United States Patent [19]

Mohr

[11] **3,864,543**

[45] **Feb. 4, 1975**

[54] **CONTINUOUSLY MODULATED ELECTRODE BOILER**

[75] Inventor: **Glenn R. Mohr,** Linthicum, Md.

[73] Assignee: **Mohr-Baker Co.,** West Chicago, Ill.

[22] Filed: **May 29, 1973**

[21] Appl. No.: **364,679**

[52] **U.S. Cl.** **219/285,** 13/5, 219/10.47, 219/10.49, 219/272, 219/289, 219/503

[51] **Int. Cl.** **H05b 3/60,** H05b 1/02

[58] **Field of Search** 219/284–295, 219/271–276, 503, 10.49, 10.51, 10.47, 10.65, 10.75, 10.77, 327; 13/5

[56] **References Cited**

UNITED STATES PATENTS

754,451	3/1904	Hill	219/285
1,239,594	9/1917	Harlow	219/503
1,289,210	12/1918	Lincoln	219/10.49
1,559,447	10/1925	Meyer-Keller	219/285
1,750,640	3/1930	Kittredge et al.	219/10.51
2,096,571	10/1937	Williams	219/503 X
2,210,758	8/1940	Hall et al.	219/285 X
2,465,532	3/1949	Hall	219/503 X
2,935,590	5/1960	Jacobs et al.	219/503 X
3,219,786	11/1965	Wenzel	219/10.49 X

FOREIGN PATENTS OR APPLICATIONS

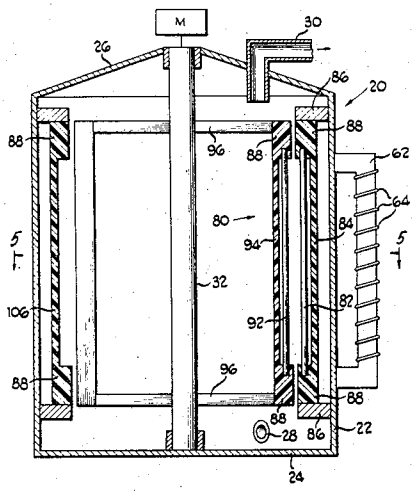
92,636	1/1922	Switzerland	219/285

Primary Examiner—A. Bartis
Attorney, Agent, or Firm—Dorsey L. Baker

[57] **ABSTRACT**

An electrode boiler apparatus for converting electrical energy to heat energy includes an electrically conductive container or pressure vessel containing an electrically conductive liquid in which is immersed at least one pair of electrodes. A variable reactance is mounted upon the container and connected to a power source to induce current into the container walls. The electrodes are mounted for movement relative to each other to vary the effective current path between the electrodes and the electrodes are connected in series with the variable reactance. Adjustment of the spacing between the electrodes provides continuous power control from full load down to 5–15 percent of the full load rating, at which point the inductive reactance of the variable reactance increases to reduce the power drawn to a no load condition. The variable reactance may comprise a saturable laminated C-shaped core mounted on the container wall and provided with a coil wound about the core and connected in series with the electrodes. Alternatively, the variable reactance may comprise a saturable reactor.

11 Claims, 8 Drawing Figures



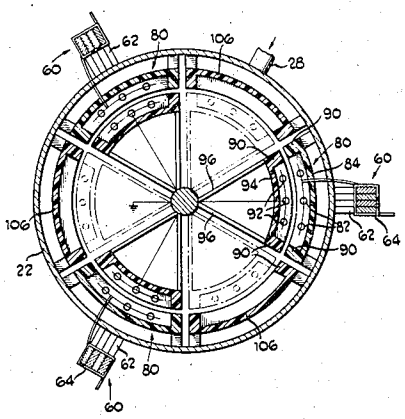


Fig 1

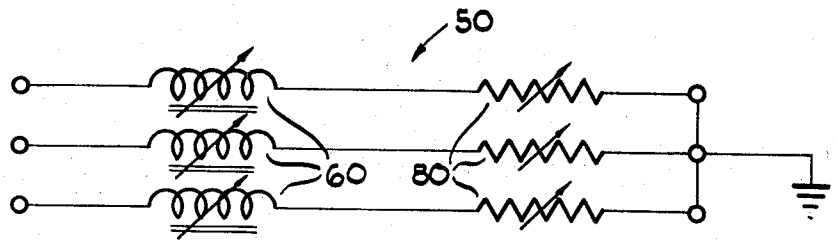


Fig 2

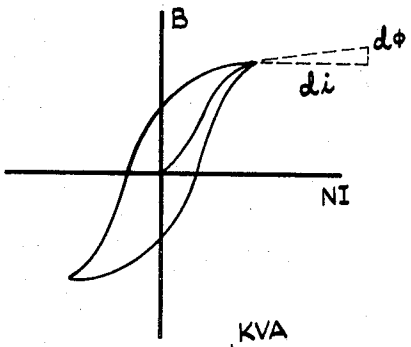


Fig 3

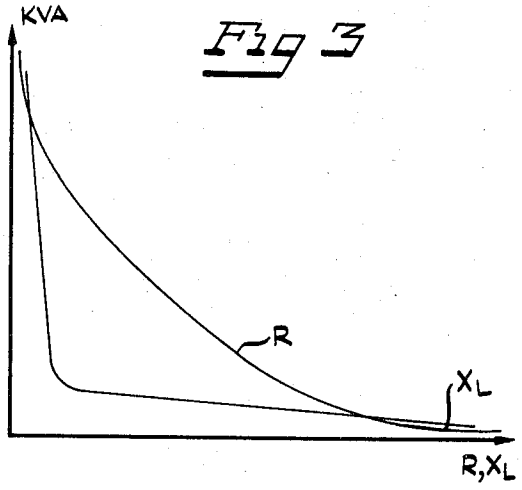


Fig 4

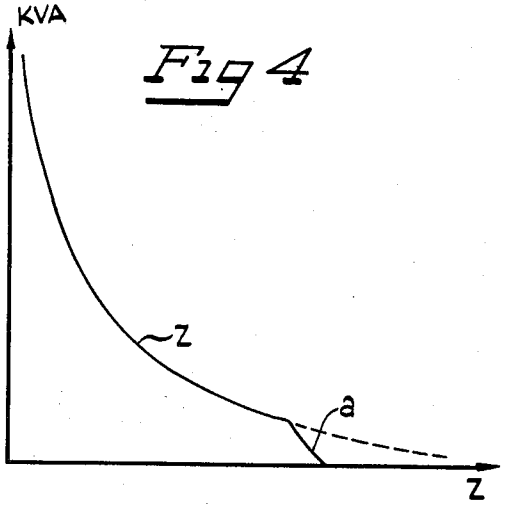
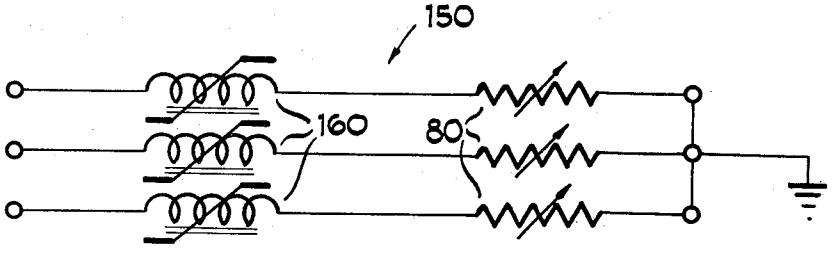


Fig 8



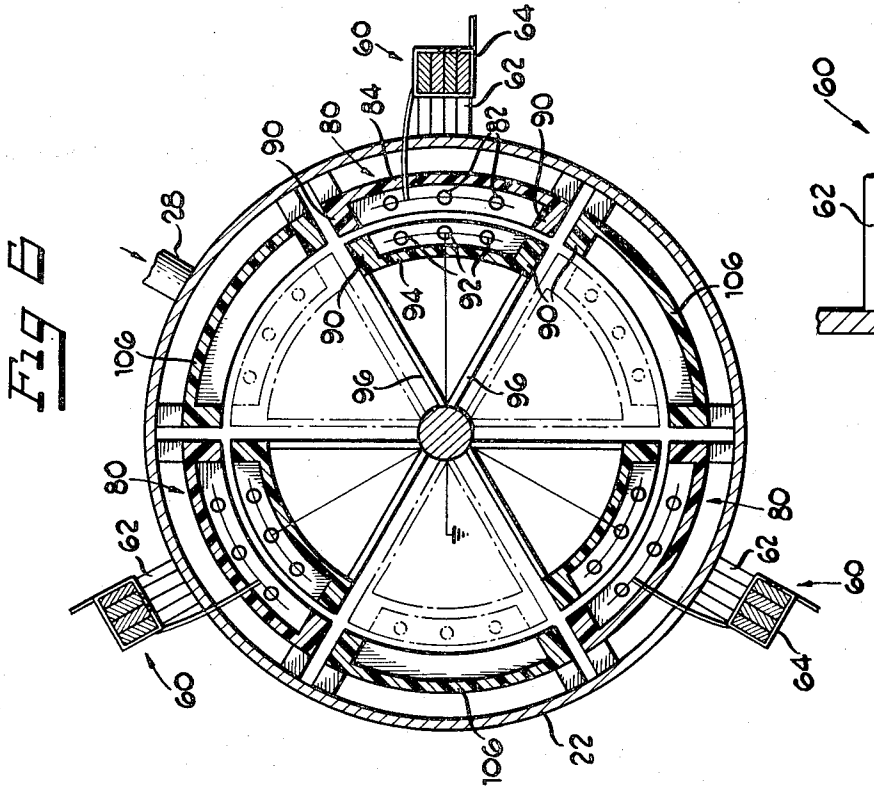


Fig 6

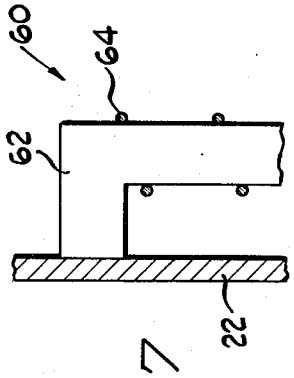


Fig 7

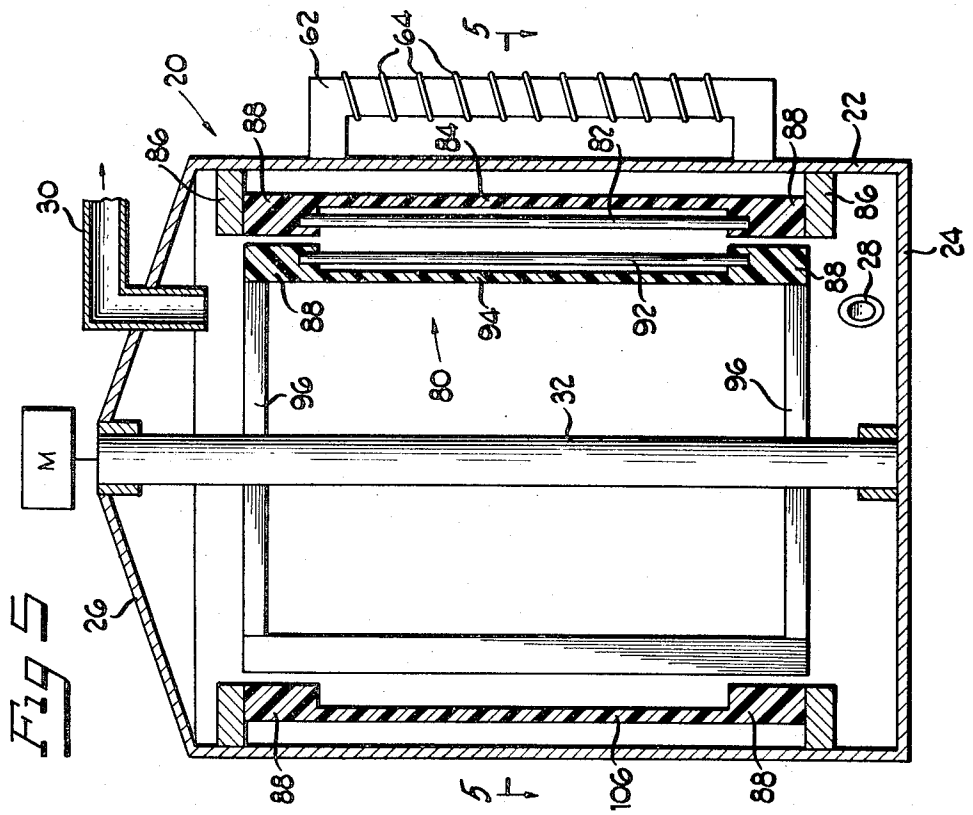


Fig 5

CONTINUOUSLY MODULATED ELECTRODE BOILER

BACKGROUND OF THE INVENTION

This invention relates to a system and apparatus for converting electrical energy into heat energy. More specifically, it relates primarily to a system and apparatus for heating water and other liquids to meet the needs of commercial buildings or industrial facilities. Such needs may relate to the usage of the fluid or the mere storage of heat energy for subsequent use.

Currently available electrical heating systems require switchgear to switch the system on and off the line as dictated by the temperature of the liquid or other control parameters. Additionally, they need protective devices which limit the maximum current which can be drawn. Finally, available systems have limited control ranges and do not permit the desired modulation by the system.

An optimum electrical heating system would have the following desirable features:

1. A large turn down ratio, exceeding 30:1;
2. A capability to remain on the line at all times regardless of the control parameters, thus eliminating the need for switch gear;
3. Continuous modulation from a no load to a full load condition;
4. A high power factor;
5. A minimum number of components, elimination of contactors and switch gear;
6. A current limiting capability;
7. An ability to vary both current and voltage within the boiler to obtain the large turn down ratio.

Finally, other considerations require that a heating system have a good wave form to prevent radiation and interference with instrumentation and television reception, be of relatively low cost with simplicity of design.

SUMMARY OF THE INVENTION

In order to obtain these desirable features, the instant invention includes a container having a variable resistance through which the electrical energy is converted to heat energy, the resistance being in series with a variable reactance. By varying the resistance, the power drawn and converted to heat energy is modulated from full load to approximately 5 to 15 percent of the full load rating. Below this level, the inductive reactance of the variable reactance reduces the power drawn to a no load condition which limits the power to a minimum core magnetizing level. Preferably, the variable resistance takes the form of at least one pair of relatively moveable electrodes while the reactance takes the form of a C-shaped core mounted or welded to the container and a coil wound about the core which is connected to one of the electrodes.

Accordingly, it is an object of the instant invention to provide a simple, high voltage electrode boiler which is of low cost and avoids exotic switch gear and power control devices. Another object of my invention is to provide an electrode boiler which has high efficiency and in which normally anticipated energy loses are converted into heat energy. Too, it is an object of my invention to transform an ordinary container or boiler wall into an inexpensive, unique induction heater to maximize system efficiency. Finally, it is an object of my invention to obtain all of the desirable features of an electric boiler previously mentioned.

DESCRIPTION OF THE DRAWINGS

The manner in which these and other objects of the invention can be obtained can be better understood with reference to the following specifications and drawings in which:

FIG. **1** is a diagram of a preferred embodiment of the electrical circuit of my invention;

FIG. **2** is a graph illustrating the hysteresis curve of the variable reactance and changes in inductance as intensity increases;

FIG. **3** is a graph illustrating the variation of the power drawn as a function of the resistance and inductive reactance;

FIG. **4** is a graph illustrating the variation of the power drawn as a function of the total impedance;

FIG. **5** is a side elevational view in section of a preferred imbodiment of my invention;

FIG. **6** is a plan view taken in section along the lines **5—5** of FIG. **5**;

FIG. **7** is an enlarged side elevational view of the variable reactor of my invention; and

FIG. **8** is a diagram of another preferred embodiment of the electrical circuit of my invention.

DETAIL DESCRIPTION

In order to obtain the aforementioned objects, the instant invention modulates the power delivered to an electric boiler by the use of a variable reactance in series with a variable resistance. The resistance comprises relatively movable electrodes. The variable reactance may comprise a saturable laminated core with a winding thereon connected in series with the resistance. At high power levels, the electrodes are adjacent one another to minimize resistance and the inductive reactance is very small to provide a good power factor. Continuous modulation down to a desired power level (5 – 15 percent of full load rating) is accomplished by increasing the effective current path between the electrodes. As the current drawn decreases below the saturation point of the core, the reactance increases. Thus with R and X_L both increasing, the high impedance reduces the current drawn to a no load condition.

The electrical circuit of the preferred embodiment of my invention is best described in FIG. **1.** The circuit **50** preferably includes three variable reactances **60** which are adapted for connection to a three phase power supply as indicated in FIG. **1.** These variable reactances take the form of a C-shaped laminated core welded to the walls of the boiler having windings connected to the power source. Preferably, the core is designed (as subsequently explained) so as to saturate when the boiler is drawing between 5 and 15 percent of the full load rating of the boiler. Connected in series with each reactor is a variable resistance **80.** These resistances preferably take the form of three pairs of wye connected electrode sets mounted within a container (as subsequently explained) for relative movement to vary the effective current path between them.

FIGS. **5** – **7** depict the preferred embodiment by which this circuit is integrated into a container **20.** This tank has an upstanding cylindrical wall **22** closed by a bottom plate **24** and a top member **26.** A fluid inlet **28** directs cold liquids to the container while outlet **30** provides heated liquids to the user upon demand.

Each of the three variable reactances **60** may take the form of laminated C-shaped sections **62** mounted by welding or other means to the container wall **22.** A winding **64** preferably of copper or aluminum is wound about the core as shown in these figures and is adapted to be connected to a three phase source. As shown in FIG. **7,** the container wall **22** in conjunction with the sections **62** form a closed core. The complete core, e.g., the C shaped sections **62** and the container wall **22** should be designed so as to saturate at a power level between 5 and 15 percent of the full load rating of the unit.

With specific reference to FIG. **7,** a preferred embodiment of my reactance **60** includes one leg (e.g., the container wall **22**) which has a smaller cross section than laminated sections **62.** It is this smaller cross section which should be designed to saturate at approximately a 15 percent power level and which functions as an induction heater (subsequently explained).

Each winding **64** is then connected to the variable resistances **80** which comprise pairs of sets of electrodes **82** and **92.** The first set **82** of each pair is carried within the tank **20** by insulators **84** which comprise upstanding arcs of electrical insulators carried by fixed supports **86.** The electrodes are mounted within flanges **88** (see FIG. **5**) at the top and bottom of the insulators, and are interconnected by a common conduit which is connected to winding **64.**

The other sets of electrodes **92** are similarily mounted on opposing arc shaped insulating units **94.** These units are rotatably carried upon a shaft **32** which is journaled in the top and bottom of the tank as shown for rotation by a motor M. Again, these electrodes are interconnected by a common conduit which is grounded after being connected to the rotable shaft **32.** As shown in full lines, the boiler is in the full load position.

The motor M and shaft **32** should be designed to rotate the second sets of electrodes **92** and their insulating units through an arc of approximately 60° which is shown in the dotted line position of FIG. **6.** In this position, these movable electrode sets are adjacent additional insulating units **106** which may be identical to the other units but have no electrodes therein. When rotated to this position, the electrodes **92** are shielded from the electrodes **82.** Too, the top and bottom flanges **88** as well as flanges **90** at each side preclude or substantially limit undesirable current flow between the opposing pairs of electrodes when the rotable sets **92** are moved to the dotted line position which represents the no load position.

MODE OF OPERATION

Assuming that the temperature of liquid in the container is to be raised, a control unit (not shown) which senses temperature will actuate the motor M to rotate the electrode sets **92** to the full line position of FIG. **6** such that the variable resistances **80** or effective current path between the pairs of electrode sets **82** and **92** is at a minimum. Considering the voltage equation $E = IR + IX_L$, the value of R is small in this position and does not inhibit current flow. Too, because the wall section **22** was saturated at a 15 percent power level, its permeability decreases and reluctance increases causing the flux per ampere to decrease. This is represented in FIG. **2** by a small change in flux compared to a large change in current. Hence, the inductive reactance X_L is also small and the unit can draw its full rated load. Thus, maximum KVA is drawn while X_L, R and total impedance are a minimum as shown in FIGS. **3** and **4.** Further, beyond saturation, the current drawn and ampere turns of the windings increases substantially. Therefore the magnetomotive force or field intensity through the wall section **22** increases to induce a voltage therein which inturn creates substantial eddy currents to transform the wall from a mere container to an induction heater.

As the temperature of the liquid rises, the control unit (not shown) will sense the temperature and actuate the motor to rotate the electrodes towards the dotted line position. Such will cause the resistance to increase and hence the voltage across the electrodes must increase. Consequently the voltage across the reactor **60** will decrease because the applied voltage is still constant. When the resistance increases sufficiently, the voltage drop (IX_L) across the reactance **60** will be below the level necessary to maintain saturation. Below saturation, the reluctance of the core decreases and for the same amount of magnetomotive force, the inductive reactance increases rapidly. The graphs of FIGS. **2, 3** and **4** are merely illustrative and are not intended to represent actual quantative values. However, it should be observed that the modulation of the power drawn by my invention is continuous from the full load condition down to the 15 percent level. The modulation below the 15 percent level is represented by a second curve (indicated at *b*) which is also continuous.

At this point it should be noted that losses due to hysteresis represent usable power. Since the tank is part of the cores, the heat generated will be delivered to the fluid. Obviously, the C-shaped cores might also be placed horizontal to the ground or at 90° to the position shown in FIGS. **6** and **7.** Such would cause the flux to flow around the tank for more uniform heating of the wall section.

ALTERNATIVE EMBODIMENTS

The power curve of the previously described embodiment is depicted in full lines in FIG. **4.** Such is continuous from the full load rating down to the saturation point (5 – 15 percent power level) of the load. However, it may be desirable to continuously modulate the power drawn down to the no load condition as indicated by the dotted curve. This can be easily accomplished by the use of the circuit **150** of FIG. **8** in which saturable reactors **160** are placed in series with the resistances **80.** However, in this case two reactors are used with each pair of electrodes. The AC windings of each reactor are connected in either parallel or in series with each other and both windings are in series with the electrodes. Wound about the same cores or an additional leg of each core are DC windings which control the amount of flux in the core. As the DC voltage is reduced, the flux decreases causing the reactance to increase as a function of the applied DC. This invention may take many other forms. For example, the electrodes may be moved vertical relative to one another or shielding may be used to provide effective relative movement. Too, the electrodes may be of carbon or iron, and the cores may be placed in various ways about the tank. Preferably, they are formed of silicon steel or less expensive materials. Finally, the use of the wall section as a part of the cores provides an induction heater

which has substantial utility without the use of electrodes. For example, the windings may be connected to the source and to a return line to obtain an inexpensive, external heater. In this case, the heating element (wall section 22) is external, visually observable and requires no maintenance. Silicon controlled rectifiers (SCR) or saturable reactors are used to control the current flow through the windings, and the electrodes or internal heating units are eliminated. Finally, this heating system will find application as an induct heater for forced air ducts and similar uses.

I claim:

1. An electrode boiler comprising:
A. An electrically conductive container means;
B. A pair of relatively movable electrodes within said container means for creating a current path through a fluid within said container means;
C. A variable reactance adapted to be connected to a power source and in series with the movable electrodes, said reactance being mounted upon said container and including an inductance means for passing flux through the container means to induce a current therein.

2. A device as recited in claim 1 in which:
A. Said variable reactance comprises a saturable reactor.

3. A device as recited in claim 1 in which:
A. Said variable reactance comprises a wall of the container means and a C-shaped core mounted thereon and carrying a winding adapted to be connected to the power source and the electrodes.

4. A boiler comprising:
A. An electrically conductive container structure;
B. Variable resistance means within said container for converting electrical energy to heat energy and for modulating the power drawn;
C. A variable reactance means mounted upon said container structure in series with said resistance means and adapted to be connected to a power source for further modulating the power drawn and for inducing current in said container structure.

5. An apparatus as recited in claim 4 in which:
A. The variable resistance means modulates the power from the rated load of the boiler down to about 10 percent of the rated load; and
B. The reactance means and resistance means modulates the power drawn from about 10 percent of the rated load down to the no load condition.

6. An apparatus as recited in claim 4 in which:
A. Said resistance means comprises three pairs of electrode units wye connected;
B. Said reactance means comprises three variable reactors adapted to be connected to a three phase power source and in series with said electrode units.

7. An electrode boiler comprising:
A. An electrically conductive container structure having a fluid inlet and outlet;
B. A variable reactance adapted to be connected to a source of electrical energy and mounted upon said container structure and for inducing current therein;
C. A variable resistance within said container, connected in series to said variable reactance and to a return conduit for varying the reactance for varying the energy drawn and converted to heat;
D. Means for varying the reactance for varying the energy drawn and converted to heat.

8. A device as recited in claim 7 in which:
A. Said resistance comprises at least one pair of relatively movable electrodes for varying the effective current path therebetween.

9. A device as recited in claim 8 in which:
A. Said variable reactance comprises a core and winding mounted upon the container.

10. A device as recited in claim 9 in which:
A. Said core comprises a section of the container wall and a C shaped lamination mounted thereon.

11. A device recited in claim 7 in which:
A. Said variable reactance comprises a saturable reactor.

* * * * *