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.
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 d-c 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 space 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 application 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 face of the tubular members within 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.

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

Referring 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-
A plurality of heat pipes 13 are disposed in the shell 10 and extend from its apertured end to engage the heater head 11 in heat transfer relationship. Thermal storage canisters 14 are disposed on the heat pipes 13 to provide heat to the heat pipes 13 when insufficient sunlight is received through the aperture 12 as would occur during part of the orbit of a space vehicle.

Heat pipes are well-known and are lined with wicking material such as wire mesh or screen. The heat pipes and screen are made of a high temperature material, such as superalloys or the like, while the working fluid is Na or K but preferably is Na. The heat pipe coupling cavity 15 is cylindrical and parallel to shell 10 with a diameter much greater than its height. Because the cavity 15 contains working fluid and wicking 17, it is essentially a heat pipe and, because of its disproportionately small height or thickness to diameter ratio, may be termed a squat heat pipe. Its diameter is perpendicular to the longitudinal axis of the shell 10 so that spout heat pipe is disposed transversely in shell 10 as shown in FIGS. 1, 3 and 4.

The storage canister 14 is made of a high temperature superalloy material and contain a thermal energy storage material such as LiF/CaF which melts at about 1050° K. Energy storage is accomplished by melting and freezing of the thermal energy storage material in the canisters.

To the end that thermal energy will be transferred from hotter heat pipes to cooler ones and that thermal energy will be applied substantially uniformly to the heater head 11, there is provided a heat pipe coupling cavity 15 through which heat pipes 13 extend in heat transfer relationship therewith. In addition to thermally coupling the heat pipes 13, coupling cavity 15 increases the efficiency of heat transfer from the heat pipes 13 to the heater head 11 by means of legs 16 which extend into the heater head 11 to provide additional, short paths for transfer of heat from the heat pipes 13 via the cavity 15 to the heater head 11. The cavity 15 and the legs 16 are lined with a wicking material 17 which transports the working fluid of cavity 15 which, as in the case of the heat pipes 13, is preferably Na or an alternate, K. The cavity 15 and the wicking material are high temperature material such as superalloys, refractories or the like.

To prevent excess working fluid from collecting in the legs 16, an absorber 18 made of a porous material such as a porous body of Inconel is attached to the inner surface of the wall of cavity 15 from which legs 16 extend. Passageways in the heater head 11 are indicated by numerals 19 and allow the working gas from the chamber 20 above the piston 21 to heat regenerator elements (not shown) of the Stirling engine after picking up heat from heat pipes 13 and cavity legs 16.

Double ended arrows 22, 23, 24, 25 and 26 identify sections of the solar energy management system embodying the invention wherein 22 is the solar energy receiving end section, 23 is the thermal energy storage section, 24 is the heat pipe coupling cavity section, 25 is the interface between the heater head 11 and the legs 16 of the coupling cavity 15, and 26 is the head portion of a Stirling engine. Sections 23, 24 and 25 comprise a heat processing section. A transverse wall 31 is attached to cavity 15. The wall 31 serves to separate section 23 from section 24 as well as supporting the heat pipe coupling cavity 15.

Generally the shell 10, heat pipes 13, thermal storage canisters 14, cavity 15 and porous block 18 are all made of a single material. This provides materials compatibility which enhances welding and minimizes corrosion.

FIG. 2 is a transverse cross section of the solar dynamic system of FIG. 1 taken along the line 2-2. Parts in FIG. 2 which are the same parts as in FIG. 1 are identified 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
double ended arrows 24 and 25 is encased in respective tubular members 30. The tubular members 30 are in heat transfer contact with the heat pipes and are also heated by the working fluid of the coupling cavity 15. The tubes 30 are also in thermal contact with the heater 11 and, additionally, are provided with longitudinal grooves 32. These grooves allow the working gas flowing from chamber 20 to the regenerators 29 and back, to pick up heat from the tubes 30. Thus, the coupling cavity, the extension of the heat pipes 13, with the tubes 30 and the grooves 31 cooperate to uniformly and efficiently deliver thermal energy obtained from the sun to the heater head of a Stirling engine.

While the invention has been described for use with a Stirling engine in a space vehicle, it will be understood that a thermal management system embodying the invention may have terrestrial applications where solar energy must be collected, stored and distributed to a utilization device uniformly and with high efficiency.

It will be understood that the above described invention may be changed or modified without departing from its spirit and scope as set forth in the claims amended hereto.

We claim:

1. A solar powered thermal management system for collecting and storing solar energy and transferring it uniformly to a heat utilization device, said system comprising:
   an insulated containment shell having a first end including an aperture for receiving concentrated sunlight and a second end engaging a heat utilization device;
   a plurality of heat pipes extending from within said heat utilization device toward said first end of said shell to be subjected to concentrated sunlight, said heat pipes being connected to said heat utilization device in heat transferring relationship;
   thermal energy storage means disposed on said heat pipes to transfer heat stored therein to said heat pipes when the solar energy received is less than a predetermined amount; and
   heat pipe coupling means disposed between said heat energy storage means and said heat utilization device including an aperture for receiving concentrated heat whereby heat input to said heat utilization device is evenly distributed.
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 65 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).
said high thermal conductivity between said squashed heat pipe, said elongated heat pipes, said heat storage canisters and said heat actuated system providing substantially uniform heat timewise and physically to said heat actuated device.

15. The apparatus of claim 14 wherein the working fluid in said squashed and elongated heat pipes is Na.

16. The apparatus of claim 14 wherein said heat storage canisters contains LiF/CalF.

17. The apparatus of claim 14 wherein said squashed heat pipe includes a plurality of hollow, cylindrical members which extend into said heat actuated device to provide heat thereto thereby supplementing the heat provided by said heat pipes.

18. The apparatus of claim 17 wherein a porous body of material selected from the group of materials consisting 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