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(54) **THERMAL ENERGY STORAGE SYSTEM WITH HEAT ENERGY RECOVERY SUB-SYSTEM**

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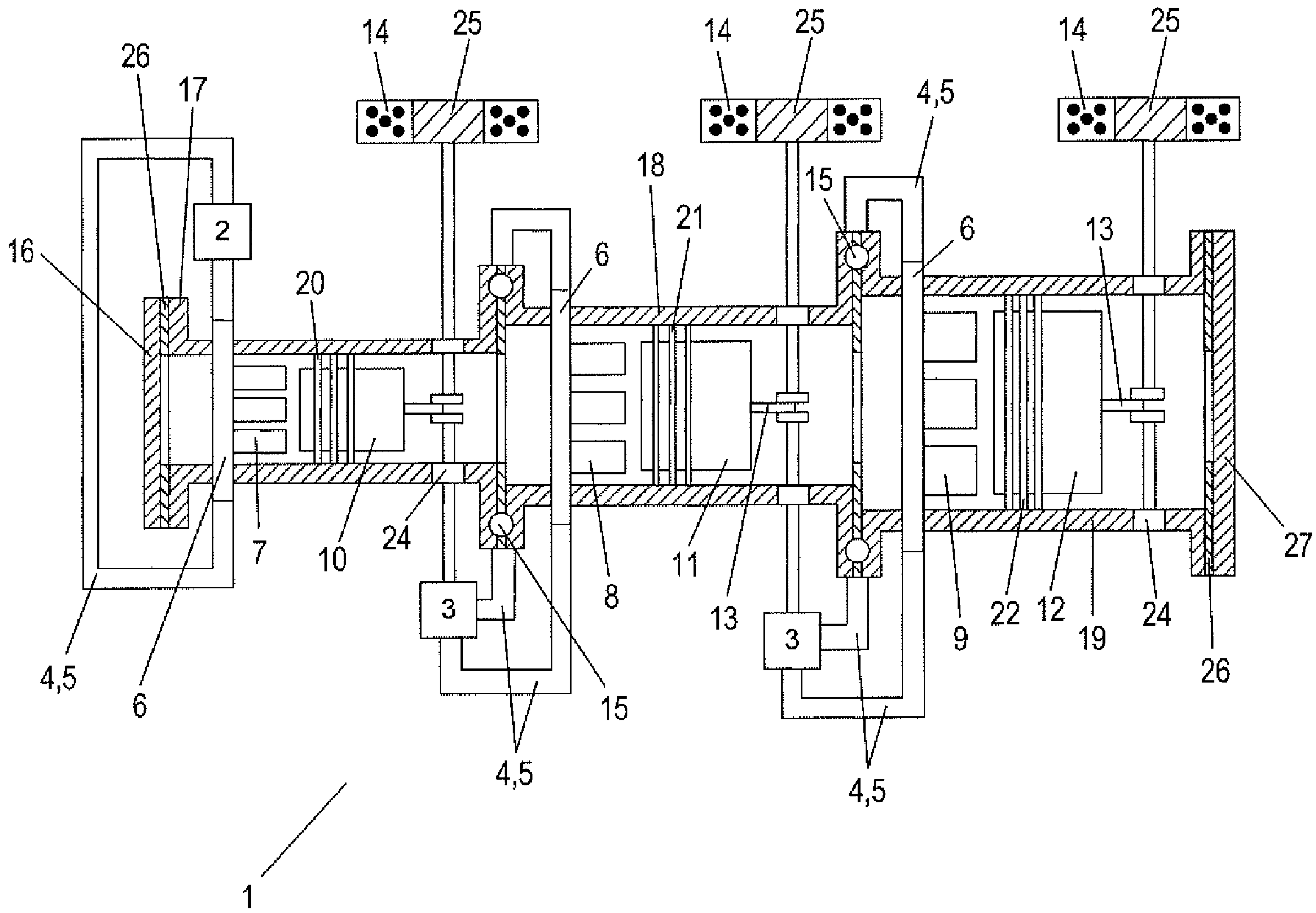
(57) **ABSTRACT**

The present application is directed to providing energy conversion and energy storage whereby inputs of electrical energy are converted into thermal energy which is stored indefinitely in an enclosure designed to retain heat and to prevent its transfer into the ambient environment. Subsequently, when the user of the device wishes to tap the stored energy to perform useful work, the thermal energy is converted back into electrical energy and the energy is released as an electrical output.



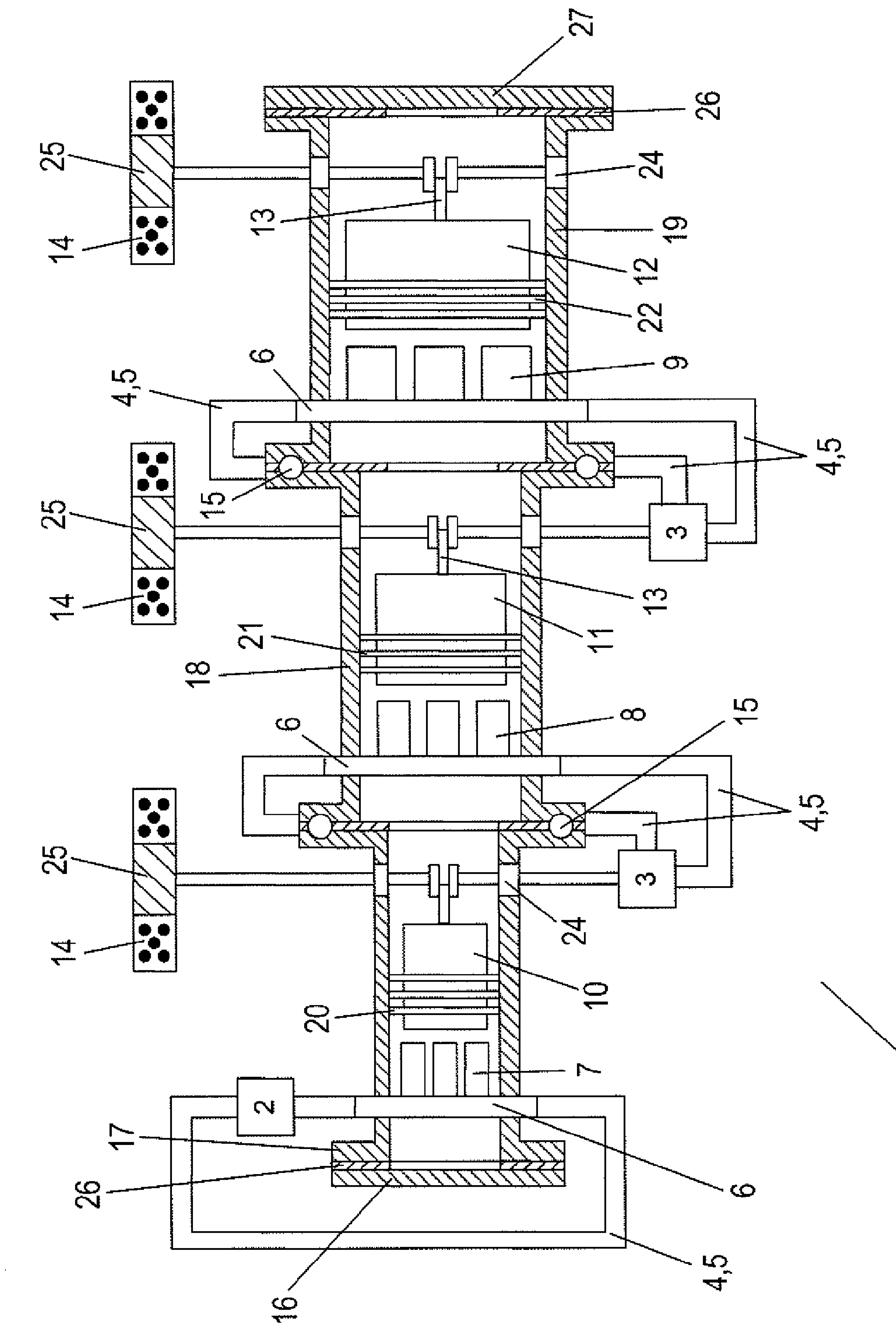


FIG. 1

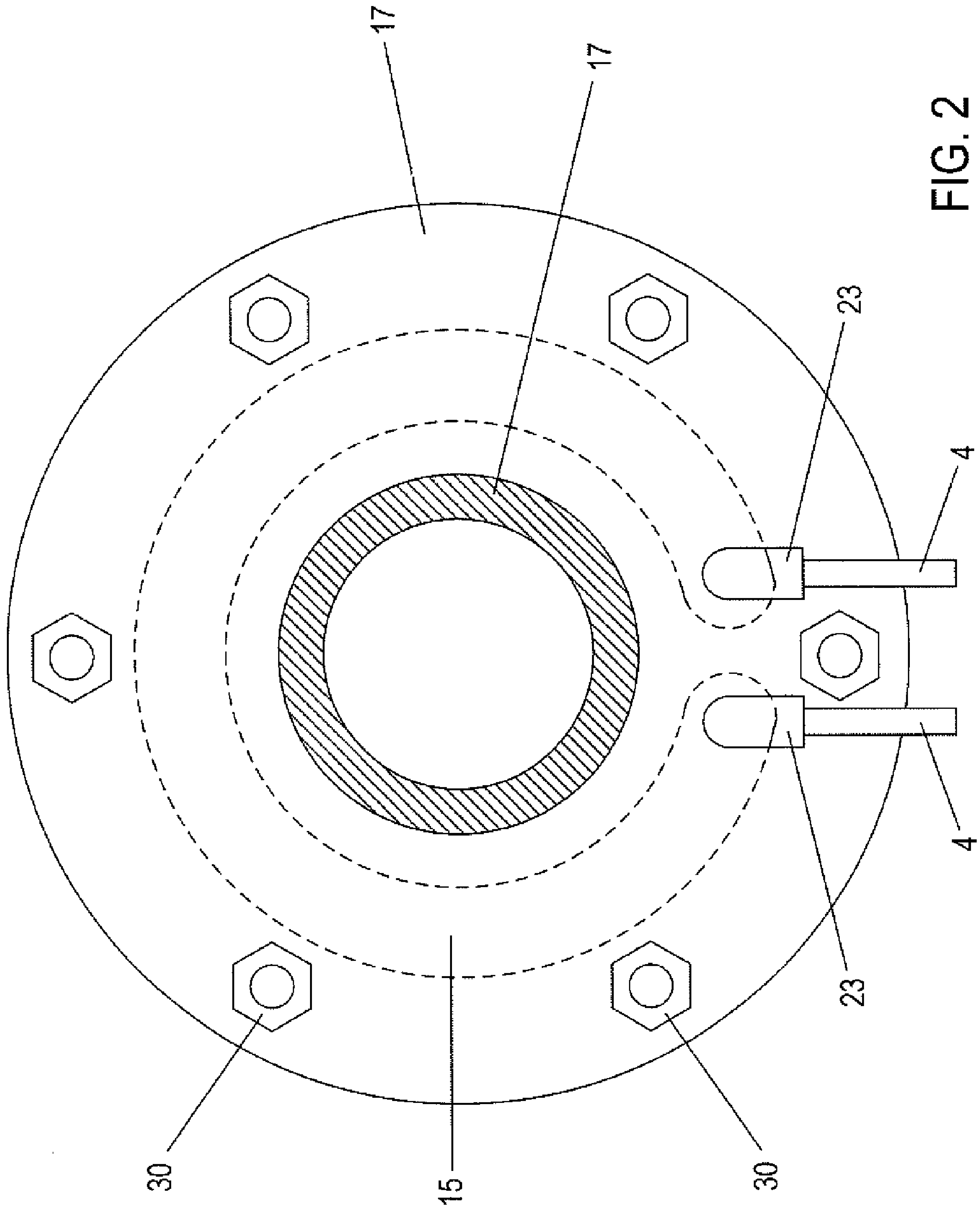


FIG. 2

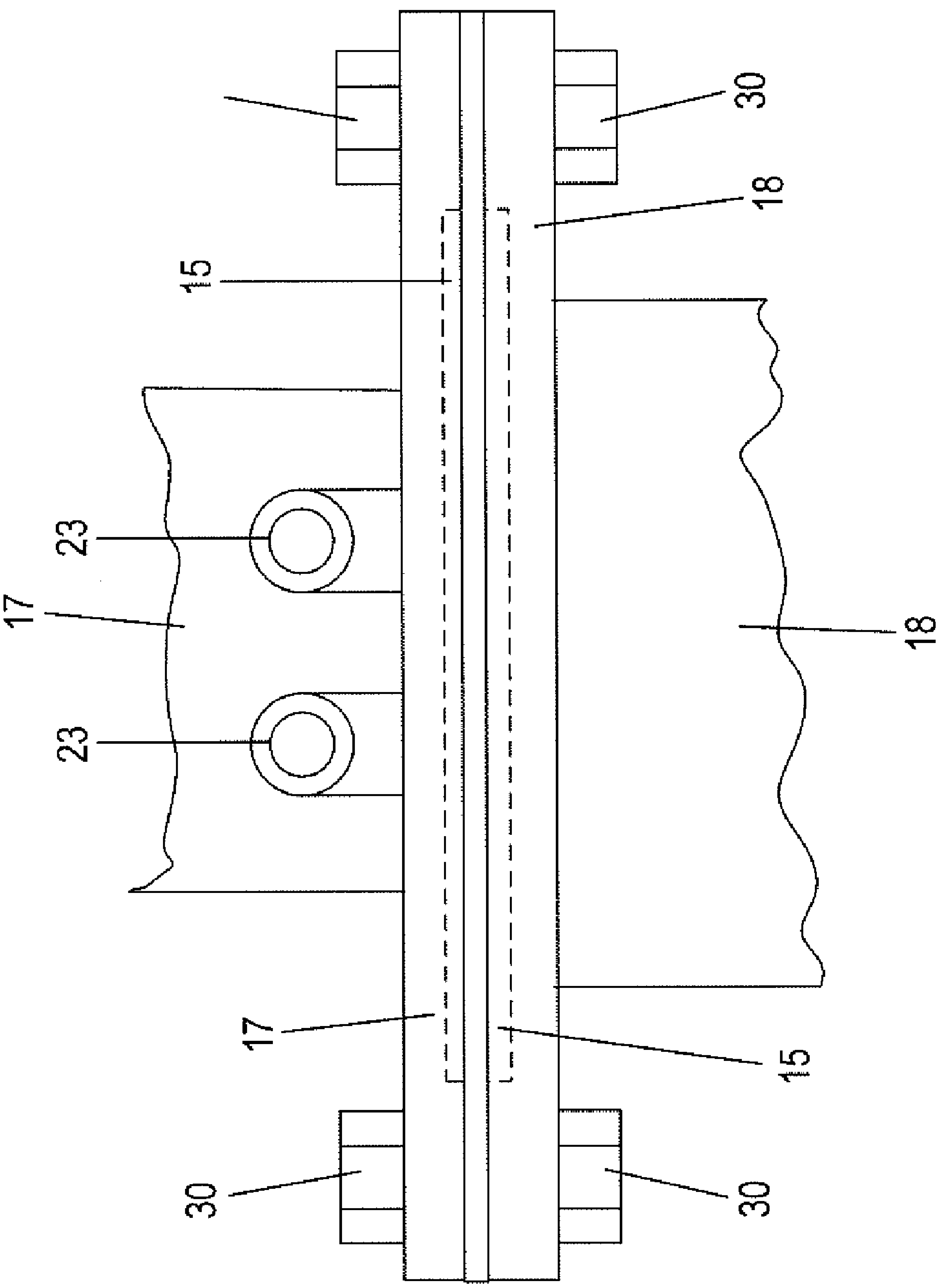


FIG. 3

THERMAL ENERGY STORAGE SYSTEM WITH HEAT ENERGY RECOVERY SUB-SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Provisional Application No. 61/450,468, filed Mar. 8, 2011.

TECHNICAL FIELD

[0002] The present invention relates generally to the field of energy storage devices.

BACKGROUND

[0003] Several means of storing electrical energy are extant in the marketplace or in the form of experimental devices, including electrochemical batteries, ultra-capacitors, flywheel generators, compressed air energy storage ("CAES"), superconducting magnetic energy storage, regenerative fuel cells, kinetic mechanical energy storage systems, such as springs under tension or compression, and pumped hydroelectric systems where a volume of water stored in an elevated reservoir provides motive power for a water turbine generator through the agency of gravity. Each method of energy storage has its own advantages and disadvantages with respect to energy and power densities, cost, scalability, life-cycle issues, constancy of output voltages and currents, and power quality. The aggregate attributes of each of the respective technologies determines its competitiveness within the various niches and applications for energy storage in the marketplace.

[0004] However, in one respect, energy density, extant commercial energy storage technologies are deficient. Compared to either fossil fuels or nuclear fuels, the rechargeable storage media capable of accepting electrical inputs (with the negligible exception of regenerative fuel cells) store relatively paltry amounts of energy per unit of mass or volume. A gallon of gasoline, for example, holds over a hundred times the energy content of an advanced battery of the same mass, and advanced batteries constitute the benchmark for energy density with respect to rechargeable energy storage devices.

[0005] Poor energy density almost inevitably results in questionable cost effectiveness with respect to any storage medium. If the medium is massive and/or capacious for a given energy volume, it will of necessity consume more materiel and need more energy for its fabrication. Low energy density also severely limits the versatility and applicability of the storage medium. A medium that is excessively massive can scarcely play in the transportation field nor can it find a home in portable devices. It will be limited to stationary power applications, assuming that its price per unit of electrical power is acceptable there.

SUMMARY

[0006] The present application is directed to providing energy conversion and energy storage whereby inputs of electrical energy are converted into thermal energy which is stored indefinitely in an enclosure designed to retain heat and to prevent its transfer into the ambient environment. Subsequently, when the user of the device wishes to tap the stored energy to perform useful work, the thermal energy is converted back into electrical energy and the energy is released as an electrical output.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a cutaway drawing of the entire thermo energy engine.

[0008] FIG. **2** is a top view of the heat sind on the cold end of the top cylinder.

[0009] FIG. **3** is a side view depicting the same features as FIG. **2**.

DETAILED DESCRIPTION

[0010] All things being equal, an ultra high energy density storage medium would be useful within existing portable and transportable electrical and electronic devices, and would make electrical power much more attractive in products and applications where it is presently underutilized or not utilized at all. More space-efficient and cost-effective energy storage would also further the cause of renewable energy generation both on a utility scale and on a domestic scale. Most renewable energy sources are intermittent in their operation and inconstant in their electrical output, and mass energy storage would provide for much greater predictability and reliability. Established energy storage media, most particularly batteries, are well characterized. The ultimate limits of the energy storage capabilities of all of commonly utilized battery chemistries are thoroughly understood, as are those of most of the dark horse energy storage technologies including flywheels and compressed air energy storage. While theoretically advanced batteries could better their existing energy density by more than one order of magnitude, proponents of these technologies have had difficulty in achieving even incremental improvements despite lavishly funded research over the course of many decades.

[0011] Batteries exhibit certain other critical limitations as well, including relatively low power densities, limited cycle lives, slow charge and discharge rates, and extreme temperature sensitivity. Nevertheless, their low storage capacities can be deemed their signature weakness, and difficulty in ameliorating this weakness suggests that other technologies should be explored as an alternative.

[0012] Unfortunately, second and third tier commercially developed energy storage technologies display even more critical liabilities and shortcomings, indicating that the discussion should be broadened to include known but largely undeveloped storage technologies.

[0013] The current application is directed to providing a unique, lightweight energy storage system with ultra-high storage capabilities, an extended operating life, selectable output voltage and current, and a low self discharge rate. One implementation to which the current application is directed is a thermal-energy storage system that consists of two principal subsystems or segments, a high-energy storage medium with associated containment measures, and an ultra-high-efficiency heat engine designed to convert the sensible or latent heat retained by the storage medium into mechanical energy and from thence into electrical energy.

[0014] The disclosed thermal-energy storage system is a closed system, in a material sense, with no substance being introduced, rejected, or exchanged with the external environment while energy transfers occur. There is no exhaust, nor are there any waste products, chemical reagents, and any release of heat involving nuclear reactions. The disclosed thermal-energy storage system utilizes at least one additional storage medium beyond the primary storage medium, and that secondary medium also serves as a working fluid. Alternative implementations of the disclosed thermal-energy storage system additionally employ a tertiary storage medium/working fluid falls and/or a fourth thermal medium.

[0015] The primary storage medium communicates with a set of electrical inputs via a resistance or inductive heater of very high efficiency (greater than 95%). The primary medium is capable of accepting and retaining very high values of thermal energy. A solid, highly refractory substance not subject to phase change at relevant operating temperatures and relatively low in mass serves as the primary storage medium in certain implementations. Graphite is an excellent candidate material. Additional candidates for the primary storage medium include molten aluminum, molten bismuth, and other phase-change materials that remain liquid over a considerable portion of the temperature range of interest. Graphite thermal storage poses the least number of technical challenges and offers excellent energy density.

[0016] Since mechanical heat engines are subject to Carnot limitations, a design objective is to diminish the impact of such limitations, and the primary means of accomplishing that is to maximize the difference between the temperatures of the heat sink and heat source per classical thermodynamic theory. In certain implementations, the thermal storage is the heat source, taking the place of a combustor or reaction chamber in a conventional heat engine.

[0017] The absolute temperature of the primary storage medium at full thermal charge is subject to the further limitations of current materials technology. Graphite itself may be elevated to temperatures exceeding 3,000 degrees Celsius, but, in the interest of efficiency, the operating temperature of the secondary storage medium/working fluid is desirably close to the temperature of the primary medium. Current materials technology does not permit operating temperatures of much above 1,500 degrees Celsius with any thermal storage medium or combination of storage media. Moreover, an impeller upon which the working fluid acts as it expands through first stage of the heat engine will be subject to extreme mechanical forces and to extreme thermal shock as the working fluid impinges forcefully upon it, and in current designs the impeller constitutes a weak link in the system.

[0018] A range of first stage operating temperatures between 1,300 C and 1,800 C may be used for the primary storage medium and the first stage of expansion based upon available or anticipated materials technology, including bonded graphite construction, ultra high temperature ceramic construction, cermet construction combining metals and ceramics, carbon-ceramic construction, amorphous tungsten construction, or high temperature superalloy construction. When sensible heat thermal storage is utilized as the primary thermal storage medium, the primary working fluid derives energy from the primary thermal storage medium and maintains a gaseous or supercritical state in which it exerts high pressure upon confining surfaces. The surface of the impeller in the first stage of expansion responds to such pressure, with mechanical movement converting thermal energy into mechanical energy.

[0019] In an alternative implementation, the primary thermal storage medium is also a working fluid and functions as a phase-change medium. When, for instance, pure elemental bismuth is utilized in this capacity, it is vaporized at its boiling temperature of 1588 Celsius, allowed it to expand through an expander which derives mechanical motive force from the expansion while, subsequently, heat is released during the condensation process. The liquid bismuth then conveys heat to the second working fluid.

[0020] The primary working fluid is a pure metal or metal alloy that is liquid at temperatures at or slightly above the ambient. Candidate substances include potassium, sodium, rubidium, and gallium-indium-tin or various eutectic combinations thereof All such substances are subject to vaporization at the highest range of operating temperatures postulated for this system. These working fluids also serve as secondary phase-change thermal-storage media, and draw additional energy from the primary thermal medium in a reheat process.

[0021] The primary expander can be a Bernoulli-effect turbine exploiting the forces of lift or a positive-displacement expander such as a radial turbine, a piston engine, a scroll expander, a helical screw expander, a Wankel engine, or a gerotor. One implementation utilizes a positive-displacement expander. Double helical screw expanders utilizing graphite rotors have been made that are capable of operating at temperatures in excess of 1,500 C, and these may be said to constitute a proven technology for an expander utilizing liquid metals at such extreme temperatures.

[0022] One implementation employs multiple oscillating linear free pistons within a cylinder. The motions of the pistons are governed by induction motors incorporated within a larger motion control system. The motor assembly also serves as a generator with the motor providing for compression and positioning of the pistons while the generator translates their motions into an electrical output. The same, electrical elements are used to perform either function so that the device constitutes a motor-generator.

[0023] In one implementation, the oscillating piston array may function as a compound-expansion engine with each succeeding cavity defined by a pair of pistons operating at a lower pressure than the preceding cavity. Separate conduits may be used to convey the output of one cavity to the succeeding cavity, or, alternatively, a common conduit with sections separated by high pressure valves may fill each cavity in turn with working fluid at progressively lower pressures.

[0024] After the fluid metal has expanded in the gaseous or supercritical state, it has lost sufficient thermal energy to condense to a liquid state whereupon it serves as a thermal transfer medium for the second stage of expansion. The liquid metal passes into a high-efficiency heat exchanger where it communicates its residual heat to the second working fluid, such as supercritical carbon dioxide. That expands within its own expander, reaching ambient temperature at the conclusion of the process. The expander for the second working fluid may utilize the same kind of reciprocating piston free-piston design as the expander for the first working fluid or may hew to some other positive-displacement design.

[0025] The heat exchanger may be a conventional shell and tube type, a plate type, a micro-channel type, or the more newly developed twisted-tube variety. The latter is efficient, withstands high pressure, and is versatile with respect to structural materials. Twisted-tube heat exchangers have been successfully fabricated out of carbon as well as various high temperature superalloys. High temperature ceramics may also be candidate materials.

[0026] Alternatively, the heat exchanger may depend upon the emission and reception of infrared radiation in order to effect thermal energy transfer. Meta materials known as photonic crystals may facilitate such operation inasmuch as they can be configured to manifest band-pass and band-gap behaviors such that energy may be released and received at specific frequencies within the infrared spectrum and blocked at all others in the interest of maximizing efficiency and the velocity of thermal transport. Such photonic-crystal radiators produce a nearly coherent radiation which may be collimated and focused for increased intensity so that the temperature of the heat sink receiving the radiation may be higher than that of the heat source transmitting it, provided the thermal mass of the heat sink is correspondingly less.

[0027] If conduction and convection are the sole mechanisms for thermal transfer, then the second working fluid constitutes a larger thermal mass than the first so as to constitute a massive heat sink facilitating the transfer of thermal energy. When radiation is dominant, then a smaller thermal mass for the receiving thermal medium is more conducive to high efficiency since a higher thermal gradient may be maintained through the stages of expansion.

[0028] The supercritical carbon dioxide expands within the second expander, which can be a Bernoulli effect turbine or a positive displacement rotary expander. A positive displacement rotary expander, such as scroll, screw, gerotor, or Wankel expander whose rotor defines a progressively larger enclosed space as it rotates can be used instead of a Bernoulli turbine, because they exhibit very predictable drops in pressure through the course of rotation coinciding with decreases in temperature such that the working fluid remains above the supercritical point and is not subjected to the turbulent effects attendant upon the generation of lift and tending to complicate greatly the modeling of engine behavior. The aforementioned oscillating piston array provides for similar benefits while also offering extreme structural simplicity and ease of fabrication. The supercritical CO_2 exits the second expander after undergoing minimally a 50 to 1 volumetric expansion and descending in temperature by an approximately similar ratio. The supercritical CO_2 is next subjected to compression and reheating. It is then sent through a third expander, where it expands by a similar ratio, i.e. over 50 to 1 and exits in the gaseous state at approximately ambient temperature.

[0029] In another implementation, linear piston expanders are employed in lieu of rotary expanders and these function as both expanders and compressors. Linear piston engines are a species of reciprocating piston engine that lacks a mechanical transmission. An oscillating piston design such as described above can utilize linear pistons, also known as free pistons. In such a linear piston design, the head of the piston forms a component of a linear alternator which translates the mechanical motion of the piston into electrical current with high efficiency. The piston may be provided with either a moving magnet or an induced magnet. At the operating temperatures for this design, an induced magnet is used to avoid the dangers of high temperature demagnetization. Air core magnetic architectures are used in magnetic architectures residing upon the piston inasmuch as magnetic metals lose their magnetic properties at temperatures in excess of 500 C.

[0030] Carbon nano materials, such as graphene or nano tubes, can be used to form the inductive coils. Such materials exhibit much lower electrical resistance than do copper or noble metals and do not exhibit linear increases in resistance with temperature and thus are well suited to very high temperature environments. They also permit the development of high flux fields without the need for a magnetic metal core.

[0031] The piston itself can be graphite or some highly refractory metal. Graphite has low moving mass, self lubricating properties, and extreme dimensional stability at elevated temperatures. Linear piston engines, also known as free piston designs, are generally much more efficient than conventional piston engines, but have seen relatively little employment previously due to the difficulty of keeping pistons in synchronicity when more than a single piston is employed and in effecting a return or compression stroke that will position the piston in the same place in the cylinder. The means for controlling piston travel and velocity have generally involved pneumatic systems where a volume of gas in a "bounce chamber" at the equivalent of a bottom dead center position for the piston exerts a restorative force on the piston after it has completed its expansion stroke. This chamber may include a reservoir and valve for varying pressure dynamically.

[0032] One can take advantage of the fact that a single electromechanical device can function as a motor, a generator, and as a position sensor. This provides the basis for a highly accurate electromechanical actuator that restores the piston following the expansion stroke to the same position in the cylinder. The same motion-control system may be used to provide the optimal electrical load for the moving coil piston so as to extract maximum energy from its stroke. A further implementation combines the free piston concept with a different but synergistic design approach which falls under the nomenclature of the aforementioned oscillating piston engine.

[0033] All oscillating piston engines made to date have been quasi-rotary types where several—usually eight—pistons are loaded into a toroidal enclosure taking the place of a straight cylinder and their several motions controlled by an external mechanical assembly which might be construed as a specialized transmission. The pistons themselves define multiple cavities in which intake, compression, expansion, and exhaust would take place, and in this manner maximal volumetric efficiency is achieved.

[0034] While the power density to be had by this means is considerable, the design in its usual form suffers from several liabilities. Continuous seals run the length of the expansion chamber maximizing the possibility of leakage, particularly at high pressures, and the abrupt rocking motion of the pistons with relationship to one another imposes very high reiterative mechanical forces on the transmission.

[0035] When the design is combined with the aforementioned free piston design with electromechanical motion control as well as power extraction by the same means, these deficiencies are avoided and a toroidal chamber is no longer needed. Successive free pistons may be distributed along a long narrow cylinder, and both the pistons and the chamber will be much easier to fabricate.

[0036] The design also permits discontinuous and non-sinusoidal operation of the piston impellers such that high velocity pistons may be operated in pulse mode and loaded with appropriate impedances by the use pulse inductors capable of efficiently storing and releasing large values of electrical energy with negligible resistive losses. A variant of the classic high voltage flyback circuit may be utilized for this purpose in the generator. A further implementation places a plurality of such cylinders within a shell structure to form a tube and shell heat exchanger in which the thermal storage medium conveys its residual thermal energy to the working fluid contained within the cylinders. A further implementation includes high speed thermal switches communicating between localized hot and cold sinks within the cylinders and the system heat source and cold sinks so that thermal gradients may be established momentarily, but dissipation of heat across the gradient may be prevented when work is not being performed. A further implementation incorporates multiple recuperators at different stages of compounding for retaining and return heat to the working fluid for highest energy efficiency. Such recuperators are characteristic of the Stirling thermodynamic cycle but have been used within other cycles such as Ericsson, Humphrey, and ideal Otto cycles. These recuperators employ phase-change storage media. A further implementation employs switches for engaging and disengaging paths from the local heat exchangers within the cylinders to the system heat source and cold sink and also to intermediate storage media serving the recuperators. By this means, parasitic losses across the thermal gradient are minimized because the working fluid only sees the gradient at the point of energy conversion during the compression and expansion strokes.

[0037] The system will be capable of outputting either or both direct and alternating current and will be endowed with the ability to provide selectable output voltages for alternating current and direct current, as well as selectable frequency for alternating current. In the case of alternating current, the system may be capable of providing balanced or unbalanced current at output.

[0038] Voltages provided in the direct current mode will be such as are commonly output by commercially available battery banks, and will include 12 volts and 48 volts. High voltage DC options in the hundreds of volts will be present for use in electric traction. At present, operating voltages for electric traction are not standardized and so a number of options are present, and the choice of operating voltage may be arbitrary.

[0039] Alternating current voltage options will reflect those of the electrical utilities in large international markets and will include 90 volts, 110 volts, and 220 volts. Higher operating voltages such as those characterizing electrical substations or distribution centers for large industrial or institutional users may be offered as well. Alternating current frequencies offered will include 50 Hz and 60 Hz, those commonly utilized by most electrical utilities around the world. A 400 Hz option may be present as well for military and maritime applications where that frequency is commonly utilized.

[0040] The direct output of the heat engine incorporated in the system will be in the 100 Hz range or less, raising the possibility of the direct provision of 50 Hz or 60 Hz alternating current from a constant speed linear alternator, as described elsewhere in this text. For a 400 Hz output, AC to DC to AC conversion will be needed. Full bridge rectification with capacitive smoothing will be utilized to provide low ripple direct current. This can be realized by those skilled in the art with stock electrical components including standard diodes and capacitors of the correct values. Silicon diodes and electrolytic or polymer capacitors would be acceptable, and polymer capacitors would be preferable in this application due to their relative insensitivity to elevated temperatures. To reduce the size of the smoothing capacitors and the transformem, a reconversion of pulsating DC to a high frequency square wave AC may be effectuated by means of a pulse width modulator utilizing switching MOSFETs or insulated gate bipolar transistors.

[0041] A combination of a pulse width modulation switching array and an electrical transformer will be used to adjust output voltage. The transformer will be of the voltage regulating type with a sliding contact across the secondary. The switching frequency or clock frequency of the pulse width modulator will be sufficiently high to minimize distortion components and switching noise within the audio band at a 50 Hz or 60 Hz output, and total harmonic distortion products in the AC output will not exceed 1% so that this section may be properly designated a sine wave current inverter. Alternatively, a simpler voltage regulating circuit using an inductor in series with a variable duty cycle electronic switch will be substituted.

[0042] AC balanced power outputs will feature hot negative and hot positive with a floating ground to which the hot terminals are referenced. At 110 volt balanced AC output the positive half of the cycle will swing to 60 volts positive and the negative output will swing to 60 volts negative with the total potential difference amounting to 120 volts between them. A 220 volt balanced output circuit will have a hot positive of 120 volt potential and a hot negative of 120 volt potential. In the case of stationary installations where the system receives AC power inputs as a source of electricity for Joule or inductive heating, third pin grounding will be provided and no dangerous electrical potentials will be present on the casing.

[0043] Alternately, the heat exchanger may depend upon the emission and the reception of infrared radiation in order to effect thermal transfer. Such a heat exchanger would preferably exploit the phenomenon of giant radiative transfer where the adjacent surfaces of the hot and cold sides of the heat exchanger are separated by a micron or submicron gap bounding a hard vacuum. The gap itself will allow for the transfer via quantum tunneling of the surface or evanescent wave of non-propagating infrared energy from the hot surface to the cold surface and will provide for significant increase in efficiency over an ordinary black body radiator. Such increases have been extensively noted in the scientific literature.

[0044] Further implementations may be had by using more complex micro or nano structures falling into the general category of meta-materials. A slotted grating may be superimposed over the hot surface at a sub-wavelength distance such that infrared energy is only emitted by the slots, which themselves are of sub-wavelength dimensions. Plasmonic resonances may thereby be invoked, resulting in pronounced electrical field intensification in the vicinity of the slots and Joule heating of the grating in the vicinity of the slots. Heat from the "hot spots" may be transported conductively via thermal superconductors such as have previously been described or may be re-radiated as propagating infrared radiation via Plasmon polariton waveguides.

[0045] Plasmonic waveguides are periodic structures with noble metal elements—generally simple geometric forms such as spheres or pillars or pyramids—regularly distributed across a flat dielectric surface. The metal surfaces provide free electrons which form a virtual plasma at the boundary of the metal structures and the underlying dielectric; the spacing between the metallic elements determines the fundamental resonant frequency of the virtual plasma.

[0046] The term Plasmon refers to a hybrid particle consisting of a photon and a bound electron, and the plasmons collectively oscillate at a frequency dependent upon the intervals between the metallic elements. When the resonant frequency of the plasmons is equivalent to that of the incident infrared light, a very high Q high amplitude resonance will arise and the local temperature of the plasmonic waveguide may become quite elevated. Electrical field intensification may exceed three orders of magnitude.

[0047] While such plasmonic heating is generally deemed an undesirable attribute of plasmonic structures, particularly when the object is to utilize such structures as solar collectors or hyper lenses, plasmonic heating has proven useful in medical applications, nano-lithography, and in phase change magnetic recording. In this invention plasmonic heating forms the basis of a new type of radiant heat exchanger where radiant energy undergoes an energy conversion to a bound surface wave which may then be transformed and propagated by means of a device known as a hyper lens or may be utilized for spot heating. Essentially the energy in the incident radiation may be confined within an area that is far smaller than the smallest focal length for the concentrated beam of the radiant energy. Such sub-wavelength focusing beyond the diffraction limit by means of meta materials is extensively noted in the scientific literature.

[0048] Such subwavelength focusing, which actually involves an energy conversion and is therefore fundamentally dissimilar to the concentration of light by means of geometric optics, may form the basis for the construction of a seeming transformation in thermal intensity. The fact that two energy conversions are involved, one from radiance to a dense wave electron oscillation and from that to phononic vibrations via electrical Joule heating explains how the thermal gradient may be raised without the violation of the Second Law of Thermodynamics or the conservation of phase space.

[0049] Such subwavelength concentration may be achieved through a number of means. A plasmonic lens consisting of nano scale or low micro scale concentric ridges or pinholes or other subminiature constructions inscribed upon a disc may be used to focus incident radiation to a point at the center of the disc. Conversely, a nano-optical fountain based upon radially converging lines of progressively larger quantum dots may be used to transfer radiant energy to a central point. Combinations of these approaches are also possible.

[0050] Joule heating takes place at the point, and the resulting local concentration of thermal energy and elevated temperature gradient may be used for conductive or convective heating. The plasmons may also be reconverted into propagating radiation at enhanced intensity and the radiation may be used for radiant thermal transfer. The energy of the plasmons, which is essentially an evanescent waveform, may also be transferred across a micron or sub-micron gap in the form of giant radiative transfer.

[0051] Next, three figures that illustrate an implementation of the thermal-energy storage system are provided. FIG. **1** is a cutaway drawing of the entire thermo energy engine **1**. The heat source **2** with integrated pump, pumps heat conductive fluid **5** to the heat resonating pipes **7** in the small cylinder **17**. The vibrations from these pipes **7** activate the small piston **10**. Piston rings **21** are included, and can be made of Teflon to avert the need for a lubrication scheme with an oil bath. The piston **10** drives a crankshaft assembly **13**, which in turn drives a generator consisting of a coil assembly **14** and a magnet assembly **25**, plus a pump **3**. Heat conducting fluid or gas heated at the cold end of the top cylinder, is pumped into the heat resonating pipes **8** of the middle or medium sized cylinder **18**. Essentially the same process occurs in the middle cylinder, as in the top one. Likewise the bottom or largest cylinder is activated. One distinction in the largest cylinder is that no further heat transfer to additional cylinders.

[0052] FIG. **2** is top view of the heat sind on the cold end of the top cylinder. The heat sind on the middle cylinder is essentially identical in principle, and is therefore not shown in a separate drawing. The top cylinder wall **17**, and the middle cylinder wall **18** are connected together with bolts, nuts, and washers **30**. A gasket **26** is placed between the flanges of these cylinder walls (**17**, **18**) to insure sealing. A channel **15** for the flow of heat conducting fluid or gas **5** comprises milled slots in the flanges of the cylinder walls (**17**, **18**) and also in the gasket (**26**). Coupling pieces **23** provide connectivity to the piping **4** and to the channel **15**.

[0053] FIG. **3** is a side view depicting the same features as FIG. **2**. To summarize, the parts shown in all three of FIGS. **1-3** include:

[0054] **1**: Complete thermo engine
[0055] **2**: Heat energy source
[0056] **3**: Pump
[0057] **4**: Pipe
[0058] **5**: Heat conductive fluid or gas
[0059] **6**: Connecting pipe
[0060] **7**: Heat resonating pipe. small
[0061] **8**: Heat resonating pipe, medium
[0062] **9**: Heat resonating pipe, large
[0063] **10**: Piston, small
[0064] **11**: Piston, medium
[0065] **12**: Piston, large
[0066] **13**: Crankshaft assembly
[0067] **14**: Generator coil
[0068] **15**: Channel for conductive fluid or gas
[0069] **16**: Small cylinder head
[0070] **17**: Cylinder wall, small cylinder
[0071] **18**: Cylinder wall, medium cylinder
[0072] **19**: Cylinder wall, large cylinder
[0073] **20**: Piston ring, small
[0074] **21**: Piston ring, medium
[0075] **22**: Piston ring, large
[0076] **23**: Coupling
[0077] **24**: Bearing
[0078] **25**: Generator magnet assembly
[0079] **26**: Gasket
[0080] **27**: Cylinder floor, large cylinder
[0081] **30**: Nut, bolt, and 2 washers

[0082] Although the present invention has been described in terms of particular embodiments, it is not intended that the invention be limited to these embodiments. Modifications within the spirit of the invention will be apparent to those skilled in the art. For example, as with any complex system, many different types of components manufactured by many different vendors can be employed in the above-disclosed implementation. Sizes and shapes of components may vary, in concert, to produce various alternative embodiments. Similarly, the material compositions of certain components may vary.

[0083] It is appreciated that the previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present disclosure. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the disclosure. Thus, the present disclosure is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

1. A thermal energy storage and energy conversion system comprising: an electrical-to-thermal energy-conversion system;

a thermal storage medium and its associated storage module; and

multiple working fluids, including vaporized metal for a topping cycle and supercritical carbon dioxide for a bottoming cycle, with the possibility of supercritical helium for a further bottoming cycle extending below ambient temperature;

a closed cycle, compound cycle, multiple expansion, positive displacement heat engine;

a heat engine capable of pulsed intermittent operation; and

a microprocessor-controlled electromagnetic motion control system performing mechanical-to-electric energy conversion as well as guidance and electrical-impedance matching for the transducer-impellers within a heat engine expander.

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