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(54) Hydraulically operated machine

(57) A hydraulically operated machine (100), typically a plastic injection moulding machine has a motor (M) drivably connected to a hydraulic pump (P) to provide pressurized hydraulic fluid flow, a hydraulic circuit (H) through which the total flow from the pump (P) is distributed to the various machine elements in accordance with the demanded flow for each element, and at least one bypass outlet (BF) through which excess fluid flow is bypassed. The motor (M) received its supply via a variable speed controller (SC) which itself is controlled by a dynamic signal (I) derived from the hydraulic circuit (H). The dynamic signal (I) is proportional to the demanded flow (TF) at any given instant in the machine so as to continuously vary the total flow to the hydraulic circuit and maintain the bypassed flow at or near a predetermined flow rate.

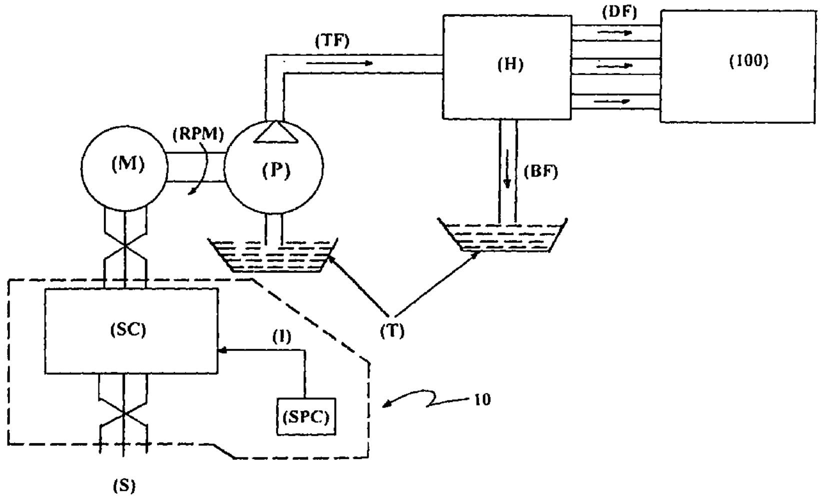

FIGURE - 2

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Description

1.BACKGROUND OF THE INVENTION

1.1 FIELD OF THE INVENTION:

[0001] The present invention relates to hydraulic operated machines, particularly plastic injection moulding machines using hydraulic systems for its movements such as clamping and injection. This invention still particularly , relates to a method for attenuating the energy required, in motor driven hydraulically operated machines, typically injection moulding machines.

1.2 DESCRIPTION OF THE PRIOR ART :

[0002] Most Plastic Injection Molding Machines use alternating current powered electric motors, typically constant speed induction motors drivably coupled to hydraulic pumps which in turn generate hydraulic fluid under pressure to perform the various movements of the machines particularly clamping and Injection .
Due to the fact that there is a typical Injection cycle, there is a variable demand on the Hydraulic power supplied to the Machine. Thus the load on the motor, to develop the required Hydraulic power is variable. However in such Standard Hydraulic Machines no provision is made to respond to the variable power demand. a constant speed motor drives a fixed displacement pump to continuously deliver flow of maximum pressurized hydraulic fluid . Even if the rower demand is low, the motor is still made to rotate at full speed providing maximum capacity flow of hydraulic fluid under pressure. The fluid in excess of the demand is returned via relief valves to the hydraulic pump reservoir. This situation occurs a number of times in a typical Injection Moulding Cycle. As the motor rotates at full speed throughout the cycle irrespective of power demand there is a substantial amount of energy wastage.

[0003] In the typical Hydraulic Injection Moulding Machine of the prior art there is no correlation between required Flow and RPM (Speed) of the Motor. A scheme of a typical hydraulically operated injection moulding machine is illustrated in Figure 1 of the accompanying drawings. For the machine 100 there is a hydraulic tank T which contains hydraulic fluid. A pump P driven by motor M is connected to the tank T and the outlet of the pump P is connected through differential distributor blocks to various hydraulic valves and elements defined in the hydraulic circuit block H of the machine 100. Only for ease of representation the hydraulic element is shown separate from the machine 100 . The total flow TF of pressurized hydraulic fluid is supplied by the pump P to the hydraulic elements H and only the demanded flow DF is supplied to the machine 100 and the excess flow BF is bypassed to the hydraulic tank T via relief valves. Since the electric supply to the machine is continuous, the motor runs at full rpm and generates pressurized hydraulic fluid flow. In the injection moulding cycle of the operating of the machine, the various hydraulic elements in the block H require a predetermined flow of pressurized fluid through them any flow in excess of the demand for the various elements generated by the pump P and flowing through the block H is by-passed via the bypass flow BF and collected and returned to the tank T. This bypassed fluid varies upon the operation taking place in the machine 100. Thus different quantities of hydraulic fluid are bypassed during the clamping, injection or cooling operations.

[0004] Disadvantages and limitations of these prior art machines can be enumerated as follows:

(1) The energy consumption is inordinately large;
(2) The hydraulic fluid used in the hydraulic system rises to an inconveniently high temperature;
(3) There is an accelerated degradation of the hydraulic fluid;
(4) Noise levels of the machine are uncomfortably high throughout the injection moulding cycle; and
(5) There is a high degree of inconsistency in the moulded parts.

[0005] Some attempts have been made in the prior art to deal with this problem:

[0006] Attention has been directed to controlling the speed of the motor to approximate it to the required hydraulic flow for a typical machine.

[0007] Thus Jones(U.S. Patent No.4,904,913) disclosed a motor control system for a plastic forming machine which includes an interface circuit and a phase inverter for sensing the individual operations steps of the machine, thereby producing a time stream of voltage levels each of which are representative of machine functions during such operation steps and thereby varying the speed of the motor through a manually set potentiometer.

[0008] A major disadvantage of this arrangement is that the output driving signals to adjust the speed of the motor are taken from the machine controller making such an arrangement highly inflexible and impractical for machines of different makes. The scheme envisaged is extremely cumbersome as a large number of signals need to be derived from the control panel and the motor speeds have to be adjusted manually making the whole system cumbersome and inaccurate.

[0009] Again Hertzer(US Patent No: 5,052,909) discloses a machine incorporating a variable speed motor, preferably a DC brushless motor. The machine controller outputs driving signals to adjust the speed of the motor so that the flow delivered by the pump substantially matches the hydraulic demand imposed during each phase of the machine operation cycle. The values of the motor driving signals are are calculated so that the motor/pump combination is operated at or near the maximum efficiency except when the pump control varies the displacement of the pump to effect pressure or flow compensation. In order to improve hydraulic transient response it is further disclosed that the output of the pump can be connected to an accumulator by way of a check valve. Thus in this arrangement the motor control signals which eventually control the flow of the pressurized hydraulic fluid to the machine is in accordance with the pressure signal from the said controller. This scheme has a fundamental limitation because the signals do not truly represent the flow required by the machine as they are based on pressure signals from the controller and are not signals based on the actual flow of the hydraulic fluid. The requirement of the accumulator and check valve makes the whole system costly, bulky and inconvenient.

2 SUMMARY OF THE INVENTION

[0010] In view of the aforesaid limitations in the prior art, it is an object of the present invention to provide a hydraulically operated machine in which the energy consumed is conserved and optimized and at the same time the efficient working of the machine is maintained.

[0011] In accordance with this invention the motor speed is controlled electronically the aim being to minimise the hydraulic fluid collected in the bypass flow in the system and regulate the flow of bypassed fluid around a preset flow rate to give maximum energy saving without significantly affecting the performance of the machine.

[0012] According to this invention there is provided a hydraulically operated machine, typically a plastic injection moulding machine having

(i) a motor drivably connected to a hydraulic pump to provide pressurized hydraulic fluid flow;
(ii) a hydraulic circuit through which the total flow from the pump is distributed to the various machine elements in accordance with the demanded flow for each element; and
(iii) at least one bypass outlet through which excess fluid flow is bypassed;
characterised in that the motor receives its power supply via a variable speed controller which itself is controlled by a dynamic signal derived from the said hydraulic circuit, said dynamic signal being proportional to the demanded flow at any given instant in the machine so as to continuously vary the total flow to the hydraulic circuit and maintain the bypassed flow at or near a predetermined flow rate.

[0013] A characteristic feature of this machine is that the motor speed control signal is proportional to the flow rate and not to the pressure of the hydraulic fluid and is continuously variable in response to hydraulic fluid needs of the various elements of the machine and is not in the form of a train of pulses. The speed control system for the motor is such that a preset minimum flow is always maintained to meet transient flow demand.

[0014] Typically, in the hydraulically operated machine the motor is an A.C. induction motor or a D.C. brushless motor.

[0015] In accordance with one embodiment of the invention an electrically operated proportional flow control valve is mounted between the pump supplying hydraulic fluid to the hydraulic circuit of the machine and the dynamic signal is derived from the signals given to the valve.

[0016] The control of the motor speed is achieved in a manner that the electrical signal given to the Flow Proportional Valve is monitored, this signal being in proportion to the flow required (which in turn gives the desired speed of the hydraulic elements like Hydraulic Piston at that moment).

[0017] As the hydraulic fluid flow through the system is proportional to motor RPM (Motor connected to hydraulic pump), monitoring the Flow Proportional Valve signal and controlling the motor RPM accordingly will give the required flow, while the motor will run only at the required RPM to generate that flow, and will not be running at full speed, as is the case with typical Machines.

[0018] Flow Proportional Valve signal can be measured by introducing a small resistance in series and tapping the voltage across it. To control the motor speed any of known technique may be used such as for example Vector Control (Close loop or Open loop), Variable Frequency Drives.

[0019] In accordance with another embodiment of the invention a flowmeter is connected in line with the bypassed flow from the hydraulic circuit and the dynamic signal is derived from signals obtained from the flowmeter.

[0020] Typically the variable speed controller is a voltage to frequency ratio controller or a vector flux controller.

[0021] In accordance with one aspect of the invention the variable speed controller and the circuitry for generating and supplying the dynamic signal is retrofitted to a conventional machine to evolve the machine in accordance with this invention. 3. BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The invention will now be described with reference to accompanying drawings in which

Figure 1 is a hydraulic controlled machine in accordance with the prior art;
Figure 2 is the explanation of a typical hydraulically controlled system for a machine in accordance with this invention;
Figure 3 illustrates one energy saving circuit in accordance with this invention ;and
Figure 4 illustrates a first circuit alternative to the circuit of Figure 3.

4. DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0023] The hydraulic circuit of the prior art is illustrated in Figure 1 of the drawings and it has been generally described hereinabove.

[0024] Referring to the Figures 2 to 4 of the drawings an energy saving device in accordance with this invention is indicated generally by the reference numeral 10.

[0025] In Figure 2, the motor driving the system is indicated by the reference numeral M. The motor drives a pump P which inturn controls hydraulic elements H of the system connected to the output of the pump P . The motor M is supplied current through a suitable electronic motor speed controller SC which receives an electrical signal I which varies depending upon the bypassed/ demanded flow (BF/DF) of the system derived through the signal processing circuit SPC. Thus the motor rpm varies in proportion to the control signal I and consequently the flow of hydraulic fluid from the pump to the hydraulic block H will vary. The idea is to arrive at an optimum signal I for which the bypassed flow BF is minimum for a given state of the machine 100. The flow to the hydraulic block H can be continuously regulated by regulating the signal I . The variance in the signal I can be achieved by various techniques and various schemes for this purpose are shown in Figures 3 and 4.

[0026] In Figure 3 , Between the Pump P and the hydraulic elements H is connected an electrically controlled flow proportional valve V. In accordance with this invention the motor M is fitted with a speed controller SC which is typically an electronic motor speed controller. The speed controller SC is fitted between the motor M and the three phase input source S.

[0027] The signal I2 given to the said valve V is sensed and an electric control signal is derived which is in turn fed to the electronic motor speed controller SC as I which drives the motor connected to the hydraulic pump P, thus reducing the flow of bypassed fluid BF around a predetermined preset rate. In Figure 3 a typical technique of deriving a signal is shown, whereby a current sensor CS in series with the valve coil CO is introduced. The voltage developed across the current sensor is further processed by a signal processing circuit SPC to derive the requisite control signal I for the speed controller SC. Alternatively other techniques to sense the voltage across the coil of the valve V or to measure the net movement of the controlling elements (spool) (not shown) of the valve V can also be used to derive the required control signal.

[0028] Another scheme is shown in Figure 4 in which the total bypassed flow BF generated by the hydraulic circuit H is made to pass through a flowmeter FM which generates an electrical signal I3 proportional to the flow of the bypassed flow BF. Since the electrical signal is proportional to the quantity of fluid bypassed by the hydraulic circuit H, it is further processed by the signal processing circuit SPC and a control signal I is again derived which is fed to the motor speed controller SC which in turn controls the rpm of the motor M and therefore the total flow TF from the pump P, again reducing the bypassed flow BF to at or near the predetermined rate.

[0029] Various other alternatives can be envisaged without departing from the nature and the scope of the invention. For instance as a third alternative any two of the above two schemes can be used in tandem. More schemes can be evolved depending upon the electronic and hydraulic circuits used in the machine.

[0030] Apart from energy saving, further benefits like low temperature rise of hydraulic fluid because of less energy released in the system, consistency and dimensional control in the moulded article also accrue. Also there is less degradation of hydraulic fluid and reduced audible noise level of the machine. As a result of lowering of the fluid temperature the heat load on the cooling circuits are also less and consequently longer life of rubber elements. There is also an improvement in the power factor of the connected loads.

[0031] The above schemes alone or in tandem can also be used for any hydraulic equipment where the load demand is fluctuating during its operating cycle, such as Hydraulic Power Presses, Hydraulic Shears, Hydraulic Bending Machines driven by a motor capable of speed control where the load demand varies during the cycle of operations.

[0032] Because the arrangement in accordance with this invention , does not require prior knowledge of the motor controller and the signal values at various points of the machine the arrangement can be built universally into any hydraulically operated machine or can be used as a retrofit to an existing machine.

[0033] The electronic motor speed controller SC must be such that the transient response of the controller SC matches the demand of the hydraulic circuit H of the machine 100. Such speed controller include a voltage to frequency ratio control V\F controller a vector flux controller or a built in device in the motor itself to make it a multispeed motor.

[0034] A typical injection moulding machine for moulding polypropylene articles was tested with the arrangement in accordance with this invention: The cycle time for forming an article with clamping force of 140 tonnes was 27.5 seconds in the machine without the arrangement of this invention with the arrangement retrofitted onto it the cycle time was 27.4 seconds. However the power consumed per hour was 10 KWHr in the standard machine and 4.8 KWHr in the machine in accordance with this invention. Thus the power saving was in the region of 52%. The maximum excess flow of hydraulic fluid during idle time was 25 GPM which was only 5 GPM in the machine in accordance with this invention.

[0035] Various modifications and workshop alterations will be apparent to those skilled in the art from the aforesaid description, without departing from the nature and the scope of the invention. while the invention has been described and illustrated with respect to a hydraulic molding machine, it will easily be apparent that the art disclosed herein is applicable to other hydraulically powered processing machines.

[0036] The claims appended hereto recite the limitations of this invention and the detailed description of the embodiment is to be treated as being illustrative and not limiting in any way.

Claims

1. A hydraulically operated machine, typically a plastic injection moulding machine having

   (i) a motor drivably connected to a hydraulic pump to provide pressurized hydraulic fluid flow;
   (ii) a hydraulic circuit through which the total flow from the pump is distributed to the various machine elements in accordance with the demanded flow for each element; and
   (iii) at least one bypass outlet through which excess fluid flow is bypassed;
   characterised in that the motor receives its supply via a variable speed controller which itself is controlled by a dynamic signal derived from the said hydraulic circuit, said dynamic signal being proportional to the demanded flow at any given instant in the machine so as to continuously vary the total flow to the hydraulic circuit and maintain the bypassed flow at or near a predetermined flow rate.

2. A hydraulically operated machine, as claimed in claim 1, in which the motor is an A.C. induction motor.

3. A hydraulically operated machine, as claimed in claim 1, in which the motor is a D.C. brushless motor.

4. A hydraulically operated machine, as claimed in claim 1 in which an electrically operated proportional flow control valve is mounted between the pump supplying hydraulic fluid and the hydraulic circuit of the machine and the dynamic signal is derived from the signals given to the valve.

5. A hydraulically operated machine, as claimed in claim 1, in which a flowmeter is connected in line with the bypassed flow from the hydraulic circuit and the dynamic signal is derived from signals obtained from the flowmeter.

6. A hydraulically operated machine, as claimed in claim 1 to claim 5, in which the variable speed controller is a vector flux controller.

7. A hydraulically operated machine, as claimed in claim 1, in which the variable speed controller and the circuitry for generating and supplying the dynamic signal is retrofitted to a conventional machine to evolve the machine in accordance with this invention.

8. A hydraulically operated machine, as described herein with reference to Figures 2 to 4 of the accompanying drawings.

9. A hydraulically operated machine, typically a plastic injection moulding machine having

   (i) a motor drivably connected to a hydraulic pump to provide pressurized hydraulic fluid flow;
   (ii) a hydraulic circuit through which the total flow from the pump is distributed to the various machine elements in accordance with the demanded flow for each element; and
   (iii) at least one bypass outlet through which excess fluid flow is bypassed;
   characterised in that the motor receives its supply via a variable speed controller which itself is controlled by a dynamic signal derived from the said hydraulic circuit, said dynamic signal being proportional to the demanded flow at any given instant in the machine.

10. A hydraulically operated machine, typically a plastic injection moulding machine having

    (i) a motor drivably connected to a hydraulic pump to provide pressurized hydraulic fluid flow;
    (ii) a hydraulic circuit through which the total flow from the pump is distributed to the various machine elements in accordance with the demanded flow for each element; and
    (iii) at least one bypass outlet through which excess fluid flow is bypassed;
    characterised in that the motor receives its supply via a variable speed controller which itself is controlled by a dynamic signal so derived from operation of the said hydraulic circuit as to maintain the bypassed flow at or near a predetermined flow rate.

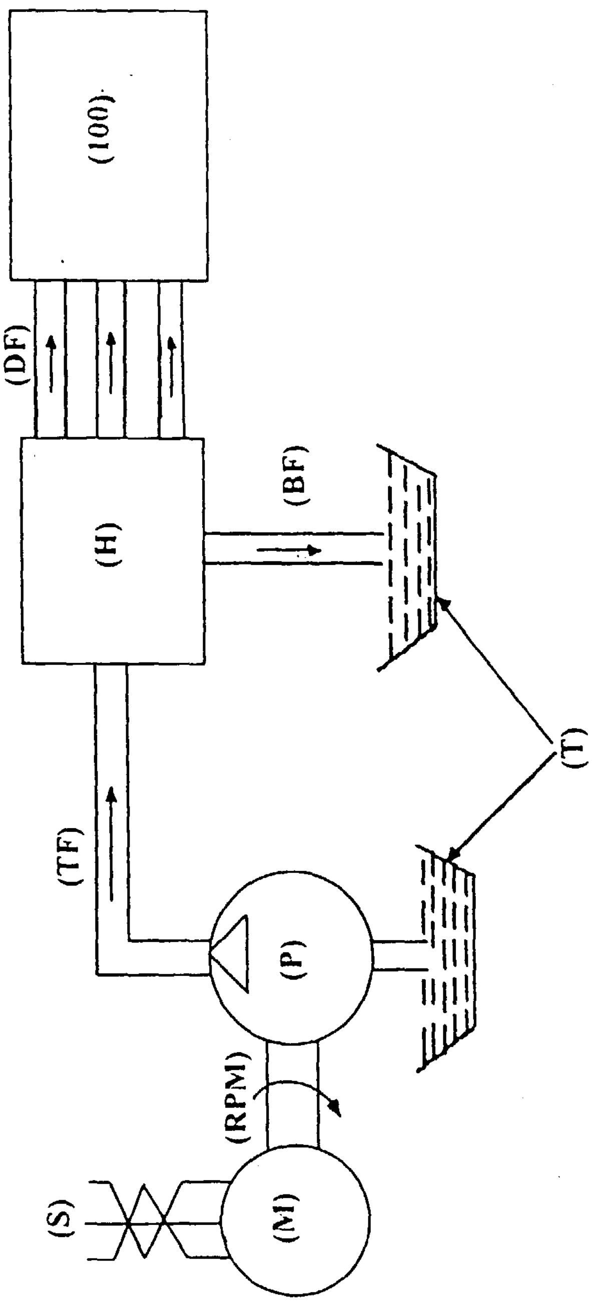

FIGURE - 1

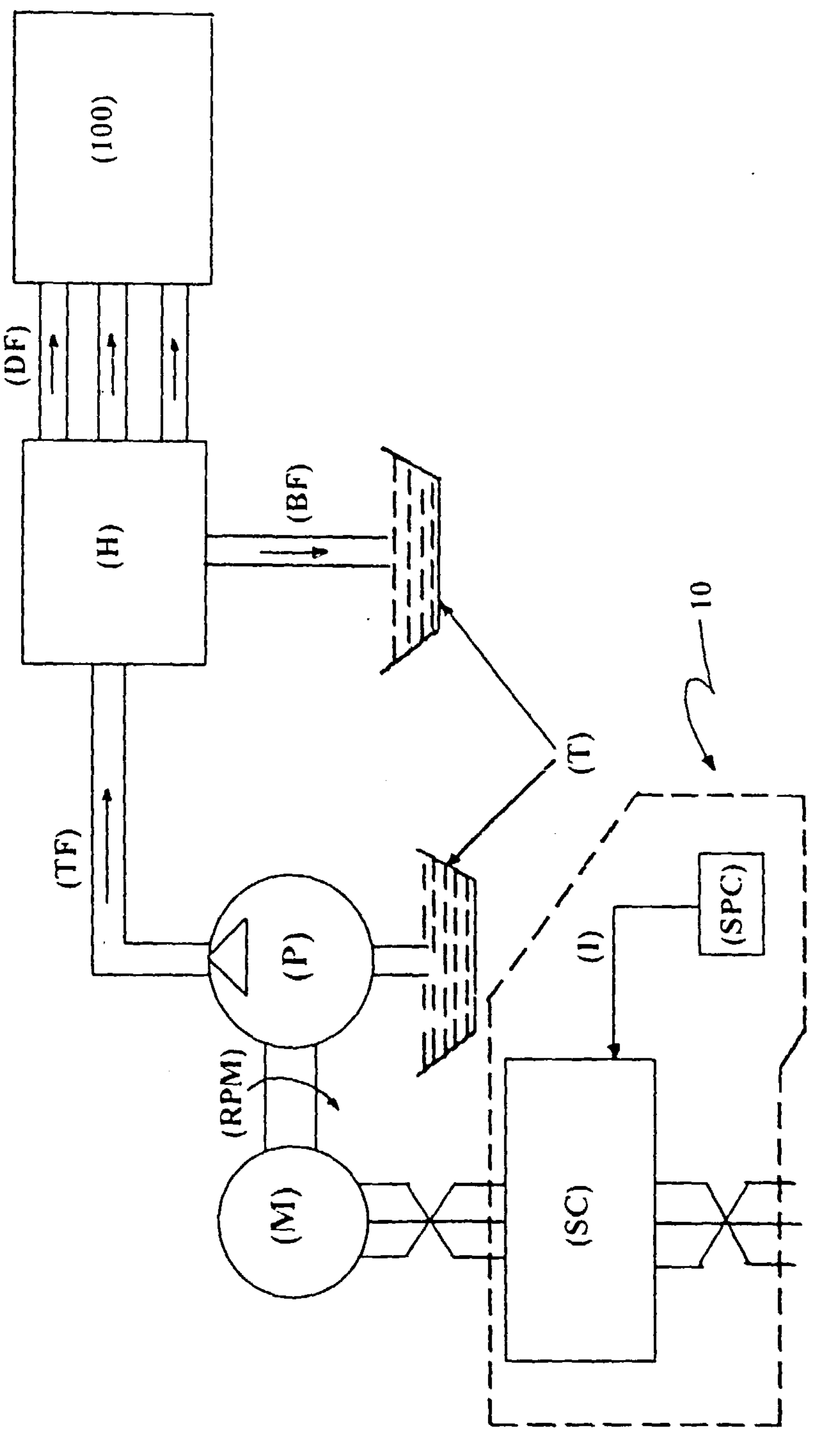

FIGURE - 2

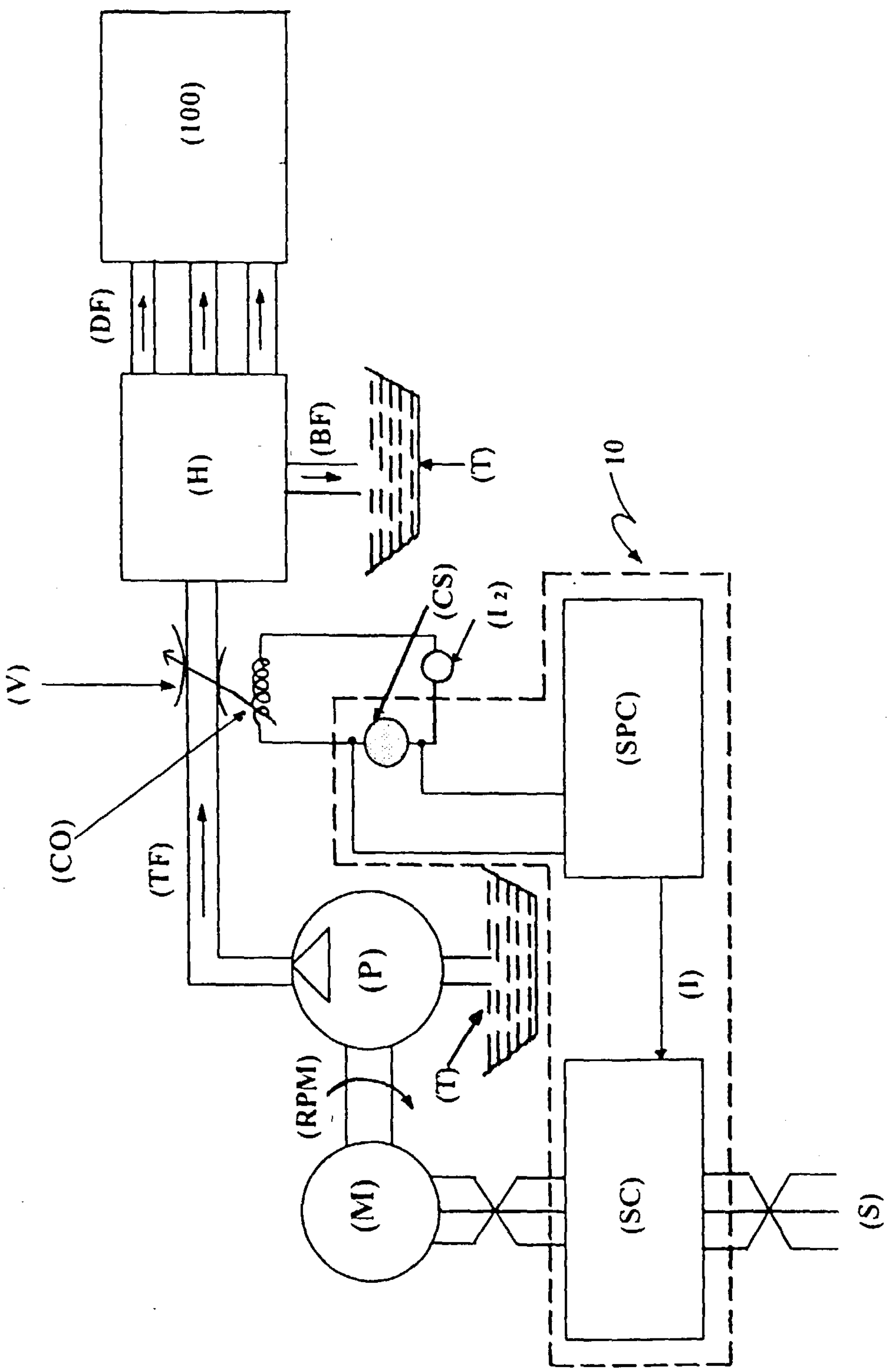

FIGURE - 3

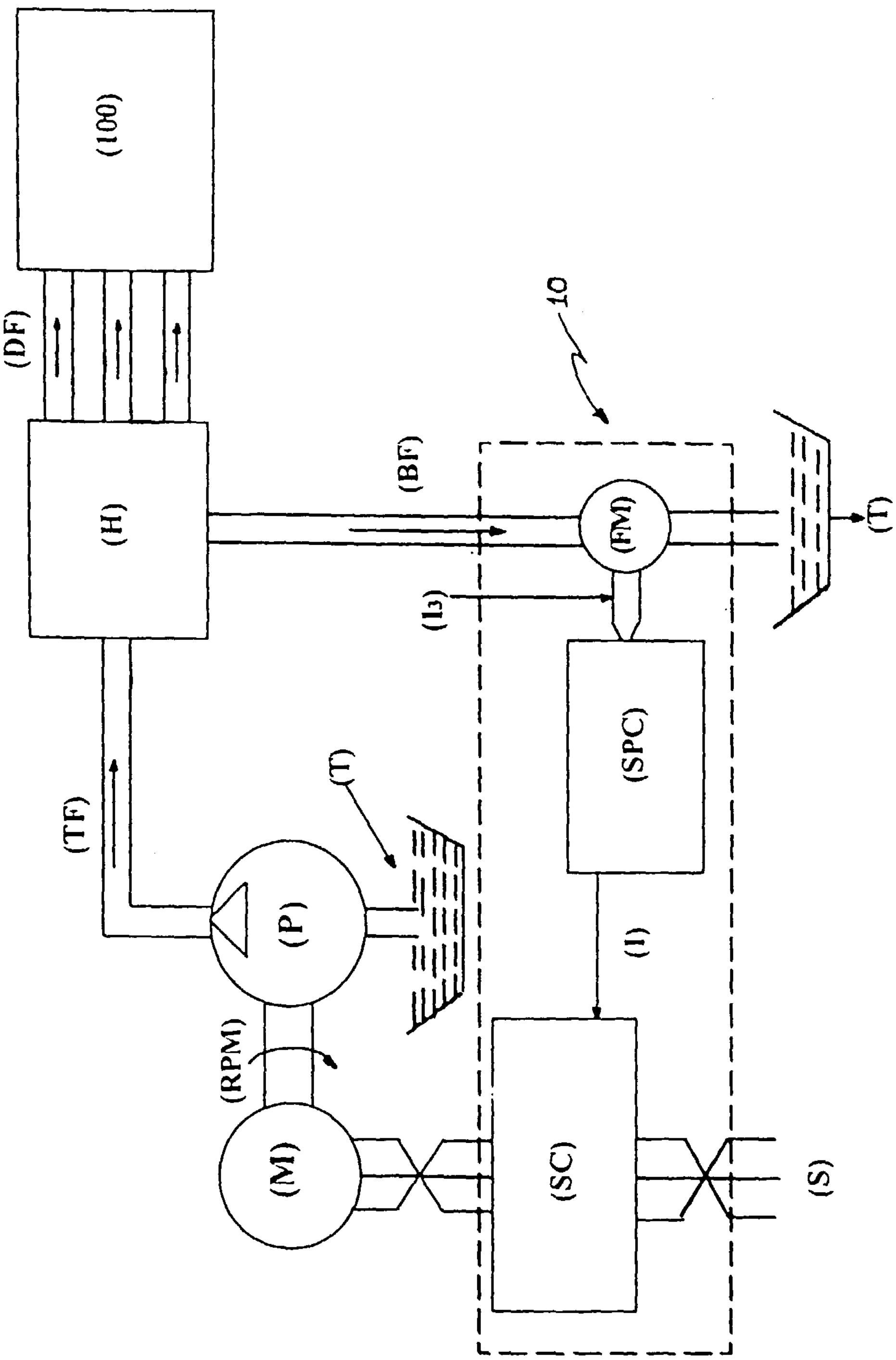

FIGURE - 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 4133

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 October 1998	SLEIGHTHOLME, G

CATEGORY OF CITED DOCUMENTS

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