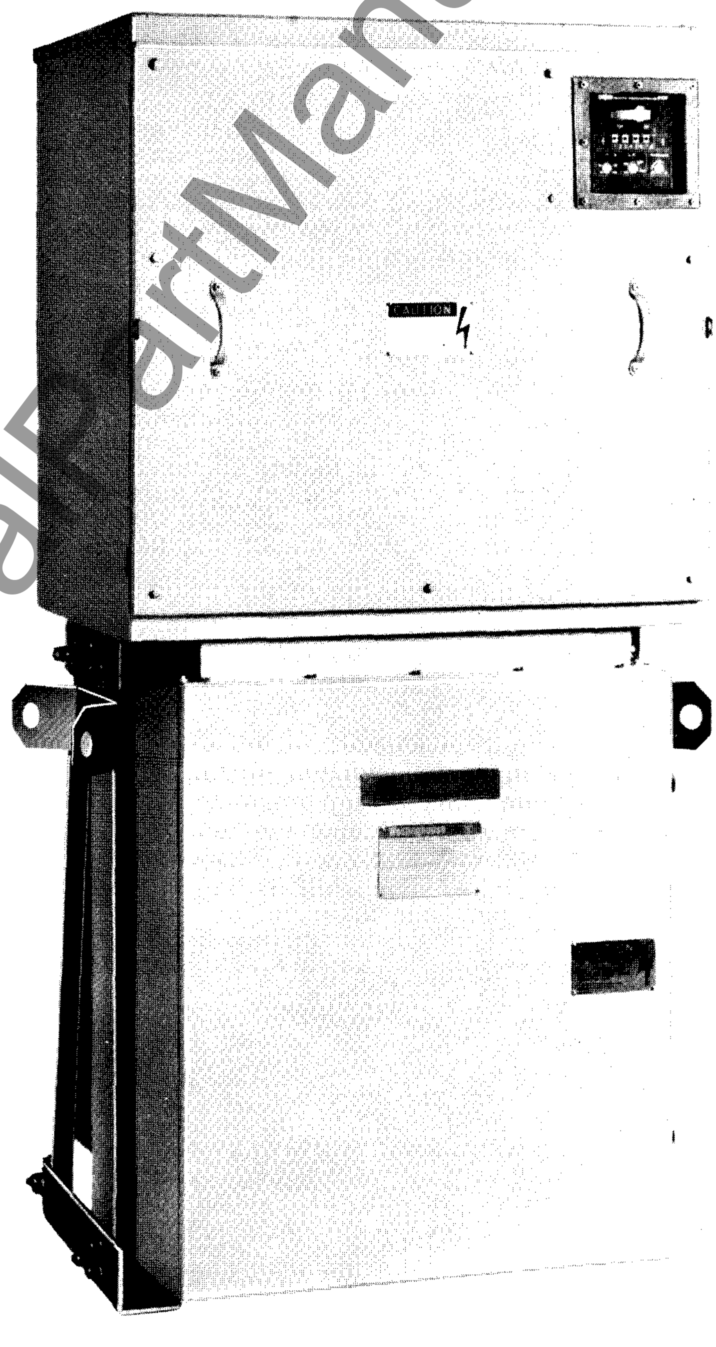
Westinghouse Electric Corporation
Distribution Apparatus Division
Bloomington, Indiana 47401

December 1980
Supersedes DB 39-251
Pages 1-4, dated Sept. 1978
Mailed to E, D, C/2001, 2002, 1709/DB

Multi-step, Automatic Power Factor Control Equipment

VAR—PAK Metal Enclosed Capacitor Bank



Application

The VAR-PAK automatic power factor correction capacitor bank is designed to provide and maintain a constant power factor level on the low voltage distribution system of an industrial plant. Utilizing a current signal from the customer's remote current transformer and a voltage signal from its own potential transformer, the automatic power factor controller in the VAR-PAK continually monitors the system load and automatically switches capacitors, either on or off the system, to maintain the proper power factor. Thus as reactive loads on the system vary, the VAR-PAK adjusts to keep a constant, desirable power factor level.

With most utility rate structures, power factor significantly influences the billing in some manner. Some utilities increase the billing if the power factor is below a specified level, while others provide a bonus for a power factor above the minimum desirable level. For most industrial plants, capacitors which supply reactive KVA, usually offer the most economical and practical means to increase the power factor to a desirable level.

Specifically, many industrial plants have sections of their plant that contain many induction motors fed through a three-phase line. Capacitors can be supplied either individually at the motors or through a centralized capacitor bank. On many systems, the motors are frequently turned on and off, causing a varying system load. For this situation, a constant fixed capacitor bank on the system may not be appropriate and supplying individual capacitors on each motor may not be as economical as the VAR-PAK. Automatic power factor correction with the Westinghouse VAR-PAK is the answer in this type of situation.

Theory of Operation

Using a customer supplied external current transformer and an internal potential transformer the electronic sensing unit measures VARS. When the measured leading or lagging value of VARS exceeds the desired value, a switching signal is transmitted to the respective switching contactor. Thus, the individual capacitor steps are switched on or off in sequence. A time delay is built into this switching procedure in order to protect the capacitors from overvoltages. This allows the internal discharge resistors to drain the trapped voltage before the capacitors are re-energized.

Benefits of Automatic Power Factor Correction

Besides the benefits from regular power factor correction, automatic power factor correction gives the customer the following advantages:

Centralize power factor correction: The VAR-PAK is a centralized capacitor bank which controls from one location the amount of power factor correction applied. This eliminates the need for smaller individual units to be placed on the distribution system. This can also mean reduced installed capacitance.

When the situation exists of having many motors on a system but seldom having all the motors on at the same time, the VAR-PAK can actually reduce the amount and number of capacitors required. Capacitance supplied by the VAR-PAK will reduce the number of capacitors when compared to having individual capacitors located next to the motors.

Flexibility for future considerations: In many cases, there will be extra space in the VAR-PAK. Thus, as the distribution load increases, additional capacitors may be installed in the VAR-PAK to a maximum of eight capacitors.

Improved Power Factor Control: Due to its multi-step arrangement, the VAR-PAK incrementally adjusts the amount of capacitors on the system to insure that the power factor stays within desired limits.

Simplified Capacitor Application: The VAR-PAK will automatically decide how much power factor correction is needed at any given time. The major decision required by the application engineer is "What is the total KVAR required to achieve the desired power factor improvement?"

Simplified Capacitor Installation: Due to its packaged design concept, the VAR-PAK includes capacitors, fuses, contactors and controller in one enclosure. This dramatically reduces the installation time required for an automatically controlled capacitor system.

Easy Maintenance and Inspection: The controller incorporates lights which indicate the energized capacitor steps. This allows for a quick, visual inspection of equipment operation. When all the lights are on, it may be an indication that additional capacitors are required.

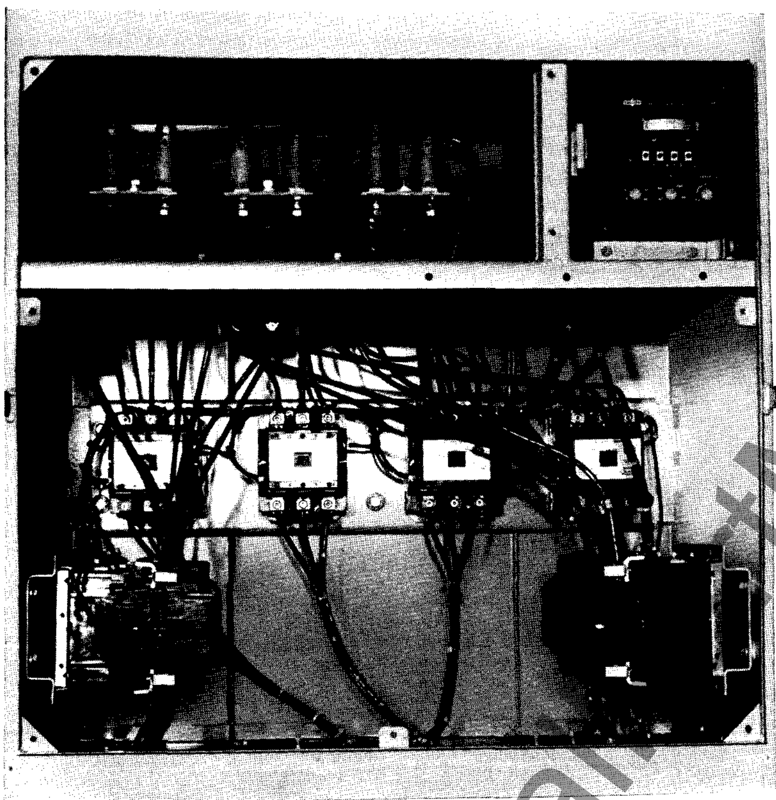
Benefits of Power Factor Correction:

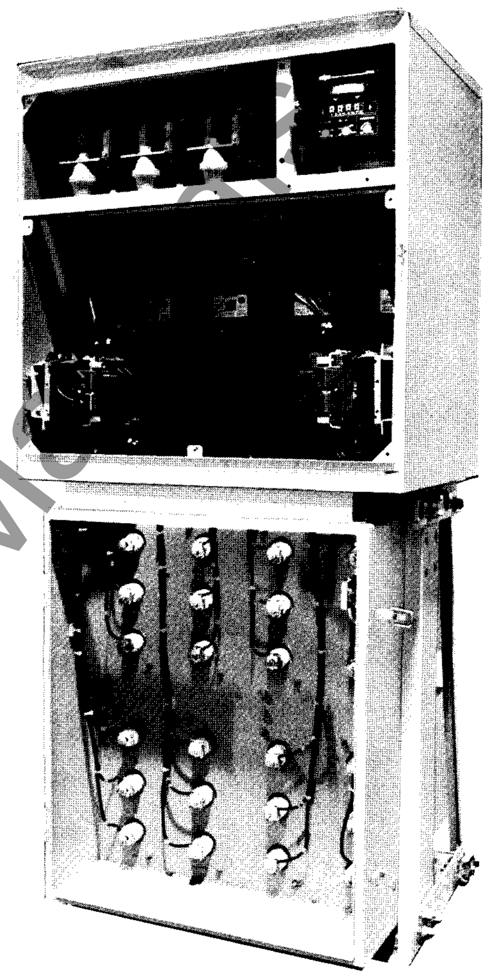
Reduced power costs: With most utility rate structures, the power factor influences the billing in some manner. Some increase the billing if the power factor falls below a specified level. Others provide a bonus for raising the power factor to desirable levels.

Depending on the plant conditions and the local utility rate practices, capacitors can often pay for themselves in as little as six to eight months.

Increased System Capacity: Magnetizing current which may increase line current flow by 2/3 or more must be supplied by the same system that supplies the working current. Capacitors supply the "non-productive" magnetizing current locally, confining it to the smallest possible segment of the system. This releases more of the system's capacity to carry useful, working current. In the case of a growing load, this may forestall the necessity of purchasing additional system capacity.

Improved Voltage Control: Low voltage is money. Excessive voltage drop increases and creates motor-killing heat. Low voltage can make an otherwise adequate lighting system ineffective. Motor controls and instruments operate below par. Furnaces may induce less than rated temperature, or take longer to reach rated heat. The use of capacitors to supply the reactive current required by inductive loads can help keep the voltage at desirable levels.





General Description

The Westinghouse VAR-PAK metal enclosed capacitor equipment consists of an upper and lower compartment. The upper compartment has an automatic power factor controller with indicating power meter, the power bus, fused potential transformer, contactors, and current limiting fuses. The lower compartment has the power factor correction capacitors. The fuses in the upper compartment are selected to provide protection for the contactors, capacitors, and all interconnecting wiring. Doors on both compartments are interlocked so that all contactors are de-energized when doors are open. The VAR-PAK is suitable for either indoor or outdoor installation.

Typical Specifications

1) Rating

The VAR-PAK is rated for up to 600 volts at 30 KV BIL. Operation is suitable in ambient temperatures up to 40°C.

a) System
Voltage L-L ____ (240, 480, 600 volts)

b) Total KVAR
Now ____
Future ____

c) KVAR Steps (Maximum of 8 equal steps)
Fixed ____
Switched ____
KVAR/STEP ____
1) At 240 V, steps of 5, 7.5, 10, 15, 20, 25, KVAC
2) At 480 V, steps of 5, 7.5, 10 15, 20, 25, 30, 35, 40, 45, 50, 60, and 75 KVAC
3) At 600 V, steps of 7.5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60 and 75 KVAC.

d) Options
Blown Fuse Indicating Lights
Kirk Key Interlock
Manual Operation Switches

2) Wiring

All wiring and circuit protection shall be in accordance with NEC applicable standards.

3) Structure

Dimensions shall be 72 inches high, 31 inches wide, and 35.5 inches deep.

Frame shall be ¼ inch mild steel, fabricated angle with structural members to be bolted.

Enclosure shall be 1/16 inch thick mild steel except capacitor mounting plate to be ⅛ inch thick. Enclosure to be protected by a zinc chromate primer and finish paint shall be ANSI #70 gray.

Incoming entrance for the electrical connection shall be a removable plate 29" x 14.375" located on top of the unit. Customer shall be able to remove plate to drill to suit needs.

Electrical interlocks shall be mounted on both the upper and lower compartment doors that de-energize the contactor when either door is open.

Lifting lugs shall be removable four bolt design with four hook lifting hitch capability.

A grounding lug shall be mounted on the bottom of the frame with two .562 inch diameter holes for connection.

Upper Compartment

Contactors – Westinghouse Type A201 contactors shall be used. Sizes 2, 3 or 4 shall be installed depending on the size of the KVAR step to be switched.

Potential Transformers – The potential transformer shall be Underwriter's Listed and provide voltage input to the controller as well as control power for the switching contactors.

Fuses – Each capacitor step shall be fused with three type CLN current limiting capacitor fuses. Fuses to be full range current limiting type with an interrupting capacity of 200,000 amps. Fuses shall be sized to protect the contactor, capacitor, and all interconnecting wiring.

Controller – A multi-step automatic VAR sensitive controller shall be used. Controller shall have step indication lights and manual override test switch. Controller to have time delay to prevent switching into a trapped charge on a previously energized step.

Power Bus – Buses shall be braced to withstand 42,000 amps symmetrical short circuit current. Each bus to be supplied with two (2) NEMA four hole drilling pads for terminal connection.

Fuse Blocks – Fuse blocks and fuses shall be provided for the control circuits.

Lower Compartment

Capacitors – Capacitors shall contain WEMCOL no PCB dielectric fluid. Fluid shall be completely bio-degradable and shall not bio-accumulate. The case to be made from heavy gauge mild steel with all joints welded and reinforced at point of wear. Capacitors to be three phase, internally delta connected.

Individual internal discharge resistors shall reduce voltage on the capacitor to 50 volts within one minute after it is removed from the system. The paper film foil construction shall have a design life of 20 years, energized 24 hours a day. Capacitors shall meet all applicable NEMA and ANSI test requirements.

All capacitors shall have Power Factor Tests and Ultra Sonic Tests performed at rated voltage and elevated temperature, (100% testing). Capacitors shall also have a switching test at rated voltage and frequency.

For Further Information
Refer to PL 39-250
AD 39-200
DS 39-253

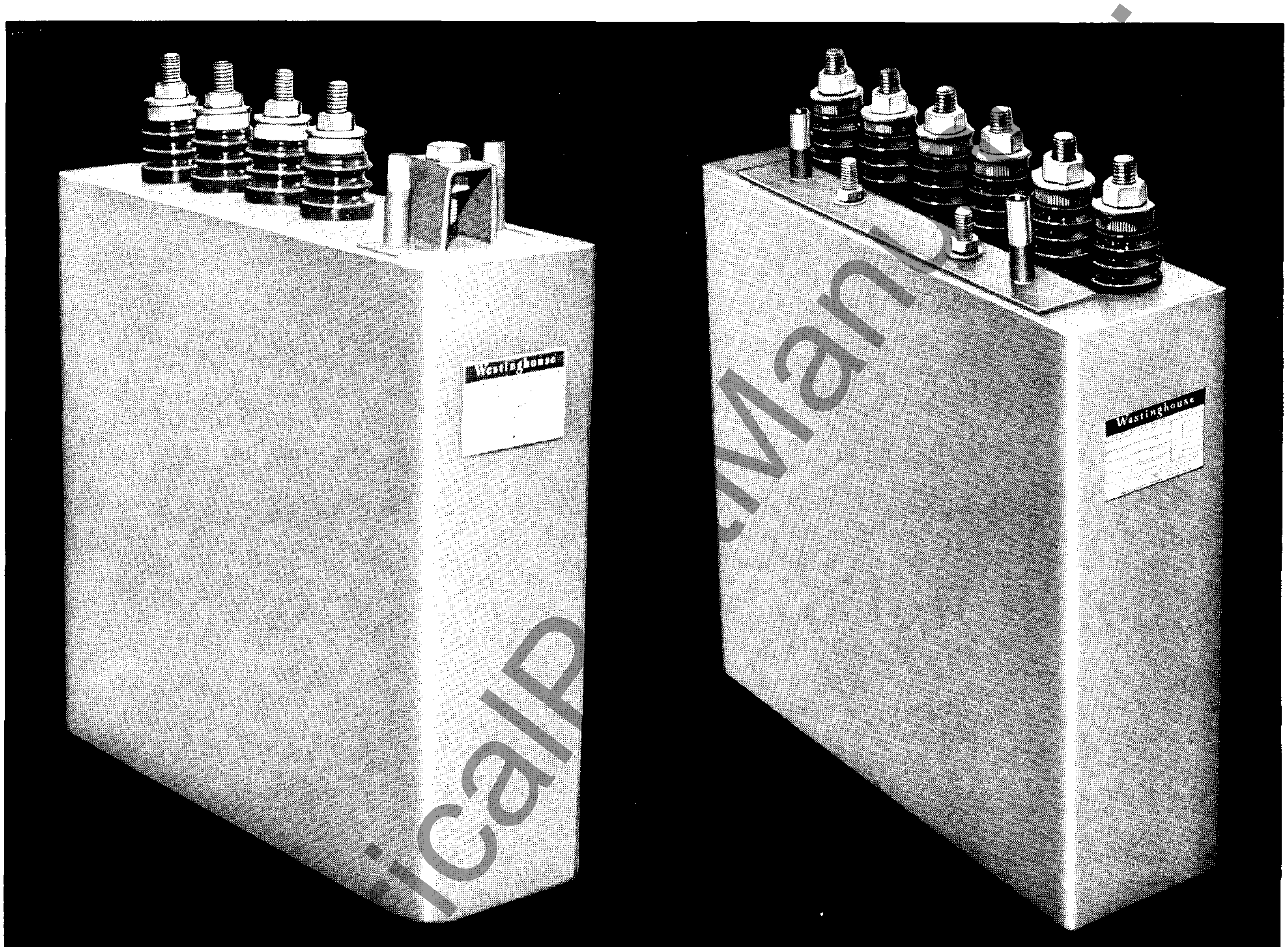
Printed in U.S.A.

Westinghouse Electric Corporation
Distribution Apparatus Division
Bloomington, Indiana 47401

Westinghouse

High Frequency Capacitors
Type FPW, Water Cooled

For Induction Heating Equipment
960 – 9600 Hertz, Up to 450 Kvar
200 – 1250 Volts



Design Features

Compact, Lightweight: Efficient design of capacitor components and cooling system results in optimum use of materials, weight and volume thereby being held to a minimum.

High Current Rating Per Unit Volume: Multiple bonding of foil electrode to cooling coil provides maximum heat transfer with minimum temperature rise.

Permanent Characteristics: The combination of Inertex™ paper with Inerteen® impregnant produces a capacitor having characteristics of stability with low loss and high dielectric constant especially suited to high frequency applications.

Hermetically Sealed: Provides a capacitor with stable characteristics assuring long, maintenance-free operation. Although vertical mounting is preferred, the units may be mounted in any position.

Application

Westinghouse type FPW high frequency water-cooled capacitors have been designed to improve the inherently low power factor associated with induction heating apparatus on melting furnaces, billet heating, forging and heat treating applications.

Based on load requirements, high frequency capacitors are usually installed in multiple unit banks with a means of switching provided to adjust capacitance and tune the circuit for efficient operation under varying load conditions.

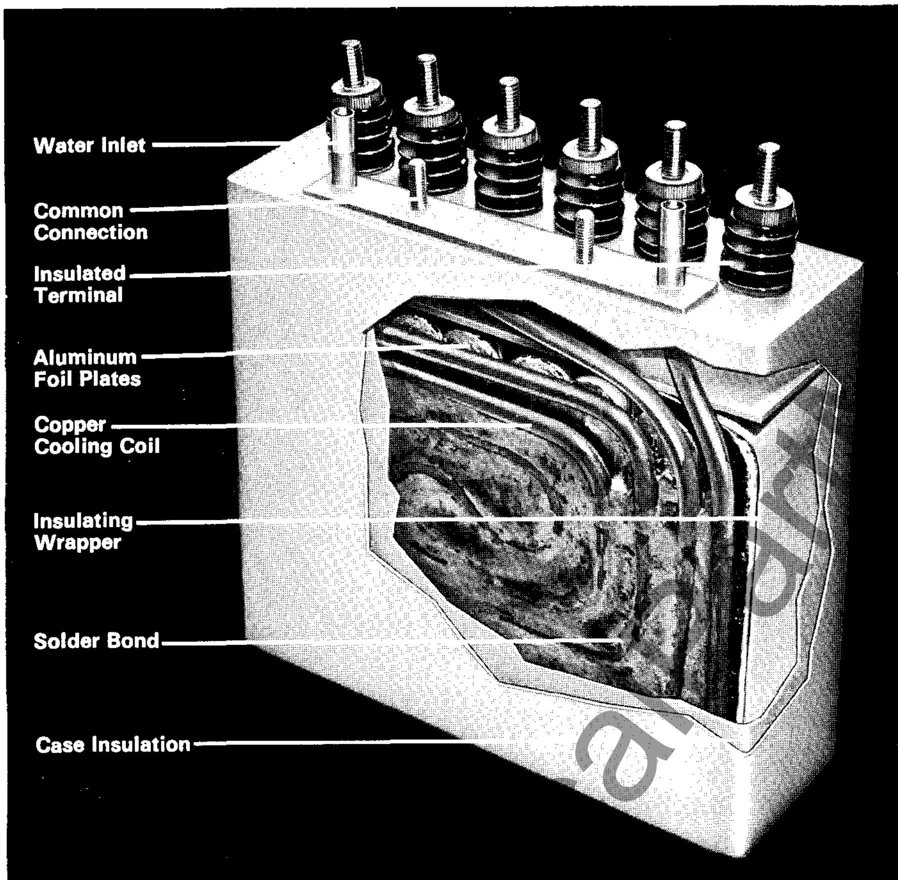
Mounting and Operation

The capacitor units may be mounted with terminals upright, or on edge with the terminals horizontal. The units have one pole grounded to the case and may be operated with the case and cooling-coil either insulated or grounded depending on the circuit.

November, 1973
New Information
E.D.C/2001, 2002/DB

Westinghouse

Construction



Type FPW capacitors are wound with aluminum foil plates separated by layers of thin Inertex paper. The extended foil construction of opposite polarity are staggered so the edges project from opposite sides of the capacitor section. The projecting edges are then bonded together using a solder alloy and a special bonding technique. The heavy braided copper leads are soldered to the bond. The foil edges of the opposite side of each section are also soldered directly to a tubular copper water-cooling coil which, in turn, extends through the cover assembly and serves as the common connection for the capacitor assemblies.

After the capacitor is assembled in its case, it is thoroughly vacuum dried. It is then filled with Westinghouse Inerteen, a synthetic, non-inflammable liquid dielectric having superior qualities at high frequency. In addition, it has stable electrical characteristics over a broad temperature range (−40°C to +46°C) low losses and is chemically inert. The capacitor is then hermetically sealed. All welded, non-magnetic case and covers are used to assure minimum heat generation when operating at high frequencies. Porcelain terminal bushings are sealed to capacitor enclosure by silicon rubber sleeves confined under pressure. This provides a seal with sufficient strength and flexibility to prevent damage to porcelain or seal that might result from excessive mechanical strains on the bus or connections. Cooling coils are permanently bonded to the enclosure and complete the hermetic seal.

One pole of all sections is common to the cooling coil and case. The other pole is brought out through one or more insulated terminals. Multiple terminals are used to provide desired kilovac steps, and also when high current capacity is necessary.

The voltage rating of a capacitor section for high frequencies must be limited to avoid damaging corona discharges at the foil edges. Since one pole of the section must be bonded to the cooling coil for good heat transfer, the practical voltage ratings of water-cooled units is restricted to 1250 volts and under.

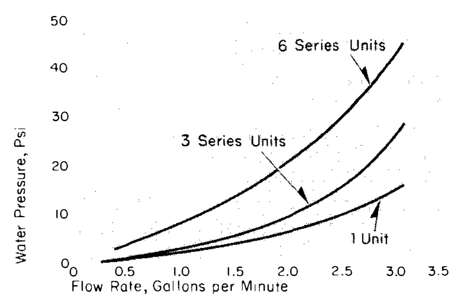
Cooling System

An adequate flow of clean water must be supplied to the capacitors. The coils of several units may be connected in series if the inlet water is cool, and the available pressure is high enough.

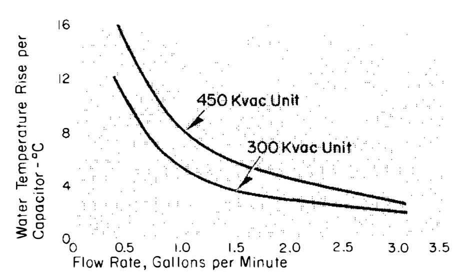
The cooling coil is a continuous copper tube terminated as shown on the outline drawings. It has no sharp turns that might become clogged. The cooling coil is designed in a double spiral, to assure uniform heat dissipation over the entire internal capacitor assembly. A recommended minimum flow rate of 0.5 gal/min. should be maintained and the outlet water temperature should not exceed 45°C (113°F). To prevent erosion of the tubing the flow rate should not exceed 4 gal/min.

A large size tubing is used so that two or more units may be connected in series if water of suitable temperature and pressure is available.

The curves below show the pressure required for various flow rates using 12 inches of ½ inch I.D. hose between each capacitor unit for the water connections. The bottom curves show the water temperature rise per capacitor for various flow rates and can be used for determining the required inlet water temperature.



Pressure required for Flow Rates using 12 inches of ½ inch I.D. Hose per Capacitor for Water Connections.



Water Temperature Rise per Capacitor Unit operated at rated KVAC in an ambient of 25°C.

High Frequency Capacitors

Type FPW, Water Cooled

For Induction Heating Equipment
960 – 9600 Hertz, Up to 450 Kvar
200 – 1250 Volts

Ratings

Type FPW high frequency, water-cooled capacitors are rated maximum continuous working current, maximum continuous working voltage, maximum kvac. The operating conditions may be varied over a wide range as long as none of these limits are exceeded. The values, given on the nameplate, are based on an outlet water temperature of 45°C. If at any time the outlet temperature is above 45°C, the voltage must be reduced 1½% for each degree above 45.

Rating limitations are voltage stress, temperature rise, and current per terminal.

The voltage rating is rms and applies for an impressed voltage having substantially a sine wave shape. If the voltage wave is distorted, its peak value must not exceed $\sqrt{2}$ times the capacitor voltage rating.

Capacitors may be operated at less than rated voltage or frequency. In some cases it may be permissible to operate at more than the rated frequency if the voltage is reduced. This involves design considerations and advice should be obtained from Westinghouse for specific cases.

If the capacitor is to be operated at some voltage or frequency below the rated value,

$$Kvac = \frac{CE^2\, 2\pi\, f}{10^9}$$

where Kvac = actual burden in kva,
E = working voltage,
C = rated capacity,
f = working frequency.

Thus, if a 61 mfd capacitor is operated at 400 volts instead of 625 volts,

$$Kvac = \frac{61 \times 400^2 \times 2 \times 3.14 \times 2000}{10^9} = 123$$

Reduced Voltage:

$$Kvac = \text{Rated Kvac} \left(\frac{\text{Applied Volts}}{\text{Rated Volts}} \right)^2$$

Reduced Frequency:

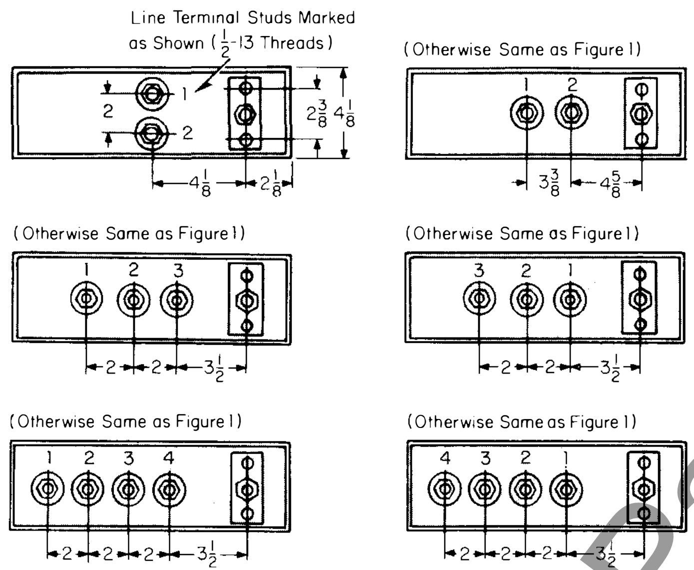
$$Kvac = \text{Rated Kvac} \left(\frac{\text{Applied Frequency}}{\text{Rated Frequency}} \right)$$

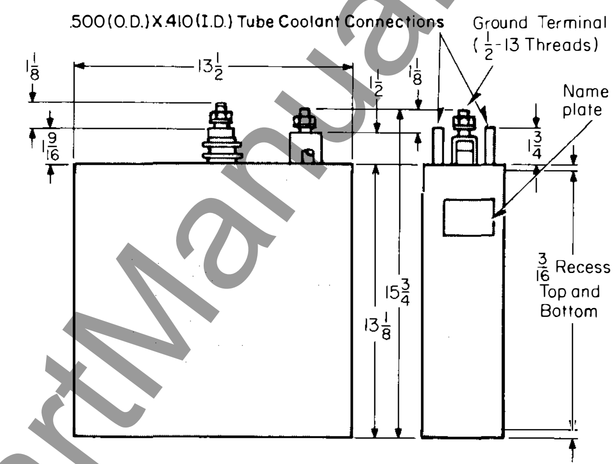
Frequency Hertz	Voltage: Common to Terminal (Volts)	Voltage: Terminal 1 to 2 (Volts)	Kvac	Total Mfd	Mfd Per Terminal from Common to Terminal — Terminal Number: 1	2	3	4	5	6	Style Number	Approx. Net Wt. Lbs.	Fig. Ref. (See Dimensions Page 4
960	400	.....	200	204	5	10	21	42	63	63	367C750A50	58	6
	450	900	160	131	65.5	65.5	(32.75 mfd terminal 1 to 2)				367C750A28	50	2
	800	.....	300	78	2	4	8	16	24	24	367C750A49	58	6
	900	.....	215	44	22	22	....	....	....	....	367C750A27	50	2
	1000	.....	215	35.7	13.4	22.3	....	....	....	....	367C750A41	50	1
	1000	.....	215	35.7	13.4	22.3	....	....	....	....	367C750A48	50	2
1000	400	.....	210	210	52.5	52.5	52.5	52.5	....	....	367C750A44	54	4
	600	.....	300	108	18.6	18.6	18.6	18.6	....	....	367C750A51	54	4
	1200	.....	300	32.0	2.0	4.0	6.0	10.0	10.0	....	367C750A97	58	5
	1250	.....	150	15	7.5	7.5	....	....	....	....	367C750A37	50	2
	1250	.....	245	25	9.4	15.6	....	....	....	....	367C750A47	50	2
2000	625	.....	300	61	8	16	37	....	....	....	367C750A04	52	3
	625	.....	300	61	37	16	8	....	....	....	367C750A13	52	3
	625	1250	300	61.2	30.6	30.6	(15.3 mfd terminal 1 to 2)				367C750A01	52	2
	800	.....	300	37.6	9.4	9.4	9.4	9.4	....	....	367C750A10	54	4
	1250	.....	300	15.3	10.2	5.1	....	....	....	....	367C750A38	52	2
3000	275	.....	300	210	52.5	52.5	52.5	52.5	....	....	367C750A29	54	4
	400	.....	300	100	25	25	25	25	....	....	367C750A17	54	4
	400	.....	300	100.5	6.7	13.4	26.8	53.6	....	....	367C750A43	54	4
	400	.....	300	99.6	31.5	31.5	21	10.3	5.3	....	367C750A20	57	5
	400	.....	300	99.9	2.7	2.7	10.5	21	31.5	31.5	367C750A32	58	6
	400	.....	450	150.0	4.0	4.0	15.8	31.5	47.3	47.3	367C750A82	58	6
	625	.....	300	41	26	10	5	....	....	....	367C750A05	52	3
	625	.....	300	41	21.6	11	5.6	2.8	....	....	367C750A39	54	4A
	625	1250	300	40.8	20.4	20.4	(10.2 mfd terminal 1 to 2)				367C750A02	50	2
	800	.....	300	24.92	6.23	6.23	6.23	6.23	....	....	367C750A16	54	4
	800	.....	300	24.9	1.3	2.6	5.2	7.9	7.9	....	367C750A19	57	5
	800	.....	450	37.3	2.0	3.9	7.8	11.8	11.8	....	367C750A69	54	5
	1000	.....	300	15.65	1.95	3.9	3.9	5.9	....	....	367C750A08	54	4
	....	1250	75	2.5	2.5	....	(terminal 1 to 2)				367C750A24	50	2
	....	1250	150	5	5	....	(terminal 1 to 2)				367C750A25	50	2
	....	1250	220	7.5	7.5	....	(terminal 1 to 2)				367C750A26	50	2
	1250	....	300	10.2	1.45	2.9	5.85	....	....	....	367C750A46	52	3
	1250	....	150	5	2.5	1.2 5	1.25	....	....	....	367C750A03	54	3
	1250	....	300	10.2	1.45	2.9	5.85	....	....	....	367C750A40	52	3A
3600	200	....	180	200	50	50	50	50	....	....	367C750A36	54	4
	400	....	300	84	21	21	21	21	....	....	367C750A35	54	4
	400	....	60	16.8	2.8	2.8	2.8	2.8	2.8	2.8	367C750A34	58	6
	400	....	300	82.8	13.8	13.8	13.8	13.8	13.8	13.8	367C750A33	58	6
4200	400	....	300	72.0	4.8	9.6	19.2	38.4	....	....	367C750A42	54	4
9600	200	....	230	96	24	24	24	24	....	....	367C750A30	54	4
	220	....	230	80	2	4	8	16	25	25	367C750A21	58	6
	400	....	230	24	6	6	6	6	....	....	367C750A18	54	4
	440	....	300	25.94	0.64	1.3	2.7	5.3	8	8	367C750A22	58	6
	440	....	450	39.0	1.0	2.0	4.0	8.0	12.0	12.0	367C750A72	58	6
	800	....	300	7.76	0.78	0.78	1.6	2.3	2.3	....	367C750A31	57	5
	800	....	300	7.8	1.95	1.95	1.95	1.95	....	....	367C750A23	54	4
	800	....	450	11.8	1.2	1.2	2.4	3.5	3.5	....	367C750A81	54	5

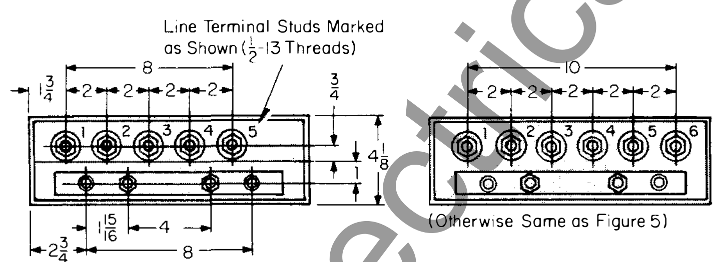
High Frequency Capacitors
Type FPW, Water Cooled

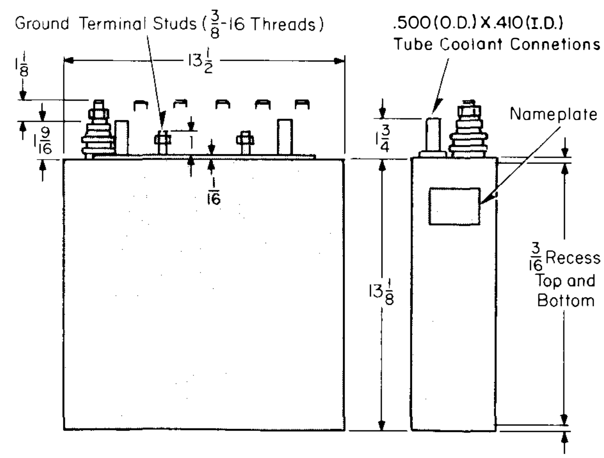
For Induction Heating Equipment
960 – 9600 Hertz, Up to 450 Kvar
200 – 1250 Volts

Dimensions in Inches
(Approx.) For cross reference to capacitor style numbers, see last column in table on page 3.









Further Information
Prices: PL 39-210

Westinghouse Electric Corporation
Distribution Apparatus Division, Bloomington, Ind. 47401
Printed in USA