# United States Patent

[11] 3,602,856

[72] Inventor **Dale White**
**Sharpsville, Pa.**
[21] Appl. No. **43,529**
[22] Filed **June 4, 1970**
[45] Patented **Aug. 31, 1971**
[73] Assignee **Westinghouse Electric Corporation**
**Pittsburgh, Pa.**

[54] **ELECTRICAL INDUCTIVE APPARATUS**
**7 Claims, 4 Drawing Figs.**

[52] **U.S. Cl.** .......... **336/57,** 165/107, 174/15
[51] **Int. Cl.** .......... **H01f 27/10**
[50] **Field of Search** .......... 336/55, 57; 165/106, 107; 174/15 R

[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,706,574 | 3/1929 | Hodtum | 336/57 X |
| 1,798,702 | 3/1931 | Roebel | 165/107 |
| 2,440,556 | 4/1948 | Palver | 165/107 X |
| 3,137,829 | 6/1964 | Dillow et al. | 336/57 |
| 3,372,738 | 3/1968 | Jan et al. | 336/57 |


*Primary Examiner*—Thomas J. Kozma
*Attorneys*—A. T. Stratton, F. E. Browder and D. R. Lackey

**ABSTRACT:** Fluid cooled electrical inductive apparatus having a heat exchanger and a pump. The apparatus has forced and self-cooled ratings, with a fluid flow bypass about the pump being provided for reducing the fluid flow resistance of the pump when the pump is not operating. The bypass is effectively closed without moving parts when the pump is operating, by a constriction on the output side of the pump which provides like pressure heads at both ends of the bypass.

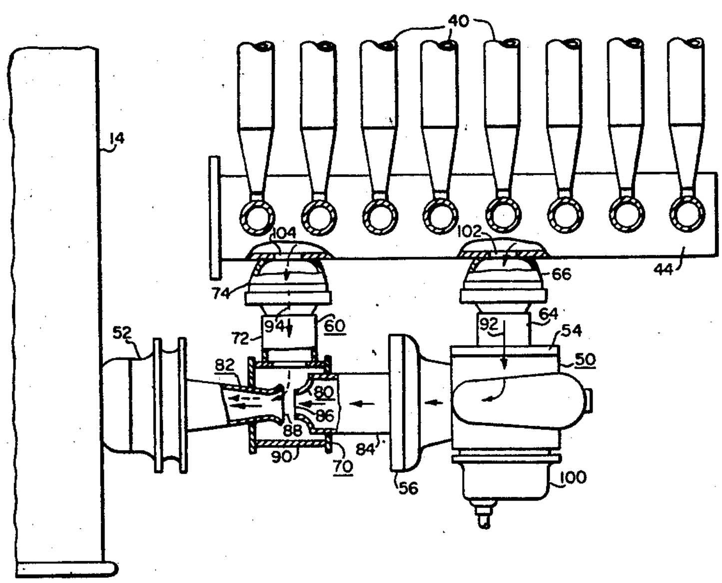
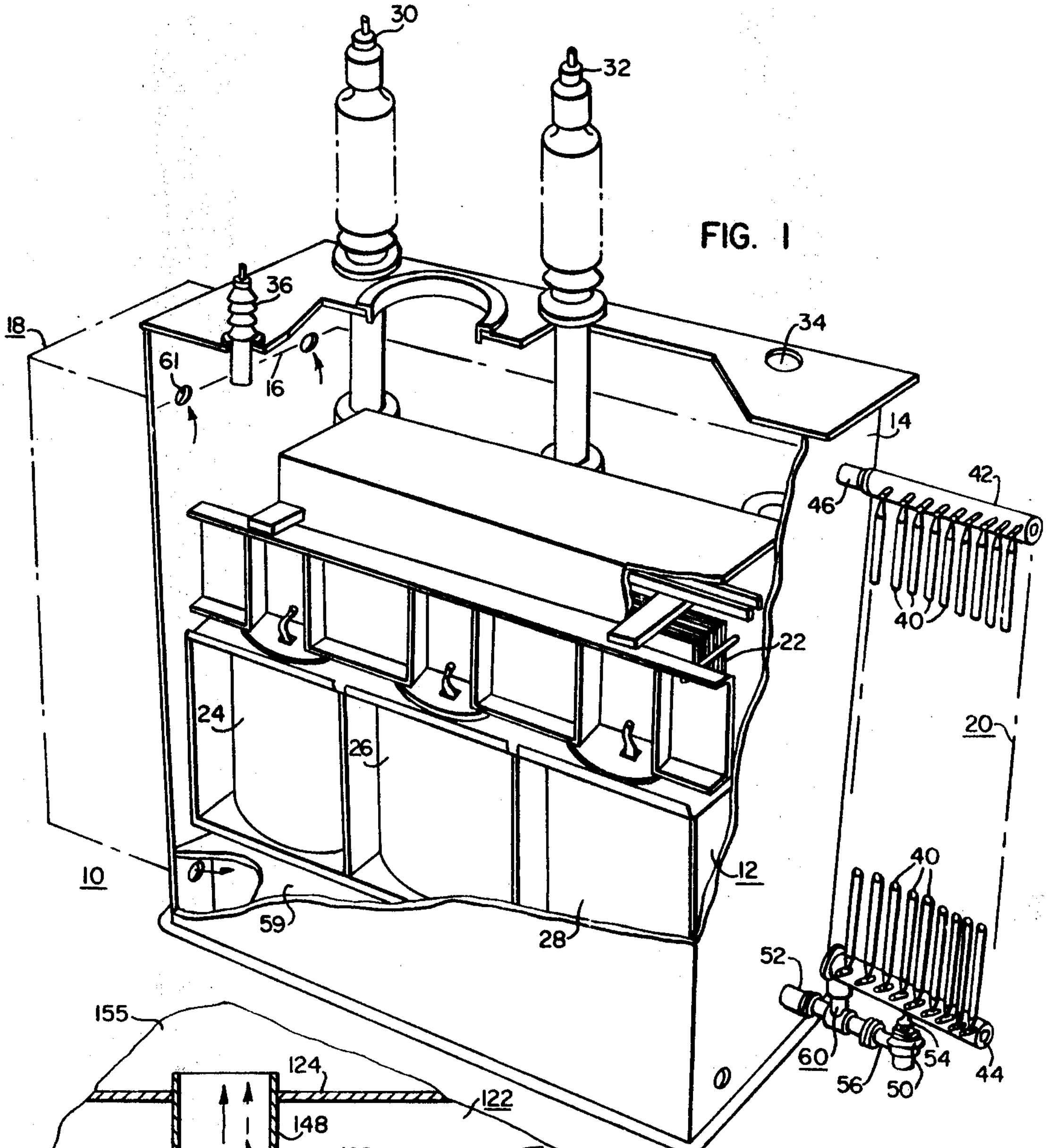


FIG. 1



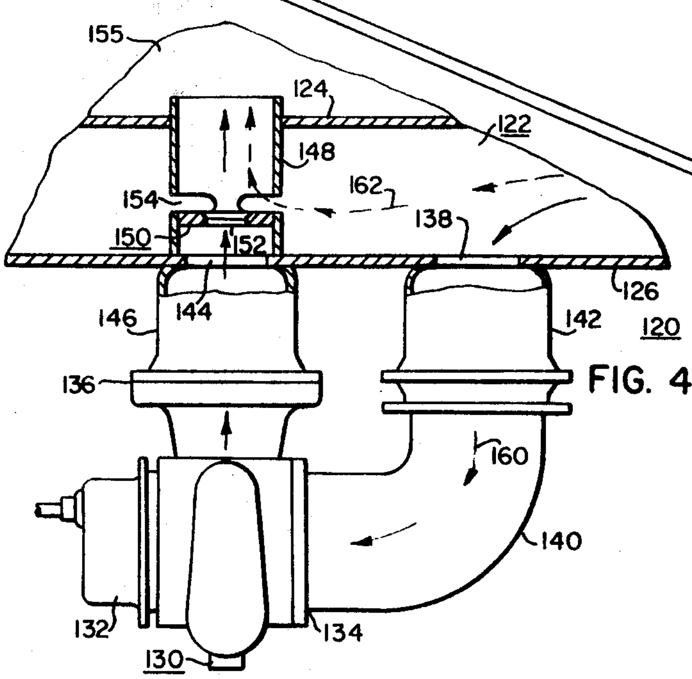




FIG. 4

INVENTOR
Dale White

ATTORNEY

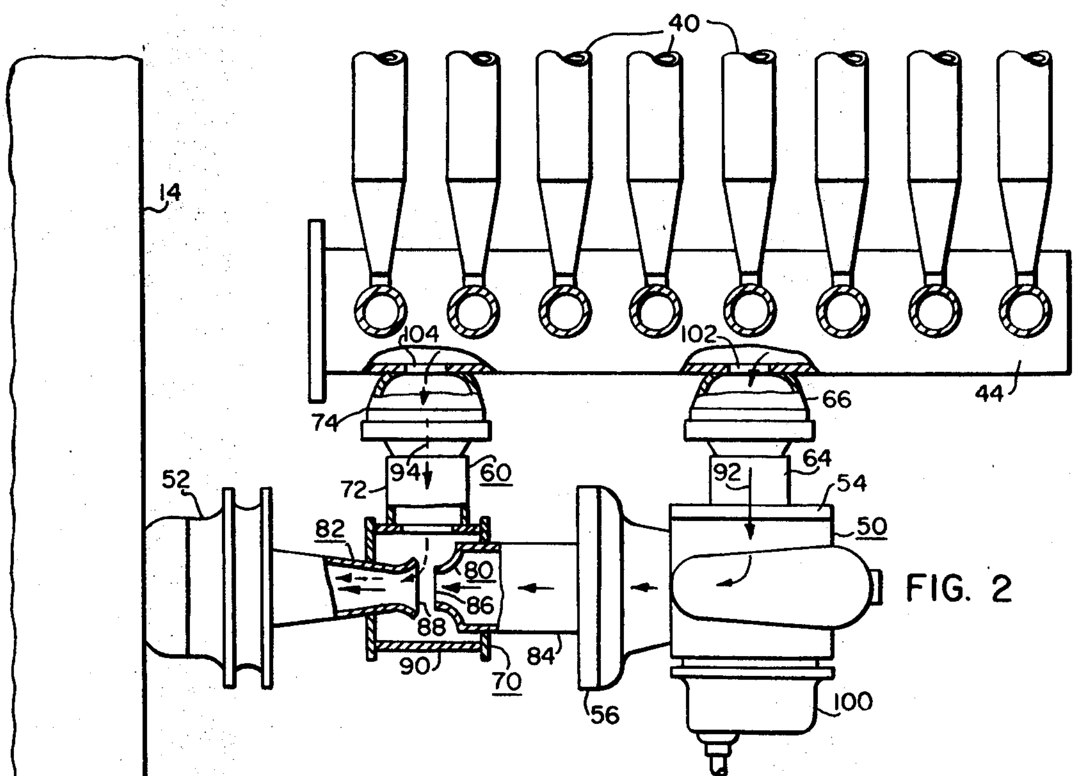

40
14
104
102
66
44
74
94
60
64
72
52
92
54
82
50
80
86
88
90
84
70
56
100

FIG. 2

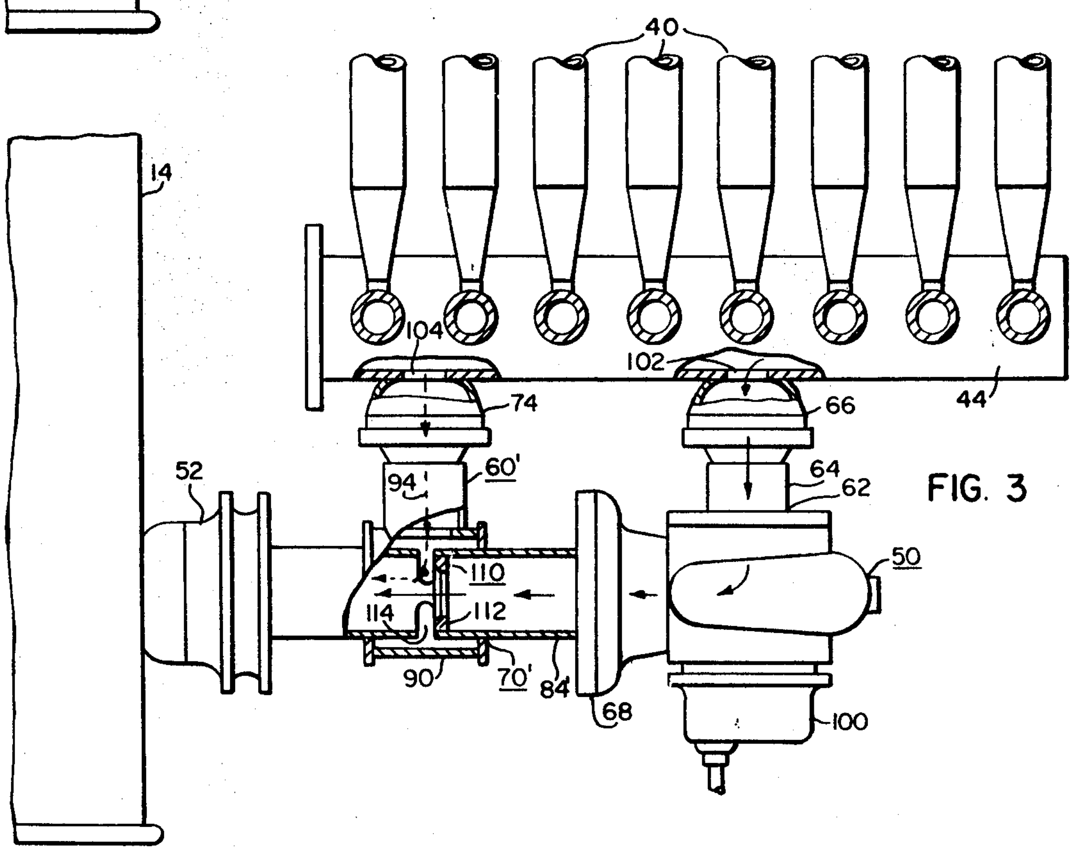

40
14
104
102
74
66
44
52
94
60'
64
62
110
50
114
112
90
70'
84
68
100

FIG. 3

## ELECTRICAL INDUCTIVE APPARATUS

### BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to fluid cooled electrical inductive apparatus, such as power transformers, and more specifically to fluid cooled apparatus having both forced and self-cooled ratings.

2. Description of the Prior Art

Certain electrical power transformers cooled with an insulating and cooling fluid, such as mineral oil, commonly have both forced and self-cooled ratings. In the self-cooled rating, the oil is heated by the transformer windings and magnetic core, and is circulated through external radiator type heat exchangers by thermal siphon effect. In the forced cooled rating, a pump, or pumps, connected in the outlet or outlets of the heat exchangers, pull the oil from the heat exchangers and force it through the transformer at rates greatly exceeding the circulation rates obtainable by thermal siphon. The particular cooling method, and thus the transformer rating, is automatically controlled and selected by temperature relays disposed in thermal communication with the transformer oil.

The self-cooled rating is not optimum due to the restriction or impedance to the thermal siphon oil flow imposed by the idle pump in the oil circuit. Bypassing the pump with a bypass pipe will remove the restriction in the oil circuit due to the pump, but the bypass pipe provides another oil path or circuit for the forced oil. Thus, a certain amount of the oil from the pump bypasses the transformer. Manual valves in the bypass pipe are not practical, as the transformers are unattended, and because they change their cooling methods automatically according to load and ambient conditions. Electrically operated valves are not practical from an economic viewpoint, as their initial cost is high, and they add additional maintenance costs. Mechanical check valves are noisy, costly, and subject to mechanical failure. Thus, it would be desirable to bypass the pump, or pumps, in the oil flow path when the transformer is depending upon thermal siphon flow of the oil, and to effectively close the bypass when the oil is being forced through the transformer by pumping means, without resorting to costly valving arrangements which require periodic maintenance to insure their reliability.

### SUMMARY OF THE INVENTION

Briefly, the present invention is new and improved fluid cooled electrical inductive apparatus, such as liquid cooled power transformers, having heat exchanger means and a pump. The electrical apparatus has both forced and self-cooled ratings, with a fluid flow bypass being provided about the pump to reduce the fluid flow resistance of the pump during the rating which depends upon thermal siphon movement of the cooling fluid.

Fluid flow through the bypass is automatically blocked when the pump is operating, without resorting to mechanical or electrical valves, or any moving parts, by a constriction which is provided on the output side of the pump. The constriction reduces the pressure head at the downstream side of the constriction, to that at the pump inlet. The bypass about the pump is disposed between the pump inlet and immediately adjacent the downstream or high velocity side of the constriction. Thus, there is substantially no fluid flow through the bypass when the pump is operating, due to like pressure heads at each end of the bypass.

### BRIEF DESCRIPTION OF THE DRAWING

The invention may be more readily understood when considered in view of the following detailed description of exemplary embodiments thereof, taken with the accompanying drawings, in which:

FIG. 1 is a perspective view, partially cut away and partially in phantom, of a liquid cooled electrical piston power transformer which may be constructed according to the teachings of the invention;

FIG. 2 is an elevational view of pump bypass means constructed according to the teachings of the invention, which may be used with the transformer shown in FIG. 1;

FIG. 3 is an elevational view of pump bypass means constructed according to another embodiment of the invention, which may be used with the transformer shown in FIG. 1; and

FIG. 4 is a plan view of pump bypass means constructed according to still another embodiment, wherein the bypass means is disposed in a radiator header.

### DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1 in particular, there is shown a perspective view, partially cut away, and partially in phantom, of an electrical power transformer **10** which may be constructed according to the teachings of the invention. Transformer **10** includes a magnetic core-winding assembly **12** disposed within a tank **14**. The tank **14** is filled to a level **16** with a liquid insulating and cooling medium or dielectric, such as mineral oil or one of the synthetic liquids broadly termed askarel, with the latter usually being a chlorinated hydrocarbon. The magnetic core-winding assembly **12** is immersed in the liquid dielectric, which aids in insulating the various electrical conductors from one another, and from ground, and the liquid dielectric also serves to cool the transformer **10**.

Heat exchangers or coolers, shown generally at **18** and **20**, are connected to the tank **14** via fluid conductor means, with the liquid dielectric circulating therethrough, either by thermal siphon or by forced circulation, to remove the heat from the liquid dielectric which it has picked up from the magnetic core-winding assembly **12**.

Transformer **10**, in this example, is a three-phase transformer of the core-form type, but it is to be understood that the invention is applicable to any type of liquid cooled electrical inductive apparatus, such as transformers and reactors, and to apparatus of both the core-form and shell-form type, single or polyphase.

More specifically, transformer **10** includes a magnetic core **22** and phase winding assemblies **24**, **26** and **28** disposed about winding legs of the magnetic core **22**. Each phase winding assembly includes low- and high-voltage windings concentrically disposed about a winding leg of the magnetic core, with the high-voltage windings being connected to high-voltage bushings, of which two bushings **30** and **32** are shown in FIG. 1, with the third high-voltage bushing being mounted in opening **34**. The low-voltage windings, if connected in wye, have their neutral ends connected to neutral bushing **36**, and their other ends are connected to low-voltage bushings disposed on the portion of the tank cover cut away in FIG. 1.

Transformer **10** is cooled by circulating the liquid dielectric upwardly through the tank **14**, entering the tank below the barrier **59**, which directs the liquid dielectric upwardly through ducts in the windings in a predetermined pattern. The liquid dielectric leaves the tank through openings disposed in the upper portion of the tank, such as through opening **61**, and flows downwardly through heat exchangers **18** and **20**, where heat is removed from the liquid dielectric, and then back into the tank below the barrier layer **59**. Each of the heat exchangers, such as heat exchangers **20**, includes a plurality of hollow, flat, fin-type elements **40**, which are in fluid communication with upper and lower headers **42** and **44**, respectively. Only a sufficient number of elements **40** and headers **42** and **44** are illustrated in FIG. 1 to properly illustrate their construction, as there are usually a large plurality of rows of such elements in each cooler or heat exchanger. Further, the heat exchangers may be disposed on one or more sides of the transformer, depending upon the specific rating and cooling requirements of the apparatus.

The upper header **42** is connected directly to tank **14**, via a suitable manual valve **46**, while the lower or collecting header

44 is connected to tank 14 through fluid conductor means which includes a liquid pump 50, and a manual valve 52. Manual valves 46 and 52 are operated manually when the heat exchanger 20 is removed from the transformer, such as for shipment, to prevent the liquid dielectric disposed in the transformer tank from escaping therefrom. The pump 50 includes an inlet 54, which is connected to header 44 via suitable fluid conductor means, and an outlet 56 which is connected to tank 14 via fluid conductor means and the manual valve 52.

Transformer 10 has both forced and self-cooled ratings, with the pump 50 operating to force the liquid dielectric about the cooling loop, which includes the transformer and the heat exchangers, in the forced cooling rating, and with the pump being idle in the self-cooled rating.

In the self-cooled rating, the liquid dielectric circulates through the transformer and heat exchangers by thermal siphon. Since in this mode the pump 50 presents an impedance to the flow of the liquid dielectric in the cooling loop, the self-cooled rating, or ratings, may be upgraded by connecting bypass means 60 to shunt the pump 50, with the bypass means 60 and pump 50 both allowing flow of the liquid dielectric from header 44 to the tank 14 during the self-cooled ratings.

The bypass means 60, however, should not allow flow of the liquid dielectric during the operation of the pump 50, as it would provide a path for the liquid dielectric to shunt the transformer, thus reducing the effectiveness of the pump. In the prior art, the bypass means 60 includes a mechanically or electrically operated valve which operates automatically when the pump is energized to prevent the pump 50 from forcing the liquid dielectric from the output of the pump, through the bypass means 60, back into the header 44, thus bypassing the transformer. Electric or mechanical valves, however, add additional cost to the apparatus, and they require periodic maintenance to assure their reliability. The present invention discloses bypass means which may be easily constructed for a relatively low cost, and which requires no maintenance, as there are no moving parts. However, the bypass means effectively blocks the flow of the liquid dielectric therethrough when the pump 50 is operating.

FIG. 2 is an enlarged elevation view of the header 44, pump 50 and bypass means 60 shown in FIG. 1 with the bypass means 60 being constructed according to a first embodiment of the invention.

Pump 50 has its inlet side 54 connected to the header 44 via an adapter and a manual valve 66, and its outlet side 56 is connected to the tank 14 via fluid conductor means and the mechanical valve 52.

Bypass means 60 includes constriction means, shown generally at 70, connected in the fluid conductor means between the pump 50 and the valve 52, an adapter 72, and a manual valve 74. Constriction means 70 includes means which narrows the diameter of the liquid flow stream emanating from the pump 50, and thus increases the velocity of the flow stream on the downstream side of the constriction means. In this embodiment, the constriction means is essentially a Venturi meter, having a nozzle or entrance cone 80, and a Venturi or diffuser cone 82. The nozzle 80 is disposed on the end of a fluid conductor 84 which is attached to the outlet side 56 of the pump 50, with the diameter of the throat 86 of the nozzle 80 being substantially smaller than the inside diameter of the fluid conductor 84.

The Venturi tube 82 includes a predetermined minimum diameter near its end 88, with the tube flaring smoothly outward from this narrow point to both ends with predetermined different angles. End 88 of Venturi tube 82, and the throat 86 of nozzle 80 are spaced a predetermined dimension apart, and a fluidtight header 90 is constructed about the spaced nozzle and Venturi tube, with the header being connected to adapter 72, and thus to the collecting header 44.

When transformer 10, shown in FIG. 1, is operating in a self-ccoled rating, the liquid dielectric flows from the collecting header 44 through the idle pump, as illustrated by arrow 92, and also in a parallel or shunt path about the pump 50 through the bypass 60, as illustrated by the broken arrow 94. The parallel paths for flow of the liquid dielectric during the self-cooled ratings of the transformer effectively remove the impedance of the pump to the flow of the liquid dielectric.

When the pump 50 is energized by the electrical motor 100, in response to a temperature relay, the liquid dielectric should not be allowed to flow from the pump outlet 68 back to the pump inlet 62 via the bypass means 60. The blocking of this path, is accomplished according to the teachings of the invention without utilizing moving parts, as will be hereinafter explained.

The internal energy in a flowing fluid is due to temperature, pressure, velocity, and height of the fluid above the datum plane. As expressed by Bernoulli's equation, these energies are mutually convertible. For example, a pressure head in a fluid may be converted entirely to velocity head. Thus, by disposing the inlet and outlet of the pump 50 at substantially the same level, the same potential head is provided at both locations. By using pipe or fluid conductors having the same internal diameters at both the pump inlet and outlet. The same velocity head may be provided at both locations. In this manner, the pump 50 acts only to increase the pressure head of the liquid dielectric. Then the pressure head provided by the pump is changed almost entirely to a velocity head by the constriction or nozzle 80, thus reducing the pressure head on the downstream side of the nozzle 80, i.e., between its throat 86 and end 88 of the Venturi tube 82, to substantially the same pressure head that exists at the pump inlet.

The bypass 60, being connected between the pump inlet and the high-velocity, low-pressure portion of the nozzle-Venturi tube combination, thus will not provide a fluid flow path while the pump 50 is operating, due to substantially equal pressure heads at both ends of the bypass.

The pressure head minus losses, is recovered beyond the bypass connection by increasing the pipe diameters, with the construction shown in FIG. 2 having extremely low losses due to the Venturi tube 82. If desired, however, the Venturi tube 82 may be eliminated, connecting a straight length of pipe between the valve 52 and the header 90, but the losses would be higher.

As illustrated in FIG. 2, the bypass 60 is not connected directly to the pump inlet 62, but the pump inlet may be assumed to be the opening 102 in header 44. The bypass 60, being connected to the header 44 via opening 104, has the same elevation as opening 102, thus providing the same potential head at both openings. The bypass 60 thus effectively extends from the pump inlet to its outlet, with the outlet of the pump 50 and the bypass 60 being separated by the constriction or nozzle 80, which changes the pressure head at the throat of nozzle 86 as at opening 104.

While he embodiment of the invention shown in FIG. 2 is an elevational view, it is to be understood that the pump 50 and the bypass 60 could be "rotated" 90°and connected to outlets on the side of header 44, thus providing a horizontal flow of the liquid dielectric from the header to the pump, and a horizontal flow through the bypass means.

As hereinbefore stated, the Venturi-nozzle arrangement shown in FIG. 2 could be modified to exclude the Venturi tube. Other types of constriction means may also be used in place of the nozzle 80, with FIG. 3 illustrating bypass means 60′ which is similar to bypass means 60 shown in FIG. 2, except for the type of constriction means utilized. Like reference numerals in FIGS. 1 and 2 indicate like components, and like reference numerals except for a prime mark indicate like functions but different structures.

Specifically, FIG. 3 utilizes a sharp edged orifice 110, instead of the nozzle 80 utilized in the embodiment of FIG. 2, with the orifice 110 having a circular opening 112 disposed concentrically with the axis of the fluid conductor 84′. Fluid conductor 84′ may extend from the pump 50 to the valve 52, with a plurality of circumferentially spaced slots 114 being disposed through its wall portion immediately adjacent the downstream or high-velocity side of the orifice **110**. Header **90** is disposed about the fluid conductor **84'** to enclose the slots and connect the bypass **60'** to the high-velocity side of the constriction or orifice **110**.

Other arrangements for the bypass about the liquid pump may be used than shown in FIGS. **1**, **2** and **3**, with FIG. **4** illustrating a bypass arrangement constructed according to an embodiment of the invention in which the bypass flow is horizontal, rather than vertical, with the bypass utilizing a portion of the heat exchanger header.

More specifically, FIG. **4** is a fragmentary plan view, partially in section, of a transformer **120**, which may be similar to he transformer **10** shown in FIG. **1**, except modified to include a different header arrangement for its heat exchangers or coolers. Instead of all of the headers being disposed externally to the transformer tank, the tank wall is used to form a part of at least certain of the collecting headers. Thus, as shown in FIG. **4**, a header **122** is partially formed of vertical, structural plate or wall members **124** and **126**, with either plate member **124** or **126** being the tank wall. A pump **130** is provided having an electrical motor **132**, an inlet **134**, and an outlet **136**. The inlet **134** of pump **130** is connected to an opening **138** in the wall member **126** via coupling or adapter **140** and a manual valve **142**, and the outlet **136** is connected to an opening **144** in the wall member **126**, which has the same elevation as opening **138**, via manual valve **146**.

A fluid conductor **148** is disposed in sealed relation through wall member **124**, with one end in communication with opening **144** in wall member **126**, and its other end extending into the bottom portion **155** of the transformer tank, for circulation upwardly through the associated magnetic core-winding assembly. Constriction means **150**, illustrated in this example as being an orifice having a circular opening **152** therein, is disposed in the portion of the fluid conductor **148** which is within the heat exchanger **122**, and the wall of fluid conductor **148** is circumferentially slotted, such as with slot **154**, immediately adjacent the downstream or high-velocity side of orifice **150**.

When the pump **130** is not operating, the liquid dielectric flows from the header **122** into the portion **155** of the transformer tank through the pump **130**, as illustrated by arrow **160**, and from the header **122** to portion **155** of the transformer tank through the slot or slots **154** and fluid conductor **148**, as indicated by the broken arrow **162**. This parallel flow path provides less impedance to the flow of the liquid dielectric than either of the paths individually, enabling highly efficient thermal siphon flow of the liquid dielectric.

When the pump **130** starts to operate in response to a temperature relay, substantially all of the liquid dielectric moved by the pump **130** is directed into portion **155** of the transformer tank, with substantially no liquid dielectric entering the heat exchanger **122** via the slots **154** in the fluid conductor **148**. This is due to the fact that the elevation of the pump inlet and outlet are the same, the velocity heads of the liquid dielectric are the same at the inlet and outlet of the pump **130**, due to the use of the same diameter pipe at the inlet and outlet, and the increase in the pressure head in the liquid dielectric provided by the pump **130** is changed almost entirely to a velocity head at the downstream side of the constriction **150**, adjacent the slots **154** in the fluid conductor **148**. Thus, the pressure heads at the two ends of the bypass, i.e., in the header **122** and at the slots **154**, are the same, and there will be substantially no circulation of pumped liquid dielectric into the header **122** through the slots **154**.

In summary, there has been disclosed new and improved electrical inductive apparatus of the fluid cooled type which includes heat exchanger means and a pump, and which has both forced and self-cooled ratings. A bypass is provided around the pump during thermal siphon flow of the liquid dielectric to effectively move the resistance of the pump in the circulation path. The bypass is automatically blocked when the pump operates, without utilizing moving parts, by disposing a constriction in the output side of the pump, and disposing the bypass between the high-velocity or downstream side of the constriction and the pump inlet. The constriction changes the pressure head in the pumped liquid to velocity head, providing substantially the same pressure head at both the inlet of the pump, and thus at one end of the bypass, and at the downstream side of the constriction, and thus at the other end of the bypass. Equal pressure heads at both ends of the bypass results in little or no movement of the liquid dielectric through the bypass when the pump is operating. The bypass may be easily manufactured for a relatively low cost, and since it has no moving parts it is noiseless in operation, and requires no maintenance.

I claim as my invention:

**1**. Electrical inductive apparatus, comprising:

a tank having a fluid cooling medium disposed therein,

a magnetic core-winding assembly disposed in said tank and immersed in said cooling medium,

heat exchanger means,

pump means having an inlet and an outlet,

fluid conductor means providing first and second flow paths between said tank and said heat exchanger means, with one of the flow paths including said pump, to provide a fluid flow path from said tank, through said heat exchanger means, and back to said tank, said fluid conductor means connecting the pump inlet to said heat exchanger means, and the pump outlet to said tank,

constriction means disposed in the fluid conductor means connecting the pump outlet to said tank, said constriction means reducing the pressure head at its downstream side to substantially the pressure head at the pump inlet, when the pump is operating,

and bypass means disposed to provide a fluid flow path between the inlet of said pump means and the downstream side of said constriction means,

said cooling medium flowing through both said pump means and said bypass means when said pump means is not operating, and substantially only through said pump means when said pump means is operating, due to like pressure heads at the inlet of said pump means and the downstream side of said constriction means.

**2**. The electrical inductive apparatus of claim **1** wherein the constriction means includes an orifice.

**3**. The electrical inductive apparatus of claim **1** wherein the constriction means includes a nozzle.

**4**. The electrical inductive apparatus of claim **1** wherein the constriction means includes a nozzle and a diffuser cone.

**5**. The electrical inductive apparatus of claim **1** wherein the constriction includes a nozzle and a Venturi tube.

**6**. The electrical inductive apparatus of claim **1** wherein the heat exchanger means includes a header, with the inlet of the pump means being connected to the header, and wherein the fluid conductor means which connects the outlet of the pump means to the tank extends through said header, the constriction means is disposed in the portion of the fluid conductor means located within the header, and the bypass means includes the portion of said header between the downstream side of the constriction means and the connection of the header to the pump inlet.

**7**. The electrical inductive apparatus of claim **6** wherein the constriction means includes an orifice.