Vacuum Electric Switch Co.

15kV 600A Three Pole, Pg. 4

34 or 46kV 600A Single Pole, Pg. 6 & 7

34kV 300A Three Pole, Pg. 8

46kV 300A Single Pole, Pg. 10

69kV 300A Single Pole, Pg. 10

69kV 600A Single Pole, Pg. 101

Switches for Special Applications

15kV 600A Two Pole, Pg.12

15kV 600A Single Pole, Pg.12

34kV 600A Sectionalizer, Pg. 13

34kV 600A Resistor Shorting Switch, Pg. 13

15/34kV 1000/600A Laboratory Switch, Pg.14

34kV 600A Harmonic Filter Switch, Pg.14

Vacuum Electric Switch Company™ products can be hazardous.

Vacuum Electric Switch Co.™ products are high voltage equipment with the potential to kill or injure individuals not following appropriate procedures. Personnel must be trained according to an established standard such as NFPA 70E, *Standard for Electrical Safety in the Workplace,* available from *www.nfpa.org or:*

National Fire Prevention Association
1 Battery March Park,
P.O. Box 9101
Quincy, MA 02269-9101 USA

This standard establishes appropriate safety training and procedures for servicing this equipment.

Vacuum Electric Switch products are not personal safety devices. They should never be used to isolate high voltages from equipment being serviced by personnel because they do not provide isolation with a visible break.

All equipment must be de-energized, locked out, grounded, and proven de-energized prior to performing maintenance. Switches have two sources of energy: one is from the high voltage source, and the other is from the control through the control cable. Switches contain stored energy in springs. Completely de-energizing a switch requires removing both sources of energy and immobilizing the springs in the switch mechanism.

Controls have both a source of energy as well as stored energy in capacitors. Controls require locking out their electric power source, and removing the stored energy in their capacitors prior to servicing.

Hi-pot testing is part of switch maintenance that uses dangerous high voltages. Safe hi-pot testing requires a cleared area between the equipment under test and personnel as specified by NPFA 70E.

Vacuum Electric Switch Company

Phone (330) 374-5159, Fax: (330) 374-5159

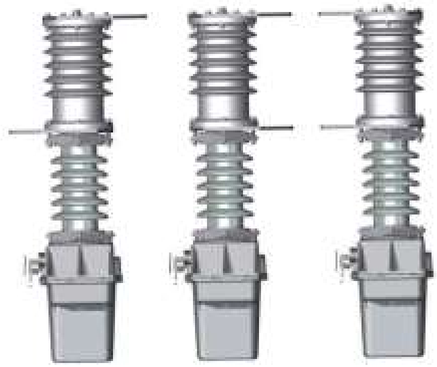
E-mail: sales@vacuumelectricswitch.com

President: Cecil Wristen
Cell (330) 842-0132 E-mail cwristen@vacuumelectricswitch.com

Manufacturing & Service Manager: Dale Mozina
Cell (330) 842-2324 E-mail dmozina@vacuumelectricswitch.com

The Vacuum Electric Switch Co. manufactures vacuum switches which are suitably interchangeable with Joslyn Hi-Voltage's vacuum switches of the same rating. The Joslyn designations VBM, VBT*, and VBU* are abbreviations for the descriptive phrases vacuum breaker miniature, vacuum breaker transformer, and vacuum breaker up-right respectively. The Vacuum Electric Switch Co.'s switches and parts are of its own design and methods of manufacture, which may not be the same as employed by Joslyn. Where product performance is reported, it is from testing of Vacuum Electric Switch Co.'s products and is not necessarily indicative of the performance of comparable products wholly manufactured by Joslyn. The Vacuum Electric Switch Co. is not endorsed or associated with the Joslyn Hi-Voltage a subsidiary of ABB.

* VBM, VBU, and VBT are Joslyn trademarks which are owned by ABB.



Alternate Terminal Pad
Arrangements

SWITCH CONFIG.	BIL kV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
3 POLE	110-150	15	600	SOLENOID	120VAC	1001057	1001055G1
3 POLE	110-150	15	600	15 PIN MOTOR	48VDC/120VAC	1001057	1002520G1
3 POLE	110-150	15	600	15 PIN MOTOR	125VDC	1001057	1002520G2
3 POLE	110-150	15	600	35 PIN MOTOR	48VDC/120VAC	1001057	1003308G1
3 POLE	110-150	15	600	35 PIN MOTOR	125VDC	1001057	1003308G2

The common uses of this switch are sectionalizing and arc furnace or capacitor bank switching. This switch may have either a motor or solenoid operated mechanism. These two mechanisms differ in the complexity of the required control systems, control current demand, available operating voltages, mechanical life, and the precision of the timing of switch contact closing.

Motor operated switches are used for capacitor bank switching and sectionalizing but not arc furnace switching. They can have simple control systems since control current demand is less than six amperes. The motor mechanism cannot be used where simultaneous contact closure in more than one switch is required. The motor mechanism has a limited life of about 30,000 operations which is much less than the more than 200,000 operations achievable by a solenoid mechanism. Motor operated switches with 15 or 35 pin connectors have two each form A (e.g., normal open) and B (e.g., normal closed) or six each form A and B contacts respectively. A common error which may damage the motor operator is to connect it to the wrong control voltage. A switch's control voltage can be determined by examining its relay panel. Relay panels are shown starting on page 40 Repair parts for this switch are found beginning on page 41 and for the motor mechanism, beginning on page 45.

Common uses of the solenoid operated switch are both capacitor and also arc furnace switching. Uncommonly, two or more of these switches may be used along with three resistor modules to form a resistor insertion switch. The solenoid operated switch can be operated with three modules connected in parallel. Each module's current rating is de-rated to 500A when connected in parallel for a total current of 1500A. Three separate switches are then required to make a three phase set. Solenoid operated switches have one form A (e.g., normal open) and one form B (e.g., normal closed) contact.

The solenoid operated switch requires a more elaborate control because each solenoid requires a current in the range of 60 to 65 amperes peak for 1½ cycles. If the solenoid takes longer than 1½ cycles to operate, the available power is inadequate for reliable long term operation. The solenoid coils may fail, and the modules may not close completely causing them to burn up. The requirement for a large current source can be overcome by using a stored energy control shown on page 20. For an existing installation the VES Boost Box on page 21 can be used to correct an inadequate current supply. The controls for arc furnace switching are shown starting on page 24. The resistor module for building a resistor insertion switch is shown on page 16

SWITCH CONFIG.	BIL kV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
3 POLE	200- 150	25	300	SOLENOID	120VAC	1004271	1004270G1
3 POLE	200-150	25	300	15 PIN MOTOR	48VDC/120VAC	1004271	1004267G1
3 POLE	200--150	25	300	15 PIN MOTOR	125VDC	1004271	1004267G2
3 POLE	200-150	25	300	35 PIN MOTOR	48VDC/120VAC	1004271	1004265G1
3 POLE	200-150	25	300	35 PIN MOTOR	125VDC	1004271	1004265G2

The common use of the 25 KV switch is capacitor switching. This switch may have either a motor or solenoid operated mechanism. These two mechanisms differ in the complexity of the required control systems, control current demand, available operating voltages, mechanical life, and the precision of the timing of switch contact closing.

The six vacuum interrupters on this switch require the power of double opening and closing solenoids . When installing a solenoid operated switch the voltage drop from the station power transformers or batteries must be taken into account for the switch to operate properly. The current of the two solenoids can be instantaneously as high as 120 amperes. The Joslyn switch pendant cable is made with 16 AWG wire and can have a substantial voltage drop in a surprisingly short length of cable. The best way to compensate for this large voltage drop is to install a stored energy control shown on page 20

Motor operated switches have a limited life of about 30,000 operations as compared to the more than 200,000 operations achievable by a solenoid mechanism. Motor operated switches with 15 or 35 pin connectors have two each form A (e.g., normal open) and B (e.g., normal closed) or six each form A and B contacts respectively. A common error which may damage the motor operator is to connect it to the wrong control voltage. A switch's control voltage can be determined by examining its relay panel. Relay panels are shown starting on page 40.

Repair parts for this switch are found beginning on page 46 and for the motor mechanism, beginning on page 58.

SWITCH CONFIG.	BIL KV (T:T-T:G)	VOLT-AGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
1 POLE	200-200	34	600	SOLENOID	120VAC	1001565	1000776G1
1 POLE	200-200	34 with grading caps.	600	SOLENOID	120VAC	1001565	1004355G1

This switch is used for both capacitor and arc furnace switching. It is solenoid operated because it is used in three phase sets requiring simultaneous contact closure. It can close at zero voltage for capacitor switching or at peak voltage for arc furnace switching. Its solenoid operating current is 60 to 65 amperes peak for 1½ cycles. If the solenoid operating time exceeds 1½ cycles, switch operation will not be reliable. An inadequate current supply is a common cause of improper operation.

When this switch is used for capacitor switching and does not have 32 inches of free space surrounding it, the switch requires grading capacitors to assure proper operation. The grading capacitors assure that the recovery voltage is equally distributed over its two vacuum interrupters in series.

For capacitor switching, this switch can be operated from a variety of AC and DC sources and is best operated by selecting from the controls shown beginning on page 20. This switch has one form A (e.g., normal open) and one form B (e.g., normal closed) auxiliary contact. Repair parts are shown beginning on page 41.

Multiple switches are used in parallel for arc furnaces with up to 4000 amperes primary current. The switch current rating is de-rated to 500A when used in parallel. Arc furnace controls that can operate from one to six switches per phase are shown on page 25. An arc furnace transformer control can optionally be operated using either resistor insertion or peak voltage closing to reduce in-rush currents.

Accessories available for this switch include both current limiting reactors and resistor modules. The 30 microhenry reactor replaces the buss bar between the two modules. The reactor is used to limit in-rush currents when two capacitor banks are installed in parallel on a single buss. This switch also can be adapted as a resistor insertion switch by installing two 80 ohm resistor modules, one each, on top of the two vacuum interrupter modules. The two resistor modules are then series connected with the buss bar and have a total series resistance of 160 ohms. The controls required are shown starting on page 24. The reactors and resistors are shown on page 16.

SWITCH CONFIG.	BIL kV (T:T-L-G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
1 POLE	200-250	46	600	SOLENOID	120VAC	1002862	1002861G1
1 POLE	200-250	46 with grading capacitors	600	SOLENOID	120VAC	1002862	1002861G3

This switch is principally used for arc furnace switching but also has limited use for capacitor switching. When the switch is used for capacitor switching and is not surrounded by 32 inches of free space, it must have grading capacitors to assure that the recovery voltage is equally distributed over the two vacuum interrupters in series. Otherwise the switch's performance will be degraded.

The switch is solenoid operated because it is used in three phase sets requiring simultaneous contact closure. Capacitor switching is limited to switching solidly grounded 46kV systems having RMS currents of 200 amperes maximum. The switch can be used to switch an arc furnace at 46kV. Its current capacity can be increased by connecting switches in parallel. Switches connected in parallel are de-rated to 500A. This switch has one form A (e.g., normal open) and one form B (e.g., normal closed) auxiliary contact. Capacitor switching is best done with a stored energy control shown starting on page 20. An arc furnace control is shown on page 24. This switch's repair parts are shown beginning on page 45.

Switches with 0.160 Inch Gap (Comparable to Joslyn™ Switches with Similar Ratings)							
SWITCH CONFIG.	**BIL kV (T:T-T:G)**	**VOLT-AGE RATING kV**	**CURRENT RATING A**	**OPERATING MECHANISM TYPE**	**CONTROL VOLTAGE**	**OUTLINE DRAWING**	**VES SWITCH PART NO.**
3 POLE	200:200	34	300	15 PIN MOTOR	24VDC	1003256	1003315G1
3 POLE	200:200	34	300	15 PIN MOTOR	48VDC/120VAC	1003256	1002521G1
3 POLE	200:200	34	300	15 PIN MOTOR	125VDC	1003256	1002521G2
3 POLE	200:200	34	300	15 PIN MOTOR	220VAC	1003256	1003315G6
3 POLE	200:200	34	300	35 PIN MOTOR	24VDC	1003256	1003316G1
3 POLE	200:200	34	300	35 PIN MOTOR	48VDC/120VAC	1003256	1003252G1
3 POLE	200:200	34	300	35 PIN MOTOR	125VDC	1003256	1003252G2
3 POLE	200:200	34	300	35 PIN MOTOR	220VAC	1003256	1003316G2
3 POLE	200:200	34	300	SOLENOID	120VAC	1003256	1002201G1

Switches with 0.160 Inch Gap with Grading Capacitors with No Known Joslyn™ Equivalent							
SWITCH CONFIG.	**BIL kV (T:T-T:G)**	**VOLT-AGE RATING kV**	**CURRENT RATING A**	**OPERATING MECHANISM TYPE**	**CONTROL VOLTAGE**	**OUTLINE DRAWING**	**VES SWITCH PART NO.**
3 POLE	200:200	34	300	15 PIN MOTOR	24VDC	1003256	1003315G5
3 POLE	200:200	34	300	15 PIN MOTOR	48VDC/120VAC	1003256	1002521G5
3 POLE	200:200	34	300	15 PIN MOTOR	125VDC	1003256	1002521G6
3 POLE	200:200	34	300	15 PIN MOTOR	220VAC	1003256	1003315G2
3 POLE	200:200	34	300	35 PIN MOTOR	24VDC	1003256	1003316G5
3 POLE	200:200	34	300	35 PIN MOTOR	48VDC/120VAC	1003256	1003252G5
3 POLE	200:200	34	300	35 PIN MOTOR	125VDC	1003256	1003252G6
3 POLE	200:200	34	300	35 PIN MOTOR	220VAC	1003256	1003316G6
3 POLE	200:200	34	300	SOLENOID	120VAC	1003256	1002201G2

Switches with 0.320 Inch Gap with Grading Capacitors with No Known Joslyn™ Equivalent							
SWITCH CONFIG.	**BIL kV (T:T-T:G)**	**VOLT-AGE RATING kV**	**CURRENT RATING A**	**OPERATING MECHANISM TYPE**	**CONTROL VOLTAGE**	**OUTLINE DRAWING**	**VES SWITCH PART NO.**
3 POLE	200:200	34	300	15 PIN MOTOR	24VDC	1003256	1003315G7
3 POLE	200:200	34	300	15 PIN MOTOR	48VDC/120VAC	1003256	1002521G7
3 POLE	200:200	34	300	15 PIN MOTOR	125VDC	1003256	1002521G8
3 POLE	200:200	34	300	15 PIN MOTOR	220VAC	1003256	1003315G8
3 POLE	200:200	34	300	35 PIN MOTOR	24VDC	1003256	1003316G7
3 POLE	200:200	34	300	35 PIN MOTOR	48VDC/120VAC	1003256	1003252G7
3 POLE	200:200	34	300	35 PIN MOTOR	125VDC	1003256	1003252G8
3 POLE	200:200	34	300	35 PIN MOTOR	220VAC	1003256	1003316G8

The Vacuum Electric Switch Co. is offering this switch in three different versions to improve restrike resistance during capacitor switching. The improvements in restrike resistance are achieved by first adding grading capacitors and second by increasing the open gap between the vacuum contacts from 0.160 to 0.320 inches.

The geometric configuration of this switch may cause the recovery voltage distribution over the two vacuum interrupter in series to be unequal. This is most likely to occur when the switch is used on poles where objects closer than 32 inches in proximity may cause a larger portion of the recovery voltage to appear across the upper module. The switches capacitor switching capability will be reduced. Grading capacitors tend to equalize the capacitance across each vacuum interrupter diminishing the effect of parasitic capacitance. The recovery voltage withstand capability is further improved by increasing the contact open gap from 0.160 to 0.320 inches. The larger gap requires more energy than is available from a solenoid mechanism, so it is only possible with motor operated switches.

The common uses of this 34kV switch are either capacitor switching or sectionalizing. It can have either a solenoid or motor operated mechanism. The principal differences between the two mechanisms are the complexity of the control, control current demand, available operating voltages, and mechanical life. A motor operated switch requires a simple control system because the control operating current is less than 6 amperes. Motor operated switches are available with a variety of control voltages. The VES motor operator has a limited life of approximately 30,000 operations as compared to the 200,000 operations for the solenoid operator.

Motor operated switches with 15 or 35 pin connectors have two each form A (e.g., normal open) and B (e.g., normal closed) or six each form A and B contacts respectively. A common error which may damage a motor operated switch is to connect it to the wrong control voltage. The appropriate voltage for a motor operator switch can be determined by examining the relay panel installed on the motor operator. Relay panels are shown on pages 40-43. Motor operator repair parts are found starting on page 58

The solenoid operated version of this switch is particularly susceptible to having its control current being inadequate because its has twice as many solenoids as the other switches. Demonstrating inadequate current requires a digital oscilloscope with a current probe. Reliable operation requires either a substantial current source or a stored energy control. Existing installations with too small a current supply can be corrected by installing the VES Boost Box shown on page 21. An adequate current on new installations can be assured by installing the stored energy control such as shown on page 20.

Switch repair parts are shown starting on page 45. Replacement modules for this 34kV 300A switch are available both with and without grading capacitors. Modules with and without grading capacitors can not be installed on the same switch.

SWITCH CONFIG.	BIL kV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAW-ING	VES SWITCH PART NO.
1 POLE	200-200	46	300	SOLENOID	120VAC	1002859	1002858G1
1 POLE	200-200	46 with grading capacitors	300	SOLENOID	120VAC	1002859	1002858G3

SWITCH CONFIG.	BIL KV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAW-ING	VES SWITCH PART NO.
1 POLE	280-350	69	300	SOLENOID	120VAC	1002341	1002865G1
1 POLE	280-350	69 with grading capacitors	300	SOLENOID	120VAC	1002341	1002865G3

The 46 and 69kV switches shown above are commonly used for capacitor bank switching in substations. They may also be used for switching induction furnaces. When the switch is used for capacitor switching and is not surrounded by 32 inches of free space, the switch must have grading capacitors to assure that the recovery voltage is equally distributed over the three or four vacuum interrupters in series. Otherwise the switch's performance will be degraded.

These switches are solenoid operated because they are used in three phase sets requiring simultaneous contact closure. The switches can precisely close at zero voltage to reduce capacitor bank in-rush currents. The solenoid operating current is 60 to 65 amperes peak for 1½ cycles per switch mechanism. If the switch solenoid takes longer than 1½ cycles to operate, switch operation will be unreliable. Failed modules or solenoid coils may be a result. This switch is best operated with a stored energy control as shown on page 22. These switches have one form A (e.g., normal open) and one form B (e.g., normal closed) auxiliary contact. Repair parts are shown beginning on page 45.

Vacuum Breaker Up-right Switch

72 kV 600A Switch

MODULES	BIL kV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	PART NO.
4	350	72	600	SOLENOID	120VAC	1001513G1
7	550	121	600	SOLENOID	120VAC	1001513G3
8	750	145	600	SOLENOID	120VDC	1001513G6

This switch is used for both arc furnace and capacitor switching and is generally known as the Joslyn™ VBU* because there is no other widely known generic name for this switch. At 69kV and above, this switch may be the only switch available with a practical operating life for switching arc furnaces.

The Vacuum Electric Switch Co. manufactures new VBU modules and switch operating mechanisms as shown on page 32. The Vacuum Electric Switch Co. builds both a capacitor and an arc furnace switch controls for the VBU switch.

The VBU switch can be used to reduce transient in-rush currents by zero voltage switching for capacitor banks or by peak voltage switching for arc furnaces. It can be used as a resistor insertion switch for arc furnaces.

* VBU is Joslyn trademark and owned by ABB..

SWITCH CONFIG.	BIL kV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
1 POLE	150	15	600	SOLENOID	120VAC	1000641	1000579G1

This solenoid operated two pole switch has two applications. The first is to achieve 1000 amperes of current capacity at 15kV by connecting the two modules in parallel with buss bars. In this configuration it is used for arc furnace switching. When the modules are connected in parallel, three separate switch mechanisms are required to make a three phase set. This switch's controls for arc furnace switching are shown starting on page 25. The second application is in conjunction with the transverse single pole switch shown below for switching capacitor banks at zero voltage. The control required for this application is found on page 21. Repair parts are the same as for a 15kV three pole switch and are found starting on page 45.

Transverse

Longitudinal

SWITCH CONFIG.	BIL kV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAW-ING	VES SWITCH PART NO.
1 POLE T	150	15	600	SOLENOID	120VAC	1003374	1001178G3
1 POLE L	150	15	600	SOLENOID	120VAC	1001182	1001178G1

This single pole switch is used for synchronous closing of capacitor banks to reduce in-rush currents. It is available with two terminal pad orientations. With the terminal pads perpendicular to the length of the switch, it is used with the two pole switch above to switch capacitor banks at zero voltage. The longitudinal form above is used in three phase sets to switch capacitor banks at zero voltage. These switches contain one form A (e.g., normal open) and one form B (e.g., normal closed) auxiliary contact. The required controls are shown on page 21. The repair parts are the same as for the three pole 15kV switch and are found beginning on page 45.

SWITCH CONFIG.	BIL kV (T:T-T:G)	VOLT-AGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
3 POLE	200:200	34	600	15 PIN MOTOR	24VDC	1002870	1003313G1
3 POLE	200:200	34	600	15 PIN MOTOR	48VDC/120VAC	1002870	1002867G1
3 POLE	200:200	34	600	15 PIN MOTOR	125VDC	1002870	1002867G2
3 POLE	200:200	34	600	15 PIN MOTOR	220VAC	1002870	1003313G2

This switch is used for sectionalizing 34kV solidly grounded systems only. The switch is motor operated because it is used as a sectionalizing switch in remote locations where a limited current supply is available and a simple control is an advantage. The control current is only 6 amperes. Switches with 15 or 35 pin connectors have two each form A (e.g., normal open) and form B (e.g., normal closed) or six each form A and form B contacts respectively.

SWITCH CONFIG.	BIL kV (T:T-T:G)	VOLTAGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAW-ING	VES SWITCH PART NO.
1 POLE	200 -350	34	600	SOLENOID	120VAC	1002864	1002863G1

This switch is a 34kV switch with 350kV BIL line-to-ground insulators commonly used on 69kV systems. The extra creepage is useful where atmospheric contamination is a problem. This switch is also used to short insertion resistors on an arc furnace having a 69kV primary voltage. This switch is solenoid operated because to prevent over heating, the resistors must be shorted at 100 milliseconds after being energized. Only the solenoid operated switch has the precision to meet this timing requirement. This switch contains one form A (e.g., normal open) and one form B (e.g., normal closed) auxiliary contact. A control for operating this switch is shown on page 25. The repair parts except for the pull rods and the line-to-ground insulators are the same as for the 34kV switch shown on page 45.

SWITCH CONFIG.	BIL KV (T:T-T:G)	VOLT-AGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
1 POLE	110/200-200	15/34	1000/600	SOLENOID	120VAC	1002860	1002831G1
1 POLE	110/200-200	15/34	1000/600	DOUBLE SOLENOID	120VAC	1002860	1002831G2

The above switch is solenoid operated for use in a laboratory where versatility is an advantage. The switch can be either a 34kV 600A or a 15kV 1000A switch by removing or installing the lower buss bar respectively. The double solenoid version of this switch has twice as many solenoids in order to increase the speed of contact closure. This switch contains one form A (e.g., normal open) and one form B (e.g., normal closed) auxiliary contact. The controls for these switches are shown on page 20. The repair parts except for the modules are the same as for the 34kV switch shown on page 45..

Right Hand Configuration

Left Hand Configuration

SWITCH CONFIG.	BIL KV (T:T-T:G)	VOLT-AGE RATING kV	CURRENT RATING A	OPERATING MECHANISM TYPE	CONTROL VOLTAGE	OUTLINE DRAWING	VES SWITCH PART NO.
1 POLE RH	200-200	34	600	SOLENOID	120VAC	1003377	1003355G1
1 POLE LH	200-200	34	600	SOLENOID	120VAC	1003376	1003354G1

This switch is for switching harmonic filters up to and including the 12th. harmonic. Unlike the Joslyn™ switch of a similar design, the modules on the Vacuum Electric Switch Co.'s harmonic filter switch contain grading capacitors to assure even distribution of the recovery voltage over the three modules. Modules with and without grading capacitors cannot be combined on the same switch and are special for this switch. The switch is solenoid operated. It comes with the buss bars on either the left or right hand sides so that switches connected in parallel on a single phase can be nested together. Having the switches close together makes the current divide more equal between switches connected in parallel. This switch contains one form A (e.g., normal open) and one form B (e.g., normal closed) auxiliary contact. A control for operating this switch is shown on page 21. The repair parts except for the modules are the same as for the 34kV switch shown on page 41.

Ratings for Vacuum Electric Switches

Design Voltage Nominal/Maximum (kV)	15/15.5[3]	25[3]	34.5/38[3]		46/48.5[3]		69/72.5[3]
Continuous current (RMS Amperes)	600[5]	300	600[5, 3]	300	600[4, 5]	300	300
Fault Interrupting Cur-rent (RMS Amperes) Max.	4000	3000	4000	3000	4000	3000	3000
Momentary Current (RMS Amperes, Asym-metric)	20,000	15000	20,000	15,000	20,000	15,000	15,000
Frequency (Hz)[3]	50/60	50/60	50/60	50/60	50/60	50/60	50/60
Two-Second Current (RMS Amperes)	12,500	12,500	12,500	12,500	12,500	12,500	12,500
Four-Second Current (RMS Amperes)	9000	9000	9000	9000	9000	9000	9000
Impulse Withstand, Ter-minal-to-Terminal (kV) Line-to-Ground (1.2 X 50 Positive Wave)	110[1]/ 150	200[1]/ 150	200[1]/ 200	200[1]/ 200	200[1]/ 250	250[1]	280[1]/ 350
Maximum 60-Cycle Withstand Line-to-Ground (kV) One Minute Dry Ten Seconds Wet	101 74	101 74	138 119	138 119	178 176	178 176	245 198
Maximum Peak Inrush Current (RMS Amperes)	20,000[2]	15,000[2]	20,000[2]	15,000[2]	20,000[2]	15,000[2]	15,000[2]

[1]The terminal-to-terminal BIL is not established by a visible open gap and therefore the switch cannot be used to establish safety clearance for personnel.

[2] When switches are used for capacitor bank switching, restrike probabilities are determined by the magnitude of the in-rush current, the contact open gap, and the contact material. This is explained in a Toshiba paper found in *IEEE Transactions on Power Delivery,* Vol 10, No. 2 April 1995. Using reactors to reduce in-rush current improves restrike probability. In back-to-back capacitor switching peak cur-rents should be limited by reactors to a switch's fault interrupting rating. The contact material used in these switches is copper tungsten the same as reported to have the lowest restrike probability in this Toshiba paper. In aged switches with high operation counts, contact welding may occur if the in-rush currents are not limited.

[3]Switching a harmonic filter requires special considerations. Consult the factory about these applications.

[4]For capacitor bank switching only, this switch is limited to being used on solidly grounded systems and solidly grounded capacitor banks with currents of less than 200 amperes.

[5]When switches are used in parallel, the continuous current rating is reduced to 500 amperes to account for unequal current distribution between switches.

Switch Accessories

80 Ohm Resistor Module

The 80 ohm resistor module is used to build resistor insertion switches for reducing in-rush currents. It has an arc horn to protect it from over voltages in the event the in-rush current is so large that its withstand voltage was exceeded.

The resistor module was originally built using eight stacked 10 ohm 10 KV resistor elements. The resistor elements were originally designed for use in oil circuit breakers where they were submerged in oil. The resistor elements have brass contact surfaces which are used to make the electrical connection from one element to another. The oil protected the contact surfaces from atmospheric corrosion which can cause large increases in module resistance..

Recently the resistor module's design has been changed to use resistor elements with aluminum contact surfaces that are not subject to corrosion and the resulting increase in resistance. The old resistor module design with the brass contact surfaces have part No. 1002256G1. The new module design with aluminum contact surfaces has part No. 1002256G2. The resistor elements in the 1002256G1 part can be replaced to convert it to a 1002256G2 part.

30 Microhenry Reactor

The above 30 microhenry reactor is used to limit in-rush current when switching back-to-back (two capacitor banks installed in parallel on the same buss) capacitor banks. It is designed to be installed in place of the buss bar on the 34kV switch shown on page 6. Its VES part no. is: 1002284G1.

Switch Accessories

Joslyn™ Cable

Number of Pins	Length ft.	Indoor Part No.	Outdoor Part No.
15	20	1000415G1	1000576G1
15	25	1000415G4	1000576G4
15	30	1000415G2	1000576G2
35	20	1004504G1	1002156G1
35	25	1004504G2	1002156G2
35	30	1004504G3	1002156G3

The above cables are for use with a Joslyn™ switch. The connector for the outdoor cable has a drip angle which guides the flow of rain water away from the connector. The cables are made with either a 15 or 35 pin connectors on one end and loose wires on the other for connecting to a terminal strip.

Vacuum Electric Switch Cable

Number of Pins	Length ft.	Part No.
15	15	1000775G8
15	20	1000775G2
15	30	1000775G3
15	35	1000775G4
15	40	1000775G5

The above cable has a 15 pin connector for connecting to a Joslyn switch. The opposite end has a connector for connecting to a Vacuum Electric Switch control.

Switch Service Stand

Description	Kit Part No.	Assembled Stand Part No.
Field service stand for a 15 or 34kV switch	1000247G2	1000247G1
Field service stand for a 46 or 69kV switch	1003557G2	1003557G1

The above picture shows a switch service stand. When a switch is mounted to the stand, it can be flipped over to work on it right side up or upside down. The field service stand can be purchased either completely assembled or as a kit ready for welding. The stand is much easier and less costly to ship as a kit.

Vacuum Switch Service Tool Kit

Vacuum Switch Service Tool Kit: Part No. 1001533G1	
Description of Tools in Kit	Qty
continuity light box with 4 circuits for synchronizing switches - 1001618G1	1
3° gauge for measuring the maximum link angle - 1001104P1	1
1° gauge for measuring the minimum link angle - 1001104P2	1
0.060”, 0.075”, 0.090” step gauge for setting solenoid nylon pin gap - 1001105P1	1
adjustment wedge for synchronizing module contacts - 1001538P1	1
digital dial indicator assembly for measuring mechanism travel and contact over travel - 1001536G1	1
Philips no. 3 screwdriver - 1001673	1
50 in.-lb. torque wrench - 1001541	1
25 in.-lb. torque wrench - 1001539	1
3/8” drive ratcheting torque wrench - 1001671	1
socket, 1/2” 6 pt. 3/8” drive standard - 1001668	1
socket, 9/16” 6 pt. 3/8” drive standard - 1001669	1
socket, 7/16” 6 pt. 3/8” drive standard - 1001667	1
socket, 7/16” 6 pt. 3/8” drive deep - 1001670	1
box end wrench, 7/16,” 1/2” deep offset - 1001672	1
open end wrench, 3/4” x 7/8” - 1001548	1

Service Parts Kit for VBM™ & VBT™ Switches

This kit was originally designed to meet the Vacuum Electric Switch's service technician's parts needs when performing service in a foreign country. One of these parts kits could be shipped ahead of the technician's arrival, and the technician could be confident that it contained every part that could conceivably be required except vacuum interrupter modules. Companies doing their own service work may find purchasing this kit to be more convenient than ordering parts individually. The kit can be restocked as parts are consumed.

The service parts kit shown to the left is more than enough parts fot routine annual service an arc furnace with a total of twelve switches. The difference between the 15kV and 34kV kits are the length of the pull rods supplied. The parts are grouped in individually numbered boxes and the entire kit is itemized in a spread sheet and indexed by description, part number, and its numbered box. The kit is packaged in a Pelican Storm™ case for convenient shipment and storage. An itemized list of the parts in the kit is available on request.

Description	Part No.
Field service parts kit for Joslyn™ VBT* 15kV switches used for arc furnace switching	1003182G1
Field service parts kit for Joslyn™ VBT* 34kV switches used for arc furnace switching	1003182G2

Portable Solenoid Operated Switch Tester

The Vacuum Electric Switch portable tester shown to the right is for dynamically testing a solenoid operated switch. It is portable and battery powered. The tester contains a capacitor discharge control for operating the switch. A selector switch selects the number of stored energy capacitors for running the test.

Solenoid operated switches may have either one or two closing or opening solenoids requiring either one or two energy storage capacitors respectively to operate the switch. A selector switch selects the number of stored energy capacitors for running the test.

The oscilloscope measure the current waveform flowing to the solenoids and the opening or closing time for the switch's vacuum contacts. The functioning of the open or closed auxiliary switch status indicating contacts is shown by indicating LED's.

This test equipment which includes the oscilloscope VES part no. 1004054G1.

The oscilloscope is used to measure both the waveform of the current flowing to the solenoid and also the switch's opening and closing time. These measurements assure that a switch is properly adjusted. The tester tests the operation of the auxiliary switch circuits. Sometimes a properly adjusted switch does not operate properly when it is installed. A common cause of such failures is an inadequate supply of current to the solenoids.

Capacitor Bank Switch Controls

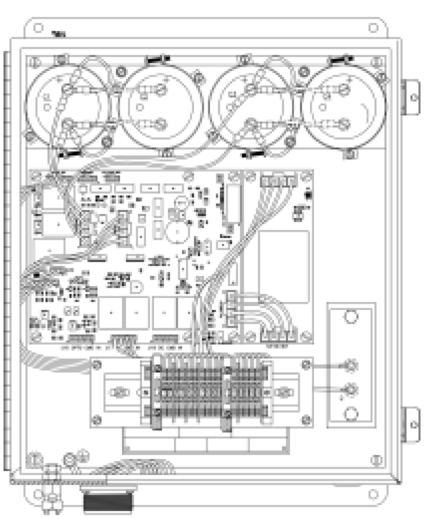
The capacitor switch controls shown on these pages are different from other controls commonly used to operate Joslyn™ switches. First, they have extremely low power demands. Second, the control is very precise in timing switch contact opening and closing. Third, the controls are connected to the switches with cables having connectors on both ends to speed installation.

The power demand is low because both the single and multiple switch controls are powered by switching power supplies with either 10, 25, or 60 watts. At these low power levels, the peak current demand is easily under 3 amperes and the maintenance charging current is a trickle. Since the power demand is so low, voltage drops in long runs of wire to the control do not cause operating problems. The controls can accept 48VDC, 120VAC, 125VDC, or 220VAC inputs.

These controls are very precise in controlling switching time because the basic electronic circuitry used in all the controls was designed for closing switches at zero voltage. The precision is achieved both by electronic switching and also having a closely regulated voltage on the stored energy capacitors. The zero voltage switching feature is optional on three switch controls, but even if this option is not elected the precision is retained by the electronics.

The controls are easy to diagnosis and repair. They are a modular assembly of circuit boards, wiring harnesses, and cables all of which can be quickly unplugged and replaced. This enables a person who is not familiar with the details of the circuitry and operation of the control to quickly isolate and determine what components are not working properly by substituting whole assemblies.

Universal Single Switch Control



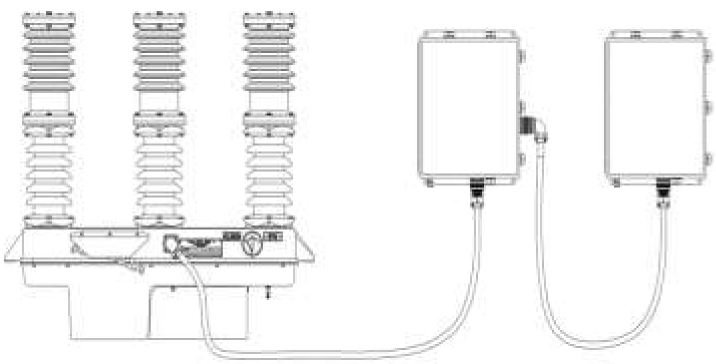
This control is called the universal control because it has field selectable options which permit it to be used in several different applications.

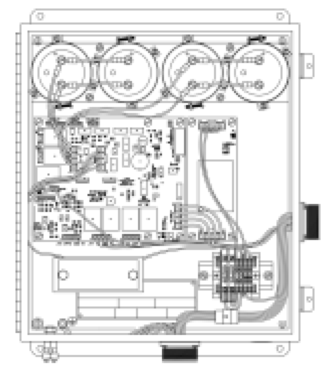
The universal control can be used with 15 kV or 34 kV single switches. The control can be powered from either 120 VAC or 125 VDC. The trip and close command voltage can be either 120 VAC or 125 VDC. It also has an opto-isolated trip and close inputs which can be used to precisely time the closing of the switch.

The control has four energy storage capacitors but as delivered only two are connected. Switches with a single close or trip solenoid such as shown on page 4 only require two capacitors. Switches with two close and two trip solenoids such as shown on pages 5 and 8 require four capacitors.

Control Voltage	Part No.
120 vac or 125vdc	1004489G1

Boost Box Control for Three Pole Solenoid Operated Switches





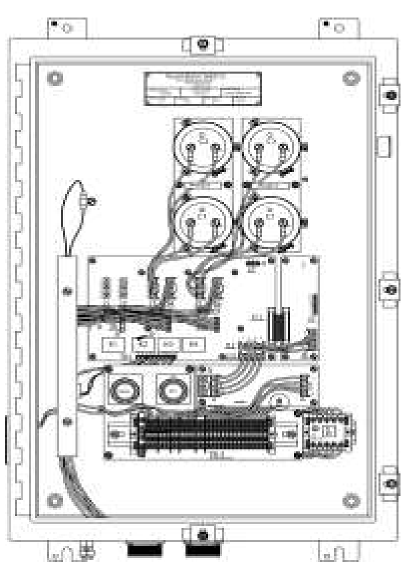
Boost Box

The Boost Box Control is designed to assure adequate power for reliable operations of VBM solenoid operated switches involving only a single switch mechanism.

Some substation layouts have long distances between the switch and the 120VAC station transformer or 125VDC battery bank. The line impedance combined with high current demand may result in an excessive voltage drop to the switch. The switch will compensate by taking longer to operate, but occasionally the compensation will be inadequate.

A boost box is a practical and simple way to offset the undesired voltage drop. The boost box contains energy storage capacitors and is inserted in series with the existing switch pendant cable going from the control to the switch. The capacitors in the boost box then supply power to operate the switch. Old Joslyn controls should be replaced with the control below rather than augmented with a boost box.

Multiple Switch Capacitor Bank Controls



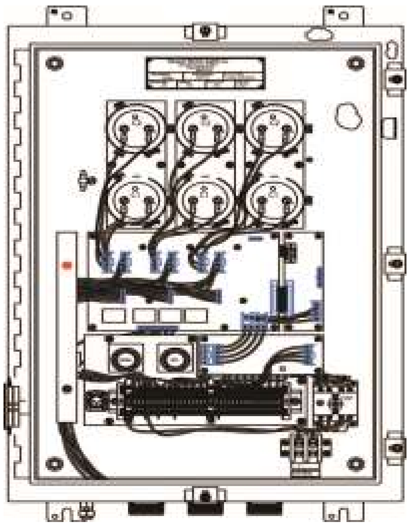
Two Switch Zero Voltage Control

The two switch control shown to the left is for switching capacitor banks at zero voltage using the two pole switch along with one single pole transverse switch as shown on page 12.

This control is calibrated using VES calibration test kit part No. 1004054G1,. During calibration test leads are connected to the de-energized switch poles to measure the switch timing. A laptop computer with a special program is connected to the control and is used to measure and set the switch timing.

Control Type	Control Voltage	Control Part No.
Zero Voltage	48VDC	1003370G1
Zero Voltage	120VAC	1003370G2
Zero Voltage	125VDC	1003370G3
Zero Voltage	220VAC	1003370G4

Three Switch Control

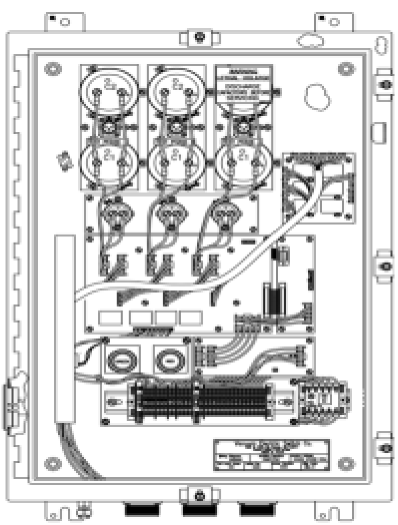


Control Type	Control Voltage	Control Part No.
Zero Voltage	48VDC	1003365G1
Zero Voltage	120VAC	1003177G1
Zero Voltage	125 VDC	1003177G2
Zero Voltage	220 VAC	1003177G3
Conventional	48 VDC	1003365G2
Conventional	120 VAC	1003369G1
Conventional	125 VDC	1003278G1
Conventional	220 VAC	1003369G2

The three switch control shown to the left can operate a three phase set of any single pole solenoid operated switch in this catalog except the VBU switch. It can be either a zero voltage or a regular control depending on the firmware installed. The three switches will achieve simultaneous contact closure within 2 milliseconds with minimal adjustment effort. The use of this control will substantially reduce the effort required to adjust switches for simultaneous operation when operated on 125VDC.

This control is calibrated using VES calibration test kit part No. 1004054G1, shown on page 18. During calibration sense leads are attached to the de-energized switch poles to measure their closing times. A laptop computer with a special program is connected to the control and is used to measure the closing time and to set the calibration.

VBU Capacitor Bank Controls

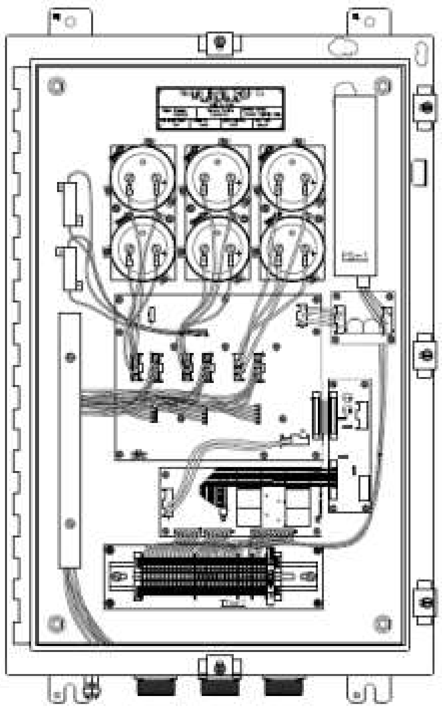


Control Type	Control Voltage	Control Part No.
Zero Voltage	48VDC	1004557G1
Zero Voltage	120VAC	1004557G2
Zero Voltage	125 VDC	1004557G3
Zero Voltage	220 VAC	1004557G4

The three switch control shown to the left can operate a three phase set of VBU poles shown on page 12. It can be either a zero voltage or a regular control depending on the firmware in-
installed. The three switches will achieve simultaneous contact closure within 2 milliseconds with minimal adjustment effort. The use of this control will substantially reduce the effort required to adjust switches for simultaneous operation when operated on 125VDC.

This control is calibrated using VES calibration test kit part No. 1004054G1.. During calibration sense leads are attached to the de-energized switch poles to measure their closing times. A laptop computer with a special program is connected to the control and is used to measure the closing time and to set the calibration.

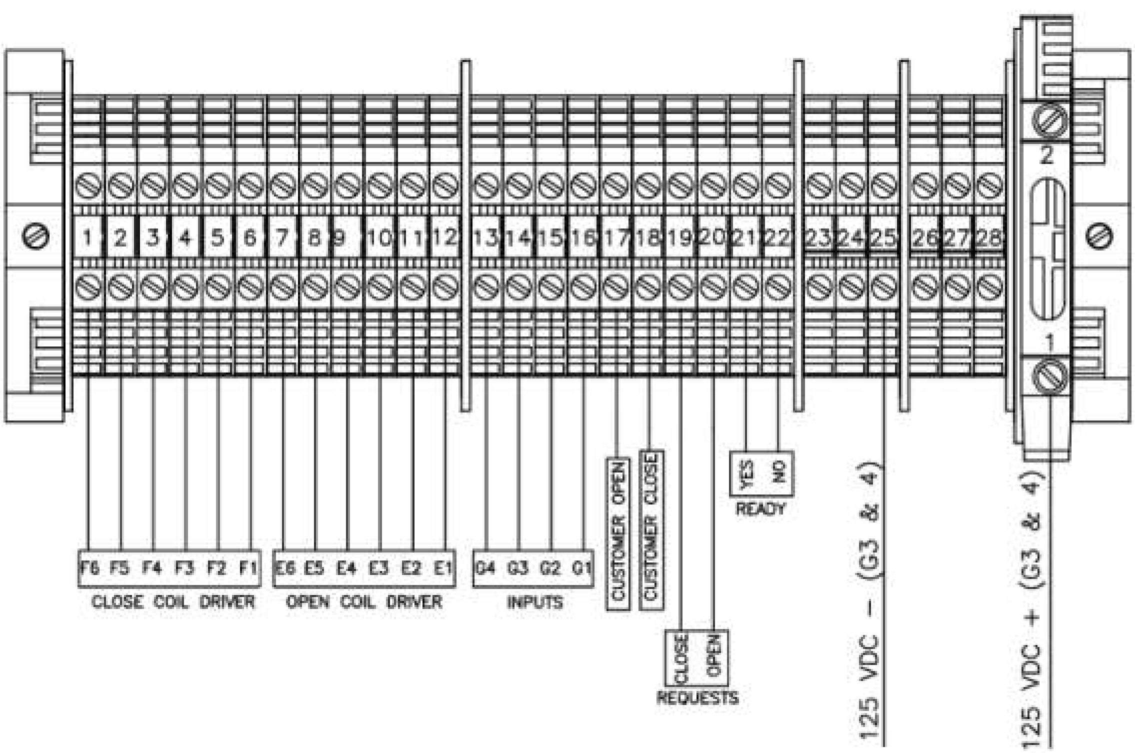
Wind Farm Controls



The wind farm control is used for dynamic VAR compensation at a wind farm. This control can operate three poles of any single pole solenoid operated switch in this catalog except the VBU switch. The control can switch the poles with precision independently of each other at a frequency of every fifteen seconds. The control is powered by 125VDC, and requires a 5kW power source with 3½% maximum impedance.

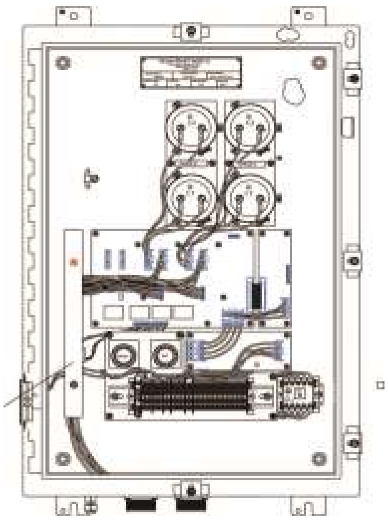
This control's interface is designed to mate with Vizimax's SynchroTeq™ control. This control has VES part No. is 1004455.

SynchroTeq Control Interface



Electric Furnace Controls

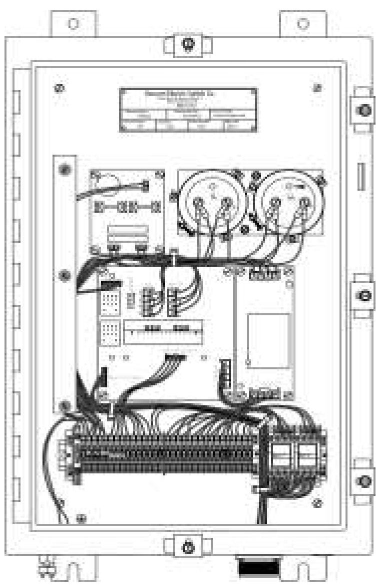
Induction Furnace Resistor Insertion Switch Control



This control operates two 15kV 600A three pole switches in a resistor insertion switch arrangement for transient in-rush control. The control first closes one switch through 80 ohm resistor modules. One hundred milliseconds later the control closes a second switch bypassing the resistors.

Control Voltage	Control Part No.
120VAC	1003248G1

Arc Furnaces 15kV or 15MVA and Less



This control is for arc furnaces that are operated by one 15kV 600A three pole switch. It is a stored energy control with a fast charging circuit to enable frequent operation of the furnace switch.

The use of this control prevents problems caused by an inadequate current source to operate the control. A single solenoid operated switch requires 60 to 65 amperes peak for 1½ cycles to operate properly. If this current is not available, it will operate slowly and may have intermittent malfunctions and failures which are difficult to explain.

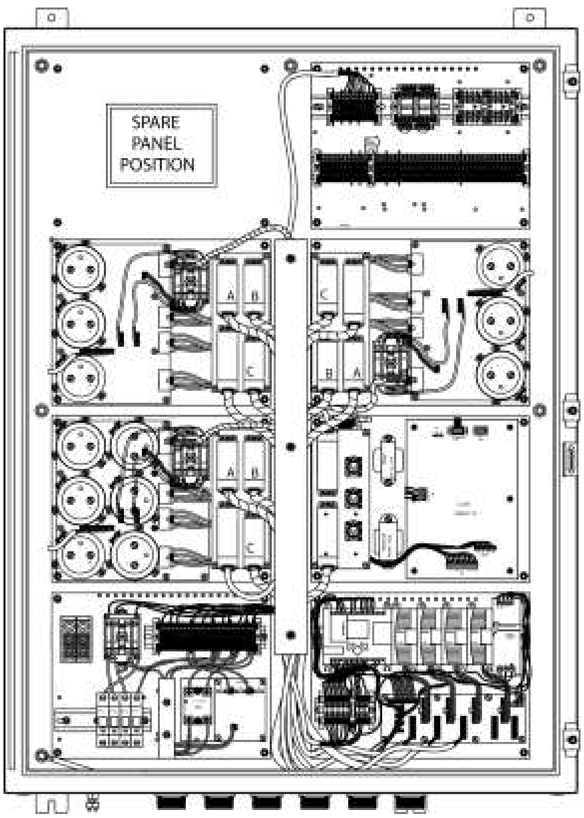
Control Voltage	Control Part No.
120VAC	1003154G1

Schweitzer™ Relays Can Prevent Catastrophic Switch Failures on Small Arc Furnaces

Catastrophic switch failures are common on small arc furnaces as a result of a switch's attempting to interrupt a current exceeding its interrupting rating of 4000 amperes. These failures happen because in an effort to save money, a circuit breaker is not installed in series with the vacuum switch. Over current relays are then connected to the vacuum switch in the absence of the breaker. Since normal switch currents are less than 600 amperes, this arrangement works well most of the time because fault currents are usually less than the vacuum switch's 4000 A rating. But occasionally the rating is exceeded, and the result is catastrophic.

The number of failures of this type can be substantially reduced by installing a Schweitzer™ over current relay as part of the above control. The intelligence in the Schweitzer relay can recognize whether a fault current is within the capability of the switch. If the current is too large, the Schweitzer relay prevents the vacuum switch from opening and allows a fuse up stream from the vacuum switch to do the interruption. The prevention of a single switch failure will pay for having a Schweitzer relay.

Arc Furnaces 15 to 46kV and Greater than 15MVA



The control to the left is for an arc furnace with 3000 amperes primary current at 15kV or 1500 amperes at 34/46kV. It can operate nine switches total or three per phase. It is a direct replacement for a Joslyn™ arc furnace control. The control shown is representative of a whole range of controls available which are capable of operating from three to eighteen switch mechanisms. The control is modular for easy diagnosis and repair.

This control can minimize transient in-rush current either with resistor insertion switches or synchronous closing with the alternating current sine wave.

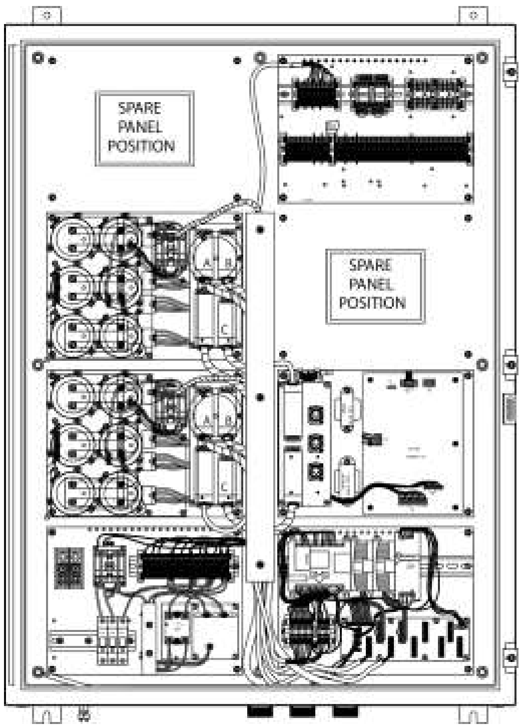
The control is operated by an Allen Bradley™ MicroLogix™ 1100 PLC. The PLC has diagnostics built into its program. The control can detect a switch mechanical malfunction and initiate an emergency trip so as to prevent single phasing of the furnace transformer. Single phase power on a furnace transformer is a frequent cause of exploding arrestors.

The control has a reset function which can reset the control following an intermittent switch malfunction. This feature enables a furnace to continue operating without down time while deferring the maintenance on switches to a convenient down day.

The MicroLogix PLC has an ethernet connection for remote monitoring with a PanelView™ monitor. The PanelView™ monitor graphically displays individual switch open or closed status and maintains a date and time stamped log of switch malfunctions which resulted in the control being reset.

Number of Switches Per Phase	Control Transformer	Control Voltage	Control Part No.
1	5kVA at 3.5% max impedance or 10kVA at 7% max impedance	120VAC	1001711G13
2	10kVA at 3.5% max impedance or 20kVA at 7% max impedance	120VAC	1001712G13
3	15kVA at 3.5% max impedance or 30kVA at 7% max impedance	120VAC	1001713G13
4	20kVA at 3.5% max impedance	120VAC	1001714G13
5	25kVA at 3.5% max impedance	120VAC	1001715G1
6	30kVA at 3.5% max impedance	120VAC	1001716G1

Controls for Arc Furnaces Using VBU* Switches



VBU Poles per Phase	Control Voltage	Control Part No.
1	120VAC	1003223G3
2	120VAC	1003223G1
3	125VAC	1003223G5

The control above is a direct replacement for a Joslyn™ VBU control. VBU switches shown on page 11 can be used at primary voltages of 69kV to 145kV. They can also be used at 34kV with 2000A and 3000A modules. The control shown operates two VBU poles per phase, but it can be expanded to operating up to five VBU poles per phase.

The control is modular in design for easy diagnosis and repair. A person who does not know all the details of the control can diagnose problems by substitution. The control is connected to the VBU switch by a cable with a connector on both ends to reduce wiring at installation. An adaptor kit is provided to install a receptacle on each VBU pole.

This control can minimize transient in-rush current either with a resistor insertion switch or by synchronous closing.

The control operates on stored energy for both closing and opening. It is operated by an Allen Bradley™ MicroLogix™ 1100 PLC which has diagnostics built into its program. The control can detect a switch mechanical malfunction and initiate an emergency trip so as to prevent single phasing of the furnace transformer. Single phase power on a furnace transformer is a frequent cause of exploding arrestors.

The control has a reset function which can reset the control following an intermittent switch malfunction. This feature enables a furnace to continue operating without down time while deferring the maintenance on switches to a convenient down day.

The MicroLogix PLC has an ethernet connection for remote monitoring with a PanelView™ monitor. The PanelView monitor graphically displays individual switch open or closed status and maintains a date and time stamped log of switch malfunctions which resulted in the control being reset.

Inspection, Testing, and Adjustment of Switches

1. Begin the inspection by recording the switch nameplate and module data. Make copies of the sample forms shown on pages 33 and 34 to aid in recording this data.
2. Close the switch and measure the resistance of all modules using a micro-ohm meter.
3. Open the switch and hi-pot each module using a 30kVAC hi-pot and record the leakage current at 30kV.
4. When doing work on switches, use the bolt torque values shown on page 32. Torque wrenches and tools for this purpose are contained in the tool kit shown on page 16.
5. Invert the switch, remove the switch cover, and place the switch in the closed position as shown in Figure 1. Place a paper towel or rag in the space between the insulator and pull rod to prevent objects from accidentally falling into the module.
6. Measure and adjust the link angle as shown below. Note that the allowable link angles on switches for motor operated or solenoid switches and with regular or double stack modules are different as shown on the inspection record sheets.
7. Measure and adjust the full travel Figure 5.

Note that the pointer is indicating that the switch is in the closed position

Figure 1

Pull Rod Bolts

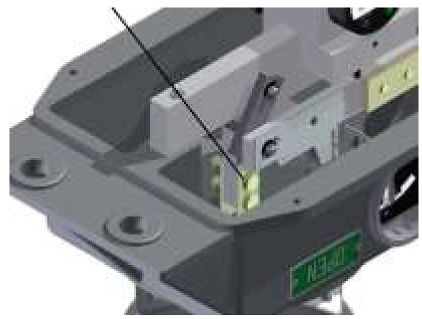


Figure 2

To Check the Link Angle

1. Start by using 1001104P1 (3 degree measuring tool) or the 1001104P2 (1 degree measuring tool) by placing it on the far end of the handle side of the support bar and against the linkage bar as shown in Figures 3 & 4.
2. The minimal gap between the link and the tool indicates the angle of the link, which corresponds to the angle of the tool.

Gap on the Bottom Edge of Setup Tool

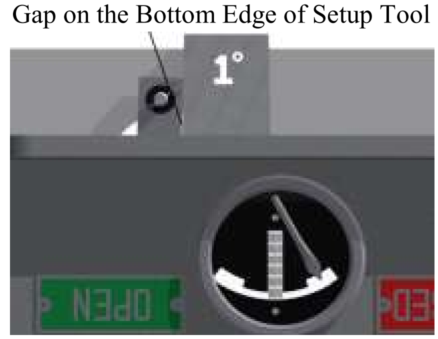


Figure 3

To Adjust the Link Angle

1. The link angle is controlled by the closing bumper which is one of two bumpers shown in Figure 5.
2. Mark the position of the closing bumper and then open the switch.
3. Loosen the two 5/16” bolts that fasten the closing bumper and move it in a direction to increase or decrease the link angle as required.
4. Re-tighten 5/16” bolts, flip the switch back to the closed position and recheck the link angle.
5. Repeat steps 2-4 until the desired degree link angle is achieved.

Gap on the Top Edge of Setup Tool

Figure 4

To Check the Full Travel

1. Flip the switch into the closed position and place the dial indicator gauge near the far end by the bumper block as shown in Figure 5.
2. Zero the dial, flip switch to the open position, and record the dial reading. A properly adjusted switch has full travel between 0.200" and 0.210" as shown in Figure 8.

Figure 5

To Adjust the Full Travel

1. Move the switch to the closed position. Mark the position of the opening bumper.
2. Loosen and move the bumper to increase or decrease the full travel as required. Tighten the bolts.
3. Repeat steps 1 and 2 until the travel is within range.

Figure 6

Figure 7

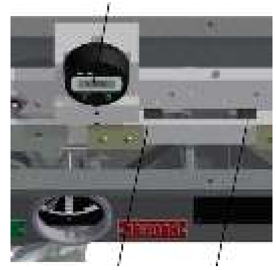


Figure 8

To Check the Synchronism Between Vacuum Bottles

1. Hook any type of continuity device (light box, ohm meter, beeper box, or etc.) to the top (red lead) and bottom (black lead) terminal pad of each module.
2. Flip switch to the closed position and zero the dial indicator.
3. Place a 3/4" open end wrench on the center link, and pull the switch open while noting the dial indicator reading for each module at moment at which continuity is lost. It should be between 0.036" and 0.044" for a properly adjusted switch.

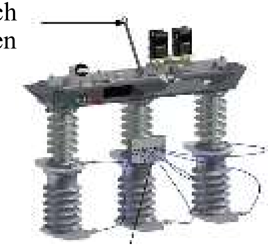


Figure 9

To Adjust Contact Synchronism

1. With the switch in the closed position loosen all pull rod bolts as shown in Figure 2.
2. Force the adjustment wedge (1001538P1) between the closing bumper block and housing until the dial indicator reads 0.040"+/-.004" as shown in Figure 10.
3. Insert and tighten the pull rod bolts and then remove the wedge.
4. Measure and record the sync of each module the same as in step 3 above.
5. Repeat steps 1-4 until all modules loose continuity between 0.036" and 0.044" of travel.

Figure 10

Adjustments for Solenoid Operated Switches Only

To Check the Auxiliary Switch Travel

1. Place the switch in the closed position, zero the dial indicator, and clamp the operating handle to the handle cover with a c-clamp so that the handle does not move.
2. Apply a 3/4" open-end wrench to the center link and open the switch by moving the wrench away from the solenoid.
3. Listen for a click sound indicating the Eaton™ auxiliary switch has changed state. It should change state before 0.175" of travel.
4. Record the dial indicator reading at the change of state.
5. Once the click is heard, return the wrench to its starting position while listening for a click again. It should change state again before the travel decreases to 0.025".
6. Record the dial indicator reading at the second change of state.
7. The auxiliary switch must change state before 0.175" on opening and again before 0.025" on closing.

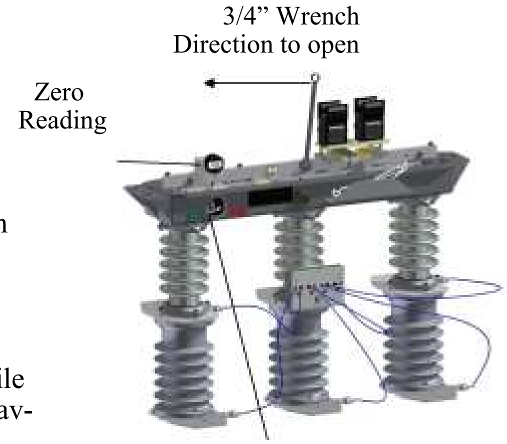


Figure 11

To Adjust the Auxiliary Switch Travel

1. With the switch in the closed position, mark a line on the support bar to indicate the position of the auxiliary switch mounting bracket.
2. Slightly loosen the two 1/4-20 bolts, move the bracket to the desired position, and retighten screws as shown in Figure 12.
3. Check the auxiliary switch travel by repeating steps 2-5 above.
4. Repeat the readjustment until the auxiliary switch changes state before 0.175" on opening and 0.025" on closing.

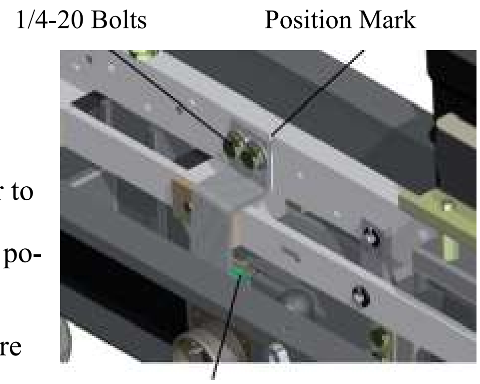


Figure 12

To Check and Adjust Solenoid Pin Gap

1. Place the switch in the closed position and measure pin gap for the opening solenoid by sliding thickness gauges between the nylon and metal pins as shown in Figure 13.
2. Place the switch in the open position and similarly measure the pin gap for the closing solenoid.
3. The pin gaps must be between 0.060" and 0.090".
4. To adjust the gap remove solenoid assembly mounting bolts one at a time and add or remove shims (1000754P1) between the solenoid mounting plate and the zinc plated spacers. This gap controls switch speed. Larger and smaller gaps increase or decrease switch speed respectively.

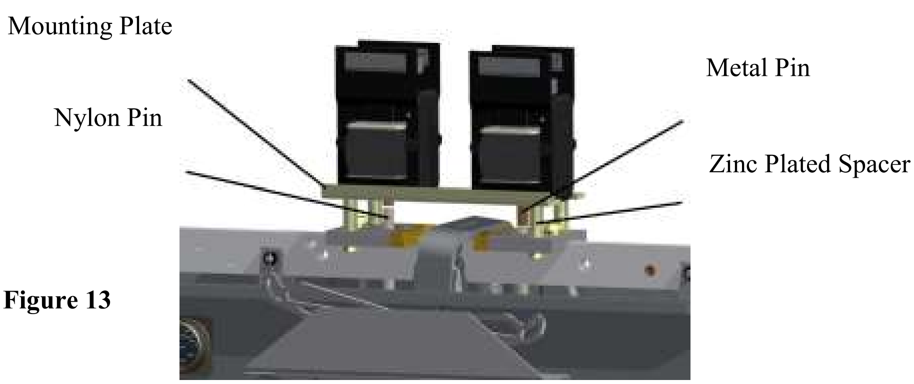


Figure 13

Maintenance of Motor Operated Switches

Motor operated switches have the same modules, pull rods, and linkages as the solenoid operated switches. Except for the link angle, the full travel and over travel adjustments are made in the same manner as for the solenoid operated switch. The link angle is set at 1 degree for a motor operated switch. The larger link angle used for a solenoid operated switch will cause the switch to immediately trip open following closing.

Motor operated switches are different from the solenoid operated switches in that the energy to open and close the switch is supplied by the motor operator mechanism. Relatively weak extension springs are installed between the toggle link and the control yoke instead of the heavy compression springs used with the solenoid operated switches.

The operation of the switch handle or the motor does not directly change the switch's state from open to closed, but its action charges a spring which then is used to open or close the switch. Motor operator switches can operate on different voltages which are determined by what relay panel is installed in the switch along with which field jumpers are installed. The relay panels and required jumpers are shown on pages 36-38.

The four major assemblies which distinguish the motor from the solenoid operated switch are:

1. **Motor Mechanism** - this mechanism consists of links, levers, shafts, and springs all held together by two side plates. This whole mechanism is somewhat like a clock mechanism and is difficult to disassemble and reassemble. Purchasing a remanufactured motor mechanism assembly is an easier alternative to disassembling and reassembling a motor mechanism. The part number of the motor mechanism without the motor assembly is 1002673G1. The four parts in the motor mechanism which commonly fail consist of the side plates, the trip link, the boomerang levers, and the spring bolts. VES has redesigned all of these parts to prevent failure. The amount of work to disassemble and reassemble the motor mechanism is so intensive that if any one of these parts is replaced, all of these potential failure parts should also be replaced to avoid subsequent failures.
2. **Motor Assembly** - Removal and replacement of the motor assembly is comparably easy. The motor assembly consists of a universal 48VDC electric motor, worm gear, speed reducing worm wheel, and cams to drive the ratcheting clutches in the motor mechanisms. Occasionally 24VDC motors are used in place of the 48VDC motor. Frequent failures which occur are worn worm wheel and shaft bearing journals. The VES Co. has redesigned the motor assembly to extend its life by changing materials and adding lubrication. The VES Co. motor assembly part no. is 1002399G1.
3. **Relay Panel** - the relay panel is mounted on the side of the motor mechanism, and it determines the operating voltage of the switch. Having the wrong relay panel installed or the wrong jumpers selected for the applied control voltage is a common cause of resistor burn out and motor failure. Many different relay panels exist. The three most common are shown on pages 36-38. Relay panels can be easily changed.
4. **Wiring Harness** - Wiring harnesses are available with 15 or 35 pin connectors. The connector with more pins offers more auxiliary contacts for customer connections. These are moderately difficult to replace because of the large number of wires.
5. **Auxiliary Switches** - Several different types of auxiliary switches have been used with Joslyn™ motor operated switches. Vacuum Electric Switch Co.'s contact block has the foot print and functionally of the original block and uses Allen Bradley™ contacts, housing, and yoke. The Allen Bradley contacts are easily replaceable. Anyone contemplating replacing an auxiliary switch should call to discuss their switch's compatibility with the Allen Bradley contact block replacement.

Instructions for Motor Operated Switches Only

To Check the Motor Mechanism

1. Position the mini cams on the motor assembly to a vertical position. Measure the large springs to verify they are 3” to 3.125” long.
2. Crank the handle of the switch 20-35 times until the switch flips to the closed position. Then slap the handle to trip the switch into the open position. If the switch cannot be changed to the open or closed state, the mechanism needs adjustment.

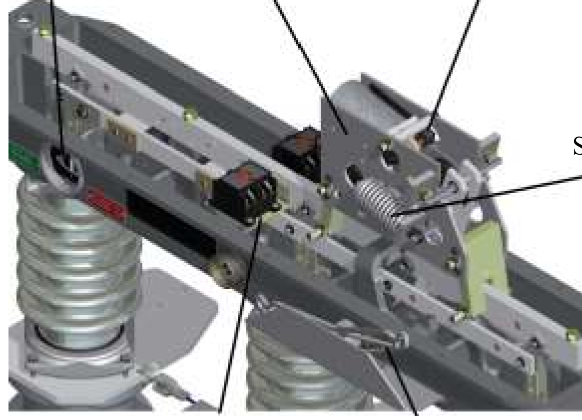


Figure 14

To Adjust the Motor Mechanism

1. Start with the switch in the open position, and unscrew the
2. 1/4-20 trip screw (1002415) until it is retracted into the middle linkage (1002031P1) and screw in the 3/8-16 stop bolts (1000480) until the heads are touching the side plate ears as shown in Figure 15.
3. Crank the handle 20-35 times until the switch closes, advance the stop bolts until they are 0.010” to 0.020” from the shaft, and then tighten the jam nut to hold in place.
4. Screw in the trip screw until the switch opens, then back it off 1 to 1½ turns, and tighten the jam nut to hold it in place.
5. Repeat steps 1-3 until the switch can be operated by the handle alone. Finally apply a small amount of thread locker on both the trip screw and stop bolts.

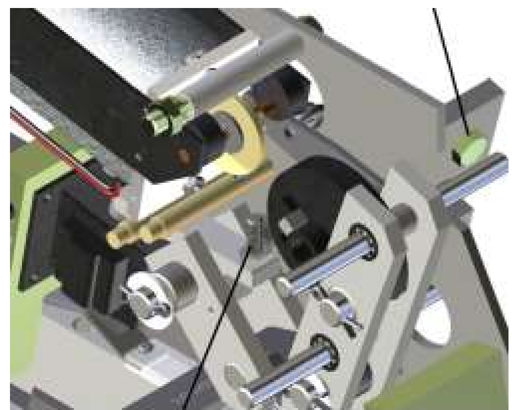


Figure 15

To Check the Allen Bradley™ Contact

1. With the switch in the open position, use a continuity device to determine aux switch state. Flip the switch to the closed position and determine that the aux switches have changed state.
2. If contacts do not change state, adjust mounting bracket to correct.

To Adjust the Allen Bradley™ Contacts

1. With the switch in the open position, draw a line on the support bar as shown in Figure 16.
2. Slightly loosen the mounting bolts and adjust aux switch.
3. Recheck with the continuity device.
4. Repeat steps 1-3 until all aux contacts fully open and close when the switch changes state.

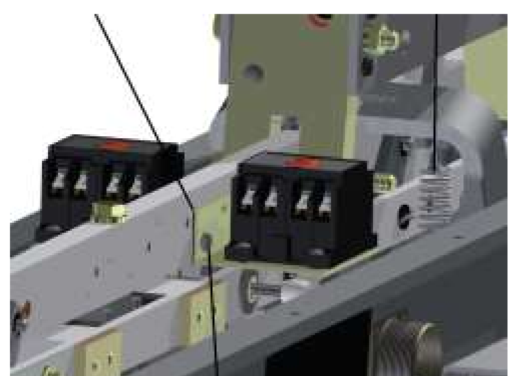
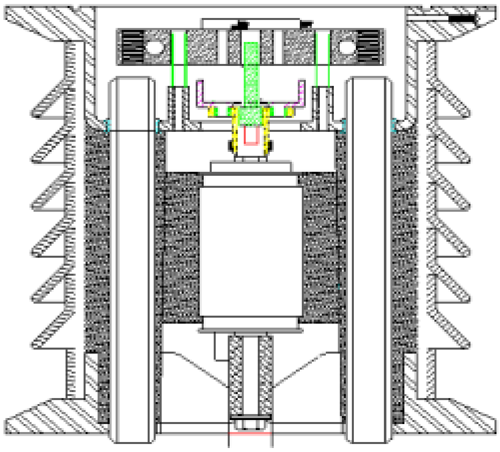
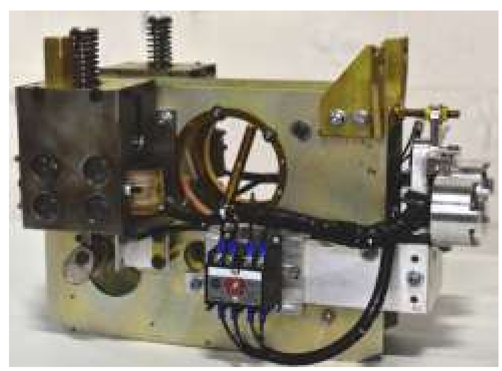


Figure 16

Vacuum Breaker Up-right Switch Parts



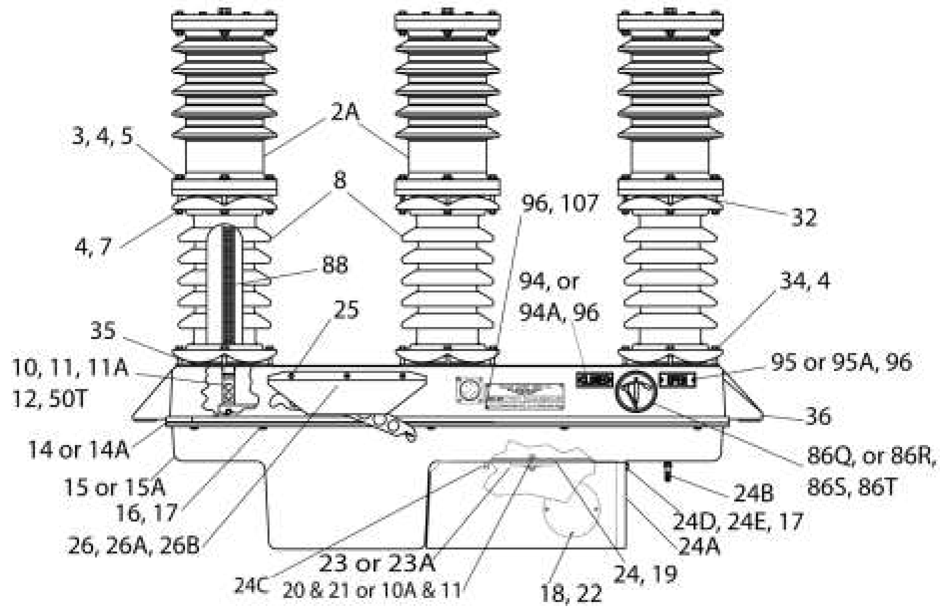
The new VBU module has part no. 1002719G2 is shown in the picture to the right. The drawing to the left shows how the Mitsubishi vacuum interrupter is installed in the module.



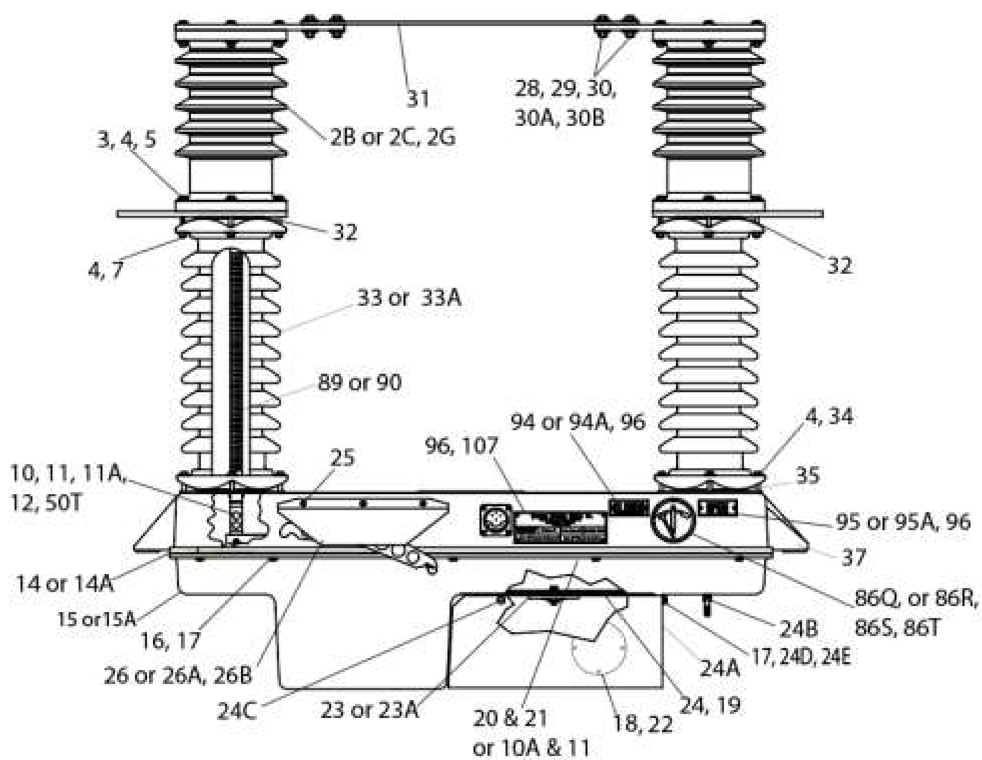
The VBU mechanism above, VES part No.1004429G1, has been reverse engineered and remanufactured to be like the original Joslyn™ mechanism design. The adjustment cams have been reincorporated the same as in the original design. The cam can be seen in the above picture. The Square D™ contact blocks shown in the schematic above have been replaced with Allen-Bradley™ contactors as shown in the center above. They are mounted on the side of the VBU mechanism as shown to the above right. Needle bearings in this mechanism frequently failed. They have been replaced with oil impregnated bronze sleeve bearings because they are better under shock loading. The needle bearings in the trip linkages have been replaced with glass filled Teflon bearings because they have very low static friction. Too much static friction can cause the trip link to not reset following a trip operation.

When VBU switches are used on arc furnaces, the causes of down time can be categorized as being attributed to modules, operating mechanisms, and controls. Design changes in remanufactured modules have eliminated almost all routine failures in modules. Design changes in the reverse engineered mechanism above have enabled that mechanism to exceed 75,000 operations in life testing. The control problems have been addressed by the control shown on page 26. Diagnostics are part of this control's program. This control is an adaptation of the control on page 25 for which there are more than forty installations.

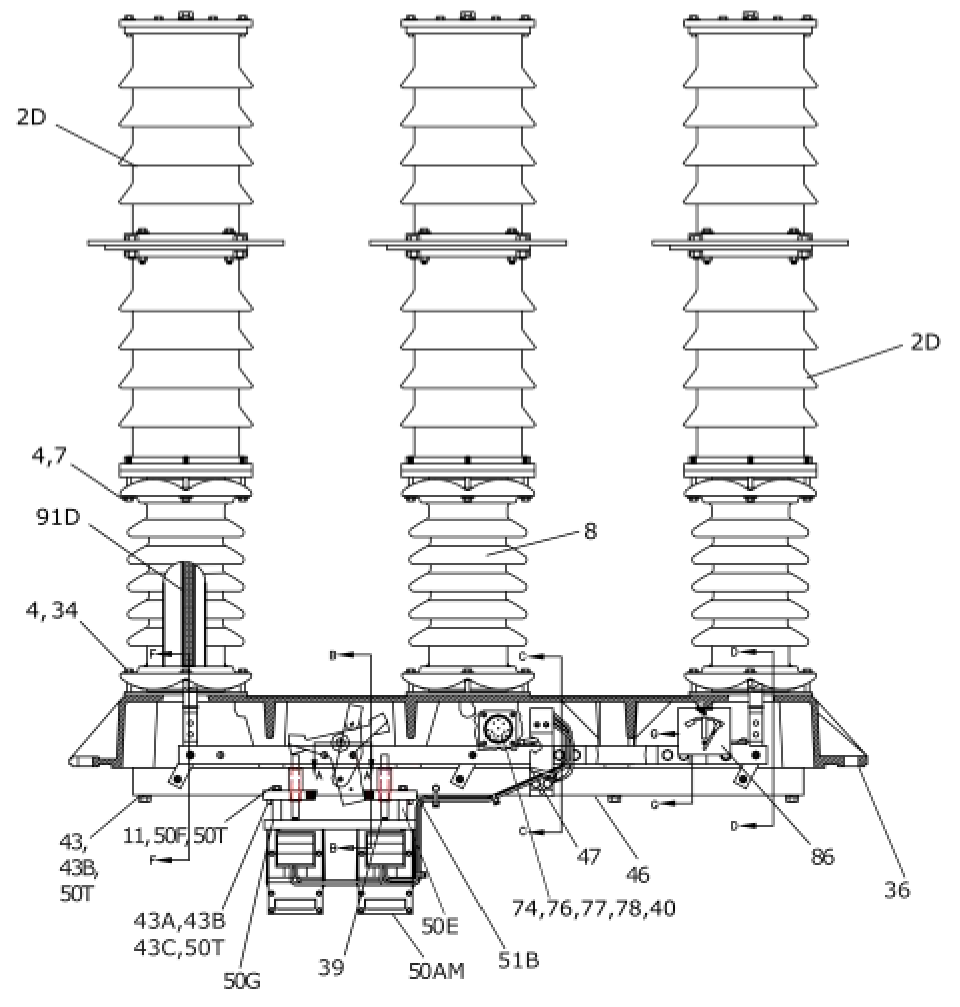
Switch Replacement Parts



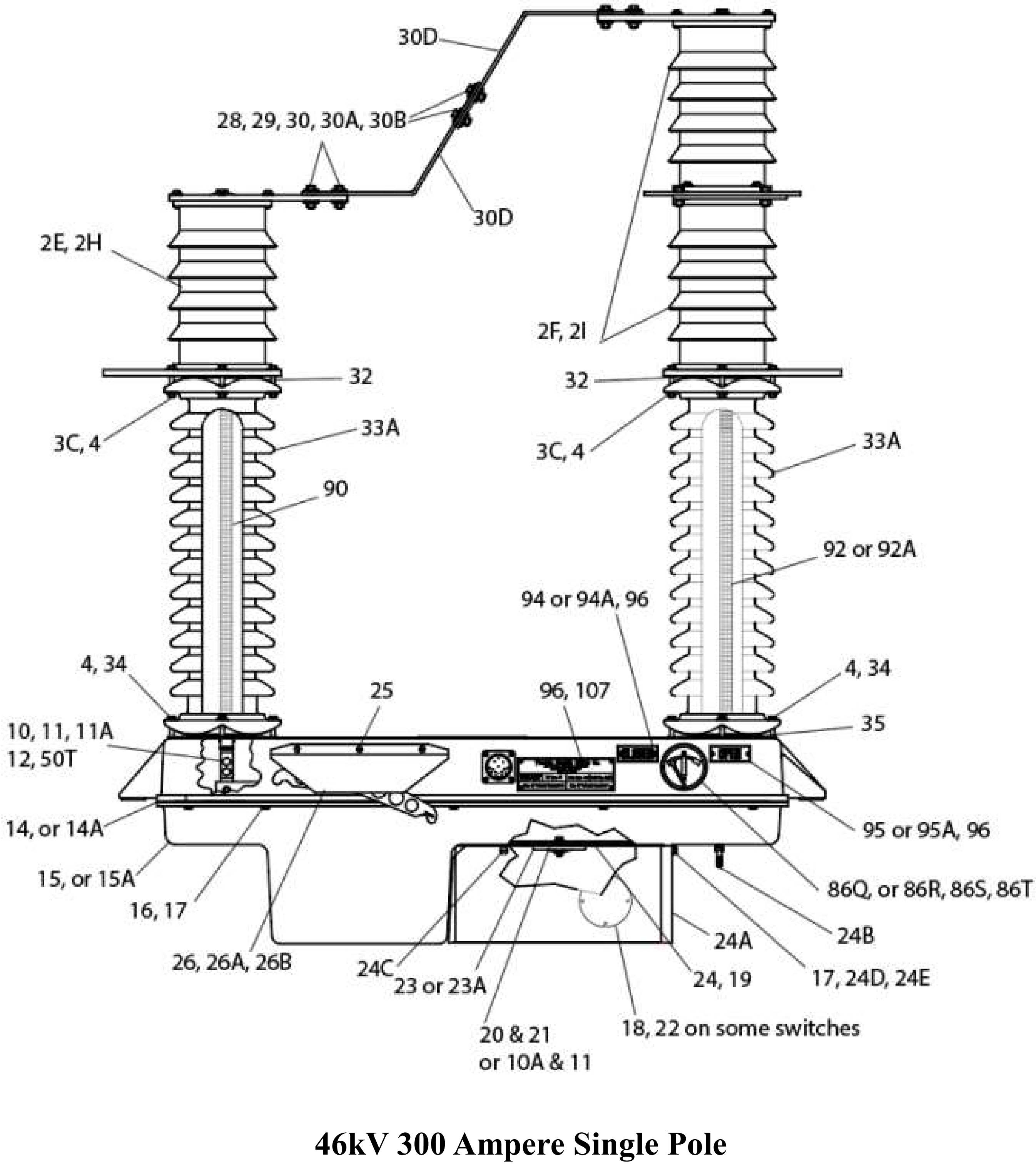
15kV 600 Ampere Three Pole Vacuum Switch



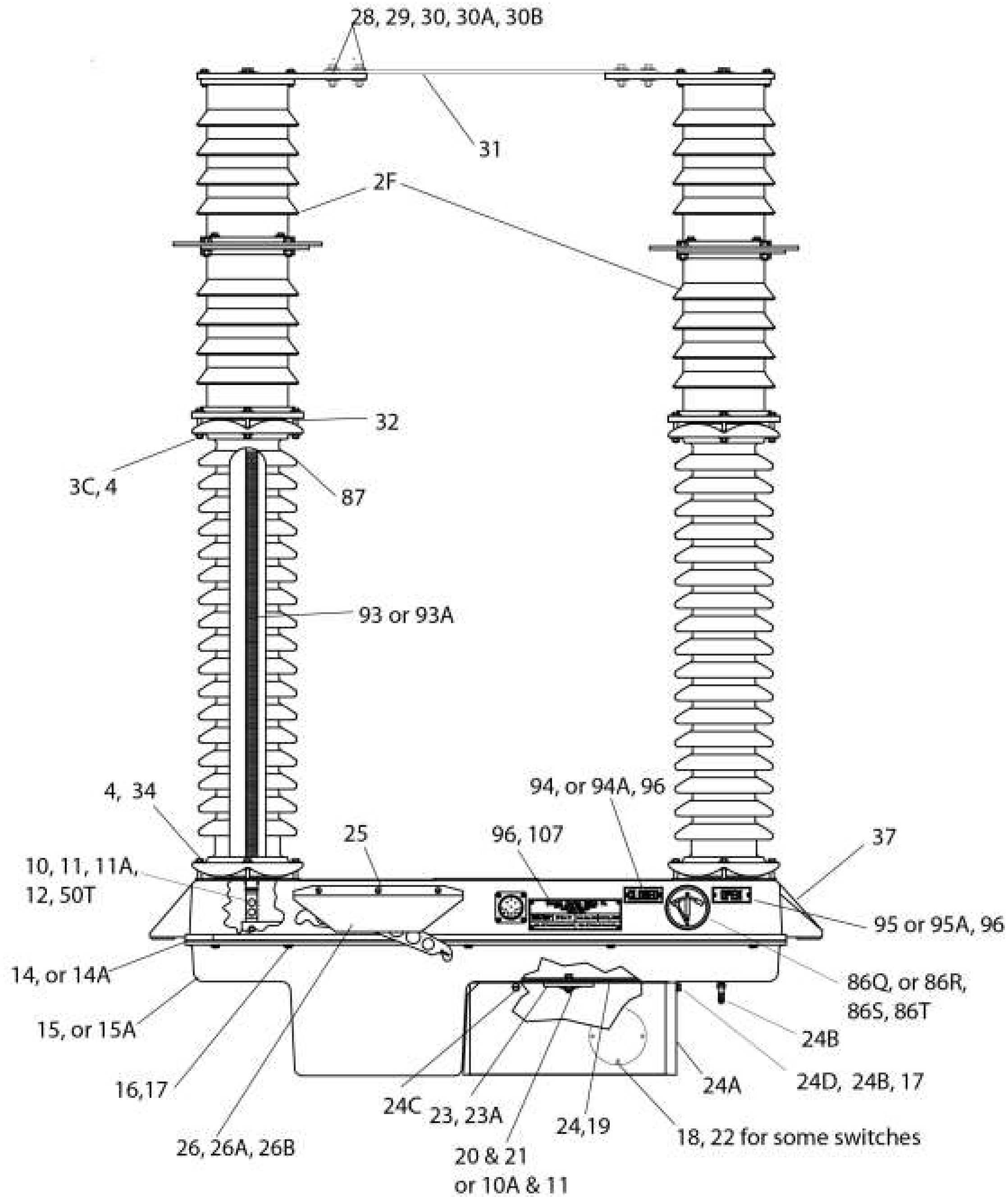
34kV or 46kV 600 Ampere Single Pole Vacuum Switch



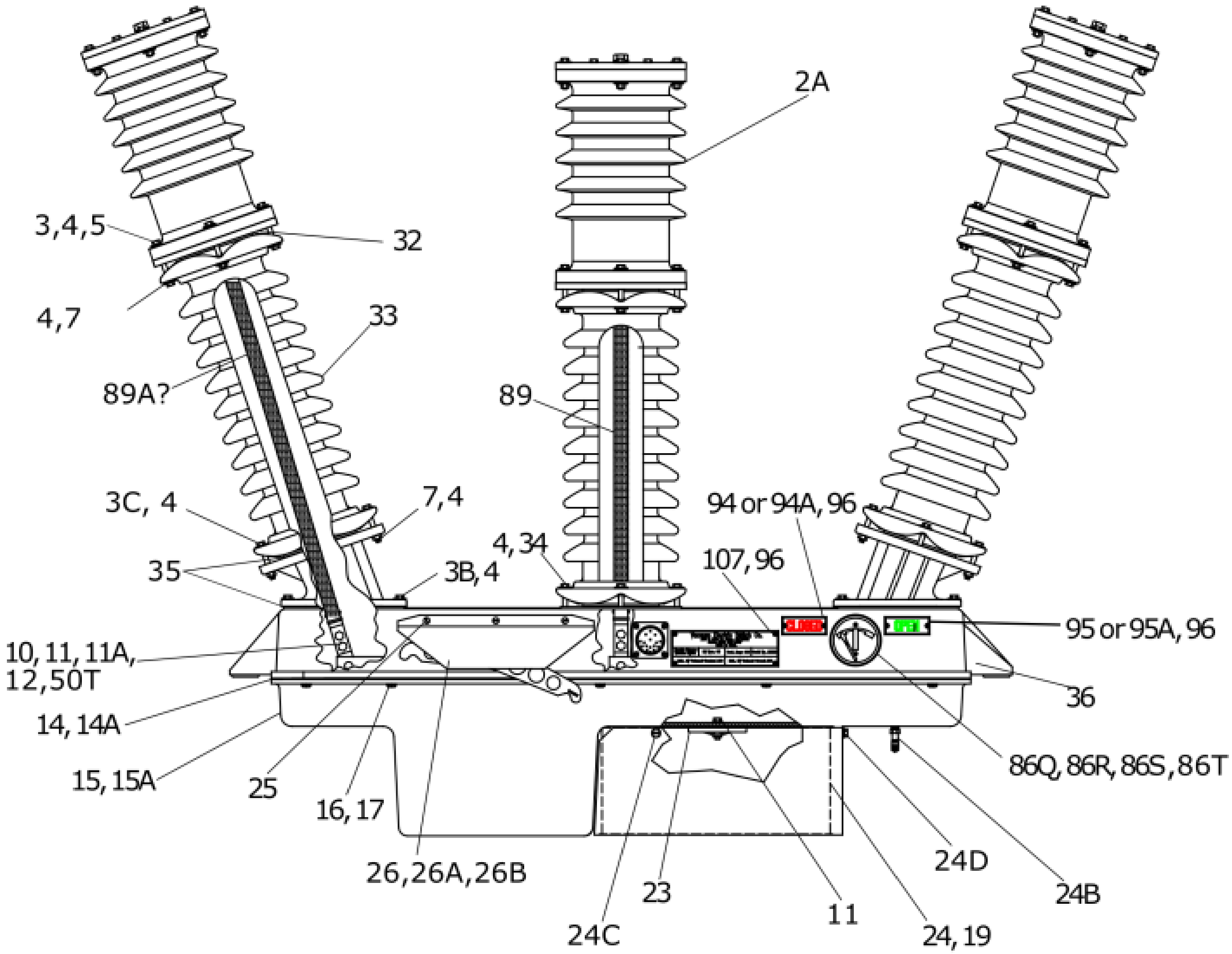
25 KV 300 A 3-Pole Solenoid Operated Switch



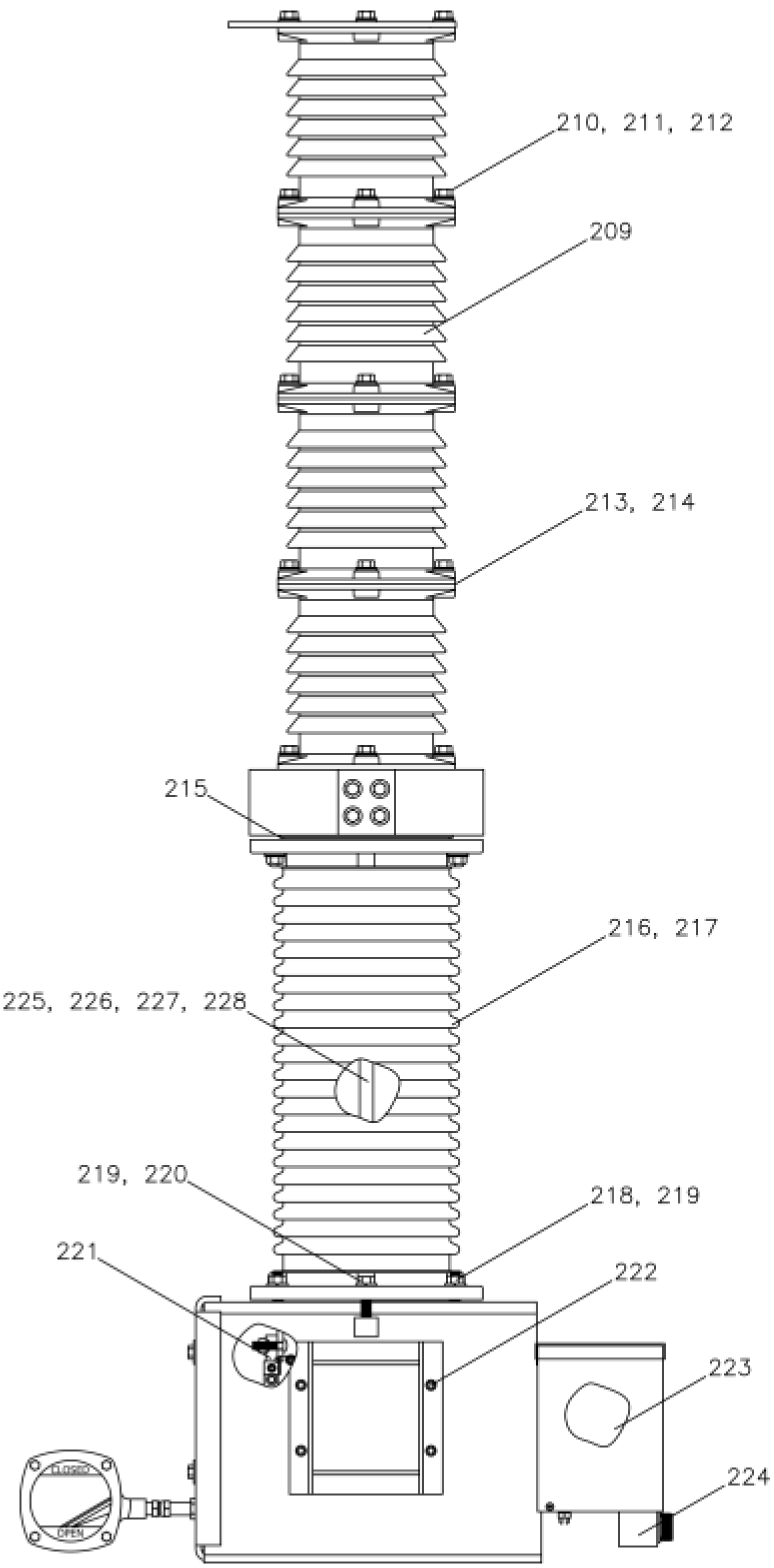
46kV 300 Ampere Single Pole Vacuum Switch



69kV 300 Ampere Single Pole Vacuum Switch



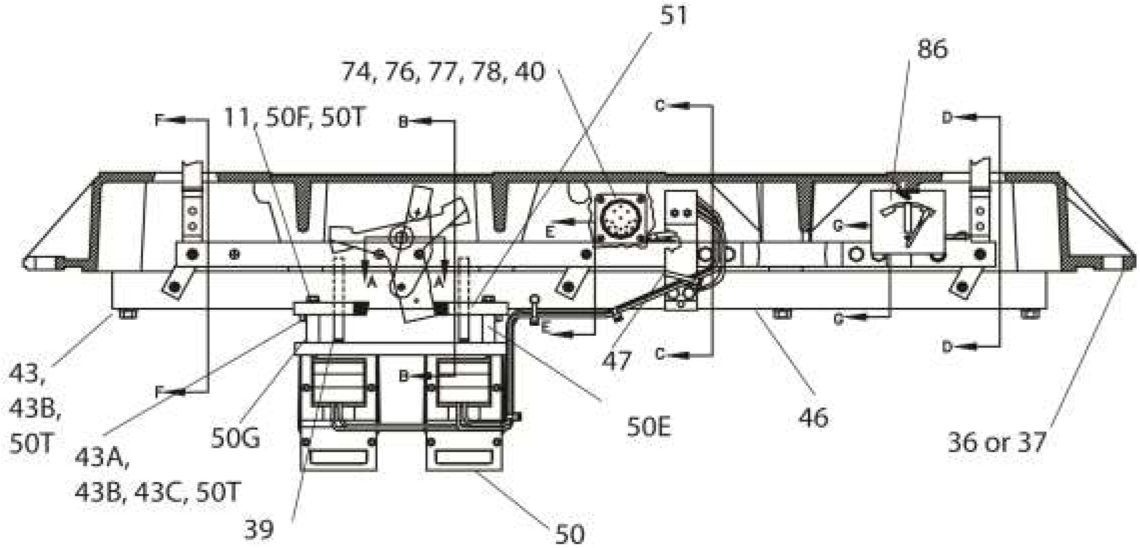
34kV 600 Ampere Three Pole Sectionalizer Vacuum Switch

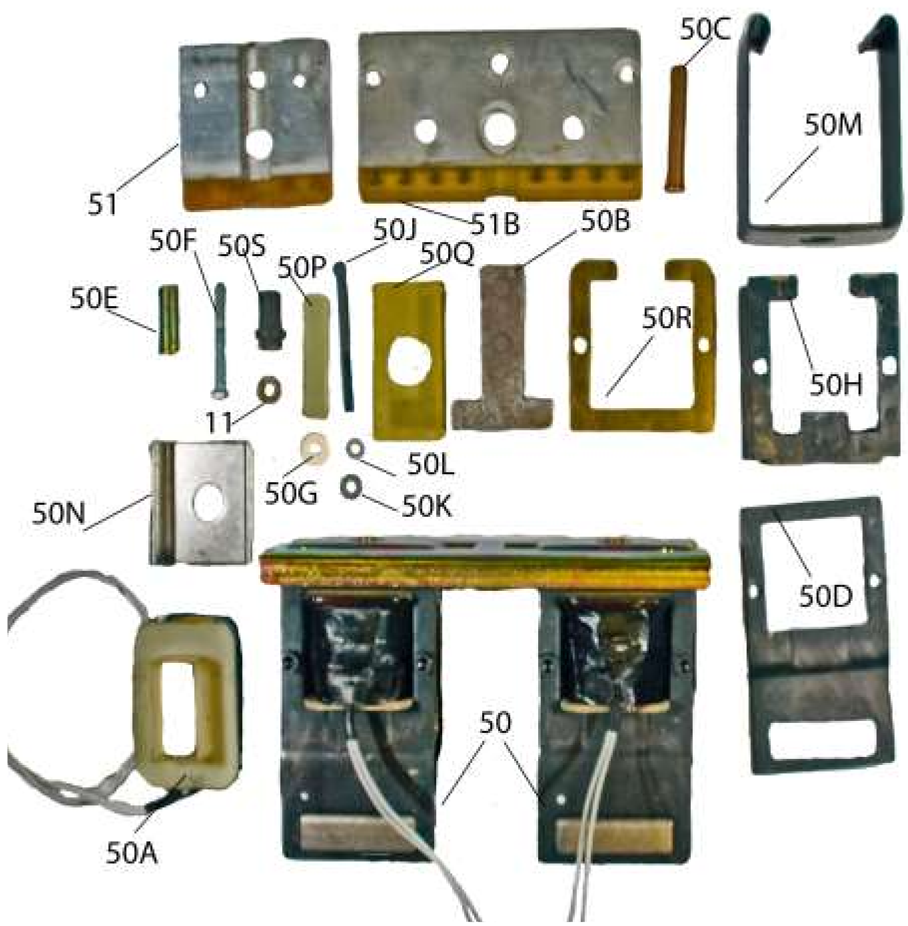

210, 211, 212
209
213, 214
215
216, 217
225, 226, 227, 228
219, 220
218, 219
221
222
223
224
CLOSED
OPEN

VBU Pole

Housings and Solenoids

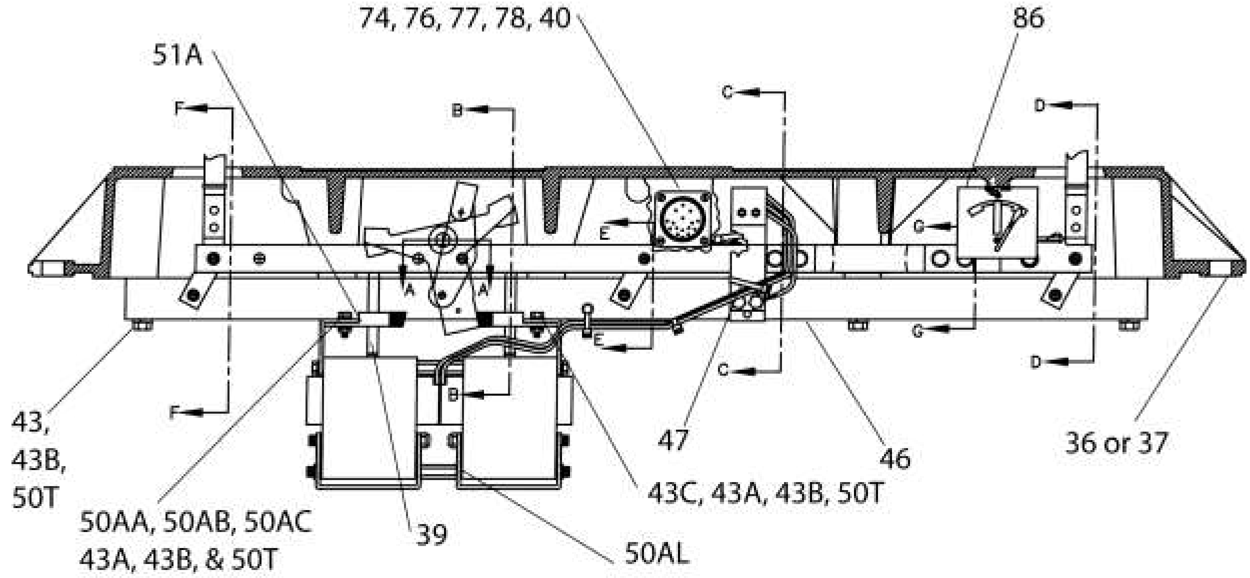
Mechanism for 15kV or 34kV Single Pole and 46kV or 69kV Switch





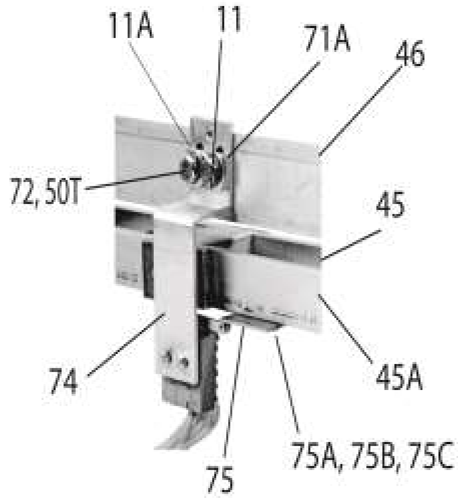
Exploded DECCO™ Solenoid and Associated Installation Parts

Mechanism for 15kV or 34kV Single Pole and 46kV or 69kV Switches with NAMCO™ Solenoids

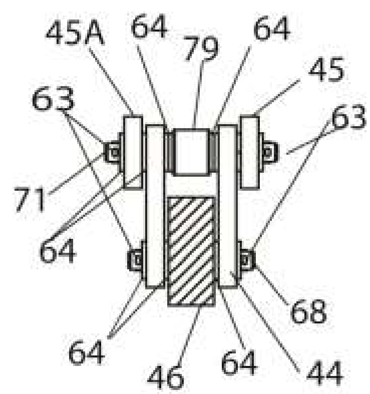


Exploded NAMCO™ Solenoid and Associated Installation Parts

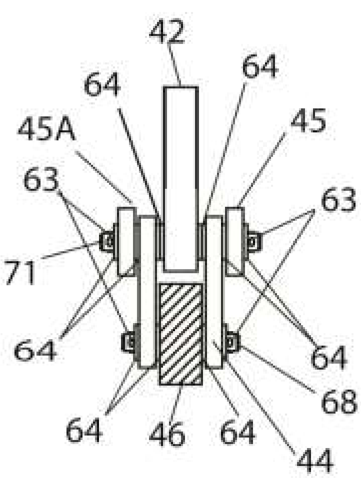
Cross Section Details from Views on Pages 45 & 46



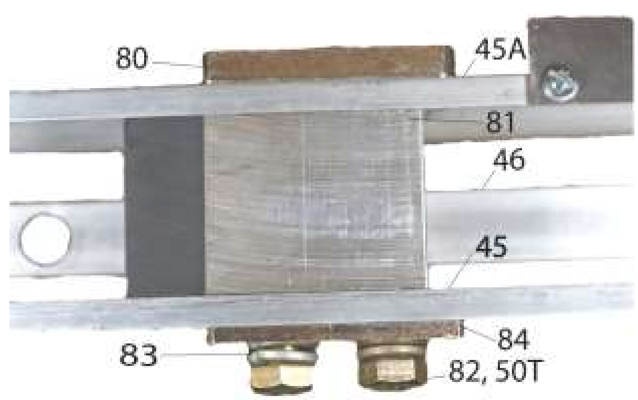
Section C-C



Section E-E

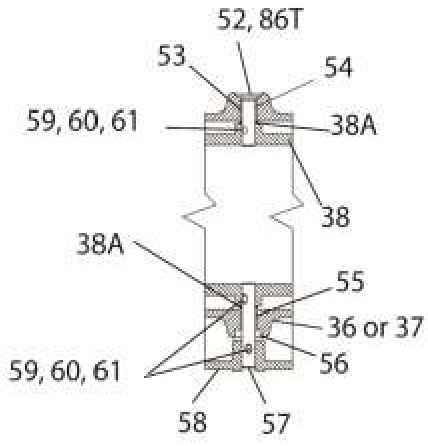


Sections D-D & F-F

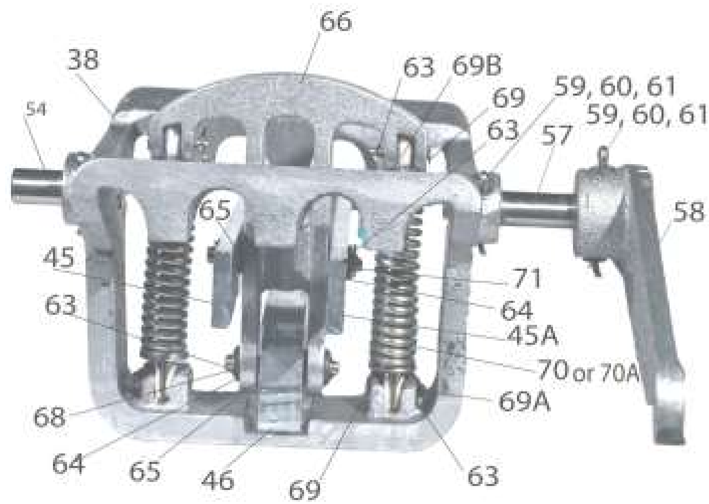


Bumper Assembly Section G-G

JOSLYN ™ Design of Control Yoke Assembly
(with cast aluminum handle & 1/2” shaft)

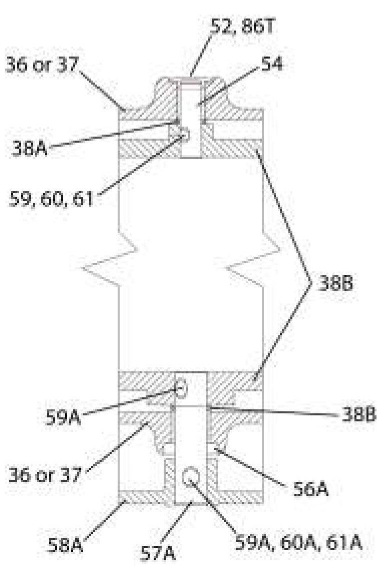


Section A-A

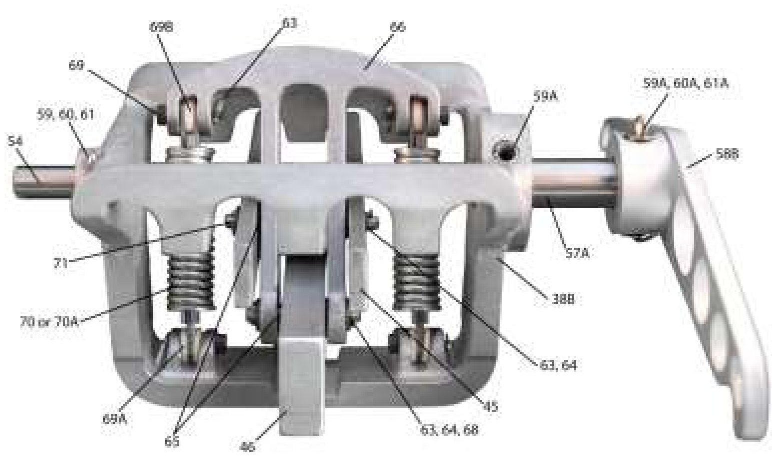


Section B-B

VES New Control Yoke Assembly
(with machined aluminum handle & 3/4” shaft)

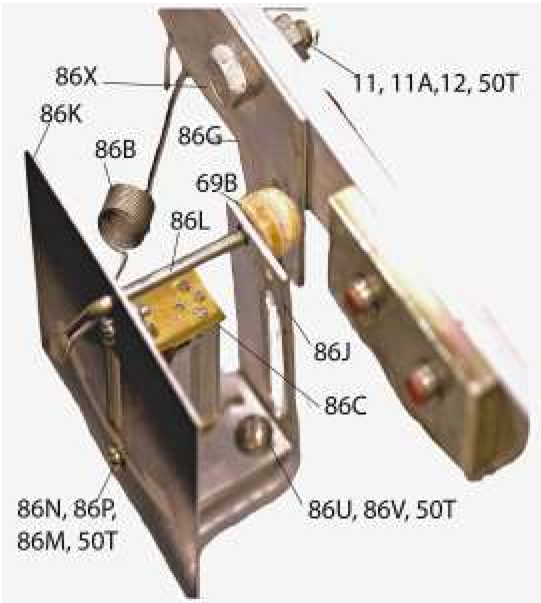


Section A-A

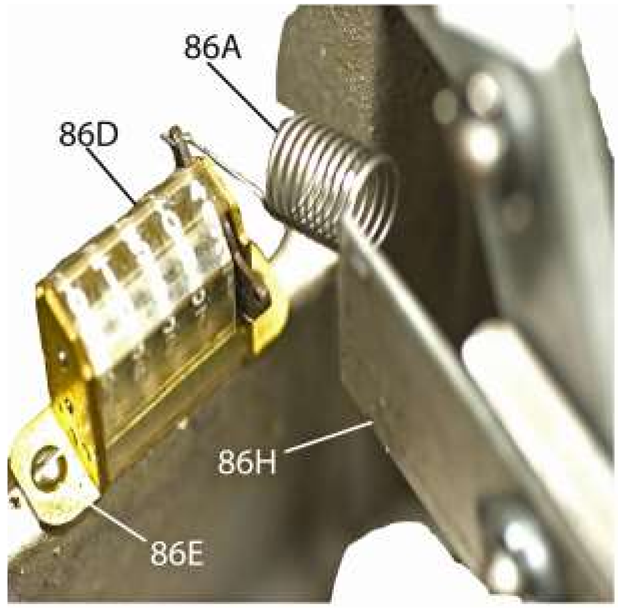


Section B-B

Counters and Position Indicators



Six Digit Counter & Position indicator



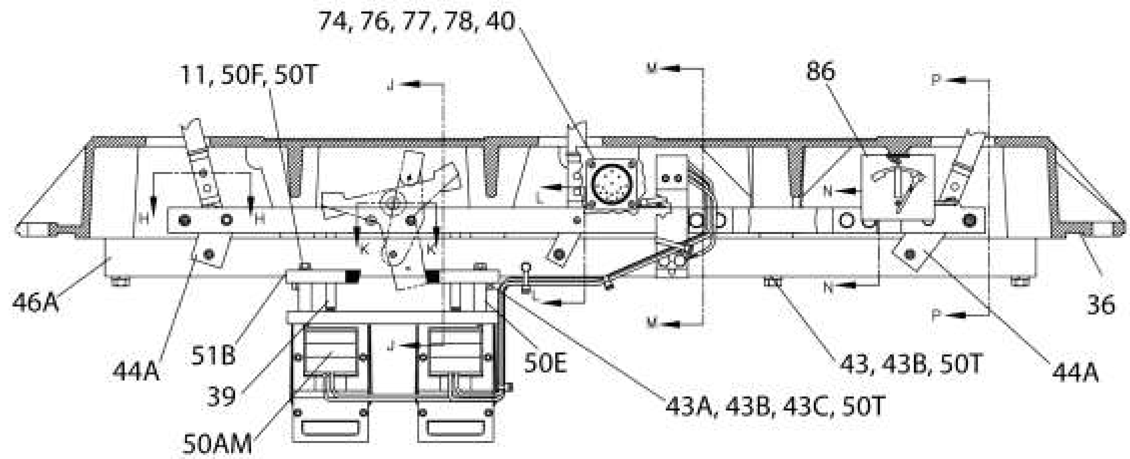
Five Digit Counter

The three different types of counters which have been used in manufacturing the VBM switch include a counter attached to the manual operating handle cover, the internal five digit counter, and the externally visible six digit counter. The five and six digit counters are shown above. The five digit and handle cover counters are not available.

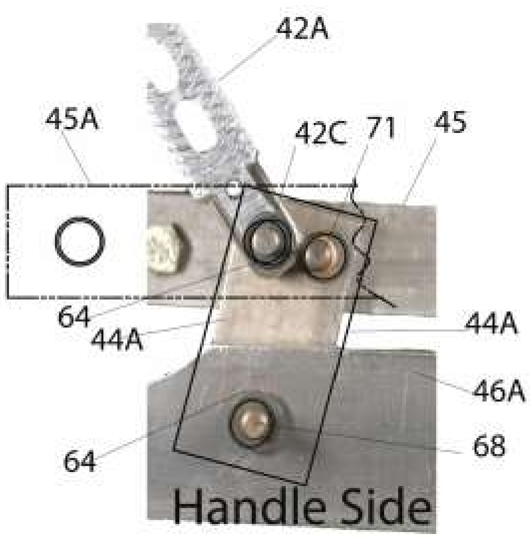
Five-Digit to Six-Digit Position Indicator Counter Conversion

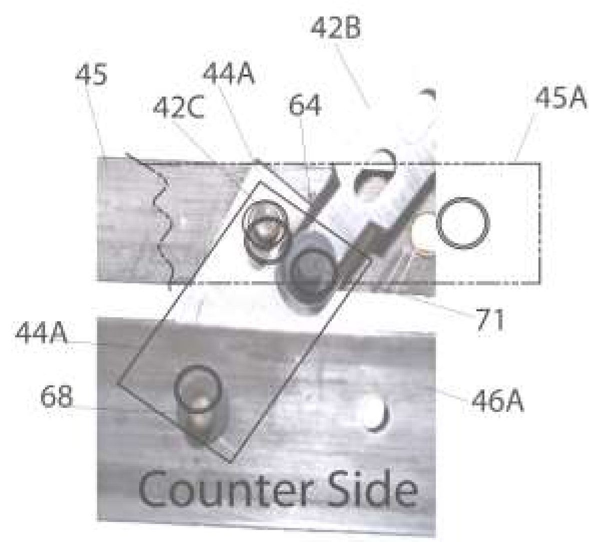
During switch overhauls at the Vacuum Electric Switch Co.™, old switches without externally visible counters are modified to use the new externally visible six digit counter with a position indicator. This upgrade makes it easier to track switch operations for purposes of scheduling maintenance. The modification can only be done in the shop because it requires welding in a boss and re-machining the switch mechanism casting. The window for the new counter and position indicator is sometimes located where the existing name plate is located. In this instance, the Vacuum Electric Switch Co. replaces the old name plate with a new name plate having the old serial number.

Mechanism for 34kV Three Pole Switch with DECCO™ Solenoids

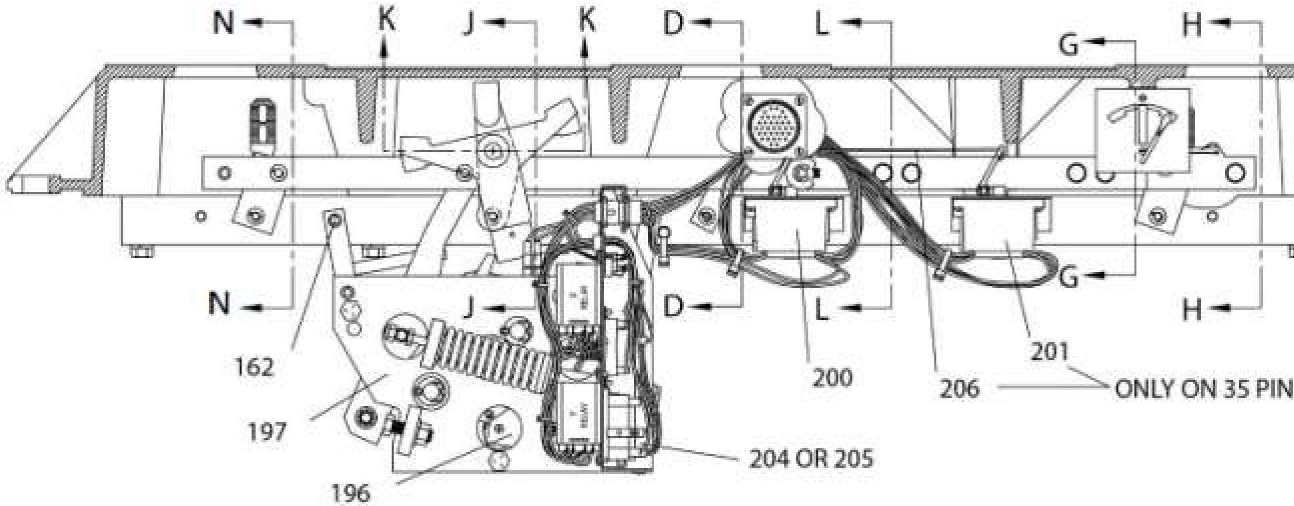


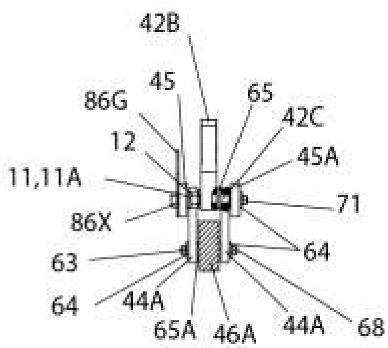
Linkage Assemblies for a 34 kV Three Pole Switch with Removed Parts Shown in Phantom



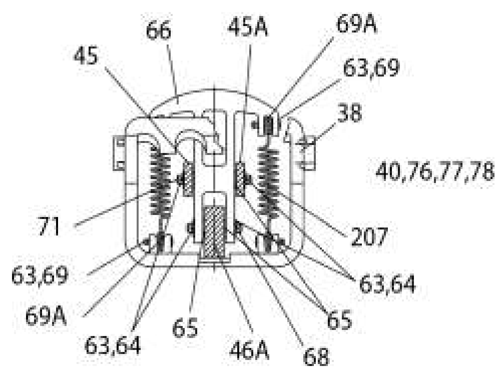


Mechanism Housing for 34kV Three Pole Motor Operated Switches
Operator Switches

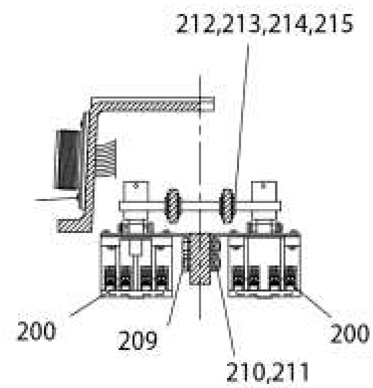




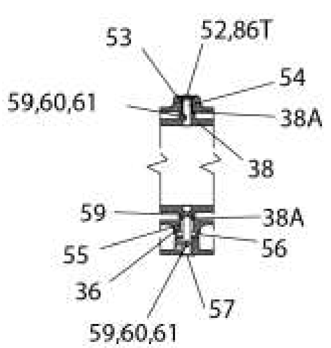
Section H-H



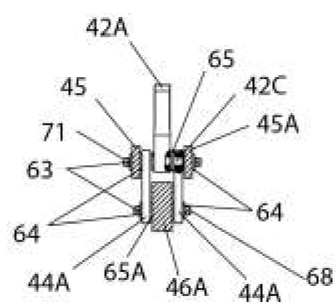
Section J-J



Section L-L

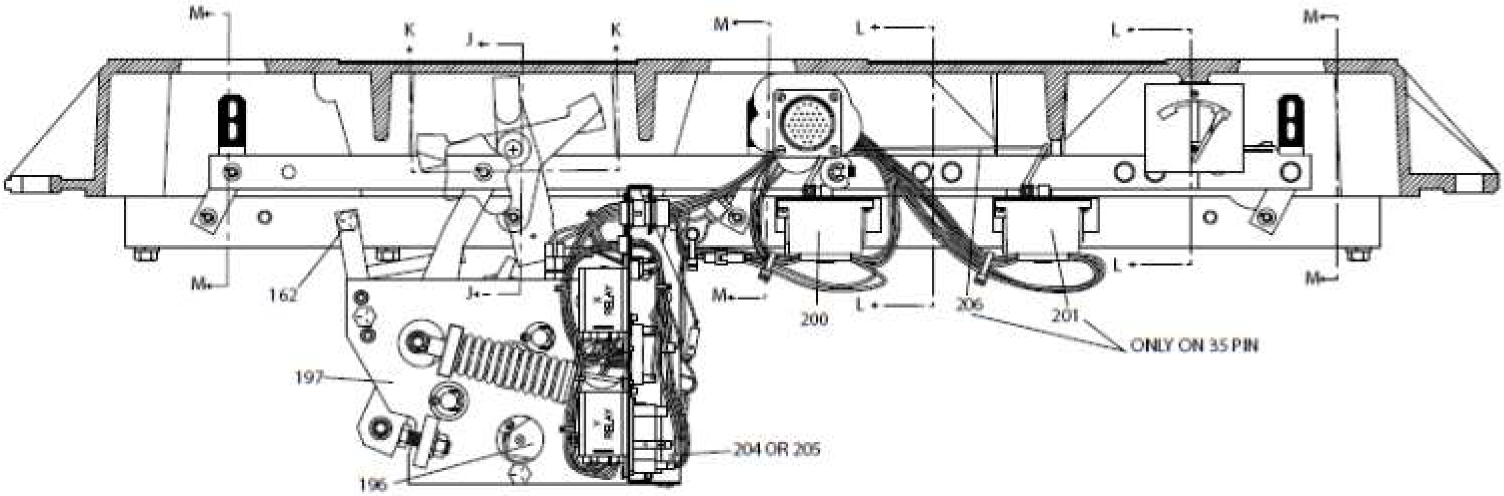


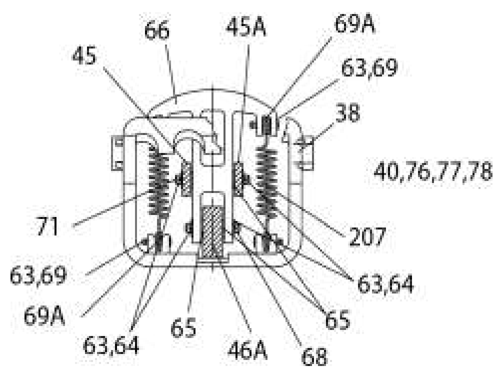
Section K-K



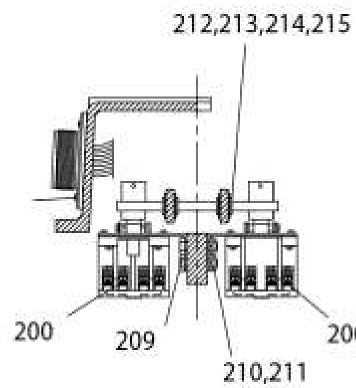
Section N-N

Mechanism Housing for 15 & 25 kV Three Pole Motor Operatated Switches

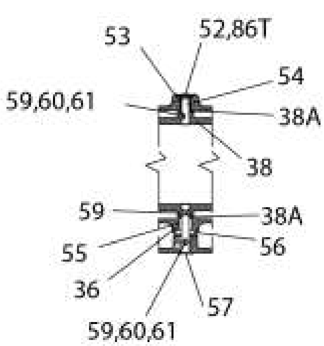




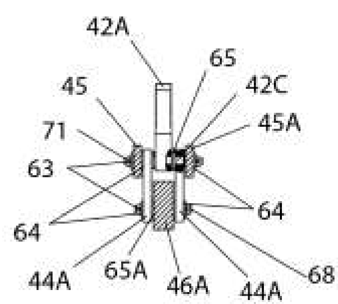
Section J-J



Section L-L

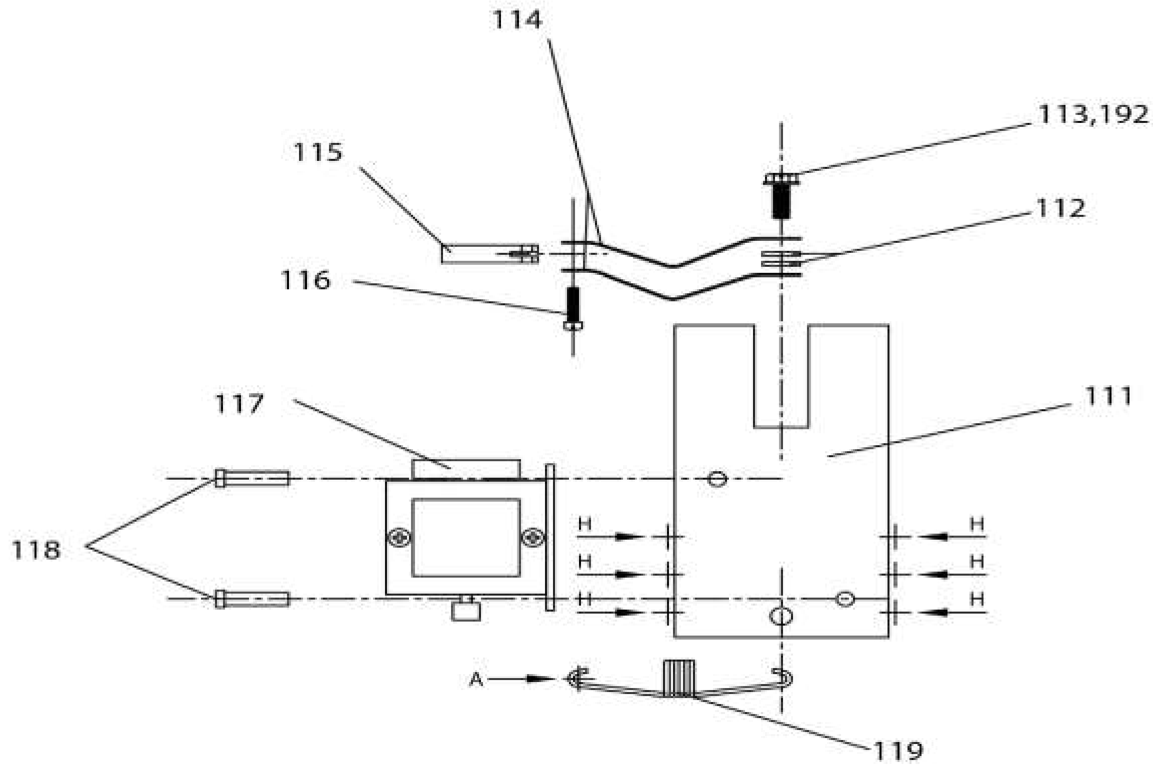


Section K-K

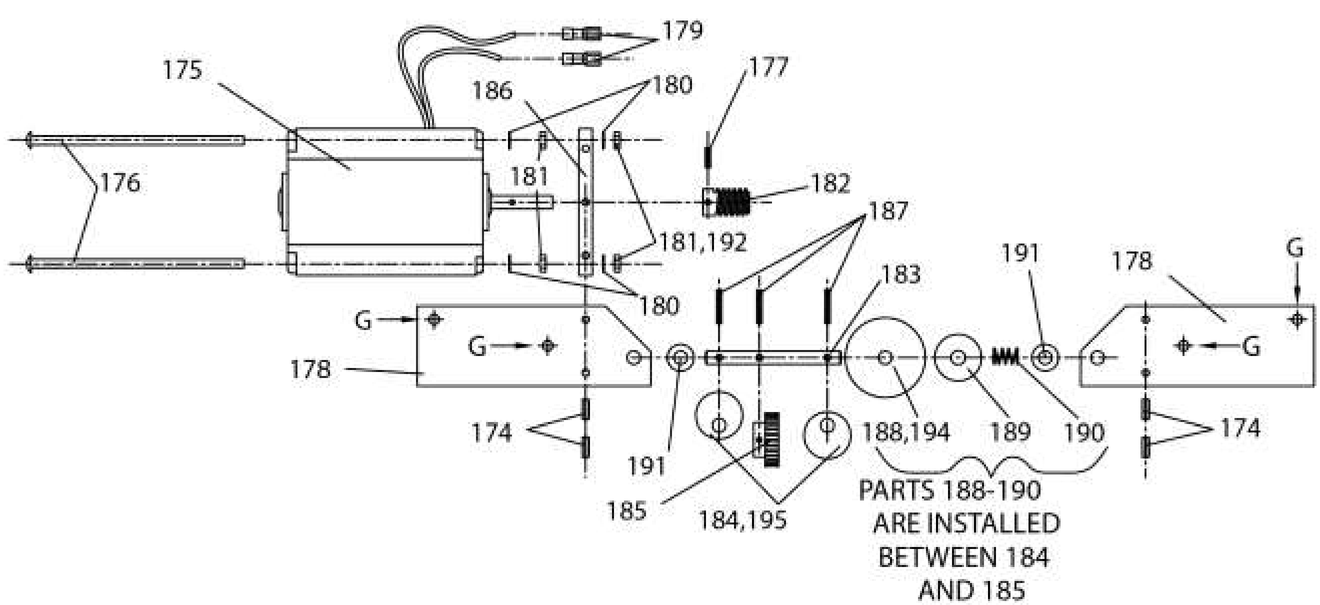


Section M-M

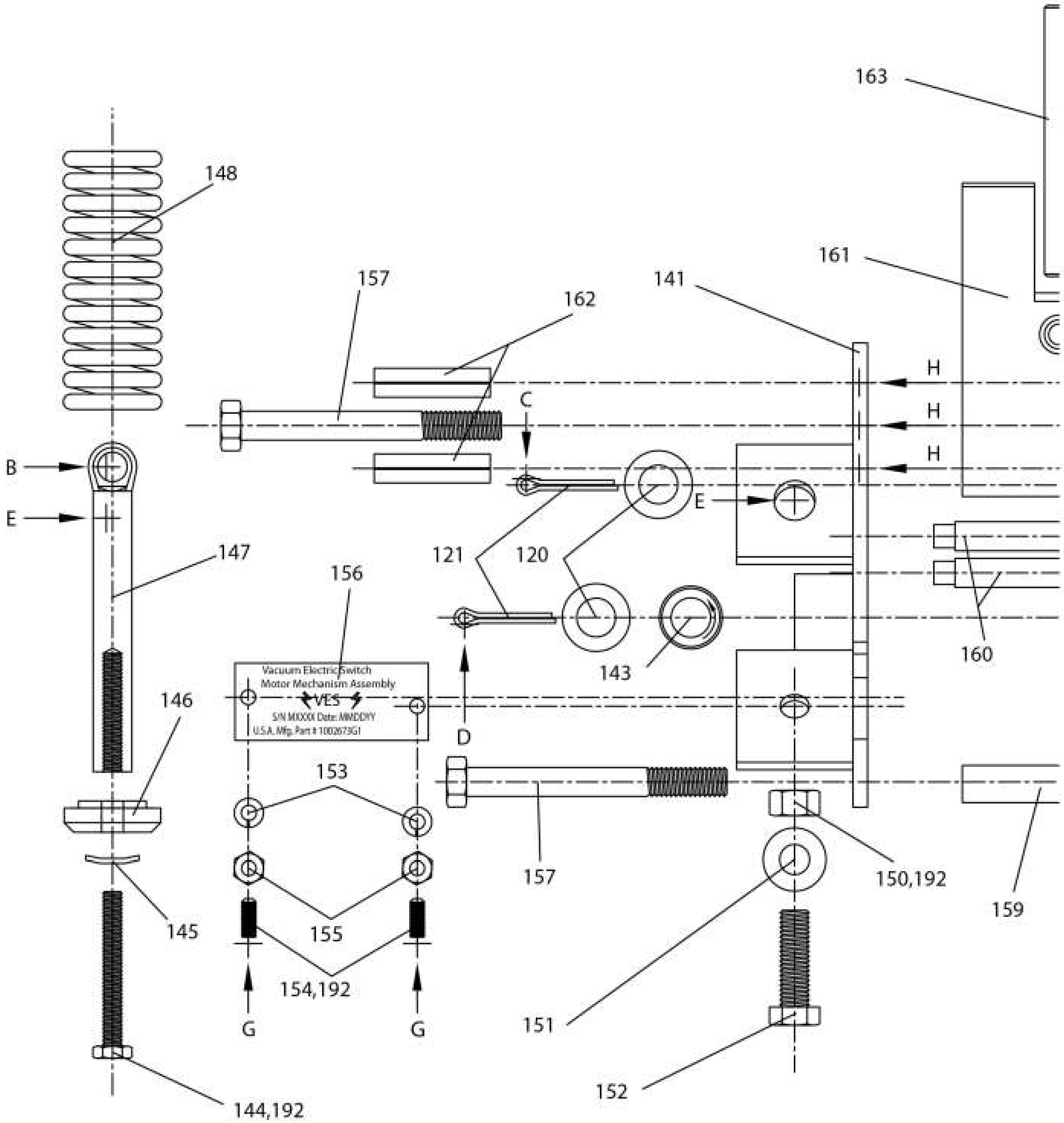
Motor Operator Rear Mounting Bracket Assembly



Motor Operator Standard Motor Assembly



Motor Operator Left Side Motor Plate Assembly

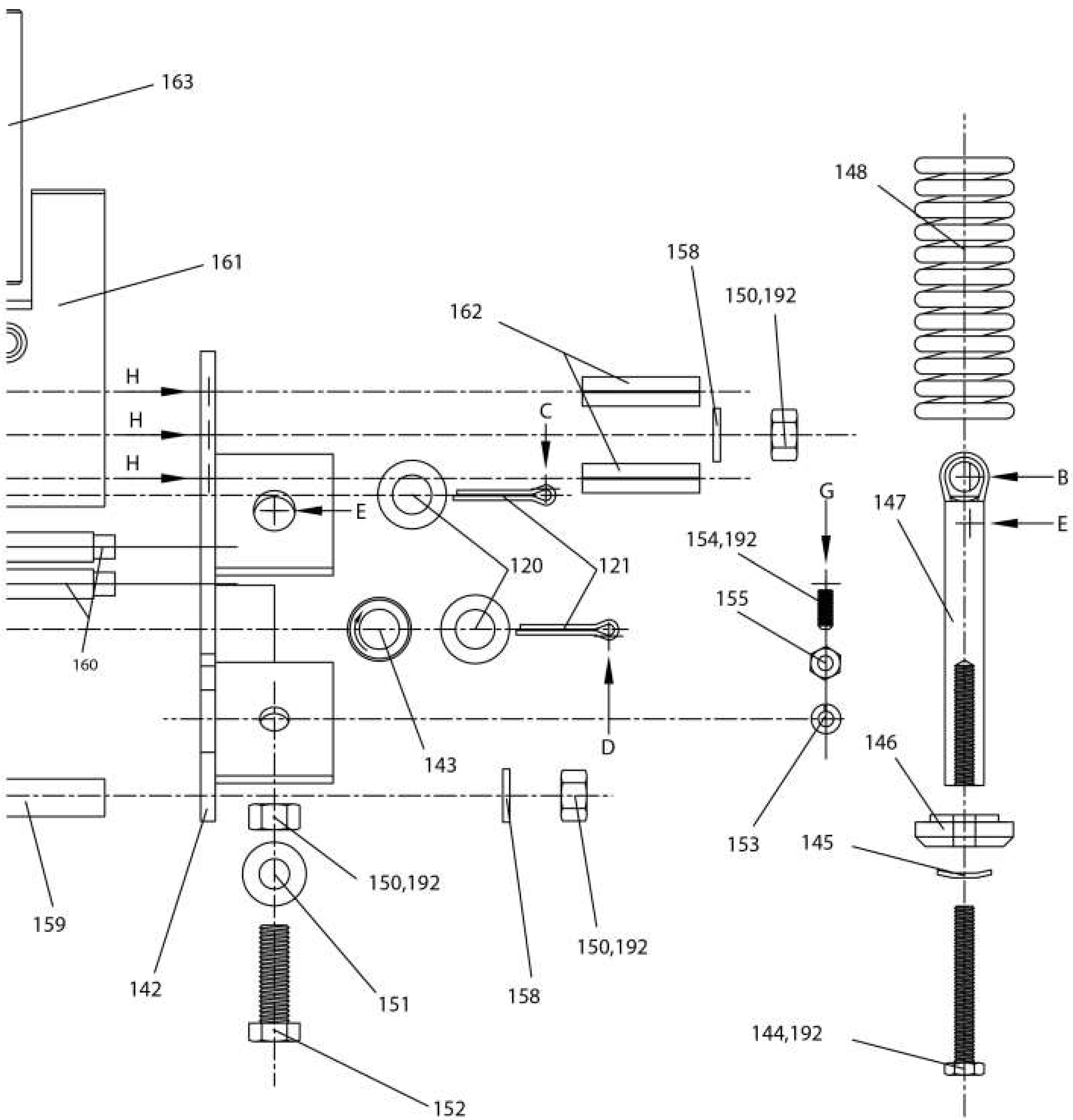


LEGEND

CONNECTION ON A DIFFERENT PLANE

CONNECTION ON THE SAME PLANE

Motor Operator Right Side Motor Plate Assembly

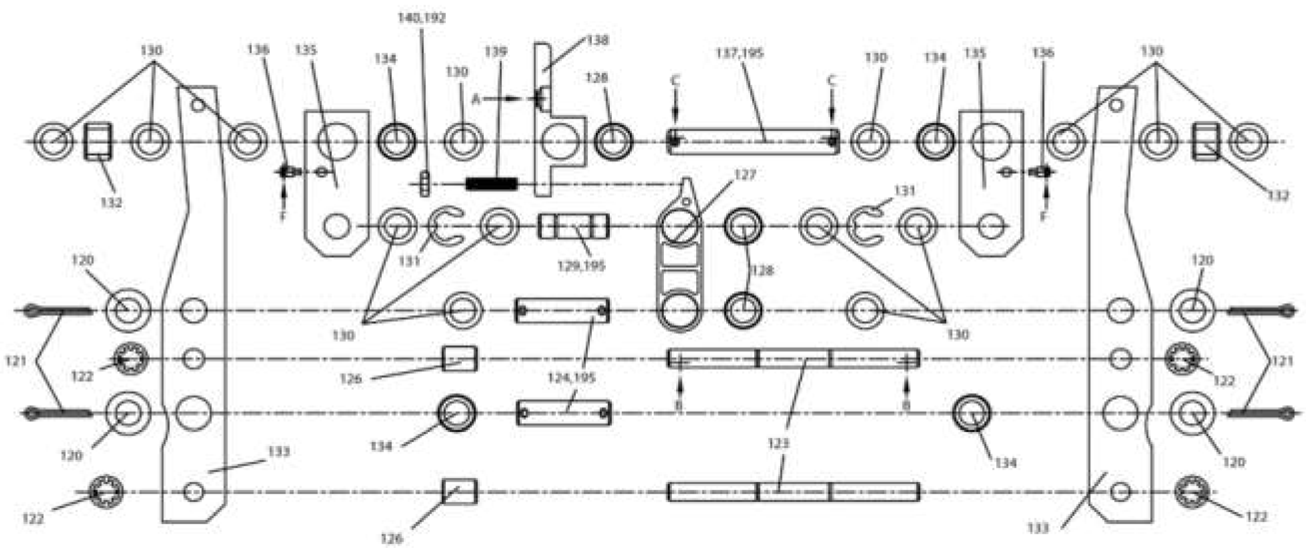


LEGEND

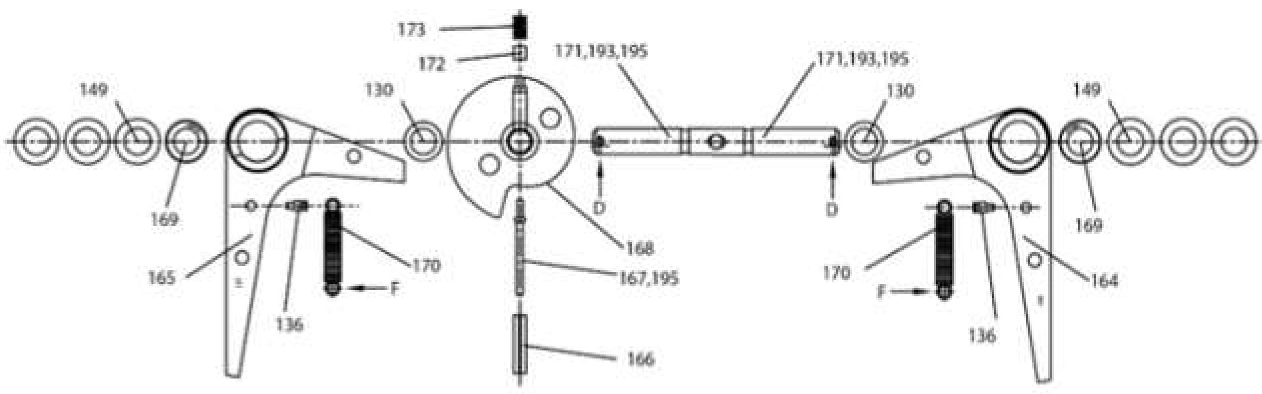
CONNECTION ON A DIFFERENT PLANE

CONNECTION ON THE SAME PLANE

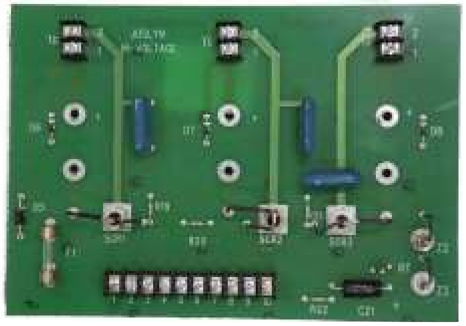
Toggle Link Components in Motor Mechanism Assembly



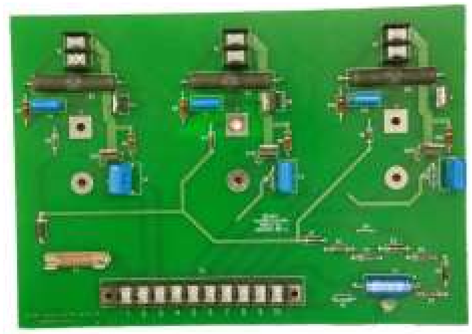
Clutch Arm Cam Motor Mechanism Assembly



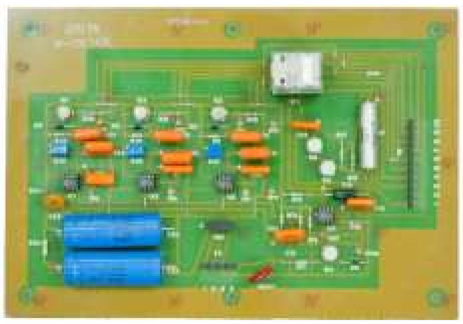
Replacement Parts for Joslyn™ Controls



Joslyn SCR Board



VES Replacement SCR Board



Joslyn Timing Board

VES Replacement Timing Board

The two Joslyn™ circuit boards shown above are used by Joslyn in both their zero-voltage control for capacitor banks and also their Point-of-Wave™ controls for arc furnaces. Shown opposite the Joslyn boards are the Vacuum Electric Switch's foot-print and plug-for-plug compatible replacement board. The SCR boards are functionally equivalent except that the VES board (part no.1002100G1) has transient suppression components on the board whereas the Joslyn board requires that they be installed at the terminal connections during the board installation.

While functionally equivalent, the timing boards are designed using different concepts. The Joslyn timing board has analog circuitry to control the timing. The timing adjustments are made by turning three trip potentiometers on the board. The Vacuum Electric Switch timing board has digital circuitry. The timing is controlled with crystal oscillator, and the switch timing can be digitally set in increments of 25 microseconds. The VES digital board has an RS232 connection which can be connected to a computer and used to measure and set switch timing.

VES Timing Boards	
Voltage	VES part No.
120VAC	1002121G1
125VDC	1002121G2
24VDC	1002121G4

Replacement Parts List

Item No.	Description	Joslyn™ Part No.	New VES™ Part No.
1	Mechanism assembly, 15kV solenoid operated three pole switches	3021X0242 P001	
1A	Mechanism assembly, 3, 46, & 69kV solenoid operated two pole switches		
1B	Mechanism assembly 34kV solenoid operated three pole switches		
1C	Mechanism assembly 34kV motor operated three pole switches		
1D	Mechanism assembly 15kV motor operated three pole switches		
2A	Fracture resistant vacuum interrupter module, 15kV 600A without pull rod	3021X0242 P003	1000674G1
2B	Fracture resistant vacuum interrupter module, 34kV 600A without pull rod	3021X0242 P005	1000674G1
2C	Fracture resistant vacuum interrupter module, 46kV 600A without pull rod	3021X0242 P007	1000674G1
2D	Double stack module, silicone rubber sheds, 300A	3021X0242 P401	1001184G1
2E	Single module with silicone rubber sheds, 300A		1001989G1
2F	Double stack module for 46 & 69kV 300A switch	3021X0242 P401	1001184G6
2G	Module with grading capacitors, 34kV 600A, without pull rod		
2H	Single module having grading capacitors with silicone rubber sheds, 300A, for 46kV switch		
2I	Double stack module having grading capacitors with silicone rubber sheds, 300A, for 46 & 69kV switch		
2J	Double stack module having grading capacitors with silicone rubber sheds, 300A for 34kV three pole switch		
3	Bolt, hex head, 1/4-20 x 2½" SST	3021X0242 P008	1000587
3A	Bolt, hex head, 1/4-20 x 2" SST		1001242
3B	Bolt, hex head, 1/4-20 x 1" SST		1001225
3C	Bolt, hex head, 1/4-20 x 1½" SST		1000120
4	Washer, Belleville SST	3021X0242 P009	1000640
5	Washer, flat, 9/32 ID x 5/8" OD x 1/16" alum.	3021X0242 P010	1000635
6	Gasket, obsolete	3021X0242 P011	
7	Nut, hex, 1/4-20 SST	3021X0242 P012	1000583
8	Insulator, 15kV, skirted	3021X0242 P014	1000662
9	Bolt, hex head, 1/4-20 x 1¼" SST	3021X0242 P015	1000106
10	Bolt, hex head, 1/4-20 x 1¼" L, Gr. 8	3021X0242 P016	1000601
10A	Bolt, hex head, 1/4-20 x 1" L, Gr. 8		1000018
11	Washer, split lock, 1/4" standard, Gr. 5 & 8	3021X0242 P017	1000008
11A	Washer, SAE flat, 1/4"		1000013
12	Nut, hex head, 1/4-20 standard, Gr. 8	3021X0242 P018	1000027
13	Obsolete		
14	Mechanism casket, 10 hole	D63293P1	1000107P1
14A	Mechanism casket, 12 hole	3021D0422P1	1000107P2
15	Mechanism cover, 10 hole	3021X0242 P021	1000568P1
15A	Mechanism cover , 12 hole		1001809P1
16	Screw, pan head, Phillips, 1/4–20 x 1" SST	3021X0242 P022	1000595
17	Washer, split lock, 1/4" standard, SST	3021X0242 P023	1000110
18	Screw, indented hex head, 6-32 x 3/8" L, SST	3021X0242 P024	1000931
19	Drierite™ desiccant 2 oz. calcium sulfate in sealed bag	3021X0242 P025	1000924
20	Bolt, hex head, 3/8-16 x 1" L	3021X0242 P026	1000111
21	Washer, split lock, 3/8" standard	3021X0242 P027	1000112
22	Closure plate	3021X0242 P101	1001996P1
23	Clamping plate, 1/4-20 tapped hole (use with parts 10A & 11)	3021X0242 P102	1000644P1
23A	Clamping plate, 3/8-16 tapped hole (use with parts 20 & 21)		

Item No.	Description	Joslyn™ Part No.	New VES™ Part No.
23A	Clamping plate, 3/8-16 tapped hole (use with parts 20 & 21)		1000644P1
24	Breather bag	3021X0242 P103	1000114P1
24A	Sheet metal shroud covers breather bag	3021D0113P2	1000580P1
24B	Valve, Schrader		1000534
24C	Screw, pan head, 1/4-20 x 5/8" plastic, black		1000414
24D	Bolt, hex head, 1/4-20" x 1/2" SST		1001821
24E	Washer, flat, 1/4" ID x 1/2" OD, SST		1001823
25	Screw, slotted head, 10-32 x 3/8" L, SST	3021X0242 P104	1000507
26	Handle cover with three screw holes	3021X0242 P105	1000578P2
26A	Handle cover with two screw holes		1000578P3
26B	Counter for handle cover, 5 digit		1000925
27	Mechanism assembly 34 & 46kV	3021X0242 P106	
28	Bolt, hex head, 1/2-13 x 1¼" L, SST	3021X0242 P107	1000029
29	Washer, Belleville, 1/2" SST	3021X0242 P108	1000055
30	Nut, hex, 1/2-13 standard, SST	3021X0242 P109	1000030
30A	Washer, flat, 1/2" thick SST		1000054
30B	Noalox™ 8 oz.		1000021
30C	Connecting bar for 34kV harmonic filter switch		1000544P1
30D	Connecting bar for 46kV double stack switch		1001983P1
31	Connecting buss bar for 34, 46 & 69kV 600A switches	3021X0242 P110	1000508P2
32	O-ring, 3½" ID x 3¾" OD x 1/8", dash 238	3021X0242 P111	1000638
33	Insulator, 34kV skirted	3021X0242 P112	1000661
33A	Insulator, 46kV skirted	3021X0242 P113	1001940
34	Bolt, hex head, 1/4-20 x 1¾" L, SST	3021X0242 P114	1000684
35	Gasket, Teflon	3021X0242 P115	1000121P1
36	Mechanism housing for 15kV or 34kV three pole	3021X0242 P116	1000564P1
37	Mechanical housing for 34, 46, or 69kV two hole	3021X0242 P117	1000563P1
38	Control yoke	3021X0242 P118	1000500P2
38A	Washer, Nylatron, 1/2" ID x 0.031"		1000610
38B	Washer, Nylatron, 1.125" OD x 0.753" ID x 0.030" thick		1002080
38C	Control Yoke, 3/4”		1002068P1
39	Nylon pin	3021X0242 P119	1000376P1
40	Dust cap	3021X0242 P120	1000124
41	Connector obsolete	3021X0242 P121	
42	Pull rod, clevis	3021X0242 P122	1000023G1
42A	Pull rod, clevis, for handle side of 34kV three pole switch		1001125G1
42B	Pull rod, clevis, for position indicator counter side of 34kV 300A three pole switch		1001122G1
42C	Clevis shaft for use with 42A & 42B		1001121P1
43	Bolt, hex head, 3/8-16 x 2¼" L, Gr. 8, SST	3021X0242 P123	1000602
43A	Bolt, hex head, 3/8-16 x 2½" L, Gr. 8		1000997
43B	Washer, split lock, 3/8", Gr. 8		1000112
43C	Screw lock, Helicoil, 3/8-16 (used with 43A)		1000012
44	Actuator bar link	3021X0242 P124	1000514G1
44A	Actuator bar link for 34kV three pole switch		1001119G1
45	Actuator bar without screw holes for aux switch plate	3021X0242 P125	1000513G1
45A	Actuator bar with screw holes for aux switch actuator plate	3021X0242P125	1000513G2
46	Support bar with mounting holes for Eaton™ aux switch	3021X0242 P126	1000512G1
46A	Support bar for 34kV 300A three pole switch		1000512G2

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
57A	Shaft (LONG) 3/4” dia.		1002062P1
58	Actuating arm, Joslyn™ design for 1/2" dia. shaft	3021X0242 P211	1000498P2
58B	Operator handle, 0.5" dia. shaft		1002063P1
59	Pin, Sel-lock, 1/4" dia.	3021X0242 P212	1000051
59A	Spring pin, 3/8"dia. x 1½"		1002289
59B	Spring pin, 3/8" dia. x 2"		1002288
60	Cotter pin, (MONEL) 1/8" x 1½"	3021X0242 P213	1000681
60A	Cotter pin, 1/8" x 2 L, zinc plated steel		1002147
61	Washer, flat, 0.156" ID x 0.375" OD x 0.036-.065" thick	3021X0242 P214	1000730
61A	Washer, 0.438" OD x 0.188" ID, 18/8 SST		1002590
62	Lockwire, 0.032 dia., 1/8 hard, 303 SST	3021X0242 P215	1000387
63	Cotter pin, (MONEL) 1/16" x 1/2"	3021X0242 P216	1000446
64	Washer, Nylatron spacer, 0.062" thick	3021X0242 P217	1000098
65	Washer, Nylatron spacer, 0.015" thick	3021X0242 P218	1000096
65A	Washer, Nylatron spacer, 0.032" thick		1000097
66	Toggle link	3021X0242 P219	1000499G1
67	Plain bearing, 1/4" x 3/8" x 1/4" L	3021X0242 P220	1000002
68	Link pivot pin (SHORT PIN) 1/4" dia.	3021X0242 P221	1000057P1
69	Clevis pin, spring retaining 1/8" dia. x 7/8"	3021X0242 P222	1000024P3
69A	Washer, wool felt, 0.062" thick		1000725
69B	Washer, wool felt, 0.125" thick		1000724
70	Spring assembly for 15, 34, 46kV 600A switch and 46 & 69kV 300A switch	3021X0242 P223	1000390G1
70A	Spring assembly for 34kV 300A three pole switch		1000390G2
71	Clevis pin, 1/4" dia.	3021X0242 P224	1000058P1
71A	Locking plate, 1.25" x 0.0625" x 0.125"		1000606P1
72	Bolt, hex head, 1/4-20 x 3/4", Gr. 8	3021X0242 P225	1000391
73	Washer, flat, 1/4" nom. x 9/16" OD, zinc plated steel	3021X0242 P226	1000392
74	Wiring harness, Eaton™ auxiliary switch, & environmental connector with bracket and crimp connectors on wires	3021X0242 P227	1000521G1
75	Plate, switch actuating	3021X0242 P301	1000530P1
75A	Screw, slotted round head, 6-32 x 3/8" L		1000460
75B	Washer, internal tooth, #6		1000604
75C	Loctite 290™, green		1000605
76	Screw, Fillister head	3021X0242 P302	1000395
77	Washer, split lock, standard, #6	3021X0242 P303	1000594
78	Gasket (RECEPTACLE)	3021X0242 P304	1000148P1
79	Spacer	3021X0242 P305	1000398
80	Tapped bar	3021X0242 P306	1000589P1
81	Bumper assembly	3972X0062 P307	1000016G1
82	Bolt, hex head, 5/16-18 x 2¼" L, Gr. 8	3021X0242 P308	1000400
83	Washer, split lock, 5/16" standard	3021X0242 P309	1000323
84	Spacer bar	3021X0242 P310	1000588P1
85	Spacer, Nylon, obsolete		
85A	Insertion resistor, 80 ohm	3021X0242P413	1002256G1
86	Six digit counter & position indicator assembly	3021X0242 P415	1000527G1
86A	Counter spring for 5 digit couner	3021X0242 P321	1000146
86B	Counter spring for 6 digit counter		1000147P1
86C	Counter, 6 digit		1000436
86D	Counter, 5 digit	3021X0242P320	1000437
86E	Screws for attaching 5 digit counter		1000479
86G	Counter actuator plate, 6 digit		1000509P1

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
57A	Shaft (LONG) 3/4” dia.		1002062P1
58	Actuating arm, Joslyn™ design for 1/2" dia. shaft	3021X0242 P211	1000498P2
58B	Operator handle, 0.5" dia. shaft		1002063P1
59	Pin, Sel-lock, 1/4" dia.	3021X0242 P212	1000051
59A	Spring pin, 3/8"dia. x 1½"		1002289
59B	Spring pin, 3/8" dia. x 2"		1002288
60	Cotter pin, (MONEL) 1/8" x 1½"	3021X0242 P213	1000681
60A	Cotter pin, 1/8" x 2 L, zinc plated steel		1002147
61	Washer, flat, 0.156" ID x 0.375" OD x 0.036-.065" thick	3021X0242 P214	1000730
61A	Washer, 0.438" OD x 0.188" ID, 18/8 SST		1002590
62	Lockwire, 0.032 dia., 1/8 hard, 303 SST	3021X0242 P215	1000387
63	Cotter pin, (MONEL) 1/16" x 1/2"	3021X0242 P216	1000446
64	Washer, Nylatron spacer, 0.062" thick	3021X0242 P217	1000098
65	Washer, Nylatron spacer, 0.015" thick	3021X0242 P218	1000096
65A	Washer, Nylatron spacer, 0.032" thick		1000097
66	Toggle link	3021X0242 P219	1000499G1
67	Plain bearing, 1/4" x 3/8" x 1/4" L	3021X0242 P220	1000002
68	Link pivot pin (SHORT PIN) 1/4" dia.	3021X0242 P221	1000057P1
69	Clevis pin, spring retaining 1/8" dia. x 7/8"	3021X0242 P222	1000024P3
69A	Washer, wool felt, 0.062" thick		1000725
69B	Washer, wool felt, 0.125" thick		1000724
70	Spring assembly for 15, 34, 46kV 600A switch and 46 & 69kV 300A switch	3021X0242 P223	1000390G1
70A	Spring assembly for 34kV 300A three pole switch		1000390G2
71	Clevis pin, 1/4" dia.	3021X0242 P224	1000058P1
71A	Locking plate, 1.25" x 0.0625" x 0.125"		1000606P1
72	Bolt, hex head, 1/4-20 x 3/4", Gr. 8	3021X0242 P225	1000391
73	Washer, flat, 1/4" nom. x 9/16" OD, zinc plated steel	3021X0242 P226	1000392
74	Wiring harness, Eaton™ auxiliary switch, & environmental connector with bracket and crimp connectors on wires	3021X0242 P227	1000521G1
75	Plate, switch actuating	3021X0242 P301	1000530P1
75A	Screw, slotted round head, 6-32 x 3/8" L		1000460
75B	Washer, internal tooth, #6		1000604
75C	Loctite 290™, green		1000605
76	Screw, Fillister head	3021X0242 P302	1000395
77	Washer, split lock, standard, #6	3021X0242 P303	1000594
78	Gasket (RECEPTACLE)	3021X0242 P304	1000148P1
79	Spacer	3021X0242 P305	1000398
80	Tapped bar	3021X0242 P306	1000589P1
81	Bumper assembly	3972X0062 P307	1000016G1
82	Bolt, hex head, 5/16-18 x 2¼" L, Gr. 8	3021X0242 P308	1000400
83	Washer, split lock, 5/16" standard	3021X0242 P309	1000323
84	Spacer bar	3021X0242 P310	1000588P1
85	Spacer, Nylon, obsolete		
85A	Insertion resistor, 80 ohm	3021X0242P413	1002256G1
86	Six digit counter & position indicator assembly	3021X0242 P415	1000527G1
86A	Counter spring for 5 digit couner	3021X0242 P321	1000146
86B	Counter spring for 6 digit counter		1000147P1
86C	Counter, 6 digit		1000436
86D	Counter, 5 digit	3021X0242P320	1000437
86E	Screws for attaching 5 digit counter		1000479
86G	Counter actuator plate, 6 digit		1000509P1

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
57A	Shaft (LONG) 3/4” dia.		1002062P1
58	Actuating arm, Joslyn™ design for 1/2" dia. shaft	3021X0242 P211	1000498P2
58B	Operator handle, 0.5" dia. shaft		1002063P1
59	Pin, Sel-lock, 1/4" dia.	3021X0242 P212	1000051
59A	Spring pin, 3/8"dia. x 1½"		1002289
59B	Spring pin, 3/8" dia. x 2"		1002288
60	Cotter pin, (MONEL) 1/8" x 1½"	3021X0242 P213	1000681
60A	Cotter pin, 1/8" x 2 L, zinc plated steel		1002147
61	Washer, flat, 0.156" ID x 0.375" OD x 0.036-.065" thick	3021X0242 P214	1000730
61A	Washer, 0.438" OD x 0.188" ID, 18/8 SST		1002590
62	Lockwire, 0.032 dia., 1/8 hard, 303 SST	3021X0242 P215	1000387
63	Cotter pin, (MONEL) 1/16" x 1/2"	3021X0242 P216	1000446
64	Washer, Nylatron spacer, 0.062" thick	3021X0242 P217	1000098
65	Washer, Nylatron spacer, 0.015" thick	3021X0242 P218	1000096
65A	Washer, Nylatron spacer, 0.032" thick		1000097
66	Toggle link	3021X0242 P219	1000499G1
67	Plain bearing, 1/4" x 3/8" x 1/4" L	3021X0242 P220	1000002
68	Link pivot pin (SHORT PIN) 1/4" dia.	3021X0242 P221	1000057P1
69	Clevis pin, spring retaining 1/8" dia. x 7/8"	3021X0242 P222	1000024P3
69A	Washer, wool felt, 0.062" thick		1000725
69B	Washer, wool felt, 0.125" thick		1000724
70	Spring assembly for 15, 34, 46kV 600A switch and 46 & 69kV 300A switch	3021X0242 P223	1000390G1
70A	Spring assembly for 34kV 300A three pole switch		1000390G2
71	Clevis pin, 1/4" dia.	3021X0242 P224	1000058P1
71A	Locking plate, 1.25" x 0.0625" x 0.125"		1000606P1
72	Bolt, hex head, 1/4-20 x 3/4", Gr. 8	3021X0242 P225	1000391
73	Washer, flat, 1/4" nom. x 9/16" OD, zinc plated steel	3021X0242 P226	1000392
74	Wiring harness, Eaton™ auxiliary switch, & environmental connector with bracket and crimp connectors on wires	3021X0242 P227	1000521G1
75	Plate, switch actuating	3021X0242 P301	1000530P1
75A	Screw, slotted round head, 6-32 x 3/8" L		1000460
75B	Washer, internal tooth, #6		1000604
75C	Loctite 290™, green		1000605
76	Screw, Fillister head	3021X0242 P302	1000395
77	Washer, split lock, standard, #6	3021X0242 P303	1000594
78	Gasket (RECEPTACLE)	3021X0242 P304	1000148P1
79	Spacer	3021X0242 P305	1000398
80	Tapped bar	3021X0242 P306	1000589P1
81	Bumper assembly	3972X0062 P307	1000016G1
82	Bolt, hex head, 5/16-18 x 2¼" L, Gr. 8	3021X0242 P308	1000400
83	Washer, split lock, 5/16" standard	3021X0242 P309	1000323
84	Spacer bar	3021X0242 P310	1000588P1
85	Spacer, Nylon, obsolete		
85A	Insertion resistor, 80 ohm	3021X0242P413	1002256G1
86	Six digit counter & position indicator assembly	3021X0242 P415	1000527G1
86A	Counter spring for 5 digit couner	3021X0242 P321	1000146
86B	Counter spring for 6 digit counter		1000147P1
86C	Counter, 6 digit		1000436
86D	Counter, 5 digit	3021X0242P320	1000437
86E	Screws for attaching 5 digit counter		1000479
86G	Counter actuator plate, 6 digit		1000509P1

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
86H	Counter actuator plate, 5 digit	3021X0242P322	1000758P1
86J	Bracket, position indicator		1000526P1
86K	Faceplate, position indicator		1000193P1
86L	Pointer, position indicator		1000192P1
86M	Screw, round head, 4-40 x 3/8" L, zinc plated steel		1000283
86N	Nut, hex, 4-40, standard, zinc plated steel		1000299
86P	Washer, split lock, #4, standard, zinc plated steel		1000279
86Q	Window retaining ring, 5/8" for thin wall casting		1000125P1
86R	Window retaining ring, 3/4" for thick wall casting		1000125P2
86S	Glass	3021X0242 P414	1000153
86T	RTV sealant		1000245
86U	Washer, internal shake proof, #10		1000608
86V	Screw, round head, #10, 3/8" L, zinc plated steel		1000293
86W	Washer, split lock, 1/4", zinc plated steel		1000304
86X	Bolt, hex head, 1/4- 20 x 3/4", Gr. 8		1000391
86Y	Nut, hex, 1/4- 20, Gr. 2, zinc plated steel		1000308
87	Insulator, 69kV	3021X0242 P402	1001152
88	Pull rod assembly, 15kV 600A module	3021B0403G1	1000402G1
89	Pull rod assembly, 34kV 600A module	3021B0403G2	1000403G1
90	Pull rod assembly, 46kV 600A module	3021B0403G3	1000404G1
90A	Pull rod assembly, 69kV 600A module		1001995G1
91	Pull rod, outer, 34kV 300A three pole with Joslyn™ module	3021B0403G6	1001062G1
91A	Pull rod, outer, 34kV 300A three pole with VES™ module		1001251G2
91B	Pull rod, inner, 34kV 300A three pole with Joslyn™ module	3021B0403G4	1001062G2
91C	Pull rod, inner, 34kV 300A three pole with VES™ module		1001251G1
92	Pull rod for 46kV 300A double module Joslyn™ design	3021B0403G7	1001988G1
92A	Pulll rod for 46kV 300A double module VES™ design		1001656G3
92B	Pull rod for 46kV 300A single module	3021B0403G3	1000404G1
93	Pull rod for 69kV 300A double module Joslyn™ design	3021B0403G8	1000993G1
93A	Pull rod for 69kV 300A double module VES™ design		1001656G4
94	Plate, closed red, 1" wide		1000540P1
94A	Plate, closed red, 3/4" wide		1001400P1
95	Plate, open green, 1" wide		1000541P1
95A	Plate, open green, 3/4" wide		1001401P1
96	Screw, sheet metal, #4 x 1/4" SST		10000479
97	Cable assembly, standard 15 pin, 40 ft.		1000576G3
98	Cable assembly, standard 15 pin, 30 ft.		1000576G2
99	Cable assembly, standard 15 pin, 25 ft.		1000576G4
100	Complete adjustment and repair kit	3090X0014G1	1000375
101	Shipping crate, one switch, 15 & 34kV		1000817G1
102	Shipping crate, two switch, 15 & 34kV		1000646G1
103	Shipping crate, three switch, 15 & 34kV		1000818G1
104	Shipping crate, one switch, 46kV		1000819G1
105	Shipping crate, two switch, 46kV		1000820G1
106	Shipping crate, three switch, 46kV		1000821G1
107	Nameplate		1000592P1
110	Insulator pedestal, 34kV for 34 kV three pole switch		1001978P1
111	Rear mounting bracket		1002040P2
112	Washer, flat, 0.44" OD x 0.20" ID		1002405
113	Screw, hex head, 10-32		1002450
114	Motor operator trip spring		1002664P1

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
86H	Counter actuator plate, 5 digit	3021X0242P322	1000758P1
86J	Bracket, position indicator		1000526P1
86K	Faceplate, position indicator		1000193P1
86L	Pointer, position indicator		1000192P1
86M	Screw, round head, 4-40 x 3/8" L, zinc plated steel		1000283
86N	Nut, hex, 4-40, standard, zinc plated steel		1000299
86P	Washer, split lock, #4, standard, zinc plated steel		1000279
86Q	Window retaining ring, 5/8" for thin wall casting		1000125P1
86R	Window retaining ring, 3/4" for thick wall casting		1000125P2
86S	Glass	3021X0242 P414	1000153
86T	RTV sealant		1000245
86U	Washer, internal shake proof, #10		1000608
86V	Screw, round head, #10, 3/8" L, zinc plated steel		1000293
86W	Washer, split lock, 1/4", zinc plated steel		1000304
86X	Bolt, hex head, 1/4- 20 x 3/4", Gr. 8		1000391
86Y	Nut, hex, 1/4- 20, Gr. 2, zinc plated steel		1000308
87	Insulator, 69kV	3021X0242 P402	1001152
88	Pull rod assembly, 15kV 600A module	3021B0403G1	1000402G1
89	Pull rod assembly, 34kV 600A module	3021B0403G2	1000403G1
90	Pull rod assembly, 46kV 600A module	3021B0403G3	1000404G1
90A	Pull rod assembly, 69kV 600A module		1001995G1
91	Pull rod, outer, 34kV 300A three pole with Joslyn™ module	3021B0403G6	1001062G1
91A	Pull rod, outer, 34kV 300A three pole with VES™ module		1001251G2
91B	Pull rod, inner, 34kV 300A three pole with Joslyn™ module	3021B0403G4	1001062G2
91C	Pull rod, inner, 34kV 300A three pole with VES™ module		1001251G1
92	Pull rod for 46kV 300A double module Joslyn™ design	3021B0403G7	1001988G1
92A	Pulll rod for 46kV 300A double module VES™ design		1001656G3
92B	Pull rod for 46kV 300A single module	3021B0403G3	1000404G1
93	Pull rod for 69kV 300A double module Joslyn™ design	3021B0403G8	1000993G1
93A	Pull rod for 69kV 300A double module VES™ design		1001656G4
94	Plate, closed red, 1" wide		1000540P1
94A	Plate, closed red, 3/4" wide		1001400P1
95	Plate, open green, 1" wide		1000541P1
95A	Plate, open green, 3/4" wide		1001401P1
96	Screw, sheet metal, #4 x 1/4" SST		10000479
97	Cable assembly, standard 15 pin, 40 ft.		1000576G3
98	Cable assembly, standard 15 pin, 30 ft.		1000576G2
99	Cable assembly, standard 15 pin, 25 ft.		1000576G4
100	Complete adjustment and repair kit	3090X0014G1	1000375
101	Shipping crate, one switch, 15 & 34kV		1000817G1
102	Shipping crate, two switch, 15 & 34kV		1000646G1
103	Shipping crate, three switch, 15 & 34kV		1000818G1
104	Shipping crate, one switch, 46kV		1000819G1
105	Shipping crate, two switch, 46kV		1000820G1
106	Shipping crate, three switch, 46kV		1000821G1
107	Nameplate		1000592P1
110	Insulator pedestal, 34kV for 34 kV three pole switch		1001978P1
111	Rear mounting bracket		1002040P2
112	Washer, flat, 0.44" OD x 0.20" ID		1002405
113	Screw, hex head, 10-32		1002450

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
115	Plastic bumper		1002670P1
116	Screw, Fillister head, 5-40		1002451
117	Trip solenoid		1001581
118	Semi tubular rivet		1002437
119	Spring, trip coil		1000789P1
120	Washer, flat, Durlin, 0 .5" shaft		1002428
121	Cotter Pin, (MONEL), 3/4" L		1002218
122	Retaining ring, self-locking, 3/8" shaft		1002429
123	Toggle link stop shaft		1002420P1
124	Toggle link shaft		1002418P1
125	Toggle link spring shaft		1002421P1
126	Tight fit spacer, alum.		1002423P1
127	Middle linkage, motor mechanism		1002031P2
128	Bearing, needle, 5/8" thick		1000787
129	Inner bearing shaft		1002419P1
130	Washer, vinyl shim, 0.5" shaft		1002427
131	Retaining ring, e-style, 0.375" shaft		1002488
132	Spacer, large, alum.		1002424P1
133	Linkage arm		1002030P1
134	Bearing, needle, 5/16" thick		1000786
135	Double linkage		1002029P1
136	Clutch arm spring pin		1002203P1
137	Motor mechanism to toggle link shaft		1002417P1
138	Trip linkage		1002032P1
139	Screw, set, 1/4-20		1002415
140	Nut, hex jam, 1/4-20		1002416
141	Side plate, non-handle side		1002182P1
142	Side plate, handle side		1002183P1
143	Bearing, one way roller clutch		1002244
144	Screw, 1/4-20 x 3/4" L		1000230
145	Washer, Belleville, 1/4" ID		1000640
146	Spring washer, motor mechanism		1002220P1
147	Spring rod end, motor mechanism		1002219P2
148	Spring, motor mechanism		1002447P1
149	Nylatron, 0 .5" shaft		1000610
150	Nut, hex jam, 3/8-16		1002226
151	Washer, Belleville, 0.386" ID x 0.813" OD		1000218
152	Screw, hex head, 3/8-16		1000480
153	Washer, split lock, #10		1000282
154	Screw, set, 10-32 x 1/2" L		1001979
155	Nut, hex, 10-32		1000302
156	Motor mechanism nameplate		1003305P1
157	Screw, hex head cap, 3/8-16		1002439
158	Washer, spring lock, 3/8"		1002474
159	Tube guard, alum.		1002479P1
160	Nylon support pin, motor mechanism		1002467P1
161	Front mounting bracket, plated		1002045P2
162	Spring pin, 3/8" dia. x 1½" L		1002289
163	Pin, Nylon, 0.375" dia. x 3.5" L		1000376P1
164	Clutch arm, right-hand		1002003P1
165	Clutch arm, left-hand		1002022P1
166	Spring pin, 1/4" dia.		1002445
167	Actuator pin		1002442P1

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
168	Motor cam		1002007G1
169	Bellcrank clutch		1000785
170	Spring, Bellspring		1000790P1
171	Cam shaft, motor mechanism		1002422P1
172	Stop lever		1002452P1
173	Mini spring, motor mechanism		1002446P1
174	Spring pin, 1/8" dia.		1000802
175	Motor, 115V, universal		1002393
176	Stud, threaded rod, 8-32		1001580P1
177	Spring pin, 3/32" dia. x 3/8" L		1000792
178	Motor side plate		1000781P2
179	Connector, quick disconnect, female		1002512
180	Washer, split lock, #8		1000281
181	Nut, hex, 8-32		1000301
182	Worm, modified		1001584P1
183	Mini cam shaft		1001583P1
184	Mini nylon cam		1001582P1
185	Worm gear modified		1001585P1
186	Motor front plate		1002663P1
187	Spring pin, 3/32" dia. x 5/8" L.		1000793
188	Washer, felt, 1/4" ID x 1.5" OD		1002999
189	Washer, steel, 1/4" ID x 7/8" OD		1003000
190	Worm gear spring, 1/4" shaft, 11/16		1003001
191	Washer, Nylatron, 0.25" shaft		1000096
192	Vibra-tite, formula 3		1000074
193	Loctite 272, red		1002682
194	Motor oil 10W30		1000754
195	Moly fortified grease		1000755
196	Standard motor assembly		1002399G1
197	Motor mechanism assembly		1002673G1
198	Cable harness, 15 connector assembly		1002817G1
199	Cable harness, 35 connector assembly		1002801G1
200	VES-M contact block assembly, handle side		1003241G1
201	VES-M contact block assembly, non-handle side		1003241G2
202	Contact block mounting kit, 15 Pin		1003360G1
203	Contact block mounting kit, 35 Pin		1003360G2
204	Relay panel assembly, 120/48V		1002823G1
205	Relay panel assembly, 125V		1002823G2
206	Transfer bar, contact block, 35 Pin		1003261P1
207	Spring, motor operator		1000788P1
208	Spring pin, 1/8" dia. x 1½" L		1002289P1
209	VBU 600 A Module		1002719G2
210	Hex HD Bolt 5/8-11 X 2-1/4 LG SST		1003608
211	Flat washer 5/8 SST 17-4-PH		1002151
212	Belleville Wsher 5/8 17-4-PH		1002152
213	O-ring 10" ID X 10-1/4" OD X 1/8" Buna N for Joslyn module		1003607
214	O-ring 1/4" dash No. 445 for VES module		1004478
215	VES-U insulator gasket teflon		1003823P1
216	18" insulator with flanges 200 kV BIL		
217	30" insulator with flanges 350 kV BIL		
218	Hex nut 5/8-11 galv Steel		1001486

Iten No.	Description	Joslyn™ Part No.	New VES™ Part No.
218	Hex nut 5/8-11 galv Steel		1001486
219	split washer 5/8" galv steel		1001487
220	Hex Hd cap screw 5/8-11 X 3" galv steel		1001484
221	VBU mechanism		1004429G1
222	Stud 3/8-16 X1-1/2" LG vibration resistant stud		1004561
223	VBU bladder		1001514P1
224	VBU adapter plug for Vacuum Electric Switch pole only		
225	Pull rod assembly for 30" line-to-ground insulator 350 kV BIL & four modules		
226	modules		
227	modules		
228	Pull rod for 30" + 30 " + 18" line-to-ground insulators 900 kV BIL & 9 modules		

1. Analyzing Vacuum Interrupter Failures

Mitsubishi™ Vacuum Interrupter

The Vacuum Electric Switch Co. uses Mitsubishi™ vacuum interrupters to build its vacuum interrupter modules. This vacuum interrupter is a load break switch and not a fault interrupter. If used to interrupt a fault current exceeding 4000 amperes, it will fail catastrophically even on the first operation.

Mitsubishi's™ vacuum interrupter intrinsic failure rate is less than three failures per 100,000 vacuum interrupters per 100,000 hours of operation.

When a vacuum interrupters can fails, it is usually a hi-pot or resistance failure. Finding the cause of a failure starts with gathering physical evidence. The physical evidence of failure can be classified as three different types. The first type is a vacuum interrupter failure with no external visible evidence of failure. The second type is a failure with evidence of overheating but no explosive force. The third type is a failure accompanied by explosive hot gases.

1.1 Vacuum Interrupter Failures with the Failure Not Visible

When a module fails without visible evidence, hi-pot or resistance test equipment must be used to detect the occurrence of the failure. Failed vacuum interrupters sometimes emit radio frequency noise which can be picked up by an ordinary AM radio in the vicinity of the vacuum switch.

1.1.1 Hi-Pot Test Failure

A failed vacuum interrupter can be identified by applying a 30kVAC voltage to the potted vacuum interrupter contacts. The vacuum interrupter under test should have leakage current of less than 2mA. Vacuum interrupter modules that have excessively contaminated surfaces should be cleaned to avoid a false test result from leakage

1.1.2 High Resistance Failure

Vacuum interrupter ordinarily has a terminal-to- terminal resistance of about 50 micro ohms. When measure from the external terminals of the vacuum interrupter module the resistance of a new vacuum interrupter module should be in the range of 75 to 100 micro ohms when measured with a Kelvin-lead micro-ohm meter. The cause of the high resistance can be external or internal to the vacuum interrupter. When the high resistance is external, it is caused by loss of bolt tension in the bolted mechanical connections in the current path through the module. Many modules with too high a resistance can be repaired by tightening its bolts. When the high resistance is internal, it is caused by insufficient force holding the contacts together. In rare instances high resistance internal to the vacuum interrupter can be caused by a vacuum leak.

The Vacuum Electric Switch Co. prevents mechanical connections from developing high resistance by using high strength fasteners such as grade 8 or stainless steel bolts. The grade 8 bolts are used inside the modules and the stainless steel bolts are used on the outside where corrosion resistance is important. Belleville washers are used with the fasteners to maintain tension in the fastener and compressive forces on the electrical joints.

Preventing Increases in Resistance

1.2 Vacuum Interrupter Failure Showing Only Overheating

When a vacuum interrupter overheats but no explosive blast has occurred, the overheating is a result of excessive leakage currents between the vacuum interrupter contacts. In this situation the module potting material will be decomposed into a sticky, tarry mess with abundant smoke. The decomposed potting material may be found everywhere, coating both inside the switch and outside the module. This type of failure can have several causes including partial loss of vacuum, excessive voltage applied to the switch, and contacts almost (but not actually) touching.

When analyzing an overheating failure, the position of the linkages inside the switch can be important evidence of how the failure occurred. The smoke and tarry mess coats the internal parts of the switch and can cast shadow images of parts on adjacent material. The contact surfaces of bumpers can shield material from being coated with the mess. These images will indicate the position of the switch mechanism when it failed and can assist in forming conclusions in how the failure occurred.

1.2.1 Partial Loss of Vacuum

Loss of vacuum normally is detected with a hi-pot test at 30kVAC which is more than twice the normal voltage applied to a vacuum interrupter. At this voltage the vacuum interrupter is rejected if the current exceeds 2mA. If the loss of vacuum is sufficient that 100mA of current can flow at the normal voltage applied to a vacuum interrupter, 15kW of heat will be generated. This is a large amount of heat that will cause abundant smoke and decomposed potting material.

1.2.2 Excessive Voltage Applied to the Vacuum Interrupter

A phenomenon called ferroresonance exists which can generate voltages many times the normal system voltages applied to a switch. Ferroresonance accidentally occurs as a result of an abnormal circuit formed by a combination of capacitors with the inductance of transformer windings causing a large leakage current to can flow though an open vacuum interrupter. Ferroresonance failures occur slowly as a large amount of heat accumulates causing a tarry and smokey mess.

1.2.3 Failure to Close Completely
Sometimes switches with multiple vacuum interrupters will fail to close completely because insufficient force was exerted on the switch contacts during switch closing. This is most likely to occur on a solenoid operated switch when insufficient electrical power is available to operate the switch.

During normal operation of a switch, the switch mechanism brings the contacts together and then compresses an overtravel spring in each module. The spring is compressed about 0.040 inch at each vacuum interrupter to assure that each has the proper amount of force on its contacts.

1.3.1 Loss of Vacuum
A vacuum interrupter can fail explosively due to loss of vacuum if the loss of vacuum is sufficiently complete. A vacuum interrupter with a very large leakage current at normal load voltages would not be able to interrupt a normal load current and would fail catastrophically.

If an adequate amount of current is not available to close the switch, the overtravel springs may not be fully compressed. The contacts of one or more vacuum interrupters may only barely touch or not even touch at all. When the current flows through the barely touching contacts a large amount of heat will be generated. The potting material will be decomposed into black sticky, tarry mess with abundant smoke.

1.3 Vacuum Interrupter Failure with Explosive Force
When explosive gases are emitted from a vacuum interrupter module, the cause is a failure to interrupt a current. The explosive gases are externally evidenced by the rupture of a breather bag or ejection of the bladder cover or blow out of panels. There are two causes of this type of failure which are both a result of failure to interrupt.

1.3.1 Loss of Vacuum
A vacuum interrupter can fail explosively due to loss of vacuum if the loss of vacuum is sufficiently complete. A vacuum interrupter with a very large leakage current at normal load voltages would not be able to interrupt a normal load current and would fail catastrophically.

1.3.2 Exceeding Vacuum Interrupter's Interrupting Rating
The 600A vacuum interrupters inside the modules have a 4000A RMS interrupting rating. The vacuum interrupter can conduct a current much higher than 4000A RMS, but it cannot interrupt the current. If an attempt is made to interrupt a current higher than the interrupting rating, the vacuum envelope at the bellows end will be breached. Arc plasma will flow down the inside of the line-to-ground insulator and flash over to ground. An up-stream breaker will interrupt the current.

Failures to interrupt most often occur when the vacuum switch is improperly connected to an over-current relay. Vacuum switches are load break switches. They should not be used for fault interrupting except in very limited cases. If the fault current can be assured to be within the switch interrupting rating, the vacuum switch can be used for fault interrupting. This is sometimes possible with very small arc furnaces.

This type of failure is distinguished from a failure with only overheating in that all the arc blast products are dry and no sticky tar is found anywhere. This is because the arc temperature is so high as to completely decompose any organic material.

Sometimes a back-up breaker and a vacuum switch are both improperly connected to the same overcurrent relay. The vacuum switch is mechanically so much faster than the breaker that it attempts to interrupt the current first but fails. The back-up breaker then opens and interrupts the current. Such an arrangement can be identified if a switch first fails to interrupt, but the destructive process is arrested before the arc blast plasma can flash over to ground.

1.3.2 Failure to Interrupt

The 600A vacuum interrupters inside the modules have a 4000A RMS interrupting rating. The vacuum interrupter can conduct a current much higher than 4000A RMS, but it cannot interrupt the current. If an attempt is made to interrupt a current higher than the interrupting rating, the vacuum envelope at the bellows end will be breached. Arc plasma will flow down the inside of the line-to-ground insulator and flash over to ground. An up-stream breaker will interrupt the current.

Failures to interrupt most often occur when the vacuum switch is improperly connected to an over-current relay. Vacuum switches are load break switches. They should not be used for fault interrupting except in very limited cases. If the fault current can be assured to be within the switch interrupting rating, the vacuum switch can be used for fault interrupting. This is sometimes possible with very small arc furnaces.

Sometimes a back-up breaker and a vacuum switch are both improperly connected to the same overcurrent relay. The vacuum switch is mechanically so much faster than the breaker that it attempts to interrupt the current first but fails. The back-up breaker then opens and interrupts the current. Such an arrangement can be identified if a switch first fails to interrupt, but the destructive process is arrested before the arc blast plasma can flash over to ground.

2. Switch Mechanical Failures

Switch electrical failures associated with the vacuum interrupters and their analysis and prevention are discussed in paragraph one under the heading "Analyzing Vacuum Interrupter Module Failures." General mechanical type failures are discussed in this section. Some switches are powered by solenoids, and the associated failures are discussed starting at paragraph 2.3, Solenoid Operated Switches. Other switches are powered by motors and their failures are discussed starting at paragraph 2.5, Motor Operated Switches.

2.1 Cotter Pin Failures

The VBM and VBT switches have many parts held together with cotter pins. The cotter pin material is important in preventing cotter pin failure. Stainless steel cotter pins should not be used in these switches. Stainless steel cotter pins are subject to stress corrosion due to chlorides in the environment. Bending the cotter pin concentrates stress at the bend, which will then be followed by breakage of the cotter pin and the switch mechanism coming apart. All of the cotter pins used in assembling VBM and VBT switches are made of Monel, which is not subject to such failures.

2.2 Module Failures

There are three types of modules associated with these switches. The first is the 600A vacuum interrupter module. For the past sixty years this module has been made with acrylic, ceramic, and epoxy housings. It is currently being made with aliphatic epoxy housings. The second type of module is a fabricated module with rubber sheds. It is built in 300A and 600A versions and one module is usually stacked on top of another making what is called a double stacked module. This module is made from a fiberglass tube with rubber sheds and aluminum flanges. The third type of module is a resistor module containing an 80 ohm power resistor.

2.2.1 Resistor Module

2.2.1.1 Too High Resistance

Sometimes the resistance of the resistor module increases so much that sufficient current cannot flow through the module. There are two possible causes. The first is moisture absorption by the resistor element inside the module. This is unlikely to occur if the resistor is being regularly energized because the heat from energization will evaporate any moisture. The moisture can be removed by heating the resistor elements at 250°F.

The second cause of increases in resistance is corrosion. The resistor elements have metalized contact surfaces for making connections between elements. These elements are an old product and as originally produced, the metalized surface was a brass material. The brass material is subject to atmospheric corrosion which then increases the resistance. More recently, aluminum has been used for the metalized surface because the aluminum is not subject to corrosion. Resistor modules manufactured by the Vacuum Electric Switch Co. after 6/7/2020 have aluminum contact surfaces.

Old Design: with Brass Contact Surface

2.2.1.2 Resistor Modules Excessive Heat

Resistor modules look similar but are different from vacuum interrupter modules. They can be identified by the rod establishing an arc gap from one terminal to another. They are sometimes stacked on top of other switch modules using special parts.

When a resistor modules fails to excessive heat, the resistor insertion switch is being cycled too fast. or the control circuitry is keeping it in the circuit for too long a time. The resistor module is supposed to be in the circuit for only 100 milliseconds before it is bypassed by a second switch.
The resistor module has a terminal-to-terminal resistance of 80 ohms and contains eight 10 ohm, 10kV rated resistor elements. One 80 ohm resistor module per phase is required to build a resistor insertion switch at 15kV and two at 34kV.

Each resistor module has an arc gap is to prevent an internal flash over inside the module housing from occurring if too much current flowed through module. The arc gap is established by a metal rod on the outside of the module.

2.2.2 600 A Module

2.2.2.1 Fractured Flanges

Fracture of the 600A module flanges from over tightening of the mounting bolts is a common problem. The mounting bolt torque limit is only 25 inch-pounds. This is only a small torque which could easily be exceeded if a torque wrench was not used when installing the module.

The Vacuum Electric Switch 600A module housing has been redesigned to include a stress reducing radius where the flange is attached to the module housing. The flange is contoured around the mounting bolt holes. This change in module design makes it difficult to accidentally crack a module housing during installation.

2.2.3 300 A Double-Stack Modules

The double-stack module housings are fabricated from filament wound resin bonded tubing. Sheds are pressed over the outside and flanges are adhesive bonded to the ends.

2.2.3.1 Flange Bonding Failure

Sometimes flanges may become unbonded from the fiberglass tube. The Vacuum Electric Switch Co. has instituted proof testing of the housings to test the adhesive bonded flange. After the housing fabrication is completed, the housing is put in a press and a 2000 pound axial proof load is applied to the housing. This load is testing the housing to the limits of its strength. A higher load would cause bending of its flanges.

At the same time the proof test is being conducted, 20 PSIG of pressure is applied to inside of the module to assure that the adhesive bond is leak tight. This leak test pressure is as compared to a 1½ PSIG leak test which is later applied to a finished switch.

2000 Pound Proof Test and 20 PSIG Leak Test

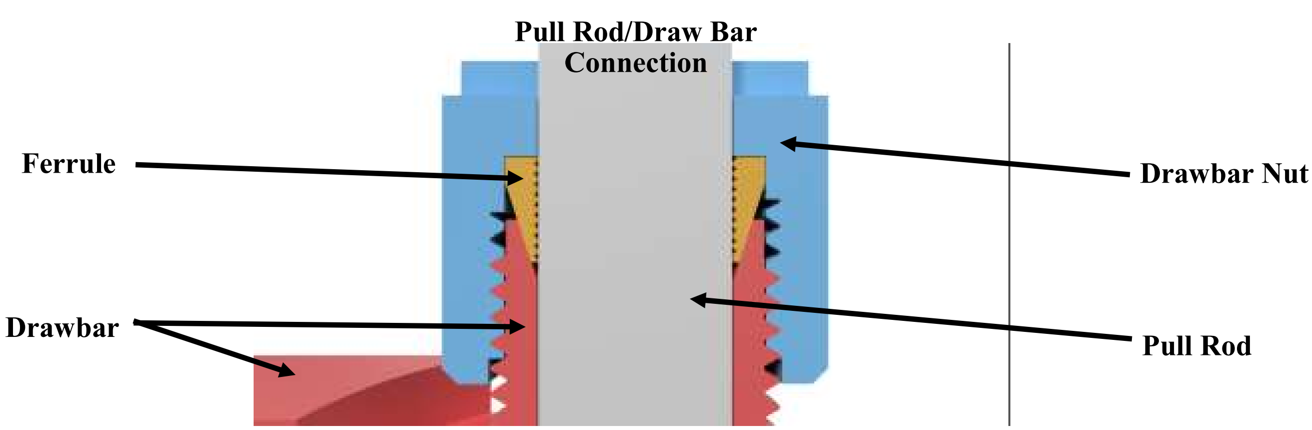
2.2.3.2 Shed Deterioration

Shed deterioration is greatly improved by making the sheds of silicone, rather than EDPM rubber.

2.2.3.3 Pull-Rod Slippage

Double stack modules have internal pull rods that connect the vacuum interrupter in the upper module with the vacuum interrupter in the lower module. Maintaining the synchronism of the upper vacuum interrupter with the lower vacuum interrupter depends on securely fastening the internal pull rods to the drawbars.

The pull rods are fastened to the draw bars with a compression type steel fitting having a ferrule with internal teeth. The fitting is tightened with an impact wrench and pinned to prevent the drawbar nut from loosening.



Lower Module of Double Stack Module

2.3 Solenoid Operated Switches

When more than one switch mechanism is used in a set, the switches are always solenoid operated. Solenoid operated switches have either two or four solenoids supplying the energy to open or close the switch. A switch with two solenoids has one solenoid for opening and a second solenoid for closing the switch. A switch with four solenoids has two solenoids mechanically connected in parallel for both opening and closing the switch. The four solenoid switch is commonly called a double solenoid switch. Solenoid operated switches always require special controls.

The number of solenoids determines how much energy is available to operate the switch. A switch with one opening and one closing solenoid can operate a switch with up to four vacuum interrupters. A switch with two opening and two closing solenoids is required for six vacuum interrupters.

Solenoid operated switches close and open in a predictable and controlled amount of time. This makes it possible to have multiple switches which are not mechanically connected to each other all operate at the same time. Switches can be connected in parallel to increase the current capacity beyond the capacity of a single switch. Solenoid operated switches have reproducible operating times which makes possible the closing of switches in synchronism with the power frequency sine wave to reduce transients.

2.3.1 Power Source Induced Failures

A solenoid operated switch can either have a stored energy control or a line-powered control. In a stored energy control, the adequacy of the available power is assured by having it stored in capacitors in the control. The only cause of inadequate power in a stored energy control is that the capacitors may lose capacitance over a period of time of ten years or more and need replacement.

In a line-powered control, the power comes from an external transformer or batteries. The conductors bringing power to the control must be adequately sized for the number of switches. Too long a distance between the switch and the power sources may reduce the amount of available current to unacceptably low levels. An individual switch needs 60 to 65 amperes peak current for it to operate properly. If the current is not available, the switch will operate slowly. If a switch has two solenoids for opening and closing, it will need twice as much current. The trip solenoid requires more current than the closing solenoid, and for this reason problems with inadequate current always are first apparent on switch opening. Having adequate available power is an essential element of a properly operating switch installation.

2.3.1.1 Blown Fuses
Repeated blown fuses in a Joslyn™ control is symptomatic of an inadequate amount of available current to operate a solenoid operated VBM or VBT switch. The fuse for each three-phase set of switches should be a 10A type FNM dual-element slow blow fuse. This type of fuse is designed to accommodate the in-rush current during the proper operation of the switch solenoids. If the switch takes too long to operate the fuse will blow, which indicates inadequate supply of electric current. Substituting a larger fuse to prevent fuse blowing will result in damage to the pins in the connector on the side of the switch.

2.3.1.1.1 Power Source for Furnace Switches
Sizing a power source for an installation of furnace switches is straight forward. A control must have 5kVA, 3½% maximum impedance of transformer capacity for each three-phase set of switches connected to the control. A 3½% impedance transformer is a special order transformer, and where it is not available, a 10kVA 7% max impedance transformer can be substituted.

The transformer must be connected to a higher voltage such as 220 or 480VAC and be physically located next to the arc furnace control. It must be directly connected to the control with sizeable wire considering that each three-phase set of switches draws 190A peak for a cycle and a half. The transformer should not be shared with other equipment operating simultaneously. A furnace control supplied with power as described above will operate properly.

2.3.1.1.2 Substation Switches
Supplying line-powered switches in a substation is more problematic. This is because they can be supplied by batteries or station transformers. Station transformers will generally have more than enough KVA capacity to operate the switches. The big problem with substation installations is the linear distance of wire run length between the station transformer or the batteries. The current that can be supplied is limited by both the wire run's resistance and inductance. The inductance will be affected by whether the wire is in a metallic or non-metallic conduit.

The 34kV three pole solenoid operated switch is particularly sensitive to being supplied by an inadequate current supply. Because this switch internally has two open and two closing solenoids, it requires 120 to 130 amperes peak to operate, which is twice as much as the other switches having only one solenoid. The current is being supplied over the same pendant cable with #16 AWG wire, resulting in a much larger voltage drop in the cable.

There is no easy way to calculate the size of wire required to deliver the required current. Rules of thumb, such as installing two #6 AWG wires in parallel, may enable a switch to operate but not necessarily under all conditions. The adequacy of an installation needs to be verified with a current measurement using a current probe with a digital oscilloscope. In an adequately sized installation the current operating the solenoid will flow for 24 milliseconds maximum. The switch may function with longer times but insufficient margin exists to assure the switch operates properly every time.

Given the many problems of assuring an adequate amount of current is available in a substation installation, using stored energy controls for solenoid operated switches in substations is recommended.

2.4 Catastrophic Switch Mechanical Failures
Catastrophic Switch failures are those which cause the switch to quit operating immediately. These types of failures are normally the result of a large accumulation of operations. A catastrophic failure is distinguished from a failure due to wear, which proceeds slowly and progressively.

2.4.1 Solenoid Failures

Solenoids used on the switches were first manufactured by NAMCO and now by DECCO. The NAMCO solenoids were larger and more rugged than the DECCO solenoids. For this reason solenoid failures normally occur with DECCO and not NAMCO solenoids.

The types of solenoid failures consist of a failed coil, sticking solenoid armatures, fractured parts, and the solenoid vibrating loose. These types of failures are usually found in switches with annual operating rates of more than 10,000 operations per year. Normally such usage is found in steel mills where switches are used to turn arc furnaces on and off.

Of the two solenoids on the switch, the trip solenoid is most likely to fail. More power is required to open the switch, and as a result, it is subjected to more wear than the closing solenoid.

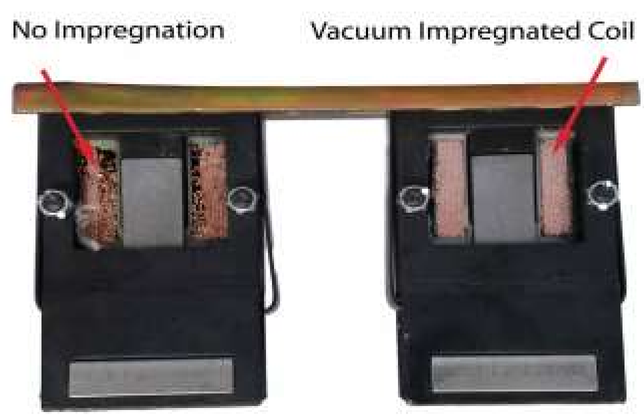
Solenoid failures can be precipitated by an inadequate amount of available current to operate the switch. If the current is inadequate, the switch will operate slowly. A slowly operating switch will initiate the opening of the switch using the under-voltage trip circuitry which is powered by charged capacitors. The energy available is larger than normal, and repeated use of the under-voltage trip circuitry may cause a solenoid failure.

2.4.1.1 Shorted Coil Turns

When a solenoid is operated, all the force exerted by the solenoid is also applied to the turns in the solenoid coil. The force on the turns can cause the wires to rub on each other which wears off the insulation. The turns may become shorted, and shorted turns cause the solenoid to lose the power to operate the switch.

DECCO solenoid coils may or may not be vacuum impregnated as indicated by the color of their leads. Coils with white leads are impregnated. Impregnated coils have all the voids between the wires filled with solidified resin which prevents the wires from rubbing on each other and becoming shorted.

Replacing coils with yellow lead wires is part of the Vacuum Electric Switch Co. normal switch overhaul process.



2.4.1.2 Loss of Solenoid Air Gap

Solenoids have an air gap intentionally designed into the magnetic circuit inside the solenoid. The purpose of the air gap is to prevent residual magnetism in the solenoid's iron from holding the armature in the closed position after the electric power is turned off. Loss of the air gap is observed as the armature sticking in the energized position. It is also observed as bent and deformed nylon pins.

During the operation of the solenoid, the repeated impact of the armature on the field stack deforms the pole faces, thus reducing the air gap. DECCO solenoids as originally designed by DECCO have a 0.009 inch air gap. Solenoids supplied by the Vacuum Electric Switch Co. have their air gaps increased to 0.030 inches, which is large enough to maintain a proper air gap for more than 1,000,000 switch operations.

If the armature sticks in the energized position due to a loss of the air gap, the nylon pin fails to fall back down when the power is turned off. On the next operation the control yoke is flipped over hitting and bending the nylon pin. The shock of the impact knocks the armature loose which then returns to its proper position. With the armature now in its proper position, evidence of the cause of the failure is lost. This type of failure is difficult to diagnose because the only surviving evidence of the cause of failure is the bent nylon pin. Replacing the nylon pin will not prevent further failures.

2.4.1.3 Fractured Parts

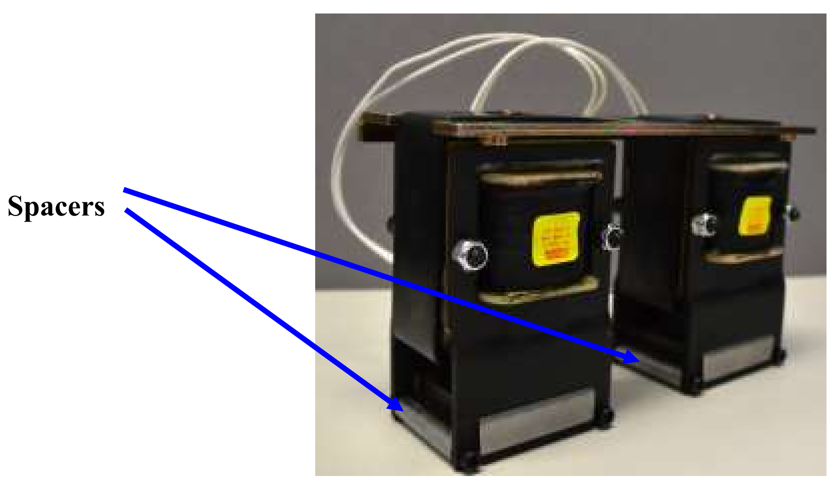
DECCO solenoid side plates may fracture in fatigue due to repeated operation of the solenoid. When the solenoid operates, the magnetic forces flex the side plates toward each other. Repeated operations can cause fracture of the side plates. See 2.4.1.3.1 and 2.4.1.3.2 for fracture prevention techniques.

2.4.1.3.1 Stress Relief Heat Treatment

The side plates are heat treated to remove the residual stress from stamping of the plate and extend the fatigue life. Side plates which have received heat treatment for stress relief are marked with a white dot.

2.4.1.3.2 Solenoid Spacers

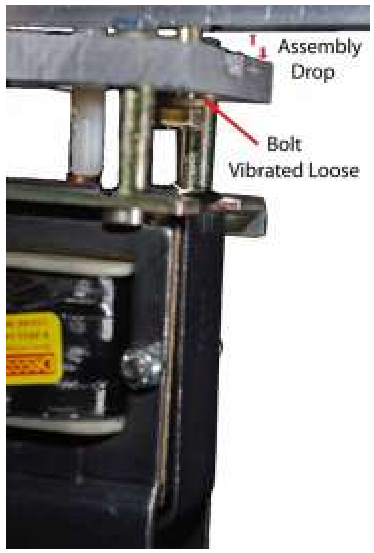
Solenoid spacers are installed between the side plates to resist the magnetic forces flexing of the plates. When switches are sent to the Vacuum Electric Switch Co. for an overhaul, installation of solenoid spacers are part of the overhaul process to prevent side plate fracture.



2.4.1.3.3 Solenoid Vibrating Loose

Solenoids may vibrate loose at their mounting bolts. After a sufficient time, the solenoid will be so loose that it will not have sufficient stroke to operate the switch.

Solenoids are prevented from vibrating lose by installing screw-lock helicals in the solenoid's mounting bolt holes in the switch casting. Installing these helicals is part of Vacuum Electric Switch's standard overhaul process.



2.4.2 Control Yoke Failures

When a control yoke fractures, the switch immediately stops operating. These fractures are generally the result of cyclic fatigue failure from many switch operations. They most frequently occur in switches used to operate arc furnaces.

2.4.2.1 Yoke Bumper Stop Induced Failure

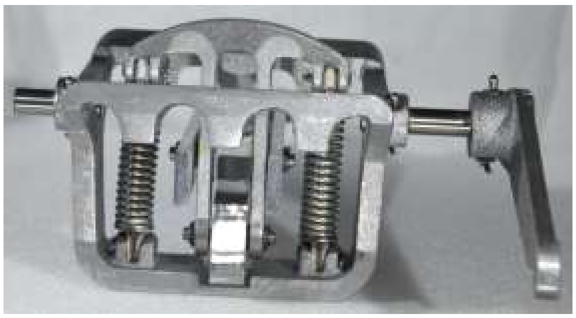
The Joslyn yoke bumper stop has a metal stop which impacts the control. Repeated impact causes an indentation in the control yoke casting. This indention can become a stress point which results in a fracture of the casting.

This failure is prevented with a yoke bumper stop that impacts the control yoke with a broad flat rubber surface. The control yoke is not damaged, and fracture does not occur.

2.4.2.1.1 Handle Induced Fracture

The speed of switch operation is so fast that the inertial forces from the mass of the external manual operating handle twist the control yoke. Over many operations the cyclic fatigue from twisting of the control yoke can cause fracture.

A handle with reduced mass is installed to extend the fatigue life of the control yoke. The original handles were cast aluminum with no holes. The reduced mass handles can be recognized from the holes in the handle..



Old Design Handle

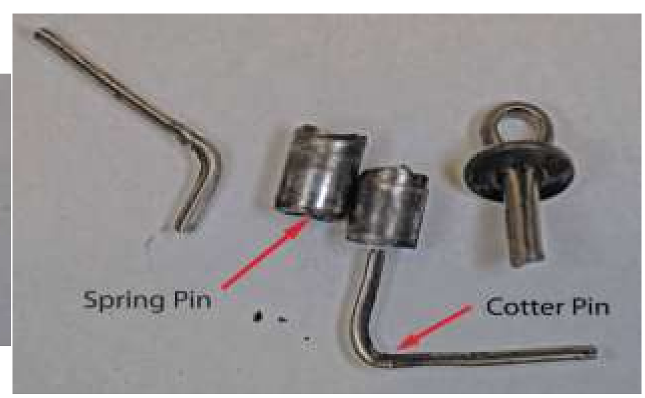
Reduced Mass Handle

2.4.2.1.2 Spring Pin Failure

Fracture of the spring pins which are used to fasten the manual operating handle to its shaft and the shaft to the control yoke, is a common problem. The cause of these failures is cyclic fatigue from the inertial forces of the handle on the spring pins. This failure is prevented by increasing the size of the spring pin from 1/4 to 3/8 inch diameter. The handle shaft diameter needs to be increased as well, which requires re-machining the switch casting for a larger bearing. Such a modification can only be done in Vacuum Electric Switch's shop. This change also requires a new control yoke with a 2 inch diameter boss on its handle side.

The use of stainless steel spring pins will result in stress corrosion fracture of the spring pins. Special Monel spring pins are used to prevent such failures.

Monel Spring Pin

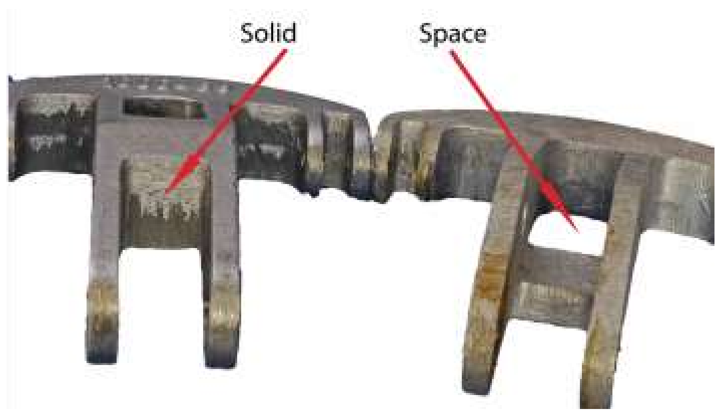


2.4.3 Spring Assembly Failure

Spring assembly failures are due to wear in the spring's draw bars. Over time the draw bar can wear through and the spring becomes detached. Such a failure is prevented by installing lubricating washers and saturating them with motor oil. The use of lubrication can extend the draw bar life to more than 500,000 operations.

2.4.3.1 Toggle Link Bushing Loss

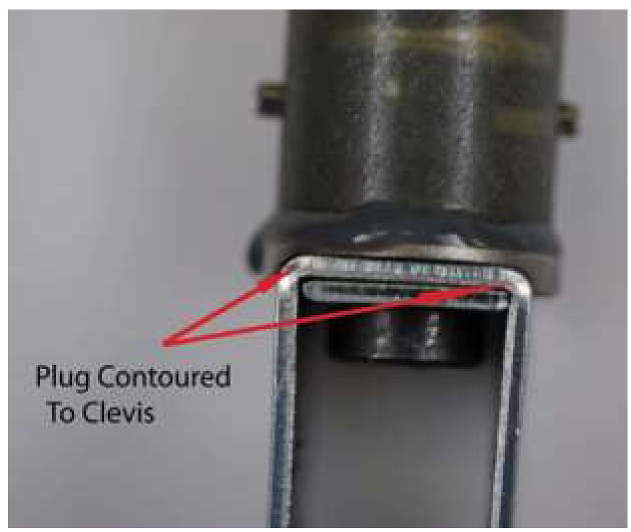
The bronze bushings in the control yoke may slide out of place and the link become only loosely attached to the operating mechanism. This failure is prevented by permanently capturing the bearing in the control. Toggle links not having permanently captured bearings are replaced as part of the Vacuum Electric Switch normal overhaul process.



Redesigned casting to permanently capture the bushings, preventing displacement.

2.4.3.2 Pull Rod
When a switch is overhauled in the Vacuum Electric Switch shop, pull rods manufactured by Joslyn™ are generally replaced. This is because Joslyn recommended replacing the pull rods each time a module is replaced. Vacuum Electric Switch is continuing this practice by replacing Joslyn pull rods. Vacuum Electric Switch pull rods do not have to be periodically replaced because they have improved wear and fatigue life.

2.4.3.3 Clevis Fracture
The pull rod clevis can fracture due to cyclic fatigue at the corners of the clevis. This is prevented by providing mechanical support at the corners.



2.4.3.4 Screw Thread Failure
Pull rods have threaded plugs in their ends which screw onto the pull rod screw in the vacuum interrupter module. The material used for this plug in the past has been aluminum, but aluminum does not wear very well. The plug material has been changed to stainless steel to improve thread life. See photograph at paragraph 2.6.4.

2.5 Motor Operated Switches

A motor operated switch gets its energy of operation from a universal motor similar to the motor found in a sewing machine. The motor itself is operable on 48VDC or 120VAC. A special motor is available that can operate on 24VDC. The switch can operate on a wide variety of voltages that are accommodated with special relay panels. A common mistake is to connect the switch to the wrong voltage, which will drastically shorten the motor's life.

When the motor operates, it stores energy in a spring which is then used to operate the switch. The electric current to operate the motor is only about five amperes, which enables it to be used in remote locations where only small amounts of electrical power is available. The small current also means that no special controls are required to operate the switch.

2.5.1 Motor Mechanism

Motor mechanisms are somewhat like a grandfather clock mechanism. If you take one apart, you will soon wish you hadn't. With the exception of replacing the motor assembly, the motor mechanism is not a part which should be repaired by an inexperienced person. The motor mechanism has seven parts: two boomerangs, two side plates, two spring bolts, and one toggle link, which commonly fail. The amount of work involved in taking a motor mechanism apart is so great that if any one of these parts needs to be replaced, all of them should be replaced at the same time. Also, the cost in time and parts is so great that purchasing a new mechanism is faster and probably less expensive than doing a repair.

2.5.1.1 Motor Assembly

The motor assembly is the one part of the motor mechanism which can easily be replaced. The motor mechanism commonly fails due to either a worn worm wheel or worn work shaft bearing journals. These failures are now prevented by changes in material and the addition of lubrication. The result is that replacement Vacuum Electric Switch motor assemblies will be less common than before.

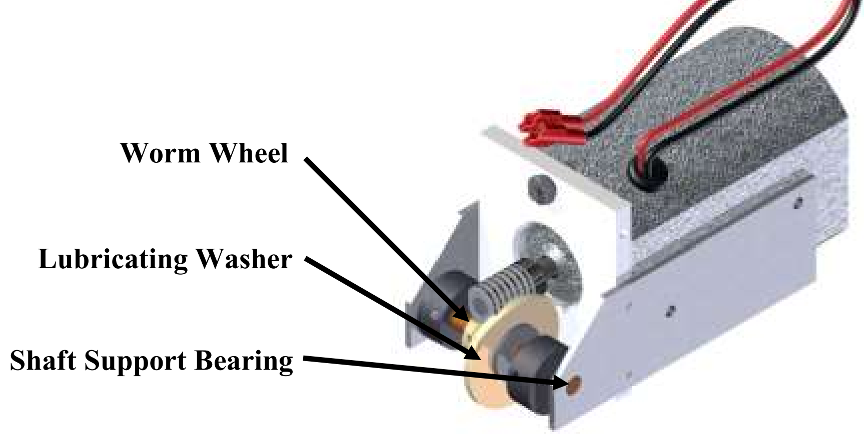
2.5.1.1.1 Worm Wheel

Joslyn motor assemblies had a fiber worm wheel which could have its teeth worn off. This worm wheel has been replaced with a metal wheel with an adjacent felt lubricating washer to provide lubricant on the wheel.

2.5.1.1.2 Shaft Support Bearing

The worm wheel is supported by a shaft with bearing journals in two side plates. Previously, the shaft was made of steel and the side plates brass. Vacuum Electric Switch motor assemblies have a bronze shaft and steel side plates with lubricating washers. The bronze on steel with lubrication is a much better wear combination so that the motor assembly does not wear out as before.

Motor Assembly



2.5.1.2 Ratcheting Cams

The motor mechanism contains four ratcheting cams. If these cams do not grip their shafts properly, the springs cannot be recharged in preparation for the next switch closing and opening operation.

It is possible for one set of cams to be working properly and the other set to fail. In this situation, the time required to recharge the springs for the next operation is doubled.

Cams fail to operate properly because they must be installed in a precisely sized hole in the boomerang. If the hole is not the correct size the cam will slip. Formerly, boomerangs were made of aluminum, but Vacuum Electric Switch boomerangs are now made of stainless steel. The stainless steel is much stronger, and the hole size better controlled to prevent cam slippage.

Boomerang

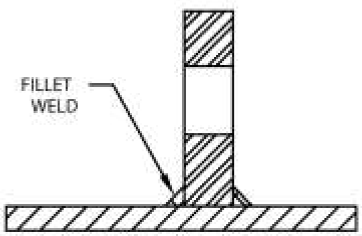
2.5.1.3 Trip Link Trip Free Failure

The trip link is adjusted by a steel screw which impacts the link. Before, trip links were made of aluminum, but now Vacuum Electric Switch trip links are made of steel. The steel has better wear characteristics so that the link does not get out of adjustment.

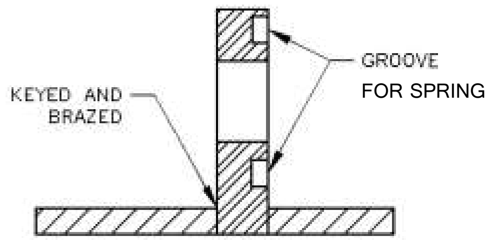
Trip Link

2.5.1.4 Spring Tab

The motor operator is powered by springs which are attached to the side plates of the motor operator mechanism. In the past, the attachments were fillet welded to the side plate. These tabs sometimes broke off and the spring would go flying. The mounting tabs on Vacuum Electric Switch side plates are keyed into the side plates and then brazed so that they cannot break off.



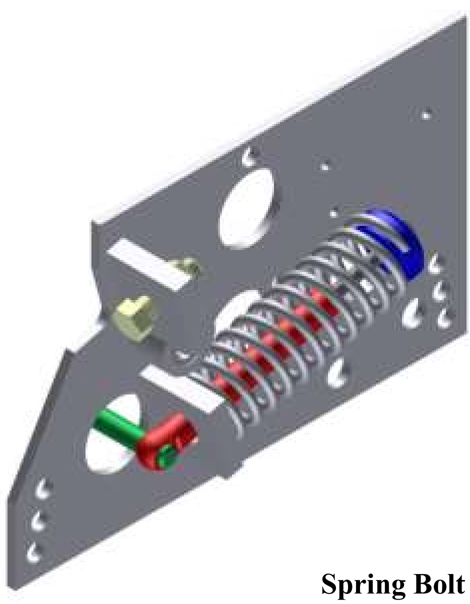
Old Design



New Design

2.5.1.5 Bolt Failure

The springs storing energy for the operation to the motor mechanism were attached by relatively small bolts which were subject to bending in the threads. The bolt could fracture, and the spring go flying. This part in the Vacuum Electric Switch motor mechanism is changed to a more substantial eye-bolt that can withstand the bending stresses of the application.



Spring Bolt

The spring shown to the left is used to store energy for the motor operator mechanism. Bolts are used to fasten the energy storage springs to the motor mechanism.

Cyclic fatigue can cause the bolt holding the spring to fail between the shaft and the jam nut. This failure can result in the bolt and the spring becoming dangerous projectiles.

This failure is prevented by redesigning the parts holding spring as a rod end, as shown to the left. The rod end has a larger diameter than the bolt formerly used and increases it’s ability to resist the bending force created by the spring. Fatigue failures are then prevented.

2.6 Loss of VBM and VBT Adjustments

2.6.1 Link Angle

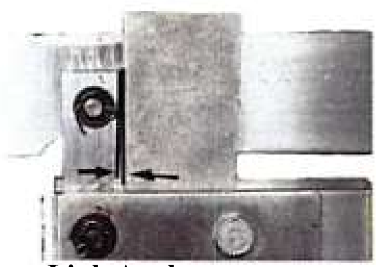
The link angle is adjusted by moving the opening bumper. The Joslyn™ switch literature says that the link angle should be set at 1 degree, tilted in the direction opening. As the bumper wears the link angle becomes smaller. If the bumper wears so much that the link angle goes over top dead center, the opening speed of the switch opening is slowed.

For solenoid operated switches, slow operations will be detected by the control and attempt to open the switch with the under-voltage-trip capacitors. A fuse will be blown. On an arc furnace this may cause an arrestor to explode. For solenoid operated switches used on arc furnaces the link angle should be set at 3 degrees to give a larger wear allowance.

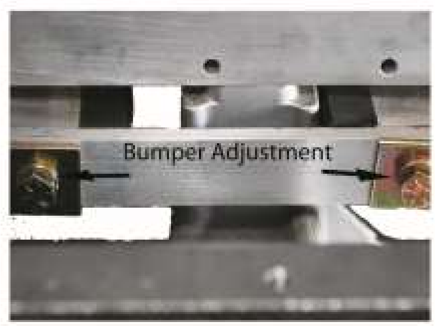
For switches having double stack modules the link angle should be set at 1 degree. Because the customary number of operations is not so large as to require the extended life required for an arc furnace switch.

The link angle for motor operated switches must be set at 1 degree. If it is set larger, the motor operator mechanism will trip free.

Bumper wear is very important in maintaining the link angle. Previously, bumpers were made with plastisol, but this material did not wear well. Vacuum Electric Switch bumpers are now made with urethane material which is very tough and durable and suffers minimal wear. Using urethane bumpers allow a switch to stay adjusted for long term operations.



Link Angle



2.6.2 Full Travel

The full travel adjustment sets the open gap of the vacuum interrupter. This adjustment should be set between 0.200 and 0.210 inches and is set by the opening bumper. Minimizing bumper wear is very important in maintaining the full travel adjustment over a large number of operations. Bumper assemblies with urethane (rather than plastisol) bumpers should be used to maintain the full travel adjustment over a large number of operations.

Full Travel Adjustment

2.6.3 Bearing Wear

The vacuum switch mechanism consisting of links, actuating bars, and the support bar is assembled using many ¼ inch diameter ground shafts. Where the shafts go through these parts, only some of the parts had oil impregnated sintered bronze bush bearings. In some locations the bearing journal was just a drilled hole through an aluminum bar. Aluminum does not wear well, and these holes would be out of round.

Worn bearings and out-of-round bearing journals make switches difficult to adjust. Bearing wear can be assessed by amount of play in the mechanism observed between rocking the mechanism in one direction and then reversing it to go the other. If the travel adjustment measurement changes on reversing directions, the bearing has too much wear.

New switches manufactured by the Vacuum Electric Switch Co. have oil impregnated bearings for all ¼ inch shaft bearing journals. On repaired switches, the old drilled journals in the aluminum bar are drilled out and new oil impregnated bronze bushings installed. All other ¼ inch bronze bushings are replaced during a switch overhaul.

2.6.4 Pull Rod Thread Wear

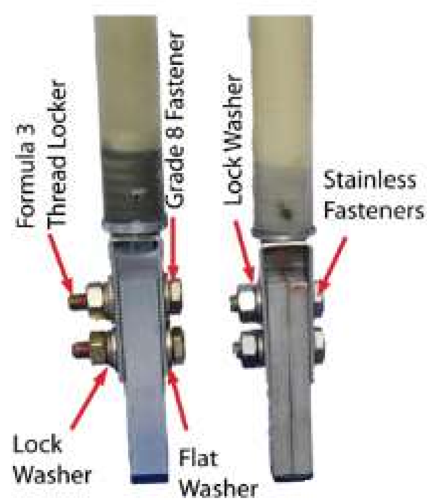
The vacuum interrupter is attached to its pull rod with a 5/16-18 threaded screw which is screwed into a threaded plug in the end of the pull rod. Formerly, parts were made of aluminum which did not wear well. Now both the screw and the plug are made of stainless steel which wears much better. The wear in these threads causes hysteresis in the module synchronism adjustment and makes a switch difficult to adjust. Changing the material of both the pull rod screw and the pull rod plug eliminates this problem.

During switch overhauls aluminum pull rod screws in Joslyn modules are removed and replaced with stainless steel screws.

2.6.5 Clevis Slippage

The pull rod clevis is used to adjust the overtravel of the vacuum interrupter contacts. If the clevis adjustment slips, the switch is out of adjustment. Slippage is prevented by machining teeth into the gripping surface of the clevis. The clevis is tightened using grade 8 high strength fasteners, flat washers, and lock washers. The flat washers distribute the bolt tension broadly over the clevis teeth.

In times past, stainless steel bolts and spring lock washers have been used for this application. Stainless steel lock washers are not appropriate because they are subject to stress corrosion fracturing, which makes them go flat. Using flat lock washers does not maintain the bolt tension and slippage becomes possible.



2.6.6 Overtravel Spring Lubrication

The overtravel spring in the vacuum interrupter is packed with molybdenum disulfide wheel bearing grease. The spring is associated with various parts including the cross pin and the pull rod screw. These parts rub on each other during the operation of the switch. If they are not lubricated, wear will prevent them from sliding smoothly on each other. The result will be a stick-slip motion that makes module synchronism adjustments difficult.

2.6.7 Pull Rods

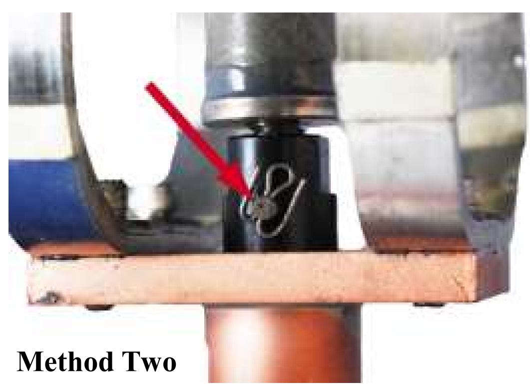
Clevis slippage will result in a switch getting out of adjustment. Refer to paragraph 2.6.5 for discussion.

2.6.8 Module Cross Pin Wear

Method One: The pull rod screw is pinned to the copper conductor with a steel pin. During operation of the switch, force is applied to the pin and over repeated operations, the hole in the soft copper slowly enlarges. Movement of the pin in the hole causes hysteresis in the contact synchronism adjustment.

Method Two: Loss of adjustment does not occur in this method, which separates the electrical and mechanical functions. Electricity is conducted by a copper sleeve which surrounds a steel sleeve. The steel sleeve makes the mechanical connection between the pull rod and the vacuum interrupter moving stem. The pull rod screw is pinned to a hole in the steel sleeve, preventing wear of the hole. A lubricant is packed inside the steel sleeve to reduce wear as the pull rod screw slides against the pin.

Method One



Method Two

2.6.9 Auxiliary Switch

Solenoid operated switches have been manufactured with many different types of auxiliary switches. Loss of adjustment of the auxiliary switch can cause improper switch operation. The two switches commonly encountered are the Eaton™ and the Square D™ switch.

2.6.9.1 Six and Four Circuit Auxiliary Switcches

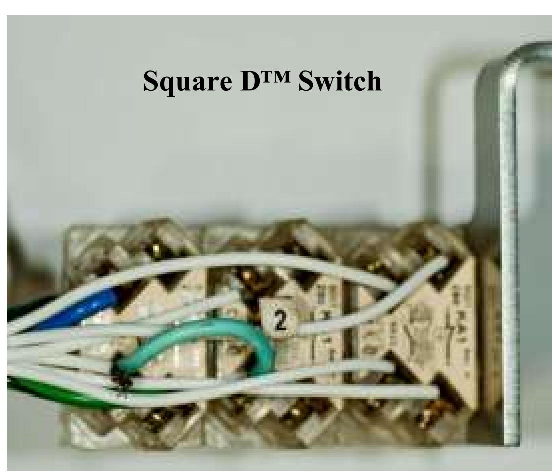
Both the six and four circuit switches shown below are made to military specifications and our testing has shown that they have a mechanical life of approximately 500,000 operations. Although we have not tested other auxiliary switches extensively, antidotal evidence suggests these switches are the most reliable. The four circuit switch is a suitable replacement for the six circuit switch because of problems with availability. If downtime is unacceptable and auxiliary switch failures are to be avoided, these switches should be replaced at 250,000 operations. These switches may not be reliable for currents through the contacts of less than 100 ma and at less than 6 volts. This means that special circuitry is required to use it to switch an input to a PLC.

Six Circuit Switch

Four Circuit Switch

2.6.9.2 Square D™ Auxiliary Switch

Switches sent in for an overhaul that have Square D auxiliary switches have these switches removed and replaced with the Eaton auxiliary switches. The reason for this is that the plastic housing for the Square D switch frequently becomes cracked and fails. Replacing the Square D switch with the Eaton switch prevents this problem. Field replacement of a Square D switch may not always be possible because the necessary mounting holes for the Eaton switch may not be available.



Square D™ Switch

3. VBU Switches

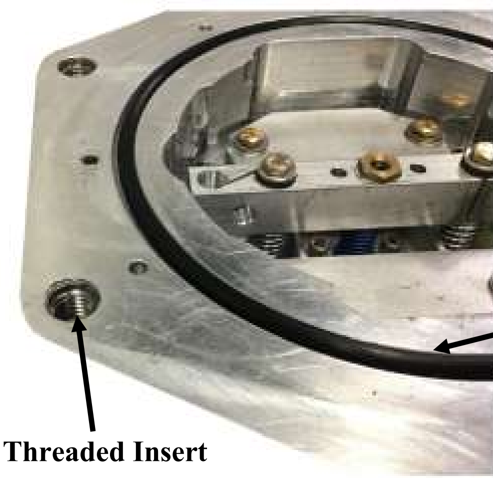
VBU switches are shown on page 10 of this catalog. The major operating components are the vacuum interrupter module and the operating mechanism which are shown on page 40. Both the module and the mechanism have undergone significant design changes that improved reliability and longevity of this switch. Improvements in the module are explained below.

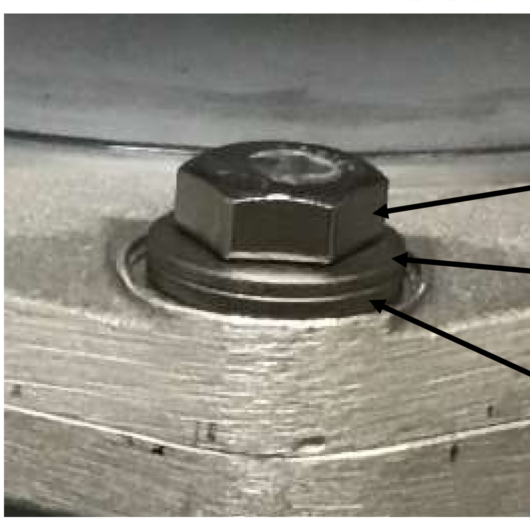
3.1 Modules

The Vacuum Electric Switch Company is manufacturing a new replacement VBU module which incorporates design improvements to keep moisture out of the module and to prevent increases in terminal-to-terminal resistance.

3.1.1 Moisture Ingress

Leakage of moisture into a VBU module stack sometimes resulted in internal flashovers. Three design changes have been implemented to eliminate this problem. First, the cross sectional diameter of the O-ring seal between the modules has been increased from 1/8 to 1/4 inch. The larger cross section allows more compression of the O-ring so that the seal is more tolerant of any joint relaxation that may occur during the module's life. The second design change was to fasten the modules together using materials that are stronger and harder than the aluminum bolts previously used. Third, the threads in the aluminum casting are strengthened with stainless steel threaded inserts.



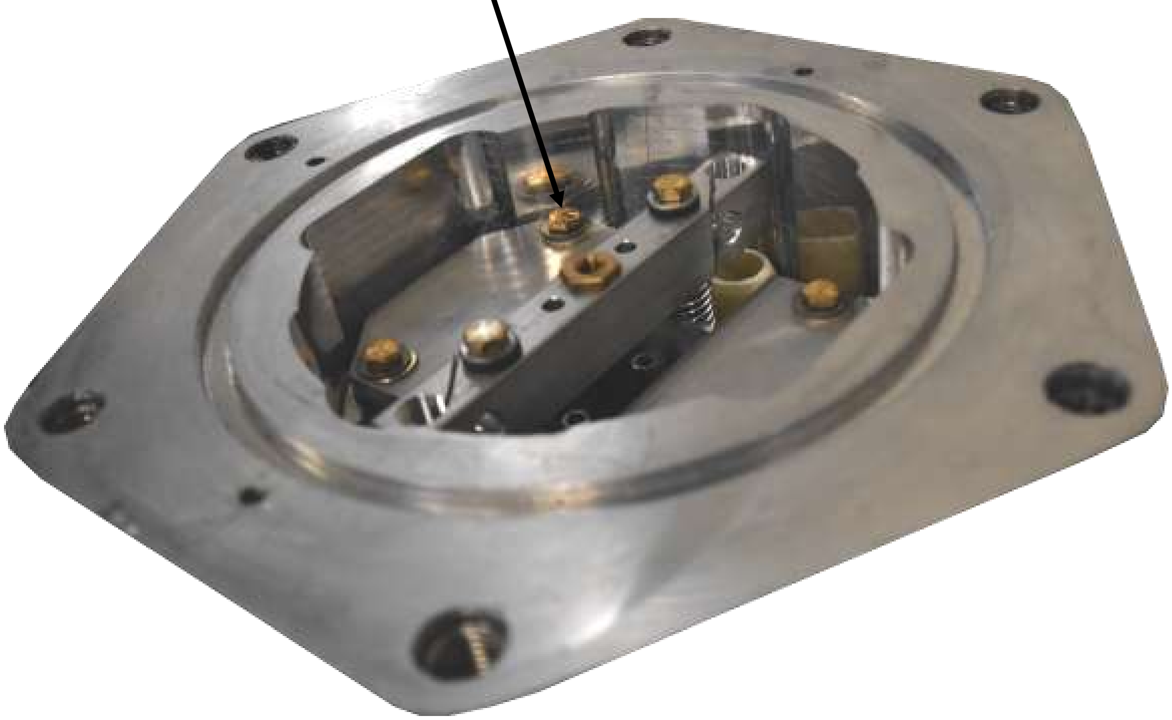


3.1.2 Increase in Resistance

Keeping the electrical resistance low requires the compressive forces on all the electrical mechanical joints to be maintained. The design improvements which prevent moisture leakage also maintain the forces on the joints and tend to prevent increases in module-to-module resistance.

VES remanufactured modules have always used high strength fasteners. Belleville and flat washers and screw-lock helical inserts in the mechanical joints inside the module prevent increases in electrical resistance. Over the long haul, these measures have prevented the internal resistance from increasing in VES remanufactured modules. These measures are continuing to be used in new VES modules.

High strength bolts, Belleville washers, and flat washers - used to prevent module electrical resistance from increasing

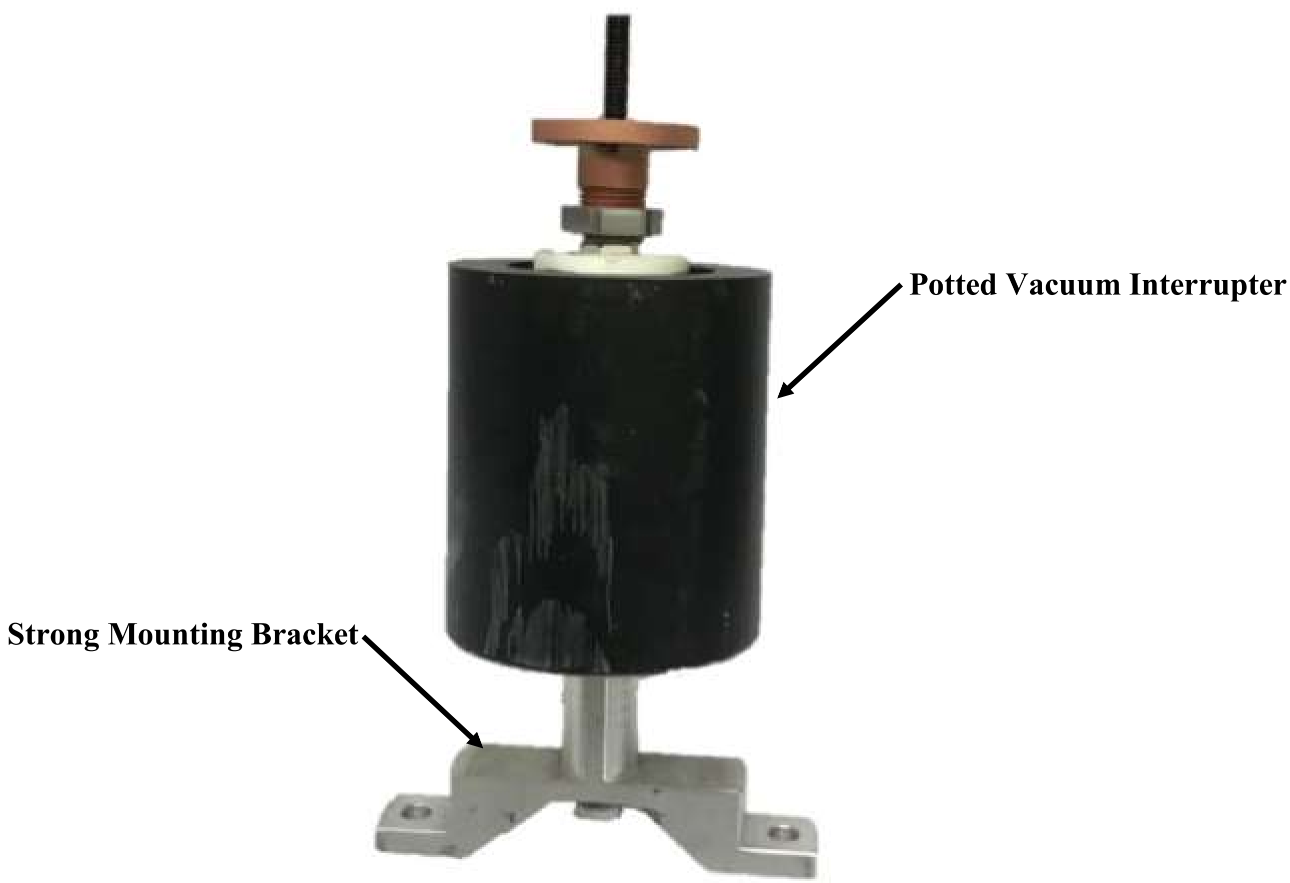


3.1.3 Loss of Adjustments

When VBU modules are stacked together to make a VBU pole, the modules must be synchronized before the switch is put into operation. Synchronizing is the adjustment of the modules so that their contacts all open and close at the same time. This synchronization must be maintained throughout the life of the switch. If it is lost, the switch might fail catastrophically.

During the operation of the switch, the vacuum interrupter contacts are subject to impact loads on closing and continuous loads of seventy pounds during switch operation. Repeated impacts of closing can slowly move the vacuum interrupter's location. The result would be that the contact buttons of the vacuum interrupters in series would no longer all open and close at the same time.

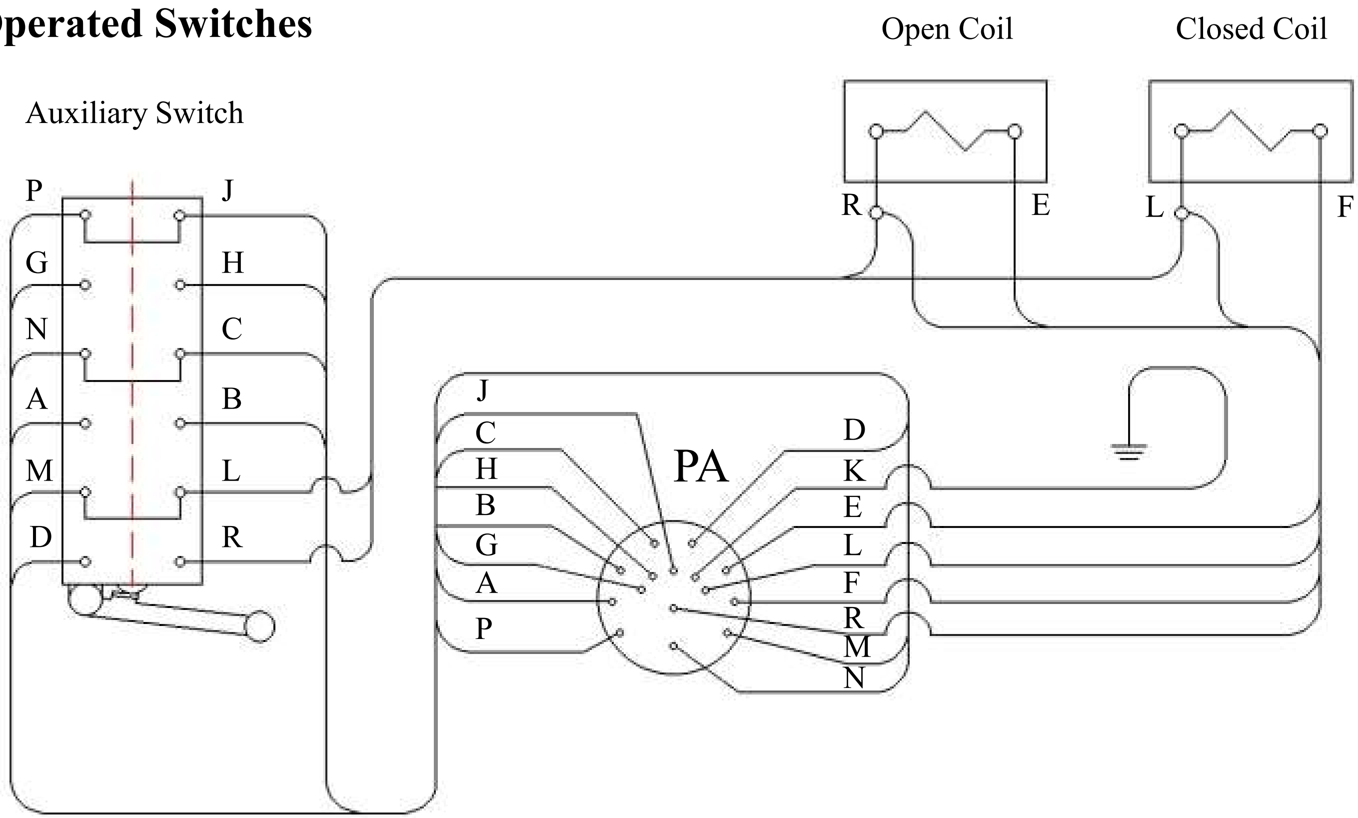
Loss of synchronization is prevented by having the vacuum interrupter solidly mounted and attached to the module housing. The vacuum interrupter is attached to a strong aluminum support bracket which is then bolted to the module housing using high strength bolts, Belleville, and flat washers. The tapped bolt holes in the aluminum flange casting are reinforced with screw-lock helical inserts.



Switch Wiring Schematics

Solenoid Operated Switches

Six Circuit Auxiliary Switch

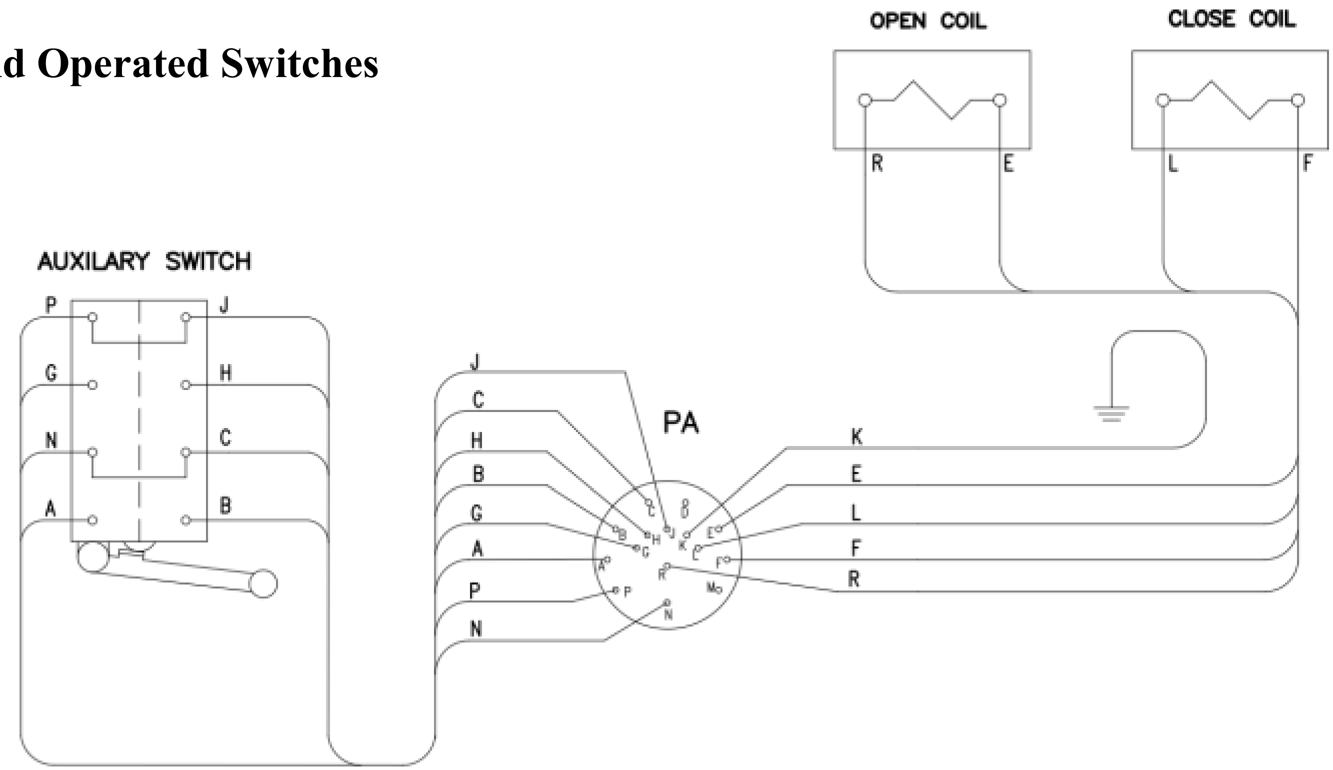


This six circuit auxiliary switch shown above is now obsolete. It dates from being used in the first Joslyn VBM and VBT switches. Two circuits M-L and D-R were only used if the switch was operated without a control. This is never done because the solenoid currents were so large that the life of the auxiliary switch would be very short without having the control. The six circuit switch has been replaced with the similar four circuit switch shown on the next page. The wiring diagram of the four circuit switch is identical except that the rarely used circuits M-L and D-R are omitted. The photograph to the left is of the Eaton™ switch depicted in this schematic. The Vacuum Electric Switch Co. manufacturers a replacement wiring harnesses using the four circuit switch shown on the next page..

Switch Wiring Schematics

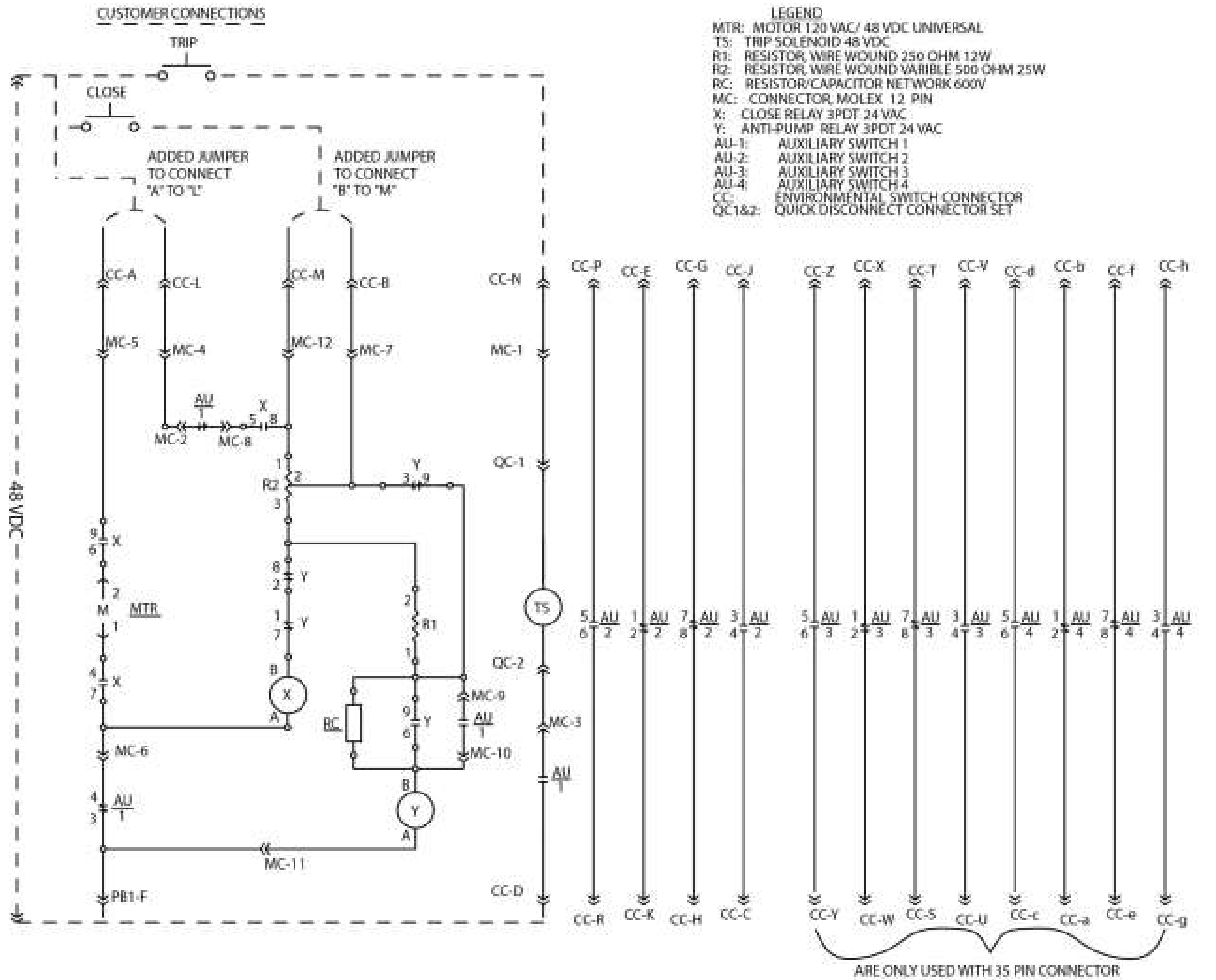
Solenoid Operated Switches

Four Circuit Auxiliary Switch



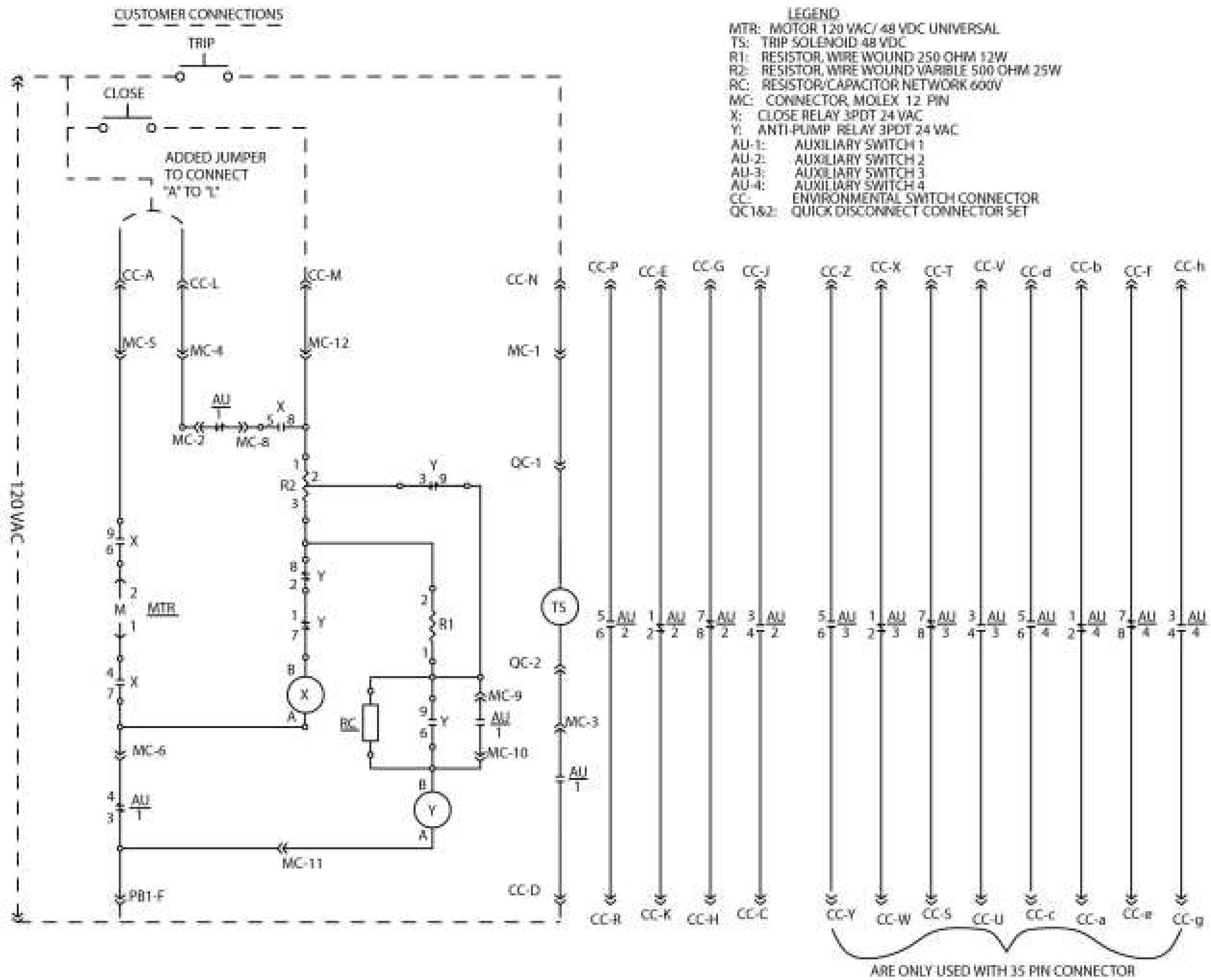
This schematic is of the four circuit auxiliary switch wiring harness used in solenoid operated switches. It replaces the six circuit auxiliary switch shown on the previous page. The photograph to the left is of the four circuit switch depicted in this schematic. The four circuit switch has two circuits omitted were which only used when a solenoid operated switch did not have a control. For practical purposes the four circuit auxiliary switch wiring harness is a suitable replacement for the six circuit wiring harness. The Vacuum Electric Switch Co. manufacturers replacement wiring harnesses using the four circuit switch.

Motor Operator 48VDC



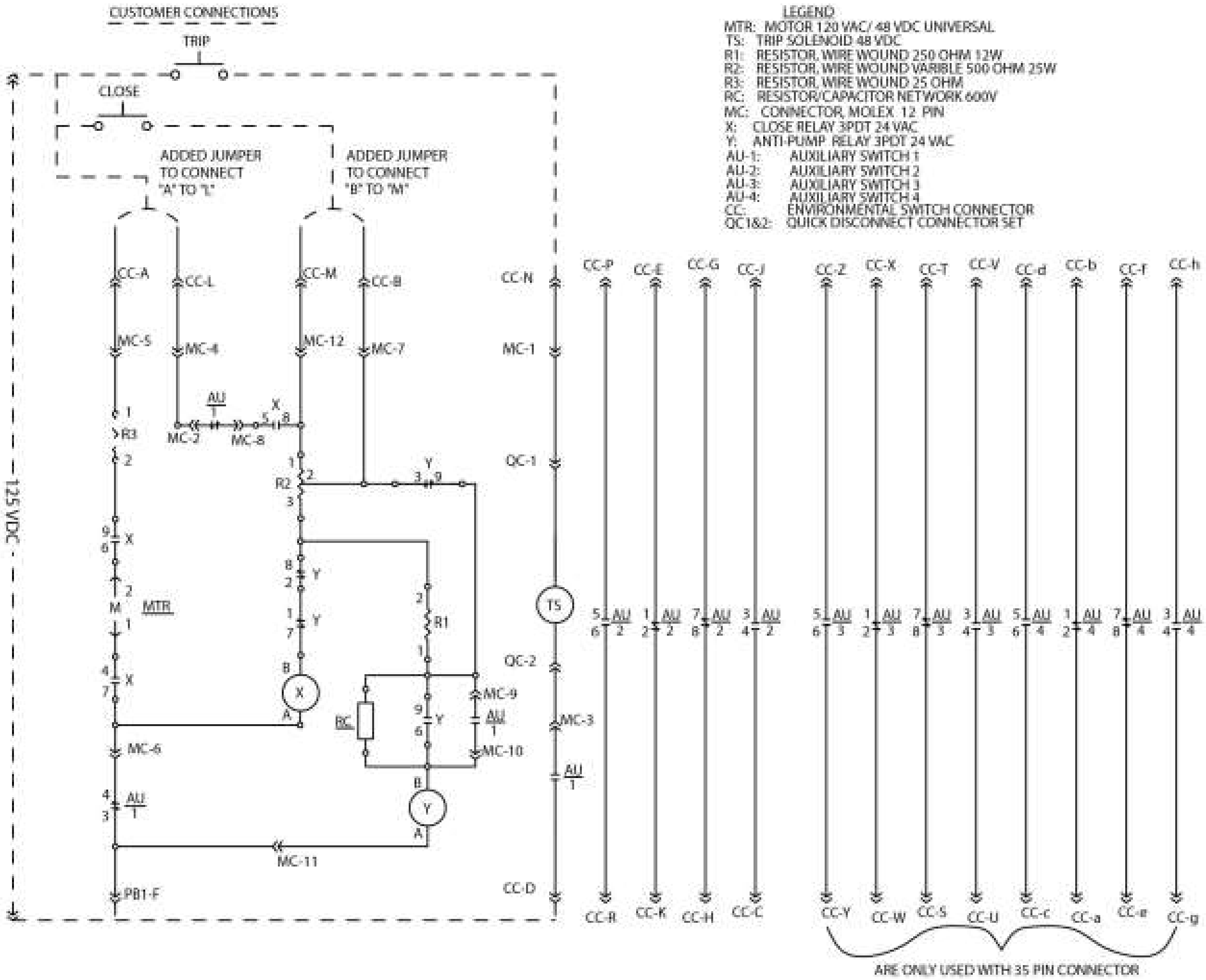
A motor operated switch, with the relay panel shown to the left, operates on 48VDC or 120VAC. The relay panel can be identified by its two resistors, one fixed and the other adjustable. The above schematic shows both the customer and internal switch wiring for operating the switch on 48VDC. Two field installed jumpers are required as shown in the schematic.

Motor Operator 120VAC



A motor operated switch, with the relay panel shown to the left, can be operated on 48VDC or 120VAC. The relay panel can be identified by its two resistors, one fixed and the other variable. The above schematic shows both the customer and internal switch wiring for operating the switch on 120VAC. One field installed jumper is required as shown in the schematic.

Motor Operator 125VDC



A motor operated switch, with the relay panel shown to the left, is operated on 125VDC. The relay panel can be identified by its three resistors. The third resistor is visible behind the other two. The above schematic shows both the customer and internal switch wiring to operate the switch on 125VDC. Two jumpers installed in the field are required as shown in the schematic.

Data Recording Sheet for Switches with Regular Modules

Name Plate Data	
VBT™ Serial Number	
Cat. No.	
Continuous Current Rating (AMPS)	
kV Rating	
G.O. No.	
Terminal-to-terminal BIL (kV)	
Terminal-to-ground BIL (kV)	

Recorded Switch Data			
	Module Data		
	Left	Center	Right
Manufacturer			
Module Serial No.			
Vacuum Interrupter Serial No.			
Sync - normal 0.040” ± 0.004			
Resistance micro ohms - normal less than 200			
Hi-pot - current normal 1mA or less at 30kV, reject at greater than 2mA			
	Mechanism Data		
1500VAC control wiring test			
Link angle - 1 to 3 degrees toward opening for solenoid operated switch, 1 degree for a motor operated switch			
Full travel - normal 0.200” to 0.210”			
Switch counter reading			
	Auxiliary Switch		
Aux switch adjustment - operate before 0.175” of mechanism travel on opening and before 0.025” on closing			
Form A (no) contacts 1, 2, or 6			
Form B (no) contacts 1, 2, or 6			
	Solenoid		
Pin gap adjustment of nylon pins for open and close coils - normal is 0.060” to 0.090”			
	Motor Operator		
Number of handle cranks to closing: 20 to 35 times is normal			
Slap handle once to open switch: ok or reject			
Time for motor to run to close: 3 sec. for AC, 5 sec. for DC control voltages			
Electrical trip: ok or reject			

Data Recording Sheet for Switches with Double Stack Modules

Name Plate Data	
VBT™ Serial Number	
Cat. No.	
Continuous Current Rating (AMPS)	
kV Rating	
G.O. No.	
Terminal-to-terminal BIL (kV)	
Terminal-to-ground BIL (kV)	

Recorded Switch Data						
	Module Data					
	Left		Center		Right	
Double stack modules	upper	lower	upper	lower	upper	lower
Manufacturer						
Module Serial No.						
Vacuum Interrupter Serial No.						
Resistance micro ohms - normal less than 200						
Hi-pot - normal 1mA or less at 30kV, reject at greater than 2mA						
Sync - normal .040” ± .004						

	Mechanism Data
1500VAC control wiring test	
Full travel - normal 0.200” to 0.210”	
Link angle - 1 degree toward opening	
Switch counter reading	
	Auxiliary Switch
Aux. switch adjustment - operate before 0.175” of mechanism travel on opening and before 0.025” on closing	
Form A (no) contacts continuity 1, 2, or 6	
Form B (no) contacts continuity 1, 2, or 6	
	Solenoid Data
Pin gap adjustment of nylon pins for open and close coils - normal is 0.060” to 0.090”	
	Motor Operator Data
Number of handle cranks to closing: 20 to 35 times is normal	
Slap handle once to open switch: ok or reject	
Determine motor operator control voltage by inspecting relay panel	
Motor run time to close: 3 sec. for AC, 5 sec. for DC control voltages	
Electrical trip: ok or reject	

Power Requirements for Solenoid Operated Switches

For a solenoid operated switch to operate reliably over time all of the time, the solenoid needs sufficient power so that it completes its stroke for both opening and closing in less than 1½ AC cycles or where powered by DC in less than 24 milliseconds. The peak current draw will be on the order of 60 to 65 amperes or 90 to 130 amperes for per switches for switches with single or double solenoids respectively. Sufficient design margin in the current supply is required to compensate for normal variations in the power actually available.

The time of solenoid operation is more important than the peak current in determining if the current is adequate. Switches operating more slowly may operate properly many times but will occasionally malfunction. The malfunctions will be difficult to diagnose. Blowing fuses, emergency trips, solenoid coil failures, exploding arrestors, and an occasional over heating of a module due to a switch not fully closing suggests that the power might be inadequate. The only way to prove that power is inadequate is to measure the time of current flow with a digital oscilloscope and a current probe.

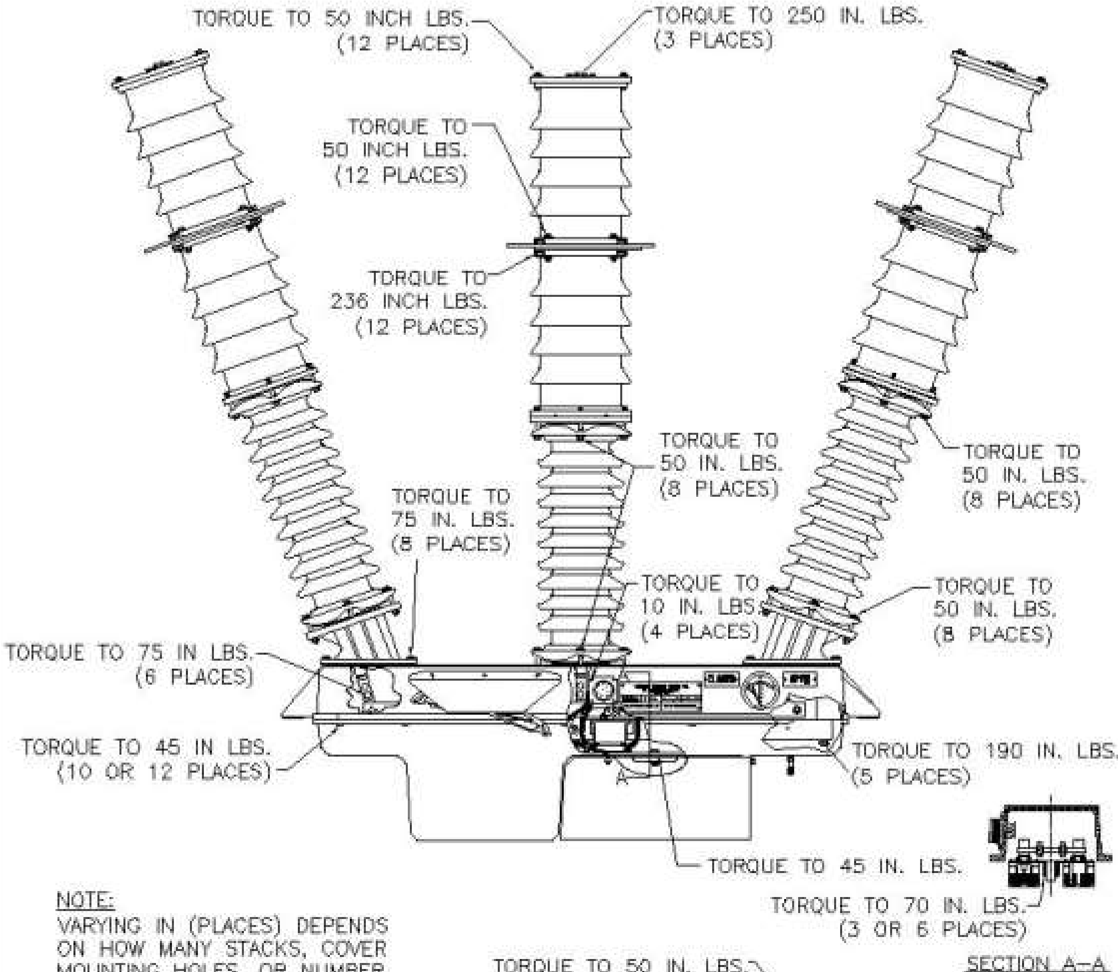
Where switches will be operated in rapid succession as on an arc furnace, they must be supplied by an adequately sized dedicated transformer. When they are only operated occasionally as on a capacitor bank, a stored energy control may be used.

Some rules of thumb are used to size an adequate power system for a switch installation on an arc furnace. Transformer capacity of 5 kVA 3½% maximum impedance step-down transformer to 120VAC is required for each three phase set of switches. Since a 5 kVA 3½% impedance transformer is a special order item, an alternative is a 10kVA 7% maximum impedance transformer which is equivalent. For arc furnaces, the transformer should be dedicated and located as close as practical to the arc furnace control and be connected by suitably large wire.

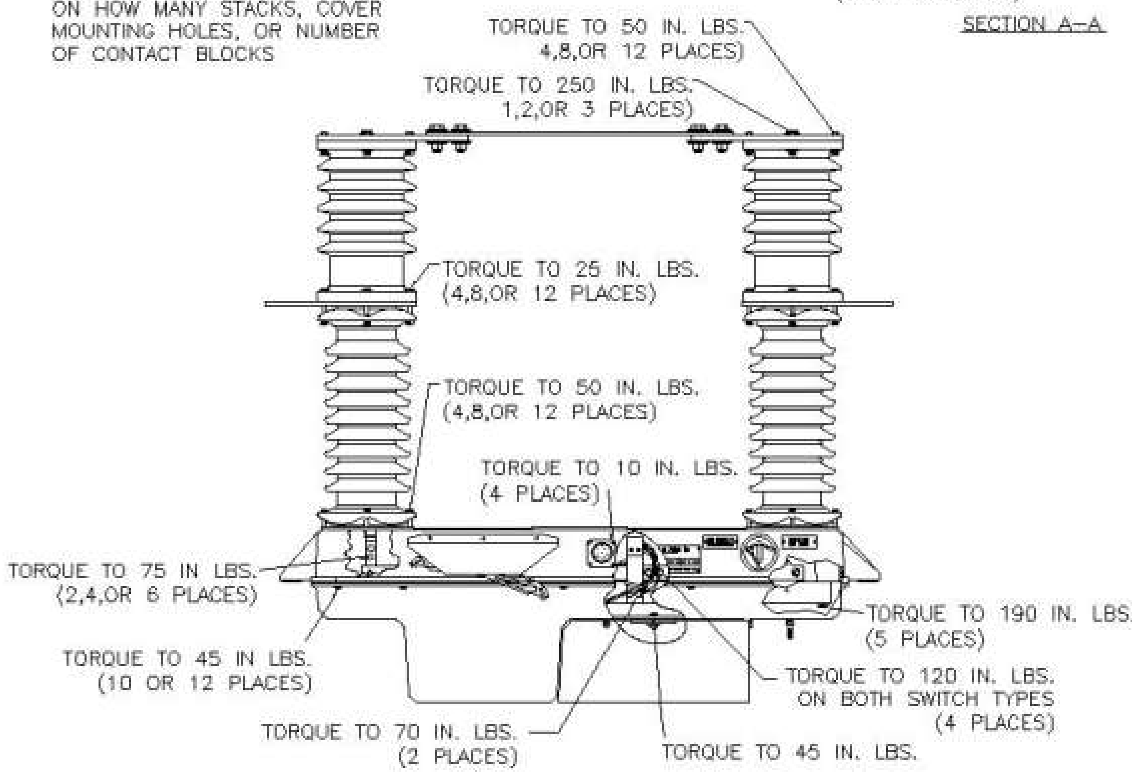
In a substation, the station transformer will normally have more than enough kVA capacity, but the wire run length from the transformer to the control may be long enough to cause excessive voltage drop. Frequently large wire is installed or even two conductors are connected in parallel, but such measures may not always be sufficient. Switch failures can be intermittent and difficult to diagnose. The voltage drop to the switch control is compounded by the small wire in the switch pendant cable. A Joslyn™ cable has #16 AWG conductors, and long pendant cables on double solenoid switches are especially problematic. At 60 or 120 amperes the voltage drop could be 3.8% and 7.7% respectively. To minimize voltage drop VES cables are made using #14 AWG wire. The voltage drop between the transformer and the control cabinet at the peak current should be held to 3% maximum.

Voltage drop problems for switches installed in substations can be prevented by installing stored energy controls. A stored energy control contains capacitors to store the energy to operate the switch. When the switch operates, the large current only has to flow the short distance from the control to the switch. Joslyn builds both stored energy and line powered controls. VES only builds stored energy capacitor controls. When a line powered control is discovered to be supplying an inadequate current to a single switch mechanism, the quick solution is to install the VES boost box shown on page 20; however, aged Joslyn controls should be replaced rather than augmented by a boost box.

Fastener Torque Requirements



NOTE:
VARYING IN (PLACES) DEPENDS ON HOW MANY STACKS, COVER MOUNTING HOLES, OR NUMBER OF CONTACT BLOCKS



Maintenance Planning for Switches and Controls Manufactured or Remanufactured by the Vacuum Electric Switch Co.

Switches manufactured and remanufactured by the Vacuum Electric Switch Co, have substantial upgrades which improve reliability and reduce the need for periodic maintenance. VES switches are expected to have operating lives of 250,000 operations in arc furnace switching duty. The recommended maintenance is preventive in nature.

Scheduled Maintenance for Applications where the Operation of the Switch is Either Frequent or the Economic Consequences of Switch Failure are Substantial

This category of application includes the operation of industrial equipment where the suspension of operations results in large economic losses that are impossible to make up because of loss of productive time. Frequent operation is once every hour or more with annual number of operations exceeding 10,000. An example is the operation of electric arc furnaces where operations are expected to continue twenty-four hours a day seven days a week with only occasional shut-downs for planned maintenance. For this category of application recommended maintenance is:

1. At Installation
    - A. Log date of installation
    - B. Log switch counter reading
    - C. Hi-pot switch modules at 30kVAC RMS - leakage current should be less than 2mA – log results by module and switch serial numbers
    - D. Measure module terminal-to-terminal resistance – should be less than 100 micro-ohms at installation, reject at greater than 200 micro-ohms – log results by module and switch serial numbers
2. For switches having Vacuum Electric Switch Co. arc furnace controls moni tor switch operation time as reported on the panelview monitor. Switches having increasing times beyond 125 milliseconds should be evaluated on a convenient down day.
3. At 100,000 operations
    - A. Hi-pot modules and log results by module and switch serial numbers
    - B. Measure module resistance and log results by module and switch serial numbers
        - D. Lubricate felt washers
        - E. Measure timing and synchronization of modules either by a dynamic test of switch operation or a static test from opening the switch and taking physical measurements. Readjust switch mechanism to specifications as necessary
        - F. Log counter reading and date and time of service

4. At 150,000 operations \
    A. Hi-pot test modules
    B. Measure terminal-to-terminal resistance of modules
    A. Lubricate the felt washers
    B. Measure and readjust link angle, full travel, and synchronism between modules
    G. Measure nylon pin gap and readjust as necessary
    H. Readjust Eaton auxiliary switch
    I. Log counter reading and date at time of service
5. At every 250,000 operations
    A. Completely overhaul switch mechanism
    B. Replace Eaton auxiliary switch and wiring harness assembly
    C. Replace module assemblies

Scheduled Maintenance for Applications where the Operation of the Switch is Occasional or the Economic Losses due to Switch Failure can be Contained to Reasonable Levels

In this category of application, the failure of a switch is basically an inconvenience characterized by reduced efficiency, increased cost, or a reduction in capacity but would not bring operations to a halt. The repair of failed equipment would not require immediate action. Economic losses are containable to reasonable levels. Occasional operation is one or two times a day and sometimes only seasonal usage. The number of annual operations is frequently less than 1,000 or but could be as much as 10,000. As switch is this type of service could be inspected once every five years. Hi-pot modules and measure terminal-to-terminal resistance. Open switch and inspect for corrosion. Replace desiccant bags. Lubricate felt washers. Measure and adjust link angle, full travel and overtravel. Readjust as necessary. Measure and adjust as necessary the operation of the auxiliary switch.

Parts Maintenance

Spare modules should be hi-pot tested every ten years to assure that they have not lost vacuum.

Controls

The electrolytic capacitors in controls require replacement every ten years. Otherwise controls do not require periodic maintenance.

Failure Diagnostic Charts

Capacitor Banks In General

Failure Mode	Possible Causes	Possible Corrective Actions
Blown capacitor fuse or capacitor can rupture with repeated occurrences	Switch restrike following switching caused by leaking vacuum interrupter, excessive in-rush current on closing, or parasitic capacitance reducing recovery withstand voltage of switch. For switches with mechanically separate mechanisms, the contacts in all three phases may not be closing or opening at the same time.	Even if vacuum interrupters pass hi-pot test replace them with vacuum interrupters with known leak tightness. Install reactors to limit in-rush current because high inrush currents can increase restrike probability. Remove physical objects close to the vacuum interrupter modules or install vacuum interrupters with grading capacitors. Install a stored energy control to assure that all switches close at the same time.
Module failure with the switch in the open position	Loss of vacuum in the vacuum interrupter.	Hi-pot test and replace failed vacuum interrupter modules.
Module overheating and failure with the switch in the closed position.	Vacuum interrupter contacts are barely touching resulting in high contact resistance and the generation of too much heat. This can be caused by either the switch being out of adjustment or for a solenoid operated switch, having inadequate power to close completely.	Check and readjust switches. Having inadequate power to operate the switch is very common when switches are operated from an AC or DC line. The available current is checked with a digital oscilloscope and a current probe. For a solenoid operated switch, the solenoid should complete its stroke in 1½ cycles. Solenoids taking longer may operate the switch but over a long period of time they many not be reliable. Correct by increasing the available current. Boost boxes or a stored energy control can solve this problem.
Radio noise in the vicinity of an open vacuum switch.	The radio noise is caused by electrical discharges in the vacuum interrupter as a result of losing vacuum.	Hi-pot test and replace failing vacuum interrupters.

Arc Furnaces In General

Failure Mode	Possible Cause	Corrective Actions
Exploding phase-to-ground arrestor	An exploding phase-to-ground arrestor is caused by applying single or two phase power to a transformer which has transient suppression capacitors connected to the transformer bushings resulting in ferroresonance. -OR- When the furnace switches are connected to the transformer by long cables, applying power to only one or two phases can cause an over voltages by ferroresonance.	The solution to this problem is to install a new control which will prevent single or two phase power from being applied to the transformer.

Arc Furnaces in General (continued)

Failure Mode	Possible Cause	Corrective Actions
Counts on the phase-to-ground arrestor discharge counters	Counts on the phase–to-ground arrestors are caused by ferroresonance resulting from brief periods of loss of power to one or two phases on a transformer with transient suppression capacitors connected to the transformer bushings.	The solution to this problem is to install a new control which will prevent single to two phase power from being applied to the transformer.
Counts on phase–to-phase arrestors.	On a transformer with transient suppression capacitors a transient discharge is occurring through a power factor correction capacitor bank in the local substation.	Install a damping resistor in series with the transient suppression capacitor to make the capacitor discharge overdamped.
Catastrophic module explosion in two phases with no prior indication of module failure	Exceeding switch's 4000 ampere interrupting rating as a result of having over current relays or emergency stop button connected to the Joslyn ™ switches. -OR- Failure to detect vacuum loss failure in one phase before a vacuum loss occurred in a second phase.	Connect over current relays & emergency button to back up breaker. Alternately, on small furnaces install a control with a Schweitzer over current relay to prevent opening the switch at excessive current. -OR- Hi-pot test vacuum interrupters every three months.

Vacuum Switch Failures in General

Failure Mode	Possible Causes	Corrective Action
Hi-pot failure of vacuum interrupter	Air leak into the vacuum interrupter.	Replace Joslyn™ module with a Module having a Mitsubishi™ vacuum interrupter. VES modules are warranted to 60,000 operations and have a recommended useable life of 250,000 operations.
High resistance failure of Joslyn™ vacuum interrupter	Relaxation of mechanical electrical connections inside the module.	VES modules are built with Belleville spring washers on all mechanical electrical connections to keep resistance low by maintaining the bolt tension.
Welding together of vacuum interrupter contact buttons	Excessive wear resulting in improper over travel setting on vacuum interrupter module so as to cause excessive contact resistance or contacts barely touching on closing.	Disassemble switch and replace bearings every 100.000 switch operations. Replace Joslyn™ pull rods, and pull rod screws with VES equivalent replacement parts. Prevent pull rod slippage by using grade 8 fasteners, flat washer, lock washers, and thread locker to clamp pull rod clevis securely. The VES parts reduce wear by replacing aluminum material with stainless steel.
Occasional out of sequencing tripping of solenoid operated switches	For three phase sets of capacitor switches, out of sequence trips will occur when all switches do not open or close within a certain time window. This may be caused by the switches being out of adjustment but also may be caused by an inadequate amount of current being available to operate the switches.	Wear in the bumper assemblies can cause a switch to operate slowly and result in out of sequence trips. Replace bumper assemblies with VES bumpers having more durable urethane bumpers. An inadequate availability of solenoid operating current will intermittently cause out-of-sequence trips. Too small wires and long wire run lengths to the power source will cause this problem.

Solenoid Operated Switches in General

Failure Mode	Possible Causes	Corrective Actions
Blowing fuses in the control	Link angle adjustment is out of spec due to bumper assembly wear. -OR- Supply transformer is too small.	Replace Joslyn™ bumper assemblies with VES bumper assemblies made with more wear resistant urethane bumpers. -OR- A 5kVA 3.5% max impedance transformer is required for each 3 phase set of switches. The transformer must be installed next to the control.
Fracture in pull rod clevis	A cyclic fatigue failure at the clevis corners.	Replace pull rod with VES pull rod having structural support to prevent flexing at clevis corners.
Thread pull out in pull rod plug	The aluminum material has poor wear characteristics.	Replace pull rod with VES pull rod having stainless threaded plugs.
Control yoke fracture at point of yoke bumper stop contact	Cyclic fatigue due to yoke bumper stop impact on control yoke.	Replace Joslyn™ yoke bumper stops with VES all rubber bumper stops.
Control yoke fracture next to nylon pin contact pad	Cyclic fatigue fracture due to nylon pin impact.	In the field, replace control yoke every 100,000 operations. In the shop, change handle shaft from 1/2” to 3/4” dia.
DECCO™ solenoid coil failure	Shorted turns in coil.	Replace coils with vacuum impregnated coils.
Mushrooming of nylon pin ends	Control malfunctioning due to excessive voltage drop in electrical supply to control or excessively high voltage being supplied to the control.	Correct the supply voltage to the control or increase kVA rating of supply transformer and wire size from transformer to control.
Fractured and bent nylon pins	Wear in the solenoid has decreased the air gap so that the solenoid sticks due to residual magnetism.	Replace solenoid with new solenoid assembly having a 0.030” air gap.
Spring assembly or spring retaining clevis pin failure	Lack of lubrication.	Install felt lubricating washers and lubricate.
Toggle link bearing journal wear	No lubrication on bearing journal.	Replace toggle link with link having an oil impregnated sintered bronze bearing.
DECCO™ fractured solenoid side plate	Cyclic fatigue of side plate.	Replace side plates with stress relieved side plates. Prevent side plates from flexing by installing spacer kit.
DECCO™ sticking solenoid armatures	Loss of air gap resulting in residual magnetism causing sticking.	Replace armature with new armature having a 0.030” air gap.
Namco™ solenoid binding of armature	Galling of stainless solenoid armature bearing plates.	Replace stainless steel bearing plates with bronze bearing plates.

Solenoid Operated Switch Failures in General (continued)		
Failure Mode	Possible Cause	Corrective Action
Solenoid mounting bolts vibrating loose	Failure to maintain bolt tension in mounting bolts.	Install screw-lock helicals in aluminum mechanism casting.
Auxiliary switch failure	Eaton™ Aux switch failure.	Replace Eaton™ switch every 250,000 operations.
Square D™ aux switch fracture	Wear in bumper assembly caused the switch adjustment to change resulting in impact forces on the plastic housing.	Replace bumper assembly with VES bumper assembly having a urethane rubber bumper. Replace Square D™ switch with Eaton™ switch.
Spring pin failure in handle or control yoke	Excessive impact forces on spring pins.	Replace Joslyn™ handle with VES low inertia handle. Install control yoke with 3/4 in shaft for handle.
Switches trip open immediately on closing	The emergency trip capacitors are tripping the switches open because one switch is slower than the others.	This problem can be diagnosed by disconnecting the emergency trip capacitors to prevent the emergency trip on closing. Close the switches electrically and observe which switch is not properly closing then install new bumpers assemblies and readjust link angle, full travel, and overtravel.

Motor Operated Switch Failures in General		
Failure Mode	Possible Cause	Corrective Action
Motor runs but switch does not close	Fiber worm wheel gear or bearing journals at the end of worm wheel shaft are worn out.	Replace motor assembly with a new motor assembly having a brass worm wheel and bronze journals for the worm wheel shaft that are lubricated with felt lubricating washers.
Motor operated switch takes too long to charge springs	Ratcheting cams are slipping in aluminum boomerang journals. The ratcheting cams are mounted in too soft aluminum boomerang material.	Replace the aluminum boomerangs with boomerangs made from stainless steel. Alternatively, replace the entire motor assembly.
Motor operator switch trips immediately on closing	The link angle is too large.	Readjust the closing bumper to reduce the link angle to 1 degree in the direction of opening.
Motor operator switch trips immediately on closing	The trip mechanism is out of adjustment possibly because the trip link is worn because it is made from soft aluminum.	Replace trip link with a trip link made from steel and readjust switch.
Spring bolt fractured	Bending stress in the bolt is concentrated at the locking nuts.	Replace bolt assembly with a new bolt assembly having an eye bolt to attach the spring to the switch mechanism. These parts remove the stress concentration.
Motor armature fails in approximately 100 operations	The wrong voltage is applied or the wrong relay panel is installed, or the wrong jumpers are installed.	Determine the voltage to be applied and then select the correct relay panel and jumpers.

Motor Operated Switch Failures in General (continued)		
Failure Mode	Possible Cause	Corrective Action
Spring tab on motor operator side plate fractured	Cyclic fatigue failure of fillet weld.	Replace both side plates with new side plates having brazed (rather than fillet) welded tabs.
Motor does not want to start after a long period of being idle	Corrosion on its armature bars interferes with the flow of current though the armature.	Spray contact cleaner on armature bars to get motor started. Install adhesive mounted heater on motor to prevent corrosion on armature bars.
Square D™ auxiliary switches crack and fail	Caused by excessive wear in the bumper assembly.	Replace both bumper assemblies with bumpers having more wear resistant urethane bumper. Replace Square D ™ auxiliary switches. Alternatively, replace Square D™ auxiliary switches with the Allen Bradley™ auxiliary switch.