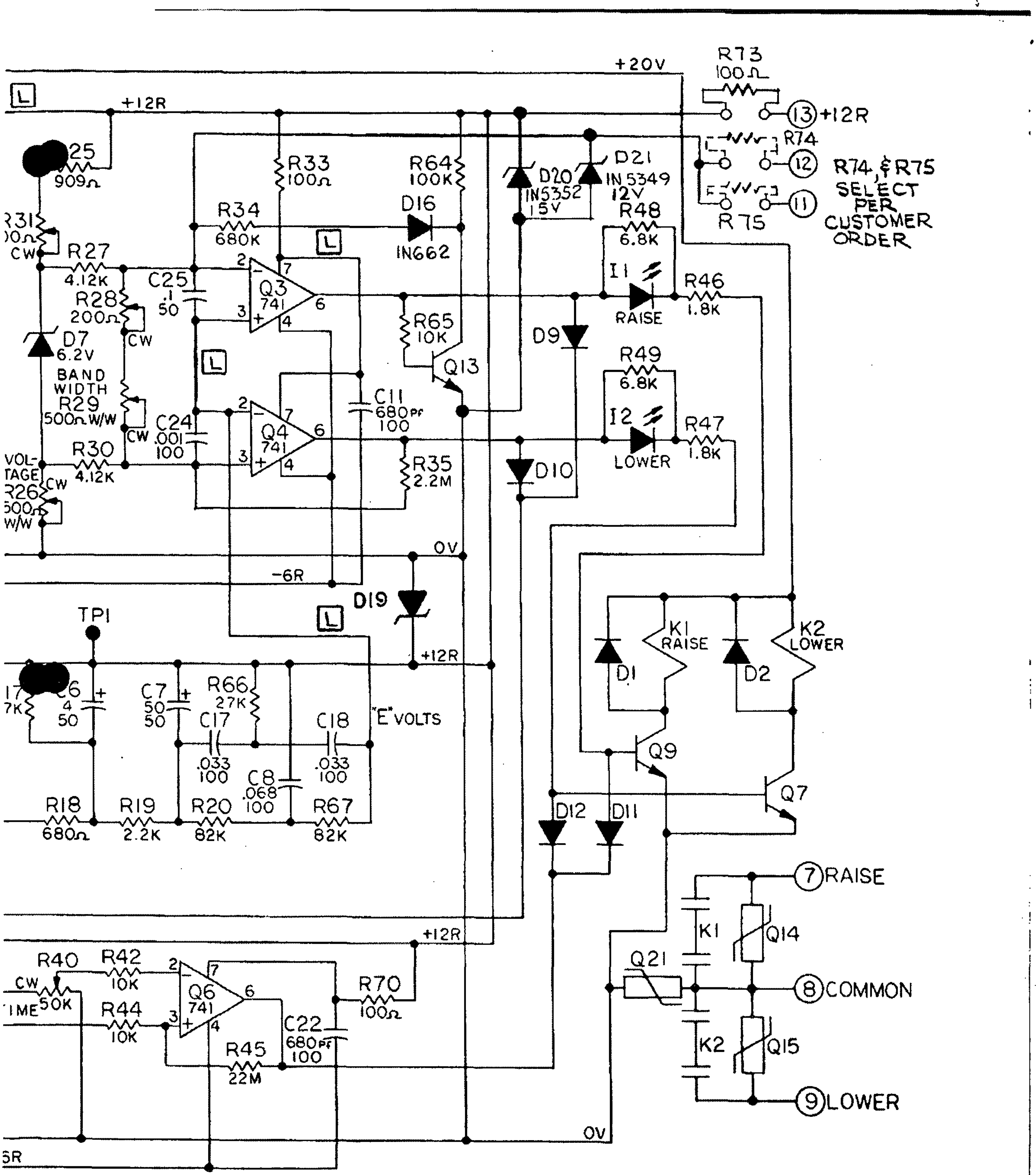
The M-0329 Instruction Book is available on request and gives added details. Since the M-0329 voltage and the fixed bandwidth value must be specified at the time of purchase, please refer to the M-0329 Instruction Book for complete ordering information.



* RESISTANCE VALUE FACTORY SELECTED

● C27 & C28 installed for 50 Hz System

FIGURE 4 Schematic


+20V
R73
100Ω
+12R
13 +12R
R74
12
11
R75
R74 & R75 SELECT PER CUSTOMER ORDER
R25
909Ω
R31
CW
R27
4.12K
R28
200Ω
CW
D7
6.2V
BAND WIDTH
R29
500Ω W/W
CW
VOL-TAGE
R26
CW
W/W
R30
4.12K
C25
.1
50
C24
.001
100
R33
100Ω
R34
680K
Q3
741
Q4
741
C11
680pf
100
R64
100K
D16
IN662
R65
10K
Q13
R35
2.2M
D20
IN5352
15V
D21
IN5349
12V
R48
6.8K
I1
RAISE
R46
1.8K
D9
R49
6.8K
I2
LOWER
R47
1.8K
D10
0V
-6R
D19
TP1
+12R
"E" VOLTS
C6
4
50
C7
50
50
R66
27K
C17
.033
100
C18
.033
100
C8
.068
100
R18
680Ω
R19
2.2K
R20
82K
R67
82K
K1
RAISE
K2
LOWER
D1
D2
Q9
Q7
D12
D11
7 RAISE
K1
Q14
Q21
8 COMMON
K2
Q15
9 LOWER
+12R
R40
CW
TIME
50K
R42
10K
R44
10K
Q6
741
R70
100Ω
C22
680pf
100
R45
22M
0V
6R

INSTALLATION

The mounting and outline dimensions are shown in Figure 5 and 6b. The M-0067E is also available in horizontal and rack mount configurations as shown in Figure 6a and 6b. The horizontal configuration uses the same mounting dimensions as the vertical configuration shown in Figure 5.

Since the compensated voltage is not available from the Beckwith Electric Tapchanger Control, the M-0329LTC Backup Control must be connected as a two terminal device to the potential transformer. Figure 7 shows the typical interconnection of the two devices with motor auxiliary relays.

Before energizing a new transformer or a modified old transformer make certain of the following:

LIGHTNING PROTECTION

It has been determined that transient voltages in excess of 1500 V ac rms can exist on the "ground" lead normally tied to terminal 3 and that these excessive voltages were causing occasional failure. In the "E" version of the M-0067 units, these voltages are suppressed by a string of varistors which still permit the unit to pass a 1500 V ac hi-pot test, all terminals to ground.

If possible, the potential transformer should be grounded at the control with a lead no longer than 6" from the M-0067 terminal 3 to ground (such as one of the M-0067 mounting screws). This will give the best protection from lightning damage to the control.

Multiple P.T. grounds far apart must be avoided, however, since a varying difference in ground potential could add or subtract from the effective potential and cause a variation in the voltage setpoint.

▲ CAUTION: The Meter Circuit is protected by a 0.25 A Axial Lead Picofuse (F2). Any external device, e.g. a voltmeter, connected to TB1-2 must not draw more than 0.25 A to ensure F2 will not be blown. Refer to the TEST CIRCUIT section for instructions on using TP1-2 for external voltage monitoring. This fuse can be replaced by unsoldering the old fuse and replacing with an equivalent fuse. Consult the PARTS LIST and Component Location, Figure 8 for the fuse type and location. Spare fuses are supplied with new M-0067E units, and additional fuses can be obtained from the manufacturers or from Beckwith Electric Co.

Units returned with only a blown fuse are not covered by warranty, and a nominal repair charge will be made for replacement of the fuse.

Please check the fuse before returning the M-0067 for repair, in order to avoid unnecessary repair charge.

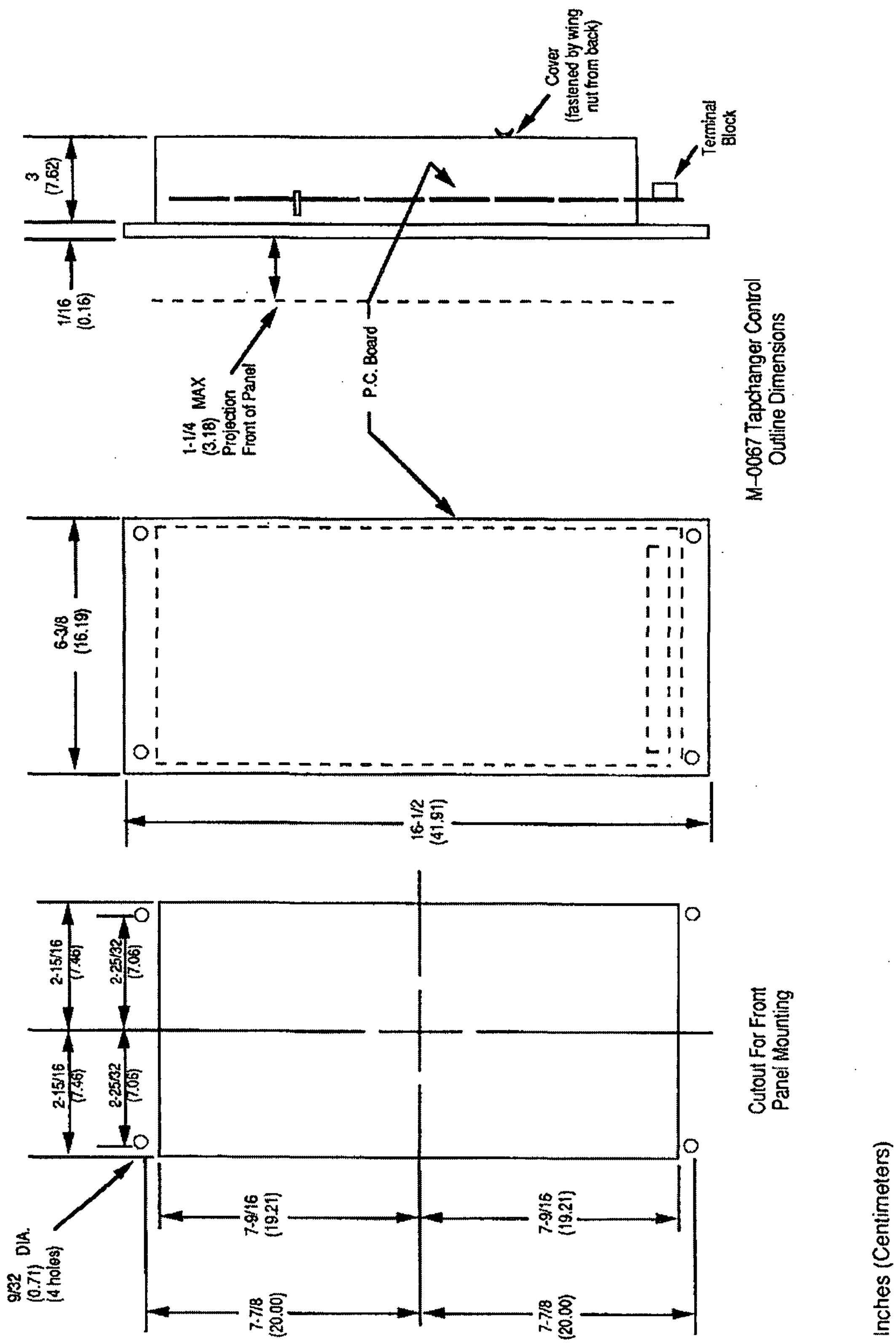


FIGURE 5 Mounting and Outline Dimensions

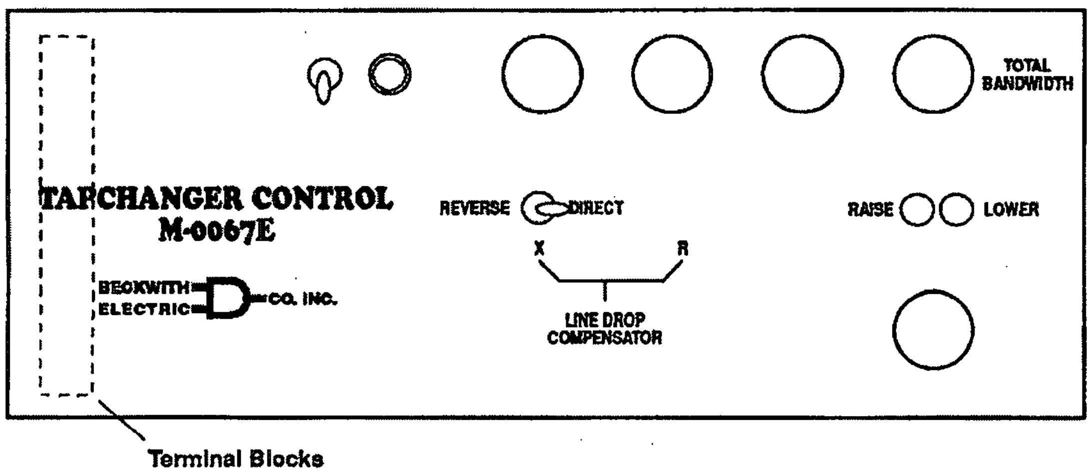


FIGURE 6a Horizontal Mounting Configuration

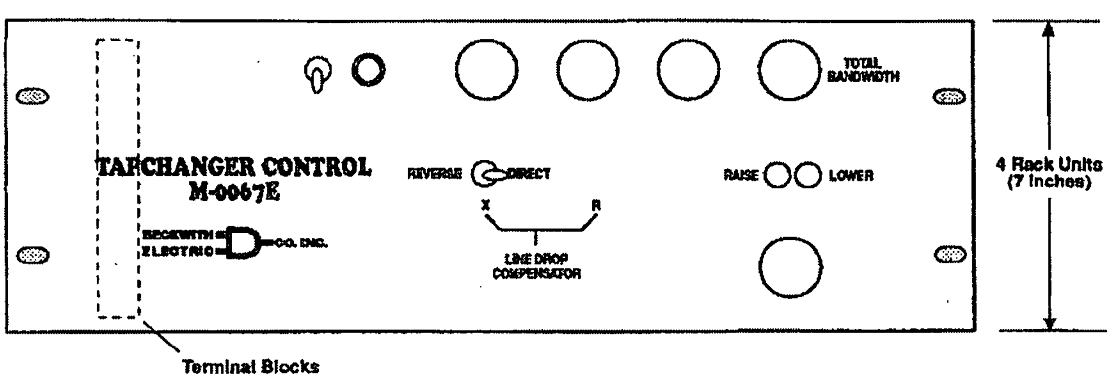


FIGURE 6b 19" Rack Mount Configuration

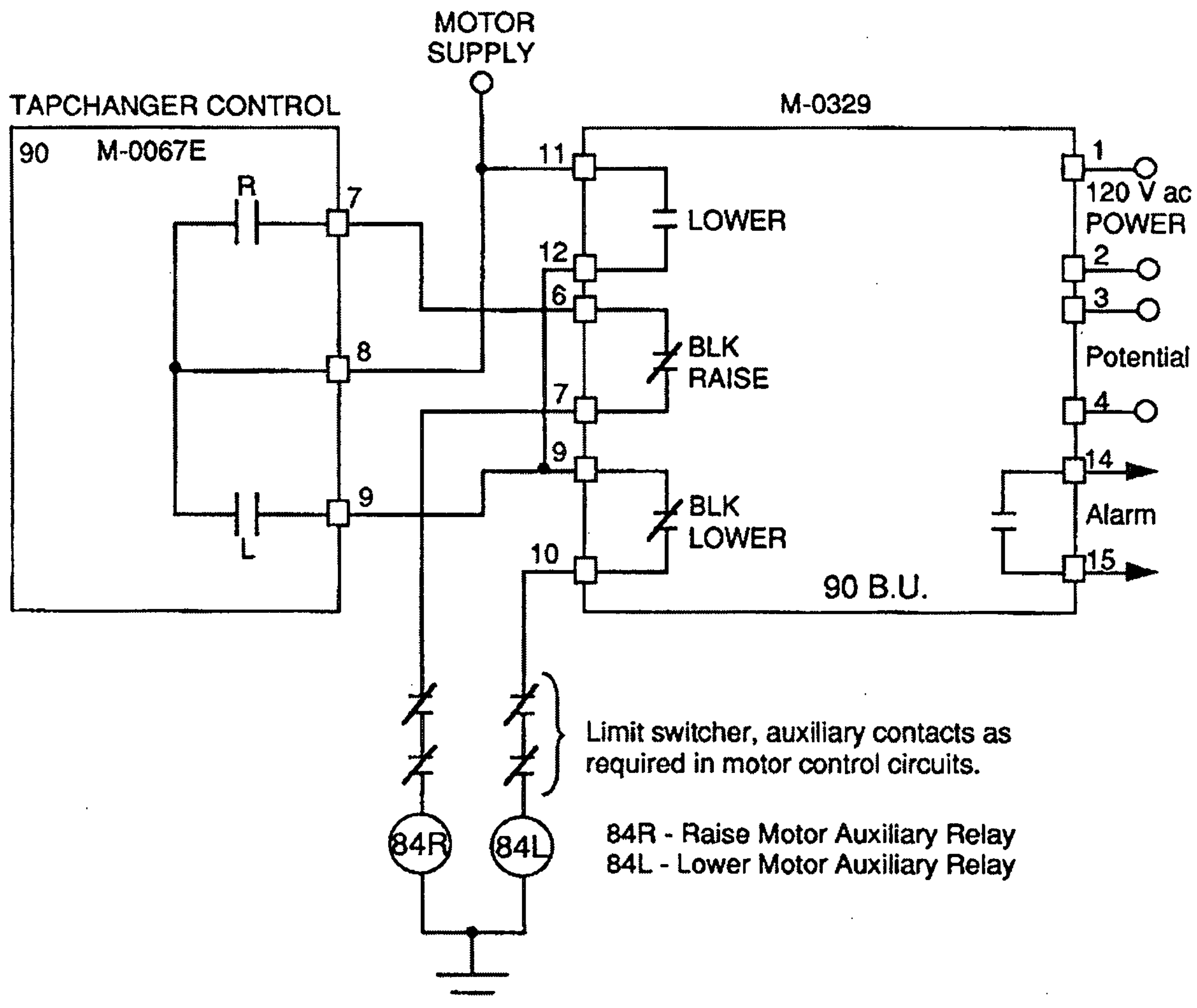


FIGURE 7 M–0329 Interconnection with Beckwith M–0067 TapchangerControl

ADJUSTMENT

The **BANDCENTER** and **BANDWIDTH** controls of the LTC Backup Control should be set so that the Block Lower limit is a small amount, (approximately 2 V), below the lower band limit of the Tapchanger Control, and the Block Raise limit is a similar amount above the upper limit if line drop compensation is not used.

If line drop compensation is used, the Block Raise limit should be set at the maximum voltage desired from the transformer.

If line drop compensation is used, the Backup Control Block Raise limit should be set higher than the highest voltage expected from the transformer under full load.

The M-0329 LTC Backup Control also includes a First Customer Protection function that regulates the maximum voltage from the transformer. This "LOWER" function operates slightly above the Block Raise limit and is connected to force the tapchanger to lower the voltage if this maximum limit is exceeded.

Figure 7 shows the interconnection of the Tapchanger Control and LTC Backup Control. The Instruction Book on the M-0329 LTC Backup Control is available on request and gives added details.

Ideally, the **LINE DROP COMPENSATOR** should be set for the impedance from the transformer to the load center. The problem is that this load center varies with distribution of load and is seldom, if ever known.

A balance of high and low voltage at full load can be achieved by using the M-0329 LTC Backup Control with the M-0067 Tapchanger Control. Connections for this combination are shown in Figure 7. With this combination, the LDC is set at a value surely greater than the impedance to the load center. The M-0329 lower output contact will operate to limit the voltage to the nearest load when the transformer load is greater than approximately 80% load.

See the M-0329 Instruction Book for further details.

CHECKOUT PROCEDURE

SETTINGS

Before power is applied to the transformer, adjust the **VOLTAGE CENTER OF BAND, TOTAL BANDWIDTH, TIME** and **R** and **X LINE DROP COMPENSATOR** knobs to the desired setting. Remove wires from terminals 7, 8 and 9 and place lead from terminal 4 temporarily on terminal 3.

POWER

Make certain by measurement, if possible, that the potential to be applied to terminals 1 through 3 is nominal 120 V ac. Apply this power but not the motor power. Turn the **TEST/OPERATE** switch to **TEST**, connect a voltmeter from 2 to 3, vary the **TEST** knob and determine that the **RAISE** and **LOWER** LEDs operate on either side of the voltage setting. With an LED lit, determine that the corresponding relay operates after the set time. Disconnect the P.T. voltage.

Connect the lead for terminal 7 to the lead for terminal 8 with a clip lead. Apply motor voltage. Ascertain that the motor runs in the Raise direction. Remove power and connect the lead for terminal 8 to the lead for terminal 9. Reapply motor power and ascertain that the motor runs in the Lower direction. Disconnect power and reconnect leads to terminals 7, 8 and 9.

Apply both P.T. and motor voltages. Using the **TEST** knob, exercise the entire control and tapchanger switch by getting a Raise light and determining that the switch raises after an appropriate time for the timer to time out. Repeat with a setting that gives a Lower light.

With some load on the transformer, measure the current in the wire from terminal 4. This should be 0.2 A multiplied by the fraction of full load on the transformer. If correct, reconnect the lead to terminal 4. If the transformer is energized when making this connection, be sure to first short the C.T secondary.

TEST CIRCUIT

This circuit permits checking the band limits as well as the operation of the tapchanger. Voltmeter terminals are ordinarily provided external to this control and tied to terminals 2 and 3 of the control. Connect a voltmeter of not less than 500 Ω per V to these terminals. With the **TEST/OPERATE** switch on **TEST**, vary the **TEST** knob and read the voltage where the band edge LEDs just light. By waiting for the timer to time out with one of the LEDs lit, operation of the tapchanger can be checked. In making this check, the potential must be approximately equal to the setting of the **VOLTAGE** knob as it would be in practice (but might not be in a laboratory test setup). The circuit depends on the voltmeter burden to lower the voltage. If the voltmeter burden is more than 500 Ω per V, connect a 50 K resistor across the voltmeter terminals or from 2 to 3 of the M-0067 control. If the voltmeter burden is appreciably less than 500 Ω per V, the **TEST** knob will be inaccurate and damage could result to the unit.

> ● **WARNING:** Some motors must be stopped in order to start in the proper direction. With such motors, never set the timer less than the time it takes the motor to stop. In such a case a setting of 15 seconds or more is safe.

Tests indicate all M-0067E units will pass the Surge Withstand Capability (SWC) test per ANSI standard C37.90.1-1989. Since serial number 5500, all units have been tested per this standard before shipment.

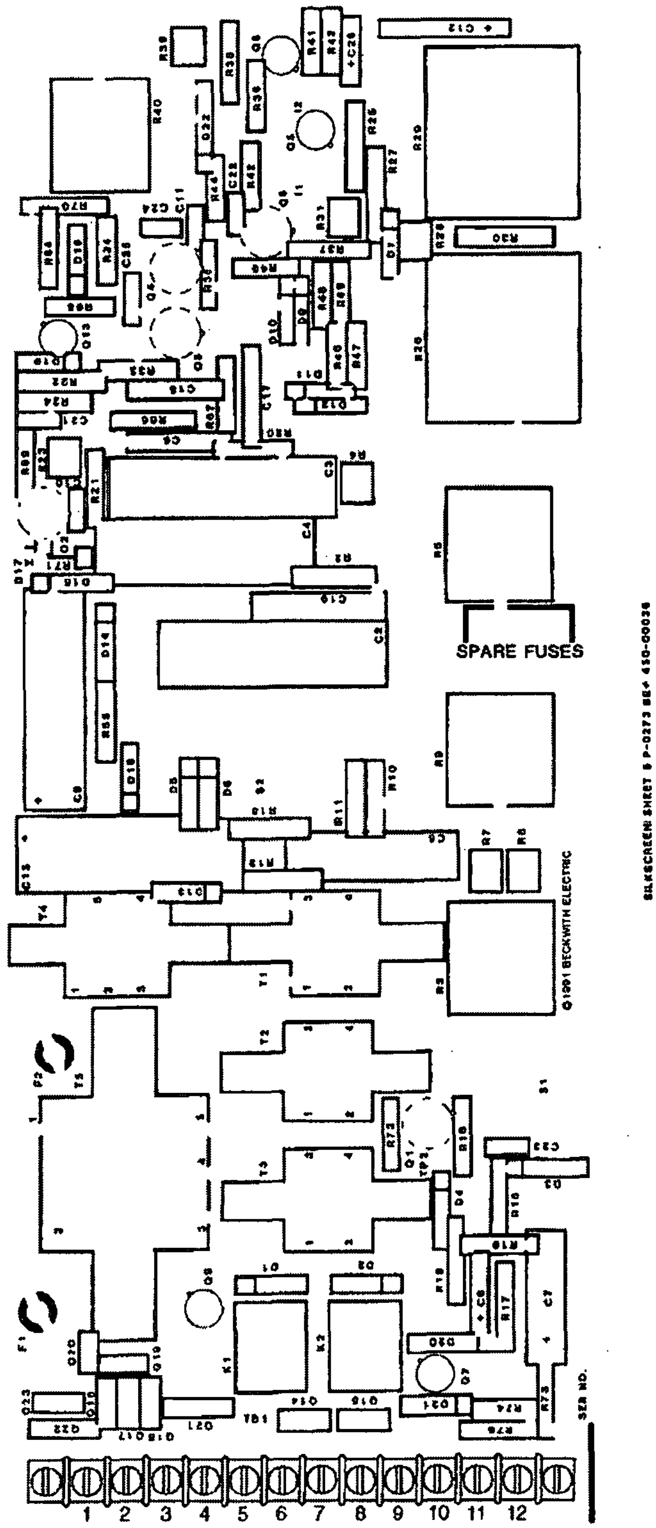


FIGURE 8 Component Location

MAINTENANCE

Due to the extremely sophisticated nature of the circuitry in the M-0067, field repair is not recommended. All units are fully calibrated at the factory prior to shipment; there is not need to re-calibrate a unit prior to initial installation. Calibration is only required after a component is replaced. In the event that a unit does not operate properly, it should be established that the problem is caused by malfunction of a Beckwith unit and not caused by an external fault or wiring error. Once this is assured, the entire unit should be returned toBeckwith Electric. Pack the unit carefully (in the original carton if possible), assuring that there is adequate packing material to protect the contents.

■ NOTE: Any equipment returned for repair must be sent with transportation charges prepaid. The equipment must remain the property of the user. The warranty is void if the value of the unit is invoiced to Beckwith Electric at the time of return or if the unit is returned with transportation charges collect.

If under warranty, units will be repaired rapidly and returned at no cost and with return transportation paid if the fault is found to be due to workmanship or failure of material. If a unit is under warranty and express shipment for return of the repaired unit is requested, shipping charges will be billed at the current rate. If the fault is due to abuse or misuse, or if the unit is out of warranty, a modest charge will be made. Repair can normally be expected to take two weeks, plus shipping time. If faster service is required, it should be requested at the time of return.

■ NOTE: Units returned with only a blown fuse are not covered by warranty and a nominal repair charge will be made for replacement of the fuse. Please check the fuses before returning the M-0067 for repair in order to avoid unnecessary repair charges.

To help in analyzing the problem, a complete description of the malfunction and conditions leading to the failure should be included with the unit.

However, if you choose to repair the unit, it is necessary to be completely familiar with the circuitry involved, and have an adequate understanding of field effect devices. Be sure to carefully read the **WARNING** page at the beginning of this manual.

If F1 blows, it is surely due to the failure of another component, which should be identified and replaced together with the fuse.

It is suggested that first a visual inspection be made for any component that does not appear normal or appears to have overheated. Analysis of the circuit will then often lead to the cause of the failure and components that need to be replaced.

If no obvious problems exist, it is suggested that the **TEST PROCEDURES** be followed until a portion of a circuit is detected which does not perform as expected or until a calibration point is found which will not meet requirements. These procedures should lead to a determination of the defective component.

It is suggested that each knob be moved rapidly back and forth a dozen times or so during routine maintenance once or twice a year. This will remove dirt or oxidation from the contacting elements within the control so as to assure trouble-free operation.

HOW TO AVOID DAMAGING YOUR CONTROL THROUGH TESTING

This solid-state control is in many ways more rugged, less affected by changes in temperature, and less sensitive to shock and vibration than the earlier electromechanical controls. It is possible to damage the circuits, however, by introduction of excessive voltage through improper test procedures. Therefore, a series of don'ts:

1. Don't hi-pot one terminal at a time to ground. When this is done to TB1–10, TB1–11, TB1–12 or TB1–13; excessive 60 Hz currents may flow through the stray capacity of the circuit to the panel and damage semiconductors.

2. Don't make measurements from "hot" 120 V ac to terminals TB1–10, TB1–11, TB1–12, TB1–13 or to any points within the circuit. In particular, a low impedance ac voltmeter will introduce sufficient current into these terminals to damage semiconductors.

3. Don't apply the SWC Test (ANSI C37.90.1-1989) to terminals TB1–10, TB1–11, TB1–12 or TB1–13. To do so may cause damage to Q3 and Q4.

▲ **CAUTION: In testing the unit, make certain that the motor starter and motor operate off a supply other than the test supply for the unit. If this is not done, the current drawn by the motor and starter may drop the voltage back within the band when checking the Lower operation. This will cause an oscillation which must be correctly attributed to the test circuit and is not an indication of improper operation of the control.**

Any attempt to measure resistance between points on the printed circuit board may cause damage to the unit.

TEST PROCEDURE

Please refer to the **WARNING** page at the beginning of this manual before proceeding.

EQUIPMENT REQUIRED

1. Regulated 60 Hz source with variable amplitude from 60 to 140 V rms.
2. 200 mA, 60 Hz current source with phase angle settings of 0° to +90°.
3. High impedance true rms digital voltmeter with accuracy on ac of at least ±0.1% of reading.
4. Solder sucking syringe or solder wick.
5. Soldering iron—Weller Controlled Output Soldering Station Model MTCPC, 60 W, 120 V, 50/60 Hz or equivalent with grounded tip.
6. An accurate stopwatch or timing device.

HINTS IN MEASUREMENTS

If possible, use a regulated ac voltage supply; however, this should not be the saturable core type regulator which has a severely distorted output.

In setting up the resistive current, use of a 100 ohm non-inductive 25 W resistor and 25 ohm potentiometer in series is suggested. The potentiometer should be at least 2 W and preferably carbon-ceramic construction. This will assure in-phase current and smooth current adjustment.

In checking the voltage and bandwidth controls, move the test voltage slowly to allow the output of the C6-C-C8 filter network to catch up.

In checking the line drop compensator, polarity must be observed, otherwise a 180° error will occur. See Figure 4 Schematic for standard polarity marking.

REMOVING THE PRINTED CIRCUIT BOARD

The circuit board and panel can be easily separated leaving a completely functional circuit. To do this, remove the knobs using a small screwdriver. Remove the nuts securing the switches and knobs. Remove all screws showing on the outside of the panel. Remove the panel. Any component can now be easily changed.

■ NOTE: The M-0067 printed circuit board is coated with a moisture resistant conformal coating. This coating must be removed from areas where components are to be replaced. Carefully scrape away the coating surrounding the component using a small, sharp knife, being careful not to damage the printed circuit board.

To replace a component, clip out the old component and discard. Remove the clipped wire using the solder wick or syringe. Be sure to leave the holes clear to facilitate insertion of the new component.

▲ **CAUTION: Do not attempt to melt the solder and push the component through the hole as the component lead is likely to catch the edge of the foil and lift it off the board.**

In replacing integrated circuits, make sure to insert the new unit into the transipad so that the tab fits into the slot. Once this is done, there is only one correct way to insert the combination into the printed circuit board.

To reassemble the unit, place the panel over the controls and secure with the screws previously removed. Replace the **TEST** knob nut and knob. Turn the knob shafts counter-clockwise and replace the pointer knobs with the pointer at the minimum calibration point. Before tightening the setscrew, back out the locking knob and temporarily place a thin cardboard spacer under the knob so as to space it about 0.010" away from the panel.

■ NOTE: The set screws securing the knobs may "seize" and be difficult to remove. If so, apply a drop of penetrating oil and try again.

WAVESHAPE

With 120 V ac from TB1-1 to TB1-3, the waveshape from TP1 to TP2 (high) should be as follows:

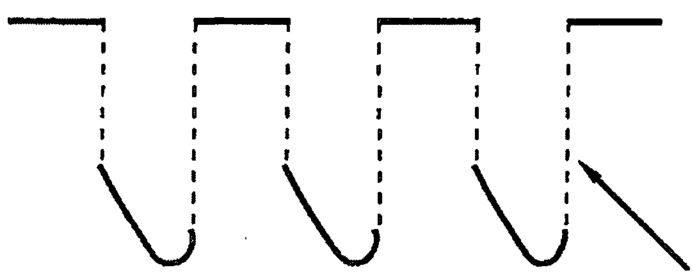


Figure 9 Waveshape

If the waveshape is found to differ, then Q1 or a closely associated component may be defective.

POWER SUPPLY

Connect 120 V ac from TB1-1 to TB1-3. Check to see that the following dc voltages are obtained.

Across C9	24 V dc Unregulated
Across D3	15 V dc
R21-R33 junction to 0 V (Trimmer R23 should vary this voltage)	12 V dc
D14 (Anode) to 0 V	-12 V dc
D14 (Cathode stripe) to 0 V	- 6 V dc

VOLTAGE AND BANDWIDTH

Place the **TEST/OPERATE** switch in the **TEST** position. Connect an accurate ac voltmeter from TB1–2 to TB1–3. Vary the uncalibrated **TEST** knob and see that the **RAISE** and **LOWER** LEDs light at correct voltages with some dead band where both are extinguished.

Set the **TOTAL BANDWIDTH** knob to 2.0 and adjust trimmer R28 to give 2 V bandwidth. Set the **VOLTAGE CENTER OF BAND** dial to 125 and the **TOTAL BANDWIDTH** knob to 1.0. Adjust R23 so that 125 V is in the center of the band as indicated by the **RAISE** and **LOWER** LEDs. Set the **VOLTAGE CENTER OF BAND** knob to 110 and adjust R31 so that 110 V is in the center of the band. Recheck 125 V and the bandwidth; these calibrations should not have changed. Note that the **TEST** knob (R3) will only raise the voltage 5% from the P.T. voltage. The higher the voltmeter current, the more the voltage will be lowered.

TIMER

Connect a reversing type motor starter from TB1–7 and TB1–9 to the low side of a 120 V ac supply. This source need not be regulated, and may be the same source that is used for calibration procedures. Connect the high side of this supply to TB1–8. If a motor starter is not available, two 60 W light bulbs may be connected from TB1–7 and TB1–9 to the low side of the ac supply.

Set the **TIME** knob to 0. The appropriate lamps or portion of the motor starter should operate immediately after the **RAISE** or **LOWER** LED comes on as the test voltage is moved suddenly out of the dead band.

Set the **TIME** knob on 40. The output device should now operate 40 seconds after the voltage is moved suddenly out of the band. If not, adjust trimmer R39 to give the proper 40 seconds time. This procedure can be shortened by quickly adjusting R39. The device will then time out a bit later, and at least close to the desired 40 seconds on the first try.

RESISTANCE COMPENSATION

Set the **VOLTAGE CENTER OF BAND** knob on 120. Connect a separate variable ac voltage from the output of a phase shifter through a 600 Ω, 10 W non-inductive resistor and ac ammeter from TB1–4 to TB1–3. Set the **LINE DROP COMPENSATOR X** knob on zero and the R knob on 12. Set the current to 0.2 A, angle to 0°. Adjust R4 so that with current present, the voltage at the center of band is increased precisely 12 V. Note that the voltage on TB1–2 is not affected by this current but that the setpoint rises 12 V.

REACTANCE COMPENSATION

Set the **VOLTAGE CENTER OF BAND** knob to 120.0 V rms. Set the **LINE DROP COMPENSATOR** switch on **DIRECT**, with the **X** knob at 24 V, and the **R** knob at 0. Apply 0.1 A in-phase current; adjust R7 for 0.6 V decrease in bandcenter to 119.4 V.

With the **X** knob at 24 V, and the **R** knob at 0, apply 0.1 A capacitive current (90° leading). Adjust R8 for 108 V bandcenter with the **LINE DROP COMPENSATOR** switch on **DIRECT** and 132 V bandcenter with the **LINE DROP COMPENSATOR** switch on **REVERSE**.

PARALLELING COMPENSATION

Switch connections from TB1–4 and TB1–3 to TB1–6 and TB1–5 respectively. Set the current at 0.1 A and its phase angle 90° lagging. The center of band should now be close to 132 V.

TYPICAL VOLTAGES

Using Simpson Model 270 Meter and Oscilloscope of 1 MΩ input impedance.

FROM	TO	CONDITION	VOLTAGE
0 V	20 V	Voltage 120 V ac, S1 on **OPERATE**	24.3 V dc
		Ac Ripple, above condition	1.0 V pp
0 V	12 V	Ac Ripple	0.01 V pp
0 V	-6 V	Ac Ripple	0.06 V pp
0 V	-12 V	Ac Ripple	0.2 V pp
12 V	"E"	Voltage 105 V ac	-7.0 V dc
		Voltage 120 V ac	-8.2 V dc
		Voltage 135 V ac	-9.1 V dc
12 V	TP-2	Voltage swing from +12 R (Regulated Voltage) (for waveshape, see **TEST PROCEDURE** section)	
		Voltage 105 V ac	+1.0 V dc to -13.0 V dc
		Voltage 120 V ac	+1.0 V dc to -15.0 V dc
		Voltage 135 V ac	+1.0 V dc to -17.0 V dc
0 V	R46-R48 Junction	R26 cw, R29 ccw	+3.2 V dc
		R26 ccw, R29 ccw	+5.1 V dc
		R26 cw, R29 ccw	+3.4 V dc
0 V	R46-R48 Junction	Voltage in band	-4.0 V dc
		RAISE LED on	+8.7 V dc
		Above condition after timing	+8.9 V dc
0 V	R47-R49 Junction	Voltage in band	-4.1 V dc
		LOWER LED on	+8.7 V dc
		Above condition after timing	+8.9 V dc
0 V	R36-R38 Junction	Voltage in band	0 V dc
		Voltage out of band	+0.6 V dc
0 V	R41-C26 Junction	Voltage in band	+0.6 V dc
		Voltage out of band	0 V dc

PARTS LIST

M-0067E Tapchanger Control

This list includes all electrical and mechanical parts which could conceivably either require replacement or be lost. The **COMPONENT DESIGNATION** is the same as that appearing on schematics or referred to in Instruction Books.

The **BECO NUMBER** refers to an index maintained by the company. This lists the currently available device which may be substituted even though the device originally supplied is obsolete and no longer available. Parts marked by an asterisk* are not available from other sources. Either the original component or a current substitute will be carried in stock by Beckwith Electric.

Parts not marked with an asterisk are normally available from an electronics components house. Those parts or a current substitute will normally be available from Beckwith Electric stock.

In either case, when parts are ordered from Beckwith Electric, we will be responsible for supplying the current replacement in the shortest possible time.

Sufficient detailed description is also given to permit purchasing from an electronics parts house, providing the part is of equal or better quality to insure reliable operation. This may require some interpretation of specifications which may be avoided by direct purchase from Beckwith Electric using the **BECO NUMBER**.

Note that in a few instances, components are selected in final test. Procedures described in the **TEST PROCEDURES** Section must be followed in replacing these components.

All resistors are 1/2 W unless noted.

COMPONENT DESIGNATION	BECO NUMBER	DESCRIPTION
	450-00036*	P.C. Board, P-0273
C1		Not Used
C2,C3,C4	000-00850	Capacitor, Polyester Film, 1 µF ±10%, 200 V
C5	010-00529	Capacitor, Mylar, 0.47 µF ±10%, 200 V
C6	000-00501	Capacitor, Tantalum, 3.9 µF ±10%, 35 V
C7	000-00617	Capacitor, Electrolytic,50 µF +75%/-10%, 50 V
C8	010-00527	Capacitor, Mylar, 0.068 µF ±10%, 100 V
C9	000-00626	Capacitor, Electrolytic, 150 µF +75%/-10%, 75 V
C10	000-00903	Capacitor, Ceramic Disc, 100 pF ±10%, 1 kV
C11,C22,C23	000-00902	Capacitor, Ceramic Disc, 680 pF ±10%, 1 kV
C12	000-00533	Capacitor, Tantalum, 150 µF±10%, 15 V

COMPONENT DESIGNATION	BECO NUMBER	DESCRIPTION
C13,C14,C16		Not Used
C15	000-00418	Capacitor, Electrolytic, 170 μF +75%/-10%, 50 V
C17,C18	010-00526	Capacitor, Mylar, 0.033 μF ±10%, 100 V
C19	010-00531	Capacitor, Mylar, 0.1 μF ±10%, 200 V
C20		Not Used
C21	000-00918	Capacitor, Ceramic Disc, 0.0047 μF ±20%, 1 kV
C24	000-00913	Capacitor, Ceramic Disc, 0.001 μF , 1 kV
C25	000-00914	Capacitor, Ceramic Disc, 0.1 μF ±20%, 50 V
C26	000-00545	Capacitor, Solid Tantalum, 2.7 μF ±10%, 15 V
C27,C28		Refer to **OPTIONAL COMPONENTS**
D1,D2,D5,D6,D13,D18	400-00211	Diode, Rectifier, 600 V, G.E. 1N5061
D3,D19	400-00030	Diode, Zener, 15 V ±5%, 400 mW, 1N965B
D4,D9-D12,D16	400-00200	Diode, 1N662/B692X13-4
D7	400-00035	Diode, Reference, 6.2 V ±5%, 400 mW, 1N823A,
D8		Not Used
D14,D15	400-00001	Diode, Zener, 6.2 V ±5%, 400 mW, 1N753A/1N5234B
D17	400-00043	Diode, Zener, 33 V ±10%, 5 W, 1N5364A
D20,D22	400-00078	Diode, Zener, 15 V ±5%, 5 W, 1N5352
D21	400-00021	Diode, Zener, 12 V ±5%, 5 W, 1N5349
F1, F2	420-00720	Microfuse, Plug-in, 1/4 A, Littelfuse 273.250
I1,I2	400-00722	Diode, Light Emitting, HP HLMP-3316
K1,K2	420-00118*	Relay, AZ, 420-07-4H
Q1,Q3,Q4,Q6	400-00600	Integrated Circuit, Op Amp, UA741, TO - 99
Q2	400-00603	Integrated Circuit, Regulator, UA723, TO - 100

COMPONENT DESIGNATION	BECO NUMBER	DESCRIPTION
Q5,Q7-Q9,Q13	400-00300	Transistor, NPN Signal, 2N1711
Q10-Q12		Not Used
Q14-Q22	400-00728	Varistor, 275 V, G.E. V275LA2
Q23	400-00733	Varistor, 460 V, G.E. V460LB20
R1		Not Used
R2	290-00152*	Resistor, Metal Film, 1.5 K ±2%
R3	360-00045*	Potentiometer, 5 K, 2 W, U-0048-1
R4,R8	360-00032	Trimmer, Cermet, 10 K ±20%, Bourns 3386P-1-103
R5,R9,R40	360-00046*	Potentiometer, 50 K, 2 W, U-0048-2
R6		Not Used
R7	360-00042	Trimmer, Cermet, 2 K ±20%, Bourns 3386P-1-202
R10	290-00274	Resistor, Metal Film, 270 K ±2%
R11	290-00364	Resistor, Metal Film, 357 K ±2%
R12	330-00647	Resistor, Metal Film, 301 K ±1%, 1/4 W
R13	330-00643	Resistor, Metal Film, 274 K ±1%, 1/4 W, RN60E
R14		Not Used
R15	200-00102	Resistor, Carbon, 1 K ±5%
R16	330-00638	Resistor, Metal Film, 243 K ±1%, 1/4 W, RN60E
R17	320-00466	Resistor, Metal Film, 4.75 K ±1%, RN65D
R18	320-00381	Resistor, Metal Film, 681 Ω ±1%, RN65D
R19	200-00222	Resistor, Carbon, 2.2 K ±5%
R20, R67	200-00823	Resistor, Carbon, 82 K ±5%
R21	200-00100	Resistor, Carbon, 10 ohms ±5%
R22	–	Resistor, Metal Film, ±1% 1/4 W, Factory Select, RN60E, U-0038

COMPONENT DESIGNATION	BECO NUMBER	DESCRIPTION
R23,R28,R31	360–00034	Trimmer, Cermet, 200 ohms ±20%, Bourns 3386P-1-201
R24	330–00469	Resistor, 5.11 K ±1%, 1/4 W, RN60E
R25	330–00393	Resistor, 909 ohms ±1%, 1/4 W, RN60E
R26,R29	360–00047*	Potentiometer, 500 ohms, 4 W, U-0031-1
R27,R30	330–00460	Resistor, 4.12 K ±1%, 1/4 W, RN60E
R32		Not Used
R33,R70,R73	200–00101	Resistor, Carbon, 100 ohms ±5%
R34	200–00684	Resistor, Carbon, 680 K ±5%
R35	200–00155	Resistor, Carbon, 1.5 M ±5%
R36	200–00683	Resistor, Carbon, 68 K ±5%
R37	–	Refer to **OPTIONAL COMPONENTS**
R38,R48,R49	200–00682	Resistor, Carbon, 6.8 K ±5%
R39	360–00044	Trimmer, Cermet, 20 K ±20%, Bourns 3386P-1-203
R41	200–00223	Resistor, Carbon, 22 K ±5%
R42,R44,R65,R72	200–00103	Resistor, Carbon, 10 K ±5%
R43	290–00434	Resistor, Metal Film, 430 K ±2%
R45	200–00226	Resistor, Carbon, 22 M ±5%
R46, R47	200–00182	Resistor, Carbon, 1.8 K ±5%
R50-R54		Not Used
R55	200–00331	Resistor, Carbon, 330 ohms ±5%
R56-R63		Not Used
R64	200–00104	Resistor, Carbon, 100 K ±5%
R66	200–00273	Resistor, Carbon, 27 K ±5%
R68		Not Used
R69	290–00202	Resistor, Metal Film, 2 K ±2%

COMPONENT DESIGNATION	BECO NUMBER	DESCRIPTION
R71	240-00151	Resistor, Carbon, 150 ohms ±10%, 2 W
S1, S2	430-00054	Switch, DPDT Toggle, U-0079
T1-T3	410-00023*	Transformer, Current, U-0025
T4	410-00022*	Transformer, Sensing, U-0027
T5	410-00017*	Transformer, Power, U-0029
TB1	420-00012	Terminal Block, Cinch-Jones 12-140-Y
REV V		

OPTIONAL COMPONENTS

Single or Multi-Step Voltage Reduction Option

R74 and/or R75		Factory select (based on reduction specified)
REV A		

Instantaneous Voltage Reduction Option

R37	200-00222	Resistor, Carbon, 2.2K ±5%
REV A		

50 Hz Operating Frequency Option

C27	000-00716	Capacitor, Polyester, .18 µF ±10%, 50 V
C28	000-00859	Capacitor, Polyester, .39 µF ±10%, 50 V
REV 0		

PATENT

The units described in this manual are protected by U.S. Patent 3,721,894; and Canaidan Patent 985,368; British Patent 1,432,607; Swedish Patent 7,301677-7; and other foreign patents applied for.

Buyer shall hold harmless and indemnify the Seller, its directors, officers, agents, and employees from any and all costs and expense, damage or loss, resulting from any alleged infringement of United States Letters Patent or rights accruing therefrom or trademarks whether federal, state, or common law, arising from the Seller's compliance with Buyer's designs, specifications, or instructions.

WARRANTY

Seller hereby warrants that the goods which are the subject matter of this contract will be manufactured in a good workmanlike manner and all materials used therein will be new and reasonably suitable for the equipment. Seller warrants that if, during a period of two years from date of shipment of the equipment, the equipment rendered shall be found by the Buyer to be faulty or shall fail to perform in accordance with Seller's specifications of the product, Seller shall at his expense correct the same, provided however that Buyer shall ship the equipment prepaid to Seller's facility. The Seller's responsibility hereunder shall be limited to the replacement value of the equipment furnished under this contract. The foregoing shall constitute the exclusive remedy of the Buyer and the sole liability of the seller and is in lieu of all other warranties, whether written, oral, implied or statutory, except as to the title of the Seller to the equipment furnished. No implied statutory warranty of merchantability or of fitness for a particular purpose shall apply. Seller does not warrant any product or services of others which Buyer has designated.

> SELLER MAKES NO WARRANTIES EXPRESSED OR IMPLIED OTHER THAN THOSE SET OUT ABOVE. SELLER SPECIFICALLY EXCLUDES THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION CONTAINED HEREIN. IN NO EVENT SHALL SELLER BE LIABLE FOR CONSEQUENTIAL, EXEMPLARY, OR PUNITIVE DAMAGES OF WHATEVER NATURE.

Any equipment returned for repair must be sent with transportation charges prepaid. The equipment must remain the property of the Buyer. The aforementioned warranties are void if the value of the unit is invoiced to the Seller at the time of return.

INDEMNIFICATION

The Seller shall not be liable for any property damages whatsoever or claims of any kind whether based on contract, warranty, tort including negligence or otherwise, or for any loss or damage arising out of, connected with, or resulting from this contract, or from the performance or breach thereof, or from all services covered by or furnished under this contract.

In no event shall the Seller be liable for special, incidental, exemplary or consequential damages including, but not limited to loss of profits or revenue, loss of use of the equipment or any associated equipment, cost of capital, cost of purchased power, cost of substitute equipment, facilities or services, downtime costs, or claims or damages of customers or employees of the Buyer for such damages, regardless of whether said claim or damages is based on contract, warranty, tort including negligence or otherwise.

Under no circumstances shall the Seller be liable for any personal injury whatsoever.

It is agreed that when the equipment furnished hereunder or any services furnished hereunder are to be used or performed in connection with any nuclear installation, facility, or activity, Seller shall have no liability for any nuclear damage, personal injury, property damage, or nuclear contamination to any property located at or near the site of the nuclear facility. Buyer agrees to indemnify and hold harmless the Seller against any and all liability associated therewith whatsoever whether based on contract, tort, or otherwise. Nuclear installation or facility means any nuclear reactor and includes the site on which any of the foregoing is located, all operations conducted on such site and all premises used for such operations. It is the intention of the parties that this is a complete indemnification and hold harmless agreement in regard to all claims arising from nuclear operations of Buyer.

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Power Transformers

McGraw-Edison® Load Tap Changer Motor Control S210-40-18

Maintenance Instructions

CONTENTS

INTRODUCTION

The Load Tap Changer (LTC) Controls are divided into four basic components: 1) Drive Mechanism, 2) Motor Control, 3) Automatic Regulation (when required), 4) Vacuum Interrupter Monitoring System (when applicable). Service Information S210-40-18 describes the standard features for the LTC motor control of **McGraw-Edison®** load tap changing mechanisms. The motor control panel is shown in Figure 1.

⚠ WARNING
YOU MUST HAVE TRAINING IN THE OPERATION OF THIS EQUIPMENT BEFORE USING IT. YOU MUST ALSO READ, UNDERSTAND AND OBEY ALL SAFETY ADVISORIES.

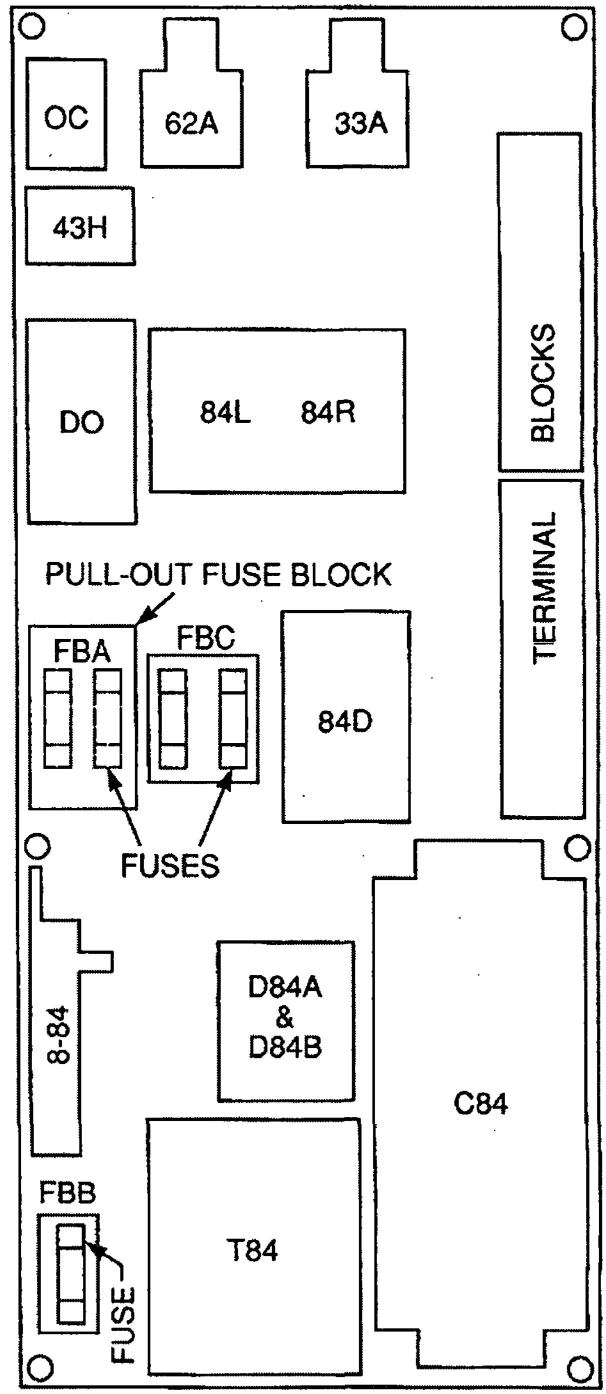

Figure 1.
Motor Control Panel

These instructions do not claim to cover all details or variations in the equipment, procedures, or processes described, nor to provide directions for meeting every possible contingency during installation, operation, or maintenance. When additional information is desired, please contact your Cooper Power Systems Representative.

SAFETY ADVISORY

This Safety Advisory is intended to identify the potential hazards and consequences to anyone who comes in contact with their contents. The supportive wording is expected to elicit a safe response from adults.

⚠ **DANGER**

IMMEDIATE HAZARDS WHICH WILL RESULT IN DEATH OR SEVERE PERSONAL INJURY OR SUBSTANTIAL PROPERTY DAMAGE, IF PROPER PRECAUTIONS ARE NOT TAKEN.

⚠ **WARNING**

HAZARDS OR UNSAFE PRACTICES WHICH COULD RESULT IN DEATH OR SEVERE PERSONAL INJURY OR SUBSTANTIAL PROPERTY DAMAGE, IF PROPER PRECAUTIONS ARE NOT TAKEN.

⚠ **CAUTION**

HAZARDS OR UNSAFE PRACTICES WHICH COULD RESULT IN MINOR PERSONAL INJURY OR PRODUCT OR PROPERTY DAMAGE, IF PROPER PRECAUTIONS ARE NOT TAKEN.

NOTICE

SITUATION WHICH COULD RESULT IN PRODUCT OR PROPERTY DAMAGE WITH NO PROBABILITY OF PERSONAL INJURY, IF PROPER PRECAUTIONS ARE NOT TAKEN.

MOTOR CONTROL

Motor control systems for Load Tap Changer transformers may be electrically hand controlled or automatically initiated, with control facilities specified to meet operating requirements.

The motor control circuit uses electromechanical contactors and relays which are both mechanically and electrically interlocked to insure positive operation of the Load Tap Changer motor.

McGraw-Edison® utilizes two similar, but slightly different, motor control panels: 1) To control a 115 volt, single phase, 60 Hertz reversible motor, 2) To control a 230 volt, single phase, 60 Hertz reversible motor.

Operating the Load Tap Changer from one operating position to another requires a single electrical control signal to initialize the motor control system. This electrical control signal or momentary contact must be closed from 0.10 to 0.25 second duration, to ensure proper operation of the motor control system. The LTC drive mechanism then completes the tap change without any interruption.

Automatic braking following a tap change is accomplished by the trouble-free DC braking method (DC voltage is applied to the motor windings in parallel), incorporating an auxiliary step-down transformer and a full wave rectifier.

Current limiting time delay fuse(s) protect the LTC supply circuit and a fuse protects the DC braking circuit. A breaker is provided for protection of the LTC drive mechanism motor.

OPERATION BY ELECTRICAL HAND CONTROL

⚠ **WARNING**

DO NOT OPERATE EQUIPMENT UNLESS IT IS COMPLETELY AND PROPERLY ASSEMBLED.

Hand-operated control switches are normally provided in the control cabinet so that the Load Tap Changer mechanism may be operated during installation or periods of preventive maintenance. All control circuits must be energized and functioning properly. The Load Tap Changer switching mechanism may be energized and carrying load.

COMPONENTS

The actual components furnished on any specific unit, along with their ratings, may be determined by reading the parts description contained on the LTC Schematic drawings issued with that particular unit. The connections to these components are also shown on these same drawings.

The motor control panel is usually equipped with the following components:

1. **Motor Reversing Contactors (84R and 84L)**
   These contactors control the application of AC voltage to the LTC motor windings when a tap change is initialized. These contactors are mounted on a common base and are electrically and mechanically interlocked with each other. Each contactor is also equipped with additional contacts to provide electrical interlocking between the LTC motor AC running and DC braking circuits.
2. **Motor Braking Contactor (84D)**
   This contactor controls the application of the DC voltage to the LTC motor windings in parallel, and is part of the automatic DC braking circuit. The duration of this application is controlled by the DC braking timing relay (62A). This contactor is equipped with additional contacts to provide electrical interlocking between the motor DC braking and AC running circuits.
3. **Sequential Timing Relay (33A)**
   This relay provides an immediate seal-in of a single electrical control signal to initialize a tap change operation. It also provides a controlled time delay at the completion of the braking cycle to assure positive operation of the Load Tap Changer.
4. **DC Power Source**
   This source is derived from a circuit consisting of a fuse, an auxiliary step-down transformer (T84), and a full wave rectifier (two diodes, D84A & D84B, on a heat sink). The transformer connections are determined by the motor used with the Load Tap Changer drive mechanism.
5. **DC Braking Timing Relay (62A)**
   This timing relay determines the duration of the DC braking action. The relay is equipped with a normally open contact which closes immediately when the relay is energized by the operation of either the 84R or 84L contactor. The 62A contact stays closed for approximately two seconds after the 84R or 84L contactor has been released, to energize the motor braking contactor (84D).
6. **Motor Breaker (8-84)**
   The motor breaker is provided and wired for motor protection only. The number of poles and current rating of the breaker are determined by the Load Tap Changer mechanism motor requirements.

7. **Operation Counter (OC)**
The operation counter keeps an accumulative total of the number of electrically controlled (motor driven) tap change operations of the LTC mechanism.
8. **Fuses**

⚠ CAUTION
DO NOT REMOVE ANY FUSE UNDER LOAD. FUSE BLOCKS ARE FOR DISCONNECT USE ONLY.

Separate fuses protect the control circuits, DC braking circuit, and auxiliary circuits. A fuse has been provided in the motor control circuit to prevent electrical operation of the LTC mechanism in the event of DC braking circuit failure. All of the fuses are 250 volt cartridge type; however, the ampere rating and type depend on the application.

NOTICE
THE PULL-OUT FUSE BLOCK (FBA) USED IN THE MOTOR CONTROL AND SOURCE CIRCUITS HAS BEEN FURNISHED AS A SAFETY FEATURE. THIS FUSE BLOCK SHOULD BE PULLED OPEN TO PROVIDE A VISUAL DISCONNECT WHEN SERVICING THE CONTROL CIRCUITS, MOTOR CIRCUITS, LTC DRIVE MECHANISM OR LTC SWITCH.

⚠ WARNING
DO NOT REPLACE PULL-OUT FUSE BLOCK WITH A BREAKER.

9. **Heater Switch (43H)**
This ON-OFF switch controls the space heater(s) located in the cabinet. It is recommended that the heater(s) be left on at all times to prevent moisture condensation and attendant corrosion.

⚠ CAUTION
ENERGIZE HEATERS DURING STORAGE TO PREVENT MOISTURE CONDENSATION AND ATTENDANT CORROSION. PROVIDE TEMPORARY HEATER POWER IF PERMANENT POWER IS NOT AVAILABLE.

10. **Convenience Outlet (DO)**
This NEMA 5-15R separately fused duplex outlet may be used for portable lights and small power hand tools.

⚠ CAUTION
DO NOT INSERT OR REMOVE ELECTRICAL PLUGS UNDER LOAD. FOR CONNECT AND DISCONNECT USE ONLY.

11. **Motor Capacitor (C84)**
This capacitor is used to both start and run the LTC motor. Its voltage rating and capacitance value are determined by the LTC drive mechanism motor requirements.

⚠ CAUTION
SHORT CIRCUIT CAPACITOR TERMINALS, TO PREVENT ELECTRICAL SHOCK HAZARD.

WIRING

⚠ CAUTION
DO NOT TOUCH BARE WIRES, LIVE PARTS, OR TERMINALS, TO PREVENT ELECTRICAL SHOCK HAZARD

Many units are furnished with special equipment. Consult the wiring diagrams furnished with each specific unit for customer conforming variations. The LTC Schematic drawings which accompany each unit must be consulted before making the power supply connections.

⚠ CAUTION
INCORRECT SUPPLY VOLTAGE MAY DAMAGE THE CONTROLS. REFER TO LTC SCHEMATIC DRAWINGS.

MAINTENANCE

⚠ WARNING
DISCONNECT AND GROUND ALL ELECTRICAL POWER SOURCES, TO PREVENT ELECTRICAL SHOCK HAZARD.

⚠ WARNING
GROUND AND SHORT CIRCUIT ALL CURRENT TRANSFORMERS, TO PREVENT HIGH VOLTAGE SHOCK HAZARD.

Maintenance and repairs must be done by authorized personnel only. Read, understand and obey all Safety Advisories, before doing any repairs, maintenance, or changing the features and accessories of this equipment.

During the performance of established maintenance procedures, annually, and every 100,000 tap changes the LTC Motor Control Panel, its components and wiring must be cleaned of all accumulated dust, dirt, and foreign debris. Make certain all electrical connections are clean and securely tightened. Inspect for worn, cracked, frayed or otherwise damaged components and wires. Keep all fasteners tight. Keep all adjustments according to factory specifications.

Immediately notify Cooper Power Systems upon the detection of probable defective parts. Failure to perform these minimal procedures could void the limited warranty.

TROUBLESHOOTING
(FOR EQUIPMENT BUILT AFTER 1/1/82)

Electrical Operation of Load Tap Changer Motor Control

1. **Load Tap Changer does not respond to RAISE-LOWER switch.**
   a. Check AUTO-MANUAL, REMOTE-LOCAL, RAISE-LOWER switches and their wiring for open circuit.
   b. Check fuses and motor breaker. Read specific LTC schematic drawings for proper ratings. If braking fuse is open, check diodes (D84A and D84B) for short circuit. If a diode shorting problem persists, check timing of 62A relay. Check station service supply for transient problems.
   c. Check position of handcrank. (Must be in storage position.)
   d. Check 84R and 84L contacts and 84D contacts.
   e. Check mechanical stop switch (if supplied). It must be closed.
   f. If reversing contactor operates and motor breaker does not trip, check motor, capacitor, reversing contactor contacts, and associated wiring for open circuit condition.
   g. If reversing contactor operates and motor breaker trips; check motor, motor capacitor, and associated wiring for short circuit condition. Check for mechanical binding in Load Tap Changer mechanism. (Read LTC Maintenance and Operating Instructions.)

2. **Load Tap Changer operates in one direction only.**
   a. Check 84R-84L contactor for mechanical binding, open contact and open coil.
   b. Check for open-limit switch (84LS/R1 and 84LS/L1). They are normally closed.
   c. Check RAISE-LOWER switch and associated wiring for open circuit condition.
   d. Check wires for loose connections or open circuit.

3. **Load Tap Changer over-runs** (makes additional uninitiated steps). Refer to Service Information instructions covering specific LTC mechanisms.
   a. Check seal-in switch (33/1) setting. Refer to instructions for LTC switch.
   b. Check 84R and 84L contactors for binding and erratic operation.
   c. Check DC braking circuit (84D contactor, 62A timing relay, rectifier diodes, 84R-84L contacts, braking transformer).

4. **Load Tap Changer stops off position.** Refer to Service Information instructions covering specific LTC mechanisms.
   a. Check seal-in switch (33/1) setting. Refer to instructions for LTC switch.
   b. Check operation of 33A relay.
   c. Check 84R and 84L contactors.
   d. Check all wiring associated with the 84R and 84L contacts, the tap changer motor and the power supply.
   e. Check 84D contactor for erratic operation.
   f. Check handcrank switch (89C) and mechanical stop switch (39) for erratic operation.
   g. Check for mechanical binding in the Load Tap Changer mechanism. Read LTC Maintenance and Instruction Manual.

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