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APPARATUS FOR HIGH FREQUENCY DIELECTRIC HEATING OF CONDENSER BUSHINGS

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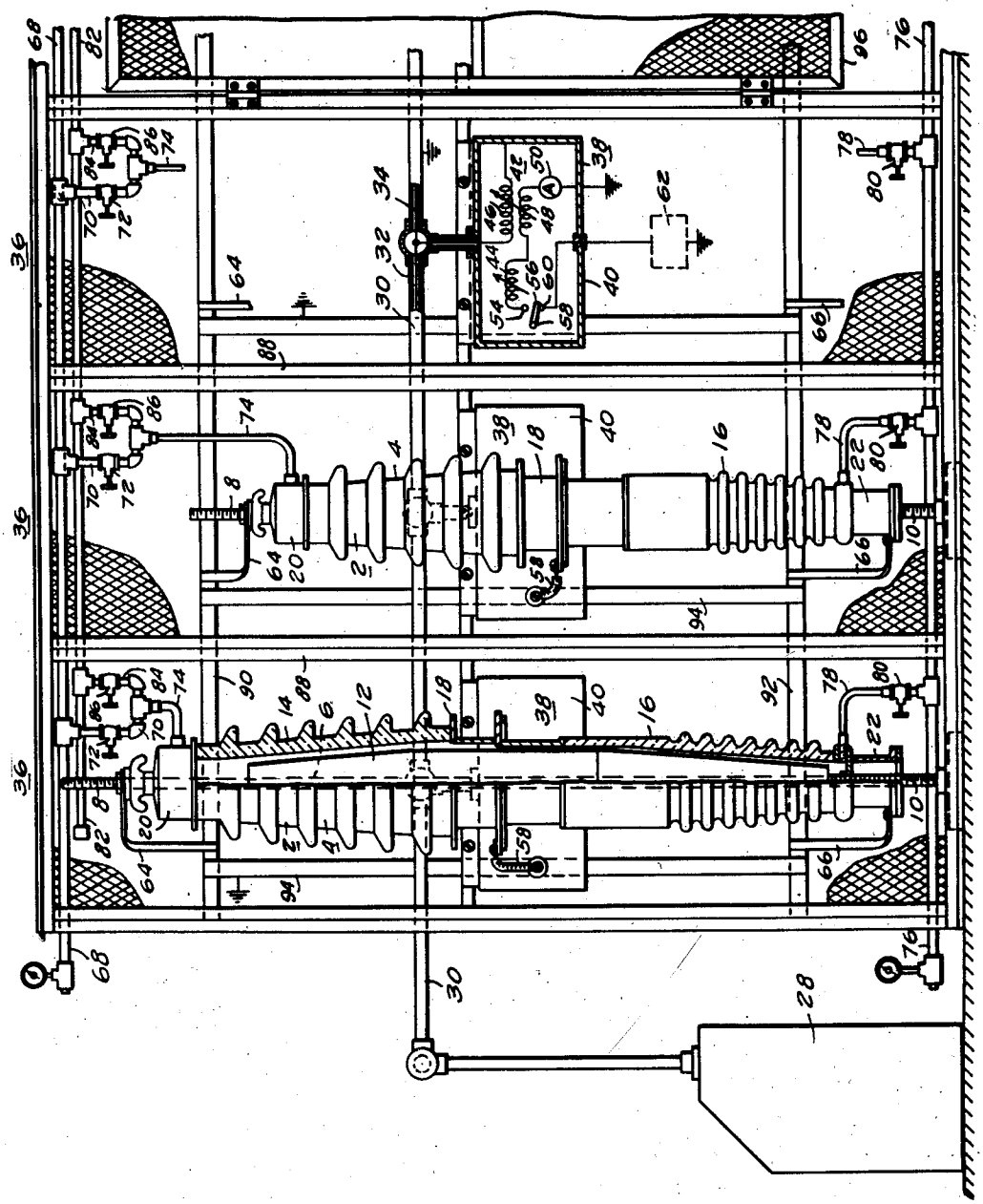

WITNESSES:

E. A. McCluskey.

Mrs. L. Groome

INVENTOR

Carl J. Madsen.

BY

B. L. Zanguill

ATTORNEY

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## APPARATUS FOR HIGH FREQUENCY DIELECTRIC HEATING OF CONDENSER BUSHINGS

Carl J. Madsen, Wilkinsburg, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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Broadly, my invention relates to the simultaneous or selective heating of one or more loads, which may be alike or different, by means of electrical power derived from a high-frequency source such as a tube-oscillator generator. More particularly, my invention relates to the dielectric heating of one or more condenser bushings such as is used to pass high tension electrical current through containers or walls for electrical apparatus.

An object of my invention is to provide a system in which a single tube-oscillator generator and a single high-frequency transmission line can be used to heat a plurality of dielectric loads of the same or different impedances at the same or different times.

Another object of my invention is to improve upon the treatment of condenser bushings which are dried, gas-exhausted and oil-filled during their manufacture.

An ancillary object of my invention is to improve upon the condenser bushing treating means and method disclosed in the copending patent application of H. J. Lingal and T. R. Watts, Serial No. 488,634, filed May 27, 1943.

My invention is of general application, and other objects, features and innovations of my invention, in addition to the foregoing, will be discernible from the following description of a preferred embodiment. The description is to be taken in conjunction with the accompanying schematic drawing which illustrates, in a general way understandable in the art, a system for heating a plurality of condenser bushings.

For convenience, the bushings are assumed to be of the same general character, and in the drawing each condenser bushing 2 comprises an outer porcelain casing 4 through which passes an axial bushing-stud or conductor 6 having threaded ends 8 and 10. Wrapped around the conductor 6 is a central capacitance wrapping 12 which tapers to the ends 8 and 10, and is spaced from the casing 4. The casing 4 also tapers toward the ends of the condenser bushing, and comprises upper and lower porcelain shells 14 and 16, respectively, separated by a central comparatively narrow metallic mounting-fitting or flange structure 18 by which the condenser bushing is supported in a customary manner when in use. The other ends of the shells 14 and 16 are maintained in position by an upper metal cap 20 and a lower metal fitting 22, both of which are electrically secured to the conductor 6. The insulating wrapping 12 may comprise alternate layers of metal foil and dielectric material, such as paper, arranged to form a capacitor which grades the voltage stresses between the central conductor 6 and the ground potential of the mounting fitting 18 which is usually secured to a wall of a grounded metal tank or similar part.

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In making high-voltage condenser bushings, it is customary to dry the capacitance wrappings under vacuum, and in some designs to fill them with oil or other suitable substance for preventing the absorption of water during the useful life of the bushings. The oil impregnates the capacitance wrapping, and in order to secure an efficient low-loss condenser bushing, the impregnation should be carried out in a manner which removes entrapped moisture and air as completely as possible. The aforesaid patent application describes a satisfactory process using steam for treating condenser bushings. The use of steam necessitates a steam piping system and a hollow axial conductor for the condenser bushing.

In accordance with my invention, the heating is performed with high-frequency currents. This means that no steam source or pipe delivery is required, and the heating is accomplished in a matter of minutes, rather than hours. Even more important, it means that the axial conductor of the condenser bushing can be either solid or hollow.

In the diagrammatic form of my invention shown in the drawing, the source of power for the heating is generated by any suitable tube-oscillator generator 28 which is provided with its own frequency-determining circuit. Power from the generator is distributed by a coaxial cable transmission line 30 which comprises an outer grounded hollow metal tubular conductor 32 containing an insulated central conductor 34. At spaced points along the transmission line, heating stations 36 are provided at each of which a condenser can be treated.

Each station includes a tuning unit 38 comprising a grounded shielding box 40 having suitable holes or other expedients through which controlling elements, mounted on the face of the box, and insulated conductors pass to parts inside. The tuning unit comprises a variable coupling transformer 42 and a variable tuning reactor 44, in the form of a variable induction coil, supported inside the box. The coupling transformer comprises a primary winding 46 and a closely coupled secondary winding 48. Electrically the primary winding is in a primary circuit connected between ground, or the ground conductor 32, and the insulated conductor 34 of the coaxial cable. Accordingly, the tuning units are separately

branched from the coaxial cable 30. The secondary winding 48 is in a secondary circuit which includes, in series inside the box 40, the tuning reactor 44 and an ammeter 50. The ammeter end of the secondary circuit is grounded and the other end is connected to a contact 54 of the equivalent of a single-pole double-throw switch having a blade 56. The blade 56 is connected to an insulated outlet conductor 58 which, in turn, is connected to the central mounting flange 18 of the condenser bushing. The other contact 60 of the switch is connected to a power factor measuring device 62 for ascertaining the power factor of the condenser bushing. The electrical connections for heating the condenser bushing are completed by connecting both ends 8 and 10 of the conductor 6 to ground by means of flexible detachable straps 64 and 66, respectively.

When the switch blade 56 engages the contact 54, power is delivered to the condenser bushing for dielectrically heating its capacitance wrapping 12 which acts as a dielectric load. In order to obtain an appreciable amount of power-delivery, the tuning unit 38 is manipulated to bring the secondary circuit with the condenser bushing in series into resonance with the frequency of the power supply. The transformer 42 is such as to introduce a high primary impedance when the secondary circuit is detuned from resonance, or is otherwise deenergized as, for example, by disengaging the blade 56 from its contact 54. By this means, it is possible to apply or remove power to any one condenser bushing without effecting the heat-treatment of the others which also derive power from the transmission line 30. It is also possible to measure the power factor of the condenser bushing for ascertaining its condition at any time, by moving the blade 56 to the contact 60.

For degassing the condenser bushings during the high-frequency heating and subsequent application of oil to the insides of the bushings, pipe connections are provided. For exhausting gas, a common vacuum line 68 is provided having a plurality of branch pipes 70 each of which includes a shut-off valve 72. A connection pipe 74, part of which may be flexible if desired, can be secured to the cap 20 of each condenser bushing, and extends to the associated branch pipe 70. Similarly, for selectively filling the condenser bushings with oil, a common oil supply pipe 76 is provided which can be connected to the bottom of the several condenser bushings through branch pipes 78, each having a shut-off valve 80. A common oil-return line 82 is provided having a plurality of branch pipes 84 connected to the connection pipes 74, each branch pipe 84 including a shut-off valve 86.

The condenser bushings may be treated individually or collectively in any grouping, along the lines described in the aforesaid Lingal and Watts patent-application; a valve or valves 72 being open and the associated oil shut-off valves 80 and 86 closed during the initial gas-evacuation, and the valves 80 and 86 open during oil treatment.

By providing individual tuning units for the several condenser bushings, it is possible to treat the condenser bushings individually, irrespective of variations in capacitance so long as the associated tuning unit, with the condenser bushing connected, can be tuned substantially to resonance. The magnetic coupling between the windings of the transformer should preferably be variable so that each of the bushings in various stages of completion (including some filled with oil) may be heated at its proper rate, irrespective of the stage of completion which has been reached by any other bushing. The high primary impedance of each transformer permits any condenser bushing to be connected to and disconnected from the power source at any time, no matter what the condition is of any other condenser bushing.

The drawing also sketchedly illustrates equipment for conveniently treating the condenser bushings. A metallic cage structure is provided having a plurality of partitions 88 dividing it into a plurality of cubicles in each of which a condenser bushing is vertically supported. Consequently each cubicle can be considered a heating station 36. Heavy copper bus bars 90 and 92, to which the straps 64 and 66 may be secured, run horizontally through the cubicles, being located so as to be near the caps 20 and fittings 22 of the condenser bushings. A vertical equalizing jumper bar 94 is provided in each cubicle, extending between the upper and lower bus bars. These bars are in intimate contact with the metallic cage structure. The coaxial cable 30 also passes horizontally along a side of the cage structure, and between the horizontal bus bars 90 and 92 so as to be conveniently located with respect to the tuning units 38 which are supported on the walls of each cubicle in the manner so that the outlet conductors 58 can conveniently be connected to the mounting flanges 18 of the condenser bushings. The common pipes for gas-evacuating and oil-filling the condenser bushings run along the top and bottom of the cage structure so as not to interfere with movement of the condenser bushings.

The back of each cubicle is provided with a door 96 through which a condenser bushing can be moved. Preferably the coaxial cable is kept filled with an inert gas such as nitrogen, and copper is the preferred material for all current-carrying parts of the treating apparatus. The cage structure is preferably thoroughly grounded; and the various bus bars, the tuning units and the outer conductor of the coaxial cable are preferably secured to the cage structure so as to make good electrical contact with it. In order to prevent localized heating in each condenser bushing, copper should also be used in the connection from the outer foil layer or layers of the wrapping 12 to the fitting 18.

The frequency for heating large-size oil-filled condenser bushings usually runs into megacycles. Exceptionally high frequencies, although usable, are not recommended because of the possibility of obnoxious standing waves. Five megacycles have been found satisfactory for heating 138 kv. condenser bushings of both the dry paper and oil-impregnated paper types, such bushings standing about 10½ feet in height. However, other frequencies more and less than five megacycles can be used.

While I have described my invention in connection with a preferred form, it is obvious that its teachings are of general application to high-frequency heating, as well as being of special merit for treating condenser bushings.

I claim as my invention:

1. A dielectric heating system for treating a plurality of condenser bushings of different sizes and of a type having a central conductor having opposite ends, a capacitive wrapping about said conductor and an outer mounting fitting about said wrapping and lying between said conductor-ends, said system comprising a high-frequency

generator, a plurality of heating stations, each adapted to receive a condenser bushing, a common power-transmission line extending from said generator to each of said stations, each station comprising a coupling transformer having a high impedance primary winding and a secondary winding, circuit means at each station connecting each primary winding to said transmission line, with the primary windings of the several stations in parallel, connection means at each station for connecting the associated secondary winding thereat across said central conductor and said mounting fitting of the condenser bushing at the associated station, the last said connection means comprising a variable inductor, the last said connection means at each station comprising a pair of conductors at a common potential, adapted to be connected to the opposite ends of said central conductor, and comprising an insulated conductor adapted to be connected to said mounting fitting.

2. A dielectric heating system for treating a plurality of condenser bushings of different sizes and of a type having a central conductor having opposite ends, a capacitive wrapping about said conductor and an outer mounting fitting about said wrapping and lying between said conductor-ends, said system comprising a high-frequency generator, a plurality of heating stations, each adapted to receive a condenser bushing, a common power-transmission line extending from said generator to each of said stations, each station comprising a coupling transformer having a high impedance primary winding and a secondary winding, circuit means at each station connecting each primary winding to said transmission line, with the primary windings of the several stations in parallel, connection means at each station for connecting the associated secondary winding thereat across said central conductor and said mounting fitting of the condenser bushing at the associated station, the last said connection means comprising a variable inductor, a cage structure at each of said heating stations, each cage structure having means for receiving a condenser bushing for dielectric heating, the last said connection means comprising a conductor in intimate electrical contact with said cage structure.

3. An invention including that of claim 2 but further characterized by said transmission line comprising a coaxial cable having an outer conductor, a metallic box at each station in intimate electrical contact with the associated cage structure, each box carrying therein the associated transformer and variable inductor, said outer conductor and an end of the primary winding of each transformer being substantially directly electrically connected to the box associated therewith at a heating station.

4. A system for treating a condenser bushing comprising a central bushing-conductor, a tapered capacitive wrapping about said bushing-conductor, and a mounting fitting of lesser length than said central bushing-conductor, said mounting fitting being about said capacitive wrapping; said system comprising a tube-oscillator generator; a metallic cage-structure spaced from said generator; a high-frequency transmission line from said generator to said cage-structure; a shielding box carried by said cage-structure and having therein a transformer means comprising a high impedance primary winding and a secondary winding; a primary circuit connected to said transmission line, comprising an insulated conductor insulatedly passing into said box and connected to said primary winding; a secondary circuit comprising, in series, said secondary winding, a tuning means, a switch means, and an insulated energizing conductor; said tuning means, switch means and energizing conductor comprising portions in said shielding box; conductor means for connecting a grounded end of said secondary winding to said central bushing-conductor; and an intermediate conductor for electrically connecting said energizing conductor to said mounting fitting of the condenser bushing.



5. A system for treating a condenser bushing comprising a central bushing-conductor, a tapered capacitive wrapping about said bushing-conductor, and a mounting fitting of lesser length than said central bushing-conductor, said mounting fitting being about said capacitive wrapping; said system comprising a tube-oscillator generator; a metallic cage-structure spaced from said generator; a high-frequency transmission line from said generator to said cage-structure; a shielding box carried by said cage-structure and having therein a transformer means comprising a high impedance primary winding and a secondary winding; a primary circuit connected to said transmission line comprising an insulated conductor insulatedly passing into said box and connected to said primary winding; a secondary circuit comprising, in series, said secondary winding, a tuning means, a switch means, and an insulated energizing conductor; said tuning means, switch means and energizing conductor comprising portions in said shielding box; means comprising a conductor on said cage-structure for connecting an end of said secondary winding to said central bushing-conductor; an intermediate conductor for electrically connecting said energizing conductor to said mounting fitting of the condenser bushing; a circuit in said shielding box including power factor measuring means having an indicator observable externally of said cage-structure; said switch means having an operating member outside said cage-structure for disconnecting said energizing and intermediate conductors from said secondary circuit and connecting them in said power factor measuring circuit.

6. A treating system for a plurality of condenser bushings, each comprising a central bushing-conductor having ends, a capacitive wrapping around said central bushing-conductor, and a mounting fitting about said capacitive wrapping, said mounting fitting lying between said conductor-ends; said system comprising a tube-oscillator generator; a cage-like structure divided into a plurality of cubicles, each of which can receive a condenser bushing; a high-frequency transmission line extending along said cage-structure; each cubicle carrying a transformer means comprising a high impedance primary winding and a secondary winding; connecting means for each cubicle for connecting the associated primary winding to said transmission line; a secondary circuit for each cubicle comprising the associated secondary winding, branch conductors spaced in each cubicle for electrical connection to the ends of said central bushing-conductor, and an intermediate conductor between said branch conductors and insulated therefrom for electrical connection to the mounting fitting of said condenser bushing adapted to be associated therewith; said secondary circuit including a circuit tuning means in series with the intermediate conductor and the secondary winding in the same cubicle.

7. An invention including that of claim 6 characterized by said spaced branch conductors comprising substantially parallel bus-bars, each bus-bar being common to said cubicles and extending across said cage-like structure in intimate electrical contact therewith.

8. An invention in accordance with claim 6 but further characterized by each cubicle having a switch means in the associated secondary circuit and a power factor measuring circuit; said switch means of each cubicle being constructed and arranged for disconnecting the associated branch conductors and intermediate conductor from the associated secondary circuit and connecting them in said power factor measuring circuit.

9. A heating station for drying condenser bushings of a type comprising an axial central conductor, a capacitance wrapping about said central conductor, and a mounting fitting centrally circumferentially around said wrapping, said station comprising a cage-like cubicle of metallic walls adapted to vertically receive a condenser bushing, a pair of spaced bus-bars carried by said cubicle in intimate contact therewith, said bus-bars having a conductor-portion attached thereto of limited length for connection to an end of the central conductor of said condenser bushing, and an intermediate conductor of limited length between said bus-bars for connection to the mounting fitting of the condenser bushing, said intermediate conductor being relatively insulated with respect to said cubicle, said cubicle having a space therein for vertically receiving said condenser bushing with its mounting fitting insulated from the metallic walls of the cubicle.

10. An invention including that of claim 9 but further characterized by said bus-bars being vertically spaced and substantially horizontal, one bus-bar being near the bottom of the cubicle and the other bus-bar near the top of the cubicle.

11. An invention including that of claim 4 but further characterized by said conductor means comprising vertically spaced substantially horizontal bus-bars, each bus-bar being in intimate electrical contact with the cage-structure.

12. A heating station for drying condenser bushings of the type comprising an axial central conductor, a capacitance wrapping about said central conductor, and a fitting mounted centrally circumferentially around said wrapping, said station comprising a cage-like cubicle of metallic walls adapted to receive a condenser bushing therein, a pair of spaced bus-bars secured to said walls in intimate electrical contact



therewith, each of said bus-bars having a conductor-portion attached thereto of limited length for connection to the ends of the central conductor of said condenser bushing, an insulated intermediate conductor of limited length inside said cubicle for connection to the mounting fitting of said condenser bushing, transformer means for providing a high frequency voltage across said intermediate conductor and said conductor-portions, said cubicle having a space therein for receiving the condenser bushing with its mounting fitting insulated from the metallic walls of the cubicle and with the ends of its central conductor position to be reached by said limited conductor-portions and its fitting positioned to be reached by said insulated intermediate conductor.

CARL J. MADSEN.

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