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(54) SLUDGE HEAT EXCHANGER

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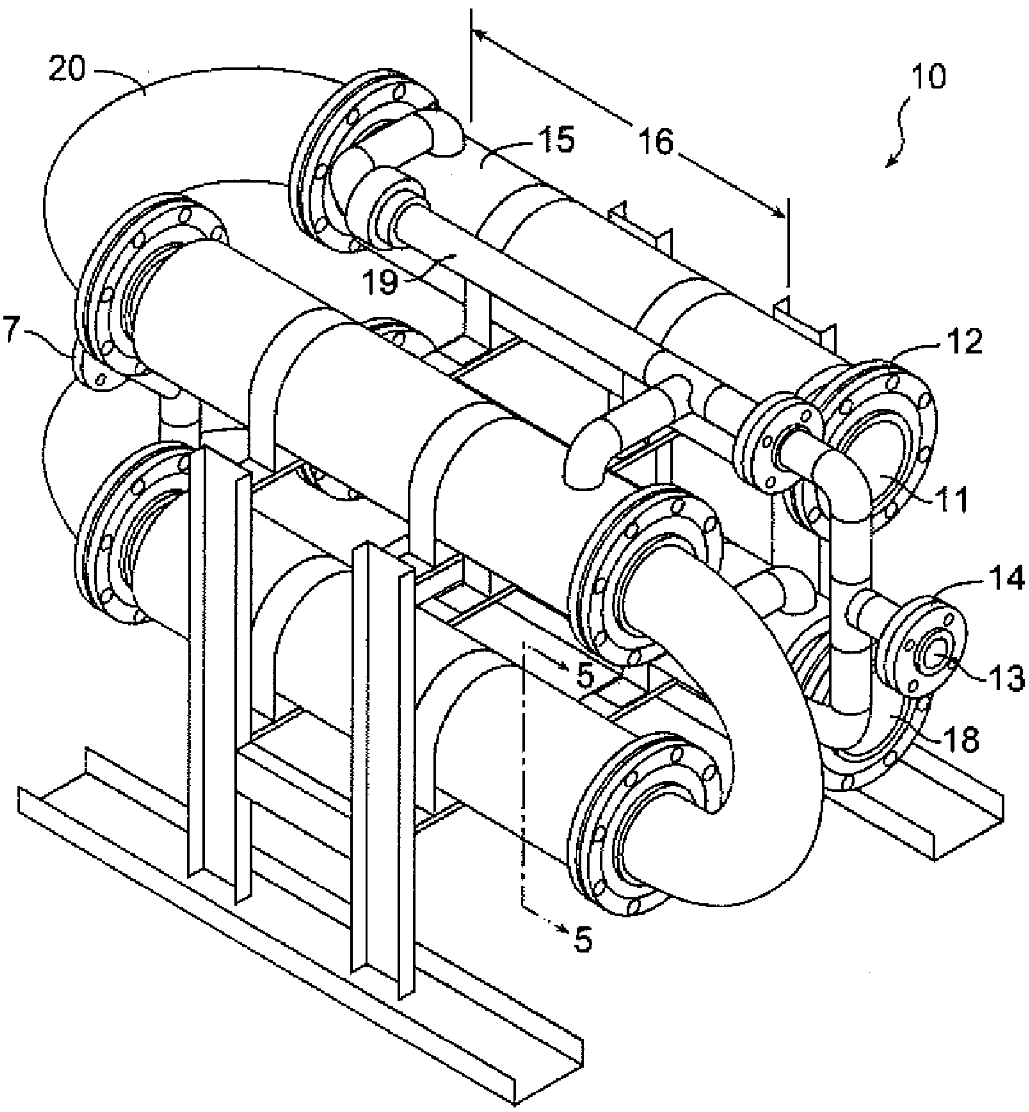
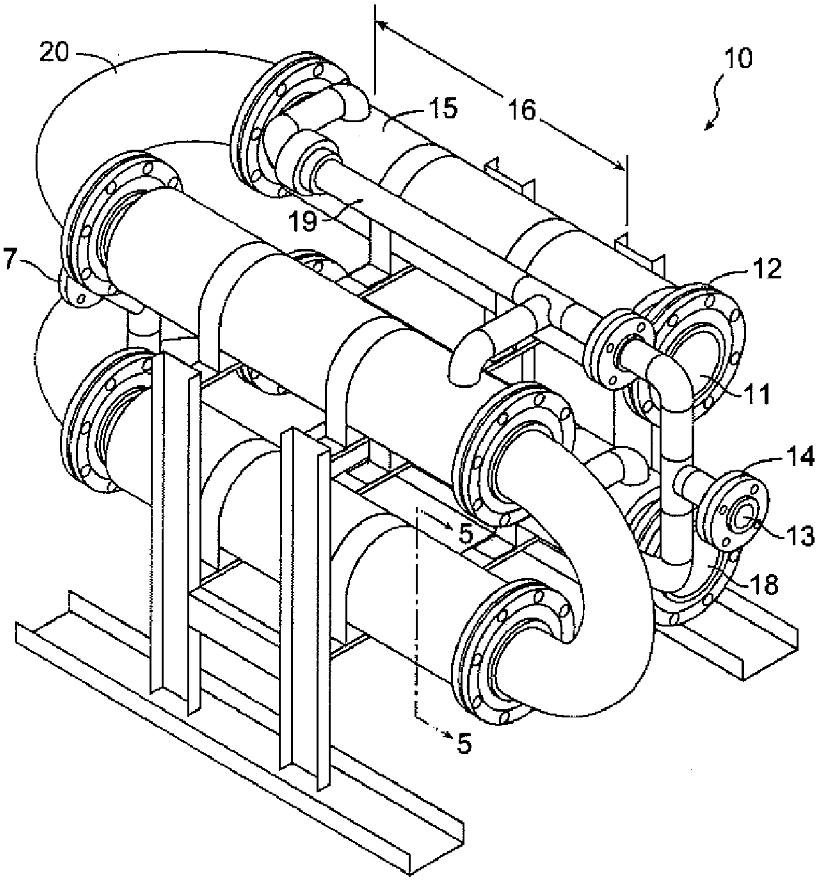
(57) **ABSTRACT**

A heat exchanger for transferring heat energy from a heated liquid at a first temperature to sludge at a second temperature. The heat exchanger includes a first conduit for receiving a stream of sludge which houses a plurality of mixing elements. The mixing elements are characterized as having no edges perpendicular to the longitudinal axis of the conduit and are sized and positioned within the conduit such that at any plane passing perpendicularly to the longitudinal axis at least 75% of the circumference of the conduit being free of any mixing elements and no mixing elements are in contact with one another resulting in an open region of travel for sludge passing through the conduit.




20
10
15
16
19
17
12
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13
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18
5

FIG. 1

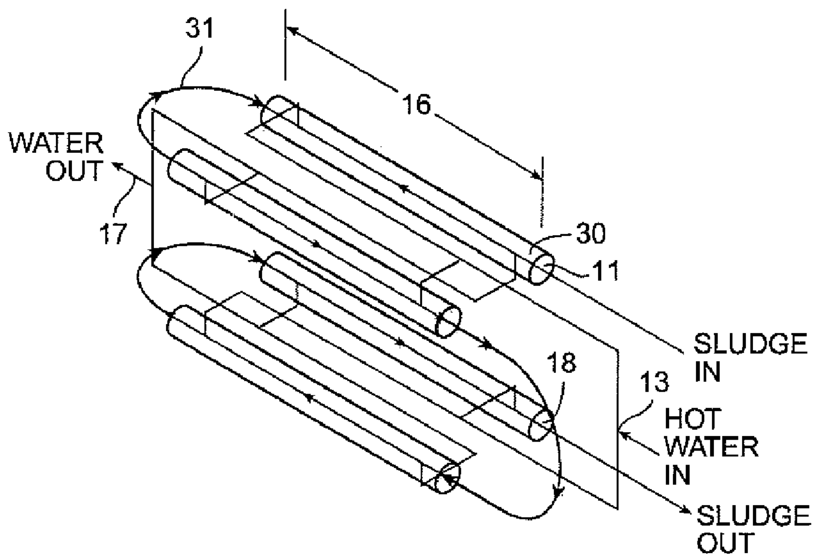
31
16
WATER
OUT
17
30
11
SLUDGE
IN
18
13
HOT
WATER
IN
SLUDGE
OUT

FIG. 2

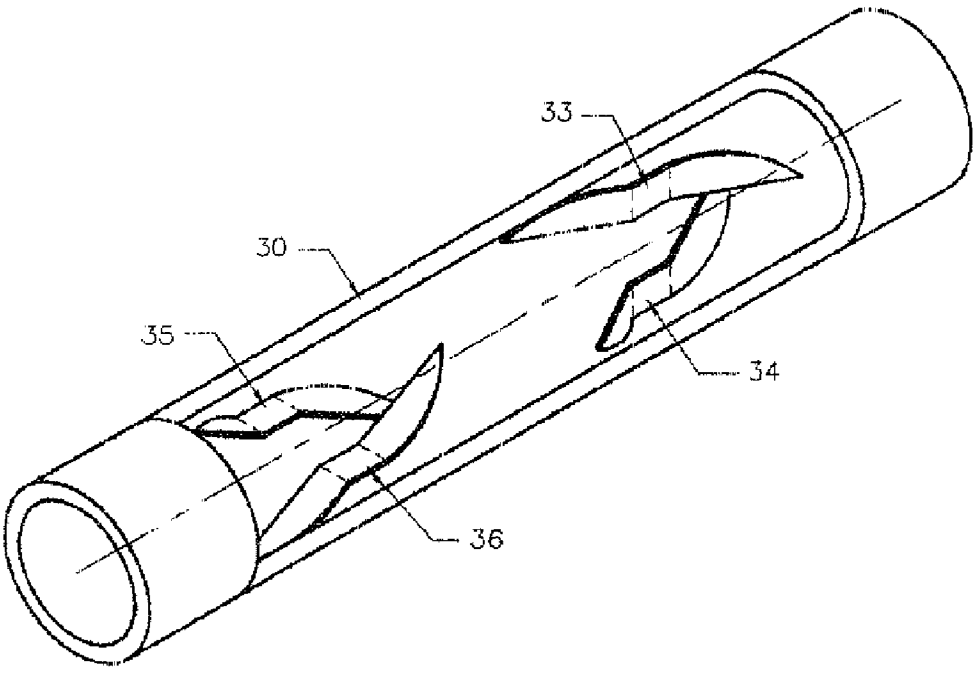

FIG. 3

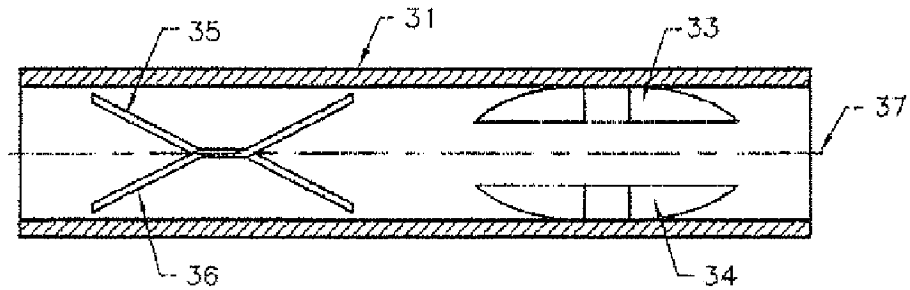

FIG. 4

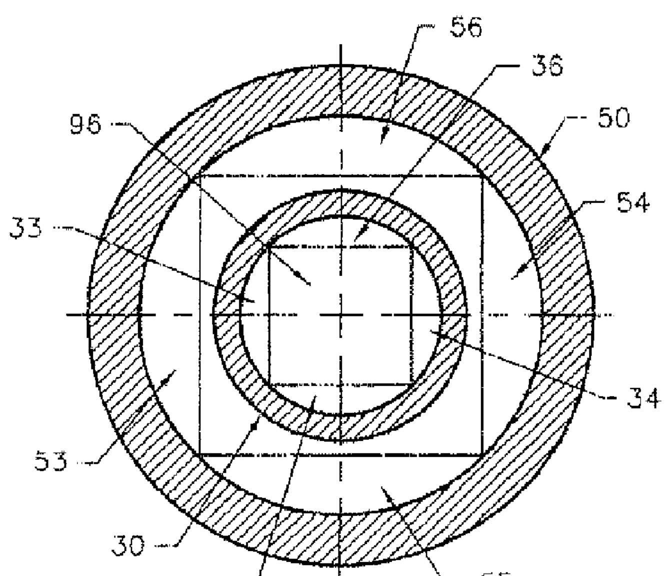

FIG. 5

SLUDGE HEAT EXCHANGER

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention is directed to a heat exchanger for transferring heat energy from a heated liquid at a first temperature to sludge at a second temperature. The heat exchanger includes a conduit containing non-clogging motionless mixing elements to optimize heat transfer while preventing clogging of sludge within the apparatus.

BACKGROUND OF THE INVENTION

[0002] Virtually every municipality has a waste water treatment system which is employed to remove nutrients such as nitrogen and phosphorus from waste water as well as to destroy pathogens and viruses which are found within waste sludge. Heating municipal sludge to 135° F. in a digester for 15 days or longer kills such pathogens. The sludge is then classified as class A sludge which may be used as commercial fertilizer for farms instead of burying it in landfills. Interestingly, the conversion of waste to class A sludge is mandatory in many jurisdictions such as the state of California; a standard which has prevailed in Europe for many years.

[0003] Most wastewater systems involve batch processing of sludge. Primary and secondary treatments zones ate employed as are are clarifiers and separators. It is common to have purified effluent discharge into streams or lakes while sludge drawn from a clarifier is oftentimes returned to the head of the activated sludge system and mixed with influent wastewater as a continuous process. As such, it is highly advantageous to have a mixer located within treatment zones and particularly within the heat exchanger to not only maximize the efficiency of the waste water treatment system, but also optimize the transfer of heat energy from a heating liquid, such as water, to the sludge and resulting digester.

[0004] Although there are various types of sludge, most can be characterized physically as including a high percentage of solids and stringy material. As such, there are basically two varieties of heat exchanger's which have been employed in this arena. The first involves a pipe with a hot water jacket. Such a configuration has the advantage of having an open six inch diameter or larger piping which eliminates plugging. However, such a heat exchanger assembly requires enormous floor space as it must be large due to the low heat transfer characteristics of the configuration. Multiple sections of jacketed piping must be used to achieve the requisite temperature increase. This results in higher installation costs than those involved in employing a spiral type of heat exchanger.

[0005] The spiral type of heat exchanger involves providing a spiraling passage for sludge and a spiraling passage for hot water. The two channels spiral in from the outside of the periphery of the system ending and exiting neat the central of the spiral. Such a configuration is relatively compact and thus results in space saving over the pipe/water jacket configuration discussed above. However, the spiral geometry characteristically results in periodic plugging of its narrow 1 inch× 30 inch sludge passage resulting in repeated weekly or monthly maintenance. It is not uncharacteristic to devote a full day of labor to opening up the heat exchanger and cleaning out the plugging debris. Despite these limitations, due to its compact size, spiral type heat exchangers are used in over 95% of the waste water treatment plant installations now in service.

[0006] It is thus an object of the present invention to provide the non-plugging advantages of a jacketed pipe type heat exchanger while enjoying the relatively compact design of the spiral type heat exchanger while eliminating plugging and maximizing heat transfer in mixing of the sludge.

[0007] These and further objects will be more readily apparent when considering the following disclosure and dependent claims.

SUMMARY OF THE INVENTION

[0008] The present invention is directed to a heat exchanger for transferring heat energy from a heated liquid at a first temperature to sludge at a second temperature. The heat exchanger comprises a first conduit for receiving a stream of sludge, the first conduit having a length, substantially circular circumference, a longitudinal axis through said length and being opened at both ends thereof. The first conduit houses a plurality of mixing elements which are characterized as having no edges perpendicular to the longitudinal axis and which are sized and positioned within the conduit such that at any plane passing perpendicularly to the longitudinal axis, at least 75% of the circumference of the conduit is free of any mixing elements and, further, no mixing elements are in contact with one another resulting in an open region of travel for sludge passing through the first conduit along its longitudinal axis. A second conduit is also provided in the form of a sleeve having a longitudinal axis coincident with the longitudinal axis of the first conduit defining an annular space open at both ends for receiving and discharging heated liquid. As a preferred embodiment, a second set of mixing elements can be located in the annular space created between the first conduit and sleeve for enhancing heat transfer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a perspective drawing of the sludge heat exchanger of the present invention.

[0010] FIG. **2** is a schematic of the sludge heat exchanger of FIG. **1** showing fluid flow paths within such device.

[0011] FIG. **3** is a schematic in partial cut away showing the mixing elements found within those straight segments of the first conduit for carrying sludge.

[0012] FIG. **4** is a side, partial cut away view of the conduit of FIG. **3**.

[0013] FIG. **5** is an end plan view of the sludge heat exchanger taken along cross section **5-5** of FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The heat exchanger of the present invention is shown, in its preferred configuration, in FIG. **1**. Heat exchanger **10** is configured as a series of straight sections **15** joined to one another by curved sections **20** producing a continuous serpentine structure. In operation, sludge is introduced within the heat exchanger at **11** noting that the heat exchanger can be connected to supporting structure via flange **12** which, in turn, can be functionally connected to a number of subsidiary devices such as purifiers, aerators and digesters. A heating liquid, such as water, is introduced within the heat exchanger at opening **13**, again being connected to a source of, for example, water, via flange **14**. The heating liquid travels through manifold **19** and introduces heating liquid in a jacket surrounding the conduit carrying sludge In this regard, the heated sludge exits the heat exchanger **10** at opening **18** while the heating liquid exits the system at exit **17**.

[0015] The schematic pathway for the sludge and heating liquid is shown in FIG. **2**. As noted, sludge is introduced to conduit **30** at opening **11** passing through conduit **30** by schematic pathway **31** to the remaining conduits, the internal details of which will be described hereinafter.

[0016] For the sake of simplicity, a single segment of conduit **30** has been selected for discussion. This conduit extends along spaced arrow **16** (FIG. **1**) although the description of the internal elements of conduit **30** could be applied to the remaining straight sections of the sludge heat exchanger as well. As noted previously, it is the intent of the present invention to provide the advantages of a spiral type heat exchanger in an environment in which sludge having a high degree of solids and stringy mass which would tend to clog spiral type heat exchanges of the prior art.

[0017] The sludge-carrying first conduit **30** of the present invention is shown in the shape of a cylinder provided with longitudinal axis **37**. As shown in FIG. **1**, end flanges **12** can be provided to enable the sludge carrying conduit to be joined with adjacent conduits for carrying the stream of sludge in employing the present invention.

[0018] The sludge carrying conduit **30** is provided with mixing elements **33**, **34**, **35** and **36** These elements are characterized as having no edges or surfaces perpendicular to longitudinal axis **37** and are sized so that no such elements are in contact with one another resulting in an open region of travel **96** for fluids passing through conduit **30** along its longitudinal axis. Ideally, each mixing element is seated within the sludge carrying conduit at an angle between approximately 30° to 45° to said longitudinal axis. Most importantly, however, the mixing elements are positioned within the conduit so that at least 75% of the conduit's circumference in any plane is free of any mixing element. Obviously, various mixing elements are provided with no points of contact so that there arc actually no "crotches" provided which would otherwise result in sludge hangup. In fact, it is the design objective of the present invention to enable debris having effective diameters of 75% or more of the conduit diameter to pass through the conduit without entrainment. Such a geometry is disclosed and claimed in applicant's U.S. Pat. No. 5,758,967. Mixers made according to the teachings of the '967 patent have been tested using flows of 2% to 4% sludge in pipe sizes for 2" to 8" in diameters. In no case did plugging occur over a period of more than six months.

[0019] As previously noted, it is the intent of the present invention to provide a device which is uniquely adaptable for the mixing of waste sludge and for enhancing heat transfer throughout a continuous stream of such material. Sludge is somewhat unique in its tendency to plug or clog mixing components for material within the sludge tends to migrate to and accumulate in low pressure or "dead spots" and long fibers will catch and build up in "crotches". Both of these effects allow and encourage more material to accumulate until the sludge carrying conduit finally plugs By providing spacing **96** and, more importantly, by providing the placement of mixing elements whereby at least 75% of the conduit circumference in any plane is clear of any ancillary structure accomplishes the goals of the present invention. Even the most problematic components "slide" over the mixing elements without clogging under both laminar and turbulent flow conditions. Ideally, the mixing elements are provided as pairs such as **33**/**34** and **35**/**36**. Each complimentary pair cause flowing material to rotate above the axis of the conduit in opposite directions. As further noted, the four mixing elements are each shown primarily as a circular segment configuration each of a height approximately D/10 and radius of D/2, wherein D is the diameter of the conduit. The various mixing segments or elements are set in a non-opposing fashion at the pipe wall so as to present to the fluid in any plane normal to the axis of conduit a non-symmetrical cross-section. This serves to break up the normal circular symmetry of flow and to substantially reduce the conduit length necessary to achieve effective mixing. As such, mixing is accomplished with minimal pressure drop and sludge hang up.

Experimental Data

[0020] The primary performance limiting factor in both pipe-in-pipe and shell and tube heat exchangers is that associated with the internal film coefficient located at the internal surface of the tube well. It is well known that static mixing elements installed in the tube or tubes can improve overall heat transfer performance by a factor of three or more, but such mixing elements, as noted above, tend to plug. The next performance limiting factor is that associated with the external film coefficient and is usually much smaller than the internal film coefficient. The present invention allows mixing elements **53**, **54**, **55**, and **56** to be installed on the outside of conduit **30** being installed in the annular space between conduit **30** and conduit **50** as shown in FIG. **5**. Although mixing elements **53**, **54**, **55**, and **56** are shown being appended to the inner wall of conduit **50**, they could have just as well been appended to the outer surface of conduit **30** which gives a modest but useful improvement in the overall heat transfer performance. In order to test the present design, a heat exchanger was built with a 2" pipe in a 3" shell having an overall length of 60". Flow rates and temperatures were measured and the data, inserted into software made available by Thermal Analysis Systems as to calculate heat exchange performance. In general, an improvement factor of more than 3 was obtained. In a typical run enclosed with a core tube velocity of 4' per second, the pipe-in-pipe result was $\Delta T=2.78$ while the experimental value was 86° F. giving an "improvement" factor of 31.

1. A heat exchanger for transferring heat energy from a heated liquid at a first temperature to sludge at a second temperature, said heat exchanger comprising a first conduit for receiving a stream of sludge, said first conduit having a length, substantially circular circumference, a longitudinal axis through said length and being open at both ends thereof, said first conduit housing a plurality of mixing elements, said mixing elements having no edges perpendicular to said longitudinal axis and are sized and positioned within said conduit such that at any plane passing perpendicularly to said longitudinal axis, at least 75% of the circumference of said conduit is free of any mixing elements and no mixing elements are in contact with one another resulting in an open region of travel for sludge passing through said first conduit along its longitudinal axis and a second conduit in the form of a sleeve having a longitudinal axis substantially coincident with the longitudinal axis of said first conduit and defining an annular space open at both ends for receiving and discharging said heated liquid.

2. The heat exchanger of claim **1** wherein said mixing elements are provided in said first conduit in complementary pairs, wherein adjacent mixing elements cause fluid passing within said first conduit to rotate in opposite directions.

3. The heat exchanger of claim **1** wherein each mixing element located within said first conduit is seated at an angle between approximately 30° to 45° to its longitudinal axis.

4. The heat exchanger of claim **1** wherein said mixing elements are in the form of primarily circular segments wherein each mixing element is characterized as being widest in profile at its midpoint and narrowest at its longitudinal end points.

5. The heat exchanger of claim **4** wherein each mixing element is of a height equal to approximately D/10 and a radius of approximately D/2 wherein D is the diameter of said first conduit.

6. The heat exchanger of claim **1** wherein said mixing elements are sized and positioned within said first conduit such that such first conduit is capable of passing therethrough solid matter contained within said sludge having a diameter of at least 75% of the diameter of said first conduit.

7. The heat exchanger of claim **1** wherein said heated liquid is water.

8. The heat exchanger of claim **2** wherein a plurality of mixing elements are located in said annular space.

9. A heat exchanger for transferring heat energy from a heated liquid to sludge, said heat exchanger comprising a plurality of inner conduits for receiving a stream of sludge, said plurality of inner conduits each having a length, substantially circular circumference, longitudinal axis through said length and each being connected to one another to provide a continuous path for said sludge whereby an entry is provided in an upstream most first inner conduit for said sludge and an exist is provided for said sludge in a downstream most inner conduit, each such inner conduit housing a plurality of mixing elements having no edges perpendicular to said longitudinal axis and are sized and positioned within each said inner conduit such that at any plane passing perpendicularly to said longitudinal axis, at least 75% of the circumference of said inner conduit is free of any mixing element and no mixing elements are in contact with one another resulting in an open region of travel for sludge passing through each of said inner conduits along its longitudinal axis and a plurality of outer conduits in the form of interconnected sleeves each having a longitudinal axis substantially coincident with the longitudinal axis of the inner conduit to which it surrounds thus defining a continuous annular space open at both ends for receiving and discharging said heated liquid.

10. The heat exchanger of claim **9** wherein said mixing elements are provided in said first conduit in complementary pairs, wherein adjacent mixing elements cause fluid passing within said first conduit to rotate in opposite directions.

11. The heat exchanger of claim **9** wherein each mixing element located within said first conduit is seated at an angle between approximately 30° to 45° to its longitudinal axis.

12. The heat exchanger of claim **9** wherein said mixing elements are primarily in the form of circular segments wherein each mixing element is characterized as being widest in profile at its midpoint and narrowest at its longitudinal end points.

13. The heat exchanger of claim **12** wherein each mixing element is of a height equal to approximately D/10 and a radius of approximately D/2 wherein D is the diameter of said first conduit.

14. The heat exchanger of claim **12** wherein said mixing elements are sized and positioned within said first conduit such that said first conduit is capable of passing therethrough solid matter contained within said sludge having a diameter of at least 75% of the diameter of said first conduit.

15. The heat exchanger of claim **9** wherein said heated liquid is water.

16. The heat exchanger of claim **9** wherein plurality of mixing elements are located in said annular space.

* * * * *