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(54) ## Turbocharger system and method of controlling heat transfer.

(57) A turbocharger system including turbine housing (28) and compressor housing (34) sections which are connected by a centre housing section (14). The centre housing section journals a shaft (20) carrying a compressor wheel (24) and a turbine wheel (22) rotatable in the respective housing sections. The centre housing section also defines a closed cavity (50) captively receiving a material (52) which both conducts heat and changes phase during hot soak of the turbocharger following engine shutdown to control bearing temperatures at the shaft (20).

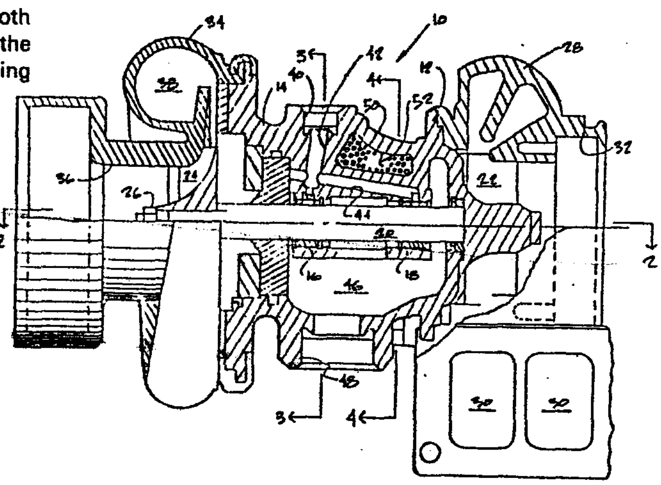

FIG. 1

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TURBOCHARGER SYSTEM AND METHOD OF CONTROLLING HEAT TRANSFER.

The present invention relates to turbocharger systems of the type used to provide pressurized combustion air to an internal combustion engine. More particularly, this invention relates to a turbocharger system including a turbocharger housing comprising an exhaust turbine section, an air compressor section and a central section between the turbine and compressor sections. In such systems, the housing journals an elongate shaft for rotation with a turbine and a compressor. The turbine and compressor are spaced apart at opposite-ends of the shaft.

Turbochargers in general are well known in the art for supplying pressurised combustion air to an internal combustion Otto or Diesel cycle engine. Historically turbochargers have been used on large engines for stationary or heavy automotive farm or construction vehicle applications. These turbochargers generally include a housing including a turbine housing section for directing exhaust gases from an exhaust inlet to an exhaust outlet across a rotatable turbine. The turbine drives a shaft journaled in the housing. A compressor is mounted on the shaft within a compressor housing and defines an air inlet for drawings ambient air and an air outlet for delivering the pressurised air to the inlet manifold of the engine, as the compressor is driven by the turbine via the shaft.

Because these past turbocharger applications involved relatively low specific engine power outputs with relatively low exhaust gas temperatures and infrequent engine shutdowns, no special precautions were necessary to cool the shaft and the bearings journaling the shaft. Experience showed that the normal engine-pressure oil flow lubrication, which was necessary during turbocharger operation, by its cooling effect maintained the shaft and bearings at a temperature low enough to prevent the oil coking in the turbocharger after engine shutdown. Because the operating temperature at the hot turbine end of the turbocharger was low enough and the mass of the turbocharger relatively large, the highest temperatures experienced at the shaft and bearings after the oil flow was stopped was not high enough to degrate or coke and oil remaining in the turbocharger after engine shutdown.

However, passenger car automotive turbocharger applications have brought to light many problems. The specific engine outputs are usually higher leading to higher exhaust gas temperatures. The turbocharger itself is considerably smaller than its heavy predecessor so that a smaller thermal mass is available to dissipate any residual heat from the turbine housing section and turbine after engine shutdown. The result has been that heat soaking from the turbine housing section and turbine into the shaft and the remainder of the housing tends to raise the temperature high enough to degrade or coke the remaining oil in the housing after engine shutdown. Of course, this coked oil may then plug the bearings so that subsequent oil flow lubrication and cooling is inhibited. This process soon leads to bearing failure in the turbocharger.

An interim and incomplete solution to the above problem was provided by the inclusion of a hydraulic accumulator with a check and metering valve in the oil supply conduit between the engine and turbocharger. During engine operation this accumulator filled with pressurised oil. Upon engine shutdown the oil was allowed to flow only to the turbocharger at a controlled rate to provide bearing and shaft cooling while the remainder of the turbocharger cooled down. However, the frequent shutdowns and restarts to which automotive passenger vehicles are sometimes subjected does not allow sufficient time for the accumulator to fill. Under these conditions failure of the turbocharger may be accelerated.

Another more recent and more successful solution to the above problem has been the provision of a liquid cooling jacket in a part of the turbocharger housing adjacent the turbine housing section. Liquid engine coolant is circulated through the jacket during engine operation by the cooling system of the engine. Following engine shutdown the coolant remaining in the jacket provides a heat sink so that residual heat from the turbine housing section does not increase the shaft and bearing temperatures to undesirably high levels. United States patents 4,068,612 of E.R. Meiners, and Re 30,333 of P.B. Gordon, Jr., et al, illustrate examples of this conventional solution to the problem.

However, these latter systems all require that engine coolant be piped to and from the turbocharger. This is usually accomplished by flexible hoses which complicate and increase to cost of the original installation of the turbocharger system. Also, this plumbing requires additional maintenance and may be subject to coolant leakage which could disable the vehicle.

In view of the above, it is an object of the present invention to provide a way of limiting the temperature at the shaft and bearings of a turbocharger following engine shutdown without the use of liquid engine coolant and the attendant plumbing that such coolant use involves.

It is a further object to provide a turbocharger system which, except for the necessary air, exhaust gas and lubricating oil connections with the engine, is a unit unto itself and is not reliant upon the cooling system of the engine to prevent overtemperature conditions within the turbocharger.

According to the present invention, a turbocharger system in characterised in that the central section includes a closed cavity and the closed cavity contains a material which both conducts and absorbs heat in the operating temperature range of the turbocharger. The system may include a turbine wheel within the turbine section, a compressor wheel within the compressor section, and a shaft which joins the two wheels and which is journalled within the central section.

Preferably, the cavity extends between the turbine wheel and the compressor wheel.

Thus, the present invention may provide a method of controlling the heat transfer within a turbocharger system following engine shutdowns by providing a captive mass of heat conductive and heat absorptive material which during turbocharger operation preferably exists in a relatively low energy molecular state and which may, upon engine shoutdown and the attendant cessation of cooling oil flow, both absorb residual heat from the turbocharger turbine housing section with an attendant phase change, and provide a heat transfer path from the turbine housing section to other relatively cool portions of the turbocharger system, bypassing the heat transfer path including the shaft and bearings where oil coking may otherwise occur.

Preferably, the cavity is saddle shaped and substantially surrounds the shaft. Preferably, the housing further defines an oil drain gallery below the shaft and disposed generally between the depending skirts of the saddle-shaped cavity. Preferably the housing further defines an upper oil inlet leading to a depending oil passage for directing oil to the shaft, the saddle-shaped cavity embracing but being spaced from the oil passage to surround substantially the shaft. The housing may define a port into the cavity and a plug closing and sealing the port.

Preferably, the material is one which undergoes a molecular change of phase at a temperature between the normal working temperature and the coking temperature of the turbocharger lubricant. The material may therefore be a metal, for example an alloy including lead and tin.

Thus, according to another aspect, the invention may provide a method of limiting the temperature of a bearing at the exhaust turbine side of a turbocharger system for an engine following engine shutdown, in which the turbocharger system includes a turbocharger housing comprising an exhaust turbine section , an air compressor section and a central section between the turbine and compressor sections, characterised in that the central section is formed with a closed cavity and in that a material is enclosed within the cavity which both conducts heat and which undergoes a molecular change of phase at a temperature between the normal working temperature and the coking temperature of the turbocharger lubricant whereby, heat present at the exhaust side of the system after shutdown is conducted by the material to the compressor side and is absorbed by the material in order to effect a change of phase in the material.

There is therefore provided according to the invention a method of limiting the maximum hot end bearing temperature attained within a turbocharger during hot soak following engine shutdown, comprising the steps of: providing a closed cavity within a centre housing of the turbocharger extending axially between a turbine housing section and a compressor housing section, and substantially surrounding the hot end bearing and the shaft journalled therein; captively disposing within the closed cavity a determined quantity of a material chosen for its heat conductance capability and for its ability to undergo a heat-absorptive change of phase at a temperature above the normal operating temperature of the relevant portion of the turbocharger housing; and using the material both to conduct residual heat from the turbine housing section towards the compressor housing section and to absorb a portion of the residual heat by a change of phase.

While such a mode of operation is preferred, in some instances, the material may limit the temperature increase, particlularly of the hot end bearing where there are two shaft bearing, by conducting residual heat towards the compressor end by defining a heat transfer path apart from the shaft and bearings, and by absorbing the residual heat with an attendant rise in temperature without changing phase.

The invention may be carried into practice in various ways and one embodiment will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a longitudinal schematic view, partly in cross section, of a trubocharger system embodying the present invention;

Figure 2 is a fragmentary cross sectional view taken along line 2-2 of Figure 1;

Figure 3 is a fragmentary cross sectional view taken along line 3-3 of Figure 1; and

Figure 4 is a fragmentary cross sectional view taken along line 4-4 of Figure 1.

With reference to Figure 1, a turbocharger system 10 includes a housing 12. The housing 12 includes a centre section 14 having a pair of spaced apart journal bearings 16, 18, in which an elongate shaft 20 is rotatably mounted. A turbine wheel 22 is attached to or integrally formed with one end of the shaft 20, while a compressor wheel 24 is carried on the opposite end and is drivingly secured thereto by a nut 26 which threadably engages the shaft.

A turbine housing section 28 mates with the centre section 14 and defines an exhaust gas inlet 30 leading to a radially outer portion of the turbine wheel 22. The turbine housing section also defines an exhaust gas outlet 32 leading from the turbine wheel 22. Similarly, a compressor housing section 34 mates with the housing centre section 14 at the opposite end to the turbine housing section 28. The compressor housing section 34 defines an air inlet 36 leading to the compressor wheel 24, and an air outlet (not shown) opening from a diffuser chamber 38.

The turbocharger centre section 14 also includes an oil inlet 40 leading to the bearings 16, 18 via passages 42, 44 , and an oil drain gallery 46 leading from the bearings to an oil outlet 48. Within the housing centre section 14 there is also a closed cavity which is best shown in Figures 2-4. The cavity 50 extends axially between the compressor housing section and the turbine housing section of the housing 14. The cavity 50 also extends circumferentially over the top and part way down each side of the shaft 20, as shown in Figures 3 and 4. Thus, it can be seen that the cavity 50 envolopes the shaft 20 and bearings 16, 18 somewhat in the shape of a saddle.

Disposed within the cavity 50 is a predetermined quantity of a material 52 selected with a view to, amongst other factors, its heat transfer coefficient, its chemical stability under thermal cycling, its cost, and its heat of fusion or other change of phase heat capacity. Also of particular importance with respect to the material 52 is the temperature at which its change-of-phase heat absorption and heat release takes place.

During manufacture of the turbocharger 10, the material 52 is loaded into the cavity 50 preferably in a solid pellet or granular form via a port 54. After the cavity 50 is substantially filled with material 52, the port 54 is permanently closed by a plug 56 which threadably engages the housing centre section 14.

By way of example only, the plug 56 may be removably secured to housing section 14 by an anaerobic adhesive, or may be permanently secured e.g. by welding. In either case, the plug 56 is intended to close the port 54 permanently so that the cavity 50 is closed for the service life of the turbocharger 10. Consequently, the material 52 is permanently captured within the cavity 50.

It will be noted that because the material 52 is loaded into cavity 50 in the form of pellets or granules, it has been so illustrated in the drawings. However, after the first time turbocharger 10 is operated with an engine, following hot shutdown, the material 52 will exist in the cavity 50 as a fused mass.

The operation of the turbocharger system 10 will now be described. During operation of the internal combustion engine (not shown) associated with the turbocharger system 10, exhaust gases at high temperatures and pressures enter the housing 12 via the exhaust gas inlet 30. There the exhaust gases flow from the inlet 30 to the outlet 32 while expanding to a lower pressure and driving the turbine wheel 22. The turbine wheel 22 drives the shaft 20 which also carries the compressor wheel 24. Consequently, the compressor 24 draws in ambient air via the inlet 36 and discharges the air, pressurised, via an outlet (not shown) communicating with the chamber 38. The exhaust gases flowing within the turbine section of housing 12 also act as a substantially continuous source of heat which is transferred to the housing 12 and the turbine wheel 22 so long as the engine and turbocharger 10 are in operation.

Consequently, during operation of the turbocharger 10, heat is almost continuously conducted from the hot turbine housing secton 28 and turbine wheel 22 to the cooler portions of the turbocharger system. This heat transfer occurs by conduction along the shaft 20 and the turbine housing centre section 14 towards the left in Figure 1.

At the same time, a flow of relatively cool lubricating oil is received via the inlet 40 and passages 42. 44. This cooling oil flow absorbs heat from and therefore cools the turbocharger 10 by passing along the passages 42,44, through and around the bearings 16,18, and across the internal surfaces of the oil drain gallery 46. The turbocharger system 10 also liberates heat to its environment by radiation and convection from its external surfaces. Also, heat may be transferred to the air traversing the compressor wheel 24 and flowing to the air outlet via the chamber 38. The summation of these heat transfer effects results in the bearings 16, 18 operating at temperatures low enough to prevent the oil coking there. Furthermore, under these conditions, the material 52 is maintained in a relatively low energy molecular state, i.e. solid.

Upon shutdown of the engine supplying exhaust gases to the inlet 30, both the source of heat energy and the source of cooling oil flow to the turbocharger cease. However, both the turbine housing section 28 and turbine wheel 22 are very hot and hold a considerable quantity of residual heat. This residual heat is conducted to the cooler parts of the turbocharger much as heat was conducted during operation. However, no cooling oil flow is now present. Consequently, the temperatures of the shaft 20 and the centre housing 14 tend to increase progressively to a level above their normal operating temperatures. This temperature increase, if uncontrolled could result in temperatures at the bearings 16,18 (particularly the latter), which would degrade or coke the residual oil present.

In order to control the heat transfer within the turbocharger system 10, the material 52 serves firstly to conduct heat from the hot turbine housing section 28 towards the cooler compressor housing section 34 via a path which bypasses the shaft 20 and the bearings 16, 18 and secondly, to absorb heat energy by a molecular change of phase. The material 52 is selected with a view to the normal expected operating temperatures of centre housing 14 so that at a certain higher temperature a change of phase to a higher energy state takes place i.e. from solid to liquid. This change of phase is accompanied by the absorption of a considerably quantity of heat. As a result, the temperatures at bearings 16,18 do not reach levels which would cause the oil to coke. Of course, with the passage of time the entire turbocharger system 10 cools as it liberates heat to its surroundings.

By way of example, the Applicants have discovered that an alloy of tin and lead which is used as a common low-temperature solder will, if employed as the material 52, give surprisingly good results. A test of the turbocharger of Figure 1 with the cavity 50 empty resulted in heat soaking from the turbine housing and turbine wheel to the bearings 16 and 18 so that maximum temperatures of 450°F (232°C), and 640°F (338°C) respectively, were reached at each bearing.

These temperatures compare with normal operating temperatures of 225°F (107°C) and 310°F (154°C) respectively, and are high enough, particularly at the bearing 18, to coke the residual oil. These temperatures are comparably to those which would be expected in a conventional turbocharger with no centre housing cooling of any type.

On the other hand, when the solder alloy was employed in the cavity 50, the maximum bearing temperatures were 480°F (249°C) and 525°F (274°C), respectively during a heat soak test under otherwise identical conditions as above. Significantly, the maximum temperature reached at the bearing 18 was 115F° (64K) lower than that experienced without the material 52 in cavity 50. The 30F° (17K) higher temperature reached at the bearing 16 is an indication that even though the material 54 absorbs a significant quantity of heat during its phase change it also conducts heat to the cooler portions of the turbocharger. This latter effect of the material 52 in the cavity 50 is of considerably benefit in itself because the cool compressor housing section is capable of absorbing considerable residual heat. Also, this compressor housing section provides additional radiation and convection cooling surface area which is an aid to rapid cooling of the turbocharger system. All of these effects together cooperate to limit the maximum temperature reached at the bearing 18 in order to prevent the oil coking.

Upon restart of the engine associated with the turbocharger 10, if significant residual heat still remains, it should be dissipatted by the initial air flow through compressor housing section 34.

In addition, the initial oil flow through the centre housing section 14 will quickly lower the temperatures there to normal levels. As a result of this cooling upon a return to normal operation of the turbocharger, the material in the cavity 52 is also cooled and experiences a heat-releasing phase change to its lower-energy molecular condition. The majority of the heat released by this cooling phase change is absorbed by the cooling oil flow through the centre housing. As a result, the turbocharger 10 is well able to endure frequent shutdowns and restarts of the engine.

An advantage of the present invention, in addition to the elimination of any engine coolant plumbing to the turbocharger and to the attendant simplified installation and mainentance, is its partiuclar suitability for air-cooled engines. These engines have no liquid engine coolant which could be used in the conventional way to cool a turbocharger, consequently, turbocharger applications to these engines have conventionally involved many problems. The present invention is believed to provide a substantially complete solution to this difficult turbocharger application problem.

CLAIMS:

1. A turbocharger system (10) including a turbocharger housing (12) comprising an exhaust turbine section (28), an air compressor section (34) and a central section (14) between the turbine and compressor sections, characterised in that the central section (14) includes a closed cavity (50) and the closed cavity (50) contains a material (52) which both conducts and absorbs heat in the operating temperature range of the turbocharger.

2. A system as claimed in Claim 1 including a turbine wheel (22) within the turbine section (28), a compressor wheel (24) within the compressor section (34) and a shaft (20) which joins the two wheels (22, 24), and which is journalled within the central section (14), characterised in that the cavity (50) extends between the turbine wheel (22) and the compressor wheel (24).

3. A system as claimed in Claim 2 characterised in that the cavity (50) is saddle shaped and substantially surrounds the shaft (20).

4. A system as claimed in Claim 3 characterised in that the housing (12) further defines an oil drain gallery (46) below the shaft (20) and disposed generally between the depending skirts of the saddle-shaped cavity (50).

5. A system as claimed in Claim 4 characterised in that the housing (12) further defines an upper

oil inlet (40) leading to a depending oil passage (42,44) for directing oil to the shaft (20), the saddle-shaped cavity embracing but being spaced from the oil passage to surround substantially the shaft (20).

6. A system as claimed in any preceding Claim characterised in that the housing further defines a port (54) into the cavity (50) and a plug (56) closing and sealing the port.

7. A system as claimed in any preceding Claim characterised in that the material is one which undergoes a molecular change of phase at a temperature between the normal working temperature and the coking temperature of the turbocharger lubricant.

8. A system as claimed in any preceding Claim characterised in that the material is a metal.

9. A system as claimed in Claim 8 characterised in that the material is an alloy including lead and tin.

10. A method of limiting the tempreature of a bearing (18) at the exhaust turbine side of a turbocharger system (10) for an engine following engine shutdown, in which the turbocharger system (10) includes a turbocharger housing (12) comprising an exhaust turbine section (28) an air compressor section (34) and a central section (14) between the turbine and compressor sections, characterised in that the central section (14) is formed with a closed cavity (50) and in that a material

(52) is enclosed within the cavity (50) which both conducts heat and which undergoes a molecular change of phase at a temperature between the normal working temperature and the coking temperature of the turbocharger lubricant whereby, heat present at the exhaust side of the system after shutdown is conducted by the material (52) to the compressor side and is absorbed by the material (52) in order to effect a change of phase in the material (52).

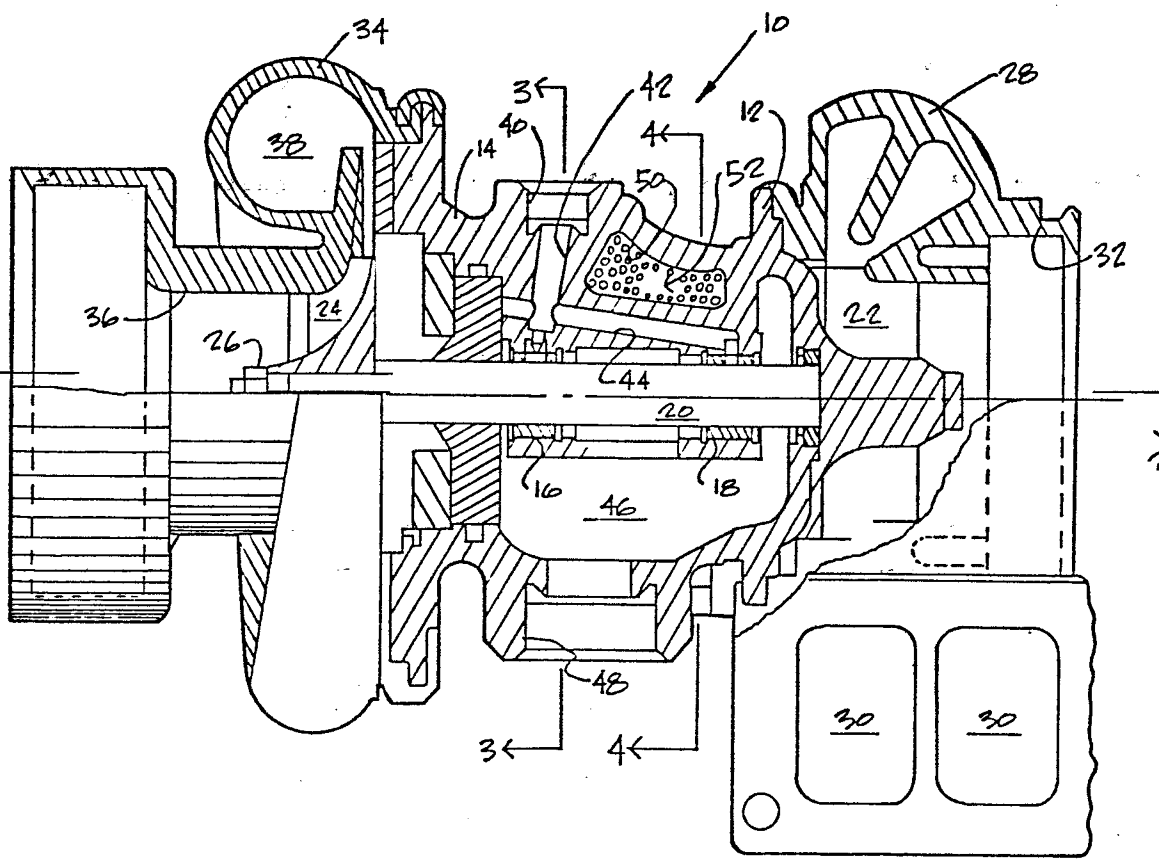
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FIG. 1

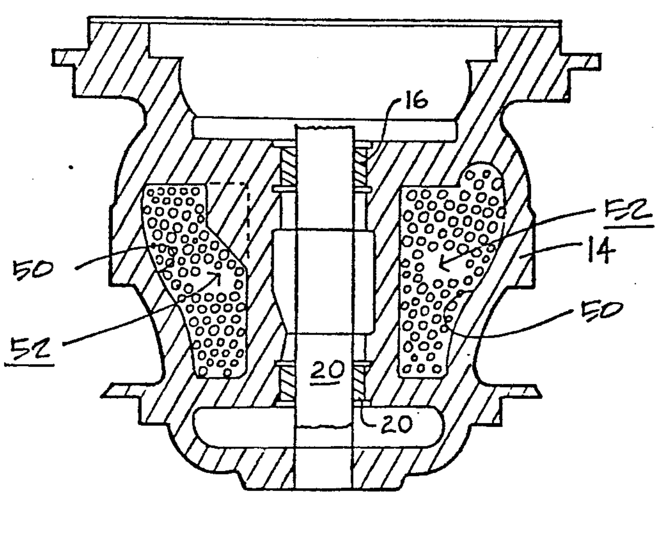
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FIG. 2

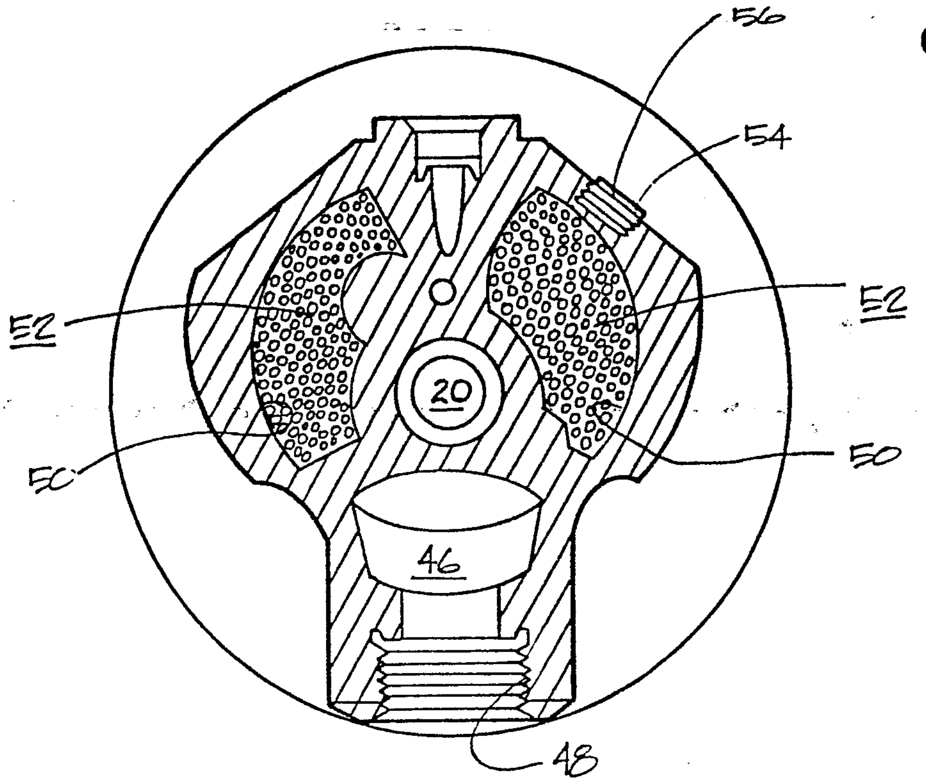

FIG 3

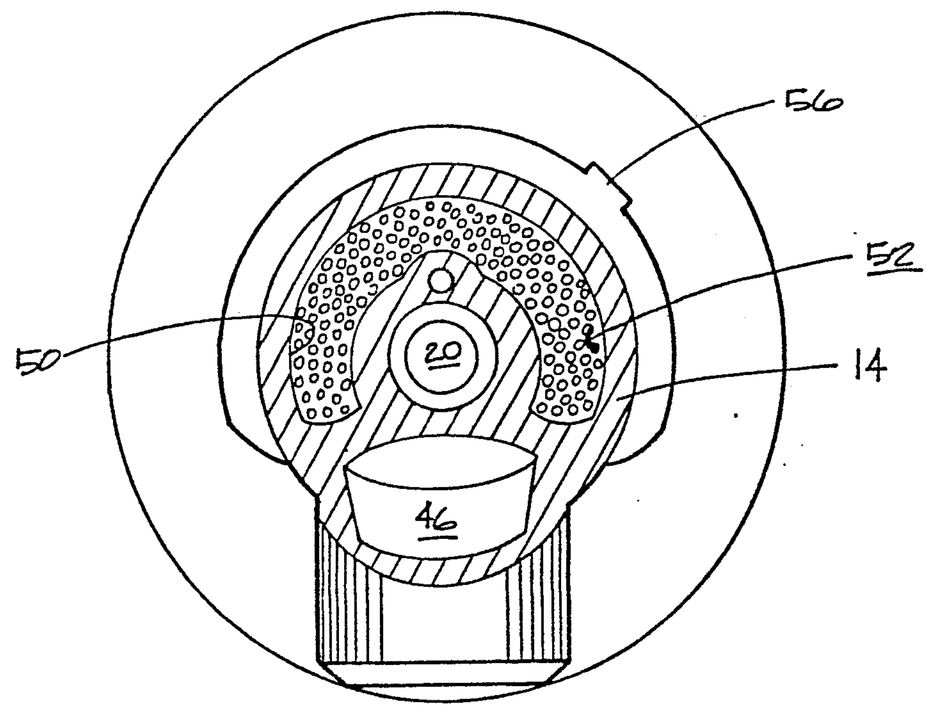

FIG 4

European Patent Office

EUROPEAN SEARCH REPORT

0186389
Application number

EP 85 30 9041

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
X	DE-C- 922 093 (ROVER) * Whole document *	1,2,7-10	F 01 D 25/12 F 01 P 9/00
A	---	3-6	
P,X	DE-A-3 430 146 (OKAZAKI) * Whole document * ---	1-10	
A	FR-A- 996 476 (ELECTRO-MECANIQUE) * Whole document * -----	1,7,8	

TECHNICAL FIELDS SEARCHED (Int Cl 4)
F 01 D F 02 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20-02-1986	IVERUS D.

CATEGORY OF CITED DOCUMENTS

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