TYPE FP INERTEEN CAPACITORS

Internally Water-Cooled For High Frequency Service

Application

During the last decade the high frequency induction furnace principle of heat treating and the melting of steel alloys, has grown to an important position in industry. Used for melting—the furnace greatly reduces time, has low metal losses, produces metal of greater uniformity, controls stirring during melt and enables making quick changes from one alloy to another.

For heat treating, the furnace—reduces time to a matter of seconds, provides close temperature control and zone hardening, prevents scale in forging, saves material and eliminates rejects. It is evident, therefore, that with these advantages, the use of high frequency equipment has many possibilities.

The component parts of an induction furnace equipment are:

(1)—Induction furnace, or inductive heating element

(2)—High frequency motor-generator set

(3)—Capacitors

(4)—Control equipment.

Due to the fact that only a relatively small portion of the electro-magnetic energy in the inductive coil or furnace can be converted into heat, the wattless component is large compared to the power component and the power factor is low, usually of the order of 10%. It is far more economical to supply this reactive component with capacitors than to build the generator for the total kv-a. load. If the power factor is corrected to unity, the size of the generator may be reduced to one-tenth the size that otherwise would be required. Without suitable capacitors, induction furnace applications would be severely handicapped—if not altogether economically impractical.

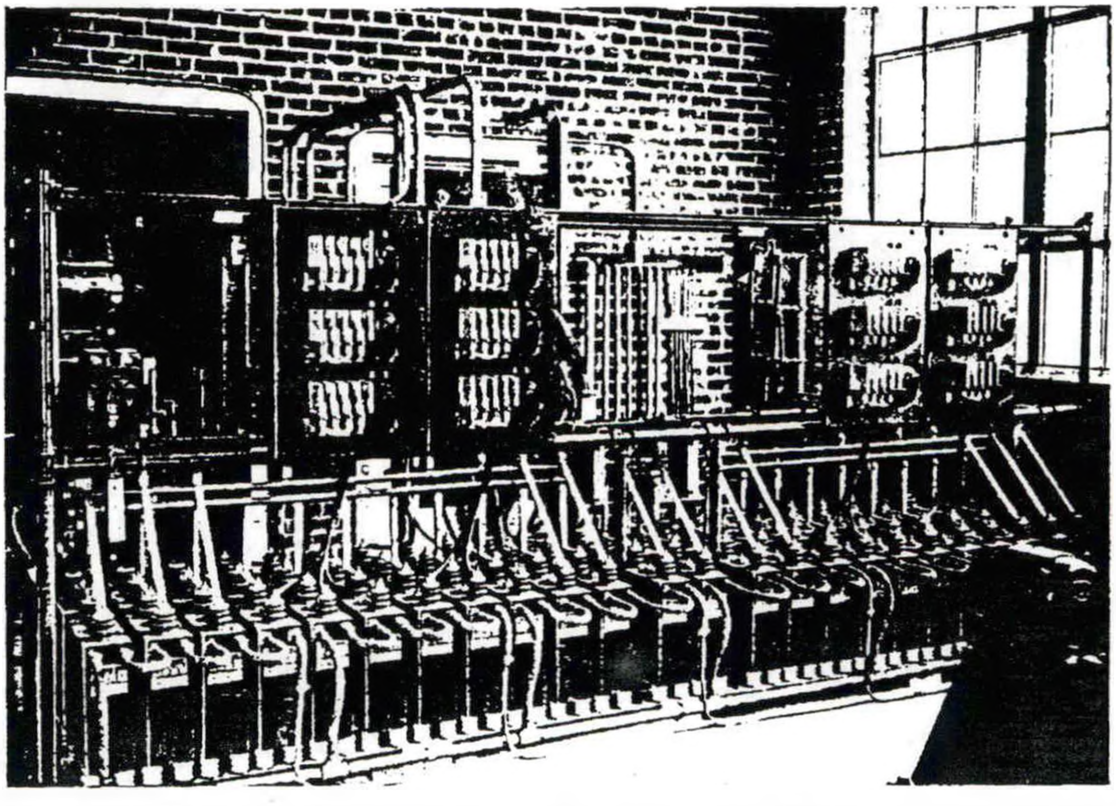

Fig. 1—Induction Furnace Capacitor Installation Consisting of 48 Units Style No. 1124042. Total Kv-a. 5280. Capacitor Units are Worked at 110 Kv-a. Each Single Phase 960 Cycles

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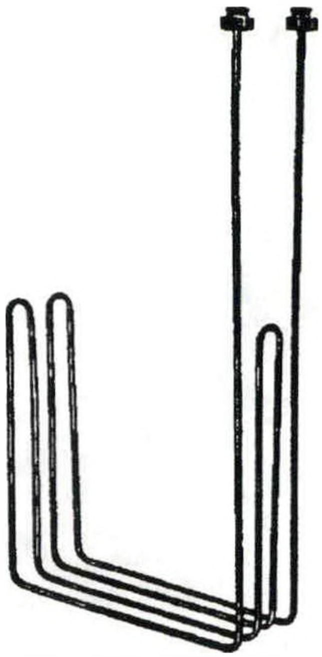

FIG. 2—COOLING COIL FOR TYPE FP WATER-COOLED INERTEEN CAPACITOR

Users of Induction Furnace Equipment

Automobile and automobile parts manufacturers, Diesel and gasoline engine manufacturers, also producers of high grade ferrous alloys are the principal users.

Scope of Activity for Induction Furnaces

Some of the uses are:

1. Induction heating for melting alloys.
2. Forging.
3. Up-setting.
4. Paint drying.
5. Induction heating for hardening internal bearing surfaces such as hubs of automobile wheels.
6. Induction heating for hardening external bearing surfaces such as crank and cam shafts.

General

In 60 cycle capacitors, the cost and size is determined largely by the voltage stress that can be put on the insulation in the design. With established values of voltage stress, the loss to be dissipated from the surface of the case is within

FIG. 3—TOP VIEW OF TYPE FP WATER-COOLED INERTEEN CAPACITOR WITH COVER REMOVED SHOWING SECTIONS CLAMPED IN PLACE

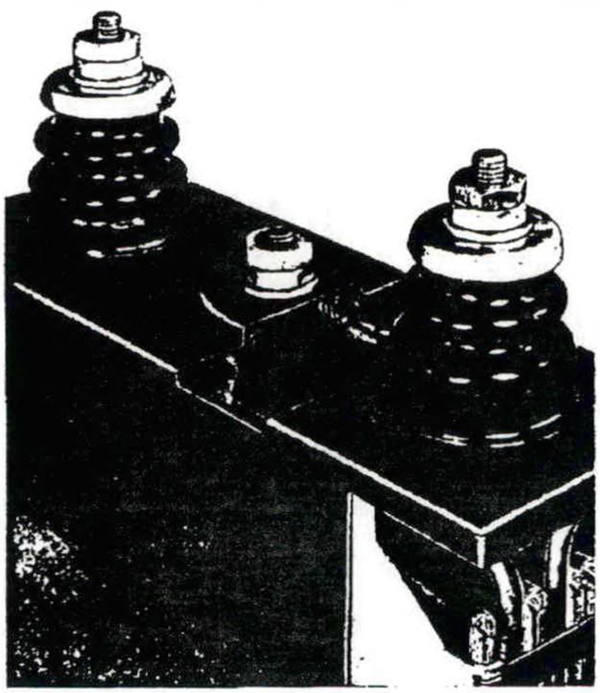

FIG. 4—DETAIL OF GROUND CONNECTION TO CENTER COMMON TERMINAL

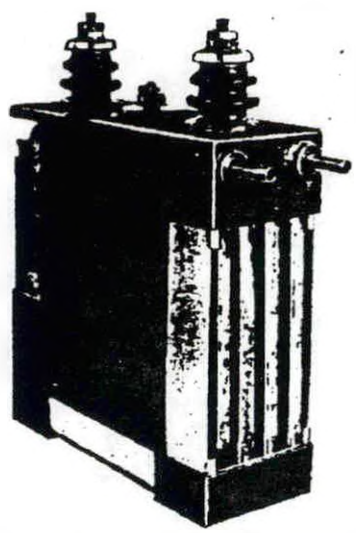

FIG. 5—CUTAWAY VIEW SHOWING METHOD OF BONDING PROJECTING FOIL ENDS OF SECTIONS TO COOLING COILS AT EACH END OF UNIT

TYPE PP INERTEEN CAPACITORS—Continued

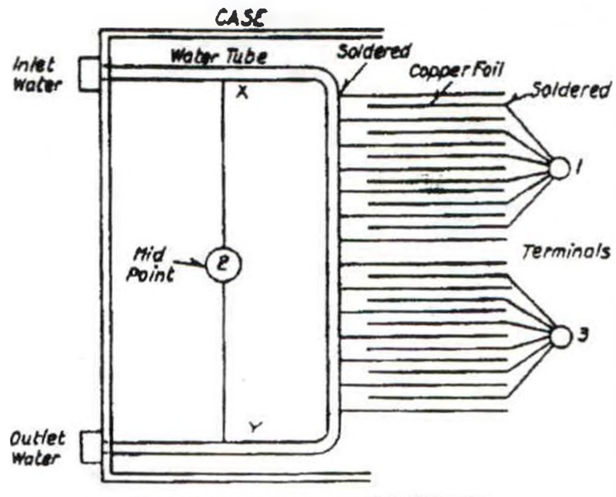

FIG. 6—SCHEMATIC ARRANGEMENT OF CAPACITOR SECTIONS WITH RESPECT TO COOLING COIL

the limits of natural cooling. Artificial cooling would not permit smaller units or larger kv-a. rating for a given unit, because although the increased loss could be removed, this increased rating would necessitate increasing the voltage applied to the material.

With higher frequencies, the cost per kv-a. may be reduced by limiting the voltage stress to or below established 60 cycle values and artificially removing the excess heat to keep the insulation working temperature within established limits.

A line of high frequency capacitor ratings has been developed employing water cooling to limit internal insulation working temperatures. Water cooling is practical for these applications because the inductive heating devices must be water cooled also and water cooling facilities are therefore available on such installations, as well as attendants to regulate the flow of water.

In a capacitor of this kind, there are two major problems not present in 60 cycle capacitors. One is the large amount of heat to be transferred from the working dielectric to the point of dissipation, which in this case, is the water coils, and the other is the large currents to be handled. The use of copper foil provides a path of high thermal conductivity and at the same time, permits efficient soldered bonds to the water coil for transferring the heat and handling the current, and soldered bonds at the other end ends for handling the current. The

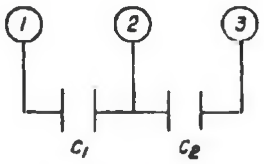

FIG. 7—SCHEMATIC DIAGRAM OF CONNECTIONS

use of copper foil with all turns bonded together with solder, keeps the I^2R loss in the foil to a minimum value, as well as rendering the sections non-inductive.

Construction

The capacitor sections or working elements are made by winding a special grade of Westinghouse Inertex paper with thin copper foil. The foils of each polarity extend beyond the paper at each side of the section. One of these extensions is bonded together and attached to a heavy flexible lead. The other is bonded together and soldered to the water coil in the final assembly. This connection serves the double purpose of conducting the heat to the water and carrying the current.

The cooling coil consists of a continuous length of special copper tubing free from sharp turns that might become clogged. See Fig. 2.

The sections are assembled between clamp plates and located within the cooling coil as shown in Fig. 3. The leads are brought out at the center as shown, and the ground terminals of each group of sections is near the ends of the case. This arrangement carries the heat from the center in both directions, resulting in uniform distribution of heat left in the case. Liberal leads and studs are provided to handle the current encountered in these ratings. The cooling tubes pass along the top edge of the clamp plates and are soldered in grooves. The ground connection or mid point of the capacitor is also made at this point. This mid point must handle the current for both groups when used. The design provides for direct cooling of this connection as shown in Fig. 4, the heavy braids conducting the heat directly to the water coils.

Fig. 5 shows a cut-away view of a complete unit. The terminals are soldered to porcelain type, having heavy studs with ½—13 threads. Figs. 6 and 6 further illustrate the scheme of connections. The main terminals are indicated as 1 and 3, Figs. 6 and 7.

The case is all welded construction with 1/16" recess at the bottom to aid in locating the unit on insulators, as in most applications, the cases must be insulated from ground. The top of the case is made of non-magnetic stainless steel on ratings of 5000 cycles and above, to limit the heat generated in the cover.

The inlet and outlet water connections are tapped for ⅛" standard pipe threads and short tubes are furnished for attaching rubber hose.

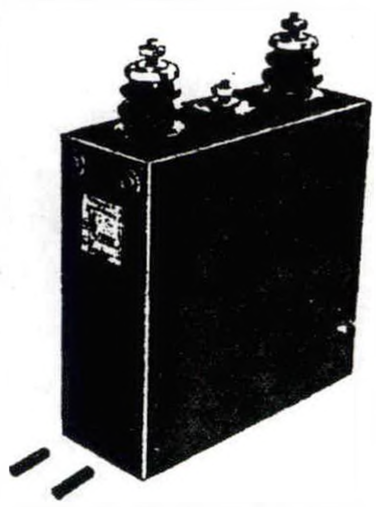

FIG. 8—TYPE PP 230 KV-A., 1250/625 VOLT, 11.7 MFD. INERTEEN CAPACITOR, STYLE NO 1124042, COMPLETE

Note—All ratings in Table I are similar in appearance

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TYPE PP INERTEEN CAPACITORS—Continued

OUTLINE DIMENSIONS IN INCHES

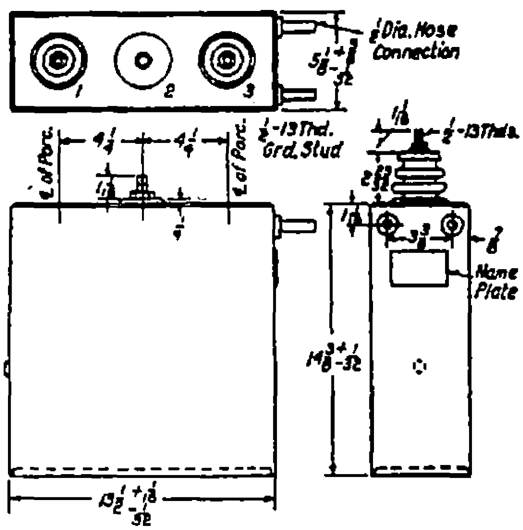

Fig. 9—Outline Dimensions of Type PP High Frequency Water-Cooled Inerteen Capacitors

Note—This outline is the same for all ratings in Table I.

The complete unit is shown in Fig. 8.

The complete assembled capacitor unit, minus the porcelain terminals, is vacuum dried and impregnated and filled with capacitor Inerteen. This fluid not only is non-inflammable but in combination with the capacitor paper used is especially suited to high frequency applications. The working losses are equal or less than ½ of 1% of the kv-a. at which the unit is being operated.

Ratings

Capacitors for high frequency service are rated in terms of maximum operating voltages for one or more frequencies. A unit having a given voltage and frequency rating may be operated at or below this voltage and any lower frequency. For a higher frequency, the unit may be worked at a lower voltage. Units should not be operated at frequencies higher than nameplate values without advice from headquarters as to the operating voltage limit at this higher frequency.

Formulas applying:

$$\text{Kv-a.} = \frac{C\ E^2\ 2\pi f}{10^9}$$

$$C = \frac{10^9\ \text{Kv-a.}}{E^2\ 2\pi f}$$

Where Kv-a. = Rating of capacitor unit.
C = Capacity of microfarads.
E = Rated capacitor voltage.
F = Frequency of generator.

Example 1

Given: Capacitor Style No. 1124042, 230 Kv-a., 11.7 mfd., 1250 volt, 2000 cycles. What Kv-a. would this unit give at 960 cycles, 1000 volts? Solution:

$$\text{Kv-a.} = \frac{11.7 \text{x} 1000^2 \text{x} 2 \text{x} 3.1416 \text{x} 960}{10^9}$$

Answer Kv-a. = 70

Example 2

Required: 230 Kv-a., 3000 cycle, 800 volt capacitor unit. What would be the capacity in microfarads? Solution:

$$C = \frac{10^9 \text{x} 230}{800^2 \text{x} 2 \text{x} 3.1416 \text{x} 3000}$$

Answer C = 19.1 mfd.

Table I on page 3 shows the ratings which can be manufactured. All units, dual rated, have the same approximate net weight, namely, 92 pounds and shipping weight 115 pounds. The outline dimensions for all the ratings listed is the same, and are shown in Fig. 9.

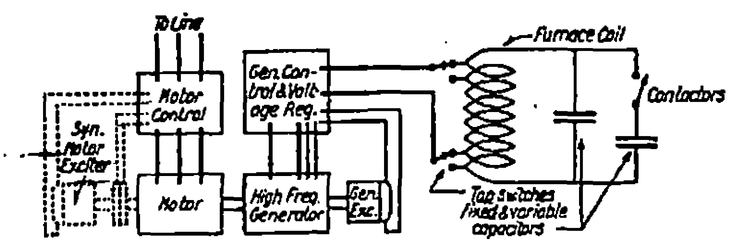

Fig. 10—Simplified Diagram of High Frequency Equipment for Melting Applications

TYPE FP INERTEEN CAPACITORS—Continued

TABLE I—LIST PRICES

Style No. of Capacitor	Frequency	Voltage	Connection	Mfds.	Kv-a.	Amperes	List Price*
1 166 981	500	500	Parallel	73	57.5	115	....
	500	1000	Series	18.25	57.5	57.5	
	960	500	Parallel	73	110	220	
	960	1000	Series	18.25	110	110	
	2000	500	Parallel	73	230	460	
	2000	1000	Series	18.25	230	230	
1 166 982	500	562	Parallel	57	57.5	102	....
	500	1124	Series	14.25	57.5	51	
	960	562	Parallel	57	110	196	
	960	1124	Series	14.25	110	98	
	2000	562	Parallel	57	230	410	
	2000	1124	Series	14.25	230	205	
1 166 983	500	625	Parallel	46.8	57.5	92	....
	500	1250	Series	11.7	57.5	46	
1 124 042	960	625	Parallel	46.8	110	176	....
	960	1250	Series	11.7	110	88	
	2000	625	Parallel	46.8	230	368	
	2000	1250	Series	11.7	230	184	
	3000	510	Parallel	46.8	230	450	
	3000	1020	Series	11.7	230	225	
1 166 984	500	750	Parallel	33.5	57.5	76.7	....
	500	1500	Series	8.37	57.5	38.3	
	960	750	Parallel	33.5	110	147	
	960	1500	Series	8.37	110	73.5	
	2000	750	Parallel	33.5	230	307	
	2000	1500	Series	8.37	230	153.5	
1 161 719	2000	250	Parallel	95.6	75	300	....
	2000	500	Series	23.9	75	150	
1 124 107	2000	625	Parallel	24	115	184	....
	2000	1250	Series	6	115	92	
	3000	625	Parallel	24	71	177	
	3000	1250	Series	6	71	89	
1 166 985	4800	562	Parallel	24	230	410	....
	4800	1124	Series	6	230	205	
1 124 106	2000	625	Parallel	12	57.5	92	....
	2000	1250	Series	3	57.5	46	
1 166 986	3000	625	Parallel	31	230	368	....
	3000	1250	Series	7.75	230	184	
1 166 987	3000	750	Parallel	22.5	230	307	....
	3000	1500	Series	5.62	230	153.5	
1 166 988	3000	800	Parallel	19.1	230	288	....
	3000	1600	Series	4.77	230	144	
	4800	630	Parallel	19.1	230	365	
	4800	1260	Series	4.77	230	182	
1 166 989	4800	750	Parallel	13.5	230	307	....
	4800	1500	Series	3.37	230	153.5	
	9600	530	Parallel	13.5	230	435	
	9600	1060	Series	3.37	230	218	
1 166 990	9600	200	Parallel	38.3	92	460	....
	9600	400	Series	9.57	92	230	
1 166 991	9600	625	Parallel	9.8	230	368	....
	9600	1250	Series	2.45	230	184	
1 166 992	9600	750	Parallel	6.82	230	307	....
	9600	1500	Series	1.70	230	153.5	
1 166 993	9600	800	Parallel	6	230	288	....
	9600	1600	Series	1.5	230	144	

Voltage values, as given on the nameplate, are maximum. Microfarad values when given on the nameplate are minimum, all manufacturing tolerances being in the plus direction.

* For prices refer to the nearest sales office.

TYPE FP INERTEEN CAPACITORS—Continued

Installation

Mounting—The bottom of the unit is provided with a $\frac{1}{16}$" recess. It may be mounted on a metal plate which is mounted on insulators, or directly on insulators using the $\frac{1}{16}$" edge to keep it in position.

Bus Bars—The bus structure should provide sufficient flexibility so that excessive mechanical strains will not be placed upon the porcelain terminals.

Water Connections—The unit is fitted with short brass tubes having $\frac{1}{4}$" standard pipe threads on one end. They may be used to attach hose connections. The hose connections should be sufficiently long to insulate for the voltage likely to appear between cases, or from case to ground both under normal and abnormal conditions. The number of units that may be placed in series on the water line depends on the minimum pressure likely to be encountered and the maximum expected water temperature. The units are designed for a normal flow of one gallon per minute and an outlet water temperature not exceeding 30°C.

The pressure drop in the cooling coil is given in the following table:

Pressure Gallons Per Sq. Inch	Gallons Per Minute	
2	.4	
5	.7	
9.5	1.0	Normal operating point
15	1.3	

The approximate rise in the water in one unit operating at 230 kv-a. and when one gallon per minute is following, is 3°C.

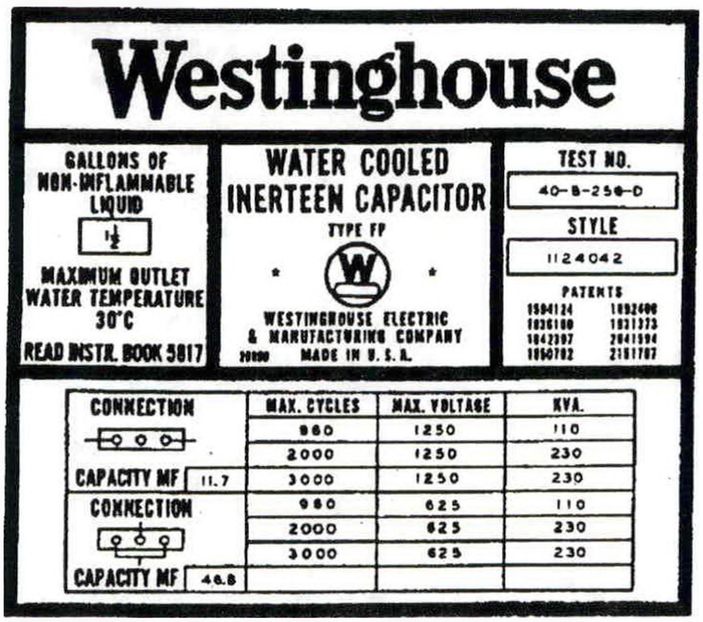

FIG. 11—TYPICAL NAMEPLATE

Precautions

It is not customary to equip high frequency capacitor installations with permanently connected discharge devices, although these can be supplied when ordered. In most applications, the circuit arrangement provides for automatic discharging. However, in all cases before handling a capacitor unit, it should be discharged, using an insulated wire and avoiding drawing the discharge arc from the threads of the capacitor terminals, as this may damage the threads.

The outlets from each capacitor or each group of capacitors which are in series on the water line should be located in an easily accessible place where the flow of water can be measured and observed and its temperature measured from time to time. Where there is likelihood of interruption of the water supply, such as stoppage of auxiliary pumps, etc., it is preferable to provide interlocking means to shut down the equipment when the flow of water through the capacitors is terminated or substantially reduced, as the capacitor might easily be damaged otherwise.

Where the capacitors are exposed to freezing temperature and are not in operation, provisions must be made for blowing the residual water out of the capacitor units by means of air pressure.

The capacitor cooling coils and the water system should be periodically blown out to eliminate the accumulation of sediment, at intervals depending upon the local water supply. Strainers should be provided on the water supply main connections.

The capacitor units covered in Table I are all equipped with a nameplate as shown in Fig. 11, giving the rating on the basis of series or parallel operation, and in some cases the rating is given for more than one frequency. This nameplate is typical of one unit, style number 1124042.

TYPE FP INERTEEN CAPACITORS—Continued

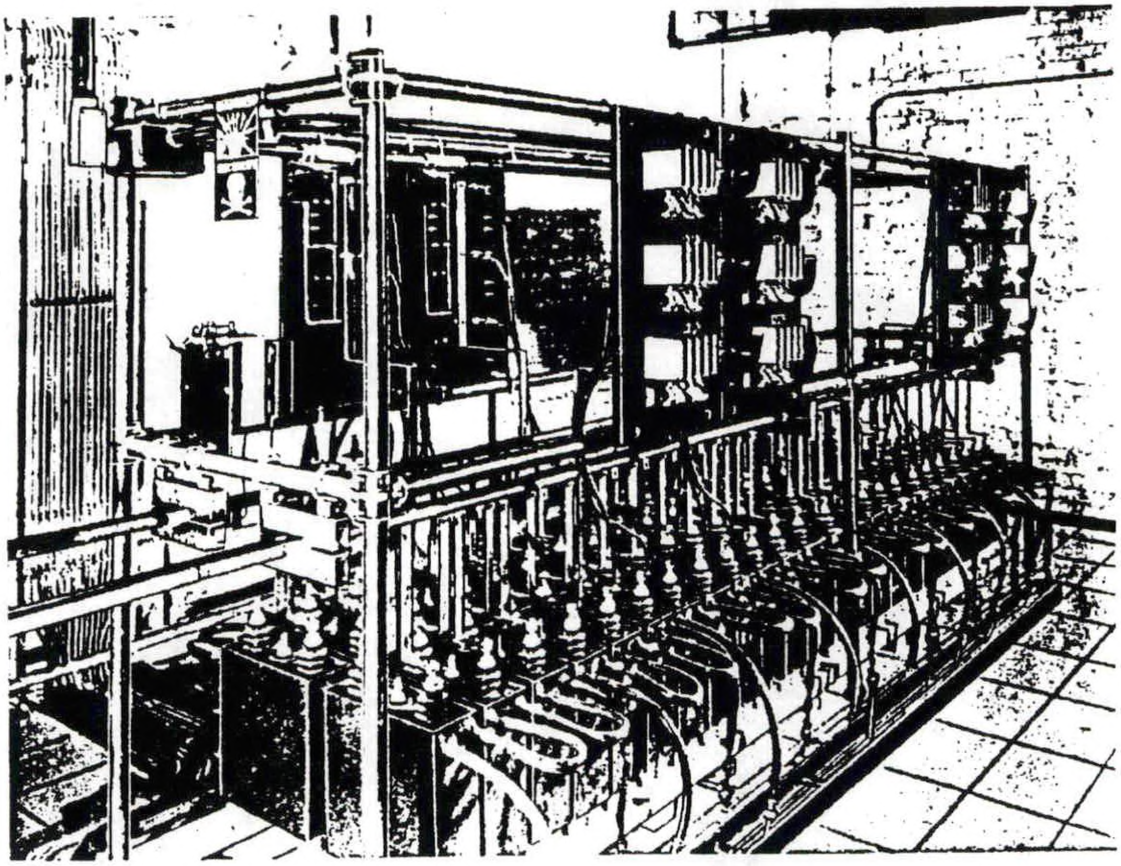

Fig. 12—Installation of Type FP Inerteen Capacitors, Internally Water-Cooled, for High Frequency Service, Total 5500 Kv-a. Consisting of 50-Style 1124042 230 Kv-a. 11.7 Mfd., 1250 Volt, 2000 Cycle Capacitors each Operated at 110 Kv-a., 1250 Volt, 11.7 Mfd., 960 Cycles