A plurality of heat pipes in a shell receive concentrated solar energy and transfer the energy to a heat activated system. To provide for even distribution of the energy despite uneven impingement of solar energy on the heat pipes, absence of solar energy at times, or failure of one or more heat pipes, energy storage means are disposed on the heat pipes which extend through a heat pipe thermal coupling means into the heat activated device. To enhance energy transfer to the heat activated device, the heat pipe coupling cavity means may be provided with extensions into the device. For use with a Stirling engine having passages for working gas, heat transfer members may be positioned to contact the gas and the heat pipes. The shell may be divided into sections by transverse walls. To prevent cavity working fluid from collecting to the extensions, a porous body is positioned in the cavity.

19 Claims, 4 Drawing Sheets
SOLAR THERMAL ENERGY RECEIVER

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

TECHNICAL FIELD

This invention relates to solar heat collectors and is directed more particularly to a solar heat management system which collects, stores and evenly distributes solar heat to a utilization device such as a Stirling engine, for example.

Space vehicles generally rely on batteries and/or solar cells to provide needed electrical power. Such devices produce d-c electrical power which requires the use of ancillary electrical equipment such as d-c to d-c converters, inverters or the like to generate a-c power or stepped-up d-c voltages. Additionally, solar cell arrays, depending on the power needed, usually are very large in area. This parameter creates a drag problem for any vehicle orbiting at a distance from earth at which the atmosphere has more than minimal density. Thus, solar cell arrays large enough to generate sufficient power for a space station, for example, would produce an unacceptable magnitude of drag.

Large space vehicles such as a space station will use great amounts of electrical power. Studies have shown that for many applications solar dynamic power systems have distinct advantages over other power systems such as batteries and solar cells.

Solar heat can provide the energy for various Rankine and Brayton cycle systems to drive a-c generators. A Stirling engine driving an alternator appears to be one of the best systems. However, it is important that heat be distributed uniformly around the heater head of a Stirling engine. Thus, failure of one or more of the heat pipes of a solar dynamic system or uneven distribution of solar energy to the heat pipes must not significantly affect the uniform distribution of heat to the Stirling engine heater head. Additionally, a heat management system used with a Stirling engine for a space vehicle must provide heat in both the sun and shade portions of an orbit and be highly reliable. Furthermore, critical thermal stresses must be eliminated to avoid failure.

BACKGROUND ART

U.S. Pat. No. 4,335,578 to Osborn et al discloses a solar converter which transports solar heat via a secondary fluid to a heat exchanger which contains a primary working fluid. The secondary fluid is contained in the space between two concentric tubes which comprise a solar receiver and is then directed to the heat exchanger. The secondary fluid changes from a vapor to a liquid in the heat exchanger.

U.S. Pat. No. 4,421,102 to Posnansky et al teaches that heat distribution in gas containing quartz tubes can be improved by disposing transparent strips in the tubes, each strip absorbing a portion of solar radiation.

U.S. Pat. No. 4,706,740 to Mahkey discloses a ventable survivable heat pipe vapor chamber for disposing of excess heat aboard a spacecraft. Multiple heat pipes utilize a capillary of wicking action between them so that failure of one does not cause a disruption of the heat emission characteristics. Wedged grooves along the interior of the radiator cavity enhance condensation and allow for the rapid return of the working fluid to the wick.

U.S. Pat. No. 4,715,183 to Meijer et al discloses an external heating system for a heat engine such as a Stirling engine, which system permits thermal energy to be provided by solar energy or fuel combustion sources. In order that either source may be employed, there is provided a complexly shaped heat pipe evaporator section having an enclosed cavity for receiving solar energy and another section forming hollow fins, the section being exposed to hot combustion gases.

U.S. Pat. No. 4,738,304 to Chalmers et al discloses a heat radiator having multiple heat pipes. Sensors monitor the flow of heat transfer fluids in each of the pipes and control respective valves in each of the pipes. A sudden reduction in flow in one of the pipes would indicate a leak and the leaking pipe would be cut out of the system by closing valves at respective opposite ends of the pipe. Thus, leaks caused in the radiator of a space vehicle by impacting particles can be isolated to prevent loss of the system.

SUMMARY OF THE INVENTION

In accordance with the invention, multiple heat pipes are disposed in an insulated containment shell which has an aperture for receiving concentrated sunlight. Heat storage means are carried on the heat pipes which extend into a heat utilization device such as a Stirling engine heater head. Disposed between the heat storage means and the Stirling engine heater head is a heat pipe coupling cavity through which the heat pipes extend in heat exchange relationship. The heat pipe coupling cavity also includes legs which extend into the heater head. Thus, the heat pipe coupling cavity not only transfers heat between the heat pipes, but enhances heat transfer to the Stirling engine heater head.

In a preferred embodiment, finned members are disposed radially outwardly of the cavity legs in good heat transfer contact both with respective heat pipes and a pair of adjacent cavity legs. Gas to be heated passes over the fins.

In an alternate embodiment, tubular members encase the heat pipes through the heat coupling cavity and into the heater head. Longitudinal grooves in the outer surface of the tubular members within the heater head provide heating passages for the Stirling engine working gas.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is an axial section of a preferred embodiment of the solar dynamic power system embodying the invention;

FIG. 2 is a transverse section of the solar heat management system of FIG. 1 taken along the line 2—2;

FIG. 3 is a partial axial section taken along the line 3—3 of FIG. 2; and

FIG. 4 is an axial section showing an alternate embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Reffering now to FIG. 1, there is shown an insulated containment shell 10 having one end attached to a utilization device such as the heater head 11 of a Stirling engine. The other end of the shell 10 includes an aper-
of the coupling cavity and the transfer relationship therewith. In addition to thermally coupling the heat pipes by numerals which are the same as the numerals of FIG. 1, as shown, a plurality of heat pipes 13 are each partially embedded in the cylindrical heater head 11 at circumferentially spaced positions.

To enhance heat transfer from the heat pipes to the Stirling engine working gas, a finned heat transfer member 28 is disposed at each heat pipe in heat transfer contact with a significant portion of the circumference of the heat pipe. The heat transfer member may be made of any material having high thermal conductivity and a coefficient of expansion which will not cause unacceptable mechanical stresses in the system. Inconel is a preferred material.

A surface of each finned member 28 opposite the surface in contact with the heat pipe is in contact with adjacent leg members 16. Working gas from the chamber 20 is forced by the piston 21 shown in FIG. 1 into heat transfer passageways 19 where it passes over the fins of the finned members 28 to pick up thermal energy. This thermal energy will be transferred to regenerators (not shown) of the Stirling engine. The Stirling engine regenerators are not part of the invention, but function to reheat the Stirling engine working gas as part of the cycle of operation.

FIG. 3 is a longitudinal section of a portion of the solar powered thermal management system of FIG. 1 taken along the line 3-3 of FIG. 2. Parts in FIG. 3 corresponding to parts in FIGS. 1 and 2 are identified by the same respective numerals. As shown in FIG. 3, heat pipes 13 extend through the heat coupling cavity 15 into the heater head 11. The heat pipes 13 are sealed where they pass through the walls of the coupling cavity 15 by suitable means such as brazing or the like. The working fluid in cavity 15 transfers heat between the various heat pipes, with the heat being transferred from the hotter heat pipes to the cooler ones. As a result, all the heat pipes 13 where they engage the heater head 11 are at substantially the same temperature. Thus, whether one or more heat pipes become inoperative or whether some heat pipes receive more solar energy than others, thermal energy is supplied relatively uniformly around the heater head 11.

The cavity legs 16 which are lined with wicking 17 as discussed concerning FIG. 1 extend, as shown, into heater head 11. This arrangement greatly increases the transfer of thermal energy from the heat pipes to the heater head 11.

During operation of the Stirling engine, the working gas passes back and forth from chamber 20 to Stirling engine regenerators 29. The fins of the heat transfer member 28 disposed between the passage 19 and a respective heat pipe 13 additionally enhance the transfer of thermal energy from the heat pipes and from the legs 16 to the working gas.

FIG. 4 is an alternate embodiment of the invention in which the portion of the heat pipes delineated by the
The system of claim 5 and including a second transverse wall in said containment shell adjacent to said coupling cavity and separating the same from the thermal storage means.

7. The thermal management system of claim 4 wherein said heat utilization device is a Stirling engine having a heater head for receiving said heat pipes and said cavity legs, said heater head including a plurality of passageways for working gas to pass back and forth from a chamber to a regenerator, each passageway lying between a heat pipe and a leg extending from said heat pipe coupling cavity to receive heat from both.

8. The thermal management system of claim 7 wherein each passageway includes a high thermal conductivity member, said member having a first surface in contact with a heat pipe and a second surface opposite said first surface and comprised of fins, said body enhancing transfer of heat from the heat pipes to the working gas.

9. The thermal management system of claim 1 wherein said heat storage canisters on any heat pipe are in heat conducting contact with the heat storage canisters on at least one other heat pipe.

10. The thermal management system of claim 9 wherein there are at least three heat pipes with the heat storage canisters on any heat pipe being in heat conducting contact with the heat storage canisters on two heat pipes adjacent thereto.

11. The solar powered thermal management system of claim 1 wherein the position of each heat pipe within said coupling cavity and within said heat utilization device is encased in a tubular member which makes high heat conduction contact with said heat pipe and with said heat utilization device.

12. The system of claim 11 wherein said tubular member is disposed coaxially in a passageway of said heat utilization device and is provided with longitudinal grooves whereby heat is transferred to a gas flowing through the grooves to or from a second passageway perpendicular to said grooves.

13. The system of claim 12 wherein said heat utilization device is a Stirling engine having a heater head forming a chamber above a piston and including a regenerator in said first passageway, said second passageway communicating with said chamber.

14. A solar heat collecting, processing and distribution apparatus for providing thermal energy to a heat actuated system, said apparatus comprising:

2. The system of claim 1 wherein said heat pipe coupling means is a thin-walled cavity through which said heat pipes extend, said cavity being lined with a high temperature wick material and including a high temperature working fluid, said cavity essentially being a squat heat pipe.

3. The thermal management system of claim 2 wherein said heat pipe coupling cavity includes a plurality of legs which extend from a first wall of said cavity into said heat utilization device in heat transfer relationship, said legs being miniature heat pipes.

4. The thermal management system of claim 3 wherein a porous body is disposed in said cavity on said first wall from which the legs extend and between the legs to absorb excess working fluid thereby preventing flooding of the legs with working fluid.

5. The thermal management system of claim 1 and including a first transverse wall which separates said containment shell into a solar energy receiving section (22) and a solar heat processing section (23, 24, 25).
The apparatus of claim 14 wherein a porous body of superalloys and refractories is disposed in said squashed heat pipe to absorb any excess working fluid thereby maintaining a prescribed amount in said hollow, cylindrical members.

19. The apparatus of claim 14 wherein said heat actuated systems is a Stirling engine.
UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,113,659
DATED : May 19, 1992
INVENTOR(S) : Karl W. Baker and Miles O. Dustin

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby
corrected as shown below:

In Column 3, line 26, delete "spout" and substitute --squat--therefor.
In Column 5, line 39, delete ".".

Signed and Sealed this Twenty-eighth Day of September, 1993

Attest:

BRUCE LEHMAN
Attesting Officer

COMMISSIONER OF PATENTS AND TRADEMARKS