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(54) **Engine oil cooling**

(57) A method and system for controlling the warming and cooling of lubrication oil for an internal combustion engine (11), in which the engine coolant and engine oil are separately circulated through a mutual heat exchanger (16), and the mutual exchange of heat between

the oil and coolant is controlled by means of a control valve (18) operable to control the flow of the coolant through the heat exchanger (16) in accordance with their respective temperatures in relation to predetermined set temperatures.

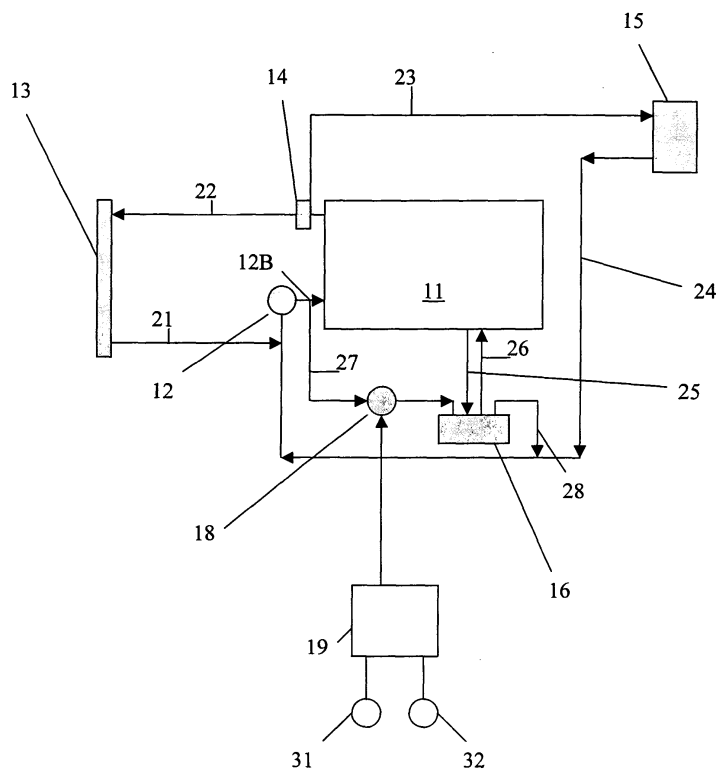


FIG 1

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Description

Field

[0001] This invention relates to a method and system for cooling of lubrication oil in internal combustion engines and in particular to the cooling or heating of Diesel engine lubrication systems of motor vehicles.

Background of the Invention

[0002] In order to improve the environment, it is highly desirable to reduce the emissions from Diesel engines and large efforts are being expended to improve fuel economy and reduce particulate and gaseous emissions. Modern Diesel engines for light commercial vehicles and passenger cars are typically provided with turbochargers, and may also be provided with intercoolers. The heat produced by these engines is such that the lubrication oil needs to be cooled to prevent degradation and consequent engine wear, and the oil is therefore passed through a heat exchanger which may in turn be cooled by air flow or by the engine coolant. The present systems cool the oil continuously and therefore the oil is overcooled in all but relatively high load hot climatic temperature conditions.

[0003] That portion of the fuel consumption of an engine due to friction within the engine is influenced by the oil temperature (due to viscosity reducing with increasing temperature) and therefore there are conflicting requirements between the improvement of fuel consumption and the cooling of the lubrication oil.

[0004] HC and CO emissions are particularly high at engine start-up and the catalytic converter will be inoperative because the catalyst temperature will be below its light-off temperature.

[0005] The present invention provides a simple way to improve both fuel consumption and engine emissions by the control of engine oil temperature and rate of rise of coolant temperature from cold.

Statements of Invention

[0006] According to a first aspect of the present invention there is provided a method of controlling the warming and cooling of lubrication oil for an internal combustion engine in which method the engine coolant and engine oil are separately circulated through a mutual heat exchanger, characterised in that the mutual exchange of heat between the oil and coolant is controlled by controlling the flow of at least one of the oil and coolant through the heat exchanger in accordance with their respective temperatures in relation to predetermined set temperatures.

[0007] Preferably only the flow of engine coolant through the heat exchanger is controlled in accordance with said relative temperatures.

[0008] There is little or no flow of coolant through the

heat exchanger when the coolant temperature and oil temperature are below a predetermined first temperature, typically 60°C. This allows the coolant to warm up as fast as possible without transferring heat to the oil and leads to a faster cylinder bore and head warm up and reduced levels of CO and HC emissions.

[0009] Preferably when either of the oil or coolant temperatures exceeds said first temperature there is full flow of coolant provided that either one of the coolant temperature and oil temperature is less than a predetermined second temperature, typically 84°C, and the oil temperature is less than the coolant temperature. Thus the hot coolant is used to heat the oil until the oil and engine are at substantially the same temperature. This will help reduce friction and improve fuel economy. Once oil and coolant are close to the second temperature, typically just below the thermostat initial opening temperature, i.e. 84 °C, the oil temperature is normally held back by the coolant. To allow the oil temperature to rise above the coolant temperature then no coolant flow is allowed until the oil temperature is in the desired oil operating range, typically 110-125° C.

[0010] If the oil is in the desired operating range, modulated flow is preferably used to maintain the oil temperature within the desired range.

[0011] Preferably, when either of the oil or coolant temperatures exceeds said first temperature and provided that one of the oil temperature and coolant temperature is greater than the other of said temperatures then the flow of coolant is controlled in accordance with the relative value of oil temperature relative to further preset higher temperature values, typically 110°C and 125°C. Preferably, the coolant temperature is less than the predetermined second temperature and the oil temperature is greater than the coolant temperature and, in some cases, the coolant temperature is higher than a predetermined second temperature and the oil temperature is greater than the coolant temperature.

[0012] The differences between the preset values of oil temperature and actual oil temperature determine the degree of modulation of the coolant flow.

[0013] The oil cooling/heating system is operable only when the vehicle ignition key is switched on and more preferably only when the vehicle engine is running:

[0014] According to a second aspect of the present invention there is provided an engine oil heating/cooling system for an internal combustion engine having an engine cooling system with a coolant pump circulating liquid coolant through cooling system, the oil heating/cooling system comprising a heat exchanger connected to the engine lubrication system for the flow through of engine oil and also being connected to the engine cooling system for the flow through of engine coolant, a control valve controlling the flow of coolant through the heat exchanger and a controller operating the valve and being connected to an oil temperature sensor and a cylinder head metal temperature sensor, the controller operating the valve in response to signals received from the two

sensors.

[0015] Preferably, the control valve is located between the pump outlet and the heat exchanger, in which case the coolant inlet for the heat exchanger may be connected to the coolant pump outlet so that coolant flows from the coolant pump to the heat exchanger and the coolant outlet for the heat exchanger is connected to the coolant pump inlet so that coolant returns back to the pump inlet or alternatively to the engine outlet (engine side of the thermostat).

[0016] The control valve may be a vacuum operated valve and is preferably an electrically operated valve operated by a pulse width modulated signal. The valve is preferably a fail open valve.

Description of the Drawings

[0017] The invention will be described by way of example and with reference to the accompanying drawings in which:

- Fig. 1 is a schematic drawing of an internal combustion engine having an engine oil cooling system according to the present invention,
- Fig. 2 is a schematic drawing of a heat exchanger used in the system shown in Fig. 1, and
- Fig. 3 is a flow chart showing the operation of the controller for the coolant flow valve used in the system shown in Fig. 1.

Detailed Description of the Invention

[0018] With reference to Fig. 1 there is shown a motor vehicle internal combustion engine 11, preferably a Diesel engine, having a cooling jacket through which a liquid coolant (typically a glycol/water mix) is pumped. The engine cooling system includes a pump 12 mounted externally of the engine and which may be driven electrically or mechanically. The coolant enters the pump 12 from a radiator 13 via conduit 21 and is pumped through outlet 12B into the engine cooling jacket and then exits the engine via a thermostatically regulated valve or valves 14. The heated coolant is then returned to the radiator 13 via conduit 22 for cooling, and some portion of the heated coolant may be diverted via conduit 23 to a cabin or passenger compartment heater matrix 15. The heater matrix 15 is connected via conduit 24 and conduit 21 to the pump 12 for the circulation of coolant back through the engine 11.

[0019] Referring also to Fig. 2, an oil heat exchanger 16 is mounted externally of the engine and hot lubrication oil is pumped from the engine 11 into the heat exchanger and then cooled oil returned to the engine via conduits 25 & 26 respectively. The engine coolant pump outlet 12B is also connected to the heating/cooling system of the heat exchanger 16 via a conduit 27 and the coolant returned to the engine via conduit 28 which in turn is connected into conduit 24. The heat exchanger

may be any suitable type of exchanger. In the present example a shell and tube exchanger is shown in Fig. 2.

[0020] The coolant is also fed from the hot side of the thermostatic valve 14 through the radiator 13 and back to the coolant pump inlet.

[0021] The volume flow of coolant direct to the heat exchanger 16 is controlled by a control valve 18. The control valve 18 may be operated by vacuum or electrically through a programmable electrical controller 19 which may be a part of the engine control unit and the valve should fail in an open condition. The controller 19 monitors engine conditions through a number of sensors, for example an oil temperature sensor 31 and a cylinder head metal temperature sensor 32. Other useful sensors may include an engine speed sensor, a vehicle speed sensor, an engine load or torque demand sensor, an ambient temperature sensor and a coolant temperature sensor.

[0022] The valve 18 regulates the coolant flow through the heat exchanger 16 in accordance with requirements that are pre-programmed into the controller 19. The valve 18 may be controlled by a pulse width modulated signal which controls the valve open position. The frequency of the control signal may be the order of 2 pulses /min due to oil temperature changes occurring slowly and the valve should go from the fully open to the fully closed conditions over several seconds in order to avoid water hammer. The separate control of the engine coolant through the oil heat exchanger 16 allows for good control without significantly affecting other components of the engine cooling circuit.

[0023] The controller 19 operates the valve 18 such that the valve is open when the vehicle ignition is switched off, or when the ignition is on but the engine is stationary. The controller 19 operates according to a general control strategy and in particular:

- a) No coolant flow (valve 18 closed) until coolant temperature or cylinder head metal temperature reached a predetermined temperature, typically within the range 50-65° C. This temperature should be below the thermostat opening temperature.
- b) Coolant flows through the exchanger 16 (valve 18 open) until the oil temperature reaches the coolant temperature.
- c) The valve 18 closes until the oil temperature reaches the optimum temperature band (110-125° C) for fuel economy, engine wear and durability.
- d) The oil cooling operation comes into effect once the oil temperature reaches the upper end of the optimum band and may comprise an on/off cooling cycle or a low coolant flow /high coolant flow cooling cycle with a built in hysteresis using oil temperature feedback. A more complicated system utilises pulse width modulated signals to operate the valve 18 at different states of closure to keep the oil at a fixed temperature. Preferably the oil temperature should be maintained within a small optimum temperature

window.

e) If the oil temperature exceeds a predetermined limit then the valve 18 is fully open to maximise cooling of the oil.

[0024] Fig.3 is a flow chart of a suitable control strategy that is programmed into the controller 19. The controller 19 is sensing the oil temperature and coolant temperatures with the engine coolant thermostat opening at T1, e.g. 88° C.

[0025] From a cold engine start up, step 1 determines if the coolant temperature is less than T2, e.g. 60° C. If yes, then step 2 determines if the oil temp is less than T2. If yes, step 3 determines that the valve 18 remains closed, i.e. no coolant flow across the exchanger. If at step 2 the oil temp is greater than T2 then the step 4 determines that the valve 18 is fully opened allowing the oil to heat the coolant. This helps increase the coolant temperature to reduce CO and HC emissions due to hotter combustion chamber temperatures..

[0026] If the engine is warm and at step 1 the coolant temperature is greater than T2, then step 5 determines if the oil temp is also less than T2 and if so step 6 determines the valve 18 is fully open allowing the coolant to heat the oil. If at step 5 the oil temperature is greater than T2, then step 7 determines if the coolant temperature is below T3, e.g. 84°C, that is just below the engine thermostat opening temperature T. If the coolant temperature is below T3 (in this example that is between 60-84°), step 8 determines if the oil temperature is less than the coolant temperature and, if so, step 9 determines that the valve 18 is opened for full flow so that the coolant heats the oil. If the oil temperature at step 8 is greater than T3 then step 10 determines if the oil temperature is less than T4, e.g. 110°C. When the oil temperature is less than T4, step 11 determines the valve 18 remains closed allowing the oil temperature to rise to the optimum operating band. When the oil temperature at step 10 is above T4 then step 12 determines if the oil temperature is less than T5 e.g. 125° and if so step 13 causes the position of valve 18 to be modulated to keep the oil temperature at a set temperature T6 e.g. about 118°. When the oil temperature at step 12 is above T5 then step 14 determines the valve 18 is fully open to cool the oil to the desired operating temperature. The steps 5-14 are operating within an engine coolant temperature range of 60-84°C to reduce CO₂ and NO_x formation and increase fuel efficiency.

[0027] When step 7 determines that the coolant temperature is above T3, then step 15 determines if the oil temperature is below T3. If the oil temperature is below then step 16 opens the valve 18 to transfer heat from coolant to the oil. When step 15 determines the oil temperature is above T3, then step 17 determines if the oil temperature is less than T4. When the oil temperature at step 17 is below T4 then step 18 determines if the oil temperature is less than the coolant temperature. If the oil temperature at step 18 is less than the coolant tem-

perature then step 19 determines that the valve 18 is fully open so that the coolant heats the oil and if the oil temperature is above the coolant temperature then step 20 closes the valve 18 preventing the oil from being over cooled and/or allowing the oil temperature to rise to T6. If at step 17 the oil temperature is above T4 then step 21 determines if the oil temperature is less than T5. If the oil temperature is below T5 then step 22 modulates the valve 18 to maintain an oil temperature of T6 and if the oil temperature is above T5 then step 23 causes the valve 18 to fully open to cause the coolant flow to reduce the oil temperature towards T6. The steps 15-23 are operating with a coolant temperature above T3 to limit CO₂ and NO_x emissions.

[0028] Maintaining an oil temperature in the range 110-125°C helps prolong oil life, improves wear characteristics and prevents emulsions forming in the oil due to water vapour present in the blow-by gases.

Claims

1. A method of controlling the warming and cooling of lubrication oil for an internal combustion engine (11) in which method the engine coolant and engine oil are separately circulated through a mutual heat exchanger (16), **characterised in that** the mutual exchange of heat between the oil and coolant is controlled by controlling the flow of at least one of the oil and coolant through the heat exchanger (16) in accordance with their respective temperatures in relation to predetermined set temperatures.
2. A method as claimed in Claim 1 in which the flow of engine coolant through the heat exchanger (16) is controlled in accordance with said relative temperatures.
3. A method as claimed in Claim 2 wherein there is no flow of coolant when the coolant temperature and oil temperature are below a predetermined first temperature.
4. A method as claimed in Claim 3 wherein if either of the oil or coolant temperatures exceeds said first temperature there is full flow of coolant provided that either one of the coolant temperature and oil temperature is less than a predetermined second temperature and the oil temperature is less than the coolant temperature.
5. A method as claimed in Claim 3 or Claim 4, wherein if either of the oil or coolant temperatures exceeds said first temperature and provided that one of the oil temperature and coolant temperature is greater than the other of said temperatures then the flow of coolant is controlled in accordance with the relative value of oil temperature relative to further preset

higher temperature values.

6. A method as claimed in Claim 5 in which the coolant temperature is less than a predetermined second temperature which is higher than said first temperature and the oil temperature is greater than the coolant temperature, 5
7. A method as claimed in Claim 5 or Claim 6 in which the coolant temperature is higher than a predetermined second temperature which is higher than said first temperature and the oil temperature is greater than the coolant temperature. 10
8. A method as claimed in Claim 6 or Claim 7 wherein the preset values determine the degree of modulation of the coolant flow. 15
9. A method as claimed in any one of Claims 1 to 8 and which is operable only when the vehicle ignition key is switched on. 20
10. A method as claimed in Claim 9 and which is operable only when the vehicle engine is running. 25
11. An engine oil heating/cooling system for an internal combustion engine (11) having an engine cooling system with a coolant pump (12) circulating liquid coolant through cooling system, the oil heating/cooling system comprising a heat exchanger (16) connected to the engine lubrication system for the flow through of engine oil and also being connected to the engine cooling system for the flow through of engine coolant, a control valve (18) to control the flow of coolant through the heat exchanger (16) and a controller (19) operating the valve (18), **characterised in that** the controller (19) is connected to an oil temperature sensor (31) and a cylinder head metal temperature sensor (32), the controller (19) operating the valve (18) in response to signals received from the two sensors. 30 35 40
12. A system as claimed in Claim 11, wherein the control valve (18) is located between the pump outlet (12B) and the heat exchanger (16). 45
13. A system as claimed in Claim 11 wherein the coolant inlet for the heat exchanger (16) is connected to the coolant pump outlet (12B) and the coolant outlet for the heat exchanger (16) is connected to the coolant pump inlet. 50
14. A system as claimed in any one of Claims 11 to 13, wherein the valve (18) is an electrically operated valve operated by a pulse width modulated signal. 55
15. A system as claimed in any one of Claims 11 to 14, wherein the valve (18) is a fail open valve.
16. An internal combustion engine (11) for a motor vehicle and which comprises an engine cooling system with a coolant pump (12) circulating liquid coolant through cooling system, and an engine oil cooling/heating system as claimed in any one of Claims 11 to 15.

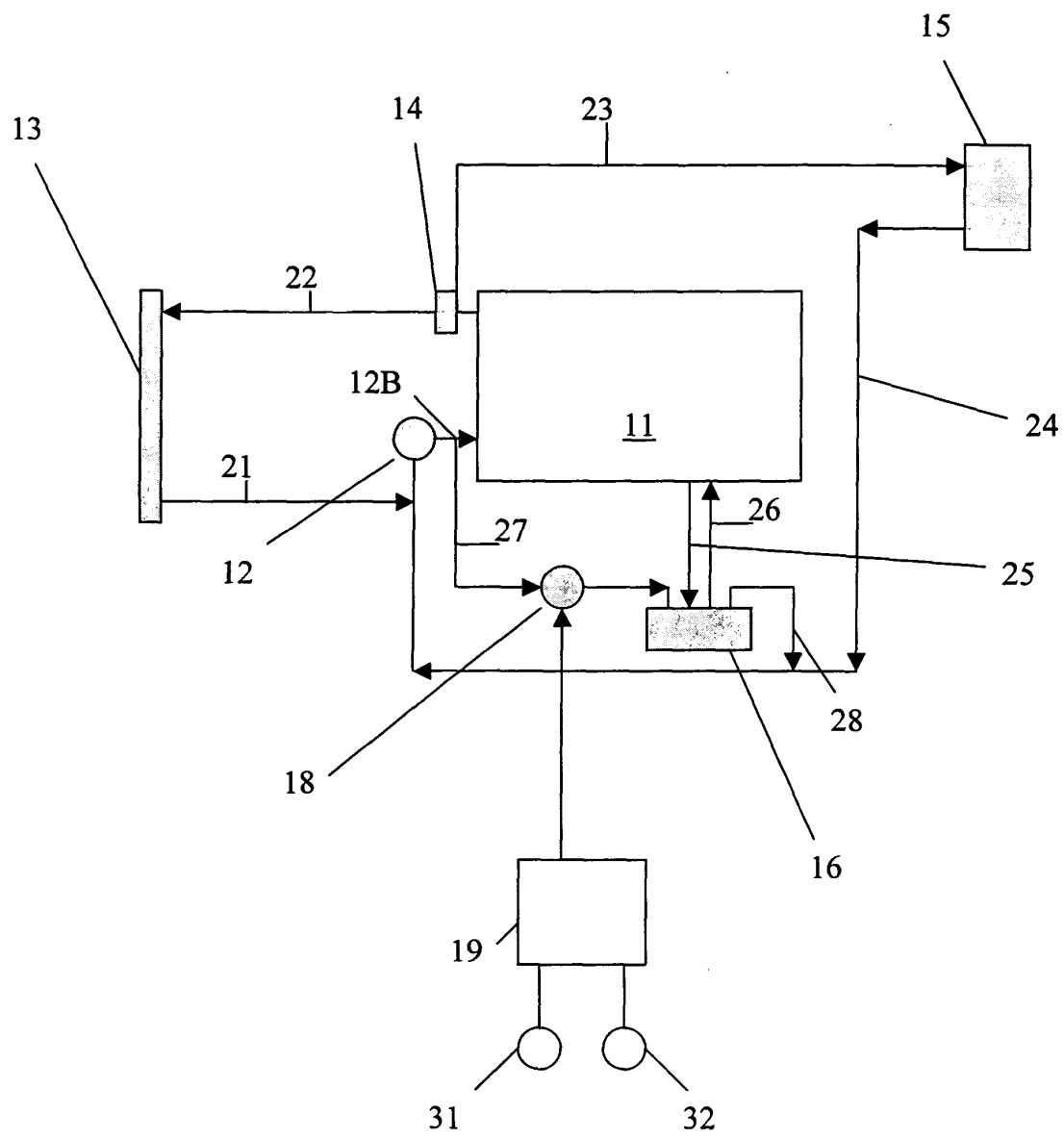


FIG 1

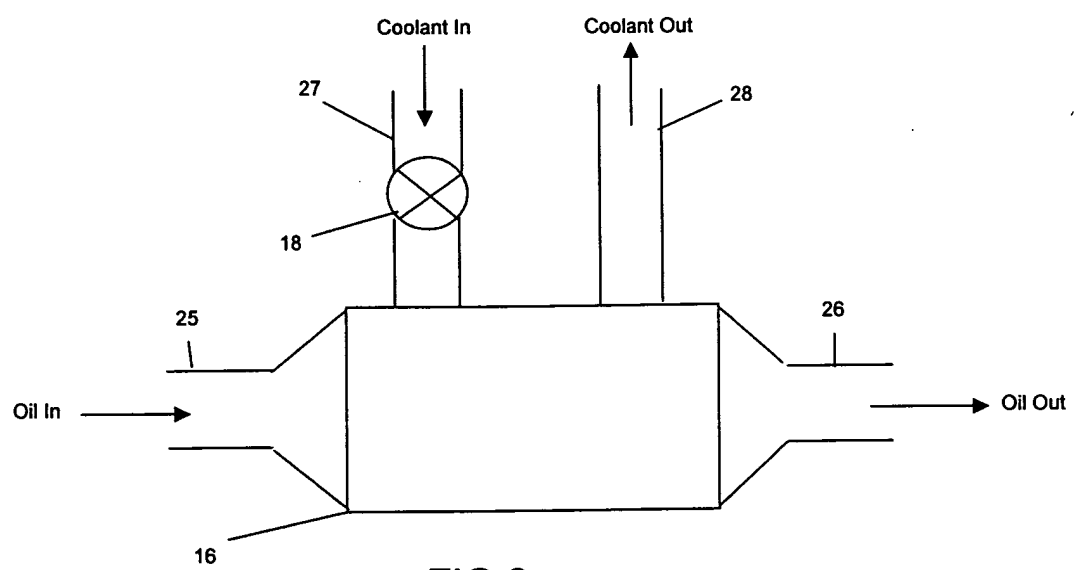


FIG 2

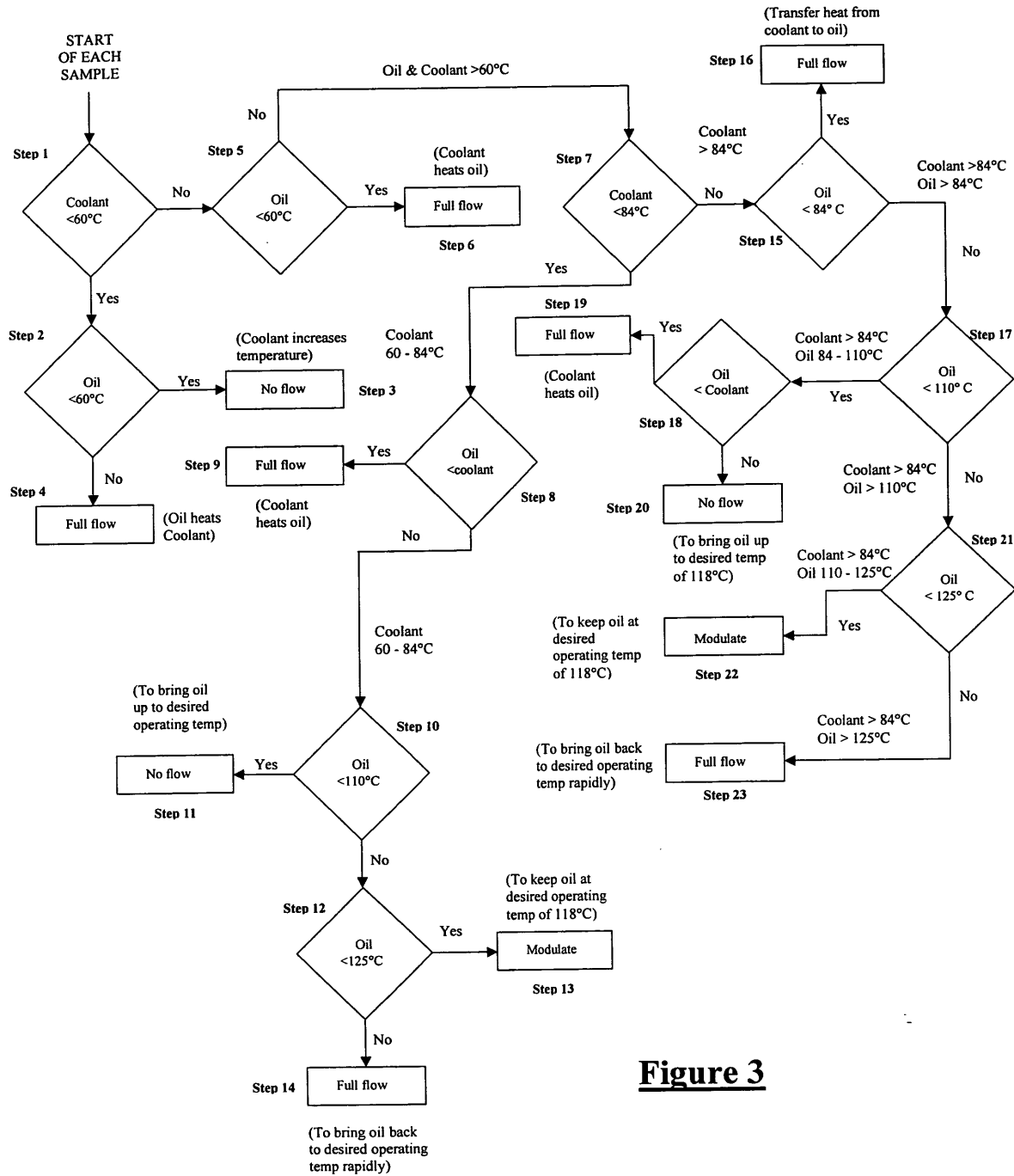


Figure 3



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 03 25 6433

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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Place of search		Date of completion of the search	Examiner
The Hague		6 January 2004	Mouton, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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