(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 308 686 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.05.2003 Bulletin 2003/19

(51) Int Cl.[7]: **F28D 15/02**

(21) Application number: **01309403.2**

(22) Date of filing: **06.11.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

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(54) **Thermal management**

(57) Thermal management is achieved by a system comprising a heat pipe (10) connected to a device or further heat pipe (102) via a connector (22). The connector (22) comprises a connector socket (23,24) for receiving a heat pipe plug that can be used to join two or more heat pipes (10,102) together in a chosen architecture. Systems are described comprising at least two heat pipes (10,102) connected via a connector (22) for transferring heat from a hot location (A) to a cool location (B) via a thermally and physically intermediate location (C). Other systems are arranged to allow thermal transfer from a hot location (A) to more than one cooler locations (C,D) via heat pipes (10,102,103) in a variety of orientations with respect to each other. Various connectors (22) are described having differing orientations of connector sockets (23,24) for connecting heat pipes (10,102) to each other in direct or indirect thermal or electrical contact.

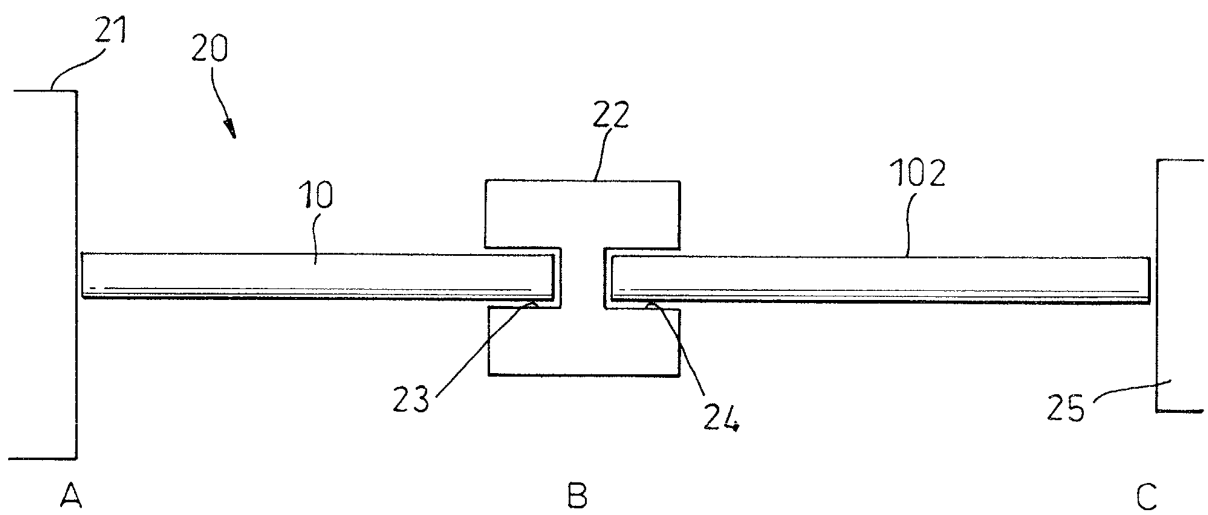

Fig. 2

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Description

Background

[0001] The invention relates, in general, to the thermal management of any device that requires temperature control during operation. For example, in relation to devices which becomes hot during normal operation, the invention can be used for heat dissipation, although it is also applicable to the warming of cool devices and to the maintenance of accurate temperatures for devices that require accurate temperature control. In particular, though not exclusively, the invention relates to heat dissipation using heat pipes, and to improvements in the organisation of heat pipes in order to improve the thermal management thereof.

[0002] A number of different devices, such as electronic devices and integrated circuits, active optical devices (e.g. semiconductor lasers), passive optical devices, such as devices which absorb significant amounts of optical radiation, resulting in temperature increases and entire modules (for example, logic-to-light modules, such as fibre-optic transceivers) all require thermal management, as well as computers and other electronic devices. Semiconductor lasers, for example, require accurate temperature control in order to tune or stabilise their wavelength. Other temperature sensitive devices such as liquid crystal displays may need to be maintained at temperatures other than their ambient environment to remain functional.

[0003] In the prior art, thermal management has been achieved in a number of ways, many of which suffer from different disadvantages. For example, it is known to mount a semiconductor laser device in a housing known as a Transistor Outline (TO) can, which has, as a base, a so-called CD header, which is used as a heat sink. However, such a heat sink supplies only modest temperature reductions. Increasing the size of a heat sink requires extra space, which frequently conflicts with other requirements. Moreover, such heat sinks are often connected to the same Printed Circuit Board (PCB) as heat sources such as integrated circuits, so that heat is unlikely to be able to be dissipated very far.

[0004] Peltier coolers are an alternative solution known in the art. However, Peltier coolers often require an extra power supply, take up extra space and require controller circuitry where active temperature control is required. Peltier coolers also contribute more heat overall, consume more power and add cost and potential unreliability.

[0005] Having a separate laser module is a solution to the problem in optical communication systems. However, this does not provide an integrated solution (e.g. logic-to-light) because an external laser driver or optical modulator is required. Such an external laser driver or optical modulator requires extra space and usually adds cost, particularly in packaging. Such an organisation also makes signal transfer difficult at high bandwidths.

[0006] As a further solution to thermal management, forced airflow is frequently used. However, this requires a fan to be included which requires additional power and space. Moreover, the use of a fan creates the potential for electro-magnetic compatibility (EMC) problems due to vents in electro-magnetic interference (EMI) shields. In addition, the use of a fan adds costs and potential unreliability to the system, and a fan cannot be used (unless recirculating) in all environments (e.g. in a vacuum or where water may surround the device at certain times).

[0007] The use of fluid cooling requires some or all of a pump, an external heat exchanger, internal and external plumbing and associated connections. All this requires extra space and usually power and adds cost and potential unreliability to the system.

[0008] It is known to use heat pipes to transfer heat from a heated location to a cooler location. A heat pipe basically consists of a hermetically sealed pipe made of a heat conducting material, such as copper at least at its ends, and having a liquid therewithin. When heat is applied to one end of the pipe, the liquid evaporates, the vapour moves to the other end of the pipe, which is cooler, and condenses. The condensed liquid then flows back to the hotter end. The evaporation of fluid within the heat pipe at the heated location (i.e. near the active device) and the condensation of the vapour at the cooler location, (usually at a second end of the heat pipe), thereby transfers heat energy due to the enthalpy change (latent heat) of vaporisation thus providing a very high effective longitudinal thermal conductivity.

[0009] The above description describes the net effect where a temperature difference exists over the length of a heat pipe with a first portion at a hotter location and a second portion at a cooler location. In reality, each region of the heat pipe is in dynamic equilibrium, with hotter regions experiencing net evaporation and cooler regions experiencing net condensation. In addition there is net flow of vapour from the evaporator (hotter first portion of the heat pipe) to the condenser (colder second portion of the heat pipe), due to the difference in vapour pressure, and net flow of liquid in the opposite direction.

[0010] Heat pipes are available from a variety of sources and can be purchased in standard sizes and configurations. If a heat pipe, or heat pipe architecture is required which falls outside of the range of available standard heat pipe sizes and shapes, it is necessary to have heat pipes custom built.

[0011] The present invention therefore seeks to provide a way of thermal management that overcomes, or at least mitigates, some or all of the disadvantages of the prior art.

Summary of the Invention

[0012] In one aspect, therefore, the invention provides a system for transferring thermal energy between locations at different temperatures, the system comprising a first heat pipe having a first portion at a hotter location and a second portion at a thermally intermediate location; a second heat pipe having a first portion at said thermally intermediate location and a second portion at a cooler location; and a connector thermally and mechanically coupled to the second portion of the first heat pipe and to the first portion of the second heat pipe, wherein thermal energy is transferred directly or indirectly between the two heat pipes.

[0013] A system, according to one embodiment of the invention may further comprise at least a third heat pipe having at least a first portion at the thermally intermediate location, thermally coupled to the connector, and a second portion at a cooler location which may be the cooler location or a further cooler location.

[0014] In a second embodiment, a system of the invention may further comprise a second connector at the cooler location, and at least a third heat pipe having a first portion thermally and mechanically connected to the second connector, and a second portion at a further, still cooler location.

[0015] By hotter location is meant a location made hot by any device, and is preferably hotter than the ambient temperature at which the device is operated. The hotter location is hotter than the cooler location, and is also hotter than the thermally intermediate location.

[0016] By cooler location is meant a location that is cooler than the hotter location, and may be cooler than the ambient temperature at which the device is operated, or may be above ambient temperature. The cooler location is cooler than the thermally intermediate location.

[0017] In this application, the term hotter location may be equated with the term hot location, and the term cooler location may be equated with the term cold location. All that is required is that the hotter or hot location is at a higher temperature than the cooler or cold location, and that the thermally intermediate location is at a temperature intermediate the hot or hotter location and the cold or cooler location.

[0018] In a further aspect, the invention provides a thermal energy coupling arrangement comprising a connector having a first aperture for receiving a portion of a first heat pipe and a second aperture for receiving a portion of a second heat pipe, whereby thermal energy is transferred directly or indirectly between the two heat pipes.

[0019] The connector of the thermal coupling arrangement of one embodiment of the invention may hold the first and second heat pipes in position mechanically. The connector may be thermally conductive or thermally insulating, and can be arranged to hold the first and second heat pipes in direct contact with each other thereby allowing direct thermal energy transfer between the heat pipes, or may hold the heat pipes in position but physically separated by a part of the said connector when the connector is itself thermally conductive.

[0020] In a further embodiment, the connector of the thermal energy coupling arrangement may also comprise at least a third aperture for receiving a portion of a third heat pipe, and connectors with more than three apertures are also envisaged.

[0021] A thermal energy coupling arrangement might further provide a further connection selected from an electrical connection, an optical connection and a mechanical motion connection or a fluid connection or any combination thereof. In one embodiment, in order to achieve electrical connection, the connector itself is electrically conductive. In an alternative embodiment the connector holds the heat pipes in direct contact thereby allowing for direct electrical conductance between the heat pipes. Additionally, or alternatively, the connector of the invention can include further apertures adapted to act as sockets for the provision of these further connections.

[0022] In a further aspect, the invention provides a thermal energy connector socket for receiving at least one heat pipe plug and mechanically holding it in position to enable thermal energy to be transferred to or from the heat pipe.

[0023] The thermal energy connector socket can mechanically hold the heat pipe plug in position by friction or by a latching arrangement, locking mechanism or thread therein. In one embodiment, the socket provides for direct or indirect thermal contact with a second heat pipe plug received in a second thermal energy connector socket.

[0024] In one embodiment, the latching arrangement comprises an O-ring located within the connector socket for frictional engagement with a heat pipe. In an alternative embodiment, a latching mechanism comprises ball bearings located in the socket for interaction with a heat pipe. Preferably the ball bearings are spring loaded and most preferably the ball bearings interact with an annular groove in a heat pipe.

[0025] In a further aspect the invention provides a method for transferring thermal energy between locations at different temperatures, the method comprising providing a first heat pipe having a first portion at a hotter location and a second portion at a thermally intermediate location; providing a second heat pipe having a first portion at the thermally intermediate location and a second portion at a cooler location; and providing a connecter thermally and mechanically coupled to the second portion of the first heat pipe and to the first portion of the second heat pipe, wherein thermal energy is transferred directly or indirectly between the two heat pipes.

[0026] In yet a further aspect, the invention provides use of a thermal energy connector in the transfer of thermal energy between at least two heat pipes

[0027] Systems according to some embodiments of the invention can be characterised by comprising any of the connectors described herein, and those connectors can be further characterised by comprising any of the connector sockets described herein. Similarly, the methods and uses of embodiments of the invention can also be further characterised by the use of any of the connectors or sockets described herein.

[0028] Particular embodiments of the invention will now be more fully described by way of example, with reference to the drawings, of which:

Figure 1 shows a typical prior art heat pipe for use with various embodiments of the invention;

Figure 2 shows a first embodiment of a system of the invention;

Figure 3 shows a second embodiment of a system of the invention;

Figure 4 shows a third embodiment of a system of the invention;

Figure 5 shows a first embodiment of a thermal energy coupling arrangement of the invention in use;

Figure 6 shows a second embodiment of a thermal energy coupling arrangement of the invention;

Figure 7 shows a third embodiment of a thermal energy coupling arrangement of the invention;

Figure 8 shows a fourth embodiment of a thermal energy coupling arrangement of the invention;

Figure 9 shows a first embodiment of a thermal connector socket of the invention;

Figure 10 shows a first embodiment of a thermal connector socket of the invention in use;

Figure 11 shows a fifth embodiment of a thermal energy coupling arrangement of the invention.

[0029] Figure 1 shows a typical heat pipe 10 for use with various embodiments of the invention. A heat pipe consists of a sealed container 11 and contains a working fluid 12 in equilibrium between a liquid phase and a vapour phase. Heat pipe 10 has a first end A which can be placed next to any hot object or at any hot location, and a second end B which is intended to be placed at a cooler location in order to allow for the transfer of heat from the hot location to the cooler location. On heating the first end, the working fluid evaporates, forming a vapour and storing a large amount of latent heat. Increased pressure at the first end caused by vaporisation results in a flow of the vapour from the first end, through chamber 13 to the second end where it condenses and is absorbed by wick 14. On condensation, the vapour releases its latent heat thereby transferring the heat from position A to position B. Continued evaporation at the first end of the heat pipe results in condensed fluid at the second end being transported by capillary action back to the first end through wick 14. In this way, transfer of heat within the heat pipe is extremely fast and efficient. Heat pipes may also be constructed from, for example, copper. Such a heat pipe may have a longitudinally-grooved interior surface to provide sufficient surface area to induce capillary action without the addition of a wick material. In this case it may be typical for the hollow centre of the heat pipe to be vapour while liquid saturates all of the interior surface (even clinging to the top of the heat pipe).

[0030] A system 20 according to one preferred embodiment of the invention is shown in Figure 2. The system comprises a first heat pipe 10 having one end located at a hot location A, which may be, for example, a computer processor 21. Heat pipe 10 has a second end located at thermally intermediate location B. Location B is at a cooler temperature than location A. At location B the first heat pipe is slidably received in a first connector socket 23 of connector 22. Connector 22 provides for thermal and mechanical coupling of the first heat pipe 10 to a second heat pipe 102. A first end of second heat pipe 102 is slidably received in a second connector socket 24 of connector 22. In the embodiment shown, first heat pipe 10 and second heat pipe 102 are physically separated by a portion of connector 22. In this example, connector 22 is itself constructed from thermally conductive material and allows heat to pass from the first heat pipe 10 to the second heat pipe 102 by a conduction through the connector itself. Heat pipe 102 has a second end at a third location C which is cooler than both the intermediate location B and the hot location A. Location C can be positioned, for example, at a part of the housing of the computer or other device to be thermally managed, or can, for example, be located at a further thermal management device such as a heat sink 25.

[0031] In operation, heat from the heat source at location A (e.g. computer processor 21) heats the fluid at the first end of heat pipe 10 which evaporates to form a vapour. The vapour travels along heat pipe 10 towards the second end at location B which is at a lower temperature. Accordingly, heat is transferred from location A to location B where it is transferred from first heat pipe 10 to second heat pipe 102 via connector 22. Heat pipe 102 is then heated at its first end located at location B (and slidably received in socket 24 of connector 22). Fluid in heat pipe 102 is vaporised at the first end and travels to the second end of heat pipe 102. At the second end of heat pipe 102 (cooler location C) the vapour condenses releasing its latent heat thereby transferring the heat from connector 22 at location B to the cool location C, for example, heat sink 25.

[0032] Figure 3 shows an alternative embodiment of the invention comprising a system 30 substantially as depicted in Figure 2 but further comprising an additional connector 222 at location C in place of heat sink 25. In this embodiment, the second end of the pipe 102 is slidably received in connector socket 31 of connector 222.

Connector 222 contains a further connector socket 32 and the system further comprises a third heat pipe 103 having a first end slidably received in connector socket 32. A second end of heat pipe 103 is located at a yet cooler location D which may be a further heat management device such as a heat sink or, for example, housing of a device requiring thermal management 33. In this embodiment, location D is at a lower temperature than location C which is at a lower temperature than location B which in turn is at a lower temperature than location A. In this way, heat passes from location A via heat pipe 10 to connector 22 at location B. Heat is then transferred to heat pipe 102 and travels from location B to location C where it is received by connector 222. Heat is transferred via connector 222 to heat pipe 103 and is further transferred to location D where it is released to a further thermal management device or, for example, to the housing of the device being managed.

[0033] In the embodiment shown in figure 3, connector sockets 31 and 32 of connector 222 are oriented perpendicular to each other in one plane. In other embodiments, systems may contain connectors with any other arrangement of connector sockets. For example, sockets might be arranged at any angle with respect to each other in any plane. In this way, it is possible to devise systems of the invention suitable for transferring heat over long distances or around particular geometries, for example, around corners, using standard size and shape heat pipes. This is advantageous, for example, in a portable (laptop) computer, where space is frequently at a premium. It will, of course, be appreciated that bent heat pipes also work, and these are likely to be preferable in a mass-produced item where a custom heat pipe can be made to suit the geometry, assuming its complex geometry doesn't prevent it from being positioned within the system during manufacture.

[0034] Figure 4 shows a third embodiment of a system 40 wherein a first heat pipe 10 has a first end at a first (hot) location A and a second end slidably received in a connector socket 41 of a connector 20 at cooler location B. System 40 further comprises a second heat pipe 102 having a first end slidably received within a connector socket 42 of connector 20 and a second end at a cold location C. Additionally, system 40 further comprises a third heat pipe 103 having a first end slidably received within a connector socket 43 of connector 20 and having a second end at a further location D. Locations C and D are at a lower temperature than intermediate location B which is at a lower temperature than hot location A. Locations C and D may be at the same or different temperatures. In a heat pipe, heat flow will begin from any hot area to all colder areas. The hot area will acts as an evaporator and the colder areas will act as condensers by comparison. Intermediate areas on a single heat pipe will act as condensers relative to the hottest area and as evaporators relative to the coldest areas (because each area is in an equilibrium between the vapour phase and the liquid phase). Heat pipes 102 and 103 may connect at their second ends (at locations C and D) to further thermal management devices such as heat sinks or parts of the housing of the device to be thermally managed. In this embodiment, heat at location A is transferred via heat pipe 10 to intermediate location B where it is transferred via connector 20 to both heat pipes 102 and 103. Heat is then dissipated in more than one direction (along the length of heat pipes 102 and 103 where it is released at locations C and D (for example at different points of the housing of the device)).

[0035] System 40 allows for further freedom in design of thermal management architecture and is not limited to the T-shaped arrangement shown in Figure 4. Connector sockets 41, 42 and 43 can be designed to be at any orientation with respect to each other in any plane, allowing for heat dissipation from location B to any point as required. Additionally, further connector sockets may be provided in connector 20 to allow for multi point heat dissipation in several directions. Of course, it is also possible for more than one hot device to be connected to the socket.

[0036] Figure 5 shows a first embodiment of a thermal energy coupling arrangement in use. The thermal coupling arrangement comprises connector 50 having first and second connector sockets 51 and 52 for slidably receiving first and second heat pipes (10 and 102). Connector sockets 51 and 52 are arranged such that in use heat pipes 10 and 102 are mechanically held in direct contact in an overlapping arrangement, thereby providing a flat thermal contact area 53 between the two heat pipes. This thermal contact area allows for direct thermal transfer between the first and second heat pipes and can also provide an electrical contact if the heat pipes are electrically conductive. In this embodiment, connector 50 may be thermally insulating or thermally conductive and may also provide an electrical insulator (although in an alternative embodiment connector 50 is electrically conductive).

[0037] The heat pipes are fixed in connector 50 by friction or by a lateral locking mechanism integral with connector sockets 51 and 52, for example, as described further hereinbelow.

[0038] An alternative embodiment of a thermal energy coupling arrangement is shown in Figure 6 and comprises connector 60 having first and second connector sockets 61 and 62 for slidably receiving first and second heat pipes. Connector sockets 61 and 62 are arranged such that in use heat pipes are held in an abutting relationship, but are separated by a part 63 of the connector 60. In this embodiment, the connector is made of a thermally conductive material and can, for example, be made of the same material as one or both heat pipes. Connector 60 is suitable for use with heat pipes having a rectangular, circular or any other shaped cross section, such as, hexagonal, pentagonal or even star-shaped. Connector 60 acts as a female connector with first and second heat pipes acting as male connectors to form the thermal energy coupling arrangement of various embodiments of the invention, for example, those shown in Figures 2 and 3.

[0039] Figure 7 shows a further embodiment of a thermal energy coupling arrangement which comprises connector 70 having first, second and third connector sockets 71, 72 and 73. In use, connector sockets 71, 72 and 73 slidably receive first, second and third heat pipes. In the embodiments shown, the sockets are oriented to form a T-shape, thereby allowing for heat dissipation in two directions from a single heat source, for example, as depicted in Figure 4. The first, second and third heat pipes are physically separated by a portion of the connector 74 although it is envisaged that a direct contact between any two or three of the second and third heat pipes could be accommodated by varying the design and relative locations of connector sockets 71, 72 and 73. Such design variations are well within the ability of the appropriately skilled person. In addition, further modifications to the orientation of the various connector sockets with respect to each other is also within the ability of the skilled person allowing for the design and manufacture of a range of different connectors thereby providing a very flexible system allowing for individual design of thermal management architecture using standard shaped and sized heat pipes.

[0040] Figure 8 shows a variation of the embodiment of the thermal energy coupling arrangement shown in Figure 7. Connector 80 comprises three connector sockets 81, 82 and 83 in a T-shaped orientation, although other orientations may be designed by the person skilled in the art. Connector socket 81 has a larger bore than sockets 82 and 83 allowing, in use, for a bigger diameter heat pipe to be slidably received therein. In this embodiment, connector 80 allows for the design or a thermal management system wherein very rapid heat transfer away from a first hot location can be achieved by virtue of a large diameter heat pipe. The heat can then be further dissipated to further cooler locations via second and third heat pipes slidably received in sockets 82 and 83. This embodiment is advantageous in the design of thermal management systems where rapid heat loss from a heat source is required, but where space or organisational constraints do not allow for a large diameter heat pipe to connect directly the heat source and the ultimate cool location. In practice, it will more often be the surface area of the socket connection that will be more important. Such thermal management systems would find application in small devices, for example, portable computers. Other applications may be in, for example, a cube structure with air-cooling. If it was not known in which direction the air-flow would normally take, stagnant air may occur in certain orientations. By supplying fin heat sinks on at least two perpendicular sides and connecting both to the heat device by heat pipes joined by connector 80 it would be possible to ensure that under more conditions there would be adequate cooling.

[0041] The embodiment of the invention shown in Figure 8 can be varied according to standard design variations that would occur to the skilled person. For example, connector sockets 82 and 83 may be of different or the same diameters and the orientation of the first, second and third sockets can be altered to provide a range of connectors allowing for appropriate thermal management system design.

[0042] Figure 9 shows an embodiment of a thermal energy connector socket of the invention. Connector 90 comprises a connector socket 91 having one or more recesses 92 located on the inner surface of socket 91 at or close to the mouth of the socket. Recess 92 contains a ball bearing 93 held by resilient means such that its surface is biased to extend beyond the inner surface of socket 91. The ball can be deflected into recess 92 by external pressure, for example on introduction of a heat pipe into socket 91 (see figure 10).

[0043] Figure 10 shows the connector 90 of Figure 9 in use with heat pipe 10. Heat pipe 10 comprises an annular groove located proximal to one end thereof such that on insertion into connector socket 91, ball 93 is received in the annular groove 111 thereby holding the connector pipe tightly within connector socket 91.

[0044] The embodiment of FIG. 11 shows two hot locations D and E connected by a heat pipe 104. In this example it will be assumed that the heat pipe has a circular cross-section for ease of explanation. Both ends of the heat pipe 104 are at relatively hot locations and act as evaporators. A portion of the heat pipe 104 between its two ends is in thermal contact with a thermal connector 230 at location F at a cooler intermediate temperature by its contact with an aperture of circular cross-section or a roughly semicircular groove in which the heat pipe 104 is held. If a semicircular groove is used, there may also be a clamping section which completes the circular cross-section for optimum heat transfer. The section at location F acts as the condenser. A second heat pipe 105 is thermally connected to heat pipe 104 by insertion of one end into a thermal socket on the thermal connector 230 as previously described. This end becomes the evaporator of the second heat pipe 105. A second end of the second heat pipe 105 at a still cooler location G forms the condenser of the second heat pipe 105.

[0045] Similarly to all the embodiments described above, the same system will work to heat up locations D and E if location G is hotter.

[0046] An alternative embodiment in the same vein contains slots or apertures for middle sections of both heat pipes (or more than two heat pipes). This allows a long transfer section where heat can transfer between the two heat pipes, which will act as the condenser on one pipe and the evaporator on the other. The slots could be parallel to maximise the length of the transfer region, which would be especially useful if the heat pipes are in direct contact, or they could be perpendicular or in any other orientation.

[0047] The above described embodiments are not intended to be limiting to the scope of the application, and variants within the scope of the invention are contemplated. For example, connectors of the invention might have further thermal energy sockets for receiving further heat pipe plugs, and the dimensions and orientation of those sockets can be altered in any way to provide connectors allowing for different system architectures. Any arrangement allowing for thermal conductivity between two heat pipes is envisaged and heat pipes may be mechanically held in direct contact or indirect contact (but thermally connected) in any orientation. Any of the connectors can be electrically insulating or conductive and the connectors can further be adapted to provide sockets for any other type of connection, for example, electrical connections, optical connections, mechanical motion connections or fluid connections. Any combination of the above is envisaged and any of the systems, methods or uses of the invention can include any of the connectors described herein.

[0048] In a further alternative, the end of one heat pipe is fitted with a male connector (e.g. screw thread), and can be inserted into a female connector (e.g. tapped apeture) at the end of a second heat pipe. Similarly any other form of connector is possible, for example a connector having both male and female components. Sockets (female) and protrusions (male - for connection to female connectors integrated into the end of a heat pipe) as previously described may be included in system elements such as heat sinks and heat sources to enable heat pipes to be easily attached and removed. It could also be useful to incorporate a pluggable heat-pipe connector in optical modules, on printed circuit board or in other systems. Furthermore, thermal transfer compounds can be provided at the connector terminations to improve the conductance of the thermal contact.

[0049] Thus, the invention provides new systems and new components for such systems for the efficient and rapid heat dissipation required in thermal management of numerous devices. The invention takes advantage of the rapid heat dissipation available from heat pipes but overcomes the inconvenience of being limited to standard sized and shaped heat pipes. Using the connectors of the invention, standard heat pipes can be used to build up complex architectures for thermal management where prior to the invention it was necessary to have heat pipes custom built if the desired design fell outside the range of available standard heat pipes.

Claims

1. A system for transferring thermal energy between locations at different temperatures, the system comprising a first heat pipe (10) having a first portion at a hotter location and a second portion at a thermally intermediate location; a second heat pipe (102) having a first portion at said thermally intermediate location and a second portion at a cooler location; and a connecter (22) thermally and mechanically coupled to the second portion of the first heat pipe and to the first portion of the second heat pipe, wherein thermal energy is transferred directly or indirectly between the two heat pipes.

2. A system as claimed in claim 1, wherein said system comprises at least a third heat pipe (103) having a first portion at the thermally intermediate location, thermally coupled to said connector, and a second portion at either said hotter or said cooler location or at a further hotter or cooler location.

3. A system as claimed in claim 1 or claim 2, wherein said system comprises a second connector (222) at said first or further cooler location, and at least a third heat pipe (103) having a first portion thermally and mechanically connected to said second connector, and a second portion at a still further cooler location.

4. A system as claimed in any one of claims 1, 2 or 3, wherein said system comprises a second connector (222) at said first or further hotter location, and at least a third heat pipe (103) having a first portion thermally and mechanically connected to said second connector, and a second portion at a still further hotter location.

5. A thermal energy coupling arrangement (60) having at least two connectors, each connector comprising a connector termination (61) for coupling to a heat pipe having a complementary connector termination, whereby thermal energy is transferred directly or indirectly between the two heat pipes.

6. A thermal energy coupling arrangement as claimed in claim 5, wherein the connector termination is a plug and socket termination.

7. A thermal energy coupling arrangement as claimed in claim 6, wherein at least one of the connectors includes a plug termination.

8. A thermal energy coupling arrangement as claimed in either claim 6 or claim 7, wherein at least one of the connectors includes a socket termination.

9. A thermal energy coupling arrangement as claimed in any one of claims 5 to 8, further comprising means for mechanically holding each of the heat pipes in position.

10. A thermal energy coupling arrangement as claimed in any one of claims 5 to 9, which provides thermally conduction between the at least two connectors.

11. A thermal energy coupling arrangement as claimed in any one of claims 5 to 10, wherein said coupling arrangement is thermally insulating.

12. A thermal energy coupling arrangement (50) as claimed in any one of claims 5 to 11, wherein said first and second heat pipes are mechanically held in direct contact with each other thereby allowing direct thermal energy transfer between said heat pipes.

13. A thermal energy coupling arrangement (60) as claimed in any one of claims 5 to 12, wherein said heat pipes are mechanically held in position and are physically separated by a part (63) of said arrangement (60).

14. A thermal energy coupling arrangement (70) as claimed in any one of claims 5 to 13, further comprising at least a third connector (73) for coupling to a third heat pipe.

15. A thermal energy coupling arrangement as claimed in any one of claims 5 to 14, further comprising at least one further connectors for providing one or more further connections selected from an electrical connection, an optical connection, a mechanical motion connection or a fluid connection or any combination thereof.

16. A thermal energy coupling arrangement as claimed in claim 15, wherein said further connector provides an electrical connection.

17. A thermal energy coupling arrangement (50) as claimed in claim 15 wherein said at least two connectors hold said heat pipes (10, 102) in direct contact thereby allowing for direct electrical conduction between said heat pipes.

18. A thermal energy coupling arrangement as claimed in claim 15, further wherein said further connector comprises a connector termination (61) for coupling to a complementary connector termination for the provision of said further connection.

19. A system as claimed in any of claims 1 to 4 wherein said connector comprises a thermal energy coupling arrangement of any one of claims 5 to 18.

20. A thermal energy connector having a socket (91) for receiving at least one heat pipe plug and means for mechanically holding it in position to enable thermal energy to be transferred to or from the heat pipe.

21. A thermal energy connector having a plug (91) for insertion into at least one heat pipe socket and means for mechanically holding it in position to enable thermal energy to be transferred to or from the heat pipe.

22. A thermal energy connector (91) as claimed in either claim 20 or claim 21, wherein said means for holding said heat pipe mechanically in position comprises a friction or latching arrangement (92, 93), locking mechanism or thread arrangement.

23. A thermal energy connector as claimed in claim 22, wherein said latching arrangement comprises an O ring located in said socket.

24. A thermal energy connector as claimed in claim 22, wherein said latching arrangement comprises one or more ball bearings (93) located in said socket for interaction with said plug (10).

25. A thermal energy connector as claimed in claim 24, wherein said ball bearings (93) are spring loaded.

26. A thermal energy connector as claimed in any of claims 20 to 25, further providing direct or indirect thermal contact with a second heat pipe coupled to a second thermal energy connector.

27. A system as claimed in any of claims 1 to 4 or 19, wherein said connector comprises a thermal energy connector as defined in any of claims 20 to 26.

28. A system as claimed in claim 27, wherein said connector (91) comprises a latching arrangement comprising one or more ball bearings (93) located in said socket and an annular groove (111) around said plug (10), for interaction with said ball bearings.

29. A thermal energy coupling arrangement as claimed in any of claims 5 to 18, wherein said a connector termination of said connector comprises either a socket or a plug as defined in any one of claims 20 to 26.

30. A method for transferring thermal energy between locations at different temperatures, the method comprising providing a first heat pipe (10) having a first portion at a hotter location and a second portion at a thermally intermediate location; providing a second heat pipe (102) having a first portion at the thermally intermediate location and a second portion at a cooler location; and providing a connecter (22) thermally and mechanically coupled to the second portion of the first heat pipe and to the first portion of the second heat pipe, wherein thermal energy is transferred directly or indirectly between the two heat pipes.

31. A method as claimed in claim 30 wherein said connector (22) comprises a thermal energy coupling arrangement according to any of one of claims 5 to 18.

32. A method as claimed in claim 30 or claim 31 wherein said connector (22) comprises a thermal energy connector (91) as defined in any one of clams 20 to 26.

33. Use of a thermal energy connector (22) in the transfer of thermal energy between at least two heat pipes (10, 102).

34. A use as claimed in claim 33 wherein said thermal energy connector (22) comprises a thermal energy coupling arrangement according to any of one of claims 5 to 18.

35. A use as claimed in claim 33 or claim 34 wherein said thermal energy connector (22) comprises a thermal energy connector (91) as defined in any one of claims 20 to 26.

36. A heat pipe having a connector termination integrated thereon for connecting to a complementary connector termination on another heat pipe or on a thermal energy connector.

37. A heat pipe according to claim 36, wherein said connector termination comprises either a plug or a socket termination.

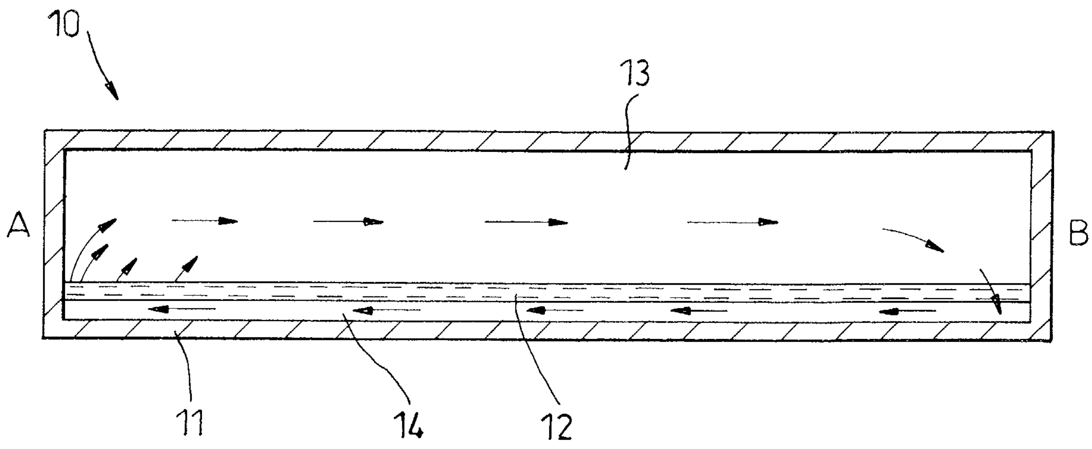

Fig. 1

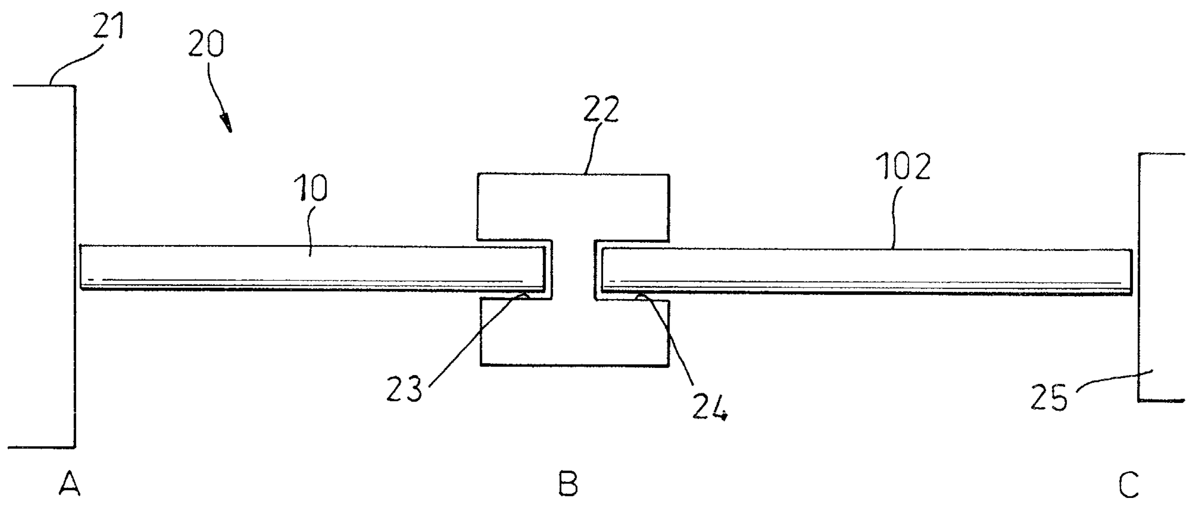

Fig. 2

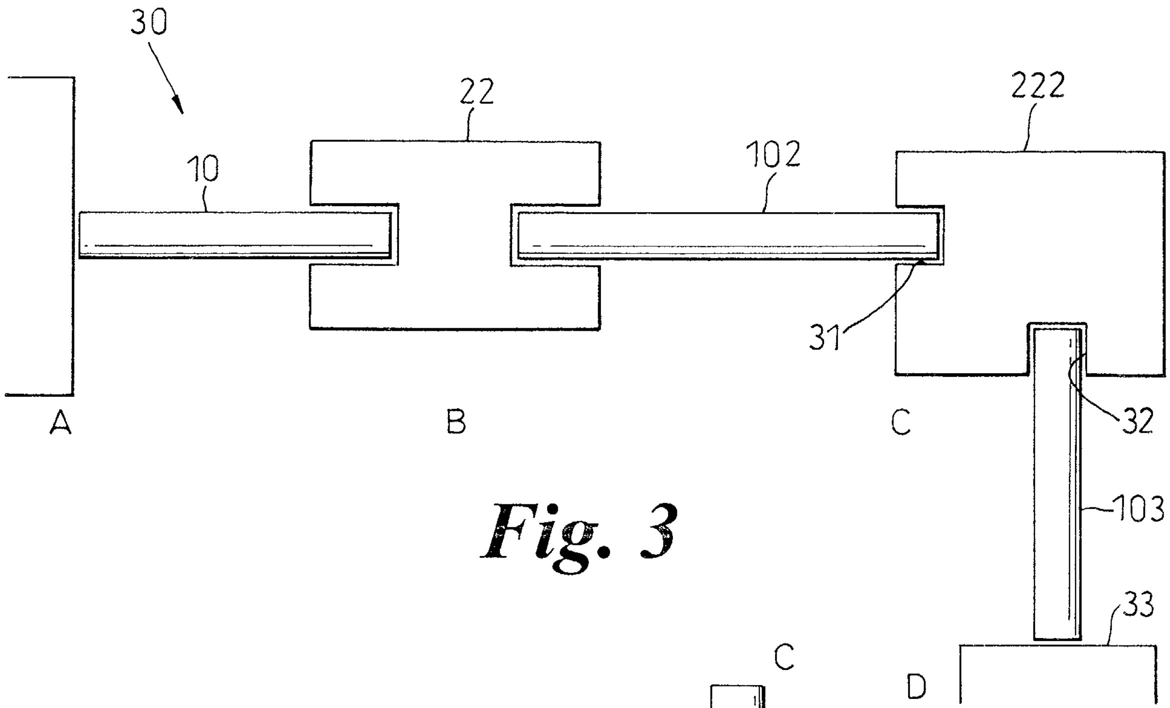

Fig. 3

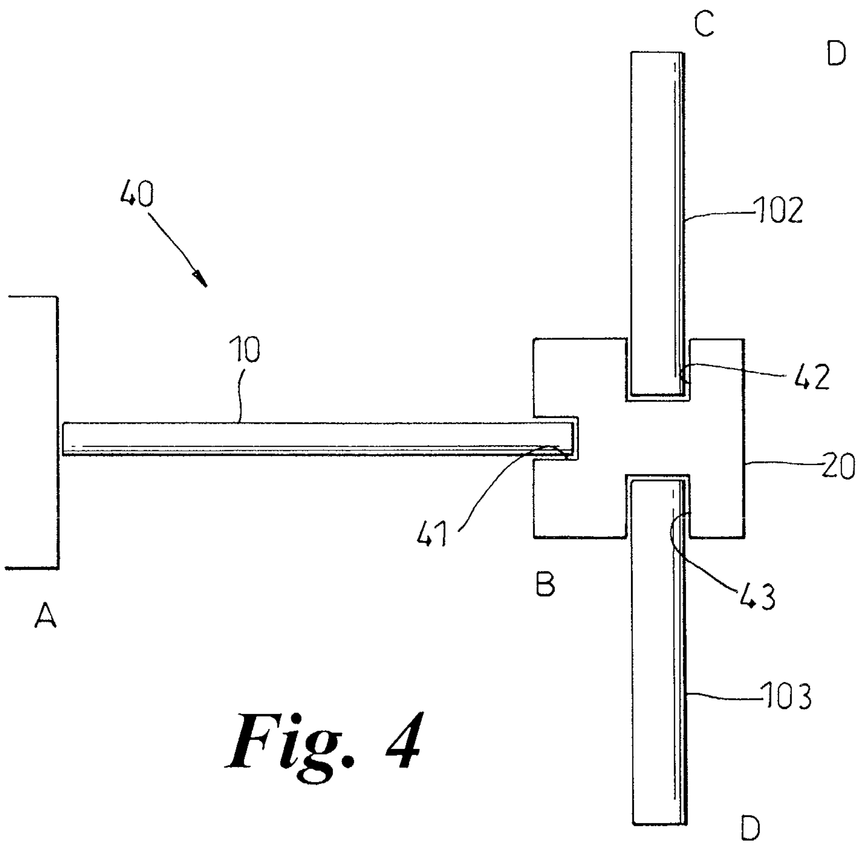

Fig. 4

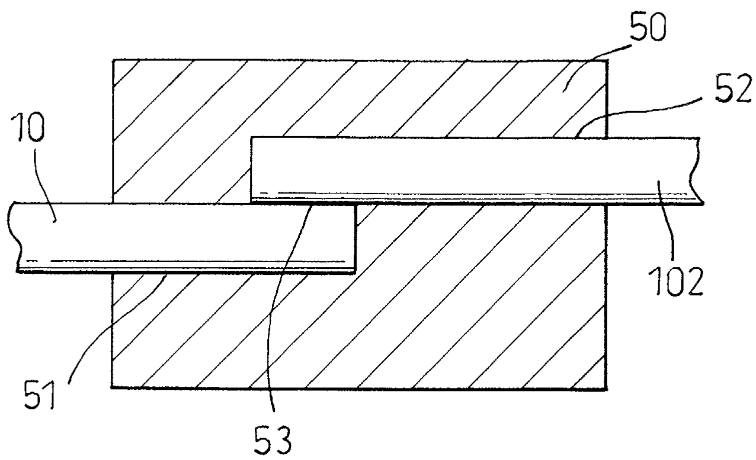

Fig. 5

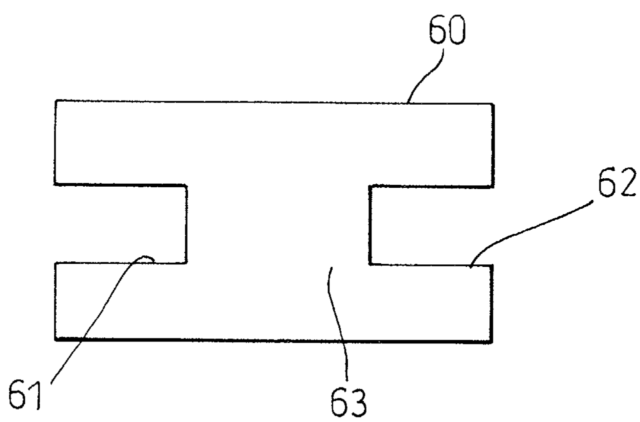

Fig. 6

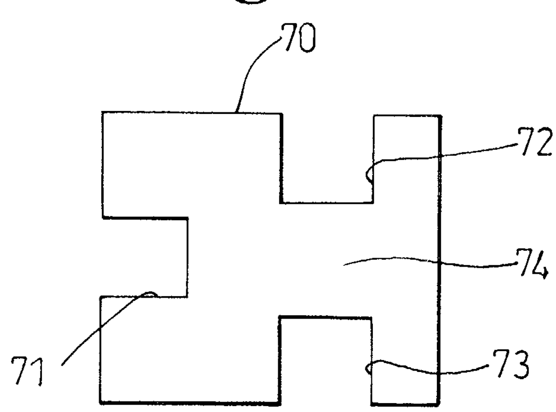

Fig. 7

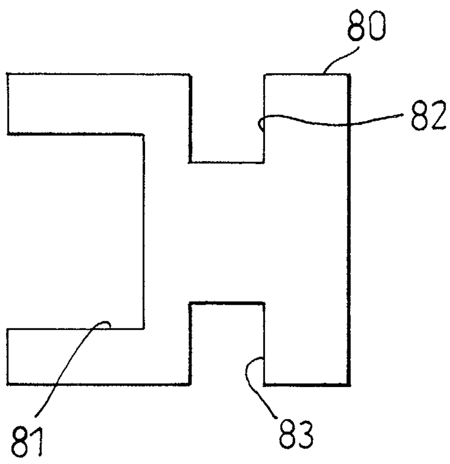

Fig. 8

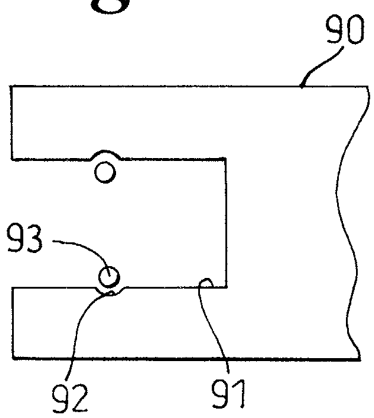

Fig. 9

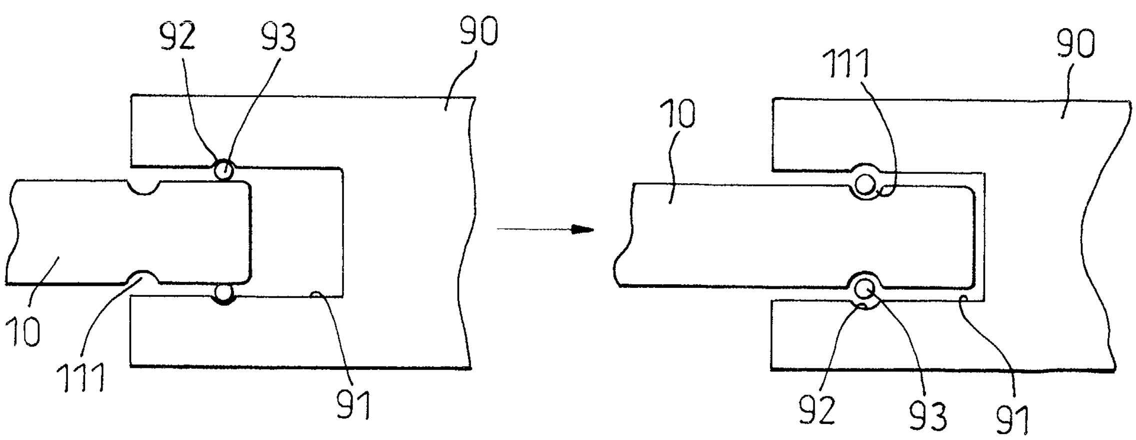

Fig. 10

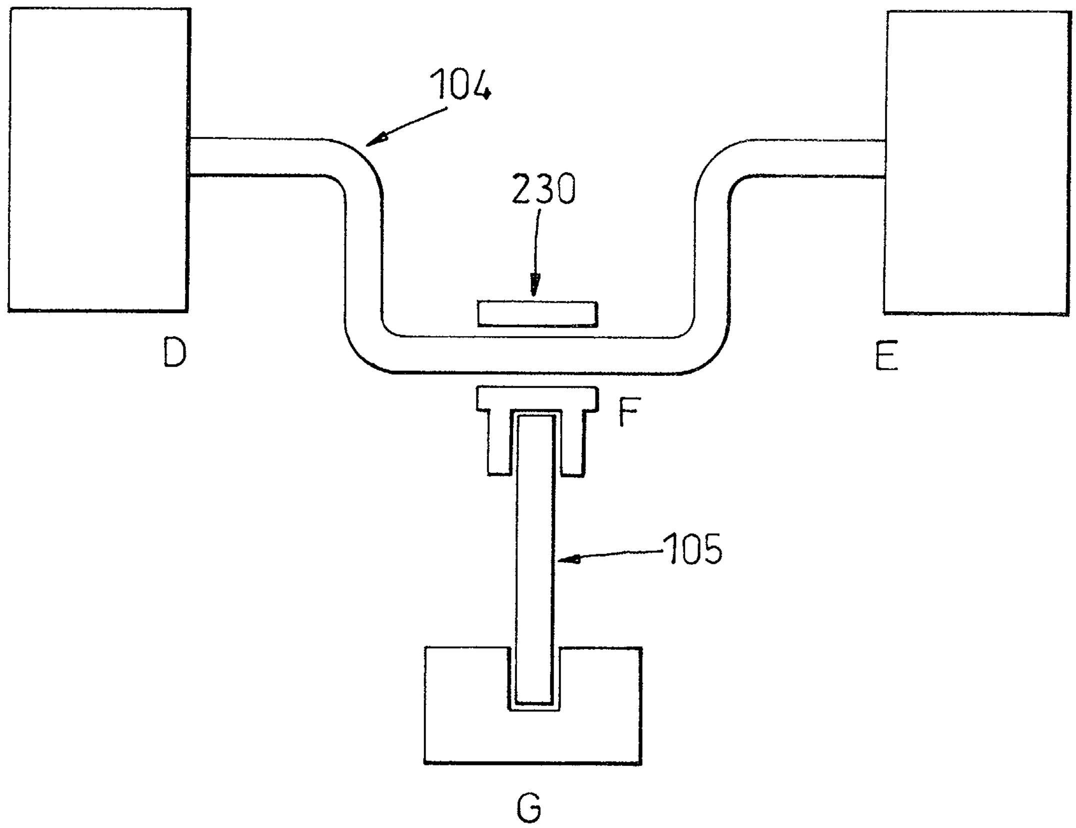

Fig. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 01 30 9403

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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)
X	PATENT ABSTRACTS OF JAPAN vol. 005, no. 166 (M-093), 23 October 1981 (1981-10-23) -& JP 56 091189 A (NEC CORP), 23 July 1981 (1981-07-23)	1,2,5,6, 8-11,13, 14,19, 20,22, 26,27, 29-35	F28D15/02
Y	* abstract; figures *	3,4,7, 16,17, 23-25,28	
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	* column 2, line 40 - column 4, line 21; figures 1,2 *		
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 09, 13 October 2000 (2000-10-13) -& JP 2000 154983 A (FUJIKURA LTD), 6 June 2000 (2000-06-06) * abstract; figures *	1,5,6, 8-10,12, 19,20, 26,27, 29-37	TECHNICAL FIELDS SEARCHED (Int.Cl.7) F28D
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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	25 April 2002	Van Dooren, M

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EUROPEAN SEARCH REPORT

Application Number
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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	25 April 2002	Van Dooren, M

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