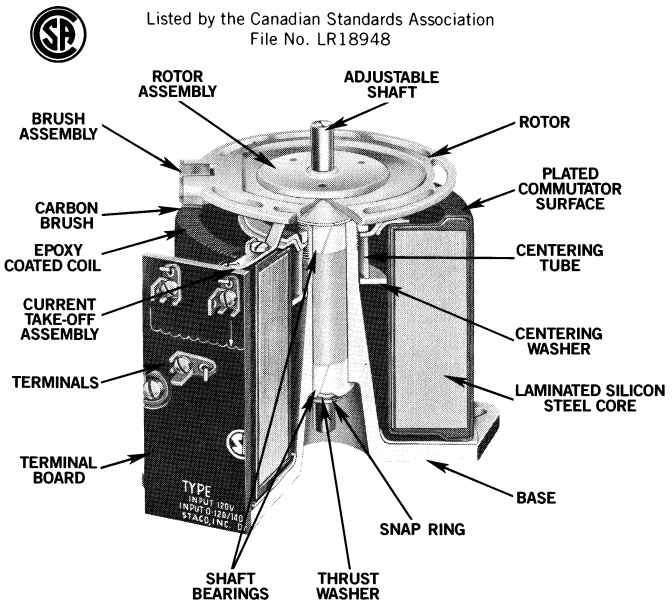
STACO
ENERGY PRODUCTS CO.

Variable Transformers
Product Design & Engineering Data



Type 1010B Cutaway

General Information

STACO ENERGY PRODUCTS CO. is a leading manufacturer of variable transformers, the most versatile and reliable voltage controls available. Variable transformers have many industrial and laboratory applications as basic components to control voltage, current, power, heat, speed, light, and electromechanical force.

A basic STACO Variable Transformer consists of a single layer, magnet wire, winding on a toroidal core of laminated silicon steel. A carbon brush, connected to an output lead, is rotated over a precision ground, plated commutator track to tap off voltage at any turn from zero to the maximum output voltage of the winding.

STACO research has developed design features and proprietary processes providing longer lasting, more reliable products. Particularly important is the high-temperature foundation material bonding the coil securely to the core assembly. This material, which has a high thermal transfer characteristic, dissipates heat from the brush contact area, increases the heat-distribution of the core itself and provides the transformer with greater tolerance to transients and short-term overloads.

VOLTAGE RATINGS

Basic single STACO Variable Transformers are rated either 120 volts or 240 volts. Higher voltage requirements are met by combining or ganging 120-volt or 240-volt units. A 480-volt, single-phase application can be met with two 240-volt variable transformers ganged in a series connection. In three-phase applications, three 120-volt units are ganged in a wye connection to result in a 240-volt line-to-line three-phase assembly. Similarly, three 240-volt units are ganged in a wye connection to result in a 380-volt or a 480-volt line-to-line three-phase assembly. In each of these instances, the individual transformers, or coils, are identified with the basic voltage rating, either 120 volts or 240 volts. When variable transformers are connected in open delta for three-phase applications, two 120-volt units are ganged for 120-volt line-to-line usage. For 240-volt open delta applications, two 240-volt units are ganged with the open delta assembly. In any of the above voltage applications, higher current requirements are met by paralleling two or more units in the ganged assembly.

EFFICIENCY & REGULATION

In contrast to inefficient, wattage-burning resistive-type controllers such as rheostats, STACO Variable Transformers have an extremely low power loss and efficiencies as high as 98%.

STACO Variable Transformers deliver any desired voltage (within the transformer rating) with negligible variation in output voltage from no-load to full-load current. Voltage drop tables and a sample regulation curve are provided in this section.

DISTORTIONLESS VOLTAGE CONTROL

STACO Variable Transformers produce an accurate transfer of input wave to output circuit, providing distortionless voltage control (a requisite of many sophisticated electronic applications).

PLATED COMMUTATOR SURFACE

The commutator surface of each coil is specially plated with precious metal, giving STACO commutators longer life, increased resistance to corrosion and the capacity to withstand greater overloads (while maintaining a constant contact voltage drop).

SIMPLE INSTALLATION AND CONNECTION

Mounting and hook-up of STACO units is convenient and easy. Most series units are designed with an adjustable shaft to accommodate either bench or panel mount (adjustable to accommodate varying panel thickness). Terminals are easily accessible: screw, lug, quick-connect or solder design. Connections deliver increasing output voltage with either clockwise or counter-clockwise knob rotation. Manually operated units have standard dials graduated 0-100 (percentage of output voltage).

LONGER LIFE WITH NEGLIGIBLE MAINTENANCE

Precise design assembly of the brush (at a constant pressure to a smoothly finished and securely bonded commutator surface) provides excellent mechanical performance, long life, and low-driving torque. Brush replacement is seldom needed, but it is easily performed. High safety margins of voltage, current-carrying capacity and dielectric strength are why you can expect longer life from STACO Variable Transformers.

SMOOTH AND LINEAR VOLTAGE CONTROL

STACO Variable Transformers are designed with a fraction of a volt per turn. Close adjustment of output voltage is easy because the brush always contacts one or more turns. Coil turns are evenly spaced, and output voltage is proportional to angular rotation. Full angular travel is approximately 320 degrees on all Series.

VOLTAGE DOUBLER (DUAL INPUT)

Most 240-volt models have an additional input voltage tap permitting normal overvoltage output, with half normal input voltage. The output current must be reduced when the output voltage exceeds 125% of the input voltage as shown in Fig. B on page 6.

TEMPERATURE & RATING

The low loss of STACO Variable Transformers allows operation at full current rating @ ambient temperatures up to 50 degrees C (122 degrees F). In locations above this temperature, the output current must be reduced according to Fig. A on page 6. On single-transient loads and on-off cycled loads, output currents up to 10 times normal may be carried for brief intervals, as shown in Fig. C on page 6.

MILITARY SPECIFICATIONS

All STACO Variable Transformer models are available on special order to meet certain military specifications. Typical of the requirements which can be met are:

ALTITUDE	PHENOLIC PARTS
CONNECTING WIRE	SHOCK
CORROSION	VIBRATION
HUMIDITY	

RUGGED MECHANICAL CONSTRUCTION

STACO Variable Transformers are precision built to exacting mechanical tolerances using the finest materials available. Quality assurance inspections are performed to insure that the high designed-in quality is maintained throughout the manufacturing cycle. A STACO Variable Transformer provides accurate, reliable and lasting voltage control for a broad variety of applications.

General Definitions

The following words or phrases are commonly used to describe characteristics of STACO Variable Transformers.

INPUT VOLTAGE: The supply voltage to which a STACO Variable Transformer is connected.

FREQUENCY: All units in this catalog operate in the range of 50 to 60 HERTZ unless otherwise noted. These units may be used on higher frequencies within the limits shown in the tabulations in the section “Operation at Higher Frequency,” page 5.

OUTPUT VOLTAGE: The range of voltage available at the output terminals.

CURRENT RATING TERMINOLOGY: To permit maximum utilization of STACO Variable Transformers, output ratings are given for both constant current and constant impedance loads.

CONSTANT CURRENT RATING: Output current that can be carried regardless of output voltage setting. (Reduce, for output above 125% of input voltage, on voltage doubler connection.)

CONSTANT IMPEDANCE RATING: Output current that can be carried with loads such as incandescent lamps or resistance heaters in which the current drawn is approximately proportional to the applied voltage, increasing to maximum current at line voltage. This rating applies only to applications where maximum output voltage is limited to line voltage.

KVA RATING: The maximum output current at maximum output line voltage multiplied by that maximum voltage and divided by 1000 for single phase. Divide by 577 for three phase ($1000/\sqrt{3}$).

OVERVOLTAGE CONNECTION: Output voltage from zero to 17% above line voltage (10% for 171 through 291 Series).

LINE VOLTAGE CONNECTION: Output voltage from zero to line voltage.

VOLTAGE DOUBLER CONNECTION: Unit gives full overvoltage output with half normal input voltage. Available on most 240- and 480-volt units. Reduce output current when output voltage exceeds 125% of input voltage.

REGULATION: $\frac{VNL - VFL}{VNL} \times 100 \text{ (percent)}$

VNL = Output Volts No Load

VFL = Output Volts Full Load

DRIVING TORQUE: Torque required to turn the STACO Variable Transformer shaft.

ROTATION: Rotation of STACO Variable Transformer shaft gives increase in output voltage (as viewed from referenced end).

SINGLE UNIT TAP AND TERMINAL DIAGRAM: Input connection is shown for normal overvoltage output. Optional line voltage and voltage doubler input are indicated. Winding section voltages are for a normal overvoltage (or voltage doubler) connection at input voltage shown. Line voltage connections give 85% of these voltages (90% on 171 through 291 Series). Cased units with line cord may omit several coil taps.

CONNECTION — SINGLE PHASE UNIT: Terminals are provided on most models for zero to 117% of input voltage (overvoltage connection) and zero to 100% of input voltage (line voltage connection).

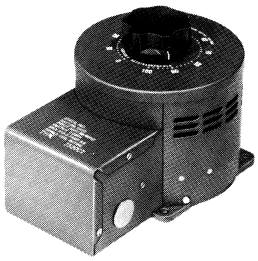
CONNECTION — SINGLE PHASE PARALLEL: Up to nine units on the same shaft may be paralleled by using suitable chokes and circuits to multiply the current and KVA rating. Parallel operation of smaller ganged units is not recommended because it is usually more economical to handle rated loads with the capacity of larger single units. (See specification charts in each transformer series section.)

CONNECTION — SINGLE PHASE SERIES: By jumpering the common connections, two equal single units (or two equal groups of paralleled units) driven by the same shaft may be used at double voltage (line-to-line) in single phase series with external connection only to the input and output terminals. The load must be grounded. If an input neutral is connected to the common, an output neutral may be used. Transformer or loads need not be balanced to neutral.

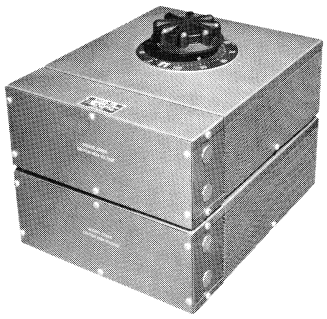
CONNECTION — THREE PHASE OPEN DELTA: By jumpering the common connections, two equal single units (or two equal groups of paralleled units) driven by the same shaft may be used at normal voltages (line-to-line) in three phase open delta. One power line, identical on input and output, connects to the common. The other input lines connect to the two input terminals, and the two output terminals feed the other output lines. (This connection is the same as single phase series with neutral, except that here voltages on all input line pairs are equal and out of phase.)

CONNECTION — THREE PHASE WYE: By jumpering the common connections, three equal single units (or three equal groups of paralleled units) driven by the same shaft may be used at double voltages (line-to-line) in three phase wye. The load must be ungrounded. Input lines connect to the three input terminals, and the three output terminals feed the output lines. If ganged units are used in a system that ordinarily has a common neutral or ground between source and load, then the neutral or ground must also be connected to the common point of the ganged variable transformer assembly. If the system has no neutral, then the loads must be balanced. Because of the 115.5% voltage on the individual single units, there are 50 HERTZ restrictions. See specifications for each Series.

BENCH MOUNTING: Mounting of STACO Variable Transformers on floor, bench, or wall where the knob and brush rotors of single units (and most multiple units) are at the same end of the coils.



CASED MODELS: All 1010B to 6020 Series models are available in cased designs (identified by the suffix "C," "CT" or "E" in the type number). "C" styles enclose only the coil, while "CT" models provide protective housing for both coil and terminal board. Knockouts are provided in the terminal board housing to accommodate conduit or cable connections. "E" styles include our NEMA 1, drip-proof, fully front accessible enclosures for our 5000/6000 Series.



BACK OF PANEL MOUNTING: Mounting of STACO Variable Transformers with shaft passing through a panel. The knob and brush rotors of single units (and most multiple units) are at opposite ends of the coils.

ISOLATED VARIABLE TRANSFORMERS: An Isolated Variable Transformer consists of two (primary and secondary) magnet wire windings on a toroidal core. The primary winding is electrically isolated from the secondary winding. The input winding has 82% of the turns of the output winding so the output voltage can be varied from 0-122% of the input voltage.

UNCASED (OPEN CONSTRUCTION) MODELS: The basic models of all series are uncased designs. The type number contains no prefix or suffix letter. These models do not have a protective housing for coil or terminal board. Adjustable shaft design on most manually operated models permits back-of-panel or bench mounting.

PORTABLE CORD & PLUG MODELS: Cased plug-in models have a ventilated steel case, line cord, receptacle, illuminated on/off switch and fuse. A three-conductor (3PN prefix) line cord and matching receptacle are available on these units. Plug-in models are connected for output voltage in a clockwise rotation and are available in each Series through the 2510/2520 units.

L SERIES: A selected grouping of variable transformers packaged in a deluxe aluminum enclosure, three-conductor line cord, plug, matching receptacle, pilot light, switch and fuse. An ammeter and voltmeter are available on the 10 amp model.

General Design Specifications

The table below lists general design values for each standard unit on a per coil basis. The DC resistance is as measured from start to finish of coil winding, no load losses are actual core losses, and the torque values are the driving torque required to move the rotor and brush assembly. Using per coil values listed, total DC resistance and core losses can be calculated for parallel or series connected ganged units, and total torque requirements can be determined.

Type	Coil DC Res. (Ohms)	Per Coil Value No Load 60 Hz Losses (Watts)	Driving Torque (oz-in)
171	23.6	1.5	6 max
201	23.8	1.5	6 max
221-B	14.5	1.8	6 max
252	115	2.0	6 max
291	8.0	2.2	6 max
501-B	4.4	3.0	10-30
511	4.4	3.0	10-30
1010B	1.2	5.4	15-35
1020B	11.4	5.2	15-35
1210B	0.6	6.4	15-35
1220B	4.4	6.4	15-35
1510	0.3	13.2	15-35
1520	1.4	18.0	15-35
2510	0.21	14.7	60 max
2520	1.7	14.5	60 max
5011	0.090	28.0	105-160
5021	0.353	28.0	105-160
6011	0.144	7.5	105-160
6020	0.478	7.5	105-160

OPERATION AT HIGHER FREQUENCY

All STACO standard Variable Transformers are designed to operate within a frequency range of 50 to 60 Hertz unless otherwise noted. While designed to operate at 50/60 Hz, Staco Variables can be operated at frequencies up to 2000 Hz. The table below lists unit maximum output current rating at 50/60, 400, 1500, and 2000 HZ.

Type	Maximum Output Current (Amperes)							
	50/60 Hz		400 Hz		1500 Hz		2000 Hz	
	Constant		Constant		Constant		Constant	
	I	Z	I	Z	I	Z	I	Z
171	1.75	2.2	1.75	2.2	1.75	2.2	1.75	2.2
201	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5
221-B	2.5	3.2	2.5	3.2	2.5	3.2	2.5	3.2
252	0.8	1.0	0.8	1.0	0.8	1.0	0.8	1.0
291	3.0	3.5	3.0	3.5	3.0	3.5	3.0	3.5
501-B	5.0	7.0	5.0	7.0	5.0	7.0	5.0	7.0
511	5.0	7.0	5.0	7.0	5.0	7.0	5.0	7.0
1010B	10.0	13.0	10.0	13.0	9.0	11.7	9.0	11.7
1020B	3.5	5.0	3.5	5.0	3.5	5.0	3.5	5.0
1210B	12.0*	15.0*	12.0	15.0	3.2	4.5	3.2	4.5
1220B	5.0*	7.0*	5.0	7.0	4.5	6.3	4.5	6.3
1510	15.0	20.0	12.5	17.0	5.0	7.0	5.0	7.0
1520	7.5	10.0	7.5	10.0	3.5	4.3	3.5	4.3
2510	25.0	30.0	18.6	30.0	9.0	11.5	9.0	11.5
2520	10.0	13.0	9.3	13.0	3.3	5.0	3.3	5.0
5011	50.0	—	22.5	22.5	—	—	—	—
5021	28.0	—	14.0	14.0	—	—	—	—
6011	60.0	—	25.0	25.0	—	—	—	—
6020	35.0	—	17.0	17.0	—	—	—	—

* 60 Hz only

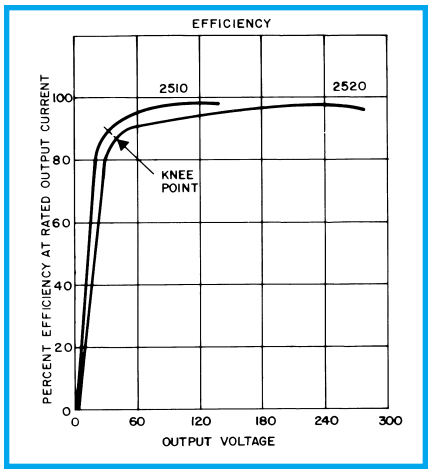
EFFICIENCY

Efficiency curves are available from STACO or can be drawn similar to the efficiency curve shown below for any units by starting at zero, passing through the knee point, and reaching 98% efficiency at rated voltage.

Knee Point Data

Model Number	% Efficiency	Volts
171	62	23
201	67	24
221-B	73	23
252	65	50
291	67	24
501-B	77	18
1010B/1210B	80	30
1020B/1220B	80	17
1510	86	10
1520	83	20
2510	90	30
2520	87	40
5011	82	27
5021	75	40
6011	87	30
6020	82	38

Efficiency



OUTPUT CURRENT LIMITS

Continuous brush output current of STACO Variable Transformers, at normal ambient temperatures, must be limited to the rated amperes. The constant current rating may be drawn at any brush position except in voltage doubler circuits.

For satisfactory life, the brush output current of STACO Variable transformers operated in hot enclosures, or other locations of high ambient temperature, must be limited as shown in Fig. A. Close exposure to radiant heat should be avoided or loading should be reduced accordingly.

For voltage doubler connections (at output voltages above 125 percent of the input voltage) the continuous brush output current must be progressively limited (as shown in Fig. B) down to 44 percent of rated amperes at maximum output voltage. Protection of this type of usage may be approximated with a dual-element lag fuse in the lead to the the input terminal and with either a quick or slow blow fuse in the brush output lead.

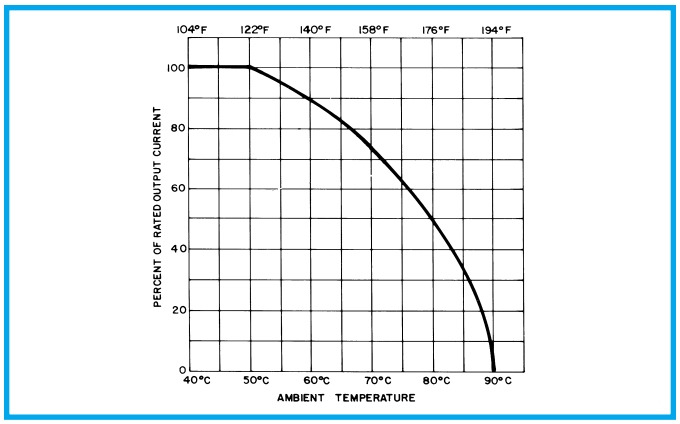


Figure A. Max output current for high temperature

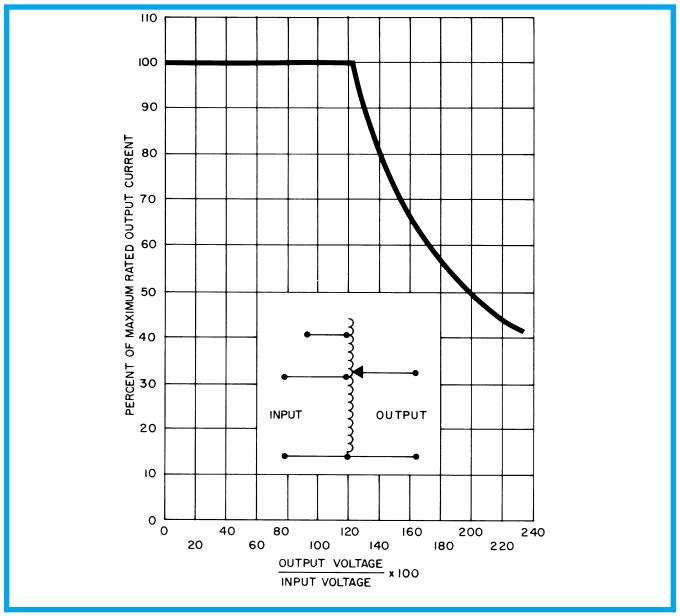


Figure B. Max Output Current — Dual Voltage

SHORT-TIME CURRENT OVERLOAD

Although STACO Variable Transformers are small and light weight for the large power ratings which they handle, brush currents up to 10 times normal may be drawn for a brief time. The maximum on time curve of Fig. C shows the duration of surge on transient currents which may be absorbed by a cold unit on motor starting or similar service. Protection for this level of service may be approximated by hydraulic-magnetic circuit breakers with trip coil in the brush output lead. If the unit is hot from previous loading, such as repetitive overloads, it must also be allowed sufficient off time as indicated on the minimum off time curve of Fig. C to prevent excessive temperatures. If the time on is less than allowed by the "on" curve, the minimum time off may be reduced in accordance with the following equation:

$$\frac{\text{OFF TIME}}{\text{ON TIME}} = \left(\frac{\text{OVERLOAD CURRENT}}{\text{RATED CURRENT}}\right)^2 - 1$$

Protection for this level of service may be approximated by a dual-element lag fuse in the brush output lead.

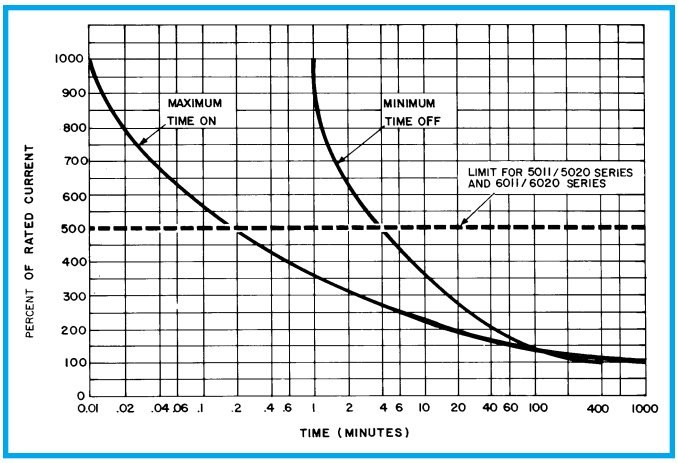
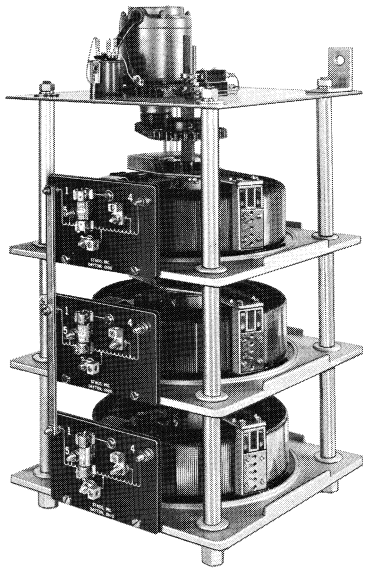


Figure C. Max On Time and Min Off Time for Various Overload Current Conditions

MOTOR-DRIVEN VARIABLE TRANSFORMERS

Motor-driven models permit remote control of large amounts of power. A STACO motor-driven Variable Transformer can be installed in any out-of-the-way space and the control station placed where desired. Extreme flexibility in system design is possible because the control location does not have to accommodate the variable transformer assembly. Motor-driven units have the same electrical ratings as their corresponding manually-operated types.

The motor drive is a compact integral unit mounted on top of the assembly. On cased models, the motor-drive assembly is enclosed and is provided with knock-outs for cable or conduit connections. The permanent magnet synchronous motor operates on 120 volt, 50/60 Hertz single phase lines. Because synchronous motors are frequency sensitive, they operate slightly slower at 50 Hertz.



Standard motor-driven models are available in speeds of 5, 15, 30 and 60 seconds at 60 Hertz for full range travel from zero to maximum output voltage. A smooth, quiet planetary gear unit is used for proper speed reduction from the motor to the STACO Variable Transformer shaft. Limit switch control at the lower and upper limits of travel prevents overtravel. The limit switches may be adjusted if desired. Additional limit switches may be added for operation and control of auxiliary circuits as required, STACO Auxiliary Switch Kit P/N 964-0057 (available separately).

To specify, prefix the desired time of travel in seconds, and the letter “M” for motor-drive to the Type number. For example: 5 seconds speed travel = 5M1010B.

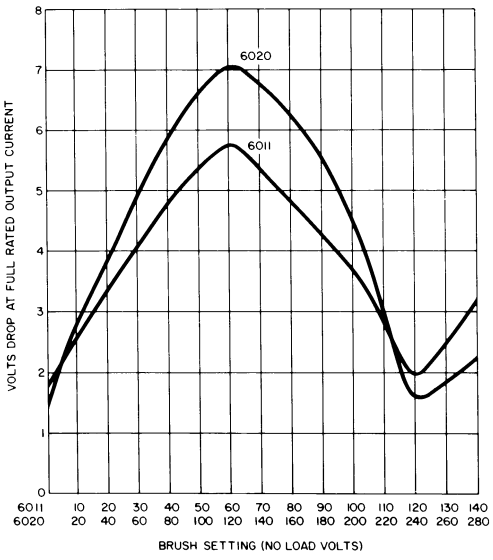
Normally, one switch is used to operate each Motor-Driven STACO Variable Transformer. Any momentary contact switch, whether lever action or push button, may be used. If desired, additional switches can be provided to permit control from any of several locations. Master control of two or more motor-driven units is also possible using relays or multiple-pole switches.

TYPE FRC-20 AND MP CONTROLLERS

For our Motor Operated Variable Transformers, we offer the FRC-20 and MP Controllers, which both position and regulate the variable transformer. For complete information refer to section on controller types, pages 38 and 39.

Regulation

These tables provide the voltage drop at selected points at the corresponding model’s regulation curve. This is the variation in the output voltage from no-load to full-load current. A sample regulation curve for the 6000 Series is illustrated below.



120 Volts - Voltage Drop At Full Rated Output Current

Type	Brush Setting (No Load Volts)						
	0	20	40	60	80	100	120
171	0.2	4.2	7.1	8.5	7.0	4.0	0.2
201	0.2	4.9	7.8	9.0	7.5	4.2	0.3
221-B	0.3	3.0	5.1	6.0	5.0	2.9	0.3
291	0.4	2.5	4.1	5.2	4.2	2.3	0.4
501-B	0.3	3.9	5.2	5.8	5.2	4.0	0.3
511	0.3	3.9	5.2	5.8	5.2	4.0	0.3
1010B	0.2	2.8	4.2	4.5	4.2	3.0	0.8
1210B	0.2	1.3	1.8	2.0	1.8	1.4	0.4
1510	0.1	0.8	1.4	1.7	1.5	0.9	0.2
2510	0.5	1.8	2.2	2.5	2.2	1.9	0.1
5011	3.0	4.2	4.8	5.4	5.2	4.1	3.0
6011	1.9	2.5	3.3	5.7	4.8	3.7	2.0

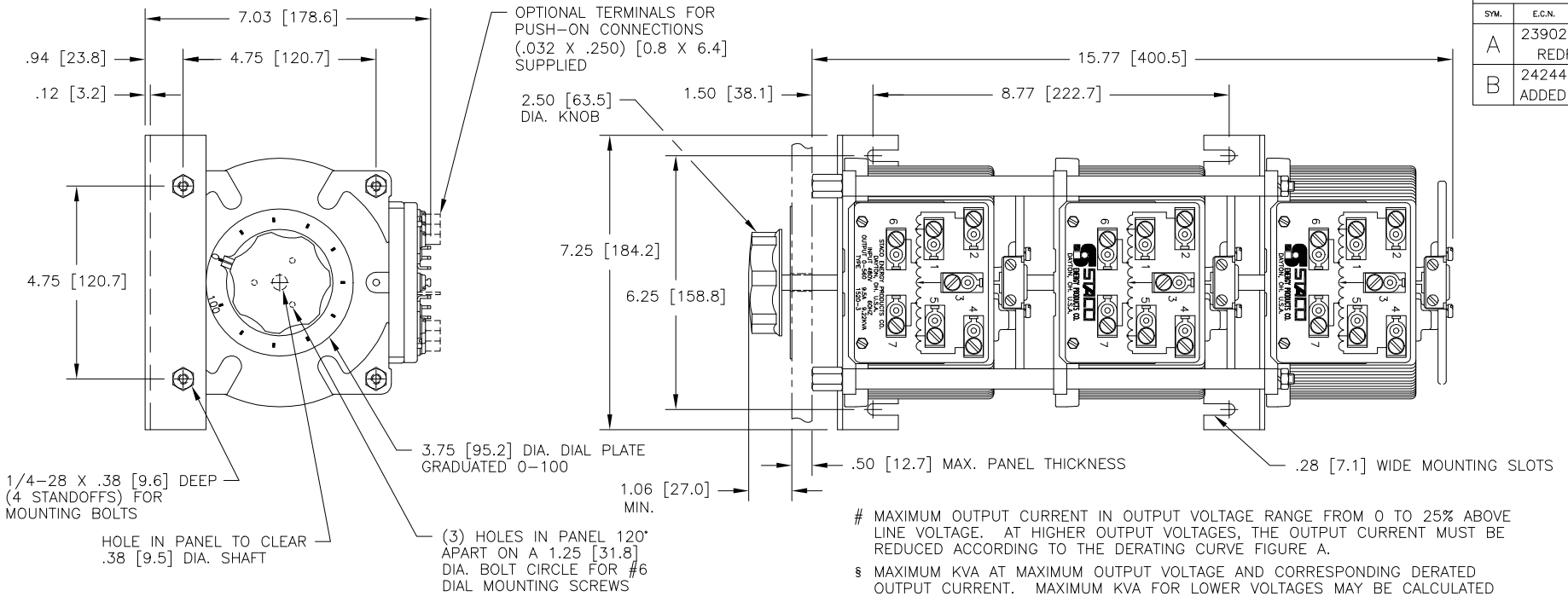
240 Volts - Voltage Drop At Full Rated Output Current

Type	Brush Setting (No Load Volts)						
	0	40	80	120	160	200	240
252	1.0	13.0	17.5	20.6	17.0	12.5	1.4
1020B	0.2	5.4	6.7	7.0	6.5	5.0	0.4
1220B	0.2	4.5	5.8	6.1	5.6	4.3	0.4
1520	0.2	2.2	3.6	4.0	3.3	2.1	0.3
2520	0.5	4.2	5.2	5.5	5.2	4.2	0.4
5021	2.5	4.2	5.8	7.0	6.6	4.6	2.6
6020	1.4	3.9	5.9	7.0	6.2	4.5	1.6

DWG. SIZE	DWG. NO.
C	031–3925

REVISIONS

SYM.	E.C.N.	DATE	APVD.
A	23902	12/17/98	
	REDRAWN ON CAD		
B	24244	5/23/00	
	ADDED OPTIONAL NOTE		



MAXIMUM OUTPUT CURRENT IN OUTPUT VOLTAGE RANGE FROM 0 TO 25% ABOVE LINE VOLTAGE. AT HIGHER OUTPUT VOLTAGES, THE OUTPUT CURRENT MUST BE REDUCED ACCORDING TO THE DERATING CURVE FIGURE A.

§ MAXIMUM KVA AT MAXIMUM OUTPUT VOLTAGE AND CORRESPONDING DERATED OUTPUT CURRENT. MAXIMUM KVA FOR LOWER VOLTAGES MAY BE CALCULATED FROM DERATING CURVE FIGURE A.

++ LINE TO LINE VOLTAGE.

π IF GANGED UNITS ARE USED IN A SYSTEM THAT ORDINARILY HAS A COMMON NEUTRAL OR GROUND BETWEEN SOURCE AND LOAD, THE NEUTRAL OR GROUND MUST BE CONNECTED TO THE COMMON TERMINALS OF THE VARIABLE TRANSFORMER ASSEMBLY. IF THE SYSTEM HAS NO NEUTRAL, THE LOAD MUST BE BALANCED OR THE TRANSFORMER WILL BE DAMAGED.

■ JUMPER PROVIDED IN STANDARD COMMON POSITION AND SHOULD BE MOVED OR REMOVED AS REQUIRED.

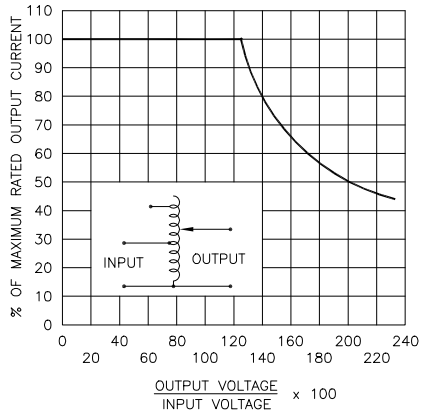
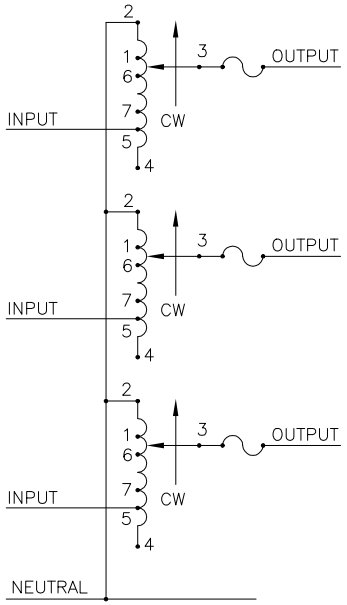


FIGURE A

MAXIMUM OUTPUT CURRENT OF ANY DUAL INPUT VOLTAGE OR VOLTAGE DOUBLER UNIT OPERATED AT LOWER INPUT VOLTAGE.



SCHEMATIC

THREE PHASE WYE

FUSES RECOMMENDED BUT NOT SUPPLIED

SPECIFICATIONS

WIRING	INPUT VOLTS	INPUT HERTZ	OUTPUT VOLTS	OUTPUT CONSTANT CURRENT LOAD MAX. AMPS	OUTPUT CONSTANT CURRENT LOAD MAX. KVA	OUTPUT CONSTANT IMPEDANCE LOAD MAX. AMPS	OUTPUT CONSTANT IMPEDANCE LOAD MAX. KVA	SHAFT ROTATION TO INCREASE VOLTAGE	TERMINAL CONNECTIONS FOR INCREASING VOLTAGE AS VIEWED FROM BASE END ■ INPUT	JUMPER	OUTPUT
THREE PHASE WYE π	480 ++	50/60	0–480	9.5	7.90	12	10	CW	2–2–2	4–4–4	3–3–3
								CCW	4–4–4	2–2–2	3–3–3
		60	0–560	9.5	9.21	——	——	CW	1–1–1	4–4–4	3–3–3
								CCW	5–5–5	2–2–2	3–3–3
	240 ++	60	0–560	9.5#	3.96 §	——	——	CW	7–7–7	4–4–4	3–3–3
								CCW	6–6–6	2–2–2	3–3–3

UNLESS OTHERWISE SPECIFIED, TOLERANCE IS ±
DECIMALS .XX ~~.010~~ .06 .XXX .005 | HOLES .002 | ANGLES 1° | DRAFT 1–1/2°

UNITS IN [mm]

MATERIAL :

ALL DIMENSIONS APPLY AFTER PLATING

TITLE: SPEC. CONTROL DWG. VARIABLE TRANSFORMER MODEL: 1520–3

STACO ENERGY PRODUCTS CO.
A COMPONENTS CORPORATION OF AMERICA COMPANY
DAYTON, OHIO U.S.A.

DRAWN BY	DATE	FIRST USED ON	DO NOT SCALE DWG.	CUSTOMER APPROVAL	DATE
S.A. SMITH	12/17/98				
CHECKER	DATE	WEIGHT APPROX. 66 LBS	CODE IDENT. NO. 83008	DWG. SIZE C	DWG. NO. 031–3925
ENGINEER	DATE	SCALE .5=1	SHEET 1 OF 1		