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(19) **United States**(12) **Patent Application Publication****Lee et al.**(10) **Pub. No.: US 2012/0104003 A1**(43) **Pub. Date: May 3, 2012**(54) **HORIZONTAL EXTRACTION AND RETURN
EXTENSIONS IN LIQUID STORAGE TANKS**(52) **U.S. Cl. 220/600**(57) **ABSTRACT**(76) Inventors: **Brian Eric Lee**, Corral de Tierra,
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Davis, CA (US)(21) Appl. No.: **13/272,210**(22) Filed: **Oct. 12, 2011****Related U.S. Application Data**(60) Provisional application No. 61/404,934, filed on Oct.
12, 2010.**Publication Classification**(51) **Int. Cl.**
B65D 6/28 (2006.01)

This invention is an improvement to the shape of liquid storage tanks, in particular to unpressurized molded polymer tanks used for thermal storage in solar systems. All aspects of this invention are well suited to solar storage tanks, and individual aspects are suited to other liquid tank applications.

This invention provides a formed horizontal extension at the bottom of the tank. From the top of this lower extension, a hollow vertical stub provides a reliable connection to a circulator pump. Thermal performance is enhanced by ensuring the lowest and coolest water is delivered to the array of rooftop solar collectors without entraining debris from the bottom of the tank.

At the top of the tank, a similar horizontal extension is used to distribute hot water returning from the solar collectors. Flow velocity is eliminated and a curving lower edge allows return water to find the matching thermocline to avoid de-stratifying.

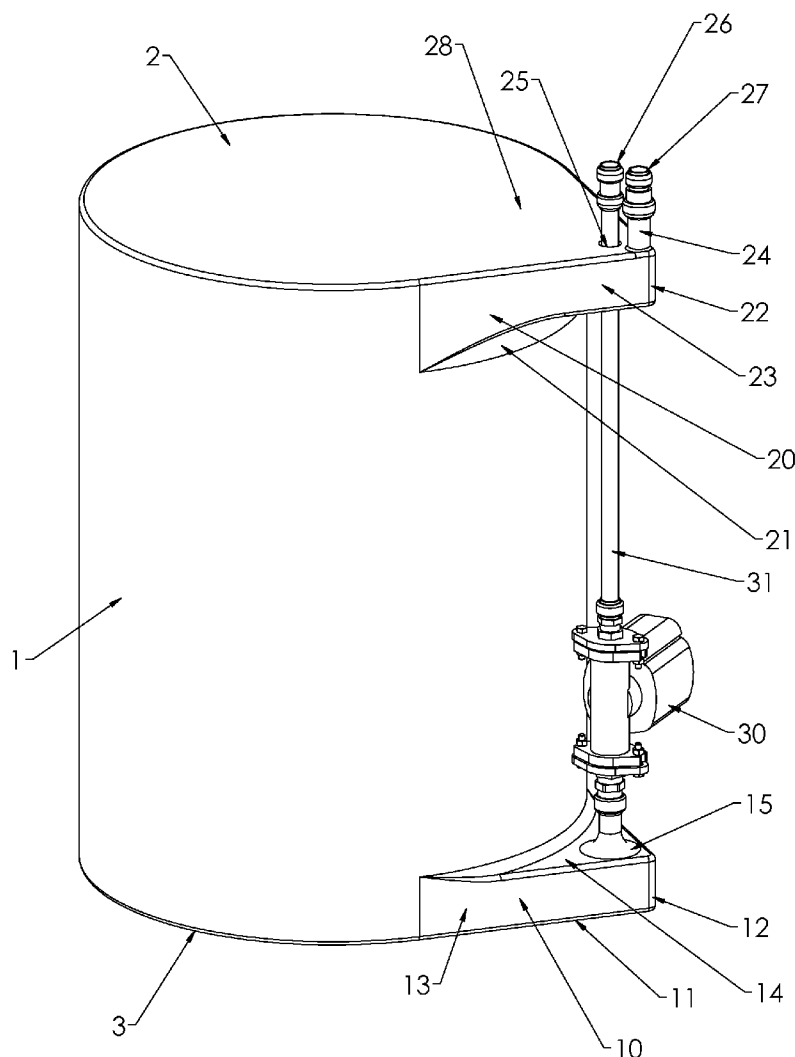


FIGURE 1

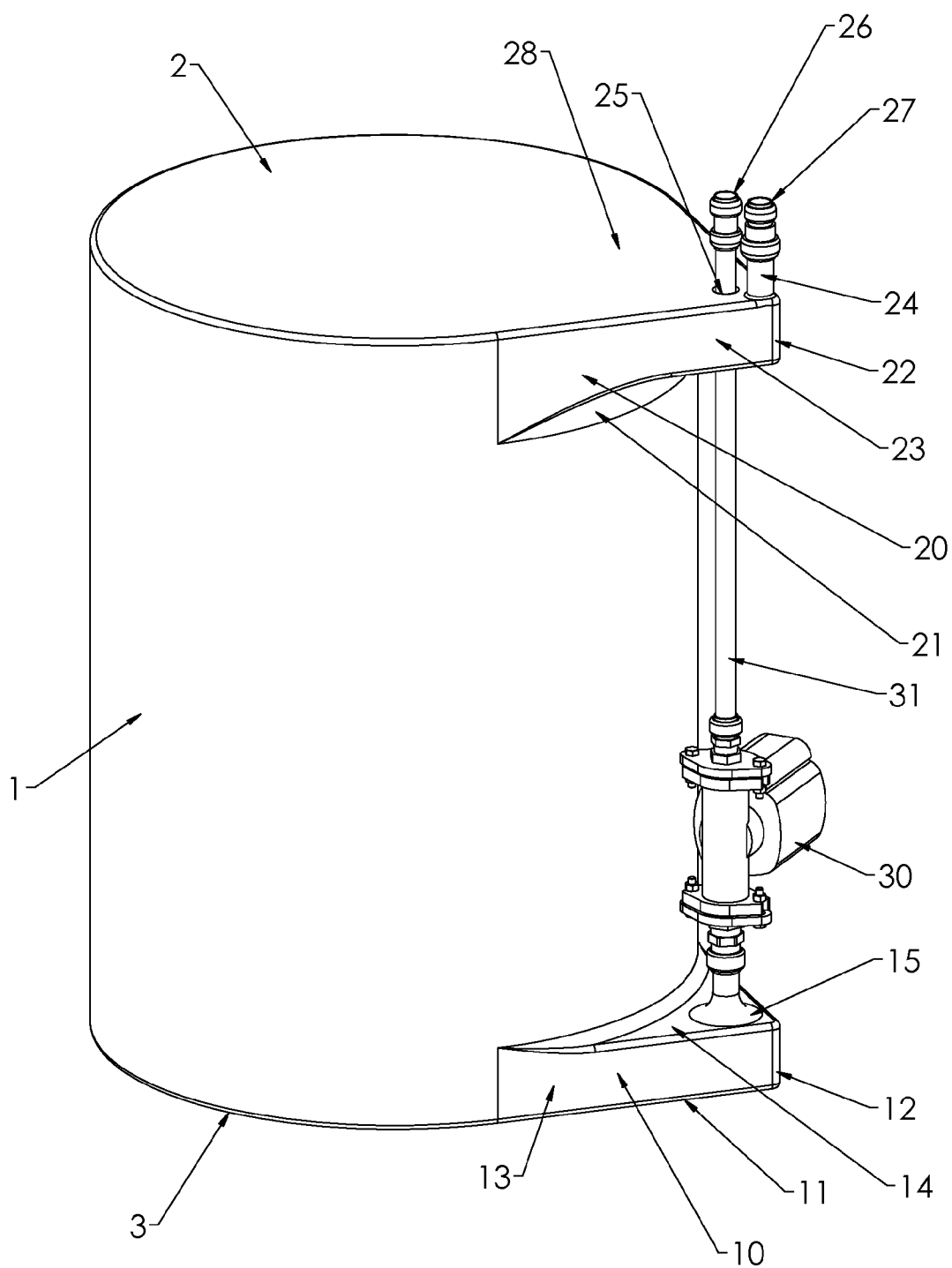


FIGURE 2

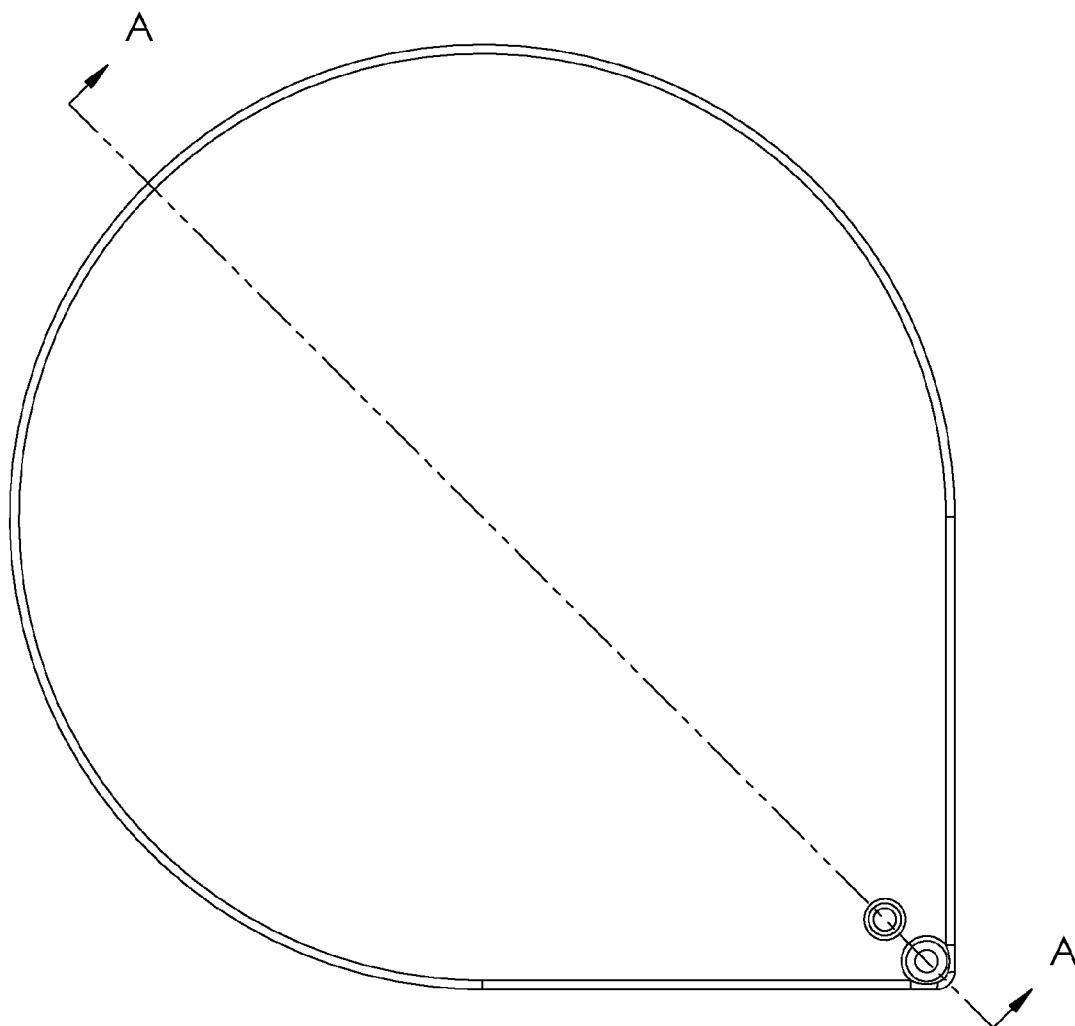
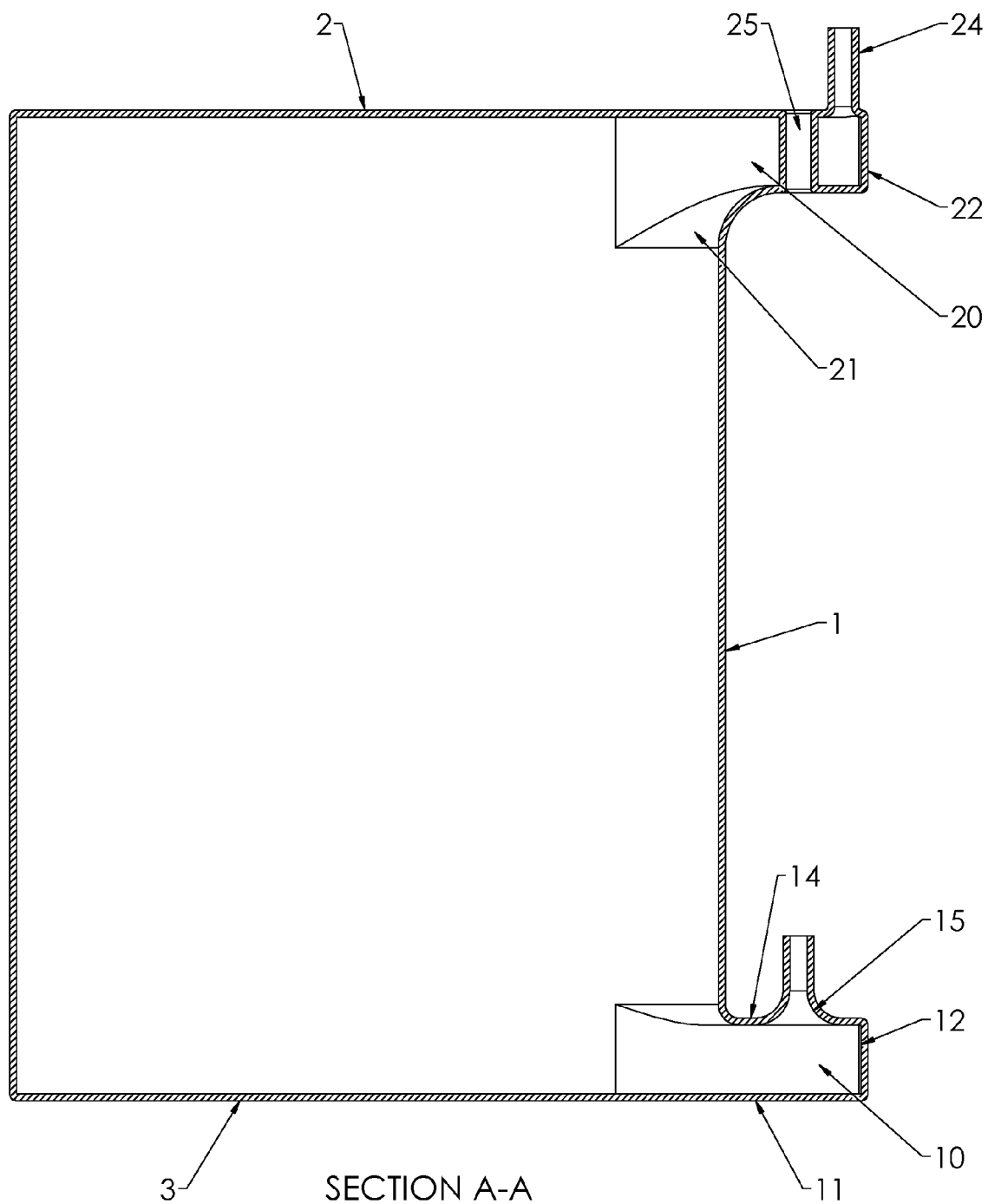


FIGURE 3



HORIZONTAL EXTRACTION AND RETURN EXTENSIONS IN LIQUID STORAGE TANKS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application does not cross-reference existing non-provisional utility patent applications. However, it is related to USPTO provisional application 61/404,934.

STATEMENT REGARDING STATE OF CALIFORNIA SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with State of California support under California Energy Commission grant number PIR-08-012. The Energy Commission has certain rights to this invention.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0003] Not applicable.

REFERENCE TO SEQUENCE LISTING, A TABLE, OR A COMPUTER PROGRAM LISTING COMPACT DISC APPENDIX

[0004] Not applicable.

BACKGROUND OF THE INVENTION

[0005] There are three methods commonly used in the production of liquid storage tanks. Steel and stainless steel tanks are fabricated from sheet material that is cut and welded, either automated or by hand. Their resistance to elevated pressures and temperatures makes them popular for domestic water heaters and many commercial and industrial applications. But rising material costs and fabrication expense result in high prices on a storage volume basis. Steel tanks generally last less than 10 years, which can be extended for a few years with glass lining. Stainless steel tanks are well suited to high-purity or corrosive chemical applications, but prices are at least double those of similar sized steel tanks. U.S. regulations require that pressurized vessels larger than 119 gallons be individually tested during manufacturing, and wall thickness must increase substantially in larger sizes to maintain the pressure rating. For these reasons and also high dry tank weights, larger liquid storage tanks are usually unpressurized.

[0006] Although some unpressurized tanks are made from steel, such as those used to store crude oil, most unpressurized tanks are made from polymeric materials due to lower cost and corrosion resistance. Polymer tanks can be broken into two basic configurations: rigid molded tanks or flexible liner tanks that use a site-built casing to resist hydrostatic loads. Rotationally molded tanks are popular for large volume outdoor water storage in residential or agricultural applications due to their durability and low cost, and some smaller rigid vessels are blow molded. Flexible liners are cut from roll material such as vinyl and welded using radio frequency or ultrasonic equipment. The structural casings are either custom built or delivered unassembled with the liner. Flexible liner tanks make it possible to install very large indoor tanks without the access doors that a rigid tank would require.

[0007] The invention described herein is best suited to rigid molded polymer tanks, which provide the most opportunity for complex tank shapes. Tooling costs may increase, but the

impact on unit tank price of increased shape complexity is minimal. However, there is no practical limitation preventing the incorporation of this invention into fabricated steel vessels or tanks employing a flexible liner.

[0008] This invention is suited to any applications of rigid molded polymer storage tanks where a low mounted penetrating connection is required, such as a drain, and where it is desired to avoid fouling of this penetration by debris that may have settled out of the stored liquid. For applications where a pump is used to move liquid from the tank through a circuit, the weight and vibration of the pump (usually cantilevered) result in frequent leaks at the penetration. The most common solution is to use a multi-piece bulkhead fitting that can be removed and a new seal fitted, but this process requires draining the tank and accessing the penetration from the inside of the tank. This invention is well-suited to thermal storage tanks where it is desired to extract the coolest, and therefore lowest, liquid from the tank. Such a tank may or may not be designed to take advantage of stratified thermal storage. For thermal storage tank designs that promote stratification, it is also important to manage the return of heated water to avoid de-stratifying the tank during certain conditions.

[0009] This invention is ideally suited to storage tanks used in solar thermal systems. "Active" solar thermal systems pump a liquid from an insulated storage tank through a "collector" panel array exposed to sunlight. The solar-heated liquid delivers heat to the tank where it can be used for various purposes. "Closed-loop" active systems use a water/anti-freeze solution that transfers heat via a heat exchanger to pressurized water stored in a steel tank, while "drainback" systems circulate water directly from an unpressurized tank through the collectors, via a circuit that slopes so that water drains out of the circuit and back into the tank when the pump turns off, in order to avoid freeze or overheat damage. Instead of using a heat exchanger to charge the storage tank during pump operation, drainback systems must use a heat exchanger to discharge heat from the unpressurized thermal storage water to pressurized domestic water during hot water draws. Active solar systems usually mount a compact but relatively heavy circulating pump to piping that extends from the wall of the tank. The pump weight stresses the connection between the horizontal pipe and the vertical tank wall, since the cantilevered pump is supported only on one side.

[0010] Maintaining thermal stratification in a solar storage tank improves system efficiency. Stratification can be promoted and maintained by extracting liquid from the bottom of the tank and returning it to the top; or, preferably, returning it at its appropriate level. Liquid in a well-designed stratified tank can be considered to comprise "thermoclines" or thin horizontal disks of liquid that are increasingly warmer with upward position in the vertical stack of disks.

[0011] Liquid from the tank bottom will always be coolest and thus should be supplied to the collector to maximize their performance. Through a typical daytime cycle, the liquid returning from the collector is usually warmer than stratified liquid at the top of the tank until late in the collection cycle, when solar input is reduced, or when clouds obstruct the sun. At these times the return liquid, though valuably warmer than the tank bottom liquid entering the collector, can be cooler than other recently-returned liquid at the top of the tank. Returned to the top, it could de-stratify the tank top down to the thermocline whose temperature matches that of the return liquid. Thus, it is preferable to admit the return liquid at the thermocline that matches its temperature.

[0012] Optimal performance results when collector flow rates are relatively low, thus saving pump energy and allowing smaller piping that minimizes heat losses. In polymeric tanks, which have very modest vertical heat conduction through the tank walls, thermal stratification of 20 to 40 degrees C. can be maintained if liquid velocities entering and leaving the tank are limited to prevent mixing. But typical, piping flow velocities of 1 m/sec or more cause mixing that damages stratification, and the impact is particularly damaging when there are vertical components to the return velocity.

[0013] Since the varying temperature of liquid returning from the collector has obvious impact on stratification, much prior effort has been devoted to perfecting devices that return liquid at the appropriate level, and that slow the return velocity and direct it horizontally. Two publicized examples (apparently unpatented) are the “large perforated vertical return tube” and the “gravity-gradient return hose.” The perforated return tube is a fixed vertical pipe in the tank, of larger diameter than the return piping from the collector, with large perforations that allow slow outward return flow into the tank at various levels. Presumably the liquid slows enough to exit the pipe at its appropriate temperature level, thanks to buoyancy effects. The gravity-gradient hose is of a neutrally-buoyant plastic. It also relies on varying density (and therefore buoyancy) with temperature, so that the return liquid temperature causes the open end of the hose to float to the right thermocline and discharge the liquid in a horizontal stream.

[0014] The value of these stratification-enhancing devices has not been widely confirmed, and less effort has been devoted to limiting flow velocities than to discharging heated liquid at the appropriate thermocline. This application discloses new art that incorporates into the design of molded polymeric tanks valuable and economical features to promote stratification. More specifically, it discloses ledge-like extensions at the tank top and/or bottom that slow and disperse inlet and outlet flows.

BRIEF SUMMARY OF THE INVENTION

[0015] This invention consists of geometric features that can be added to the shape of existing liquid storage tanks. The larger tank to which this invention is applied can be of any shape, such as cylindrical or rectangular prismatic. All aspects of this invention are well suited to thermal storage tanks used for solar thermal systems, and individual aspects are suited to many other tank applications, such as domestic water heaters, or water and chemical storage tanks.

[0016] When applied to various basic tank shapes, this invention provides a formed horizontal extension at the bottom of the tank. From this lower horizontal extension, a stub is directed upwardly to provide a secure and easily-maintained connection to a circulator pump. Because the stub is oriented vertically, the structural load of the pump is well transmitted to the tank with minimal stresses within the tank material.

[0017] At the top of the tank, a similar horizontal extension is used to distribute hot water returning from the array of rooftop solar collectors (or some other heating process such as a boiler). This extension acts like a baffle to reduce or eliminate the flow velocity and enhance thermal stratification within the tank. A curving lower edge to the upper horizontal extension allows return water to find the thermocline with matching temperature. This allows useful heat to be added to the storage tank without disrupting stratification even if the return water is cooler than the water at the top of the tank.

[0018] The ideal embodiment of this invention incorporates both lower and upper horizontal extensions. Used in a solar thermal system, the upper horizontal extension would include a cylindrical through passage to support a riser pipe mounted to the discharge side of the pump. This places both connections together at the top of the tank for convenient connection to the collector array, and also makes it easy to deliver tanks to the site with pumps pre-installed at the factory. With careful design of the tank, the pump can be contained entirely within the footprint of the tank.

OBJECTS OF THE INVENTION

- [0019] 1. To provide the lowest possible horizontal exterior tank surface from which an upward, vertically-directed flow stream can enter the circulator pump after being drawn slowly and horizontally from the lowest level of the tank without entraining any debris that may have settled out of solution and collected on the tank bottom.
- [0020] 2. To form a molded tank that maximizes stratification in solar heating applications by incorporating extensions designed to slow and disburse liquid flow streams leaving and entering the tank.
- [0021] 3. To provide the highest possible horizontal exterior tank surface from which a downward, vertically-directed flow stream can enter the tank slowly and horizontally at the highest level of the tank, and entering along an outer tank wall, allowing, the slow-moving return liquid to ooze downward toward its own temperature level when return liquid is cooler than tank-top liquid.
- [0022] 4. To locate an upper “return liquid” tank extension directly above a lower “pump support” extension to permit the upper extension to support an upward riser from the pump.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0023] This application includes three figures, all of which show the same preferred embodiment of the invention.

[0024] FIG. 1 is an isometric view indicating the shape of the lower and upper horizontal extensions. The invention is shown on a tank of generic cylindrical shape, along with representative pump and plumbing connectors.

[0025] FIG. 3 is a cross-section of the molded tank at the sectional line indicated in FIG. 2. Features are identified by number, with many features indicated on both FIG. 1 and FIG. 3. (FIG. 2 does not contain feature numbers, but is included only to shown the orientation of the cross section in FIG. 3.)

DETAILED DESCRIPTION OF THE INVENTION

[0026] The tank 1 is a vertical-axis cylinder with planar top 2 and bottom 3; and with relatively thin, hollow bottom and top extensions 10 and 20. The bottom extension 10 has its bottom surface 11 co-planar with the tank bottom 3. The extension 10 comprises vertical surfaces 13 that extend tangentially from the circumference of the tank 1 and meet approximately at a right angle at a vertical extension corner 12. From the upper horizontal surface 14 of the bottom extension 10 extends a vertical pipe connection 15 that flares smoothly from flat to an upward vertical cylindrical shape that allows connection to the circulating pump 30. The radius

of the corner **12** may vary but will normally be less than the radius of the flared pipe connection **15**. This design allows the pump **30** to draw water smoothly upward with minimal pressure drop, minimal tendency to draw debris into pump **30**, and with transition flow characteristics that minimize the tendency of the pump inlet flow stream to mix the tank water. The extension **10** is preferably formed integrally with the tank in a molding process.

[0027] At the top of the tank **1** is a second possible extension that minimizes the mixing potential of water entering the tank. The upper extension **20** is an independent feature that can be anywhere on the upper circumference of tank **1**, but is conveniently placed directly above a lower extension **10**, if used. The upper extension **20** has its upper surface **28** coplanar with the tank top **2**. The extension **20** comprises vertical surfaces **23** that extend tangentially from the circumference of the tank **1** and meet approximately at a right angle at a vertical extension corner **22**. From the upper horizontal surface **28** of the upper extension **20** extends a vertical pipe connection **24** near the corner **22**. Connection **24** receives water from return pipe **27** and helps the return water spread smoothly across upper extension **20** and into the tank **1**. The radius of the corner **22** may vary but will conveniently equal the radius of the pipe connection **24**. The underside **21** of upper extension **20** can curve slightly downward as it approaches the wall of the tank cylinder **1**, to allow inlet water to flow downward along the tank wall without mixing the tank water. Since this return water may or may not be warmer than water on top of the tank, the slowing and smoothing of inlet water caused by the features of the upper extension **20** allow water to move downward to its own temperature-based thermocline. At this point the water will move laterally from buoyancy effects without de-stratifying the water layers above. The extension **10** is preferably formed integrally with the tank in a molding process.

[0028] If upper extension **20** is located directly above lower extension **10**, the upward supply pipe **31** from pump **30** to the supply connection **26** can be held in proper vertical alignment by securing it to the upper extension **20**. In a preferred embodiment, the pipe **31** is held in position by passing

through hole **25** formed in upper extension **20**. Alternately a slot recess can be molded into the side of the upper extension **20** to hold the pump discharge pipe. Hole **25** can be molded into a polymeric tank if a rotational molding process is used. Tank **1** can also be blow molded with extensions **10** and **20**.

1. A molded storage tank that incorporates an essentially horizontal and hollow foot-like extension at the tank bottom, whose outer extremity includes an upwardly-directed tank outlet.

2. Claim 1 where the tank shape is a vertical-axis cylinder.

3. Claim 1 where the tank shape is a rectangular prism.

4. Claim 1 with the outlet designed to support a circulating pump.

5. Claim 4 where the outlet is vertical.

6. Claim 1 with the extension having two essentially vertical outer edges that form a 90 degree angle and which extend tangentially from a cylindrical tank.

7. Claim 1 where the underside of the extension is coplanar with the tank bottom.

8. A molded storage tank that incorporates an essentially horizontal and hollow extension at the tank top, whose outer extremity includes an upwardly-directed tank inlet.

9. Claim 8 where the tank is a vertical-axis cylinder.

10. Claim 8 where the tank shape is a rectangular prism.

11. Claim 8 with the extension having two essentially vertical outer edges that form a 90 degree angle and which extend tangentially from a cylindrical tank.

12. Claim 8 where the top side of the extension is coplanar with the tank top.

13. Claim 8 where there is a large radius fillet at the intersection of the lower surface of the extension and the tank wall.

14. Claim 8 where the top extension includes holding means for a pipe extending vertically from the circulating pump.

15. Claim 14 where the holding means is a molded hole through the top extension.

16. Claim 14 where the holding means is a molded slot recess in an edge of the extension.

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