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**ES-HCE Drawings**

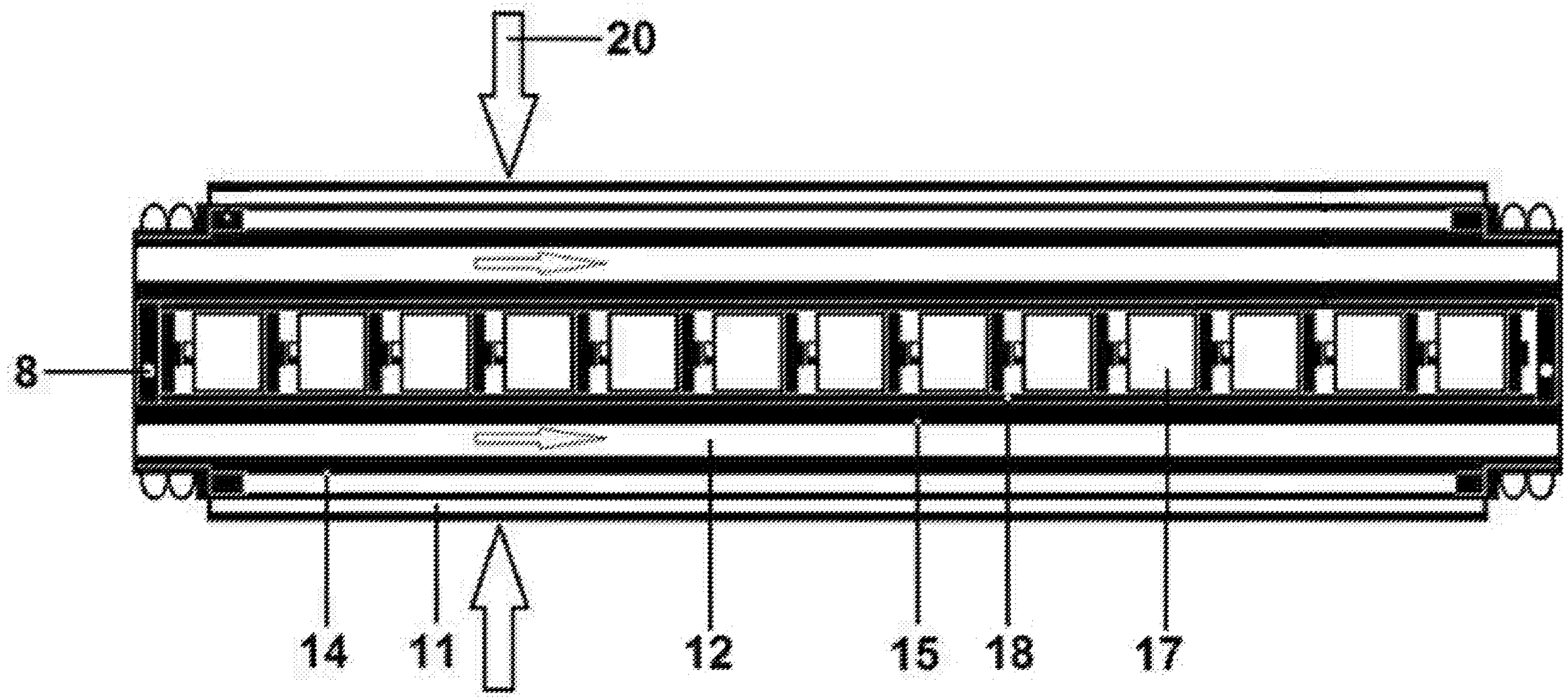


**Figure 1: Schematic showing the internal construction of the ES-HCE**

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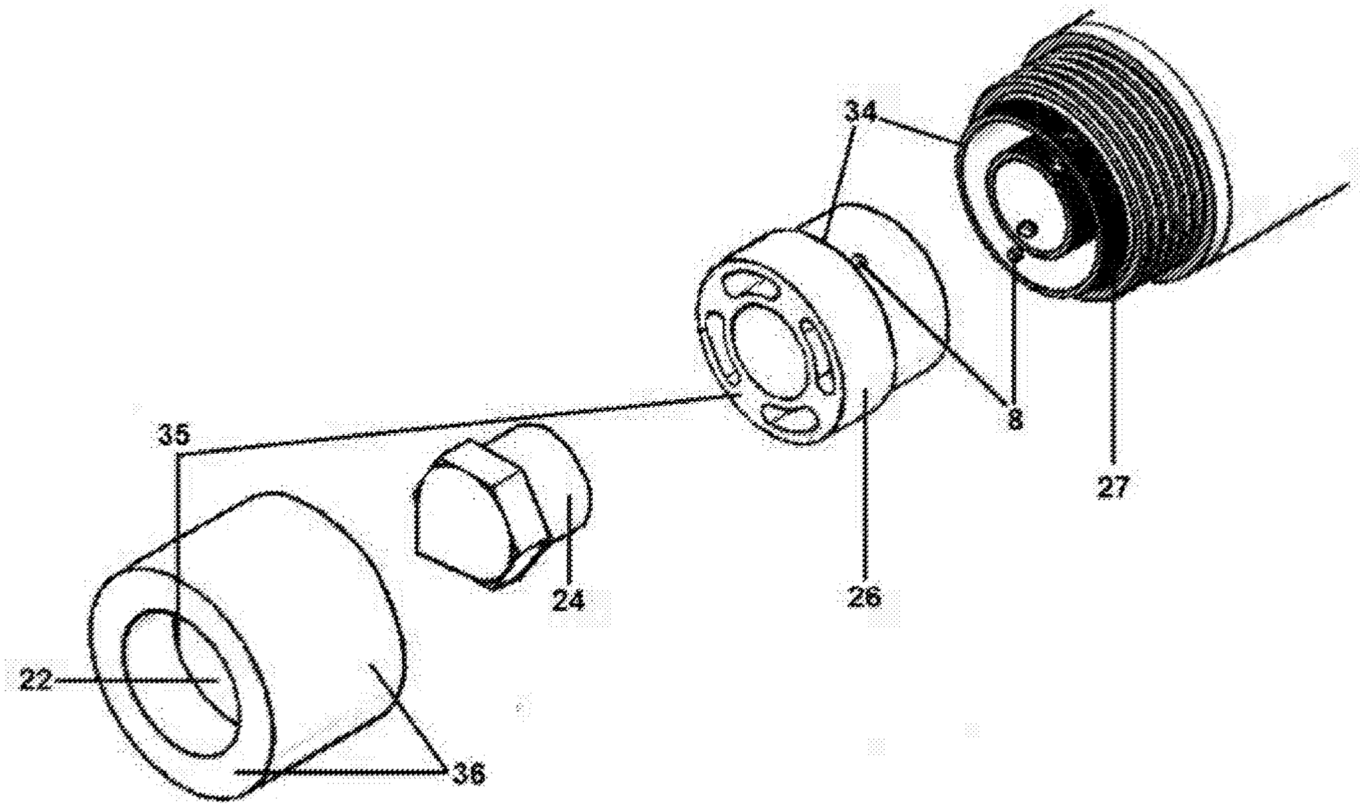


Figure 2: Schematic showing tube termination and interconnection

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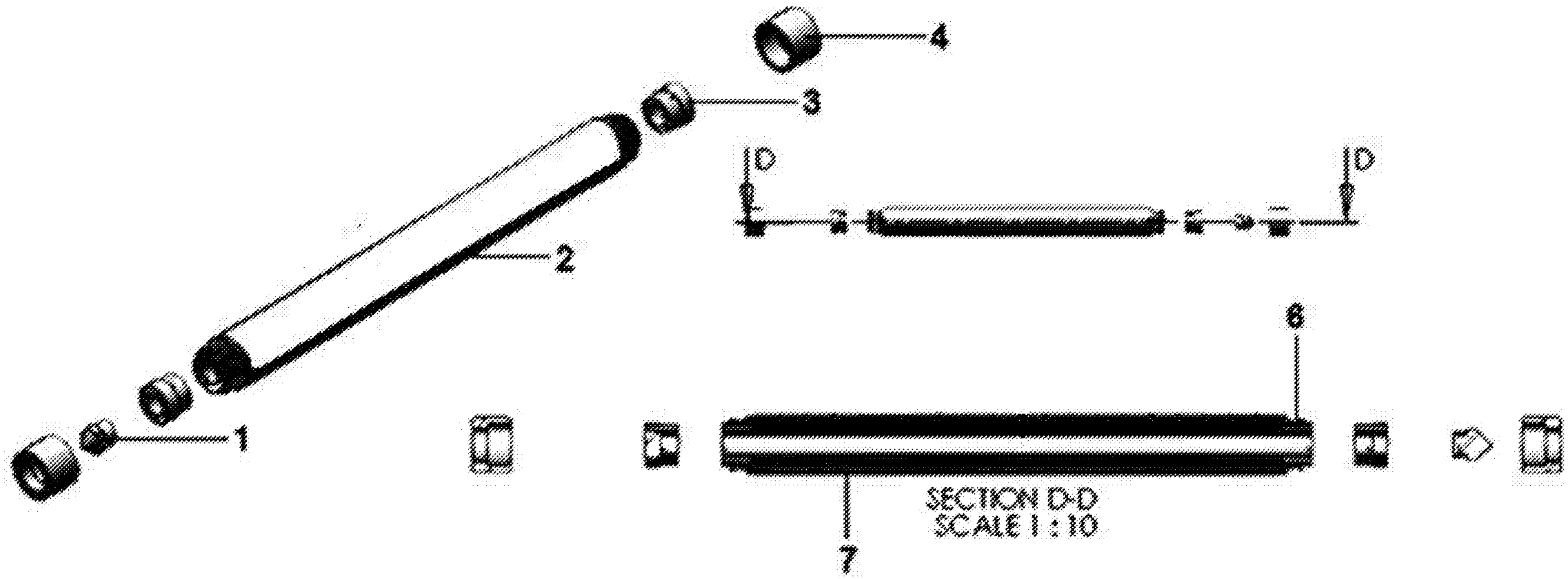


Figure 3: Exploded  and coss sectional view of ES-HCE components

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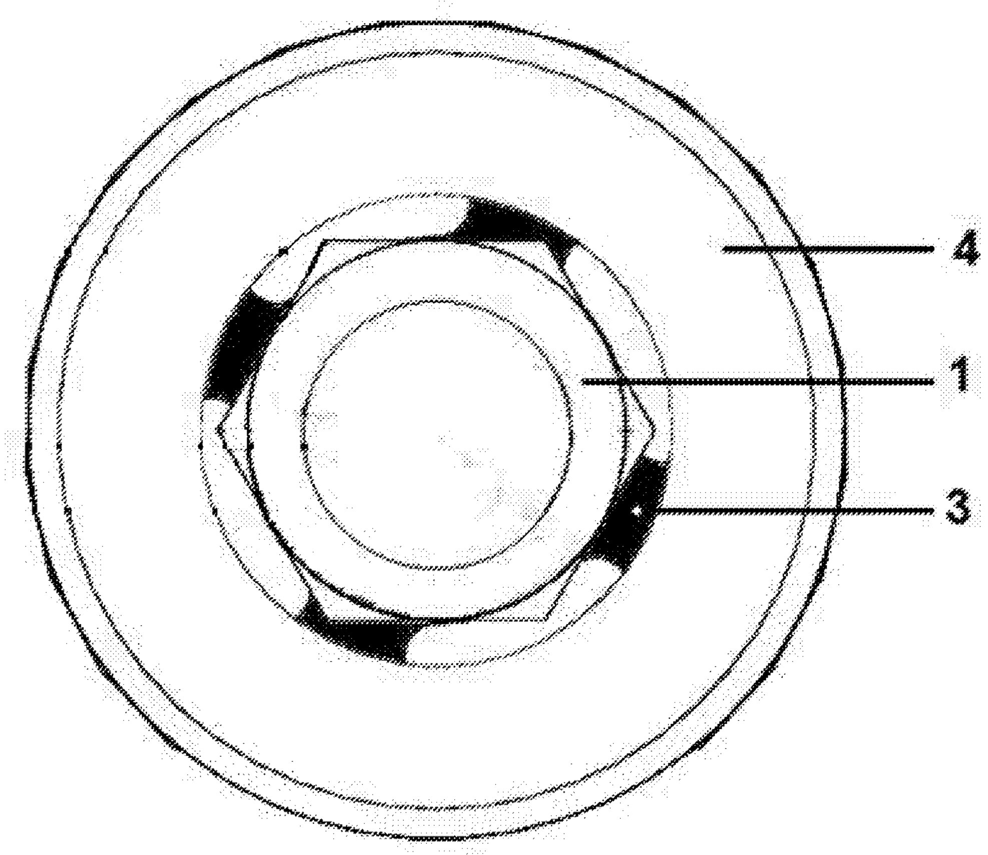


Figure 4: End view of the ES-HCE

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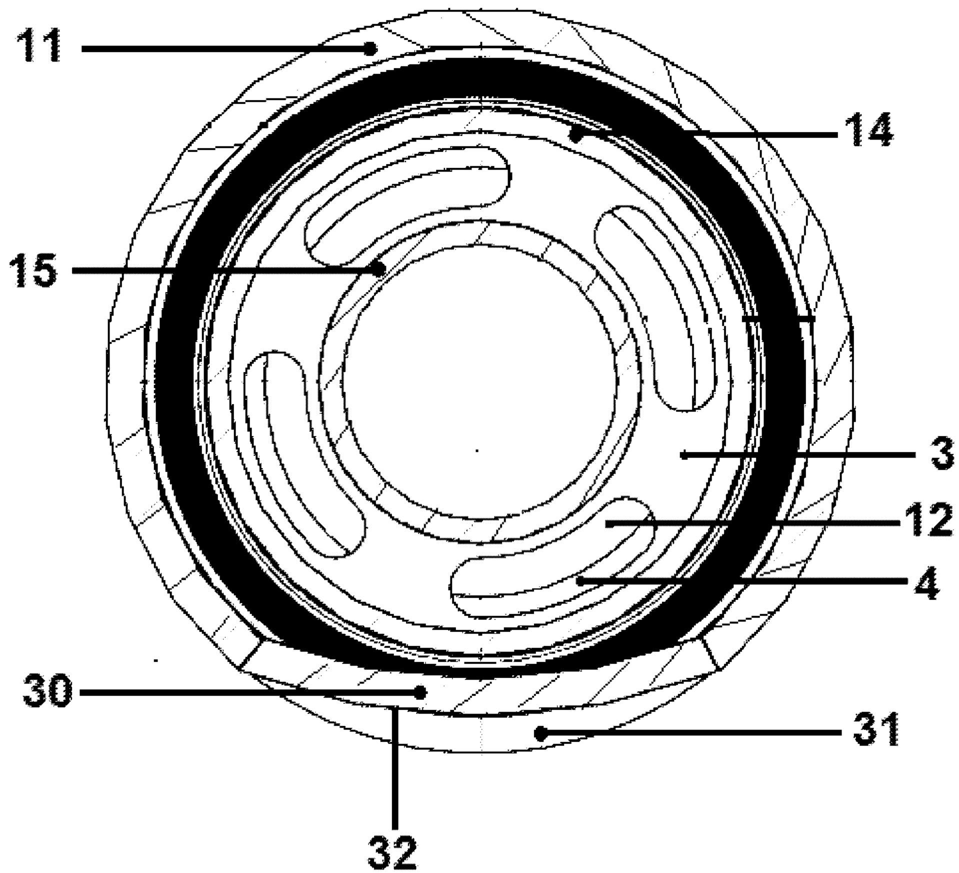
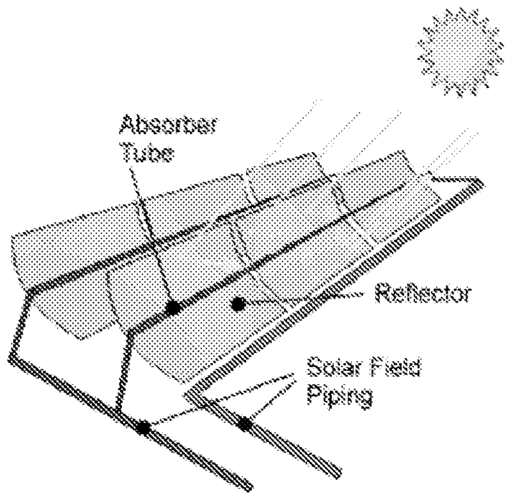



Figure 5: Cross sectional view of ES-HCE




**A Parabolic trough collector field (Source: NREL, USA)**

Title: Energy Storage Heat Collecting Element

Background to the invention

Concentrating solar power (CSP) power plants are the largest commercial producers of electricity from solar energy. The four main types of CSP plants are; Parabolic Trough Collector (PTC), solar tower, linear Fresnel and dish power plants. Of these four, parabolic trough collector (PTC) plants have the most proven track record along with a long and successful history of deployment which goes as far back as the 1980's. Parabolic trough plants consist of large fields of parabolic trough reflectors (mirrors) that concentrate solar radiation onto a central absorber tube or heat collecting element (HCE) in the focal axis of the reflector. The absorber tube heats up and heat energy is transferred through the absorber tube walls to heat transfer fluid flowing inside.

It is agreed by experts in the field that with the projected future increase of renewable power sources connected to the grid, there will be an increased need for these sources to be able to store energy due to the intermittent nature of renewable power sources, namely the sun.



Parabolic trough power plants traditionally store power in thermal form using hot and cold molten salt tanks, and this is a proven storage method. However since the energy is stored in thermal form, before it can reach the grid it has to be converted to electrical energy by the plant's power block. This time delay lessens the ability of the power plant to respond to ramping of demand from the grid, and therefore places great demand or electrical stress on the plant's ramping generators.

*Major benefits the invention could provide*

The main benefits that this invention could provide are:

- Energy is already in electrical form, therefore no thermal-electric conversion delay
- Lower conversion losses (power electronics losses lower that heat exchange losses)
- Better power quality of the power plant, better ramping response and voltage/frequency control
- Battery discharge heat during no-sun hours helps to provide freeze protection in solar fields with molten salts HTF.

<u>Description</u>

The ES-HCE (figure 1) is a special hybrid absorber that could provide a solution to this problem. It stores solar energy in electrical form in high energy density thermal batteries (17) placed inside the absorber (HCE) itself. These battery cells are electrically connected and controlled in series and/or parallel and may be sodium sulphur (NaS), Zebra, sodium nickel ($Na\text{-}NiCl_2$) or any other suitable thermal battery. They are called “thermal” because they must be heated up to certain operating temperature before they can be charged or discharged. These cells are currently being used to store electrical energy for wind farm applications and grid support because they can store 4-5 times more energy than a traditional lead acid battery in the same volume. In the ES-HCE, these thermal cells are “cylindrical”, like regular flashlight battery cells, possessing a positive (+) and a negative (-) terminal for electrical connection.

They are heated up in the ES-HCE by heat passing to them through a battery tube wall (15) from a heat transfer fluid (HTF) flowing in the system. The heat transfer fluid (HTF) which may be synthetic oil, mineral oil, an ionic fluid, steam/water or other appropriate fluid is heated up by solar heat absorbed through the absorber tube walls (14), which have a specially selected coating (27). Heat flow to and from the thermal cells is regulated by controlling the mass flow rate of the HTF and /or defocusing (moving out of line) the ES-HCE from the solar radiation using the tracking mechanism of the PTC. The ES-HCE also utilizes a borosilicate or similar transparent tube (11) with anti-reflective coating to cover the absorber tube (14) and prevent or lower convective heat transfer to the ambient.



Figure 1 shows a cross section of the ES-HCE. It can be seen that the ES-HCE is essentially a hybrid solar absorber with an inner battery tube (15) containing the thermal-electric batteries (17) and an outer absorber tube (14) that is heated by solar radiation. Between the inner battery tube and the outer absorber tube is defined an annular space (12) through which heat transfer fluid (HTF) flows for heating or cooling of the thermal batteries.

*<u>Tubes</u>*

The NaS cells are placed inside a steel or aluminium “battery tube” (15) for protection, while allowing effective heat transfer to the cells. It can be seen from figure 1 that a low cost ceramic tube (18) is placed between the NaS cells (17) and the battery tube (15), serving to electrically insulate the NaS cells from the battery tube, so as to prevent short circuiting. The battery tube (15) and the absorber tube (14) are spaced from each other by a special steel bush (3) which slips between them. The space (37) between the transparent cover (11) and the absorber tube (14) is evacuated of air, with a steel bellows mating this cover to the steel absorber tube via an appropriate hermetic sealing device. The transparent cover (11) for passing solar radiation (20) may be totally circular (31) or it may have a parabolic glass segment (30) built into it for reflecting visible solar spectrum onto a photovoltaic cell strip placed directly below the absorber under the normally shaded area. The reflection of the visible spectrum onto PV cells is achieved by coating the parabolic segment with a “cold mirror” coating (32). This cold mirror coating (32) passes the infrared and ultraviolet portions of the solar spectrum through the transparent parabolic segment for heating up the absorber tube (14), but reflects the visible part of the solar radiation downwards to a photovoltaic surface placed directly beneath and in line with the ES-HCE absorber.

*Tube termination and inter-connection*

The battery tube channel containing the cells and is enclosed by a special cap (1) which has a cylindrical bung (24) which may be threaded for screwing in, or interference fitted to ensure a leak proof seal. The cap (1) also has a cone shape at the other end for providing a more streamlined HTF flow characteristic in the flow channel. The steel bush sits inside an outer steel connector cap (4) with the bush face (26) mating with the connector cap face (22). There is a special set of battery wire holes (8) which must be aligned before the surfaces (34) are welded. It is important that the weld is leak free so as to prevent heat transfer fluid getting into the battery channel. The connector cap surfaces (36) may be adapted in any way required (machined or welded connection) to mate a given ES-HCE in series with another. A special compression spring or spring washer (19) serves to ensure that the cells are in firm electrical contact with each other.

## Claims

This invention applies to:

1. A solar heat collecting element comprising an inner tube, an outer tube surrounding the inner tube and defining an annular space between the tubes through which in use, heat transfer fluid can flow, the inner tube enclosing a plurality of thermal-electric batteries and the heat transfer fluid within the annular space providing heating or cooling of the thermal batteries.

2. A solar heat collecting element as outlined in claim 1, the heat transfer fluid (HTF) comprising at least one of a mineral oil, synthetic oil, molten salt, water/steam mixture, or an ionic fluid.