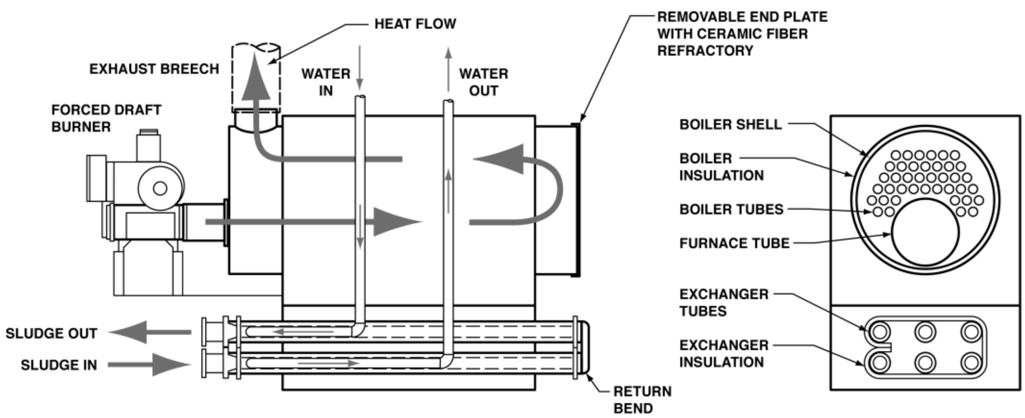
ANAEROBIC DIGESTER HEATING

The use of an external heat exchanger is the most common means of maintaining the proper temperature in an anaerobic digester. Raw sludge is sometimes pumped through these units before it enters the digester and in most cases sludge from the digester is re-circulated through a heat exchanger to maintain a digester temperature of about 95 degrees F.

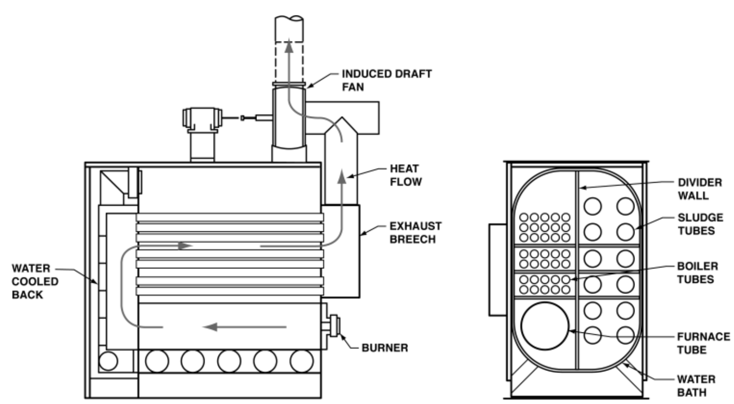
External Sludge Heating Systems:

The figures below illustrate the two predominant types of sludge heating systems used in municipal anaerobic digestion systems. One type uses a *tube-in-tube* type heat exchanger with a separate boiler and the *other uses a shell-and-tube* combination boiler/heat exchanger.



DRYBACK-FORCED DRAFT BURNER

Tube-In-Tube
by
Walker Process Equipment

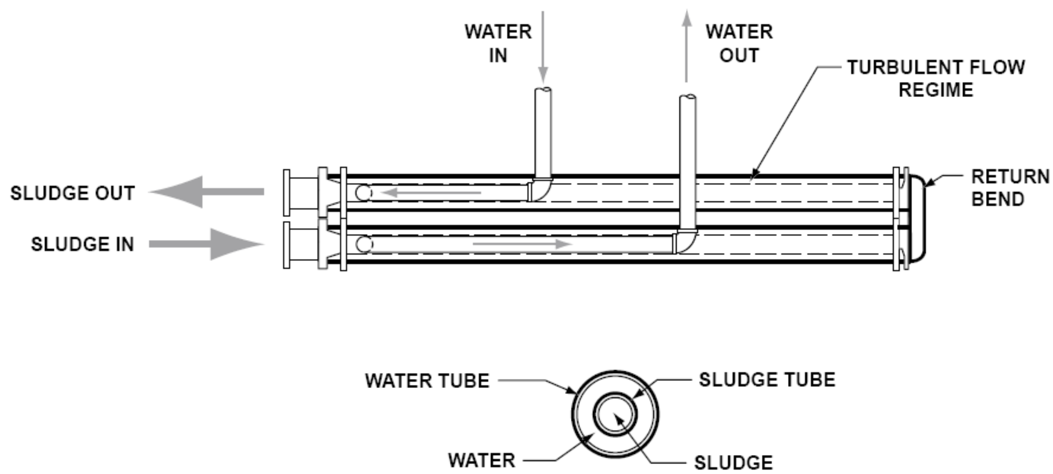


WATER BATH
INDUCED DRAFT BURNER

Shell-And-Tube

The ***shell-and-tube*** type operates with a convection bath.

Walker Process uses a ***tube-in-tube*** type heat exchanger that operates by forced (pumped) circulation of the sludge and hot water. The exchanger unit consists of a bundle of sludge tubes that are concentric with and located inside of larger diameter water tubes so that the hot water tubes surround the sludge tubes.



Tube-In-Tube Exchanger with Counterflow Circulation

Hot water at 150 degrees F is pumped from the boiler to the exchanger. A temperature differential of about 45 degrees F between the sludge and water is common with a maximum hot water temperature of 150 degrees F maintained to avoid sludge baking on the tubes. The boiler temperature is maintained at 180 degrees F to provide sufficient heat and to prevent damaging corrosion that may result from condensation that may occur at lower boiler temperatures.

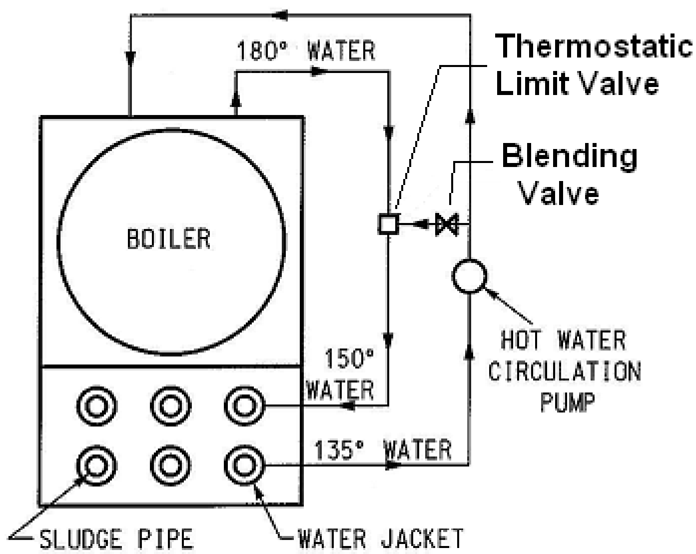
When heat transfer is desired, the exchanger water pump is energized to produce positive, counter flow circulation of the water to the sludge flow. Sludge flows through the smaller center tube, while water flows in the annular space formed by the outside of the smaller pipe and the inside of the larger pipe. With the counter-flow piping arrangement, the mean temperature differential between the two fluids is maximized, which results in the most efficient transfer of heat from the water to the sludge. The high turbulence of the flow in a tube-in-tube exchanger further improves the transfer characteristics by reducing the film coefficients between the fluids and the exchanger tubes. Further enhancement of heat transfer characteristics are obtained in the tube-in-tube type exchanger by providing rifling in the sludge return bends. This rifling tends to "spin" the sludge as it travels within the exchanger, which promotes even heating due to the increased turbulence. The potential for scaling or "sludge baking" is reduced by the scouring action of the flow.

In contrast, a shell and tube exchanger (water bath) is not as efficient as the tube-in-tube exchanger because the water bath surrounding the tubes does not provide counter-flow circulation to the sludge tubes. In some units, a booster pump circulates water from the boiler side to the exchanger side of the water bath; however, high turbulence and correspondingly lower transfer coefficients cannot be assured because of the large cross sectional area of the water bath in comparison to the small annular area in a tube-in-tube exchanger. As a result, more sludge tubes and more surface area is required to transfer the same amount of heat to the sludge.

In the shell and tube arrangement, only relatively thin sludge tubes separate the hot boiler water and the sludge. When the sludge is not being circulated it tends to heat up until it reaches the temperature of the hot water that may be as high as 180 degrees, causing a potential for the sludge to “bake” on to the interior of the sludge tubes that will contribute to loss of heat transfer efficiency and overheat any sludge in the tubes at the time.

BOILERS

Walker Process Boilers can be provided separately or in combination with the exchanger making a space saving arrangement. The combination unit (Illustrated in the Figure on the right) is the type most commonly supplied.



COMBINATION EXCHANGER/BOILER

Boiler Construction:

Walker Process uses a double pass, dryback type boiler, generally known as a Scotch Boiler that heats water to approximately 180 degrees F within a compact vessel by burning either sludge gas or an auxiliary fuel (natural gas, LP gas or fuel oil). This boiler may be arranged in the heating system as a stand-alone unit or stacked upon the heat exchanger to form a compact combination unit as shown in the diagram. In either case the boiler is a completely independent unit from the heat exchanger.

The shell-and-tube type heating system utilizes a wet-back type boiler that is an integral shell and tube (water bath) type arrangement where sludge tubes are located in the hot water reservoir of the boiler. The wet-back type design operates at lower boiler temperatures (about 160-degrees F) that may allow condensation of the “dirty” digester gas components, which forms highly corrosive acids that will attack the boiler surfaces.

One of most significant advantages of designing a sludge heating system with the boiler as a separate unit from the tube-in-tube exchanger is that the boiler water temperature and the exhaust gas can be maintained at a higher temperature than a water bath (wet-back) arrangement. A sufficiently high boiler water temperature allows the exhaust gas temperature to be maintained well above the dew point and reduces the chance of sulphurous acid condensing out of the flue gas and falling back into the boiler where it will cause damage. Exhaust gas that falls below the dew point will produce condensation.

Upon ignition of the burner, hot gasses pass from the furnace tube to the refractory at the end of the boiler where they are turned 180 degrees for a return path through the boiler tubes and up through and out the exhaust breech. During this circuitous route the hot gasses lose heat that is transferred to the boiler water. The boiler water gains heat as the products of combustion lose heat. If the exit temperature of the exhaust gas is below the dew point there will be condensation. In the case of a boiler fueled by digester gas the condensation will contain water and sulfurous acid. A stack temperature that is well above the dew point can generally be maintained if the boiler water temperature is above 160 degrees F. The Walker Process boiler water temperature is maintained between 180 – 200 degrees F.

Another advantage of a separate boiler is that, when heat demand has been satisfied, the hot water circulation stops, while the sludge flow continues for a short period of time to cool the hot water remaining in the tubes to avoid “baking” of sludge. With a shell-and-tube design, the sludge in the tubes are always exposed to the hot water, even when heat demand has been satisfied; the solution is to operate at lower temperature, thus causing the potential for condensation mentioned above.

The dryback boiler uses a refractory lining to protect the boiler end plate where the heated gases turn back and enter the boiler tubes, while in the wetback boiler; the water protects the end plate from becoming too hot. A major advantage of dryback construction is that is allows for removal of the back plate without having to drain the water from the boiler. This feature permits routine inspection and cleaning of the boiler tubes to maintain peak boiler efficiency. Leakage problems and boiler corrosion, caused by more frequent changing of the boiler water, are avoided with the dryback design. It should be noted that dryback boilers, due to their design and reliability, are favored by the commercial boiler industry as well.

Boiler construction also directly affects the ratings that manufacturers apply to their units. Equipped with a forced draft burner, the Walker Process boiler uses a nominal rating guide of 10,000 input BTU/Hr/Ft^2. Output heat is conservatively based on 80% efficiency. The conservative nature of these ratings is proven by both a long list of successful installations, as well as by Shop verification tests.

Other manufacturers attempt to directly relate boiler surface area with heat output. Surface area, however, is just one of many variables that influence heat transfer characteristics. Of equal importance are; the firing rate of the boiler, the temperature differential between the combustion products and the water, the velocity of the gases through the fire tubes, and the recirculation rate of the water. A more practical approach to specifying boiler size is to avoid the use of surface area requirements and simply specify Shop verification of the manufacturer's rating instead.

Burner Types:

There are two basic types of burners that are used to fire sludge heating boilers: induced draft and forced draft. Walker Process selected the forced draft burner many years ago as the preferred burner type due to the many design advantages that it offers:

1. Combustion control - Mounted upstream of the furnace, the forced draft fan is in contact with only cool ambient air of constant density. The uniformity of the intake air ensures accurate control of the air-fuel mixture. Contrary to this scheme, an induced draft fan is mounted on top of the exhaust breaching. As such, the fan is in contact with the hot combustion gases that vary in density depending on stack temperatures that result in less reliable control.

2. Maintenance Requirements - Blower reliability and longevity is another area where the forced draft fan is favored. Again, since the forced draft fan sees only cool, clean air, it is less prone to maintenance problems than an induced draft fan. Also, because the forced draft fan is directly coupled to the blower, there are no V-belts to adjust or replace.

3. Energy Savings - Due to the location of an induced draft fan in the exhaust stream, extra air must be admitted to the breaching to keep stack temperatures low. Therefore, electricity savings can also be realized with a forced draft fan because of their smaller horsepower requirements.

4. Emissions Control – Walker Process can supply a U.L. listed and factory tested Lo-NOx burners to meet emission standards for release of nitrous oxide.

Burner Safety Controls:

Walker Process Equipment boilers use the most current, state-of-the-art, burner control system to ensure safe operation and utilize a microprocessor based burner management system that monitors the operation and performance of all electro-mechanical safety devices.

IN SUMMARY:

- Counter-Flow Tube-in-Tube type heat exchangers are the most efficient means of safely transferring heat to sludge without the risk of overheating and baking sludge to the inside of the tubes.

- Walker Process heat exchangers are designed with end castings with sufficient pressure capacity for use with high-head applications such as in systems utilizing "Egg" digesters.

- The Walker Process forced-draft type dry-back burner/boiler combination provides the most efficient means of combustion control that also provides the additional benefits of lower blower maintenance and less energy usage than induced draft type blowers.

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In stationary service, boilers are either of the **Dry-Back** or **Wet-Back** type.

SOME DEFINITIONS:

DRY-BACK – The baffle provided in a firetube boiler joining the furnace to the second-pass to direct the products of combustion that is so constructed to be separate from the pressure vessel and constructed of heat resistant material.

WET-BACK – A baffle provided in a firetube boiler of water leg construction covering the rear end of the furnace and tubes and is completely water cooled. The products of combustion leaving the furnace are turned in this area and enter the tube bank.

SCOTCH BOILER – A cylindrical steel shell with one or more cylindrical internal steel furnaces located (generally) in the lower portion and with a bank or banks (passes) of tubes attached to both end closures.