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(54) **HEAT DISSIPATION SYSTEM FOR SOLARLOK PHOTOVOLTAIC INTERCONNECTION SYSTEM**

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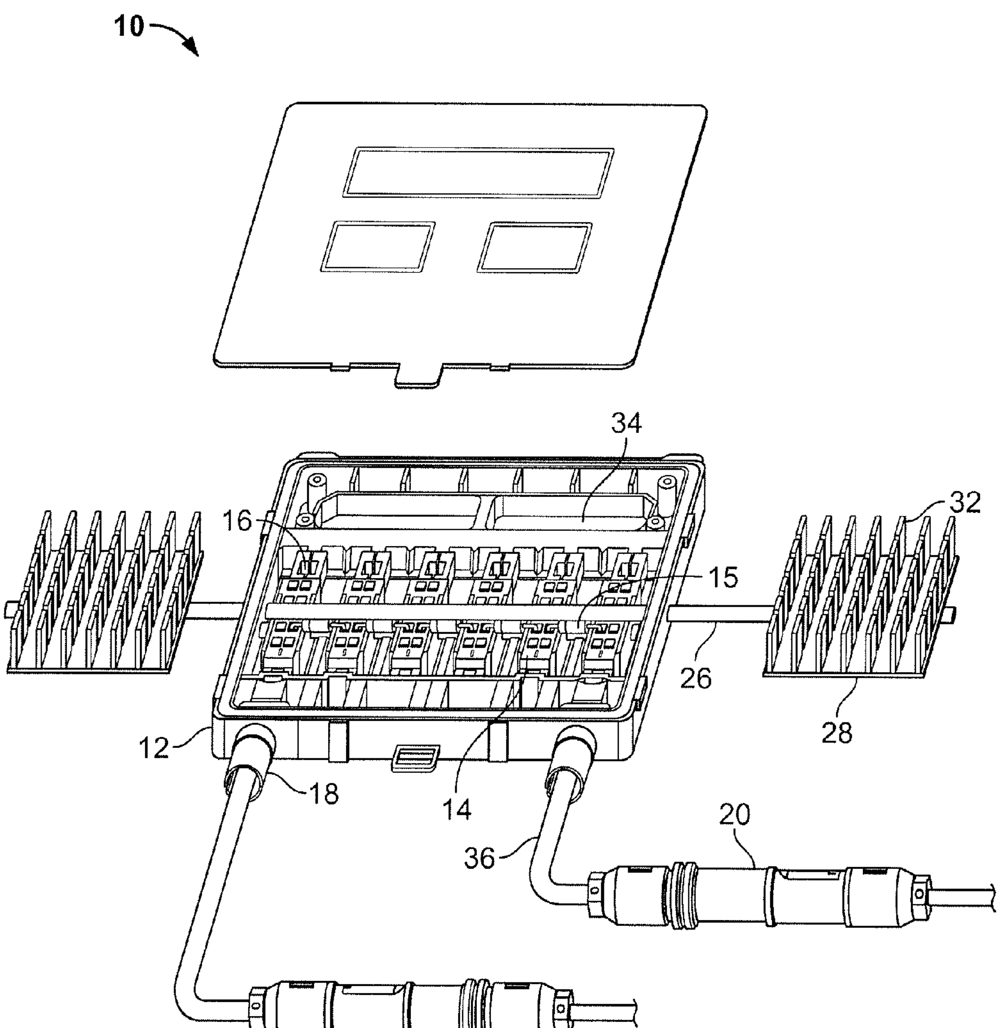
(57) **ABSTRACT**

A heat dissipation system for a photovoltaic array (PV) interconnection system includes an enclosure containing one or more diode elements. A heat pipe system has heat sinks attached to one or both ends. The heat pipe passes through the enclosure in thermal contact with the diode assemblies. Cooling fins are arranged on the heat sink such that heat from the heat pipe is conducted into the fin and the fin dissipates the heat to the ambient atmosphere outside of the enclosure to cool the components within the enclosure.



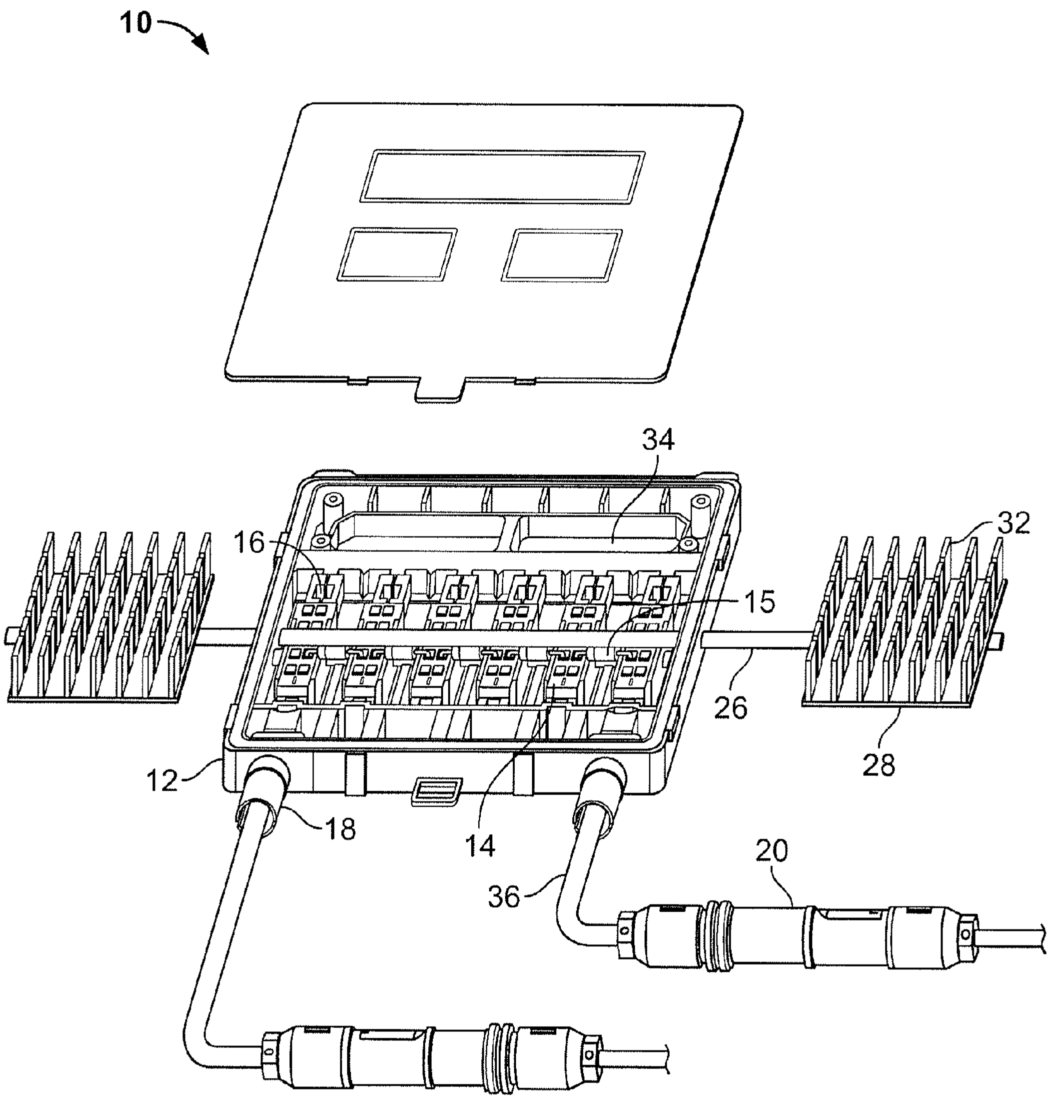


FIG. 1

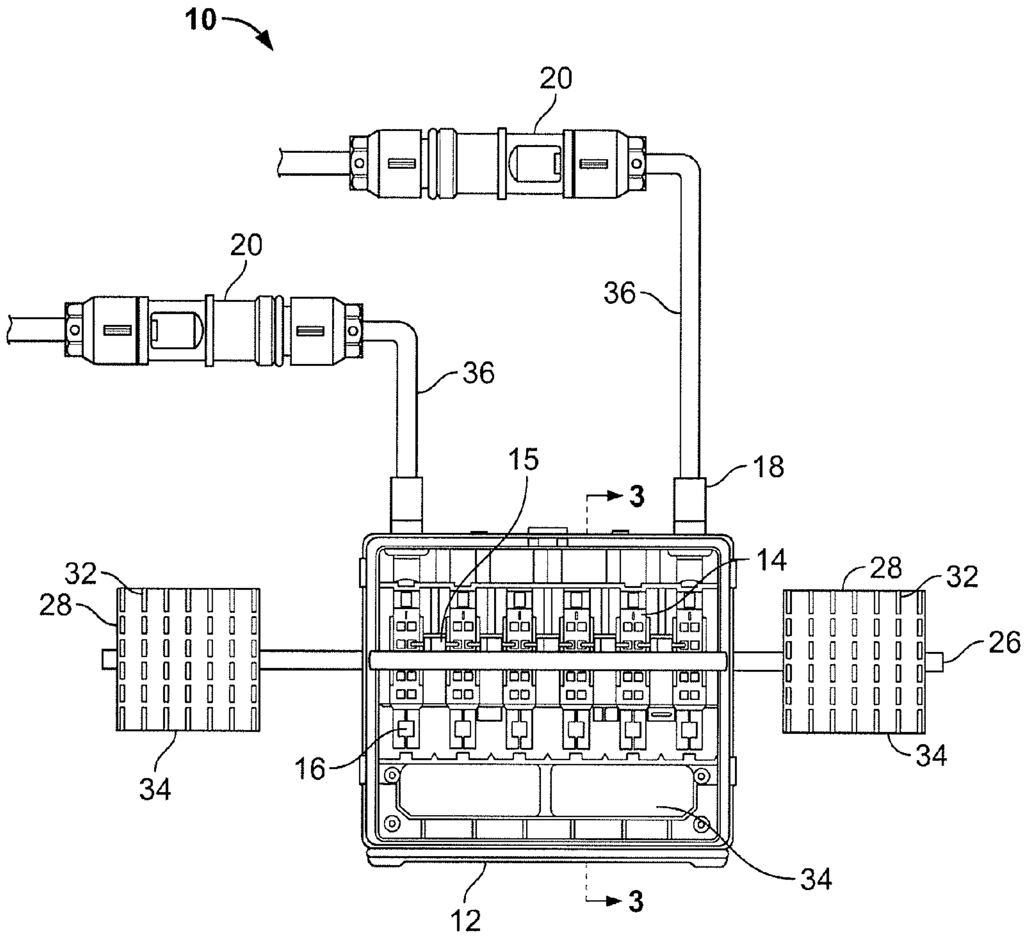

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FIG. 2

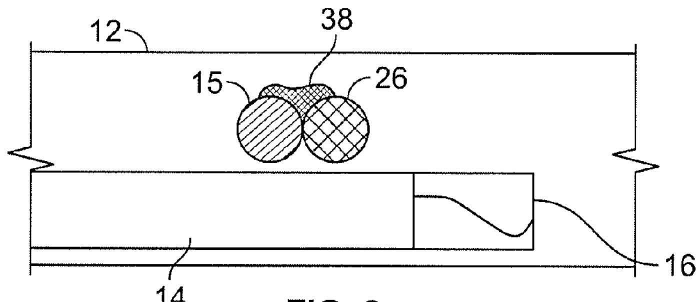
12
38
15
26
16
14

FIG. 3

HEAT DISSIPATION SYSTEM FOR SOLARLOK PHOTOVOLTAIC INTERCONNECTION SYSTEM

FIELD OF THE INVENTION

[0001] The present invention is directed to a heat dissipation system for a photovoltaic array interconnection system, and more particularly to a connection box having a heat pipe for dissipating heat generated by internal components of the photovoltaic interconnection system.

BACKGROUND OF THE INVENTION

[0002] Existing photovoltaic (PV) interconnection systems lack efficient means for expelling heat generated from internal system electronic components, e.g., diode assemblies, to the exterior of the interconnection enclosure. This inability to expel the heat more rapidly causes a risk of heat rise sufficient to damage the enclosure and/or the internal components of the interconnection system.

[0003] Heat pipes are devices that are well known, for example, for use in space technology, dehumidification and air conditioning applications, and laptop CPU cooling systems. "Heat pipe" is a term that refers to a closed pipe containing a working fluid such as water which is present in two phases, liquid and gas. A heat pipe consists of a sealed aluminum or copper container whose inner surfaces have a capillary wicking material. The heat pipe, however, has the ability to transport heat against gravity by an evaporation-condensation cycle with the help of porous capillaries that form the wick. The wick provides the capillary action that returns the condensate to the evaporator. In operation, a portion of the heat pipe is placed over the hot spot and thereby serves as an evaporator, while a portion remote from the evaporator serves as a condenser, which returns liquid to the evaporator. The evaporation and condensing cool the component efficiently until the heat load becomes so great that the working fluid evaporates faster than the condensing fluid can return to the evaporator, at which point the evaporator "dries out". Once the evaporator dries out, the increase in temperature with increased power is orders of magnitude greater than before the dry out point was reached. The process of moving heat is essentially reduced to conduction by the thin walled tube. The basic components of a heat pipe are the container, the working fluid, and the wick (or capillary) structure. The container isolates the working fluid from the outside environment, is leak-proof, maintains the pressure differential across its walls, and enable transfer of heat to take place from and into the working fluid. The container material is non-porous to prevent the diffusion of vapor, and has high thermal conductivity to minimize the temperature drop between the heat source and the wick. The wick generates capillary pressure to transport the working fluid from the condenser to the evaporator, and distributes the liquid around the evaporator section to any area where heat is absorbed by the heat pipe. Internally, a liquid that enters the pores of the capillary material under its own pressure, thereby saturating all internal surfaces. Applying heat at any point along the surface of the heat pipe causes the liquid at that point to boil and enter a vapor state. When that happens, the liquid absorbs the latent heat of vaporization. The vaporized liquid has a higher pressure, and moves inside the sealed container to a portion of the container at a lower temperature, where it condenses. Thus, the gas expels the latent heat of vaporization and moves heat from the input end to the output end of the heat pipe.

[0004] Heat pipes are used in air-conditioners, refrigerators, heat exchangers, transistors, capacitors, etc. Heat pipes are also used in laptop computers to reduce the working temperature for better efficiency. They are essentially maintenance free. Heat pipes have proven to be an accepted method of providing thermal control in notebook computers and portable personal computers (PCs) to transfer and dissipate CPU-generated heat selectively throughout the system without adversely impacting temperature-sensitive components.

[0005] Therefore, there is a need for an interconnection system for a PV array employing sophisticated heat dissipation techniques to accommodate increasing power requirements of the internal system components.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to a heat dissipation system for a photovoltaic array interconnection system. The heat dissipation system includes an enclosure, one or more diode elements, a heat pipe system, and one or more heat sinks attached either end of the heat pipe system. The enclosure includes apertures for inserting power cables. The heat pipe system is in thermal communication with the diode elements, and the heat pipe system penetrates the walls of the enclosure between the diode and the heat sink. The heat sink is disposed on an exterior of the enclosure. Cooling fins are arranged on the heat sink such that heat from the heat pipe is conducted into the fins, and heat from the fins is dissipated to the ambient atmosphere on the exterior of the enclosure.

[0007] In another aspect, the present invention is directed to a connection box for a photovoltaic array interconnection system. The connection box includes an enclosure, one or more diode elements, a heat pipe system, and one or more heat sinks attached either end of the heat pipe system. The enclosure includes apertures for inserting power cables. The heat pipe system is in thermal communication with the diode elements, and the heat pipe system penetrates the walls of the enclosure between the diode and the heat sink. The heat sink is disposed on an exterior of the enclosure. Cooling fins are arranged on the heat sink such that heat from the heat pipe is conducted into the fins, and heat from the fins is dissipated to the ambient atmosphere on the exterior of the enclosure.

[0008] An advantage of the present invention is increased heat dissipation characteristics for connection boxes in a photovoltaic array interconnection system.

[0009] Another advantage is the use of heat pipe technology for eliminating heat generated by interconnection components in a connection box.

[0010] Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a perspective view of the PV interconnection system of the present invention.

[0012] FIG. **2** is a sectional plan view of the PV interconnection system.

[0013] FIG. 3 is a cross-sectional view of the PV interconnection system taken along the lines 3-3 in FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The heat dissipation system of the present invention is applied to an interconnection system for photovoltaic (PV) arrays, and preferably to a roof mounted PV array, although the PV arrays may be independently mounted on frames, building facades or other configurations.

[0015] Referring to FIGS. 1-3, the interconnection system is generally designated as 10. A connection box 12 houses the components of the interconnection system 10, including a series of electrical connectors 14 for connecting conductors of the PV array (not shown). Connectors 16 are mounted to rail assemblies 14. Up to six rail assemblies 14 per connection box 12 is the preferred arrangement, although more than six rail assemblies 14 may be enclosed within a connection box suitable for larger configurations. The rail assemblies 14 provide mechanical support for the connectors 14. Connectors 16 are electrically isolated from the diode assemblies 15.

[0016] The connection box 12 has cable couplers 18, and an aperture or apertures 34 disposed on the underside of the box 12 in the area opposite of the cable couplers 18. The cable couplers 18 are sealed penetrations for the external connection cables 36 that interconnect to other interconnection systems [not shown] in order to form parallel or series wiring configurations for the power system. The cable couplers 18 seal the interior of the connection box 12 from water or other liquids, as well as dirt and dust, while allowing the cables 36 to enter the connection box 12. The cable couplers 18 are designed for high voltage and high current carrying capacity, and preferably conform to the established International Protection (IP) standard IP-67, for sealing requirements in the photovoltaic industry. External plug connectors 20 provide disconnect means for isolating the connection box 12 from the other connection boxes in the power system. Proper mating of the cable couplers 18 is ensured by polarity keyed housing, fully shrouded contacts, and squeeze to release connection system. It should be understood that the connection box 12 also may include additional interconnection system components, for example, diode assemblies, jumpers, printed circuit boards, etc., which are omitted from the figures for simplicity.

[0017] The heat pipe 26 extends through the connection box 12 in thermal contact with all of the diodes 15. The diodes 15 are suspended between the rail assemblies 14. The diodes 15 may have a semicircular recess (not shown) conforming to the outer diameter of the heat pipe 26. The recesses are configured to receive the heat pipe 26 transversely in the connection box 12, so as to maintain thermal conductivity between the heat pipe 26 and the diodes 15. The heat pipe 26 is preferably bonded to the diodes 15 with thermally conductive epoxy or adhesive 38. Alternately, the heat pipe may be embedded in an overmolded cover which mates with the diode 15 when attached to the box portion 12. The heat pipe 26 penetrates the connection box 12 on opposite sides. There is a heat sink 28 attached to either or both ends of the heat pipe 26. The heat sinks 28 are also preferably bonded to the heat pipe 26 with a thermally conductive adhesive material. Alternate means for bonding the heat pipe 26 with the heat sink 28 may be employed, for example, embedding the pipe in the heat sink 28, threaded connections, soldering or brazing. The heat sinks 28 may be any type of conventional heat sink. Preferably the heat sinks 28 include a plurality of cooling fins 32 that provide expanded fin surface area and airflow paths for optimum heat transfer. The cooling fins 32 are connected by a common base portion 32. The heat sinks 28 expel the heat to the ambient environment outside of the connection box 12, for example, the outdoor air surrounding an array of PV roof tiles. The liquid contained within the heat pipe 26 condenses and is returned by capillary action to the inside of the connection box, and the cycle is continuously repeated, thereby efficiently removing greater heat than can be passively radiated through the surfaces of the connection box 12.

[0018] In some applications requiring greater heat dissipation, more than one heat pipe 26 with heat sinks 28 may be installed, for example, where the diode assemblies 15 may be arranged in tandem or in multiple rows, where a single heat pipe 28 cannot contact all of the diode assemblies. Also, the heat pipe 26 may be configured in a variety of non-linear shapes, for example, U-shape, W-shape or S-shape, where the heat pipe 26 is configured for a similarly configured diode arrangement.

[0019] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

1. A heat dissipation system for a photovoltaic array interconnection system comprising:
 an enclosure, at least one diode element, a heat pipe system and at least one heat sink attached to at least one end of the heat pipe system, the enclosure including at least one aperture for inserting power cables;
 wherein the heat pipe system is in thermal communication with the at least one diode element, and the heat pipe system penetrating at least one wall of the enclosure between the diode and the heat sink, the heat sink being disposed on an exterior of the enclosure; and at least one cooling fin arranged on the heat sink such that heat from the heat pipe is conducted into the fin and the fin dissipates the heat to an ambient atmosphere on an exterior of the enclosure.

2. The system of claim 1, wherein the heat pipe system penetrates the enclosure at a first and a second opposing sides

3. The system of claim 2, wherein both ends of the heat pipe system being attached to one of the heat sinks.

4. The system of claim 1, wherein the diodes and the heat sinks are bonded to the heat pipe system by a thermally conductive adhesive.

5. The system of claim 1, wherein the heat pipe system is bonded with the heat sink by one of the following: embedding the pipe in the heat sink, threading the heat pipe system into the heat sink, soldering or brazing.

6. The system of claim 1, wherein the heat sinks having a plurality of fins connected by a base portion in thermal communication therewith, the fins arranged on the base portion to provide airflow paths for transferring heat from the heat sink to the ambient air.

7. The system of claim 1, wherein the heat pipe having an internal liquid, a wick and a container, arranged such that the

liquid is repeatedly condensed by the heat sink, returned by capillary action to an interior of the enclosure, and evaporated within the enclosure by heat absorbed from the diodes.

8. The system of claim **1**, wherein the diode elements being arranged in tandem in a plurality of rows, and having one heat pipe system and at least one heat sink for each row of diode elements.

9. The system of claim **1**, wherein the heat pipe system being configured in a non-linear shape corresponding to a nonlinear configuration of diode elements.

10. The system of claim **9**, wherein the nonlinear shape is selected from a U-shape, a W-shape or an S-shape.

11. The system of claim **1**, wherein the enclosure includes a plurality of electrical connectors for connecting conductors of a PV array.

12. The system of claim **11**, wherein the enclosure also includes a plurality of cable couplers comprising sealed penetrations for the external connection of electrical cables.

13. The system of claim **12**, wherein cable couplers have high voltage and high current carrying capacity, and are in conformance with the International Protection (IP) standard IP-67.

14. The system of claim **1**, wherein the at least one aperture is disposed on the underside of the enclosure in the area opposite of the cable couplers.

15. The system of claim **1**, wherein the enclosure also includes at least one additional component, the additional component selected from the group consisting of: diode assemblies, jumper wires or printed circuit board.

16. The system of claim **1**, wherein the heat pipe system extends through the enclosure in thermal contact with all of the diode assemblies.

17. A connection box for a photovoltaic array interconnection system comprising:

an enclosure, at least one diode element, a heat pipe system and at least one heat sink attached to at least one end of the heat pipe system, the enclosure including at least one aperture for inserting at least one power cable;

wherein the heat pipe system is in thermal communication with the at least one diode element, and the heat pipe system penetrating at least one wall of the enclosure between the diode and the heat sink, the heat sink being disposed on an exterior of the enclosure; and at least one cooling fin arranged on the heat sink such that heat from the heat pipe is conducted into the fin and the fin dissipates the heat to the ambient atmosphere outside of the enclosure.

18. The connection box of claim **17**, wherein the enclosure is a component of a solar energy roof panel system comprising an array of PV cells arranged as a roof mounted system for conversion of solar energy to electrical power.

19. The connection box of claim **19**, wherein the enclosure includes a plurality of electrical connectors for connecting conductors of a PV array.

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