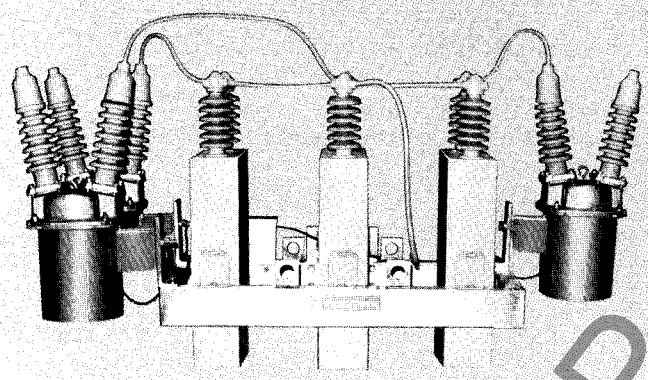
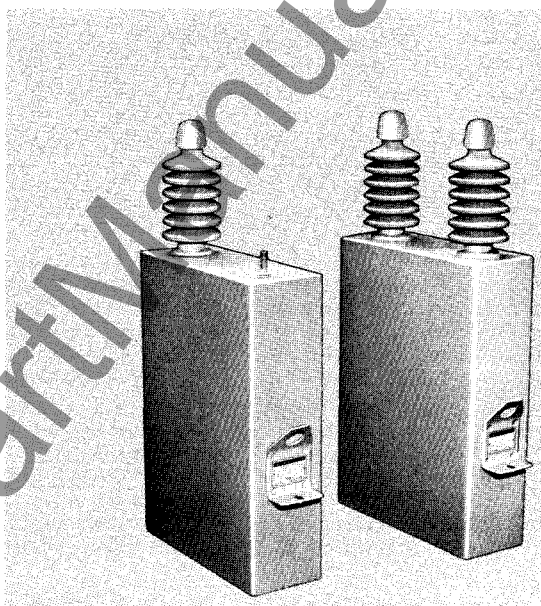
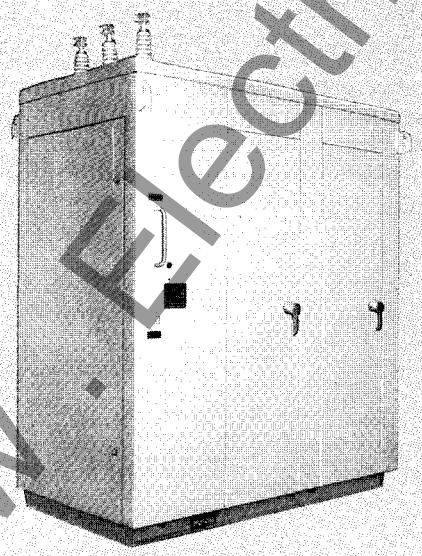
WEMCOL Impregnated High Voltage Capacitor Units and Equipment



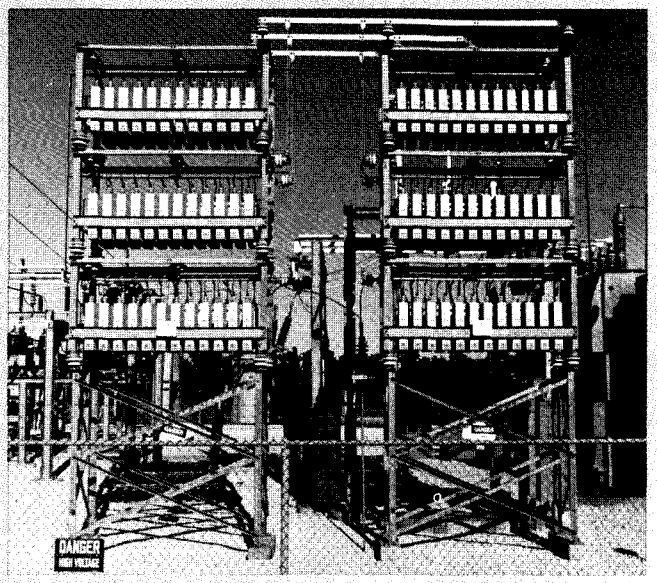
Pole Mounted Capacitor Assemblies



Capacitor Units



Substation Capacitor Assembly Metal Enclosed

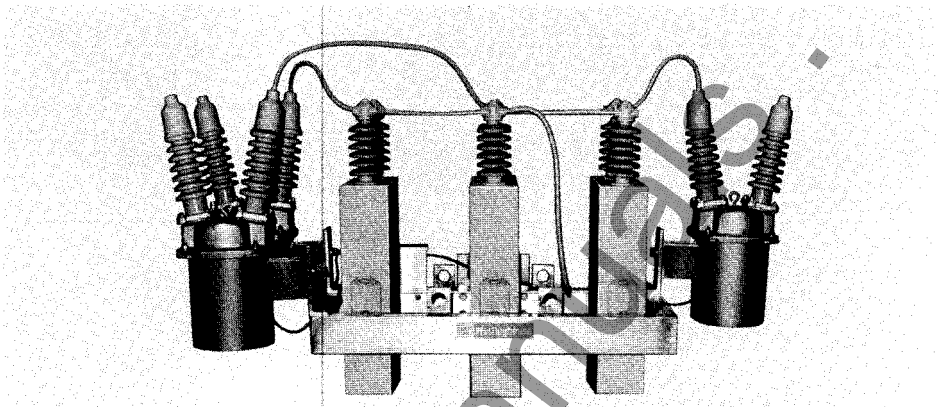


Substation Capacitor Assembly Open Rack

Application

Capacitor Assemblies
To simplify the application of capacitors to distribution or transmission systems Westinghouse offers three basic types of equipment designs.

Pole Mounted Capacitors
The most efficient application of capacitors is close to the load. Pole mounted capacitor banks provide a simple installation that may be located close to the load on the distribution system. Banks may be fixed or switched depending on the system needs. Pole mounted capacitor assemblies ranging in size from 150 KVAC to 2400 KVAC are available for systems up to 34.5 kV. Overcurrent protection can be provided by separately mounted fused cutouts.



Pole Mounted Capacitor Assemblies

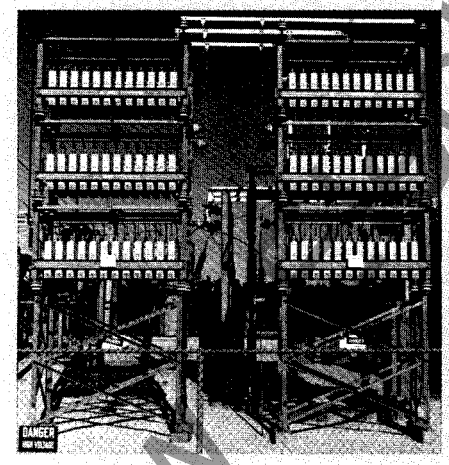
Open Rack Substation Capacitors
Open rack substation capacitor banks are used to provide medium to large blocks of KVAR on the distribution or transmission system at voltages up to 765 kV. Groups of capacitors are connected in series to match any system voltage. Each capacitor is individually fused with an expulsion or current limiting fuse.

Capacitor units can be mounted vertically or horizontally in aluminum or galvanized steel frames.

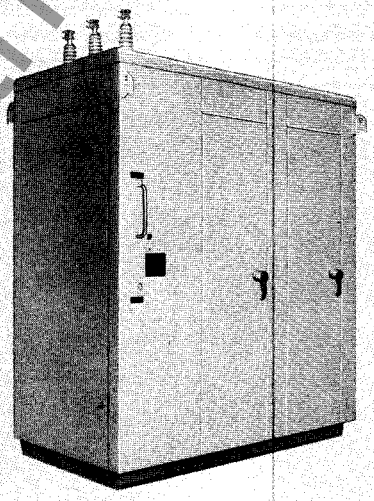
Substation capacitor banks can be supplied with unbalance protection schemes and switching equipment.

Metal Enclosed Substation Capacitors
Metal enclosed capacitor banks are used to apply medium size blocks of KVAR to the distribution system (up to 34.5 kV) where a completely enclosed assembly is advantageous for space or safety reasons. Capacitors are individually fused with current limiting fuses for maximum protection and all access doors can be interlocked for safe operation. An externally operated grounding switch in the capacitor compartment is standard on all assemblies.

The basic enclosure can be expanded to add compartments containing capacitor switches, vacuum circuit breakers with overcurrent relays and disconnect switches.



Substation Capacitor Assembly Open Rack



Substation Capacitor Assembly Metal Enclosed

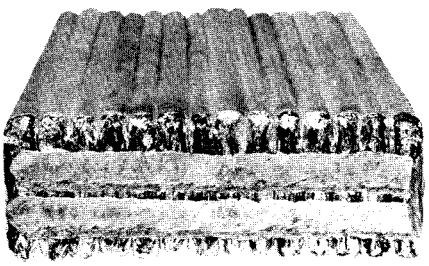
Design Features

Biodegradable Fluid
Film-Var capacitors are impregnated with WEMCOL, a biodegradable dielectric fluid.

WEMCOL Biodegrades rapidly and completely. In sewage sludge tests it biodegrades 60% in 24 hours and 100% in less than 7 days.

WEMCOL'S characteristics include: high dielectric strength, resistance to gassing at high voltage stress, low dissipation factor and excellent stability at high temperatures.

Low Losses
All large power capacitors are assemblies of individual capacitor segments connected in a series/parallel arrangement depending upon the capacitor unit voltage. The service performance of the capacitor depends significantly on the quality of these connections. In this area, Westinghouse utilizes a technique called **extended foil.** Each capacitor section consists of two aluminum electrodes separated by a film dielectric. During the section winding operation, one edge of each electrode is extended beyond the film dielectric at opposite ends of the section winding. These extensions of the electrode provide the connection points for the series/parallel connections required in the capacitor.



When the required number of sections are assembled together the series/parallel connections are made by soldering directly to the extended edge of the electrode.

The soldering technique provides connection points at every turn of the section winding.

- The length of the current path is shortened which reduces resistance losses significantly (Fig. 1).

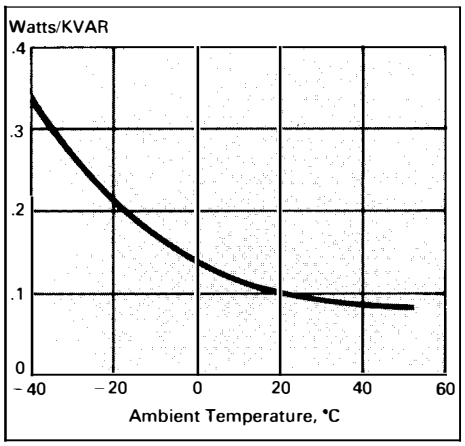


Figure 1 – Capacitor Losses Vs. Temperature

- Current density at the connection points is reduced which further reduces losses and also provides superior performance in high current discharge tests which demonstrate the capacitor's ability to withstand repeated switching operations.

At least two separate solder paths are used to ensure adequate contact and provide a sound current path for total current from the individual capacitor sections.

Reduced Edge Stress
Examination of the dielectric field in a capacitor shows that the critical area of maximum stress occurs at the edge of the electrodes. Stress in this area is affected by electrode alignment, electrode thickness, and electrode edge conditions.

The Westinghouse folded foil design addresses each of these areas and achieves a significant reduction in maximum stress levels.

A field plot of dielectric stress at the electrode edges shows that when the electrodes are perfectly aligned a stress concentration occurs close to the electrode edge that is significantly higher than the average stress in the dielectric system. Any misalignment of the electrodes increases the magnitude of the stress concentration and the maximum value occurs at the edge of the shorter, recessed electrode. It can clearly be seen that in a normal capacitor dielectric system with electrode spacings of .001 to .0015

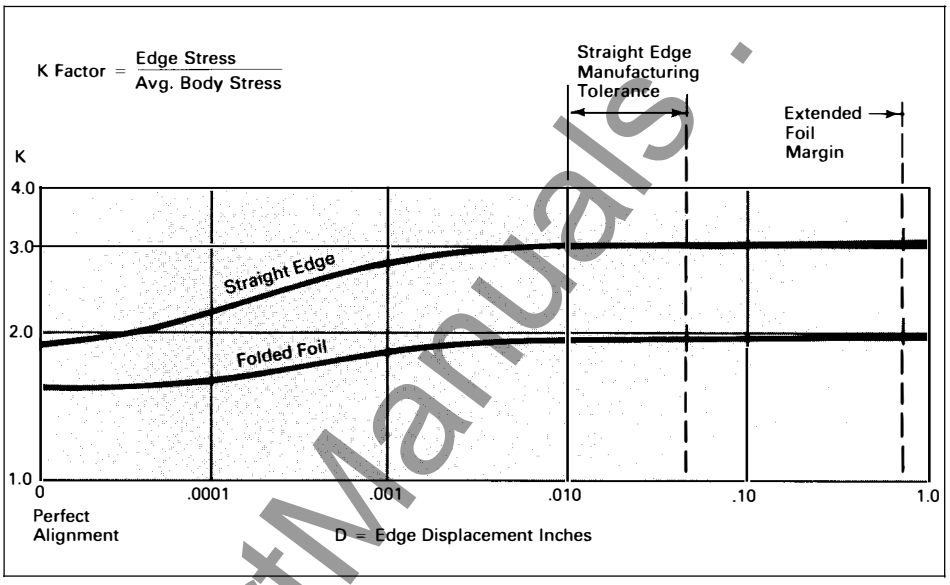


Figure 2 – Dielectric Stress Vs. Edge Displacement

inches, even a small misalignment produces significantly higher stresses (Fig. 2).

On a production basis with manufacturing tolerances on the foil and high speed winding machines it is not possible to hold the electrodes in perfect alignment and displacements of .010 to .050 are normal. For all practical purposes there is no further increase in the dielectric stress level for any value of misalignment above the normal production range.

The folded foil design creates a deliberate offset in the alignment of the foil edges (Fig. 3). This ensures that the recessed edge subject to the maximum stress is always the folded edge where the double thickness and rounded edge are very effective in reducing the maximum stress levels (Fig. 2).

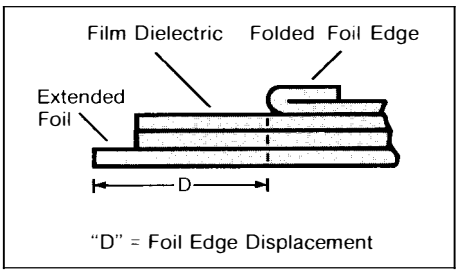


Figure 3 – Westinghouse Capacitor Unit

The effect of the increase in thickness and rounded edge reduces the maximum stress to 1.9 times the body stress.

The reduction in maximum stress improves the corona inception and extinction levels and reduces potential damage to the dielectric system due to the transient overvoltages associated with lightning surges or capacitor switching.

Film-Var Capacitors
Design Standards
Film-Var capacitor units meet or exceed all the requirements of the following standards:
ANSI C55.1, NEMA CP.1, IEC 70, AS 1013

Frequency. Either 50 or 60 Hertz available as standard.

Construction Features

Dielectric System. Film-Var capacitor units utilize a dielectric system consisting of electrical grade polypropylene film.

Capacitor Bushings. Film-Var units utilize wet process porcelain bushings coated with a compressive, nontracking glaze. Bushings are solder-sealed to capacitor case.

Case material and Finish. Film-Var units include #409 stainless steel cases painted with one coat each of zinc chromate primer and oven-cured acrylic enamel ASA-70. Finish color is Munsell #5BG7.0/0.4.

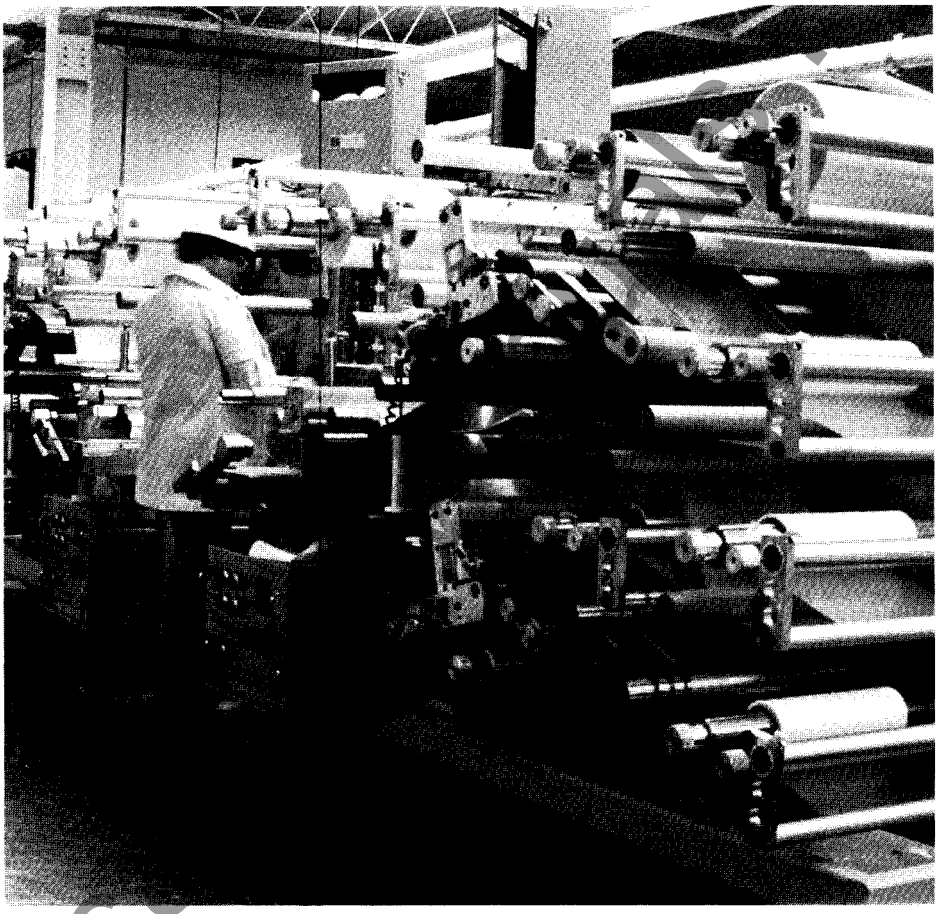
Discharge Resistor. Connected internally between terminals, discharge resistors are sized to reduce the residual voltage to 50 volts within 5 minutes.

Connectors. Clamp type parallel groove connectors accommodate one or two conductors from AWG #12 solid to #1 stranded; copper or aluminum (approx. 2 to 8.5 mm diameter).

Nameplate. Nameplates list style and serial numbers, KVAR, rated voltage, frequency, number of phases and BIL.

Manufacturing Quality and Testing

Sound design is only the first step in producing a reliable capacitor. Manufacturing and quality control methods must match the design in quality and consistency.



Clean Room

All Westinghouse HV power capacitor sections are wound on automatic winding machines in a clean room where the environment is totally controlled for temperature pressure, humidity, and dust free atmosphere. All employees wear lint free protective clothing when working in the clean room to prevent contamination from the outside.

Quality Control

Components are tested at every step of the manufacturing process:

- Every shipment of film and foil and Wemcol is subject to extensive tests before it is accepted for manufacture.
- Every capacitor section winding is tested for capacitance and dielectric strength before release to the assembly sections.
- Every complete assembly of sections is tested for resistance, capacitance and dielectric strength before the final case welding operation.
- Every capacitor is given a preliminary leak test before release to the impregnation cycle.
- Every batch of Wemcol is tested for dielectric constant and power factor before release to the impregnation cycle.
- Every finished capacitor must pass all final production tests.

Testing

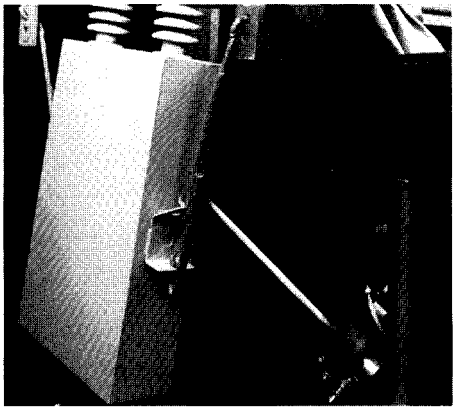
All Film-Var capacitors are designed and tested to meet the following standards: ANSI C55.1, NEMA CP.1, IEC 70, AS1013.

Production Tests
All Film-Var capacitors are subjected to the following routine production tests.

1. Leak test
2. Initial capacitance measurement
3. AC high voltage test 26, 34 or 40 kV terminal to case, 10 seconds (two bushing units only)
4. Terminal to terminal 10 seconds overpotential test at 4.3 times rated voltage DC
5. Discharge test. One shot 500 – 1000 times rated current
6. Terminal to terminal discharge resistor test
7. Final capacitance measurement

Additional tests not required by standards

8. Power factor of all Film-Var capacitors is measured at elevated temperature and rated voltage. Tests at temperatures above ambient are significantly more sensitive in detecting improper impregnation and fluid contaminants.
9. Sonic corona – While the capacitor is energized at rated voltage a sonic detection probe is placed in contact with the capacitor case. If low level corona discharges occur in the capacitor the acoustic emission will be transmitted to the capacitor case and will pass through the probe to the detector. This test provides a very sensitive non-destructive test for complete impregnation of the capacitor unit.



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