United States Patent Application Publication 20250257707
Kind Code A1
Publication Date August 14, 2025
Inventor(s) French, SR.; William L.

## MODULAR HYDROPOWER SYSTEMS AND METHODS WITH PUMPED STORAGE

### Abstract

A power generation system may include an impoundment structure at least partially defined by a plurality of precast segments. At least one of the precast segments may include a precast form and at least one precast infill block.

**Inventors:** **French, SR.; William L. (Lexington, MA)**

**Applicant:** **W.L. French Hydropower Holdings LLC** (Chelmsford, MA)

**Family ID:** **96660609**

**Appl. No.:** **18/924991**

**Filed:** **October 23, 2024**

### Related U.S. Application Data

us-provisional-application US 63552088 20240209
us-provisional-application US 63552655 20240212
us-provisional-application US 63701484 20240930

### Publication Classification

**Int. Cl.:** **F03B13/06** (20060101); **F03B13/08** (20060101)

**U.S. Cl.:**

CPC **F03B13/06** (20130101); **F03B13/08** (20130101);

### Background/Summary

RELATED APPLICATIONS [0001] This application claims the benefit of U.S. Provisional Application No. 63/552,088, filed on Feb. 9, 2024. This application claims the benefit of U.S. Provisional Application No. 63/552,655, filed on Feb. 12, 2024. This application claims the benefit of U.S. Provisional Application No. 63/701,484, filed on Sep. 30, 2024. The entire teachings of the above applications are incorporated herein by reference.

BACKGROUND

[0002] Pumped storage hydropower systems produce electrical power from the kinetic energy of running water. Pumped storage hydropower systems typically include two water reservoirs, one water reservoir being located at a higher elevation than the other. Power is generated (via a turbine or other power generation components) as water moves from the upper reservoir to the lower reservoir. The system is "recharged" by pumping water from the lower reservoir to the upper reservoir. There is a need for improved hydroelectric power generation systems.

SUMMARY

[0003] A power generation system may include an impoundment structure at least partially defined by a plurality of precast segments. At least one of the precast segments may include a precast form and at least one precast infill block.

[0004] In some example embodiments, the impoundment structure may define an intake or egress configured to receive or output fluid with a fluid supply via a flow path.

[0005] In some example embodiments, the power generation system may further include a power generation module configured to pump fluid from the fluid supply and into the impoundment structure via the flow path.

[0006] In some example embodiments, the power generation system may further include a power conversion module configured to convert kinetic energy of fluid released from the impoundment structure and travelling through the flow path into electric energy.

[0007] In some example embodiments, the power conversion module may include an intake support structure, a power generator support structure, and a draft support structure. The intake support structure may be configured to support at least one intake tube, the intake tube at least partially defining a flow path. The intake support structure may be at least partially constructed of precast segments. The power generator support structure may be configured to support weight of a power generator in an arrangement operably disposed within the flow path. The power generator support structure may be at least partially constructed of precast segments. The draft support structure may be configured to support at least one draft tube, the at least one draft tube at least partially defining the flow path. The draft support structure may be at least partially constructed of precast segments positioned above the at least one draft tube.

[0008] In some example embodiments, the power generation system may further include a flow path structure coupled to the impoundment structure, the flow path structure at least partially defining the flow path. The flow path structure may include at least one precast segment.

[0009] In some example embodiments, the precast infill block may be fixedly couped to the precast segment.

[0010] A power generation system may include an impoundment structure. The impoundment structure may include a containment wall and at least one inner wall. The containment wall may define at least a portion of a boundary of a containment volume. The containment volume may be configured to store a volume of fluid. The at least one inner wall may be positioned within the containment volume and offset from the containment wall. The at least one inner wall may define at least one aperture.

[0011] In some example embodiments, the impoundment structure may include at least one precast segment. The at least one precast segment may include a precast form and at least one precast infill block.

[0012] In some example embodiments, the power generation system may further include one or

more supports coupling the containment wall with the inner wall.
[0013] In some example embodiments, one or more of the one or more supports may define at least one aperture configured to allow fluid to pass therethrough.
[0014] In some example embodiments, the power generation system may further include at least one energy dissipation element disposed within the impoundment structure. The at least one energy dissipation element may be configured to redirect the flow of the pumped fluid entering the-impoundment structure.
[0015] In some example embodiments, the at least one energy dissipation element disposed within the impoundment structure may cause the flow of the pumped fluid to be redirected to be in a circulating direction between inner wall and outer wall.
[0016] In some example embodiments, the containment wall or the at least one inner wall may be at least partially defined by a plurality of precast segments.
[0017] In some example embodiments, at least a subset of the plurality of precast segments may be interconnected via complementary coupling elements.
[0018] A power generation system may include a powerhouse. The powerhouse may include an intake support structure, a power generator, and a draft support structure. The intake support structure may be configured to support at least one intake tube, the intake tube at least partially defining a flow path. The intake support structure may be at least partially constructed of precast segments.
[0019] The power generator support structure may be configured to support weight of a power generator in an arrangement operably disposed within the flow path. The power generator support structure may be at least partially constructed of precast segments. The draft support structure may be configured to support at least one draft tube, the at least one draft tube at least partially defining the flow path. The draft support structure may be at least partially constructed of precast segments positioned above the at least one draft tube.
[0020] In some example embodiments, the at least one precast segment may include a precast form and at least one precast infill block.
[0021] The power generation system may further include a stabilization system. The stabilization system may include at least one support structure configured to be positioned below a lower surface of the powerhouse; and an attachment mechanism configured to couple the at least one support structure with the powerhouse.
[0022] A power generation system may include a water intake structure configured to intake fluid and configured for fluid communication with a powerhouse via a flow path. The water intake structure may be at least partially constructed of precast segments.
[0023] The power generation system may further include a flow path structure configured to facilitate fluid communication between the water intake structure and the powerhouse. A first end of the flow path structure may be coupled to the water intake structure and a second end of the flow path structure may be coupled to the powerhouse.
[0024] In some example embodiments, the water intake structure may include one or more layers. Each layer may include one or more precast segment.
[0025] In some example embodiments, each layer may include at least one protrusion.
[0026] In some example embodiments, at least one of the precast segments may include a precast form and a precast infill block.

---

## Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0027] The foregoing will be apparent from the following more particular description of example embodiments, as illustrated in the accompanying drawings in which like reference characters refer

to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments.
[0028] FIG. **1**A shows a schematic of an example embodiment of a pump storage system.
[0029] FIG. **1**B shows a schematic of an example embodiment of a pump storage system.
[0030] FIG. **2** shows a top view of an example embodiment of a pump storage system comprising three intake modules, each being coupled to a powerhouse via a fluid conduit.
[0031] FIG. **3**A shows a side view of an example embodiment of an intake module.
[0032] FIG. **3**B shows a perspective sectional view of an example embodiment of an intake module.
[0033] FIG. **3**C shows a perspective view of an example embodiment of a layer of an intake module.
[0034] FIG. **4** shows a side view of a schematic of a portion of an example embodiment of a powerhouse.
[0035] FIG. **5** shows a top view of a schematic of a portion of an example embodiment of a powerhouse.
[0036] FIG. **6** shows a top view of a schematic of a portion of an example embodiment of a powerhouse.
[0037] FIG. **7** shows a perspective view of a schematic of a portion of an example embodiment of a powerhouse.
[0038] FIG. **8**A shows a top view of an example embodiment of a modular block.
[0039] FIG. **8**B shows a bottom view of the example embodiment of a modular block of FIG. **8**A.
[0040] FIG. **8**C show s bottom view of the example embodiment of a modular block of FIG. **8**A.
[0041] FIG. **9**A is a perspective view of an example embodiment of three modular blocks in a stacked configuration.
[0042] FIG. **9**B is a side view of the example embodiment of FIG. **9**A.
[0043] FIGS. **10**A-**10**B are perspective views of an example embodiment of three modular block in a stacked configuration and shows example levels to which the cavity of each modular block may be filled.
[0044] FIG. **11** shows an example embodiment of two stacks of modular blocks, the two stacks being coupled together laterally.
[0045] FIG. **12** shows an example embodiment of four stacks of modular blocks and precast concrete infill blocks.
[0046] FIG. **13** shows example dimensions for an example embodiment of a modular block.
[0047] FIG. **14** shows an example embodiment of a rectangular modular block.
[0048] FIG. **15**A shows a perspective of an example embodiment of a working platform coupled to rock anchors.
[0049] FIG. **15**B shows a close-up view of the example embodiment of a working platform of FIG. **15**A.
[0050] FIG. **16**A shows a perspective view of an example embodiment of a working platform coupled to multiple rock anchors.
[0051] FIG. **16**B shows a perspective view of an example embodiment of a working platform coupled to multiple cleats, rock anchors, and diffusers.
[0052] FIG. **17** shows an example embodiment of an earthquake prevention system.
[0053] FIG. **18** shows an example embodiment of a powerhouse configured to be at a cavernous subterranean location underground.
[0054] FIG. **19** shows an example embodiment of a powerhouse configured to be at a cavernous subterranean location underground.
[0055] FIG. **20** shows an example embodiment of a powerhouse configured to be at a cavernous subterranean location underground.
[0056] FIG. **21** shows an example embodiment of a precast powerhouse configured to be at a

cavernous subterranean location underground.
[0057] FIG. **22** shows an example embodiment of a precast powerhouse in an excavated cavern.
[0058] FIG. **23** shows example embodiments of modular blocks for mass and powerhouse galleries.
[0059] FIG. **24**A shows an example embodiment of a water storage tunnel.
[0060] FIG. **24**B shows a top view of an example embodiment of a tunnel precast module.
[0061] FIG. **24**C shows a side view of an example embodiment of a tunnel precast module.
[0062] FIG. **24**D shows a perspective view of an example embodiment of a water storage tunnel.
[0063] FIG. **25** shows an example embodiment of a seismic relief fluid conduit system.
[0064] FIG. **26**A shows an example of a fan configured to provide suction to pull fluid to the upper impoundment structure.
[0065] FIG. **26**B shows an example configuration for pulling fluid to an upper impoundment structure.
[0066] FIG. **27** shows an example of an assembly of an example embodiment of an impoundment structure.
[0067] FIG. **28** shows an example of an assembly of an example embodiment of an impoundment structure.
[0068] FIG. **29** shows an example embodiment of an impoundment structure comprising energy dissipation elements (also referred to as diffusers).
[0069] FIG. **30** shows an example embodiment of an impoundment structure or tank comprising energy dissipation elements.
[0070] FIG. **31** shows an example embodiment of an impoundment structure or tank comprising energy dissipation elements.
[0071] FIG. **32** shows an example embodiment of an impoundment structure comprising energy dissipation elements.
[0072] FIG. **33** shows an example embodiment of an impoundment structure or tank comprising energy dissipation elements.
[0073] FIG. **34** shows an example embodiment of an impoundment structure comprising a sensor system configured to monitor conditions in the impoundment structure.
[0074] FIG. **35**A shows an example embodiment of tube gates at fluid conduits.
[0075] FIG. **35**B is a side view of an example embodiment of gates configured to translate in the direction of the arrows.
[0076] FIG. **35**C is a side view of an example embodiment of gates configured to translate in the direction of the arrows.
[0077] FIG. **35**D is a top view of an example embodiment of gates configured to translate in the direction of the arrows.
[0078] FIG. **36** is an example embodiment of an environmental protective system.

## DETAILED DESCRIPTION

[0079] A description of example embodiments follows.
[0080] Traditional pumped storage facilities typically require complex custom civil designs that are expensive to build, especially in remote mountainous areas. Blasting, excavating, embankment building, and rock-tunneling are examples of costly and time-consuming civil construction activities typically involved in building traditional pumped storage facilities, and these activities leave permanent environmental scars on the landscape. Accordingly, there is a need for improved pumped storage systems.
[0081] Systems, devices and methods described herein may involve pumped storage hydropower (PSH) systems that include components constructed from precast segments. As used herein, the term “precast segment” refers to precast modules of particular shape and size formed of a structural material, such as, concrete. Precast segments can include coupling elements to enable the segments to be interconnected during construction of a structure, such as a reservoir or impoundment module. Precast segments can be manufactured off-site, providing for increased control over

manufacturing conditions, thereby providing for more robust and uniformly constructed segments for forming a structure, as compared with a structure formed by on-site concrete pouring. For some construction projects, a temporary facility may be constructed to manufacture precast segments on-site, whereby the temporary facility itself may be formed of precast segments.

[0082] Hydroelectric power generation systems described herein can provide for more versatile and facile construction than existing hydroelectric power systems, and with less environmental impact. Such systems can be constructed with precast segments, which can provide for faster construction with more robust structural components, and which can provide for construction in areas that would otherwise be inaccessible or that would require more environmentally-destructive construction.

[0083] In various embodiments, a power generation system may include a reservoir or impoundment structure that is at least partially defined by a plurality of precast segments. At least a subset of the precast segments may be interconnected via complementary coupling elements. The reservoir or impoundment structure may be elevated with respect to a fluid supply. The system may further include a flow path providing fluid communication between the reservoir or impoundment structure and the fluid supply, a power generation module configured to pump fluid from the fluid supply and into the reservoir via the flow path, and a power conversion module configured to convert kinetic energy of fluid released from the reservoir and travelling through the flow path into electric energy.

[0084] The power generation system can be an open-loop system or a closed-loop system. For example, for an open-loop system, the fluid supply can be a natural water supply, such as a river or lake or rain. For a closed-loop system, the system can further include a lower reservoir or impoundment structure that houses the fluid supply.

[0085] The reservoir(s) or impoundment structures of the system can include energy dissipation elements that are configured to disrupt a direction of fluid flow and/or reduce a velocity of flowing fluid that is being pumped into the reservoir or impoundment structure. Such energy dissipation elements can be auxiliary precast segments, or can be at least partially defined by one or more auxiliary precast segments. Optionally, an auxiliary precast segment can include a coupling element for mechanical coupling to a precast element of the reservoir or impoundment structure. The energy dissipation elements can be disposed substantially vertically with respect to a base of the reservoir or impoundment structure and, optionally, provide for the multifunction purpose of supporting a roof that permanently covers or selectively covers the reservoir or impoundment structure. Vertically-disposed auxiliary precast segments can be further supported by auxiliary precast segments that extend between the vertically-disposed auxiliary precast segments. For example, auxiliary precast segments with a non-vertical orientation can be disposed between the vertically-disposed auxiliary precast segments. The energy dissipation elements can comprise perforated structures, such as defined by one or more precast segments. Energy dissipation elements can also be disposed in a fluid supply for an open-loop system. For example, energy dissipation elements can be disposed in an area at which water is released back to the natural water supply, so as to reduce impact of the flowing water on natural structures and on wildlife.

[0086] The reservoir(s) or impoundment structure(s) of the system can each include a continuous base, with precast segments forming the reservoir impoundment structure configured to couple to an upper surface of the base. Precast segments forming the reservoirs or impoundment structures can include precast segments having at least two opposing surfaces of a substantially triangular or truncated triangular shape. Such shape can provide for the precast segments to be alternately arranged to define a wall of the reservoir/impoundment structure and/or to define a buttress structure to support a wall of the reservoir/impoundment structure. Other shapes that define straight or curvilinear edges that enable adjacent arrangement to define a buttress structure may also be employed.

[0087] The flow path(s) of the system can be defined by at least two fluid conduits that are

individually selectable for fluid transfer between the fluid supply and the reservoir/impoundment structure. For example, one of the fluid conduits can be utilized for upward flow, and the other for downward flow, with an option to alternate direction in each conduit. At least one dedicated pump can be included at each of the at least two fluid conduits. The fluid pump(s) of the system can be disposed at varying elevations. For example, at least two fluid pumps can be disposed at a conduit that defines a flowpath, the fluid pumps disposed at varying elevations. Optionally, one or more intermediary reservoirs/impoundment structures can be included, where the intermediary reservoirs/impoundment structures may include aspects constructed through the use of precast segments, such as any of the precast segments described herein. The inclusion of multiple fluid pumps for a flow path and intermediary reservoirs/impoundment structures along the flow path can provide for a configuration in which work is distributed throughout the system rather than performed by a single pump. Similarly, intermediate reservoirs/impoundment structures can be included along the flow path for downward flow, so as to not overwhelm a lower reservoir/impoundment structure or naturally water supply during periods of power generation.
[0088] In some embodiments, the fluid pump(s) may be used to force fluid to an upper reservoir/impoundment structure to retain the pumped fluid as potential energy and convert kinetic energy of fluid flowing downward into electrical power. For example, in one embodiment, the power generation module and power conversion module may be integrated into a single module that includes a turbine configured to rotate in a first direction to pump the fluid from the fluid supply and into the reservoir via the flow path and to rotate in a second direction to convert the kinetic energy of fluid released from the reservoir into electric energy.
[0089] Various configurations of precast segments can be used to construct or define the system. Precast segments can be provided for foundation segment(s) of the reservoir(s)/impoundment structure(s), as impound segments configured to encase infill to at least partially define the reservoir(s)/impoundment structure(s), and/or as fluid conduit segments to define the flow path(s) of the system. The reservoir(s)/impoundment structure(s) can include one or more precast segment(s) defining an outlet port for fluid released from the reservoir/impoundment structure and defining an inlet port for fluid pumped into the reservoir/impoundment structure. One or more inlet and/or outlet ports can be included. The inlet port can be disposed at a higher elevation than the outlet port.
[0090] The power generation system may have the power generation module and power conversion module integrated into a single module that includes a turbine configured to rotate in a first direction to pump the fluid from the fluid supply and into the reservoir/impoundment structure via the flow path and to rotate in a second direction to convert the kinetic energy of fluid released from the reservoir/impoundment structure into electric energy.
[0091] The power generation system may further comprise material flowed and coupled to a precast segment. The material may be positioned over a seam between adjacent precast segments or define an energy dissipation element.
[0092] The power generating system may comprise a three-dimensional (3D) material printing system coupled to a precast segment on a base of or at an upper surface of the reservoir/impoundment structure. In such an embodiment, the 3D material printing system may access material from a source of material located at the reservoir/impoundment structure and transfer the material to a different precast segment via a boom.
[0093] A power generation method includes, with a power generation system, transferring fluid from the fluid supply to the reservoir/impoundment structure via the flow path, releasing fluid from the reservoir/impoundment structure to the fluid supply via the flow path, and storing energy converted by the energy conversion component during fluid release.
[0094] In various embodiments, transferring of water from the water supply to the reservoir/impoundment structure can occur during a period of low-energy use by a community associated with a power grid that may supply power to or receive power from the power generation

system such that the cost of energy is low while water is being pumped upward to the reservoir. Releasing of water from the reservoir/impoundment structure to the water supply occurs during a period of high-energy use such that power generated by the power generation system is available to serve the community via the power grid.

[0095] FIG. **1**A shows a schematic of an example embodiment of a pump storage system **100**. In various embodiments, such as the one shown in FIG. **1**A, a pump storage system **100** may comprise an impoundment structure **101**, at least one fluid conduit **120**, and a powerhouse **110**. The powerhouse **110** may be above ground or below ground. In various embodiments, the powerhouse may be mounted on a foundation that doesn't penetrate the ground. The pump storage system **100** may also be referred to as a power generation system herein.

[0096] The impoundment structure **101** is constructed and arranged to store a volume of fluid. In various embodiments, each impoundment structure **101** is composed of at least one precast segment. The at least one fluid conduit **120** (also referred to as a flow path structure) may be coupled to the impoundment structure **101** and the powerhouse **110** such that the fluid can flow from the impoundment structure **101** to the powerhouse **110** and then to a second location. In some embodiments, the second location is a second storage location, for example a second impoundment structure. In various embodiments, at least one of the fluid conduits comprises at least one precast segment. In some example embodiments, the impoundment structure includes a roof. In some example embodiments, the impoundment structure does not include a roof.

[0097] In various embodiments, such as the one shown in FIG. **1**A, the pump storage system **100** comprises at least one intake module **130**, each intake module **130** being configured to receive or emit fluid. Each of the at least one intake module **130** is coupled to a corresponding fluid conduit **120**. In the embodiment shown FIG. **1**A, the pump storage system **100** comprises three intake modules **130***a*-**130***c*. In alternative embodiments, the pump storage system comprises a different number of intake modules.

[0098] In the embodiments shown in FIG. **1**A the three intake modules **130***a*-**130***c* are arranged in a row. In alternative embodiments, the different intake modules may be arranged differently.

[0099] In various embodiments, such as the one shown in FIG. **1**A, the intake modules **130***a*-**130***c* are located at an upper impoundment structure **101**. In various embodiments, at least one intake module may be located at a lower impoundment structure or natural fluid storage location (e.g., a river, lake, pond, etc.).

[0100] In the embodiment shown in FIG. **1**A the pump storage system comprises three fluid conduits. In alternative embodiments, the pump storage system may comprise a different number of fluid conduits. The fluid conduits may be arranged in different configurations. For example, the fluid conduits shown in FIG. **1**A are straight. In alternative embodiments, one of more of the fluid conduits may be arranged differently. In some example embodiments, one or more of the fluid conduits may have a circular cross-section. In alternative example embodiments, one or more fluid conduits may have a cross-section of a different shape, for example square, rectangular, triangular, etc. In some example embodiments, one or more fluid conduits may include a precast segment.

[0101] In some example embodiments, one or more fluid conduits may be open (i.e., configured such that a fluid in the fluid conduit is exposed to the environment). In some example embodiments, one or more fluid conduits may be closed. In some example embodiments, precast structures define a flowpath.

[0102] In some example embodiments, one or more structures may secure the position of one or more fluid conduits. In some example embodiments, one or more of the one or more structures may include at least one precast segment. In some example embodiments, one or more of the structures may be configured to be secured to the ground for stability.

[0103] FIG. **1**B shows a schematic of an example embodiment of a pump storage system **100**. In FIG. **1**B the impoundment structure has been removed for clarity. In some embodiments, such as the one shown in FIG. **1**B the fluid conduits are configured at a right angle.

[0104] In various embodiments, such as the ones shown in FIGS. **1**A-**1**B, each intake module **130** comprises a support base **132**. In alternative embodiments, one or more of the intake modules may not comprise a support base. In various embodiments, each intake module comprises an axial channel and the axial channel is coupled to the at least one of the at least one of the fluid conduits such that fluid passes down to the powerhouse.
[0105] In the example embodiment shown in FIGS. **1**A and **1**B, the powerhouse **110** includes three houses. In alternative embodiments, the powerhouse may include a different number of houses.
[0106] In some example embodiments, the powerhouse includes at least one valve house. The valve house may include at least one valve coupled with a fluid conduit. In some example embodiments, a house closest to the impoundment structure is a value house.
[0107] In some example embodiments, the powerhouse includes at least one electric house. In some example embodiments, a house farthest from the impoundment structure is an electric house.
[0108] In some example embodiments, the powerhouse includes at least one turbine house. The turbine house may include at least one turbine. In some example embodiments, a turbine house is between a valve house and an electric house.
[0109] FIG. **2** shows a top view of an example embodiment of a pump storage system **200** comprising three intake modules **230***a*-**230***c*, each being coupled to a powerhouse **210** via a fluid conduit **220***a*-**220***c*. The impoundment structure is not shown in this view. In various embodiments, such as the one shown in FIG. **2**, the powerhouse **210** comprises three turbines. In alternative embodiments, the powerhouse may comprise a different number of turbines. In those embodiments in which the powerhouse is underground, the associated fluid conduits may also be underground. In various embodiments, the pump storage system may comprise more than one powerhouse.
[0110] In various embodiments, such as the one shown in FIG. **2**, the powerhouse may comprise one or more modular blocks. In various embodiments, the modular blocks are precast.
[0111] FIG. **3**A shows a side view of an example embodiment of an intake module.
[0112] FIG. **3**B shows a perspective sectional view of an example embodiment of an intake module.
[0113] FIG. **3**C shows a perspective view of an example embodiment of a layer of an intake module.
[0114] One or more of the intake modules **330** may be constructed using precast components. In various embodiments, an intake module **330** may comprise a support base **332** and an at least one intake region **331**. In the embodiment shown in FIG. **3**A, the intake module **330** comprises one intake region **331**. In alternative embodiments, the intake module may comprise more than one intake region coupled to a support base.
[0115] In various embodiments, the intake region **331** may comprise one or more layers **333**. One or more of the one or more layers **333** may comprise precast segments. A portion of a layer may be a precast segment. An entire layer may be a precast segment. Multiple layers may together be a precast segment.
[0116] One or more of the one or more layers may comprise one or more apertures. In the embodiment shown in FIGS, **3**A-**3**C, each layer **333** comprises one circular central aperture **334** and the circular aperture **334** is positioned at the center of the layer **333**. In alternative embodiments, one or more of the layers may not comprise an aperture. In alternative embodiments, one or more of the layers may comprise more than one aperture. In alternative embodiments, one or more of apertures may comprise a different shape. In alternative embodiments, one or more of the apertures may be positioned off-center at the corresponding layer.
[0117] One or more apertures of the layers may form one or more axial channels **335** through the intake region **331** of the intake module **330**. In the embodiment shown in FIGS. **3**A-**3**C, the intake region **331** comprises one channel **335**. In alternative embodiments, the intake region may comprise more than one channel.
[0118] The axial channel of the intake region may be aligned with an axial channel of the support

base. The axial channel of the support base may be aligned with a channel of a fluid conduit.

[0119] One or more of the one or more layers **333** may comprise one or more protrusions **336**. In various embodiments, a first layer **333***a* and a neighboring second layer **333***b* may be arranged such that the arrangement of protrusions **336** create apertures **337** at the sides of the intake region **331**. These apertures **337** are configured to allow fluid to enter the intake module **330** and flow to an axial channel **335**. In various embodiments, the protrusions **336** may be configured differently than the configuration shown in FIGS. **3**A-**3**C.

[0120] In some example embodiments, one or more of the apertures **337** may be at least partially blocked with a cover (not shown). One or more of the one or more covers may be in communication with a controller. The controller may control the opening and/or closing of one or more of the covers. In some instances, the covers may all be opened and/or closed together. In some instances, some of the covers may be opened and/or closed selectively. In some instances, the covers at a specific layer may be opened and/or closed together. One or more of the covers may be opened and/or closed using any suitable mechanism, for example pneumatic controls, electromagnetic controls, and/or one or more screw drive actuators.

[0121] In some example embodiments, a user may control the opening and/or closing of covers using the controller. In some example embodiments, a user may control the opening and/or closing of covers using a local interface. In some example embodiments, a user may control the opening and/or closing of covers using a remote interface. In some example embodiments, the opening and/or closing of covers may be controlled automatically. In some example embodiments, the opening and/or closing of covers may be controlled based, at least in part, on environmental conditions, for example fluid levels.

[0122] In some example embodiments, the intake module may be in communication with one or more powerhouses. In some example embodiments, the intake module may be in wireless communication with one or more powerhouses. In some example embodiments, the intake module may be in wired communication with one or more powerhouses. In some example embodiments, communication between one or more intake modules and one or more powerhouses may determine settings at one or more intake module or one or more powerhouse. For example, flow control gate configurations at a powerhouse may be based, at least in part, on information from an intake module.

[0123] In the embodiment shown in FIGS. **3**A-**3**C, each layer **333** comprises a circular shape. In alternative embodiments, one or more of the layers may comprises a different shape. In the embodiment shown in FIGS. **3**A-**3**C each support base **332** comprises a circular shape. In alternative embodiments, the support base may comprise a different shape.

[0124] In some embodiments, the top of the intake region comprises a cover **338**. In alternative embodiments, the top of the intake region may comprise at least one aperture. In various embodiments, at least one aperture of the at least one aperture at the top of the intake region may be aligned with at least one axial channel. In various embodiments, the cover of the intake region may comprise one or more precast components.

[0125] One more intake module may be located in or near an upper impoundment structure, a lower impoundment structure, an intermediary impoundment structure, a dam, or a natural water source (e.g. a river, lake, pond, etc.). In various embodiments, the intake module may be constructed using cast in place techniques.

[0126] FIG. **4** shows a side view of a schematic of a portion of an embodiment of a powerhouse **410**. In various embodiments, such as the one shown in FIG. **4**, the fluid conduit into the powerhouse (**420***a*, left) may be at a different height than the fluid conduit leaving the powerhouse **420***b*. In various embodiments, one or more of the fluid conduits may comprise a steel lining. In some example embodiments, the fluid conduit may include at least one penstock. In at least some instances, a flow path structure may be a fluid conduit. In at least some instances, an intake tube may be a fluid conduit. In at least some instances, a draft tube may be a fluid conduit.

[0127] FIG. **5** shows a top view of a schematic of a portion of an example embodiment of a powerhouse **510**. As shown in FIG. **5**, the fluid conduits into the powerhouse (**520***a*-**520***c*, left) may comprise Y-junctions. As shown in FIG. **5**, the fluid conduits out of the powerhouse (**520***d*-**520***f*, right) may comprise Y-junctions. In alternative embodiments, the fluid conduits into and/or out of the powerhouse may not comprise Y-junctions.
[0128] FIG. **6** shows a top view of a schematic of a portion of an embodiment of a powerhouse **610**. In embodiment, the intake fluid conduits are coupled to six turbines. In alternative embodiments, the powerhouse may comprise a different number of turbines. In the embodiment shown in FIG. **6** the turbines are arranged in a row. In alternative embodiments, the turbines may be arranged differently.
[0129] FIG. **7** shows a perspective view of a schematic of a portion of an embodiment of a powerhouse **710**. In this embodiment, the powerhouse **710** comprises different types of modular blocks. In some embodiments, such as the one shown in FIG. **7**, the power generation system, comprises an intake support structure **722**, a power generator support structure **724**, and a draft support structure **726**.
[0130] In some example embodiments, the intake support structure **722** may be configured to support at least one intake tube, the intake tube at least partially defining a flow path. In some example embodiments, the intake support structure **722** may be at least partially constructed of precast segments.
[0131] In some example embodiments, the power generator support structure **724** may be configured to support weight of a power generator in an arrangement operably disposed within the flow path. In some example embodiments, the power generator support structure **724** may be at least partially constructed of precast segments
[0132] In some example embodiments, the draft support structure **726** may be configured to support at least one draft tube, the draft tube at least partially defining the flow path. In some example embodiments, the draft support structure **726** may be at least partially constructed of precast segments. In some example embodiments, the precast segments may be positioned above the at least one draft tube. In some example embodiments, such as the one shown in FIG. **7**, the precast segments of the draft support structure function as thrust blocks to control thrust from the draft tube.
[0133] In some example embodiments, at least one of the precast segments of the power generator support structure **724** includes a form that defines an internal cavity. In some example embodiments, at least one of the precast segments of the intake support structure **724** includes a form that defines an internal cavity. In some example embodiments, at least one of the precast segments of the draft support structure **724** includes a form that defines an internal cavity.
[0134] In some example embodiments, one or more precast segments of the intake support structure may be positioned above the at least one draft tube. In some example embodiments, one or more precast segments of the power generator support structure may be positioned above the at least one draft tube.
[0135] In some example embodiments, at least two of the intake support structure **722**, the power generator support structure **724**, and the draft support structure **726** are removably coupled.
[0136] In some example embodiments, for example the one shown in FIG. **7**, one or more prestressed beams may be coupled to one or more elements of the powerhouse. In some example embodiments, one or more of the prestressed beams may be oriented vertically. In some example embodiments, one or more of the prestressed beams may be oriented horizontally.
[0137] In some example embodiments, the powerhouse may include one or more cranes. For example, if the powerhouse includes multiple houses, there may be a crane associated with each house. In some embodiments, there may be more than one crane at a house of the powerhouse. In some embodiments, a house of the powerhouse may not include a crane. In some example embodiments there may be at least one crane associated with the intake support structure. In some

example embodiments there may be at least one crane associated with the power generator support structure. In some example embodiments there may be at least one crane associated with the draft support structure.

[0138] In some example embodiments, a powerhouse may include one or more flow control gates. In some example embodiments, one or more flow control gates may be positioned in a fluid conduit.

[0139] FIG. **8**A shows a top view of an example embodiment of a modular block **815**. In various embodiments, such as the embodiment shown in FIG. **8**A, the modular block **815** comprises a square shape. In alternative embodiments, the modular block may comprise a different shape, including, but not limited to rectangle, circle, trapezoid, any such suitable polygon, or combinations thereof.

[0140] FIG. **8**B shows a bottom view of the example embodiment of a modular block of FIG. **8**A.

[0141] FIG. **8**C show s bottom view of the example embodiment of a modular block of FIG. **8**A. In various embodiments, such as the one shown in FIG. **8**A, the modular block **815** defines a cavity **816** configured to receive a filling material. Example filling materials may include, but are not limited to: concrete, cement, ecomaterials, volcanic ash, glass, portions of brick, rubble, ground auto tires, steel fibers, fiber mesh, carbon fiber, flowable fill, or portions of solar panels.

[0142] In various embodiments, such as the embodiment shown in FIG. **8**C, the modular block **815** defines a cavity **816** with a square shape. In alternative embodiments, the modular block may define a cavity with a different shape, including, but not limited to rectangle, circle, trapezoid, any such suitable polygon, or combinations thereof. In alternative embodiments, the cavity may comprise a different volume.

[0143] In alternative embodiments, the cavity may be divided into different sections.

[0144] In various embodiments, such as the one shown in FIGS. **8**A-**8**C, the modular block **815** defines at least one aperture **817**. In the embodiment shown in FIGS. **8**A-**8**C the modular block **815** comprises one aperture **817**. In alternative embodiments, a modular block may comprise a different number of apertures.

[0145] In various embodiments, such as the one shown in FIGS. **8**A-**8**C, the aperture has a circular shape. In alternative embodiments, the modular block may define an aperture with a different shape, including, but not limited to rectangle, square, trapezoid, any such suitable polygon, or combinations thereof.

[0146] In various embodiments, such as the one shown in FIGS. **8**A-**8**C, the aperture **817** is centrally located in the cavity **816** of the modular block **815**. In alternative embodiments, at least one aperture may be located at a different location.

[0147] In various embodiments, the modular block may comprise one or more curing chambers. In various embodiments, one or more of the curing chambers may comprise characteristics identical or similar to those characteristics described in connection with any other figure.

[0148] In various embodiments, such as the one shown FIGS. **8**A-**8**C, the modular block **815** comprises one or more attachment mechanisms constructed and arranged to allow the modular block to couple to other modular blocks or structures. The embodiment shown in FIGS. **8**A-**8**C shows different attachment mechanisms including dowels, elongated members, and/or vertical linkages. The modular block attachment mechanism may comprise one or more elongated members. At least one of the elongated members may be configured to couple one modular block to a neighboring modular block. For example, as shown in FIGS. **8**A-**8**C, one or more elongated members may pass through the aperture **817** of the modular block **815** and be arranged in a bent configuration. Some elongated members may be used to secure other elongated members in place. The elongated members may comprise any suitable material, including, but not limited to metal, plastic, or combinations thereof. Different modular blocks may comprise different numbers of elongated members. The modular block may also be configured to include one or more lift points. In some example embodiments, one or more modular blocks may be coupled using one or more

expandable linkages.
[0149] FIG. **9**A is a perspective view of an example embodiment of three modular blocks **915** in a stacked configuration. In various embodiments, such as the one shown in FIG. **9**A, one or more modular blocks may be stacked, with at least one of the blocks coupled to a neighboring block. In this embodiment, elongated members from a modular block are coupled to elongated members of the neighboring modular block. In various embodiments, the elongated members of a modular block may be indirectly coupled to the elongated members of a neighboring modular block. In various embodiments, the elongated members may be arranged such that when a filling material is inserted into the cavity of a modular block, it will submerge one or more of the elongated members.
[0150] In some instances, filling material may be poured through an aperture of one modular block to fill a lower modular block. In various embodiments, a modular block at the top of a stack of modular blocks is capped.
[0151] FIG. **9**B is a side view of the example embodiment of FIG. **9**A.
[0152] FIGS. **10**A-**10**B are perspective views of an example embodiment of three modular block in a stacked configuration and shows example levels to which the cavity of each modular block may be filled. The level to which the cavities may be filled may be similar (or approximately the same) or the levels may be different for different blocks. In some instances, one or more of the blocks that are coupled may not include a cavity.
[0153] FIG. **11** shows an example embodiment of two stacks of modular blocks **1115**a-**1115**f, the two stacks being coupled together laterally. In different configurations a different number of modular blocks may be coupled vertically and/or horizontally.
[0154] In various embodiments, one or more modular blocks may be configured to individually serve as a capacitor. In various embodiments, one or more modular blocks may be coupled to collectively serve as a capacitor.
[0155] In various embodiments, one or more of the modular blocks may be coupled using at least one dowel, at least one bolt, at least one keyway, at least one re-rod, or at least one port. In various embodiments, one or more of the modular blocks may be coupled using at least one expandable linkage, at least one automatic linkage (that locks itself), at least one prestressed cable (vertical configuration, horizontal configuration, or other configuration), at least one linkage port, or any other mechanism suitable for connecting items.
[0156] In various example embodiments, spaces between neighboring precast segments may be filled with concrete, grout, liners, or water stopping agents. In various example embodiments, spaces between precast segments and other elements (for example, fluid conduits) may be filled with concrete, grout, liners, or water stopping agents. In various example embodiments, spaces within precast forms may be filled with concrete, grout, liners, or water stopping agents. In various example embodiments, spaces between any elements associated with a powerhouse or dam may be filled with concrete, grout, liners, or water stopping agents.
[0157] In various example embodiments, one or more nanotech coatings may be applied to seals or filler materials between neighboring precast segments. In various example embodiments, one or more nanotech coatings may be applied to seals or filler materials between precast segments and other elements (for example, fluid conduits). In various example embodiments, one or more nanotech coatings may be applied to seals or filler materials between spaces or filler material within precast forms. In various example embodiments, one or more nanotech coatings may be applied to seals or filler materials associated with a powerhouse or dam.
[0158] FIG. **12** shows an example embodiment of four stacks of modular blocks **1215** with precast concrete infill blocks **1214**. In some example embodiments a precast segment includes a precast form and a precast infill block **1214**. The precast form may be sized and shaped to accept one or more precast infill blocks **1214**. In some example embodiments, the tolerances (i.e., spaces) inside the modular blocks **1215** may be filled with fine processed stone, rubber grindings, or any such similar or suitable material, for example other materials described herein.

[0159] In the example embodiment shown in FIG. **12**, precast infill blocks **1214** are defined by a rectangular shape. In alternative embodiments, one or more of the precast infill blocks may be defined by a different shape.
[0160] In the example embodiment shown in FIG. **12**, two precast infill blocks **1214** are positioned in a modular block **1215**. In alternative embodiments, a different number of precast infill blocks may be positioned in a modular block **1215**.
[0161] In the example embodiment shown in FIG. **12**, two precast infill blocks **1214** are oriented next to each other. Alternatively or additionally, in some example embodiments precast infill blocks **1214** may be stacked on each other.
[0162] In some example embodiments, one or more of the precast infill blocks are fixedly coupled to a precast segment. In alternative embodiments, one or more of the precast infill blocks may not be fixedly coupled to a precast segment.
[0163] FIG. **13** shows example dimensions for an example embodiment of a modular block. In alternative embodiments, the dimensions may be different. In some embodiments, a modular block may be about 18 feet by 18 feet. In some embodiments, the modular block may be about 4 feet thick. In some embodiments a cavity of a modular block may be about 15 feet by 15 feet. In some embodiments, a cavity of the modular block may be about 3 feet deep. In some embodiments, a keyway may be at a lower surface of the block and have dimensions of about 12 feet by 12 feet. In some embodiments, a modular block and/or keyway may have dimensions that are different than those shown in FIG. **13**.
[0164] FIG. **14** shows an example embodiment of a rectangular modular block **1415**. In this embodiment the rectangular modular block **1415** comprises a rectangular cavity **1416**. In alternative embodiments, the cavity may be a different shape.
[0165] In various embodiments, such as the one shown in FIG. **14**, the rectangular modular block **1415** may comprise one or more attachment loops **1418** configured to allow for coupling to other structures or coupling to fillable material. In the embodiment shown in FIG. **14**, the modular block **1415** comprises attachment loops **1418** both in the cavity and outside the cavity. In alternative embodiments, the modular block may comprise attachment loops in a different configuration. In alternative embodiments, the modular block **1415** may comprise attachment loops only outside the cavity. In alternative embodiments, the modular block **1415** may comprise attachment loops only inside the cavity. In alternative embodiments, the modular block **1415** may not comprise attachment loops.
[0166] A modular block may comprise different curing compartments. In the embodiment shown in FIG. **14**, the modular block **1415** comprises five curing compartments **1419***a*-**1419***e*. In alternative embodiments, the modular block **1415** may comprise a different number of curing compartments. In the embodiment shown in FIG. **14**, the curing compartments **1419** are arranged such that they extend along a shorter dimension of the modular block **1415**. In alternative embodiments, the curing compartments **1419** extend along the longer dimension of the modular block **1415**. In alternative embodiments, the curing compartments **1419** extend along a diagonal dimension of the modular block **1415**. In alternative embodiments, the curing compartments **1419** extend along a different dimension of the modular block **1415**. In various embodiments, the rectangular modular block **1415** may comprise at least one aperture.
[0167] FIG. **15**A shows a perspective of an example embodiment of a working platform **1581** coupled to rock anchors **1582**.
[0168] FIG. **15**B shows a close-up view of the working platform **1581** of FIG. **15**A. In some example embodiments, such we the one shown in FIG. **15**B, the working platform **1581** comprises pleats and/or grooves configured to couple with segments of a powerhouse or dam. In alternative embodiments the working platform may not comprise pleats and/or grooves.
[0169] In some embodiments, such we the one shown in FIG. **15**B, the working platform **1581** is coupled to connectors (for example, bolts) to couple with segments of a powerhouse or dam. In

alternative embodiments, the working platform may not be coupled to connectors.

[0170] FIG. **16**A shows a perspective view of an example embodiment of a working platform **1681** coupled to multiple rock anchors **1682**. In the example embodiment shown in FIG. **16**A a cutoff wall **1683** is coupled to a lower surface of the working platform **1681**.

[0171] FIG. **16**B shows a perspective view of an example embodiment of a working platform **1681** coupled to multiple cleats **1674**, rock anchors **1682**, and diffusers **1642**. In the example embodiment shown in FIG. **16**B the diffusers are coupled to a downstream side of the working platform **1681**. In alternative embodiments, the working platform may not be coupled to cleats. In alternative embodiments, the working platform may not be coupled to rock anchors. In alternative embodiments, the working platform may be coupled to diffusers at the upstream side of the working platform. In alternative embodiments, the working platform may not be coupled to diffusers.

[0172] FIG. **17** shows an example embodiment of an earthquake prevention system **1780**. Any of the structures described herein such as an impoundment structure, tank, or powerhouse may comprise an earthquake prevention system **1780**. In various embodiments, the earthquake prevention system **1780** may comprise at least one platform **1781** coupled to a lower surface of a powerhouse **1710** (or other structure such as an impoundment structure or tank). In various embodiments, such as the one shown in FIG. **17** the platform is coupled to multiple blocks or precast segments. In various embodiments the platform is coupled to modular blocks. The earthquake prevention system **1780** may comprise one or more precast components. In various embodiments, one or more components of the earthquake prevention system **1780** are constructed with precast components.

[0173] In various embodiments, the earthquake prevention system **1780** may comprise at least one cleat **1774**. In various embodiments, the earthquake prevention system may comprise at least one cleat **1774** coupled to at least one of the at least one platform **1781**. In alternative embodiments, the platform may be coupled to a different number of cleats. In various embodiments, processed stone is positioned around the cleats. In various embodiments, the earthquake prevention system **1780** is configured such that water can be injected around at least one of the cleats.

[0174] In various embodiments, the earthquake prevention system may comprise at least one subsurface structure **1785** coupled to the platform. In various embodiments, the earthquake prevention system or stabilization system **1780** may comprise at least one subsurface structure **1785** coupled to the platform using at least one corresponding cable **1786**. In the embodiment shown in FIG. **17**, the earthquake prevention system **1780** includes three subsurface structures **1785*a*-1785*c***. In alternative embodiments, the earthquake prevention system **1780** may include a different number of subsurface structures.

[0175] In the embodiment shown in FIG. **17**, at least two of the subsurface structures **1785** are coupled to a platform **1781** with a cable **1786**. In alternative embodiments, a different configuration of cables may be used.

[0176] In various embodiments, at least one of the at least one platform comprises at least two segments. In various embodiments, the at least two segments are coupled using rubberized interconnections. In various embodiments, the at least two segments are coupled using keyway linkages.

[0177] In various embodiments, the earthquake prevention system may comprise a first platform and a second platform, the second platform being larger than the first platform.

[0178] In various embodiments, the earthquake prevention system may comprise one or more snubbers. Snubbers may comprise insulators that reduce vibrations and allow for little movement.

[0179] FIG. **18** shows an example embodiment of a powerhouse **1810** configured to be at a cavernous subterranean location underground. In some example embodiments, a powerhouse may be positioned 400 feet underground. In some example embodiments, a powerhouse may be positioned 2000 feet underground. In alternative embodiments, the powerhouse may be a different depth underground. In some example embodiments, an upper impoundment structure may be positioned 400 feet above sea level. In alternative embodiments, an upper impoundment structure may be positioned at a different height.

[0180] In some example embodiments, the powerhouse is composed of precast segments. In some example embodiments, the powerhouse is composed of poured concrete. A flow path may extend from the cavernous powerhouse to one or more impoundment structures. The flow path may be composed of precast segments and/or poured concrete.

[0181] FIG. **19** shows an example embodiment of a powerhouse **1910** configured to be at a cavernous subterranean location underground.

[0182] FIG. **20** shows an example embodiment of a powerhouse **2010** configured to be at a cavernous subterranean location underground.

[0183] FIG. **21** shows an example embodiment of a precast powerhouse **2110** configured to be at a cavernous subterranean location underground.

[0184] FIG. **22** shows an example embodiment of a precast powerhouse **2210** in an excavated cavern. In some example embodiments, such as the one shown in FIG. **22**, an access tunnel **2278** may facilitate access to the powerhouse. In some example embodiments, such as the one shown in FIG. **22**, a hole **2276** above the powerhouse may facilitate access to the powerhouse. In some example embodiments, the hole is part of a channel to the powerhouse. In some example embodiments, a man-made structure (e.g., tube) may fit inside the channel to facilitate access to the powerhouse.

[0185] FIG. **23** shows example embodiments of modular blocks for mass and powerhouse galleries.

[0186] FIGS. **24**A-D show an example embodiment of a water storage tunnel **2484**. In various embodiments, a tunnel may be constructed with precast components **2415**. A tunnel may be constructed (FIG. **24**A) to allow for underground transmission lines. FIG. **24**A illustrates use of a tunnel boring machine that employs circular cutting to excavate earth to form a tunnel and use of a conveyor belt to move soil to a soil deposit area. In various embodiments, underground tunnels may comprise rails to transport material. In various embodiments, underground tunnels may be accessible via one or more access points at a surface. In various embodiments, one or more or the one or more access points may be covered using rubberized manhole covers. FIG. **24**B shows that a tunnel wall is strengthened with precast modules after the tunnel boring machine of FIG. **24**A has completed its work. FIGS. **24**C and **24**D shows top and side views, respectively, of a precast segment that has rock bolts that extend from the precast segment to a solid underground formation, such as bedrock, to secure the precast segment in place. FIG. **24**D shows a completed structure defining the tunnel **2484** used, for example, to water flow.

[0187] Fluid may be pumped from a lower position to a higher position using a local power source. In various embodiments, the local power source may be solar, geothermal, nuclear, wind, gasoline, biomass, or any other suitable power source.

[0188] FIG. **25** shows an example embodiment of a seismic relief fluid conduit system **2590**. In various embodiments, such as the one shown in FIG. **25**, the seismic relief fluid conduit system **2590** may comprise a base holder **2592**, a fluid conduit **2520**, and fill material. The base holder **2592** may comprise an inner diameter greater than the outer diameter of a fluid conduit **2520**. In various embodiments, the base holder **2592** may be configured to surround at least a portion of the fluid conduit **2520**. In some example embodiments, the base holder **2592** surrounds a portion of the fluid conduit **2520** along the direction of extension of the fluid conduit **2520**. In various embodiments, the base holder **2592** surrounds all of the fluid conduit **2520**. In various embodiments, the base holder **2592** surrounds a portion of each cross-section of the fluid conduit **2520**.

[0189] The seismic relief fluid conduit system **2590** may comprise fill material positioned between the inner diameter of the base holder **2592** and the outer diameter of the fluid conduit **2520**. The fillable material could be any material suitable for absorbing seismic waves. In various embodiments, the fillable material may comprise soft earth material, for example, soil, rocks, etc.

[0190] In the embodiment shown in FIG. **25**, the base holder **2492** has a circular cross-section. In alternative embodiments, the cross-section of the base holder **2492** may have a different shape. In various embodiments, the base holder **2492** may be constructed using one or more precast segments.

[0191] FIGS. **26**A-**26**B show example configurations for pulling fluid to an upper impoundment structure. In various embodiments, pump storage system comprises a vacuum house **2693**. In various embodiments, the vacuum house **2693** comprises at least fan **2694** (see FIG. **26**A) configured to provide suction to pull fluid to the upper impoundment structure. The speed of at least one of the at least one fan **2694** may be adjusted to adjust the fluid flow speed. In various embodiments, the vacuum house **2693** may be positioned at a height that is different than the height shown in FIG. **26**B.

[0192] FIG. **27** shows an example of an assembly of an example embodiment of an impoundment structure **2701**. The impoundment structure could be an upper impoundment structure, a lower impoundment structure, or an intermediate height impoundment structure. In some example embodiments, assembly includes securing a position of a working platform. In some example embodiments, assembly includes securing one or more precast segments to the working platform using one or more connectors. In some example embodiments, a precast segment is secured to a working platform using one or more bolts. In some example embodiments, one or more precast segments are secured together using any suitable means, including means described herein. In some example embodiments, one or more precast infill blocks are secured to a precast form using any suitable means, including means described herein.

[0193] FIG. **28** shows an example of an assembly of an example embodiment of an impoundment structure **2801**. The impoundment structure could be an upper impoundment structure, a lower impoundment structure, or an intermediate height impoundment structure.

[0194] FIG. **29** shows an example embodiment of an impoundment structure **2901** comprising energy dissipation elements (also referred to as diffusers). The impoundment structure could be an upper impoundment structure, a lower impoundment structure, or an intermediate height impoundment structure.

[0195] In various embodiments, such as the one shown in FIG. **29**, the impoundment structure **2901** may comprise at least one diffuser **2942** configured to reduce the velocity and/or redirect the flow of fluid in the impoundment structure. In the embodiment shown in FIG. **29**, the impoundment structure **2901** comprises four triangular shaped diffusers **2942*a*-2942*d*** arranged in a row. In alternative embodiments, there may be a different number of diffusers. In alternative embodiments, one or more of the diffusers may be shaped differently. In alternative embodiments, one of more of the diffusers may be arranged in a different position and/or orientation. In various embodiments, one or more of the diffusers may comprise precast material or neoprene.

[0196] In various embodiments, such as the one shown in FIG. **29**, the impoundment structure **2901** may comprise at least one rudder **2944** configured to redirect the flow of fluid. In various embodiments, one or more or the rudders may be hydraulic rudders. In the embodiment shown in FIG. **29**, the impoundment structure **2901** comprises six triangular shaped rudders arranged in a row. In alternative embodiments, there may be a different number of rudders. In alternative embodiments, one or more of the rudders may be shaped differently. In alternative embodiments, one of more of the rudders may be arranged in a different position and/or orientation. One or more of the rudders may be controlled independent of the others. In some instances, one or more of the rudders may adjust their position/orientation based on flow conditions. In some instances, one or more of the rudders may adjust their position/orientation based on operator control input. In some instances, one or more of the rudders may adjust their position/orientation based on predetermined configuration settings. In various embodiments, one or more of the rudders may rotate every hour to change water pressure on the walls of the impoundment structure.

[0197] In various embodiments, such as the one shown in FIG. **29**, the impoundment structure **2901** may comprise a modular water deflector **2946** configured to redirect the flow of fluid. The embodiment shown in FIG. **29** comprises one modular water deflector **2946**. Alternative embodiments may comprise a different number of modular water deflectors. In alternative embodiments, the modular water deflector may be positioned and/or arranged and/or shaped differently. In alternative embodiments, the modular water deflector may comprise a different radius of curvature. In various embodiments, the modular water deflector may comprise a first radius of curvature on one side and a second, different, radius of curvature on a second side. In various embodiments, the modular water deflector may comprise the same radius of curvature on each side.
[0198] In various embodiments, the impoundment structure may comprise a solar heating system. In various embodiments, an impoundment structure with one or more of the characteristics described in connection with FIG. **29** may be constructed using precast segments.
[0199] FIG. **30** shows an example embodiment of an impoundment structure or tank **3001** comprising energy dissipation elements. The impoundment structure or tank could be an upper impoundment structure or tank, a lower impoundment structure or tank, or an intermediate height impoundment structure or tank.
[0200] In various embodiments, such as the one shown in FIG. **30**, the impoundment structure or tank **3001** comprises at least one flow control rudder and/or gate **3044** configured to direct the flow of fluid. The rudders and/or gates may be automated in view of conditions or may be directly controlled by an operator. The rudders and/or gates may be different shapes, sizes, or orientations. The rudders and/or gates may be arranged differently than the arrangement shown in FIG. **30**.
[0201] In various embodiments, impoundment structure or tank may comprise a protective inner shock and cushion system **3048**. In various embodiments, the shock and cushion system may comprise a baffle wall.
[0202] FIG. **31** shows an embodiment of an impoundment structure or tank **3101** comprising energy dissipation elements. The impoundment structure or tank could be an upper impoundment structure or tank, a lower impoundment structure or tank, or an intermediate height impoundment structure or tank. In various embodiments, such as the one shown in FIG. **31**, the impoundment structure or tank **3101** comprises at least one flow control gate **3149** configured to direct the flow of fluid. The gates may be automated in view of conditions or may be directly controlled by an operator. The gates may be different shapes, sizes, or orientations. The gates may be arranged differently than the arrangement shown in FIG. **31**. In various embodiments, such as the one shown in FIG. **31**, the gates **3149** may be arranged in a circular pattern at different radial positions relative to the center of the impoundment structure inner cavity. In various embodiments, the gates **3149** comprise different access points for water flowing at one radial distance to flow into a channel at a different radial distance. In various embodiments, control of these gates access points may or may not be automated. In various embodiments, the impoundment structure may comprise one or more features described herein.
[0203] In various embodiments, impoundment structure or tank may comprise a protective inner shock and cushion system. In various embodiments, the shock and cushion system may comprise a baffle wall.
[0204] FIG. **32** shows an embodiment of an impoundment structure **3201** comprising energy dissipation elements. The impoundment structure could be an upper impoundment structure, a lower impoundment structure, or an intermediate height impoundment structure.
[0205] As shown in FIG. **32**, at least a portion of the impoundment structure **3201** may comprise an inner wall **3251** defining at least one aperture **3254**. Fluid flowing in the impoundment structure may pass through at least one of the at least one aperture. A portion of the fluid is configured to flow between the inner wall **3251** and an outer wall **3252** of the impoundment structure **3201**. The fluid flowing along the perimeter of the impoundment structure between the inner wall **3251** and

the outer wall **3252** may reduce the pressure of fluid flow at an inner surface of the outer wall **3252**.

[0206] In various embodiments, such as the one shown in FIG. **32**, the impoundment structure **1701** comprises multiple supports **1754** positioned between the inner surface of the outer wall **3252** and the inner wall **3251**. The supports **3254** each comprise at least one aperture **3255** constructed and arranged to allow fluid flow between the inner surface of the outer wall **3252** and the inner wall **3251**.

[0207] In various embodiments, such as the one shown in FIG. **32**, the apertures of the inner wall are circular. In alternative embodiments, at least one of the at least one aperture may comprise a different shape.

[0208] In various embodiments, such as the one shown in FIG. **32**, the apertures of the inner wall are the same size. In alternative embodiments, at least one of the at least one aperture may comprise a different size.

[0209] In various embodiments, such as the one shown in FIG. **32**, the apertures of the supports are circular. In alternative embodiments, at least one of the apertures of at least one of the supports may comprise a different shape.

[0210] In various embodiments, such as the one shown in FIG. **32**, the apertures of the supports are the same size. In alternative embodiments, at least one of the apertures of at least one supports may comprise a different size.

[0211] In various embodiments, each support may comprise more than one aperture. In various embodiments, each support may comprise more than one aperture, each aperture being at a different height.

[0212] In various embodiments, the inner wall is configured to flex in response to water pressure.

[0213] In various embodiments, the impoundment structure may comprise multiple walls comprising the characteristics described in connection with the inner wall of FIG. **32**. In such embodiments, water may flow between each one of the multiple walls to reduce the pressure of water flow along an outward direction (relative to the center of the impoundment structure). In various embodiments at least one of the walls of the impoundment structure may be configured to rotate.

[0214] FIG. **33** shows an embodiment of an impoundment structure or tank **3301** comprising energy dissipation elements. The impoundment structure or tank could be an upper impoundment structure or tank, a lower impoundment structure or tank, or an intermediate height impoundment structure or tank.

[0215] In various embodiments, the impoundment or tank may comprise one or more baffle walls **3303** configured to reduce the water pressure at an outer wall. The embodiment shown in FIG. **33**, the impoundment structure **3301** comprises two baffle walls **3303***a*, **3303***b*. Alternative embodiments may comprise a different number of baffle walls. In alternative embodiments, the configuration of the baffle walls may be different, for example, rather than curving toward a front end of the impoundment structure (relative to the fluid conduits), the baffle walls may be curved in a different direction. Alternatively, one or more of the baffle walls may not be curved. At least one of the baffle walls may be configured to flex.

[0216] In various embodiments, at least one of the at least one baffle wall may comprise one or more protrusions **3356**. In various embodiments, at least one of the protrusions may define port holes. In the embodiment shown in FIG. **33**, the protrusions are at both sides of each baffle wall. In alternative embodiments, the protrusions may be on only one side of the baffle wall.

[0217] In various embodiments, such as the one shown in FIG. **33**, the impoundment structure or tank **3301** may comprise rudders **3344** as previously described. In various embodiments, the impoundment structure **3301** may comprise at least one swing guide **3345** with at least one of the rudders **3344**.

[0218] In various embodiments, such as the one shown in FIG. **33**, the impoundment structure may comprise baffled walls near the outer wall, as previously described.

[0219] FIG. **34** shows an embodiment of an impoundment structure **3401** comprising a sensor system configured to monitor conditions in the impoundment structure **3401**. In various embodiments, one or more sensors **3458** are arranged on a track **3459** and travel to various positions near the edge of the impoundment structure **3401** to monitor water flow and/or damage to walls of the impoundment structure **3401**. In alternative embodiments, the sensors may not be on a track. In various embodiments, one or more sensors may monitor turbine activity. Such sensors may operate automatically based on predetermined configurations or may operate based on user control in real-time.
[0220] FIG. **35**A shows an example embodiment of tube gates **3562** at fluid conduits **3520**. The tube gates **3562** may be configured to redirect flow of fluid and/or reduce the velocity of the fluid. The fluid gates may be automated or controlled by an operator. The fluid gates may be configured to direct the fluid flow evenly or not evenly. The fluid gates may be automated based on characteristics of fluid flow.
[0221] In the embodiment shown in FIG. **35**A, the fluid gates **3562** are on each fluid conduit **3520**. In alternative embodiments, the fluid gates may not be on each fluid conduit.
[0222] In the embodiment shown in FIG. **35**A, the fluid gates **3562** are arranged in an orthogonal pattern aligned with a vertical and horizonal orientation. In alternative embodiments, the fluid gates may be arranged orthogonally, but at an angle relative to vertical and horizontal axes. In alternative embodiments, the fluid gates may not be arranged in an orthogonal pattern. In alternative embodiments, at least a portion of at least one gate may be curved. The fluid gates may be configured to rotate about their elongated axis. The fluid gates may be configured to translate in a plane orthogonal to the direction of fluid flow. The fluid gates may be configured to reduce or eliminate fluid flow into the impoundment structure or tank.
[0223] FIG. **36** shows an example embodiment of an environmental protective system **3670**. In some embodiments the environmental protective system **3670** comprises multiple barriers **3672** at a natural water impoundment location (e.g., a river, lake, ocean). In alternative embodiments, the environmental protective system may comprise a different number of barriers. In alternative embodiments, the size, shape, and/or arrangement of the barriers may be different.
[0224] Example Embodiment 1: A power generation system, comprising: an impoundment structure at least partially defined by a plurality of precast segments, at least one of the precast segments including a precast form and at least one precast infill block.
[0225] Example Embodiment 2: The power generation system of Example Embodiment 1 or any other Example Embodiment, wherein the impoundment structure defines an intake or egress configured to receive or output fluid with a fluid supply via a flow path.
[0226] Example Embodiment 3: The power generation system of any one of Example Embodiments 1-2 or any other Example Embodiment, further comprising a power generation module configured to pump fluid from the fluid supply and into the impoundment structure via the flow path.
[0227] Example Embodiment 4: The power generation system of any one of Example Embodiments 1-3 or any other Example Embodiment, further comprising a power conversion module configured to convert kinetic energy of fluid released from the impoundment structure and travelling through the flow path into electric energy.
[0228] Example Embodiment 5: The power generation system of any one of Example Embodiments 1-4 or any other Example Embodiment, wherein the power conversion module includes: an intake support structure configured to support at least one intake tube, the intake tube at least partially defining a flow path, the intake support structure being at least partially constructed of precast segments; a power generator support structure configured to support weight of a power generator in an arrangement operably disposed within the flow path, the power generator support structure being at least partially constructed of precast segments; and a draft support structure configured to support at least one draft tube, the at least one draft tube at least

partially defining the flow path, the draft support structure being at least partially constructed of precast segments positioned above the at least one draft tube.

[0229] Example Embodiment 6: The power generation system of any one of Example Embodiments 1-5 or any other Example Embodiment, further comprising a flow path structure coupled to the impoundment structure, the flow path structure at least partially defining the flow path, the flow path structure including at least one precast segment.

[0230] Example Embodiment 7: The power generation system of any one of Example Embodiments 1-6 or any other Example Embodiment, wherein the precast infill block is fixedly couped to the precast segment.

[0231] Example Embodiment 8: A power generation system, comprising: an impoundment structure, including: a containment wall defining at least a portion of a boundary of a containment volume, the containment volume configured to store a volume of fluid; and at least one inner wall positioned within the containment volume and offset from the containment wall, the at least one inner wall defining at least one aperture.

[0232] Example Embodiment 9: The power generation system of Example Embodiment 8 or any other Example Embodiment, wherein the impoundment structure includes at least one precast segment, the at least one precast segment including a precast form and at least one precast infill block.

[0233] Example Embodiment 10: The power generation system of any one of Example Embodiments 8-9 or any other Example Embodiment, further comprising one or more supports coupling the containment wall with the inner wall.

[0234] Example Embodiment 11: The power generation system of any one of Example Embodiments 8-10 or any other Example Embodiment, wherein one or more of the one or more supports defines at least one aperture configured to allow fluid to pass therethrough.

[0235] Example Embodiment 12: The power generation system of any one of Example Embodiments 8-11 or any other Example Embodiment, further comprising at least one energy dissipation element disposed within the impoundment structure, the at least one energy dissipation element being configured to redirect the flow of the pumped fluid entering the impoundment structure.

[0236] Example Embodiment 13: The power generation system of any one of Example Embodiments 8-12 or any other Example Embodiment, wherein the at least one energy dissipation element disposed within the impoundment structure causes the flow of the pumped fluid to be redirected to be in a circulating direction between inner wall and outer wall.

[0237] Example Embodiment 14: The power generation system of any one of Example Embodiments 8-13 or any other Example Embodiment, wherein the containment wall or the at least one inner wall is at least partially defined by a plurality of precast segments.

[0238] Example Embodiment 15: The power generation system of any one of Example Embodiments 8-14 or any other Example Embodiment, wherein at least a subset of the plurality of precast segments are interconnected via complementary coupling elements.

[0239] Example Embodiment 16: A power generation system, comprising: a powerhouse, the powerhouse comprising: (1) an intake support structure configured to support at least one intake tube, the intake tube at least partially defining a flow path, the intake support structure being at least partially constructed of precast segments; (2) a power generator support structure configured to support weight of a power generator in an arrangement operably disposed within the flow path, the power generator support structure being at least partially constructed of precast segments; and (3) a draft support structure configured to support at least one draft tube, the at least one draft tube at least partially defining the flow path, the draft support structure being at least partially constructed of precast segments positioned above the at least one draft tube.

[0240] Example Embodiment 17: The power generation system of Example Embodiment 16 or any other Example Embodiment, wherein at least one of the precast segments includes a precast form

and at least one precast infill block.
[0241] Example Embodiment 18: The power generation system of any one of Example Embodiments 16-17 or any other Example Embodiment, further comprising: a stabilization system, the stabilization system including: at least one support structure configured to be positioned below a lower surface of the powerhouse; and an attachment mechanism configured to couple the at least one support structure with the powerhouse.
[0242] Example Embodiment 19: A power generation system, comprising: a water intake structure configured to intake fluid and configured for fluid communication with a powerhouse via a flow path, the water intake structure being at least partially constructed of precast segments.
[0243] Example Embodiment 20: The power generation system of Example Embodiment 19 or any other Example Embodiment, further comprising a flow path structure configured to facilitate fluid communication between the water intake structure and the powerhouse, a first end of the flow path structure being coupled to the water intake structure and a second end of the flow path structure being coupled to the powerhouse.
[0244] Example Embodiment 21: The power generation system of any one of Example Embodiments 19-20 or any other Example Embodiment, wherein the water intake structure comprises one or more layers, each layer including one or more precast segment.
[0245] Example Embodiment 22: The power generation system of any one of Example Embodiments 19-21 or any other Example Embodiment, wherein each layer comprises at least one protrusion.
[0246] Example Embodiment 23: The power generation system of any one of Example Embodiments 19-22 or any other Example Embodiment, wherein at least one of the precast segments includes a precast form and a precast infill block.
[0247] The teachings of all patents, published applications, and references cited herein are incorporated by reference in their entirety.
[0248] The features and/or dimensions shown and/or described in this application are not necessarily to scale. Features and/or dimensions may be any size and/or any shape. Example dimensions may be provided herein. In alternative embodiments, one or more of the example dimensions may be different. In some embodiments, one or more characteristics described in connection with an embodiment described or shown herein may be used with any other embodiment described or shown herein.
[0249] While example embodiments have been particularly shown and described, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the embodiments encompassed or contemplated herein or in the drawings being filed herewith.
[0250] While example embodiments have been particularly shown and described, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the embodiments encompassed by the appended claims.

## Claims

**1**. A power generation system, comprising: an impoundment structure at least partially defined by a plurality of precast segments, at least one of the precast segments including a precast form and at least one precast infill block.
**2**. The power generation system of claim 1, wherein the impoundment structure defines an intake or egress configured to receive or output fluid with a fluid supply via a flow path.
**3**. The power generation system of claim 2, further comprising a power generation module configured to pump fluid from the fluid supply and into the impoundment structure via the flow path.
**4**. The power generation system of claim 2, further comprising a power conversion module

configured to convert kinetic energy of fluid released from the impoundment structure and travelling through the flow path into electric energy.
**5**. The power generation system of claim 4, wherein the power conversion module includes: an intake support structure configured to support at least one intake tube, the intake tube at least partially defining a flow path, the intake support structure being at least partially constructed of precast segments; a power generator support structure configured to support weight of a power generator in an arrangement operably disposed within the flow path, the power generator support structure being at least partially constructed of precast segments; and a draft support structure configured to support at least one draft tube, the at least one draft tube at least partially defining the flow path, the draft support structure being at least partially constructed of precast segments positioned above the at least one draft tube.
**6**. The power generation system of claim 2, further comprising a flow path structure coupled to the impoundment structure, the flow path structure at least partially defining the flow path, the flow path structure including at least one precast segment.
**7**. The power generation system of claim 1, wherein the precast infill block is fixedly couped to the precast segment.
**8**. A power generation system, comprising: an impoundment structure, including: a containment wall defining at least a portion of a boundary of a containment volume, the containment volume configured to store a volume of fluid; and at least one inner wall positioned within the containment volume and offset from the containment wall, the at least one inner wall defining at least one aperture.
**9**. The power generation system of claim 8, wherein the impoundment structure includes at least one precast segment, the at least one precast segment including a precast form and at least one precast infill block.
**10**. The power generation system of claim 8, further comprising one or more supports coupling the containment wall with the inner wall.
**11**. The power generation system of claim 10, wherein one or more of the one or more supports defines at least one aperture configured to allow fluid to pass therethrough.
**12**. The power generation system of claim 8, further comprising at least one energy dissipation element disposed within the impoundment structure, the at least one energy dissipation element being configured to redirect the flow of the pumped fluid entering the impoundment structure.
**13**. The power generation system of claim 12, wherein the at least one energy dissipation element disposed within the impoundment structure causes the flow of the pumped fluid to be redirected to be in a circulating direction between inner wall and outer wall.
**14**. The power generation system of claim 8, wherein the containment wall or the at least one inner wall is at least partially defined by a plurality of precast segments.
**15**. The power generation system of claim 14, wherein at least a subset of the plurality of precast segments are interconnected via complementary coupling elements.
**16**. A power generation system, comprising: a powerhouse, comprising: an intake support structure configured to support at least one intake tube, the intake tube at least partially defining a flow path, the intake support structure being at least partially constructed of precast segments; a power generator support structure configured to support weight of a power generator in an arrangement operably disposed within the flow path, the power generator support structure being at least partially constructed of precast segments; and a draft support structure configured to support at least one draft tube, the at least one draft tube at least partially defining the flow path, the draft support structure being at least partially constructed of precast segments positioned above the at least one draft tube.
**17**. The power generation system of claim 16, wherein at least one of the precast segments includes a precast form and at least one precast infill block.
**18**. The power generation system of claim 16, further comprising: a stabilization system, the

stabilization system including: at least one support structure configured to be positioned below a lower surface of the powerhouse; and an attachment mechanism configured to couple the at least one support structure with the powerhouse.