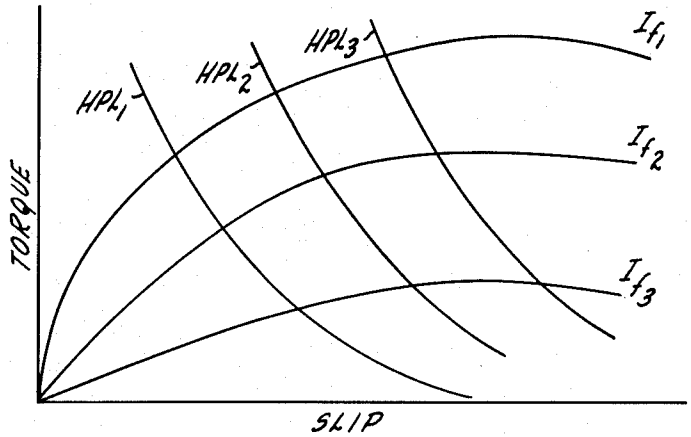
Dec. 14, 1965 C. L. MUNSON 3,223,864

MAGNETIC CLUTCH COOLANT CONTROL

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fig. 1.



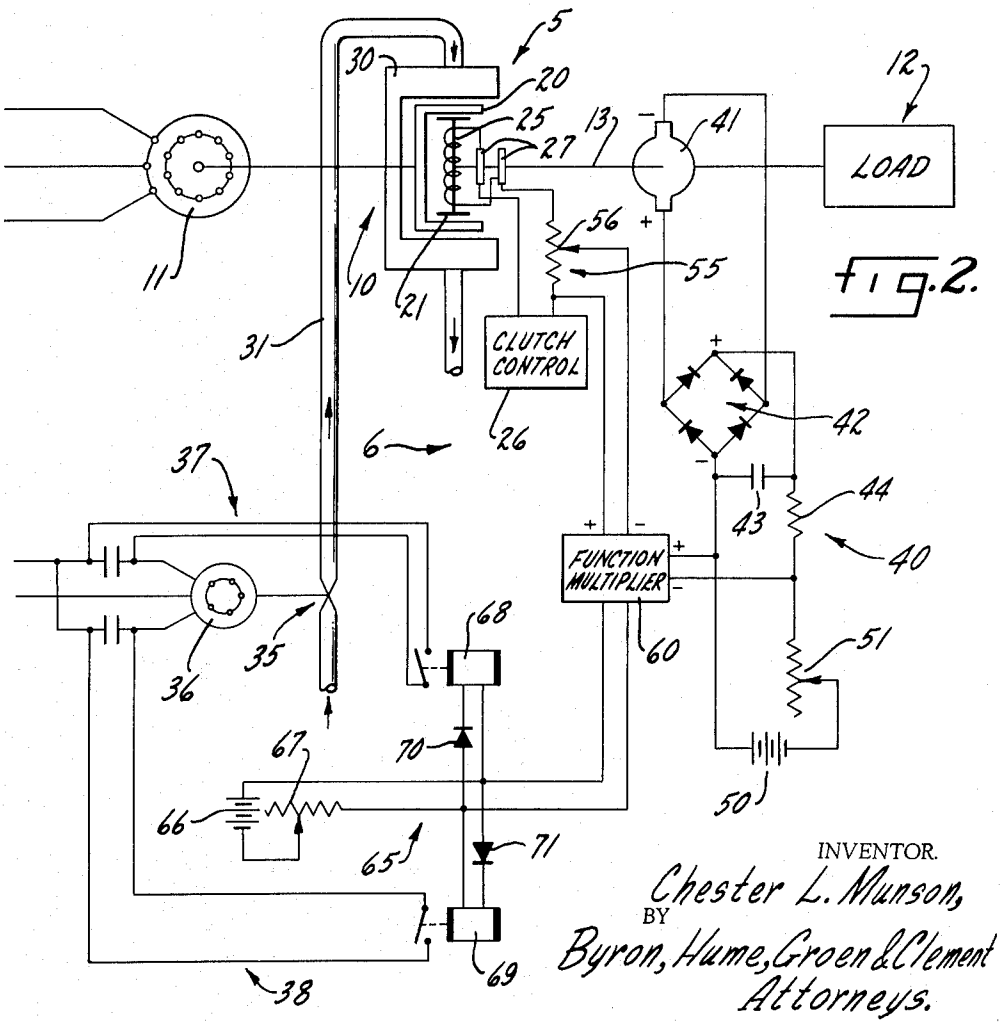


fig. 2.

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MAGNETIC CLUTCH COOLANT CONTROL

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Fig. 3.

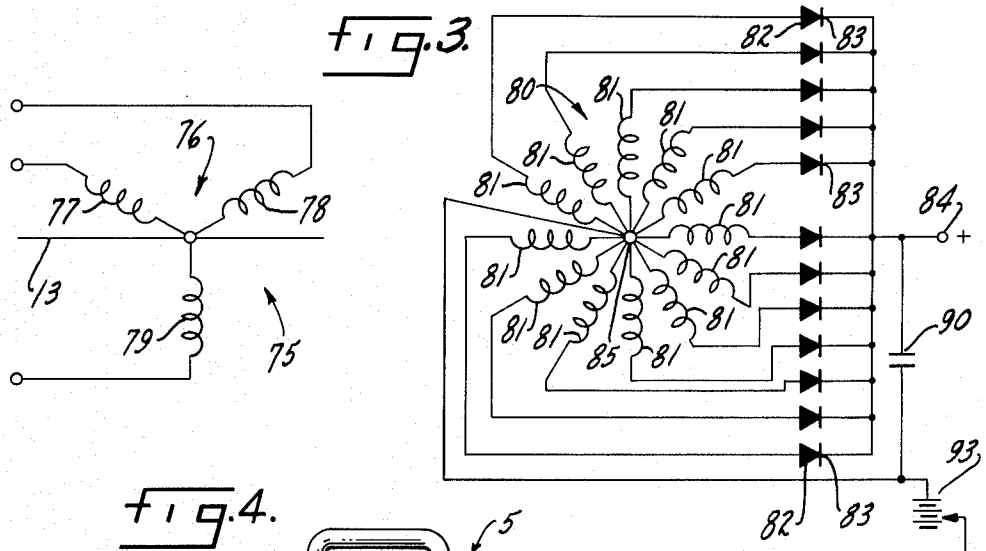
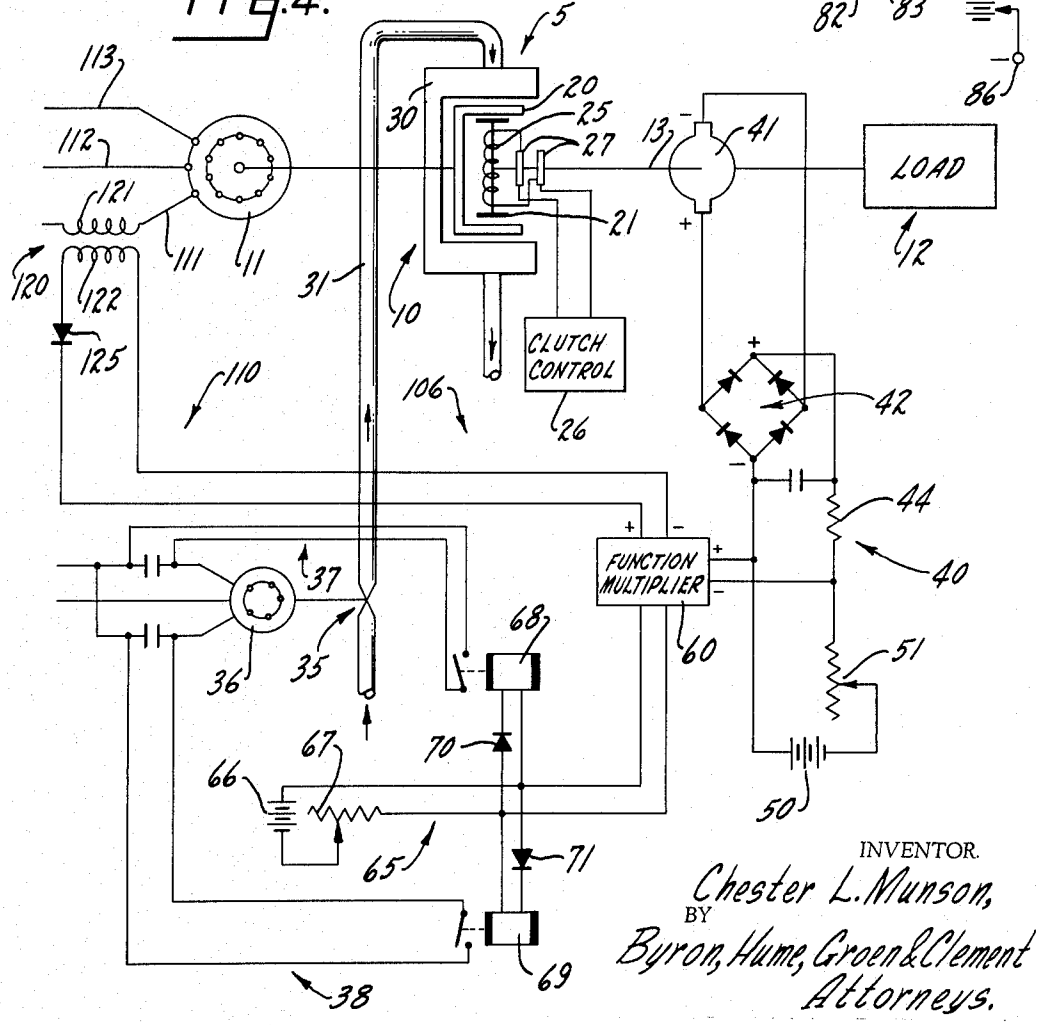


Fig. 4.



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MAGNETIC CLUTCH COOLANT CONTROL

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13 Claims. (Cl. 310—94)

This invention relates in general to a magnetic clutch arrangement and more particularly to a liquid cooled eddy current clutch. It deals specifically with a new and improved control apparatus for the liquid cooling system of an eddy current clutch.

Eddy current clutches are widely used in industry for providing a variable speed and torque output from a constant speed source, such as an alternating current induction motor, for example. In conventional form, the clutch includes an inductor drum driven at a constant speed in surrounding relationship with a rotor from which an output shaft extends. The rotor carries an annular field coil which generates a magnetic flux and creates magnetic poles in the rotor. As the drum rotates at a constant speed around the rotor, small sections of the drum pass over the magnetic poles, creating eddy currents in the drum. The magnetic field set up operates to transmit torque from the drum through the rotor to the output shaft.

At the same time, however, the eddy currents create considerable heat in and around the drum and rotor. Further heat is developed from the torque absorbed by by the clutch, and more from resistance heating of the field coil itself. This heat must, in some way, be substantially dissipated.

In clutches having a relatively low horsepower rating, below 70 H.P., for example, the total heat generated can ordinarily be satisfactorily dissipated by directing an air stream over the heat generating components of the clutch. For clutches having horsepower ratings in the higher ranges, however, it is necessary to use some other cooling medium, generally a liquid such as water, for example, or oil. In such case, the liquid coolant is conventionally piped into the clutch, splashed over the heat generating parts, and drained away.

It is a conventional practice to liquid cool an eddy current clutch with a cooling system which includes a source of coolant, such as a water main, a solenoid valve which starts the liquid flowing when the clutch is energized, a pressure switch which stops the clutch if the coolant pressure falls below a safe minimum, a proportioning valve which modulates the coolant flows as required to cool the clutch, and an over-temperature switch in the liquid drain which shuts off the unit if it exceeds a safe temperature. The proportioning valve is ordinarily controlled by a feedback heat sensing device located in the liquid drain so that an increase in the temperature of the coolant being discharged causes the valve to supply more liquid coolant to the clutch.

The use of a feedback heat sensing device in the manner hereinbefore described gives rise to several serious deficiencies in the cooling system, however, For example, there is often a considerable time lag in supplying adequate coolant when a load is suddenly applied to the clutch, since the clutch elements must first heat the coolant, the coolant must fall into the drain and heat the sensing device, and the heat sensing device must actuate the proportioning valve. The time required for all these steps to take place, however, short, frequently allows the clutch to seriously overheat before sufficient additional coolant is supplied. This is particularly true when a heavy load is suddenly placed on the clutch resulting in a rapid increase in heat generation.

Furthermore, when the clutch is initially engaged, some of the heat generated is lost in warming up the mechanical structure. Consequently, the heat generated in the clutch is actually greater than the reactor cooling influence initiated by the sensing device. As a result, the clutch might become dangerously overheated before corrective action is taken.

In either of the foregoing instances, when substantial heat is generated in the clutch, the eventual influx of coolant is often effective to cause thermal shock in the clutch members. In other words, the large quantity of cold coolant which is eventually supplied to the clutch when the proportioning valve finally does respond to the increase in heat generation is effective, upon heating the hot clutch members, to cause rapid contraction of the clutch members. A frequent consequence of such contraction is that the outer drum, which is conventionally spaced from the inner rotor by only a slight clearance, shrinks onto the inner rotor and freezes the clutch members or, in other words, creates a direct drive. This is a highly undesirable result, of course. In addition, as can well be understood, the application of cold coolant to overheated clutch members generally results in the deposition of minerals on the clutch members and erosion thereof.

Accordingly, it is an object of the present invention to provide new and improved control apparatus for the liquid cooling system of a magnetic clutch.

It is still another object to provide coolant control apparatus which assures coolant flow in direct proportion to the amount of heat being generated in the clutch.

It is another object to provide coolant control apparatus which assures adequate cooling of the clutch under all operating conditions.

It is a further object to provide coolant control apparatus which instantaneously senses an increase in the rate of heat generation in the clutch and takes corrective action top revent overheating of the clutch.

It is still a further object to provide control apparatus of the aforedescribed character which is simple and inexpensive to set up and adjust and requires little maintenance.

These and other objects are realized in accordance with the present invention by providing a new and improved liquid coolant control apparatus for an eddy current clutch or the like. Briefly, the invention contemplates controlling the flow of liquid coolant to a clutch as a function of sensed conditions which are indicative of the amount of heat being generated in the clutch. Since conditions indicative of the amount of heat being generated are directly sensed, rather than the clutch temperature itself, there is no time lag in the flow of coolant as higher temperatures, for example are generated in the clutch.

The invention, both as to its organization and method of operation, taken with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a graph of the approximate relationship between several factors which are compositely indicative of the amount of heat being generated in an eddy current clutch;

FIGURE 2 is a schematic view of an eddy current clutch and cooling system incorporating a liquid coolant control apparatus embodying features of a first form of the present invention;

FIGURE 3 is an enlarged diagrammatic view, in perspective, of electrical circuitry embodying a modification on the first form of liquid coolant control apparatus shown in FIGURE 2; and

FIGURE 4 is a schematic view, similar to FIGURE 2, illustrating a second form of liquid coolant control apparatus embodying features of the present invention.

Turning now to a brief general discussion of liquid cooling systems for eddy current clutches, it will be appreciated that the rate at which heat can be removed from any such clutch is dependent upon the clutch area exposed for cooling, the specific heat of the liquid coolant utilized, the flow volume of the liquid coolant, and the permissible temperature rise of the coolant. The first two factors, that is the area of the clutch arrangement exposed to the coolant, and the specific heat of the coolant itself, are generally fixed at the time the clutch arrangement is designed and cannot be varied to increase or decrease the rate of heat removal from the clutch. The permissible temperature rise of the coolant is dependent upon the coolant inlet temperature and the safe operating temperature of the clutch, and control of this factor is generally unsatisfactory in regulating the operating temperature of the clutch. Consequently, it is the remaining factor, that of controlling coolant flow volume, which is presently most commonly used to control the amount of heat removed from an eddy current clutch.

Considering the generation of heat in an eddy current clutch, it can be generally stated that it is proportional to the horsepower loss (HPL) across the clutch. Regarding the first form of the control apparatus embodying features of the present invention, it has been found that this horsepower loss (HPL) can be approximated by multiplying a function of the slip speed (S) of the clutch and a function of the magnetic field excitation (I_f) thereof. Referring to FIGURE 1, the relationship between clutch slip speed, horsepower loss, field excitation of the clutch, and torque output of an eddy current clutch is graphically illustrated. It will be seen in the graph that at a given field excitation (I_f), torque (T) and horsepower loss (HPL) and consequently heat generation) increase as the slip speed (S) increases. Correspondingly, for a given slip speed (S), torque (T) and horsepower loss (HPL) (and consequently heat generation) increase as the field excitation (I_f) increases. The relationship between these various factors is not precise of course, as can readily be understood, since the generalization would have to be modified to include additional torque losses due to windage and friction of the clutch members at slow slip speeds, for example, to obtain a precise answer. However, the generalization may be expressed by the relationship $\text{Heat} \approx \text{HPL} \approx I_f \cdot S$. This relationship is of a sufficiently precise nature to afford a practical measurement of the heat generation in an eddy current clutch by a control apparatus embodying features of the first form of the present invention.

With the coolant control apparatus embodying features of this first form of the present invention, the flow of liquid coolant is controlled by multiplying a signal of strength generally proportional to the amount of slip (S) in the eddy current clutch and a signal of strength generally proportional to the strength of the field excitation (I_f) thereof, balancing the product of these signals against a reference signal (R) and utilizing the error (E) signal resulting from any imbalance between the signals to drive a motor operated liquid coolant proportioning valve. This relationship may be expressed by the relationship $R-(I_f \cdot S)=\pm E$. Thus, if the rate of heat generation should rise, signalling that the temperature will subsequently rise over a preselected optimum operating temperature, as sensed by either an increase in slip speed (S) or an increase in the field excitation current (I_f), or both, a positive error signal (+E) is created and allows more coolant to flow through the clutch. Similarly, a reduction in the rate of heat generation is signalled by a reduction in field excitation, slip speed, or both, and results in a lessening in the flow of coolant. Coolant is thus supplied to the eddy current clutch in relation to the amount of heat being generated with no appreciable time lag.

In contrast, with a coolant, control apparatus embodying the second form of the present invention, a signal of strength generally proportional to the strength of the alternating current input (I_{ac}) to the clutch drive motor is utilized in lieu of a signal proportional to the strength of the field excitation (I_f) of the clutch. This is possible because the alternating current input (I_{ac}) to the clutch drive motor is approximately proportional to the horsepower input (HPI) to the clutch and it can be shown that the product of the horsepower input (HPI) and the slip speed (S) is approximately proportional to the horsepower loss (HPL) across the clutch. Since the horsepower loss (HPL) across the clutch approximates the amount of heat generated in the clutch, as has been pointed out, the coolant control apparatus embodying features of this second form of the present invention is also effective to control a motor-operated coolant proportioning valve in the manner hereinbefore described.

Referring now in detail to the first form of the present invention, wherein clutch heat generation is approximated utilizing a signal proportional to the clutch slip speed (S) and a signal proportional to the clutch field excitation current (I_f), a liquid-cooled clutch arrangement **5** incorporating a coolant control apparatus **6** embodying features of this form of the present invention is shown in FIGURE 2. The clutch arrangement **5** includes an eddy current clutch, indicated generally at **10**, driven by an alternating current induction motor **11**. The clutch **10** transmits power to a conventional rotating load, seen generally at **12**, through a shaft seen diagrammatically at **13**.

The clutch **10** comprises an inductor drum **20** which is driven at the output speed of the induction motor **11**. Inside the inductor drum **20** is a conventional rotor **21** connected to the shaft **13**. The clutch **10** provides a variable speed and torque drive between the motor **11** and the load **12**.

The output speed and torque of the clutch **10** is varied through the medium of the field coil **25** mounted on the rotor **21** and adapted to create magnetic poles in the rotor when the coil is energized. The field coil **25** is energized by a magnetic clutch control **26** of conventional construction through a pair of conventional slip rings **27**, and is adapted to provide variable, direct current excitation (I_f) to the field coil **25** to control the output speed and torque (T) of the clutch **10**.

Surrounding the rotating inductor drum **20**, the rotor **21**, and the field coil **25** of the clutch **10** is a coolant jacket **30** through which cooling liquid courses to remove the heat generated in the clutch **10**. Though a jacket-type construction is illustrated, however, it should be understood that other methods of cooling might be utilized, such as spraying coolant directly into the clutch **10**. The jacket **30** is supplied with cooling liquid through a pipe **31**. Liquid flow is regulated by a conventional restrictor valve, diagrammatically shown at **35** which is opened and closed by the action of a conventional, reversible electric motor **36** operated by a relay circuit **37** for rotation in one direction and by a relay circuit **38** for rotation in the opposite direction to open and close the valve **35**.

The coolant control apparatus **6** illustrated in FIGURE 2 includes an electro-mechanical circuit seen generally at **40**, which measures the slip speed (S) of the clutch **10**, the slip speed (S) being the output speed of the clutch **10** minus the input speed thereto. The circuit **40** includes a tachometer generator **41** which is connected to the output shaft **13** of the clutch **10** and produces a signal proportional to the output speed of the clutch. The output speed of the tachometer generator **41** is converted to a D.C. voltage signal proportional to the output speed of the clutch **10** by a rectifier bridge **42** of generally conventional construction, a filter capacitor **43** and a resistor **44**.

To produce a resultant signal proportional to slip (S) across the clutch **10**, the D.C. voltage signal proportional to the output speed of the clutch **10** (as produced in the foregoing manner) is balanced against a reference voltage proportional to the input speed of the clutch. A battery

50 in series with an adjustable resistor 51 is regulated to produce this voltage proportional to the input speed of the clutch. As a result, the differential signal between the voltage produced by the tachometer generator 41 and the voltage produced by the battery 50 is proportional to the slip (S) speed of the clutch 10.

To provide a signal proportional to the excitation current (I_f) of the clutch field coil 25, a conventional potentiometer 55 is connected in series with the clutch field coil 25. An appropriate signal proportional to field coil excitation (I_f) may thus readily be removed from the center tap 56 of the potentiometer 55 in a well known manner.

The signal proportional to the slip speed (S) of the clutch 10 and the signal proportional to the field excitation (I_f) of the clutch field coil 25 are both fed into a function multiplier 60 which generates an output signal proportional to the product of the slep speed signal (S) and the field excitation signal (I_f). The function multiplier 60 might be any one of a number of well known commercial models, such as a Hall generator, for example. The output signal represents the rate of eddy current generation in the clutch 10. For a certain rate of eddy current generation in the clutch 10, of course, heat is being generated in the clutch at a corresponding rate.

Under normal operating load conditions, heat is generated at a predetermined rate, as can be readily understood. To assure a corresponding predetermined flow of cooling liquid the function multiplier 60 is balanced against a reference circuit 65 comprised of a battery 66 and an adjustable resistor 67. The reference circuit 65 is adjusted by moving the adjustable resistor 67 to equal the signal output of the function multiplier 60 under conditions of normal clutch 10 operating load. Under these conditions, of course, the restrictor valve 35 is also adjusted to provide an adequate rate of flow of coolant for the normal load. Should the output signal ($S.I_f$) of the function multiplier rise or fall, above or below a signal corresponding to the predetermined normal operating load signal (R) produced by the reference circuit 65, an error signal (E) is produced. This error signal (E) is preferably one of positive polarity if the output signal of the function multiplier 60 is of greater strength than the reference signal (R) of the reference circuit 65, and of negative polarity if the output signal of the function multiplier 60 is of lesser strength than the reference signal (R) of reference circuit 65. The arbitrary assignation of positive polarity to an increased strength signal and negative polarity to a decreased strength signal is not significant, of course, and they might readily be reversed, being described here in the foregoing manner merely to simplify a description of the invention.

A positive signal (+E) operates through a solenoid coil to close the relay circuit 37 and direct power from a source (not shown) to turn the motor 36 in a direction which opens the valve 35 and allows more liquid coolant to flow through the pipe 31 into the coolant jacket 30 of the eddy current clutch 10, since a positive signal indicates that the rate of heat generation in the clutch is above that rate anticipated for normal operating conditions. Similarly, a negative signal (—E) is effective through a solenoid coil 69 to close the relay circuit 38 and turn direct power from the source (not shown) to the motor 36 in a direction which closes the valve 35 further and reduces the flow of liquid coolant, since the negative polarity signal indicates that the rate of heat generation in the clutch is below that anticipated for normal operating conditions. A pair of rectifiers 70 and 71 in the reference circuit 65 is provided to assure separate operation of the solenoid coils 68 and 69 according to the polarity of the combined signal.

Referring now to FIGURE 3, an alternative arrangement for generating a signal proportional to the slip speed (S) of the eddy current clutch 10 is illustrated generally at 75. The alternative arrangement 75 is a slip generator which includes a three-phase rotor 76 having three windings 77, 78, and 79, adapted for connection to a three-phase alternating current input (not shown). A twelve-stage stator 80 acts as a field for the slip generator arrangement 75 and has twelve windings 81, and twelve rectifiers 82 in series connection with corresponding windings 81. The output sides 83 of these rectifiers 82 are all connected to a positive output terminal 84 while the common connection 85 of the windings 81 is connected to a negative output terminal 86. A capacitor 90 is connected across the input and output terminals 84 and 86, respectively, for maintaining an average output signal. The slip generator arrangement 75 output signal is taken across the capacitor 90 at terminals 84 and 86.

The slip generator arrangement 75 shown in FIGURE 3 acts as a frequency converter to provide a D.C. voltage signal, at the terminals 84 and 86, which is proportional to the combined slip speed of the induction motor 11 and the eddy current clutch 10. The three-phase rotor 76 is mounted on the output shaft 13 (shown diagrammatically) of the clutch 10 and three-phase alternating current is supplied to the rotor, as it is to the drive motor 11. The rotor 76 is mounted on the shaft 13 for rotation in a direction opposite to the rotation of the alternating current field established in it by the three-phase input. Under these circumstances, when the three-phase rotor 76 is rotating at synchronous speed the rotor appears stationary to the stator field 80 so that there is no output signal produced at the terminals 84 and 86. However, when slip occurs in the induction motor 11, or in the eddy current clutch 10, the three-phase rotor 76 rotates more slowly than its rotating alternating field and consequently an alternating current voltage whose frequency is proportional to total slip is induced in the stator winding 80 of the slip generator arrangement 75. Consequently the rectifiers 82, in conjunction with the capacitor 90, produce a voltage signal at the terminals 84 and 86 which is proportional to the total slip occurring in the induction motor 11 and the eddy current clutch 10.

Since it is desirable to have a signal proportional to the slip (S) of the eddy current clutch 10 alone, a small variable voltage source 93 is inserted in the output circuitry of the stator 80 to supply a signal proportional to the slip of the induction motor 11. This signal increases the signal emitted by the slip generator arrangement 75 by an amount equal to the slip of the induction motor 11, thus making the signal equal only to the slip of the eddy current clutch 10. This signal is then multiplied with the field excitation current signal (I_f) in the function multiplier 60, and the resultant output signal controls the operation of the motor 36 and regulates the coolant flow in the manner hereinbefore described.

Turning now to FIGURE 4, the second form of the coolant control apparatus embodying features of the present invention is illustrated generally at 106. In describing and illustrating the apparatus 106, which is identical in most respects to the coolant control apparatus 6 hereinbefore discussed, like reference numerals are utilized to identify corresponding components of the two control apparatuses. In turn, reference numerals in the 100–199 series are utilized to identify components in the apparatus 106 which differ from those described in the aforementioned coolant control apparatus 6.

Briefly, the coolant control apparatus 106 differs from the coolant control apparatus 6 in that a reference signal is taken from the alternating current input signal (I_{ac}) to the induction motor 11, rather than from the field coil 25 of the eddy current clutch 10, and fed to the function multiplier 60 to be multiplied with the slip signal (S) hereinbefore referred to. The alternating current input signal (I_{ac}) is approximately proportional to the horsepower input supplied to the eddy current clutch 10 by the induction motor 11. Since it can readily be shown that the horsepower loss (HPL) across the clutch 10 equals the slip (S) in the clutch 10, over the input speed to the

clutch **10** (which is constant), times the horsepower input, it follows that the horsepower loss (HPL) can also be equated in terms of the slip (S), times the input current (I_{ac}) to the indction motor times a constant (K) or $HPL=KS\cdot I_{ac}$.

It has already been pointed out, of course, that the horsepower loss across the clutch **10** is substantially proportional to the heat generated in the clutch. Consequently, utilizing the function multiplier **60** to multiply a signal generally proportional to the input current to the induction motor **11**, times a signal generally proportional to the slip of the eddy current clutch **10**, provides results substantially identical to those described in relation to the coolant control apparatus **6** embodying the first form of the present invention, as hereinbefore discussed.

Referring especifically to FIGURE 4, the coolant control apparatus **106** includes a pick up circuit **110** which is adapted to pick up a signal proportional to the A.C. input current in one phase input **111** of the three-phase inputs **111**, **112**, and **113** to the induction motor **11**. The circuit **110** accomplishes this end through the medium of a transformer **120** having one winding **121** in the motor phase input **111** and one winding **122** in the circuit **110**. The transformer **120** develops an alternating current signal in the circuit **110** which is proportional to the input signal in the phase input **111**. A conventional rectifier **125** in the pick up circuit **110** converts the alternating current signal to a proportional direct current signal and the direct current signal is fed to the function multiplier **60** where it is combined with the slip signal picked up by the electro-mechanical circuit **40** and fed to the function multiplier **60** also. The output signal which emanates from the function multiplier **60** is then balanced against a reference circuit **45**, as has previously been pointed out, and any error signal (E) developed is effective to actuate a corresponding relay circuit **37** or **38** and operate the motor driven restrictor valve to vary the flow of liquid coolant to the coolant jacket **30** of the eddy current clutch **10**.

It will be understood, of course, that control apparatus for the liquid cooling system of a magnetic clutch have been illustrated which assure optimum clutch cooling under all operating conditions. Coolant is provided the eddy current clutch in relationship to the amount of heat being generated in the clutch. Furthermore, coolant flow is instantaneous upon the sensing of an increase in the rate heat generation in the clutch above a normal rate.

In addition to being highly effective in controlling liquid coolant flow to an eddy current clutch and forestalling thermal shock, for example, to the clutch members, as well as obviating deposition of mineral and corrosion of the various clutch members, the coolant control apparatus embodying features of the present invention are also simple and inexpensive in construction. Furthermore, their various adjustments can readily be made by unskelled personnel since the apparatuses are initially made operational by merely balancing electrical signals.

It should be noted also that under circumstances in which the rate of heat generation may be expected to vary widely, it is desirable to provide a reference circuit wherein adjustable resistor **67** is operated by motor **36**, to provide a balance signal which is proportional to the position of valve **35** and, hence, the instantaneous rate of flow of coolant therethrough. By use of a balance signal proportional to the instantaneous rate of coolant flow, rather than a predetermined standard rate of coolant flow, faster response over the wider range may be obtained.

While several embodiments described herein are at present considered to be preferred, it is understood that various modifications and improvements may be made therein, and it is intended to cover in the appended claims all such modifications and improvements as fall within the true spirit and scope of the invention.

What is desired to be claimed and secured by Letters Patent of the United States is:

1. A system for controlling the temperature of magnetic clutch means by controlling the flow of a cooling fluid from a source thereof to a cooling unit operatively associated with the clutch means wherein the clutch means includes a driving member rotatably driven from a power source and a driven member rotatated by the driving member through the medium of a variable strength electromagnetic field set up in the members, said system compraising; means for generating a signal generally proportional to the rate of heat generation in the clutch means, means for generating a balance signal generally proportional to the rate of flow of the cooling fluid, and means responsive to the relationship between said signals to vary the rate of flow of cooling fluid as the rate of heat generation in the clutch means varies.

2. The system of claim **1** further characterized in that said means for generating a product signal of a strength generally proportional to the rate of heat generation in the clutch means includes means for generating an electrial slip signal of a strength generally proportional to the amount of slip between the driving and driven members.

3. A system for controlling the temperature of magnetic clutch means for controlling the flow of a cooling fluid from a source thereof to a cooling unit operatively associated with the clutch means wherein the clutch means includes a driving member rotatably driven from a power source and a driven member rotated by the driving member through the medium of a variable strength electo-magnetic field set up in the members, said system comprising; means for generating an electrical slip signal of a strength generally proportional to the amount of slip between the driving and driven member, means for generating an electrical input signal of a strength generally proportional to the strength of current supplied to the clutch means, means responsive to said slip and input signals to produce a product signal of a strength generally proportional to the rate of heat generation in the clutch means, means for generating a balance signal of a strength generally proportional to the rate of flow of cooling fluid, an actuator means responsive to the relationship between the said product signal and said balance signal to vary the rate of flow of cooling fluid as a function of variation in the rate of heat generation in the clutch means.

4. The system of claim **3** further characterized in that said actuator means is responsive to said relationship to produce an error signal of a predetermined polarity when the strength of said product signal is greater than the strength of said balance signal, and an error signal of opposite polarity when the strength of said product signal is less than the strength of said balance signal, said actuator means including control means responsive to both polarities of the resulting error signal to vary said flow of cooling fluid.

5. The system of claim **4** further characterized in that its control means includes valve means for varying the flow of cooling fluid from the source to the cooling unit, and motive means for controlling said valve means responsive to the polarity of said resulting error signal to alternatively increase and decrease the rate of flow of the cooling fluid as a function of the variation in the rate of heat generation.

6. A system for controlling the temperature of magnetic clutch means by controlling the flow of a cooling fluid from a source thereof to a cooling unit operatively associated with the clutch means wherein the clutch means includes a driving member rotatably driven from a power source, and a driven member rotated by the driving member through the medium of a variable strength electromagnetic field set up in the members, said system comprising; first means for producing an electrical signal of a strength generally proportional to the amount of slip between the driving and driven members, said first means including a generator arrangement responsive to the speed

of the driven member to generate a first speed signal of a strength generally proportional to driven member speed, control circuit means for producing a second speed signal of a strength generally proportional to the speed of the driving member, said control circuit means balancing said first and said second speed signal to produce said electrical slip speed signal, means for generating an electrical input signal of a strength generally proportional to the strength of current supplied to the clutch means, means responsive to said slip and input signals to produce a product signal of a strength generally proportional to the rate of heat generation in the clutch means, means for generating a balance signal of a strength generally proportion to the rate of flow of the cooling fluid, and actuation means responsive to the relationship between said product signal and said balance signal to vary the rate of flow of cooling fluid as the rate of heat generation in the clutch means varies.

7. The system of claim **6** further characterized in that said electrical input signal is of a strength generally proportional to the strength of the input current supplied to the power source which rotates the driving member.

8. The system of claim **6** further characterized in that said electrical input signal is of a strength generally proportional to the strength of the current establishing the electro-magnetic field.

9. A system for controlling the temperature of magnetic clutch means by controlling the flow of a cooling fluid from a source thereof to a cooling unit operatively associated with the clutch means wherein the clutch means includes a driving member rotated at susbtantially constant speed by a power source and a driven member rotated by the driving member through the medium of a variable strength electro-magnetic field set up in the members, said system comprising; slip generator means for producing an electrical slip signal of a strength generally proportional to the amount of slip between the driving and the driven members, means for generating an electrical input signal of a strength generally proportional to the strength of current supplied to the clutch means, means responsive to said slip and input signals to produce a product signal of a strength generally proportional to the rate of heat generation in the clutch means, means for generating a balance signal of a strength generally proportional to the rate of flow of the cooling fluid, and actuator means responsive to the relationship between said product signal and balance signal to vary the rate of flow of cooling fluid as the clutch means operating temperature tends to vary with variations in the rate of heat generation.

10. The system of claim **9** further characterized in that said electrical input signal is of a strength generally proportional to the strength of the current supplied to the power source.

11. The system of claim **9** further characterized in that said electrical input signal is of a strength generally proportional to the strength of the current supplied to the electro-magnetic field.

12. A system for controlling the temperature of magnetic clutch means by controlling the flow of a cooling fluid from a source thereof to a cooling unit, operatively associated with the clutch means wherein the clutch means includes a driving member rotated at substantially constant speed by a power source and a driven member rotated by the driving member through the medium of a variable strength electro-magnetic field set up in the members, said system comprising; slip generator means for producing an electrical slip signal of a strength generally proportional to the amount of slip between the driving and driven members, said slip generator means including rotary means carrying a three-phase rotor circuit driven rotatably with the driven member, three-phase current supplied to said three-phase circuit and to the power source, a twelve-phase stator circuit fixed relative to said three-phase rotor circuit and acting as a field therefor, rotation of the driven member at a speed less than the speed of the drive member inducing an electrical slip signal in said stator circuit which is generally proportional in strength to the amount of slip between the driving and the driven members, means for generating an electrical input signal of a strength generally proportional to the strength of the current supplied to the electro-magnetic field, means responsive to said slip and input signals to produce a product signal of a strength generally proportional to the rate of heat generation in the clutch means, means for generating a balance signal of a strength generally proportional to rate of flow of the cooling fluid, and actuator means responsive to the relationship between said product signal and said balance signal to vary the rate of flow of cooling fluid as the rate of heat generation in the clutch means varies.

13. A system for controlling the temperature of magnetic clutch means by controlling the flow of a cooling fluid from a source thereof to a cooling unit operatively associated with the clutch means wherein the clutch means includes a driving member rotated at substantially constant speed by a power source and a driven member rotated by the driving member through the medium of a variable strength electro-magnetic field set up in the member, said system comprising; slip generator means for producing an electrical slip signal of a strength generally proportional to the amount of slip between the driving and driven member, said slip generator means including rotor means carrying a three-phase rotor circuit driven rotatably with the driven member, three-phase current supplied to said three-phase circuit and to the power source, a twelve-phase stator circuit fixed relative to said three-phase rotor circuit and acting as a field therefor, rotation of a driven member at a speed less than the driving member inducing an electrical slip signal in said stator circuit which is generally proportional in strength to the amount of slip between the driving and the driven members, means for generating an electrical input signal of a strength generally proportional to the strength supplied to the power source, means responsive to said slip and input signals to produce a product signal of a strength generally proportional to the rate of heat generation in the clutch means, means for generating a balance signal of a strength generally proportional to the rate of flow of the cooling fluid, and actuator means responsive to the relationship between said product signal and said balance signal to vary the rate of flow of cooling fluid as the rate of heat generation in the clutch means varies.

No references cited.

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