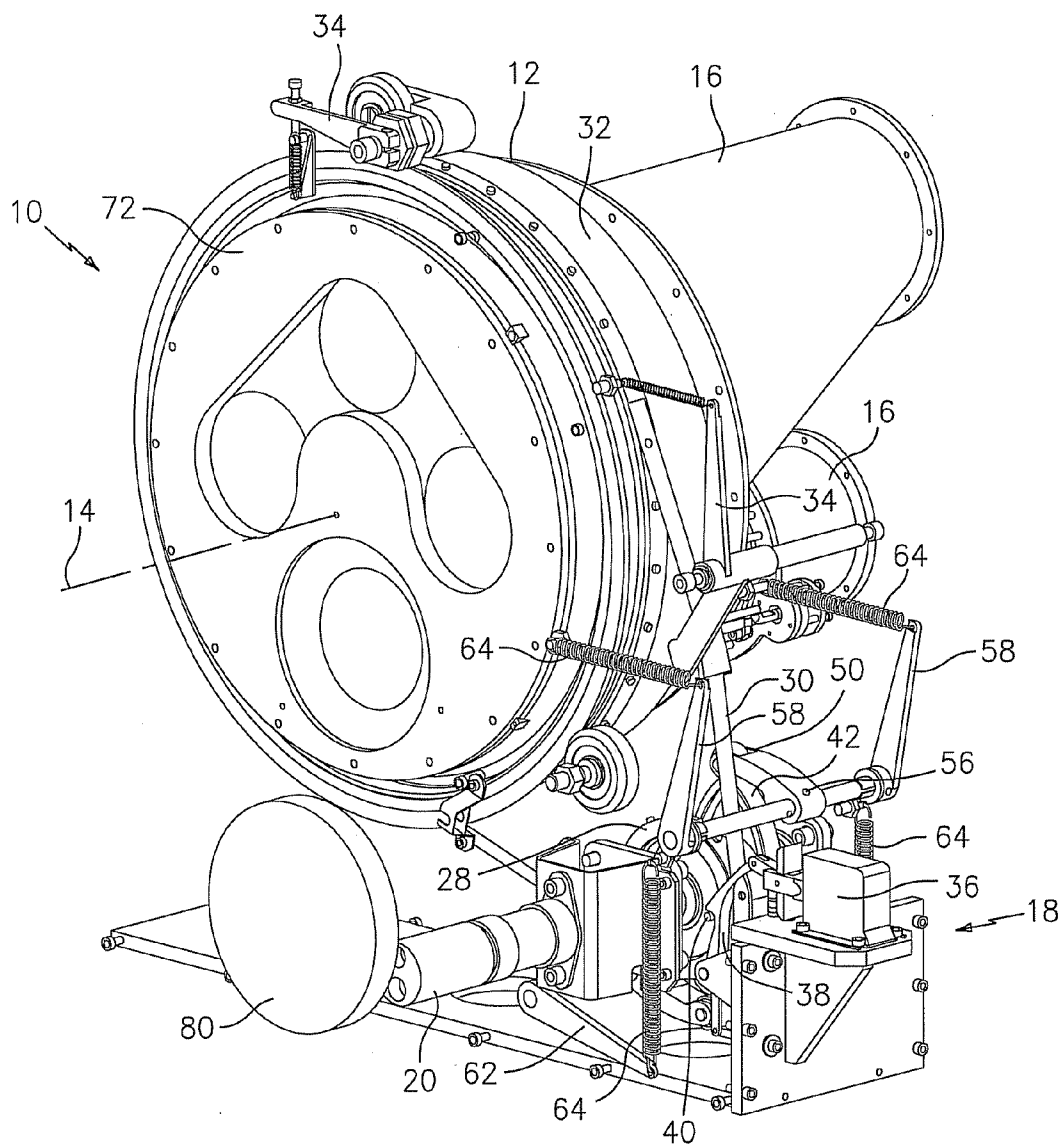




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Wilson et al.(10) **Pub. No.: US 2009/0000761 A1**(43) **Pub. Date: Jan. 1, 2009**(54) **REGENERATIVE HEAT EXCHANGER WITH
ENERGY-STORING DRIVE SYSTEM****Publication Classification**(75) Inventors: **David Gordon Wilson**, Winchester,
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Woburn, MA (US)(21) Appl. No.: **11/770,960**(22) Filed: **Jun. 29, 2007**

A regenerative heat exchanger having an energy-storing drive system includes a high heat capacity matrix rotatable about an axis and a drive system that is in operable communication with the high heat capacity matrix and is capable of rotating the high heat capacity matrix about the axis. An energy-storage mechanism is in operable communication with the drive system. The energy-storage mechanism is capable of controlling an acceleration and/or deceleration of rotation of the high heat capacity matrix thus reducing an amount of energy required to be input into the drive system to rotate the high heat capacity matrix.



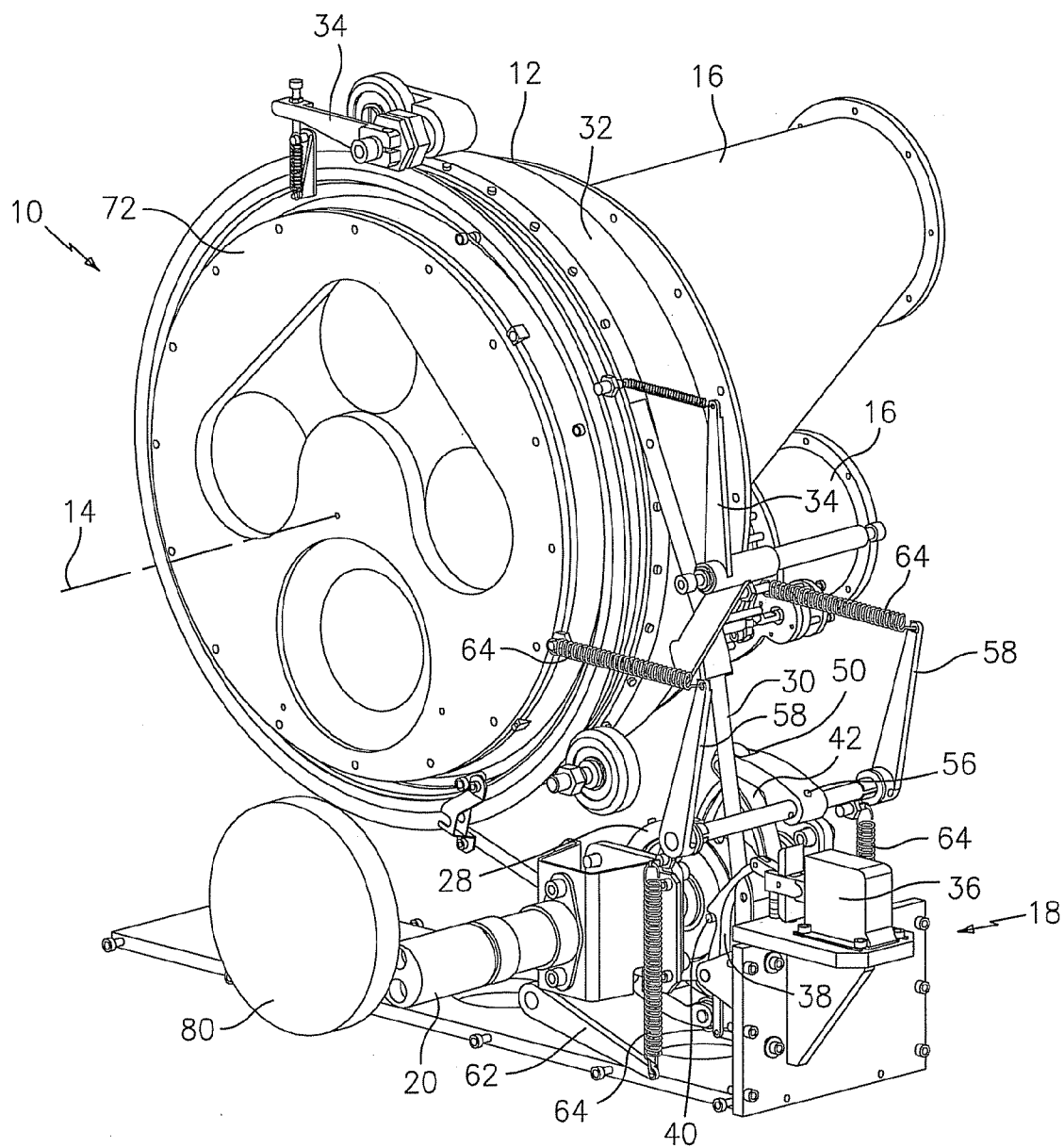


FIG. 1

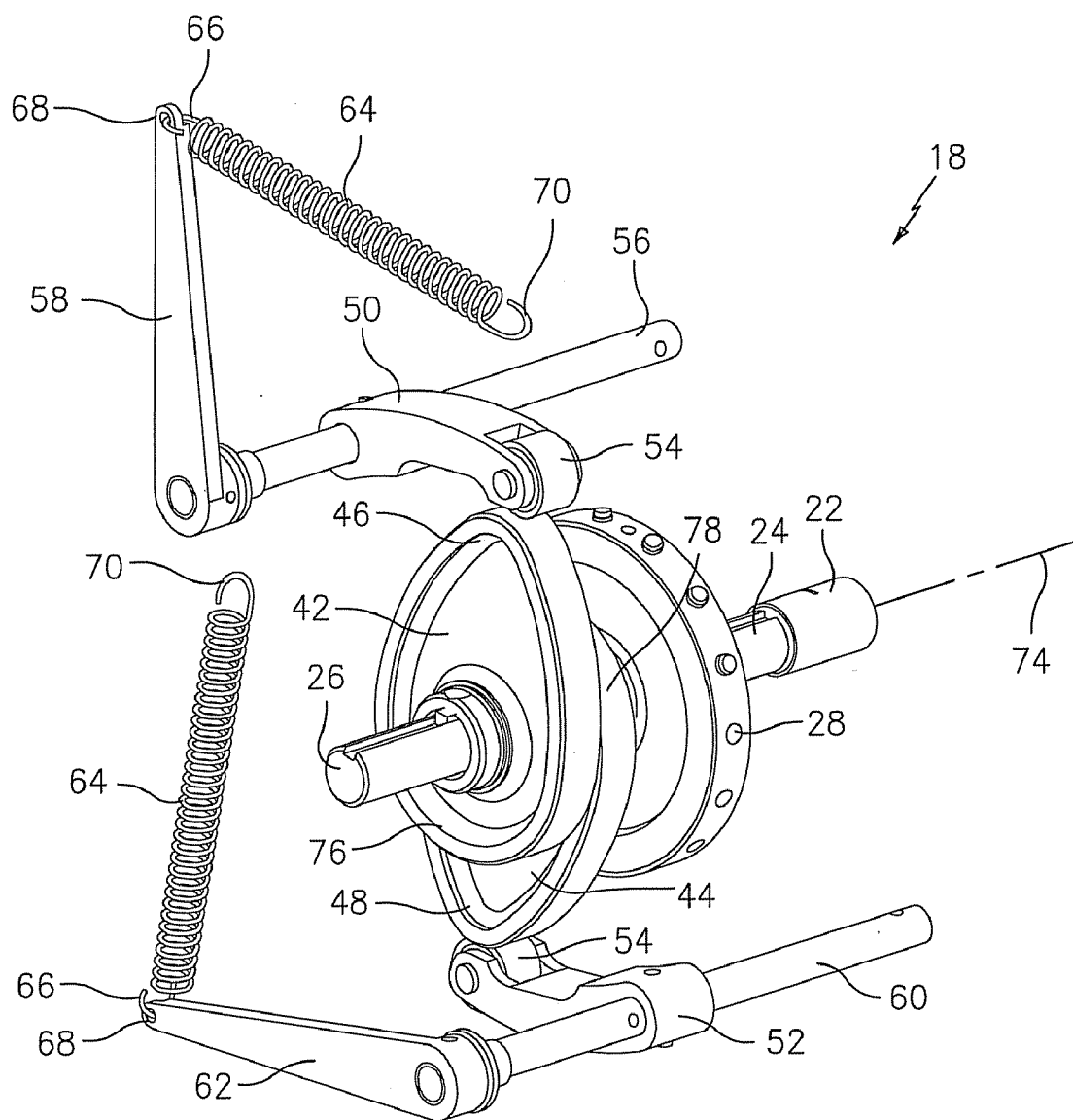


FIG. 2

REGENERATIVE HEAT EXCHANGER WITH ENERGY-STORING DRIVE SYSTEM

BACKGROUND OF THE INVENTION

[0001] This invention generally relates to regenerative heat exchangers. In particular, the present invention relates to drive systems for discontinuously rotating matrices of regenerative heat exchangers.

[0002] A regenerative heat exchanger (regenerator) uses a regenerator matrix which is rotated through a hot and a cold stream consecutively to transfer heat from the former to the latter. The device can also be used to transfer mass between two fluids differing in concentration in a targeted constituent and the exchange (be it mass and/or heat) can involve any number of flows greater than one.

[0003] It is often desirable for the regenerator matrix to be rotated discontinuously, or indexed, through the fluid streams to reduce fluid leakage and thereby to increase the efficiency of heat transfer. The indexed rotation of the regenerator matrix involves repeated accelerations and decelerations of the regenerator matrix which requires that mechanical energy be continually provided to the system, usually by a motor. The energy input necessary to maintain the discontinuous rotation of the regenerator matrix negatively impacts the efficiency of the regenerator, especially in regenerators with matrices having a large mass which require greater amounts of energy to accelerate and decelerate the matrix. Energy must also be continually dissipated in braking the regenerator matrix, a process that can involve high torques and potentially rapid wear of components.

[0004] The art would welcome a drive system for a regenerator having a discontinuously rotating matrix that provides smooth acceleration and deceleration of the regenerator matrix and limits the amount of energy input necessary to achieve the acceleration and deceleration. A drive system such as this would reduce the negative impacts of the drive system on overall regenerator efficiency.

BRIEF DESCRIPTION OF THE INVENTION

[0005] A regenerative heat exchanger having an energy-storing drive system includes a high heat capacity matrix rotatable about an axis and a drive system that is in operable communication with the high heat capacity matrix and is capable of rotating the high heat capacity matrix about the axis. An energy-storage mechanism is in operable communication with the drive system. The energy-storage mechanism is capable of controlling an acceleration and/or deceleration of rotation of the high heat capacity matrix thus reducing the amount of energy required to be input into the drive system to rotate the high heat capacity matrix, and also reducing the braking energy that otherwise must be dissipated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of preferred embodiments when considered in light of the accompanying drawings in which:

[0007] FIG. 1 is a perspective view of an embodiment of a regenerative heat exchanger; and

[0008] FIG. 2 is a partial perspective view of an embodiment of a power-train of the regenerative heat exchanger of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Shown in FIG. 1 is a regenerator 10 which includes a high heat capacity matrix 12 which rotates about an axis 14 through fluid streams 16 of differing temperatures. An example of a high heat capacity matrix 12 is described in U.S. Pat. Appl. Pub. 2006/0054301 A1, the contents of which are incorporated herein by reference. Rotation of the matrix 12 is controlled by a drive system 18.

[0010] The drive system 18 comprises a motor 20 that outputs a constant torque to an overriding clutch 22. The motor 20 in one embodiment is a pneumatic motor, but it will be appreciated that other types of motors may be utilized. Referring now to FIG. 2, the overriding clutch 22 is disposed at a first end 24 of a drive shaft 26. Also disposed on the shaft is a pulley 28 which, as shown in FIG. 1, carries a first end of a drive belt 30 which may take the form of a toothed belt (often referred to as a 'timing belt') or chain or the like. A second end of the drive belt 30 is disposed on a sprocket 32 that is integral to, or fixed to, the matrix 12. The drive system 18 may include one or more tensioning devices 34 to prevent slippage of the drive belt 30. The pulley 28 and sprocket 32 are sized and configured to achieve a desired amount of rotation of the sprocket 32, and thus the matrix 12, for each rotation of the pulley 28. In embodiments where an incremental rotation of the matrix 12 is desired, the pulley 28 and sprocket are configured for drive reduction, such that a 360 degree rotation of the pulley 28 results in the amount of incremental rotation of the matrix 12 that is desired. For example, if a 90-degree incremental rotation of the matrix 12 is desired, the pulley 28 and the sprocket 32 are configured for a drive reduction ratio of 4:1, such that a 360 degree rotation of the pulley 28 urges the drive belt 30 to rotate the matrix 12 by 90 degrees about the axis 14. An example of a regenerative heat exchanger capable of incremental rotation is described in U.S. Pat. RE37,134 E, the contents of which are incorporated here by reference.

[0011] Rotation of the pulley 28 is controlled by a switch 36. The switch 36 is in mechanical communication with a hook 38, or the like. The hook 38, when engaged with a corresponding pin 40 disposed on an axial face of the pulley 28, prevents the pulley 28 from rotating and driving the drive belt 30. When it is desired to rotate the matrix 12, the switch 36 causes the hook 38 to be moved out of engagement with the pin 40, thus the pulley 28 begins to rotate, driving the drive belt 30 which in turn urges the matrix 12 to rotate. To stop rotation of the matrix 12, once the pin 40 rotates past the hook 38, the hook 38 is returned to its original position. When the pulley 28 completes a full rotation, the pin 40 will again engage with the hook 38 thus stopping rotation of the pulley 28 and the matrix 12. It is to be appreciated that the indexing rotation can be achieved with various other methods including barrel cams, parallel plate cam configurations, Geneva wheel configurations and others and still be contained within the scope of this invention.

[0012] Referring again to FIG. 2, acceleration and deceleration of the matrix 12 during rotation is controlled by two single-lobe cams 42, 44 disposed on the drive shaft 26. In one embodiment, the cams 42, 44 are disposed in the drive shaft 26 such that a peak 46 of the first cam 42 is positioned 180 degrees from a peak 48 of the second cam 44. A first cam

follower 50 is disposed in mechanical communication with the first cam 42, and a second cam follower 52 is disposed in mechanical communication with the second cam 44. In one embodiment, the first cam follower 50 is positioned 180 degrees from the second cam follower 52 such that when first cam follower 50 is located over peak 46 of the first cam 42, second cam follower 52 is similarly located over peak 48 of the second cam 44. In one embodiment, the cam followers 50, 52 include low-friction rollers 54.

[0013] The first cam follower 50 is affixed to a first follower bar 56, from which one or more first arms 58 extend. In one embodiment, two first arms 58, one first arm 58 extending from each end of the first follower bar 56, are employed. It is to be appreciated, however, that other quantities and locations of first arms 58 are contemplated. The second cam follower 52 is affixed to a second follower bar 60, from which one or more second arms 62 extend. In one embodiment, two second arms 62, one second arm 62 extending from each end of the second follower bar 60, are employed. It is to be appreciated, however, that other quantities and locations of second arms 62 are contemplated.

[0014] One or more of the first arms 58 and/or second arms 62 are each connected to one or more springs 64. In one embodiment, each first arm 58 and second arm 62 is connected to one spring 64, however utilization of more or fewer springs 64 is contemplated. In one embodiment, a first end 66 of each spring 64 is substantially hook-shaped, and connects to a first arm 58 or second arm 62 by passing the first end 66 through an arm hole 68 in the first arm 58 or second arm 62. A second end 70 of each spring 64 may similarly be substantially hook-shaped. As shown in FIG. 1, the second end 70 of each spring 64 is stretched to attach to a substantially stationary part of the regenerator 10, for example a housing 72.

[0015] Returning to FIG. 2, in one embodiment, the first cam follower 50 is initially positioned to contact peak 46 and exerts a force thereon. The force is caused by springs 64 pulling on first arms 58, and is directed toward an axis 74 of the drive shaft 26. Similarly, the second cam follower 52 is initially positioned to contact peak 48 and exerts a force thereon. The force is caused by springs 64 pulling on second arms 62, and is directed toward the axis 74. When the cam followers 50, 52 are in this initial position, no torque is exerted on the drive shaft 26 because the force is directed toward the axis 74.

[0016] To initiate rotation of the matrix 12, the switch 36 is engaged causing hook 38 to retract and release pin 40. The motor 20, which is providing a constant torque at low rotational speed, overcomes friction forces and urges the drive shaft 26 into motion. The drive shaft 26 drives the pulley 28 and the drive belt 30 which urges the matrix 12 to rotate. Rotation of the drive shaft 26 additionally rotates the first cam 42 and second cam 44 from their initial positions. Once the first cam 42 and second cam 44 are rotated from their initial positions, a spring force applied by the springs 62 to the cam followers 50, 52 causes the cam followers 50, 52 to apply a torque on the cams 42, 44 thus accelerating the rotation of the drive shaft 26 faster than the speed provided by the motor 20. This "over-speed" of the drive shaft 26 is permitted by the over-running clutch 22. The drive shaft 26 continues to accelerate until the drive shaft 26 and cams 42, 44 have rotated 180 degrees and the cam followers 50, 52 press on a first cam lobe 76 and a second cam lobe 78.

[0017] When the cams have rotated 180 degrees, continued rotation of the drive shaft 26 and the cams 42, 44 exerts a force

onto the cam followers 50, 52 which causes the springs 64 to extend and decelerates the rotation of the drive shaft 26. This deceleration continues until the drive shaft 26 reaches the motor 20 speed. (Friction will prevent the drive shaft 26 from accomplishing a full rotation from spring action alone.) The over-running clutch 22 then couples the motor 20 to the drive shaft 26, and the motor 20 accomplishes the rest of the full rotation. Upon completion of a full rotation, the drive shaft 26 and cams 42, 44 are again in their initial positions and the matrix 12 has completed the desired incremental rotation of, for example, 90 degrees.

[0018] In an alternative embodiment, the motor 20 is an electric motor which is capable of functioning as an alternator. Energy to accelerate the drive shaft 26 is provided entirely by the motor 20. Energy is recovered during deceleration by the motor 20 and stored using, for example, one or more capacitors. The acceleration and deceleration can be controlled to follow an optimum velocity-time relationship to limit forces on the matrix 12, for instance.

[0019] In another embodiment, a flywheel 80 illustrated in FIG. 1 is utilized as an energy-storage device. The flywheel 80 is disposed in operable communication with the motor 20 and the matrix 12, and energy is stored in the rotating flywheel 80. When it is desired to accelerate the matrix 12, energy is transferred from the flywheel 80 to the matrix 12, thus decelerating the flywheel 80. When the matrix 12 is decelerated, rotational energy is transferred to the flywheel 80 thus accelerating the flywheel 80. To make up for losses from friction, the motor 20 provides the remaining energy needed to accelerate the flywheel 80 to a desired speed.

[0020] Use of this drive system to rotate the matrix produces substantially shock-free and smooth acceleration and deceleration of the matrix 12 through the utilization of the motor 20 which is sized and configured to provide enough torque only to overcome friction in the drive system 18. The energy input required to rotate the matrix 12 is minimized, and impact to an overall efficiency of the regenerator is likewise minimized.

[0021] While embodiments of the invention have been described above, it will be understood that those skilled in the art, both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow. These claims should be construed to maintain the proper protection for the invention first described.

What is claimed is:

1. A regenerative heat exchanger comprising:

a high heat capacity matrix rotatable about an axis;
a drive system in operable communication with the high heat capacity matrix, the drive system capable of rotating the high heat capacity matrix about the axis; and
an energy-storage mechanism in operable communication with the drive system, the energy-storage mechanism capable of controlling an acceleration and/or deceleration of rotation of the high heat capacity matrix.

2. The regenerative heat exchanger of claim 1 wherein the energy-storage mechanism comprises:

one or more cams disposed on a drive shaft of the drive system;

one or more cam followers, each cam follower having a first end contacting a cam of the one or more cams; and

at least one spring in operable communication with each cam follower of the one or more cam followers, the at least one spring urging the first end of each cam follower toward an axis of rotation of each cam.

3. The regenerative heat exchanger of claim 2 where the first end of each of the one or more cam followers comprises a roller.

4. The regenerative heat exchanger of claim 1 further comprising a motor in operable communication with the drive system capable of initiating rotation of the high heat capacity matrix.

5. The regenerative heat exchanger of claim 4 wherein the motor outputs a constant torque.

6. The regenerative heat exchanger of claim 5 wherein the motor is connected to the drive system via an overriding clutch.

7. The regenerative heat exchanger of claim 4 wherein the motor is a pneumatic motor.

8. The regenerative heat exchanger of claim 4 wherein the motor is an electrical motor capable of operating as an alternator and as the energy storage mechanism.

9. The regenerative heat exchanger of claim 8 wherein the electrical motor includes capacitors capable of energy-storage.

10. The regenerative heat exchanger of claim 1 wherein the energy-storage mechanism is a flywheel.

11. The regenerative heat exchanger of claim 1 wherein the drive system is configured for drive reduction.

12. The regenerative heat exchanger of claim 11 wherein a drive reduction ratio is substantially 4:1.

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