Brown AND Caldwell

201 N. Civic Drive - Suite 115
Walnut Creek, CA, 94596
Tel: 888-299-0000
Fax: 925-937-9026

Technical Memorandum 4.3B

Digester Heating and Mechanical Modifications

Prepared for: San Jose/Santa Clara Water Pollution Control Plant

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To: Ravi Kachhapati, Project Manager

From: Steve Krugel, Senior Vice President, Project Manager

Prepared by: Lloyd Slezak, PE, Vice President
Engineer in Responsible Charge, License No. C61492

Reviewed by: Ken Hopkins, Technical Expert
Steve Krugel, Senior Vice President, Project Manager

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1. EXECUTIVE SUMMARY

The digester heating system at the San Jose/Santa Clara Water Pollution Control Plant (WPCP) has been noted by operations staff as a significant problem area during field visits on October 30, 2008 and November 21, 2008. Difficulties are reported in maintaining digester temperatures throughout the complex. Review of the operation of the existing heat distribution system revealed limitations in the hydraulic operation and configuration of the system. The system operates in an unbalanced configuration and the control capability of three-way valve heat controllers is non-functional. Brown and Caldwell (BC) recommends implementing an automatic flow rate controller configuration at each digester load circuit location. We also recommend replacing the hydronic distribution pumps in the Blower Building in order to provide equipment more closely matched to the flow and pressure loss characteristics of the hydronic system.

Heating requirements were estimated for future sludge loading estimates for a range of digester solids concentrations, a range of digester hydraulic residence times, and for two process heating scenarios; mesophilic and thermophilic. These scenarios are the most likely and most severe, respectively, of several future biosolids processing configurations that are being considered by the Master Plan process and that are addressed in TM 3.3. In general, existing digester heating components appear to be adequately sized to serve future sludge loadings for mesophilic digestion scenarios. However, digesters that are upgraded with submerged fixed covers may require additional heat exchanger (HEX) capacity due to the volume increase associated with new covers. It is recommended that a pilot test of existing HEXs be conducted with higher hot water temperatures and/or increased circulating sludge flow rates to determine if they are sufficient for digesters equipped with submerged fixed covers or whether an additional HEX is required for each digester.

Thermophilic scenarios significantly increase the requirements for heat exchange and hydronic distribution capacities. Additional predesign effort should be undertaken if the City chooses to plan for a thermophilic biosolids processing configuration in order to make supplemental decisions regarding sludge heat recovery as well as determining the locations of and configurations for raw sludge heating. Alternatively, if thermophilic operation capability is designated for a future phase of digestion improvements, existing vessels may be retrofitted to optimize for mesophilic requirements, while at the same time preserving the capability to easily convert to thermophilic operation at some future time.

In order to optimize sludge digestion heating systems (and processes) in the future, we recommend implementing diurnal sludge equalization and blending system (blended sludge storage tank or equivalent) with a continuous digester feeding system that feeds all digesters a portion of raw sludge simultaneously.

2. INTRODUCTION

This Technical Memorandum (TM 4.3B) describes the evaluation of Digester Heating and Mechanical Systems and provides recommendations for improvements as part of the rehabilitation of the digestion facilities at the WPCP.

2.1 Scope of Work

The scope of work for Service Order No. 1 calls for evaluation of digester heating options for the sixteen existing digesters. The following subjects are covered in the scope of work:

- Capacity analysis of the existing hot water heating system and HEXs;
- Estimation of future heating requirements, including provisions for future thermophilic digestion processes;
- Evaluation of alternative heat distribution and HEX equipment options; and
- Evaluation of digester feed, circulation, and drainage piping systems.

Evaluation and analyses are to be based on an assumed range of raw sludge solids concentrations in the range of 3 percent to 8 percent, expanded from the 3.5 and 5.5 percent design points evaluated in TM 3.3 to test heating capabilities at an expanded range of solids concentrations. Evaluations and analyses are also to be cognizant of current and future operations and maintenance issues with the systems and the possibilities of changes to the liquid treatment and dewatering processes anticipated from the WPCP Master Plan.

3. CAPACITY ANALYSIS OF EXISTING HOT WATER HEATING SYSTEM AND HEAT EXCHANGERS

3.1 Existing System Description

Sixteen anaerobic digesters are heated via a circulating sludge loop from each digester receiving heat from a concentric tube hot water HEX dedicated for each digester. Each of the sixteen sludge/hot water HEXs receives heat distributed to it via a plant wide hydronic supply system. Heat input for the hydronic system is predominantly provided by cogeneration engines located at three different buildings on the WPCP site. An overall schematic of the hydronic system is presented in Figure 3-1.

3.2 Heat Sources

Heat is produced at three buildings on the WPCP site as indicated in Table 3-1. Most heat production units are cogeneration engines, meaning that gas fuel (digester gas, landfill gas, or natural gas) is used to drive stationary internal combustion engines that cogenerate to produce two forms of useful energy (electricity plus recovered heat or aeration air plus recovered heat). Heat is recovered from engine jacket water and from exhaust gas heat recovery silencers. All recovered heat is transferred into the site wide hydronic distribution system. In addition to the cogeneration engines, Building 40 houses two natural gas-fuelled steam boilers (10 million BTU/hr each) that can supplement heat production.

The cumulative capacity of the heat producing units is not necessarily reflective of the ability to produce adequate heat for the WPCP needs. Rather, the demand for the cogenerated energy sources (electricity and aeration air) are the determining factors for the amount of cogenerated heat that can be available to heat digesters and other site space heating requirements. Table 3-2 presents a summary of cogenerated power demand in recent years and an estimate of the recoverable heat available from that activity. Table 3-2 assumes that cogeneration heat recovery equipment is maintained in good working order.

It is not within the scope of this TM or project to evaluate the current condition or address the future of heat production sources at the WPCP. The City has engaged other consultants to analyze the available heat sources at the WPCP (CDM, 2009). They have reported on a varied range of equipment conditions and heat recovery capabilities. Some of the reported data is difficult to reconcile with fundamental engine operating requirements. Nonetheless, the WPCP has a complex array of cogeneration engines and there are a multitude of factors that determine which are operating, at what load they are operating, and the service status of heat recovery. Moreover, the future disposition of cogeneration engines at the plant is not known at this time. Engine systems may be near the end of useful life, air emission standards may preclude continued use of some units, and it may prove favorable in the future to replace engine drives on pumps and blowers with electric motors. Some of these outcomes could lead to new electric generator cogeneration units that provide greater flexibility for power distribution and may have higher fuel-to-power and heat conversion efficiencies. Consequentially, this TM reports both the estimated potentially recoverable heat based on data from manufacturers of similar engines and the actual heat recovered reported from CDM (2009). This provides bounds for potential heat recovery improvements and the range of potential future need for supplemental boiler operation to provide required digester heat.

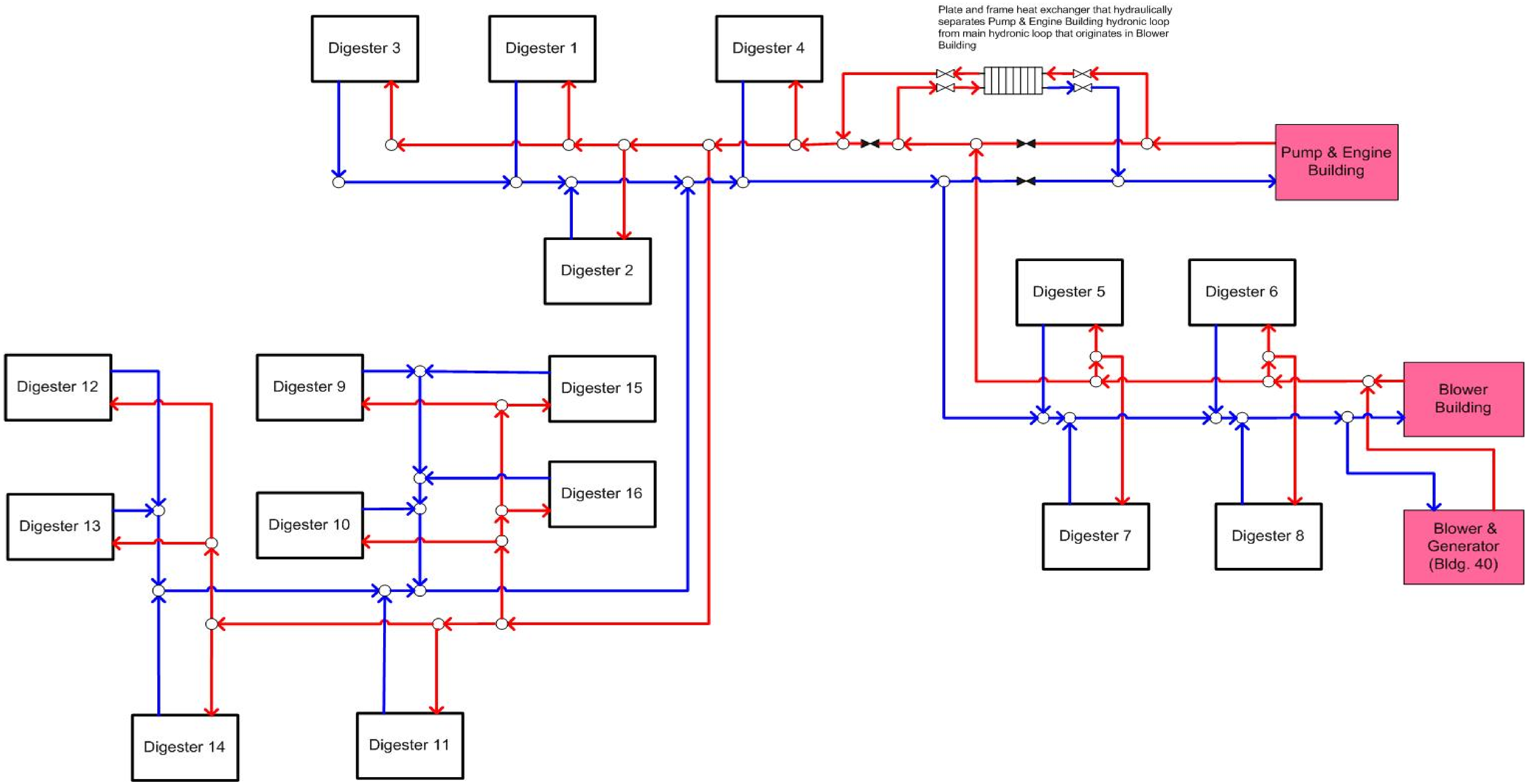

Figure 3-1. Schematic diagram of WPCP hydronic distribution system.

Table 3-1. Heat Production Sources					
Heat Production Facility	Heat Production Units	Description	Prime Mover Power (Hp)	Estimated Potential Recoverable Heat Capacity* (10^6 BTU/ HR)	Reported Recovered Heat ** (10^6 BTU/ HR)
Pump & Engine Building	Engine No. E-1	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	1130	2.4	NA
	Engine No. E-2	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	1130	2.4	0.97
	Engine No. E-3	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	1130	2.4	0.97
	Engine No. E-5	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	2466	5.6	0.58
	Engine No. E-6	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	2466	5.6	NA
Blower Building	Engine A-1	Stationary Engine – Aeration Blower – Engine Jacket Water and Engine Exhaust Heat Recovery	2350	5.6	0.58
	Engine A-2	Stationary Engine – Aeration Blower – Engine Jacket Water and Engine Exhaust Heat Recovery	2350	5.6	3.39
	Engine A-3	Stationary Engine – Aeration Blower – Engine Jacket Water and Engine Exhaust Heat Recovery	2350	5.6	0.58
	Engine B-1	Stationary Engine – Aeration Blower – Engine Jacket Water and Engine Exhaust Heat Recovery	1855	4.5	2.29
	Engine B-2	Stationary Engine – Aeration Blower – Engine Jacket Water and Engine Exhaust Heat Recovery	1855	4.5	2.29
	Engine B-3	Stationary Engine – Aeration Blower – Engine Jacket Water and Engine Exhaust Heat Recovery	1855	4.5	0.46
Blower & Generator Building (Bldg. 40)	Engine EG 1	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	3,900	9.4	3.26
	Engine EG 2	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	3,900	9.4	4.64
	Engine EG 3	Stationary Engine – Electric Generator – Engine Jacket Water and Engine Exhaust Heat Recovery	3,900	9.4	4.64

** Recoverable heat estimated by assuming that prime mover power rating represents approximately 37 percent fuel conversion efficiency and that approximately 35 percent fuel usage can be recovered as heat, these values taken from Enterprise Engine data for similar engines. Accuracy of estimate is limited but estimation provides reasonable assessment of general magnitude of heat available.*

$$\mathrm{Re\,cov}\,erableHeat(10^6\,BTU\,/\,HR) = \mathrm{Pr}\,imeMoverPower(HP)\times\frac{0.00254(10^6\,BTU\,/\,HR)}{1(HP)}\times\frac{1(10^6\,BTUFuelUse\,/\,HR)}{0.37(10^6\,BTUPower\,/\,HR)}\times\frac{0.35(10^6\,BTU\ \mathrm{Re\,cov}\,erableHeat\,/\,HR)}{1(10^6\,BTUFuelUse\,/\,HR)}$$

*** Reported recovered heat from "Heat Balance Study Technical Memorandum", May 28, 2009, CDM Engineers. Engine loading and fuel consumption information associated with measurements were not reported. Balance of unrecovered heat was not measured or reported. Some recovery values appear far less than that necessary to prevent engine overheating.*

NA – Not Available

Table 3-2. Estimated Power and Heat Production				
Year	On-Site Power Production Fuel Usage (therm/yr)	Estimated Potential Recoverable Heat* (10^6 BTU/hr)	Reported Recoverable Heat** (10^6 BTU/hr)	CDM 2009 Estimated Potential Recoverable Heat (10^6 BTU/hr)
Current (Fuel Usage from data presented in TM 3.3)	9,103,000	36	15.6	32
2030 Design (Estimated 20% Increase)	10,920,000	43	18.7	NA

**Potential recoverable heat estimate based on assumption that 35 percent of fuel usage can be recovered as heat.*

$$Estimated\ RecoverableHeat(10^6\,BTU/HR) = On-SitePowerFuelUsage\left(\frac{therm}{yr}\right)\times 0.35\left(\frac{therm\ RecoveredHeat}{thermFuelUsed}\right)\ldots$$

$$\times 100{,}000\left(\frac{BTU}{therm}\right)\times\frac{1}{1{,}000{,}000}\left(\frac{10^6\,BTU}{BTU}\right)\times\frac{1}{365\times 24}\left(\frac{yr}{hr}\right)$$

***Reported recovered heat based on overall heat recovery capacity of 15% reported by "Heat Balance Study Technical Memorandum", May 28, 2009, CDM Engineers. This heat recovery rate is less than engine jacket water heat rejection requirements of engines and would likely, if actual, result in unsustainable engine overheating.*

3.3 Heat Distribution

Distribution of heat from the heat production sources to the digesters and other space heating loads is via a hydronic system. A hydronic system uses a heat transfer fluid to carry heat to a location where heat is exchanged from the transfer fluid to the demand load (digester or space heater) and then transports the exchange fluid back to the production sources to accept more heat. The result is a continuous loop of heat transfer. Figure 3-2 describes a hydronic loop in concept. The WPCP's hydronic system is based on this typical schematic.

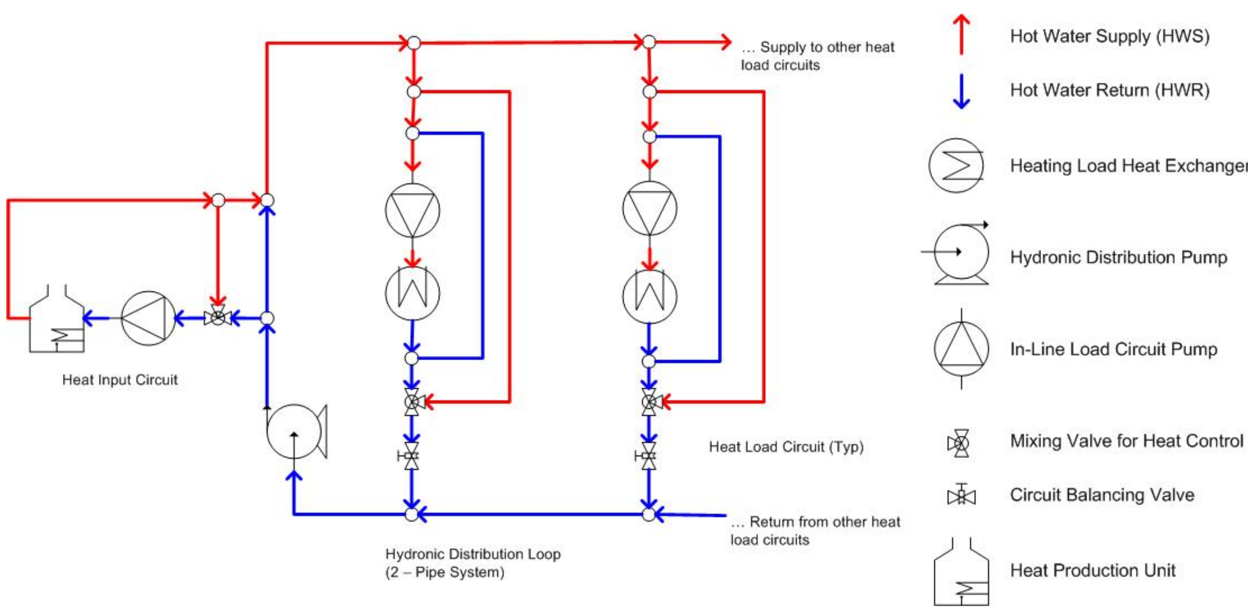

Figure 3-2. Conceptual diagram of a typical hydronic loop for heat distribution.

Hydronic systems are classified in textbook[1] by the characteristics of the exchange fluid, layout of the distribution piping system, and characteristics of the load connections. Table 3-3 summarizes our assessment of the major characteristics of the WPCP hydronic system.

Table 3-3. Hydronic System Characteristics at San Jose / Santa Clara WPCP

Characteristic	Description
Exchange Fluid	Low Temperature Water (160° F to 200°F)
Distribution System (2-Pipe or 1-Pipe)	2-Pipe System, Direct Return
Load Connection	Primary – Secondary, Constant Volume Flow, Temperature Modulation on Hydronic Side

Use of low temperature water (instead of steam) as the exchange fluid creates a need to pump more fluid through the hydronic system for heat delivery, but avoids the additional design and safety challenges of handling steam in the pipe galleries and at the load connections.nWhile more complex to balance, a 2-pipe distribution system is an efficient means of supplying a large number of load connections with an equal volume of exchange fluid at equal temperature. Equal heat capacity is intended to be available at each load connection.

The Primary – Secondary load connection allows each load connection to modulate the heat drawn from the system in accordance with the heat demand measured from the process at that point. The three-way valve controls the amount of hot water supply (HWS) directed through the heating load versus the amount of HWS that bypasses the heating load to flow directly to the return piping. It is important to note that the primary function of the in-line load circuit pump is to provide constant flow through the heat load HEX, regardless of the amount of HWS bypassed directly to the hot water return (HWR) side for temperature control.

Figure 3-3 describes the pressure distribution for a hydronic loop feeding multiple load circuits. For the practical case of the loop piping being the same nominal size, load circuits at the front end of the loop will have a higher pressure gradient from the supply to the return side pipes and, hence, will pass proportionally greater flows across the load circuit. Without the use of circuit balancing valves to correct for the differences in pressure gradient, it is challenging to control the heat distribution properly to all load circuits (digesters).

[1] Hansen, Erwin G.*Hydronic System Design & Operation*. First. New York: McGraw-Hill, 1985. Print.

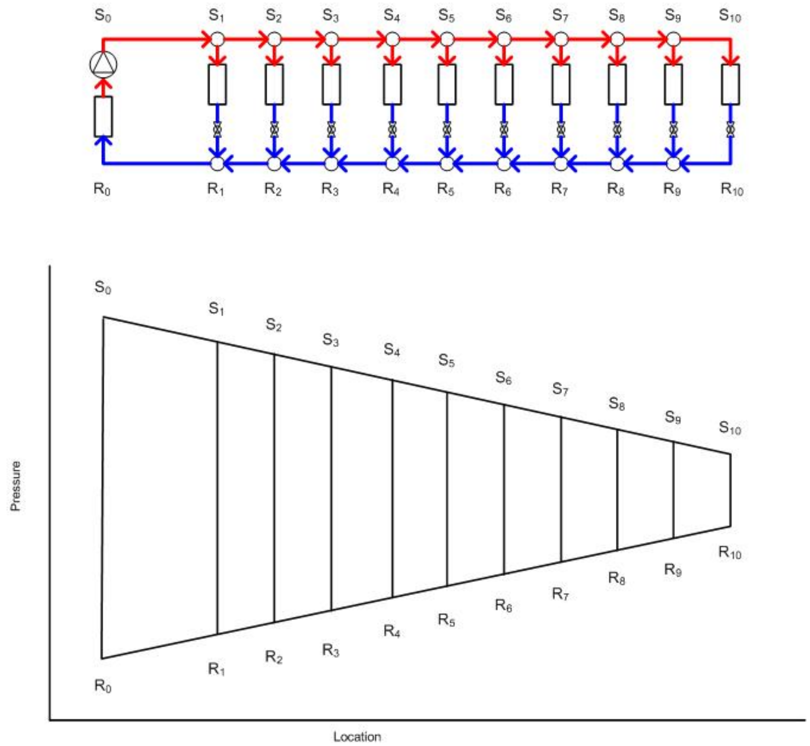

Figure 3-3. Pressure diagram for conceptual 2-pipe, direct return hydronic loop system.

Lower diagram describes relative pressures at locations in overlying schematic hydronic loop diagram. Pressure differential from S_1 to R_1 is much greater than S_{10} to R_{10}. Balancing valves are used to equalize pressure differentials so that flows through each load circuit are equal.

The hydronic distribution system at the WPCP departs from the concepts described here in several important respects as listed below.

- Comparing the WPCP schematic in Figure 3-1 to the conceptual hydronic loop schematics, it can be seen that the WPCP system is not organized in a traditional loop. The system more resembles a networked distribution system with several dead end loops. Brown and Caldwell and industry standard design practice are to configure hydronic loops without dead end loops. In addition, the design literature on hydronic loops does not describe networked systems with dead end loops. Rather, all design examples are configured in a formal loop arrangement. This is an important aspect of system control. The ability to properly balance flows in the WPCP's system is suspected to be very difficult in practice.
- Our site observations at the WPCP indicated that the system is not balanced with the balancing valves provided for the system. All circuit balancing valves appear to be operated wide open.
- Because all circuit valves are operated wide open, WPCP staff have observed that the distribution pumps trip on over amperage when run in the normal piping configuration. In order to address this condition, the standard operating procedure at the distribution pumps is to throttle the discharge valve at the distribution pumps to increase the discharge pressure at the pumps to 110 pounds per square

inch (psi) in order to control the flow output of the pumps. The unregulated downstream pressures are less than 50 psi.

- A consequence of throttling the pressure gradient at the pump and operating with all circuit valves wide open is that the HWS pressures quickly approach the HWR pressures and, in the further extremities of the system, the HWS pressures are actually lower than the HWR pressures, unlike the intended pressure distribution depicted in Figure 3-3.

In order to provide a basis for analyzing the distribution system, a rough hydraulic model (Bentley Systems WaterCAD™) of the system was developed for this TM. Figure 3-4 presents some field observations of distribution system pressures and the results of modeling the system pressures for a similar configuration of operating digesters. Both the observed and the modeled data confirm that the system operates far from the ideal pressure distribution described in Figure 3-2. All observed values and all but one modeled results show that supply pressures are less than return pressures. Figure 3-4 also shows the corresponding distribution of HWS flows to the operating digester load circuits. A significant imbalance can be seen, emphasizing the impact of an unbalanced hydronic distribution system.

Figure 3-5 presents the model calculated distribution of HWS to digesters if all digesters are placed in service. The unbalanced flow to the various digesters is readily apparent. Also, the figure indicates the impact on the distribution of flows by the actions of the three-way temperature mixing valves. Flow reversals are very likely common occurrences in the system as operated today.

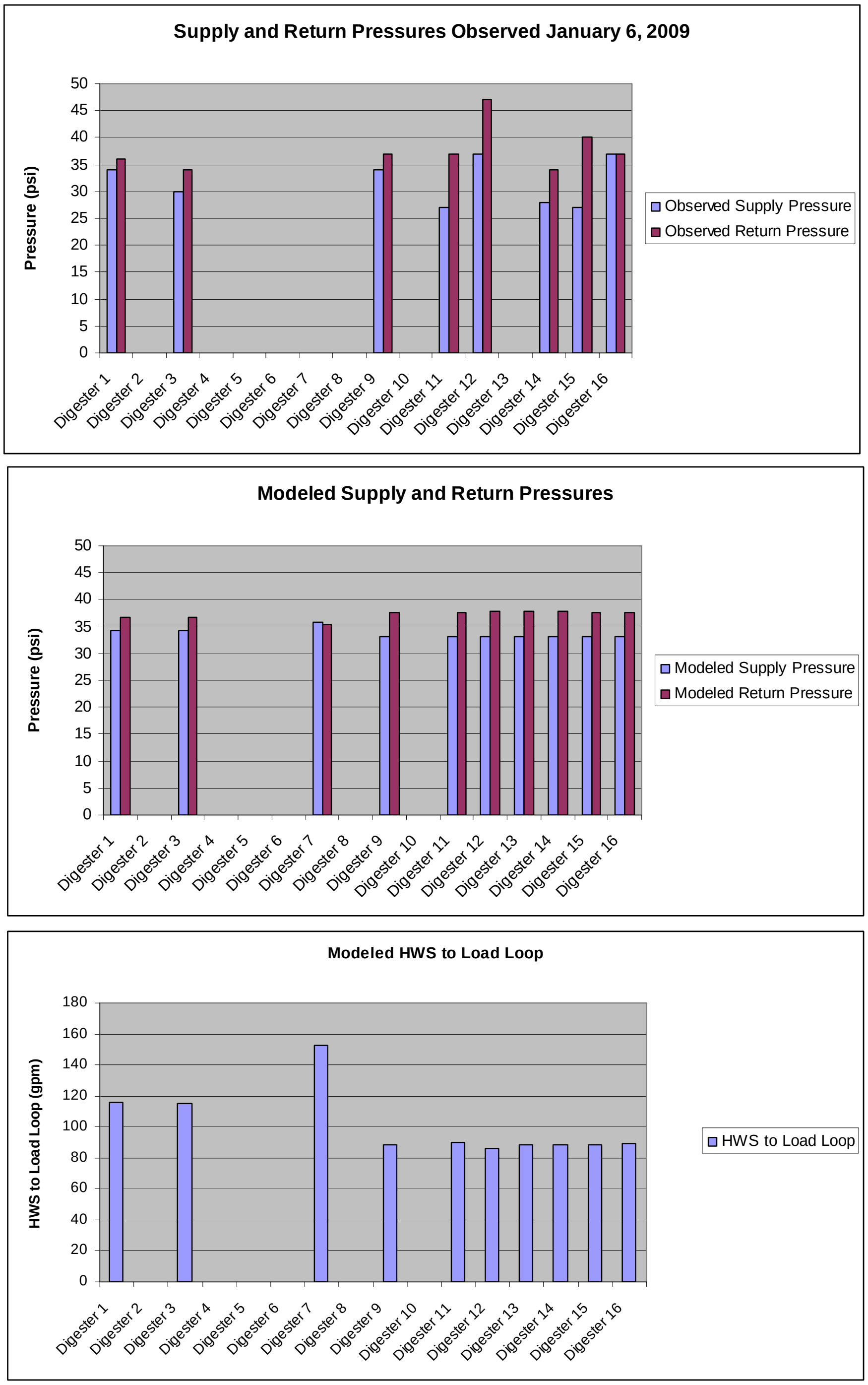

Figure 3-4. Observed supply and return pressures to digester HEX load circuits, modeled supply and return pressures to digester HEX load circuits, and modeled distribution of HWS flows to digester load circuits for configuration matching the observed values. Supply pressures should be higher than return pressures.

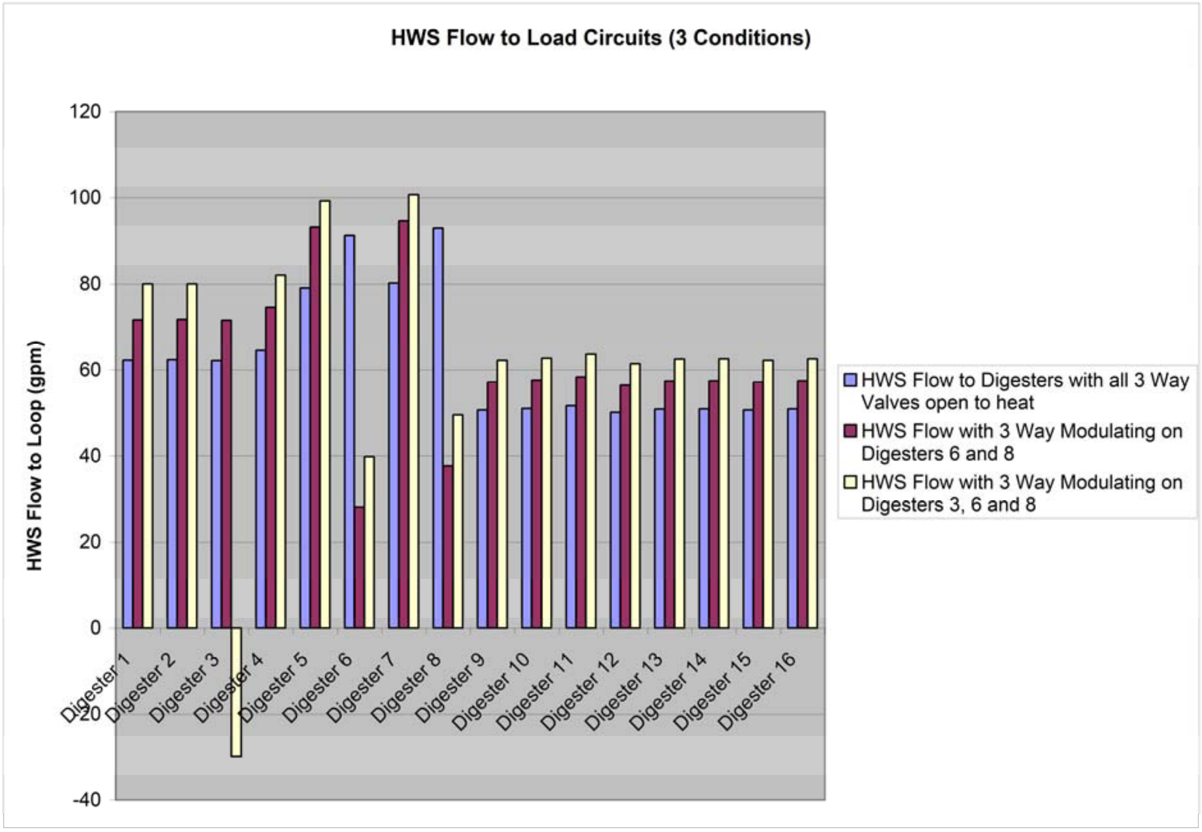

Figure 3-5. Modeled results of flows to Digester load loops. Flows should be equal to each other (balanced) in all conditions. Note in last condition that HWS flow to Digester 3 is negative, meaning that return flow is feeding back to supply side at that load loop.

Operating the hydronic system with the current pressure distribution defeats the ability to effectively control the heat delivery rate to the various digesters. Figure 3-6 shows how a typical load circuit will behave when the return pressure is higher than the supply pressure. Operation of the three-way valve results in flow reversals with return side (lower temperature) fluid being forced back through to the supply side of the heating loop. This condition creates unpredictable responses in the temperature control system with various positions of the three-way mixing valves.

Figure 3-7 indicates how a typical load circuit will behave when it is operating under an appropriate pressure distribution environment where the supply side pressure is higher than the return side pressure. In these conditions, operation of the three-way valve properly varies the proportion of supply side fluid that is passed through the HEX versus the proportion that is bypassed directly to the return side. In general, the flow through the load circuit should be the same under all three-way valve positions and the flow rate through the HEX should be the same through all three-way valve positions.

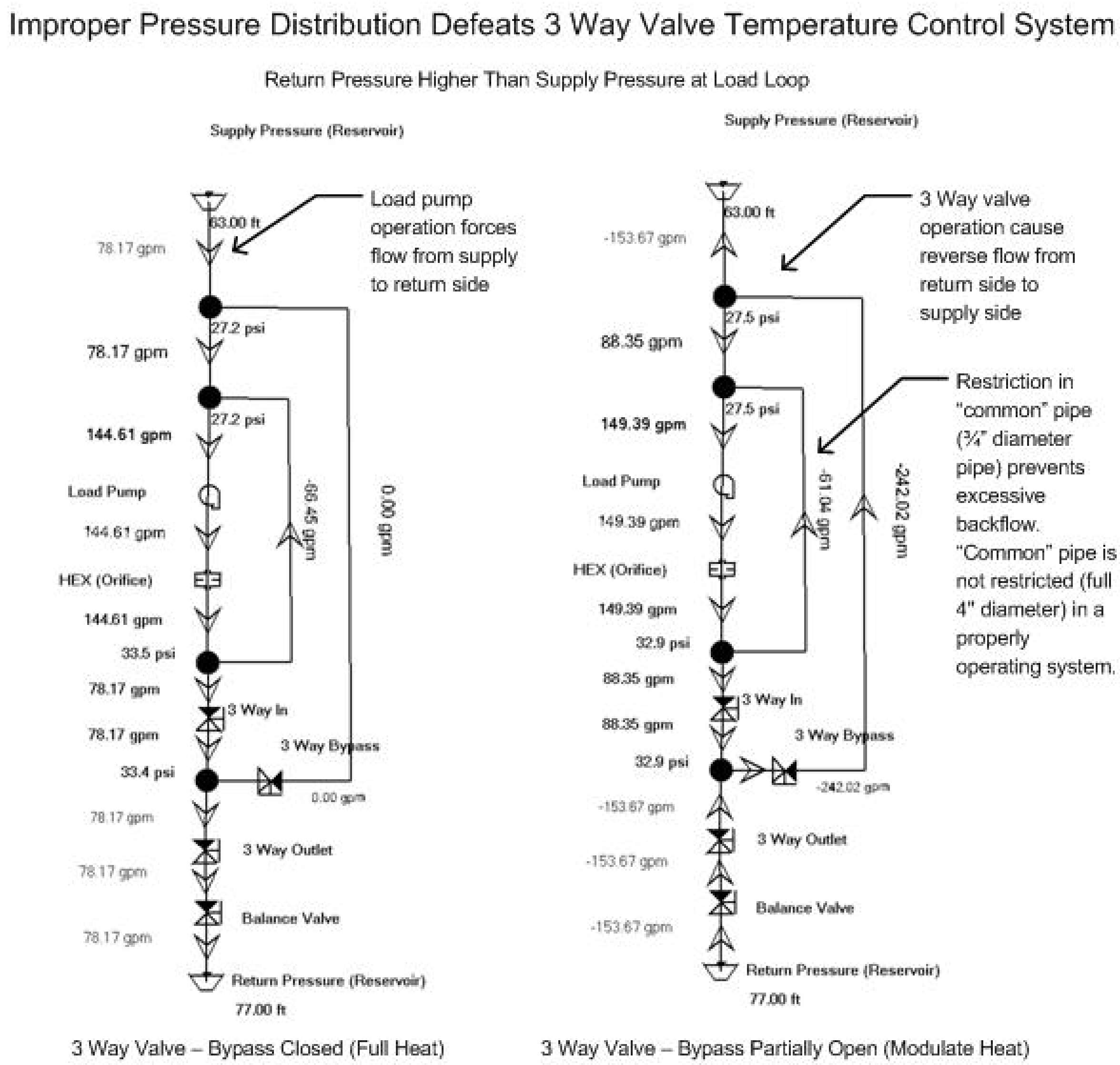

Figure 3-6. Output diagrams from hydraulic model of load circuit illustrates loss of temperature control capability when return pressure is higher than supply pressure.

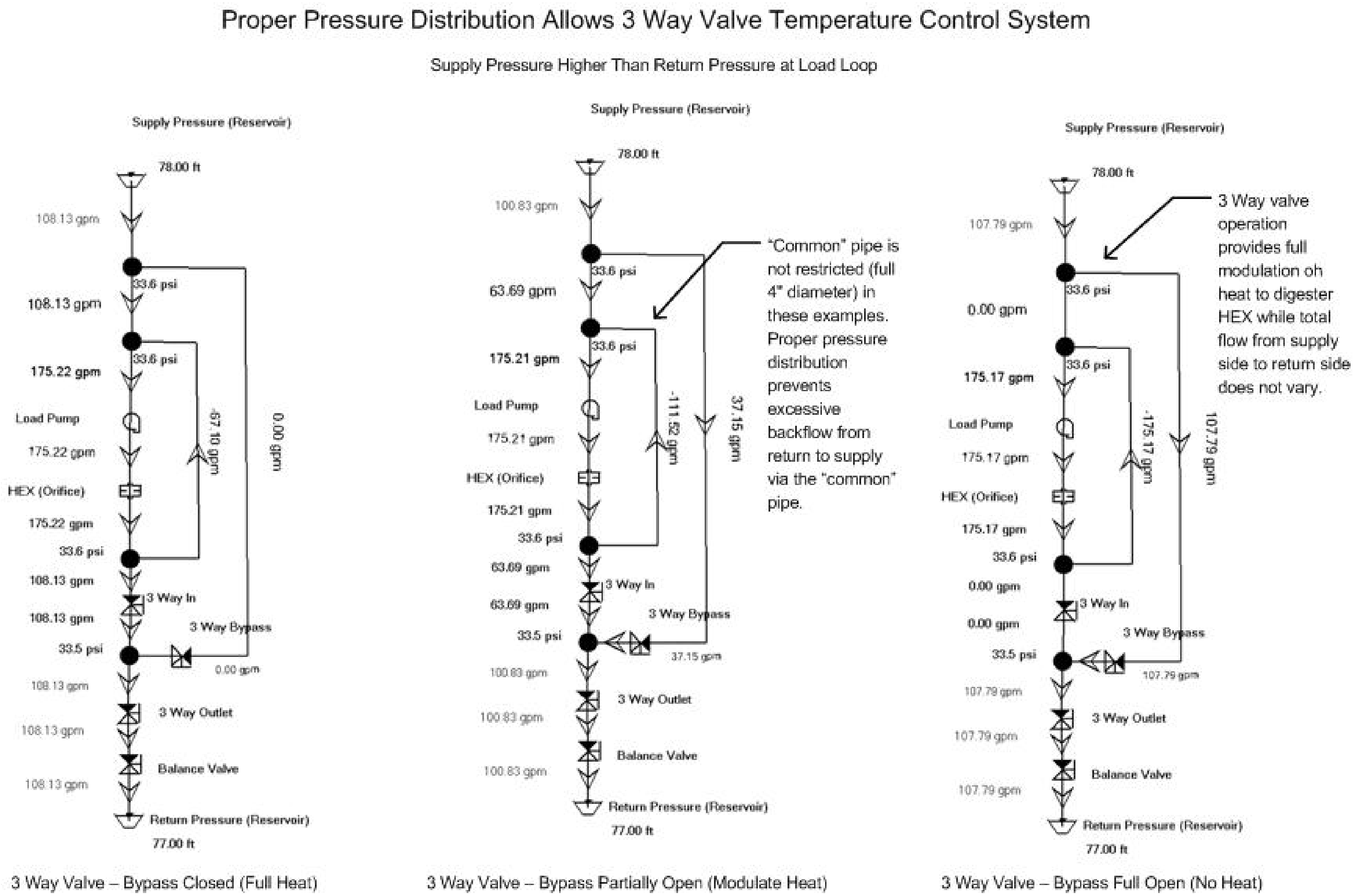

Figure 3-7. Output diagrams from hydraulic model of load circuits illustrates proper temperature control capability when supply pressure is higher than return pressure. Balance valve is normally used to adjust the load circuit loss in order to compensate for variable pressure drops from supply to return in different load circuits throughout the distribution system.

Figures 3-6 and 3-7 also make note of the unique configuration of the "common" pipe in the load circuits at the WPCP. The "common" pipes are an essential and fundamental feature of properly operating load circuits in hydronic systems. Their purpose is to fully equalize the pressure upstream of the load circuit pump and downstream of the load appliance HEX. This creates the conditions that force the load circuit pump to maintain a constant flow rate through the HEX through the full range of bypass conditions created by operation of the three-way valve. Review of design documents indicate that "common" pipes were originally installed with check valves (also inappropriate), but observation of current conditions in the field reveal the restricted configuration shown in Figure 3-8. Our system model indicates that, when the system is operated with the inappropriate pressure distribution as is currently found, restricting flow through the common pipe is necessary to prevent totally out of control reverse flow conditions from the return to the supply side of the distribution system. However, if the system is configured to run properly, the restrictions in the "common" pipes should be removed in order to optimize temperature control at each of the load circuits.

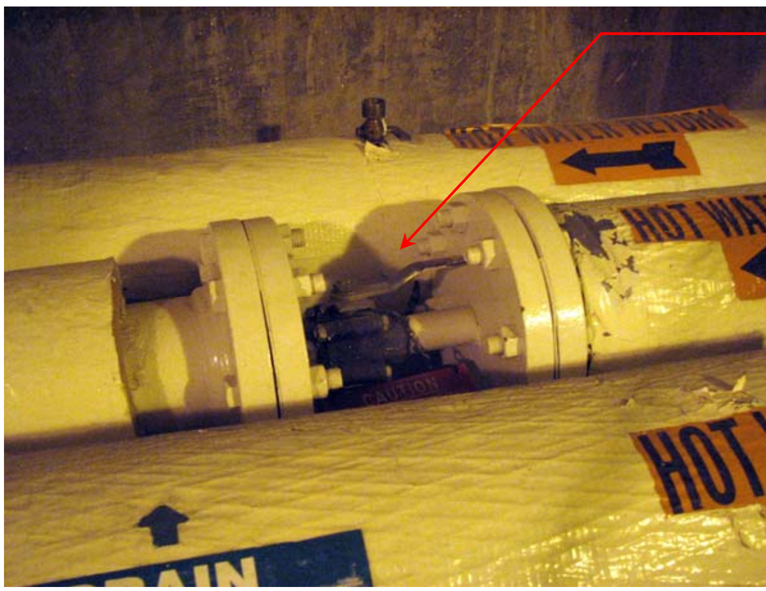

Figure 3-8. Restriction in "common" pipe on load circuits.

In summary, heat distribution system at the WPCP is operating in a significantly impaired hydraulic configuration and this is likely the principal source of perceived inadequacies of the digester heating system.

- The overall system is not configured in a traditional loop arrangement but rather is a networked distribution configuration with several dead end loops. While the system can theoretically operate in such a configuration, we suspect that attempts to manually balance the system have proven difficult. We suspect that the current mode of completely unbalanced operation may have resulted from frustration in balancing this complex and geographically large network system.
- Unbalanced operation creates an inappropriate distribution of pressures through the hydronic network. Most of the load circuits operate with return pressure being greater than supply pressure. This operational condition defeats the systems ability to control temperatures at the individual load circuits. It also limits the capacity to deliver sufficient quantities of hot water to the extreme ends of the system.

The Blower Building hydronic loop distribution pumps appear to be oversized with respect to pressure capacity. It appears that there is 35 to 45 psi of excess pressure developed and wasted with throttling valves at the pumps. The system could be properly operated with less energy input into the distribution system if the pumps were properly sized. Based upon the estimate required flow capacity of the pumps (see Section 3.3) and the amount of wasted pressure development, the estimated market value of this wasted energy may be on the order of $27,500 per year. It is also likely that pump maintenance costs could be reduced with operation more closely matched to a Best Efficiency Point (BEP) on the pump operating curve. Building 40 pumps were also observed operating at 110 psi but it was not apparent where the excess pressure was being throttled.

$$PumpFlow := 1500 \cdot \frac{gal}{min} \qquad ExcessPressure := 40 \cdot \frac{lb}{in^2}$$

$$PumpEff := 0.75 \qquad MarketPowerRate := 0.09 \cdot \frac{dollar}{kW \cdot hr}$$

$$g = 32 \frac{ft}{sec^2}$$

$$PowerSavings := \frac{PumpFlow \cdot ExcessPressure \cdot g}{PumpEff} \cdot MarketPowerRate$$

$$PowerSavings = 27454 \frac{dollar}{yr}$$

The following actions are recommended to alleviate poor operating conditions in the heat distribution system.

- Implement system modifications to automate flow balancing to the individual load circuits. We remain concerned that attempts to use the manual balancing valves for this system will be difficult to achieve and maintain. A flow-rate controlling valve at each load circuit location would achieve flow and pressure balancing across the system and return the system to a state where temperature control can be achieved at every load circuit location.
- With implementation of the flow-rate controlling valves at each load circuit, replace the restriction in the “common” pipes with a full pipe diameter connection.
- Replace the hydronic loop distribution pumps with more appropriately sized pumps in order to lower energy usage in the hydronic distribution system.

Figure 3-9 schematically describes the flow rate controlling valves for automatic balancing of the load circuits. The purpose of the flow rate controlling flow valves is to ensure that each circuit is fed an equal flow rate by adjusting a balancing headloss at each digester HEX circuit. An existing 3-way control valve at each circuit will then modulate what portion of the equalized flow rate is fed to the HEX and what portion is bypassed around it, depending on the temperature of the hot water and the heat required by the HEX. The 3-way control valve accomplishes this by modulating to maintain a temperature set point for sludge exiting the digester HEX.

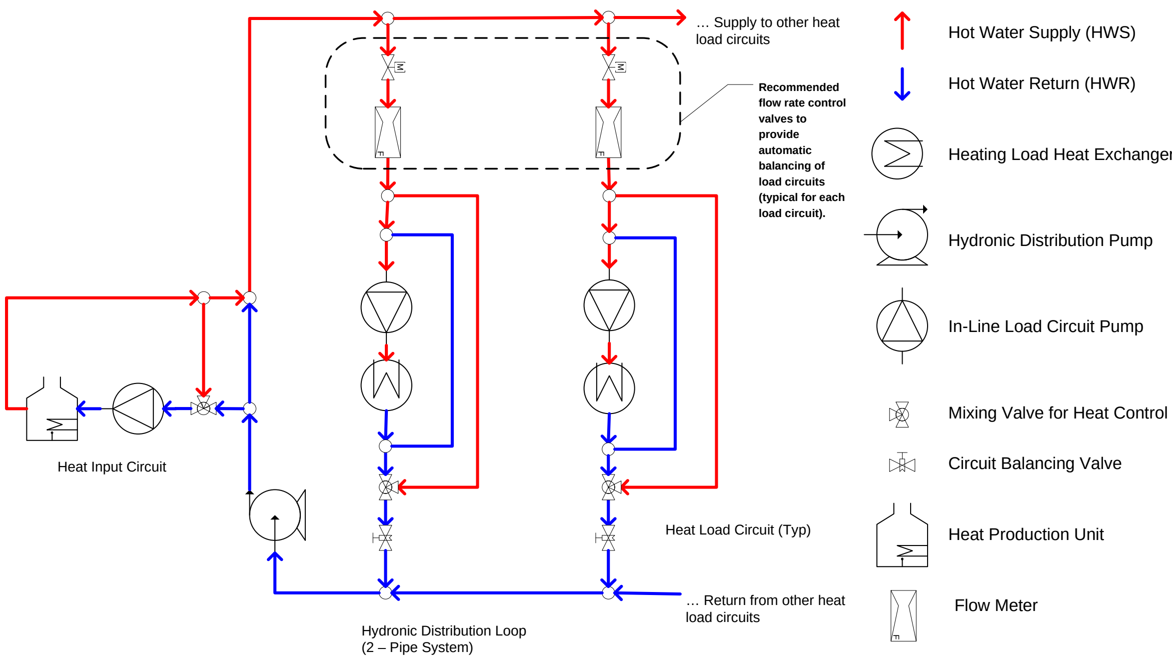

Figure 3-9. Schematic description of recommended flow rate control valves for automatic balancing of load circuit flows.

3.4 Heat Exchanger Appliances

The existing HEXs (Figure 3-10) are concentric flow modules with circulating sludge flowing through multiple return pipe passes. The circulating sludge pipe paths are surrounded by a large pipe carrying hot water exchange fluid. The HEXs divide sludge and hot water into two separate flow paths. Review of WPCP design documents and our field observations of installed equipment indicate hot water flow rates through the units are rated at 180 gpm and circulating sludge flow rates are rated at 900 gpm. The HEXs are rated at 2,226,000 BTU/hr with 180 gallons per minute of 160°F hot water (minimum hot water temp) and at 3,260,000 BTU/hr with 250 gallons per minute of 180°F hot water (maximum hot water). Figure 3-11 presents mapping of HEX capacities as a function of flow rates for the minimum and maximum hot water temperatures (assuming cold sludge at 95°F). We are unaware of any specific operational problems associated with these units.

Figure 3-10. WPCP digester HEX

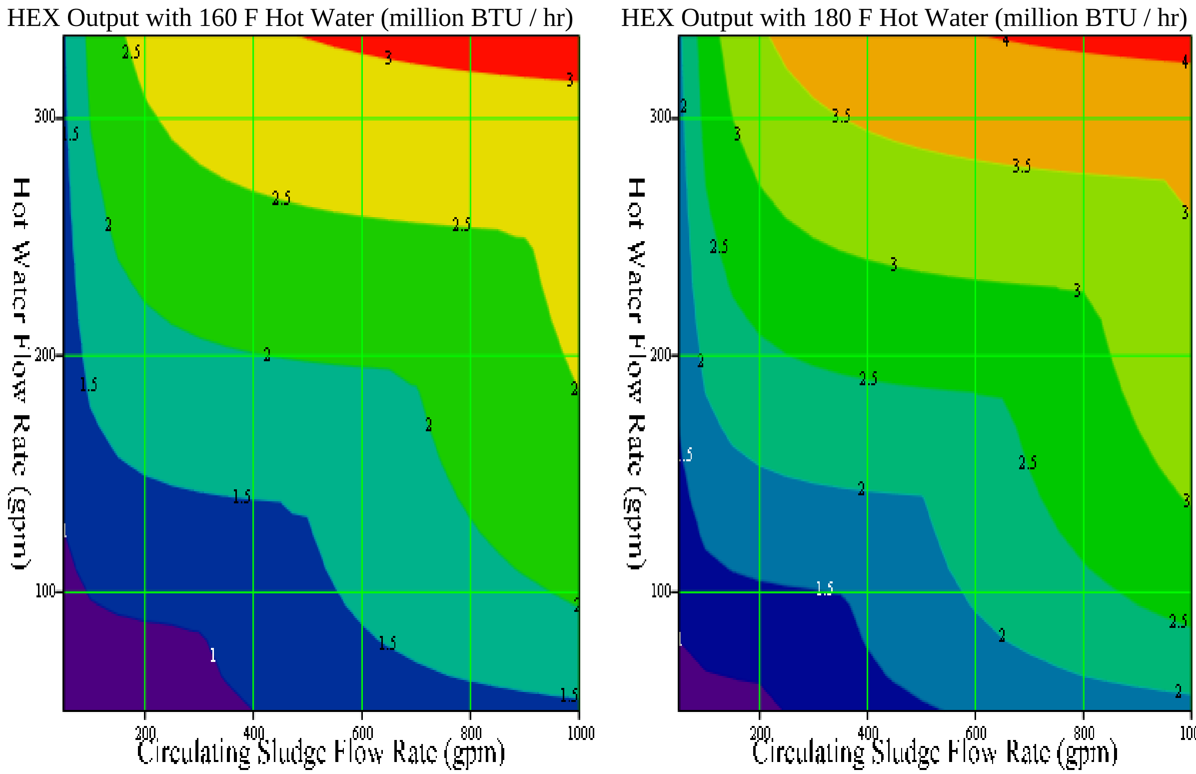

Figure 3-11. HEX Capacity Charts for 160°F and 180°F Hot Water
(incoming sludge 95°F) based on specified HEX capacity and equivalent HEX capacity calculation methodology.

3.5 Summary of Existing System Capacity Analysis

Operational data indicates that the digesters heating system may be deficient based upon our observations that digesters operate at seasonally fluctuating temperatures slightly lower than most mesophilic digestion operations. This can reduce volatile solids (VS) destruction and gas production (see TM 3.3). In addition, WPCP staff (field visit 10/30/2008 – Neil Metzger) indicated their concerns with the robustness of the digester heating system and identified the system as a high priority concern for consideration with digester system improvements.

The rated capacities of the various elements of the heating system appear to be adequate to properly heat the existing digesters. However, operational issues appear to be contributing to perceived overall deficiencies of the digesters heating system. As discussed in this TM, we believe improper hydraulic operation of the hydronic distribution system is the predominant contributor to weakness in the digesters heating system. These issues should be addressed with recommended improvements in order to more effectively transport and control heat delivery throughout the digester complex.

4. ESTIMATE OF FUTURE HEATING REQUIREMENTS

4.1 Planning Assumptions

This TM estimates a range of future heating requirements based upon a range of feed sludge solids concentrations from 3 percent to 8 percent, expanded from the 3.5 and 5.5 percent design points evaluated in TM 3.3 to test heating capabilities at an expanded range of solids concentrations. This range also encompasses candidate biosolids processing configurations (i.e. mesophilic, thermophilic, etc.) that are being contemplated by the Master Plan effort. This TM also adjusts individual digester heating requirements to account for the recommended future digester volume and load following upgrades (i.e. conversion to submerged fixed covers with greater individual digester volume than existing).

4.1.1 Solids Loading Sources

Solids loading sources are discussed in TM 3.3. The most significant scenario for analysis in this study is the combination of Primary Sludge (PS) and Thickened Waste Activated Sludge (TWAS) and Fats, Oil, and Grease (FOG) waste at 2030 maximum 2-week loading rate of 619,900 lb/day TS. The quantities of food waste are not estimated, however capacity available is estimated based on spare digester capacity that becomes available if higher solids concentrations are fed to a number of digesters originally sized for thinner sludge. Results in this analysis can be applied to that approach for accommodating food waste or other co-digestion substrates.

4.1.2 Process Configurations

Table 4-1 presents a range of candidate digestion process configurations that were shortlisted in TM 3.3 and are considered for this heating evaluation. These configurations are more completely described in TM 3.3. They are presented here as background for definition of possible heating scenarios upon which to make estimates of system heating requirements.

Table 4-1. Summary of Digestion Alternatives

Alternative	Sub-Alternative	Feed Sludge Concentration, percent TS
Mesophilic Digestion	Complete Mix	3.5
Mesophilic Digestion	Complete Mix	5.5
Cambi™(WAS Only)	Complete Mix	6.5
Cambi™ (Primary and WAS)	Complete Mix	9.5
Thermophilic Digestion	Complete Mix	5.5
Thermophilic Digestion	Series (Extended Thermophilic, TPAD, Batch Class A)	5.5
Preprocessing with Mesophilic Digestion	Many	5.5

Note: Modified from Table 6-2 in TM 3.3.

While there are several potential process configurations that could be pursued in the future, from a heating perspective, they lead to the two fundamental alternative heating system scenarios listed below.

- Single-stage, complete mix mesophilic digestion with raw sludge heat requirements distributed among all operating digesters fed in parallel.
- Multi-stage digestion with the first heated stage as higher temperature thermophilic digestion. This configuration requires that raw sludge heating be accomplished among only the number of digesters allocated to the first stage process or by an independent sludge pre-heating system upstream of the first stage digesters.

Mesophilic digestion is the most likely near term operating scenario and multi-stage thermophilic represents the worst case heating scenario. Heating estimates in this technical memorandum are presented in terms of these two heating system scenarios. The process configuration for the Cambi™ process is not considered here because that proprietary process would require its own 150 psi steam based heat distribution system. Consideration of that specialized system should be addressed if other factors lead to a selection of the Cambi™ process for future sludge operations. That process selection would still retain the need for a hot water hydronic system that would serve a smaller number of mesophilic digesters. TM 3.3 recommends that the digester rehabilitation project not design to accommodate the Cambi™ process.

Energy to provide the amount of heat required to achieve thermophilic digestion is sometimes mitigated with the installation and operation of digested sludge heat recovery systems. These systems transfer heat from hot sludge exiting the thermophilic vessels to cold sludge that is entering them. A decision to implement a sludge heat recovery system involves a significantly larger investment in sludge HEX equipment, sludge pumping equipment, and sludge transport piping. The additional equipment requires additional operations and maintenance investments as well. These costs must be offset by a return value in offset energy consumption costs. At many WPCPs, the heat that is potentially saved may already be generated in a combined heat and power system, and wasted if no alternative heat demand is available. The end result may be simply that more of the generated heat is wasted to effluent or atmosphere and little cost savings are realized.

Based upon our experience with thermophilic digestion projects, a sludge heat recovery system, depending on system and equipment choices, could recover anywhere from 50 percent to 90 percent of the additional heating requirements above that needed for mesophilic digestion. Figure 4-1 shows a conceptual heat balance schematic showing that conditions for full heat recovery with an intermediary heat exchange fluid are favorable. Direct sludge-to-sludge heat exchange for heat recovery is also a possibility, with specialized heat exchange equipment. Heat recovery systems will generally require that all raw feed sludge and thermophilically digested sludge are brought to a single location for exchange. This entails significant changes to the sludge distribution system. If a decision is made in the future to move to a biosolids processing configuration that includes staged thermophilic digestion, an additional analysis of the costs and benefits of a sludge heat recovery system should be made at that time.

For this analysis, thermophilic sludge heating requirements are presented assuming that no sludge heat recovery system is provided. This is a conservative assumption and achieves the objective of testing adequacy of heat supply under worst-case conditions. Whether heat recovery was provided or not, additional HEXs and appurtenant equipment would be required to migrate to thermophilic. Sufficient space is available adjacent to existing HEXs for this additional equipment and no modifications are being considered that would hinder or eliminate the potential for adding that equipment in the future. The rehabilitation final design should consider and allocate space for future thermophilic HEXs and potential additional heat distribution piping.

Choosing a thermophilic (or Cambi™) process would also require a future analysis of sludge cooling system options. Heat must be removed from the hotter sludges as they are introduced to downstream mesophilic stages or to dewatering or lagoon storage. In simplest form, this may involve installing a WPCP effluent distribution system or a chilled water distribution system to serve circulating sludge cooling HEXs at mesophilic digester locations. Cooling may be adequately accomplished by a heat recovery system discussed previously.

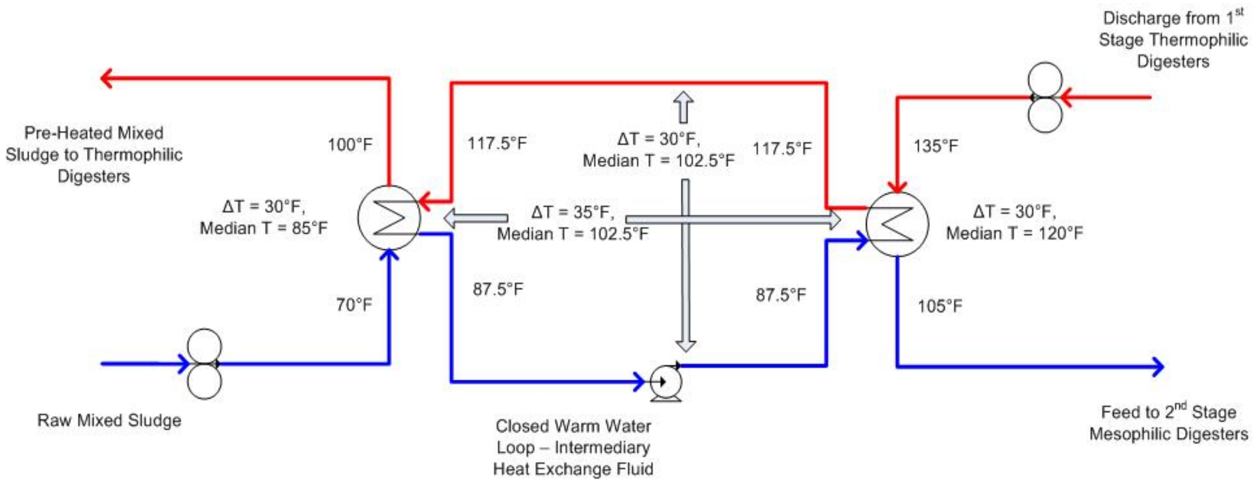

Figure 4-1. Conceptual sludge heat recovery schematic with simplified heat balance. Assume all fluids pumped at equal mass flow rate. Diagram illustrates that system conditions are favorable for virtual full recovery of excess thermophilic heat. Staged thermophilic digester system can be operated with virtually same heat source capacity as mesophilic digestion system.

4.1.3 Design Temperatures

This section defines the principal assumptions for temperatures that form the basis of estimating heat requirements.

4.1.3.1 Feed Sludge

For mesophilic digestion scenarios, raw feed sludge is assumed to be as cold as 65°F and must be heated to 100° F. For thermophilic digestion scenarios, raw feed sludge is assumed to be the same as for mesophilic scenarios and must be heated to 135°F.

4.1.3.2 Reactor Heat Transfer Loss Environment

The winter atmospheric design temperature is assumed to be 50°F. Based upon our calculations that consider vessel geometry, vessel materials of construction, process temperatures, soil temperatures, and atmospheric temperatures, estimated heat loss rate during coldest weather conditions for a digester vessel operating at mesophilic temperature is 895,000 BTU/hr. Estimated heat loss rate for a digester operating at thermophilic temperature is 1,520,000 BTU/hr.

4.1.3.3 Heat Exchange Fluid

As described above, existing WPCP operations are based upon low temperature water distribution as the means of heat distribution throughout the digesters complex. For estimating volumetric flow rates required for heat distribution system, a “delta T” of 40°F is assumed; this is the design temperature differential between HWS and hot water return in the distribution system. For mesophilic scenarios HWS at 180° F and HWR at 140° F are assumed. For thermophilic scenarios HWS at 200°F is assumed and HWR at 160° F are assumed.

For circulating sludge, a 10°F "delta T" is assumed for transferring heat into sludge, meaning that heated sludge cannot be heated to a temperature more than 10° F greater than the operating temperature of the digester vessel.

4.1.4 Vessel Configuration

The heating requirements for individual digesters will depend on the ultimate volume and load on that digester following upgrades. Final economic analysis of alternatives to upgrade digester covers has led to the recommendation to upgrade with a submerged fixed cover design with an active volume of 2.89 million gallons (see TM 4.2). Calculations and presentations of estimated load requirements have been adjusted in this TM to be reflective of individual digesters having an active volume of 2.89 million gallons each. (Note: The original draft version of this TM assumed existing digester active volume of 2.29 million gallons each.)

4.2 Estimated Requirements

This section presents estimates of required system capacities. Estimates are provided for both mesophilic digestion scenarios and the conservative scenario of thermophilic digestion without heat recovery.

4.2.1 Heat Production Requirements

Total maximum month heat production requirements are dictated by the solids concentration of the feed sludge, the hydraulic residence time (HRT) desired, and the digestion process scenario. Figure 4-2 presents the range of estimated total heat requirements for mesophilic digestion scenarios. The figure also indicates how HRT assumptions effect the number of digesters assumed to be in operation for determination of the heat production requirements. With more digesters in operation, heat loss from the digesters is increased.

For solids concentrations greater than 3 percent, the total heat production requirements appear to fall within the estimated range of potential heat production that may be expected by the available heat production operations at the WPCP. With thinner sludge, the maximum total heat requirements exceed the estimated potential recoverable heat from combined heat and power operations at the WPCP (43 million BTUs/hr, as described in Table 3-2). Meeting these peaks may require supplemental boiler operation for maintaining digester heat requirements. As discussed earlier, the future configuration of heat production sources is unknown, but is anticipated to be enhanced in the future as more gas is available for beneficial use.

Figure 4-3 presents total heat production requirements for thermophilic digestion scenarios without heat recovery from the sludge stream. With feed solids concentrations less than 6.5 percent, the total heat production requirements appear to exceed the limits of estimated potential heat production rates at the WPCP (43 million BTUs/hr, as described in Table 3-2). Additional boilers may be required if sludge heat recovery is not employed.

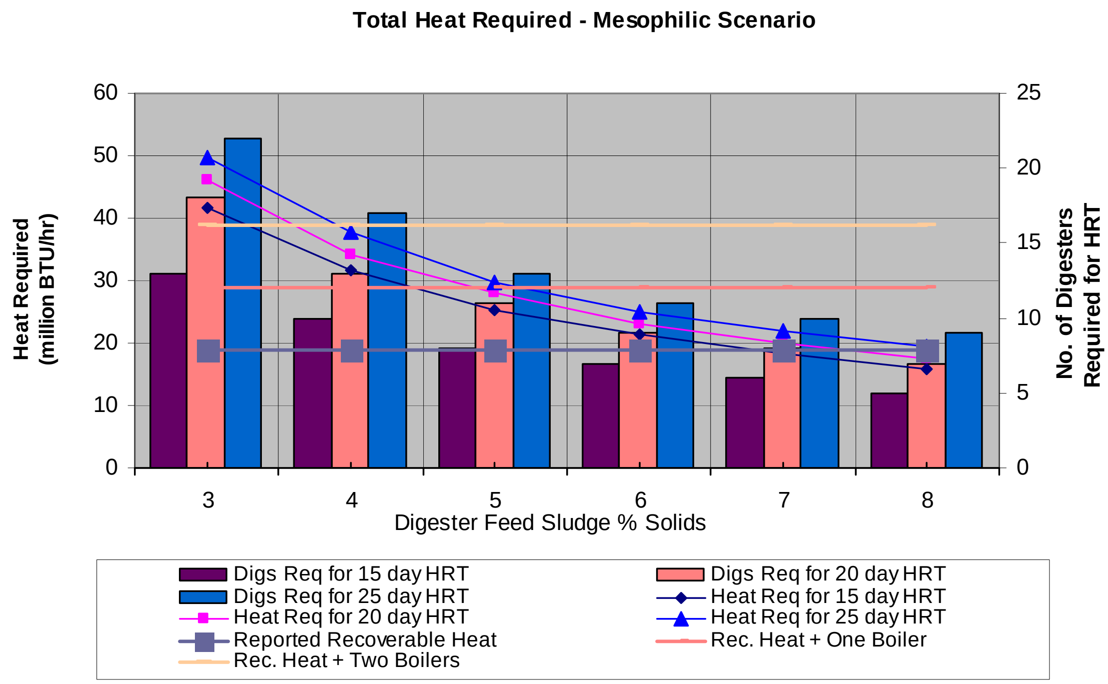

Figure 4-2. Total heat production requirements for mesophilic digestion scenarios. Also shown are estimated heat production capacities.

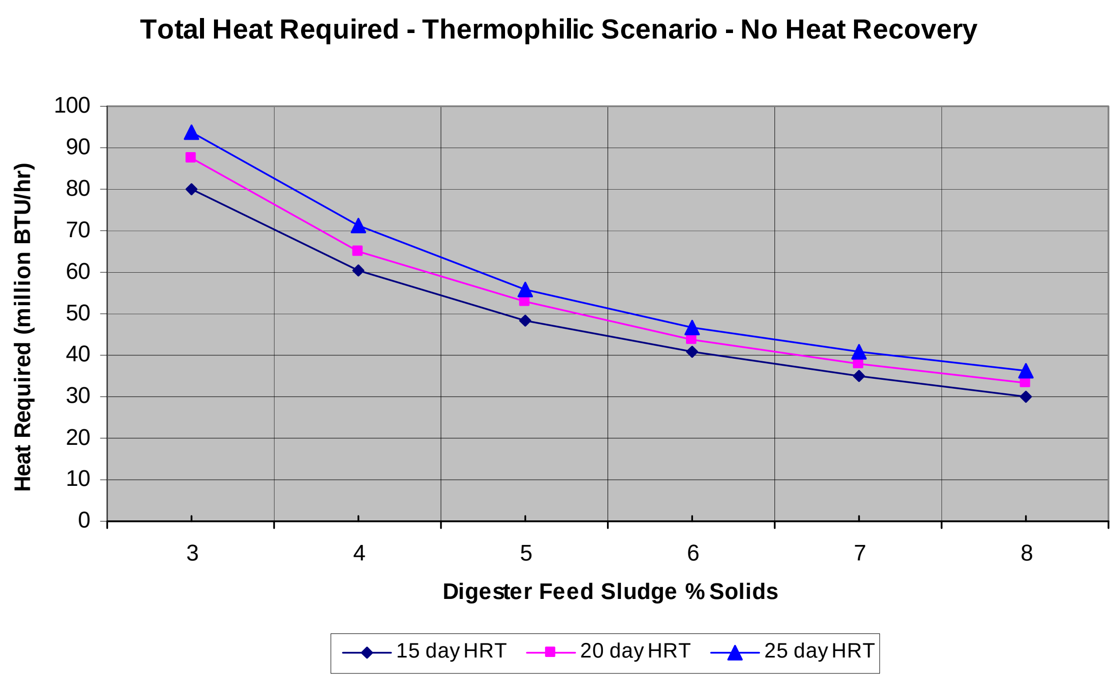

Figure 4-3. Estimated heat production requirements for thermophilic digestion scenarios.

4.3 Heat Distribution

Figure 4-4 estimates the total volumetric flow rate required for a circulating hot water system to transfer the estimated heat production requirements to digester HEX appliances for a mesophilic operating scenario. Seven existing hydronic loop distribution pumps are nominally sized at 435 gpm each are distributed between the Blower Building and Building 40 and, as such, may be short of requirements unless sludge is thickened to 5 percent or greater. It was previously discussed in this TM that those pumps are oversized with respect to system pressure requirements. Selection of replacement pumps should consider increase in volumetric capacity and reduction in pressure to more appropriately conform to future mesophilic scenario heat distribution requirements.

At 2,000 gpm, the flow velocities in existing 10-inch HWR and HWS pipelines would approach 10 feet per second. This is the upper limit of velocity that would be recommended for a network distribution system. This consideration is another driver for achieving higher digester feed solids concentrations in the biosolids processing configurations. Continued mesophilic operation at 3.5 percent solids would require and upgrade to the capacity of the hot water distribution system. However, mesophilic operation with a thicker feed sludge as is contemplated with co-thickening upgrades to the existing dissolved air flotation thickeners (DAFTs), no distribution system capacity upgrades would be required.

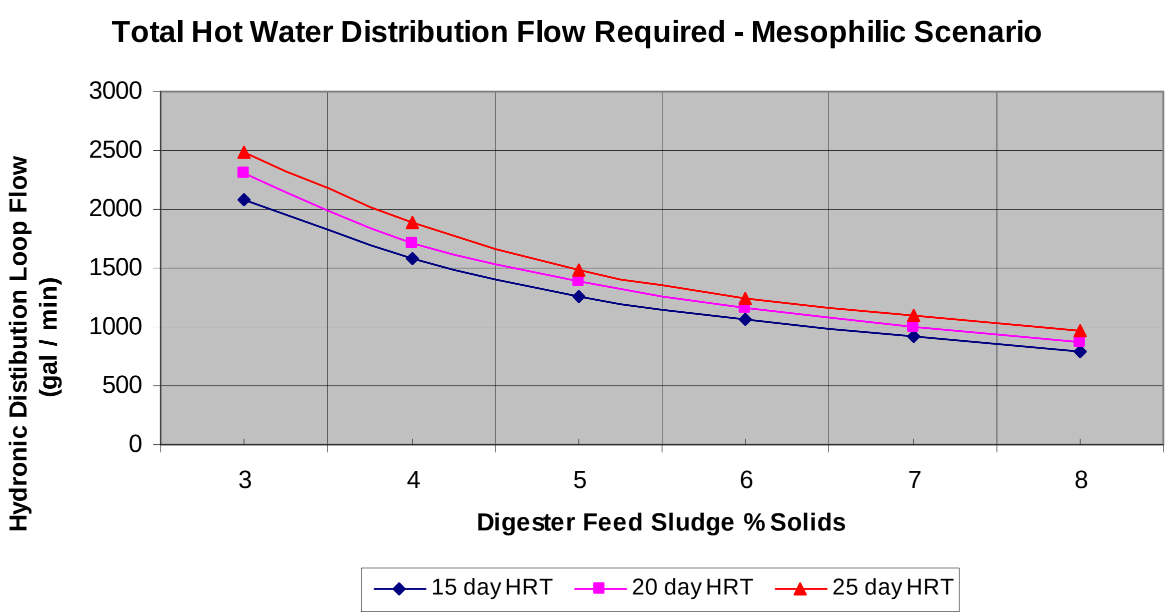

Figure 4-4. Total hot water distribution flow rate requirements for mesophilic digestion scenarios.

Figure 4-5 shows total hot water distribution flow requirements for thermophilic digestion scenarios. The figure indicates the desirability of using higher feed solids concentrations for thermophilic digestion scenarios. Operating below 7 percent feed solids would require some heat distribution capacity improvements. Some runs of the hydronic distribution system would require upsizing to operate at these distribution flow rates. An alternative means of heat distribution may be to use hotter water (temperatures greater than boiling with adequate pressure maintenance to prevent flashing) or to implement a steam distribution system.

Alternatively, a heat recovery system could be installed as discussed above. Review of alternative approaches to meeting thermophilic digestion scenario requirements should be conducted in a future evaluation if a decision is made to adopt a thermophilic process configuration.

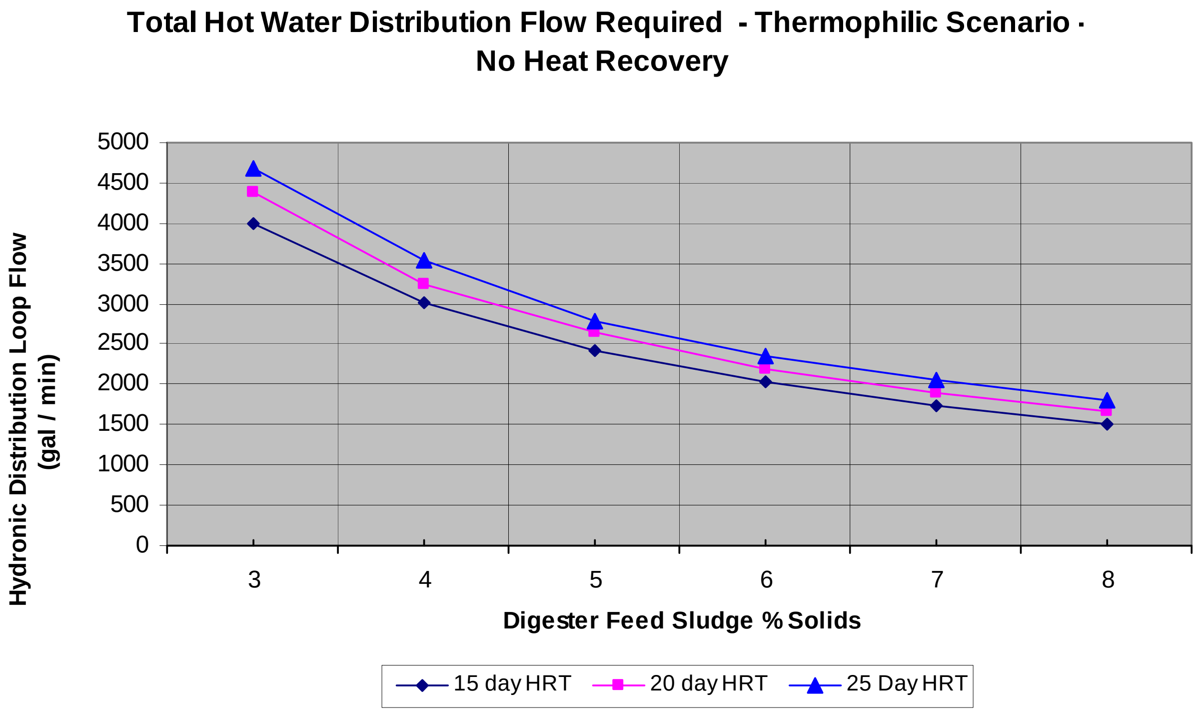

Figure 4-5. Total hot water distribution flow rate requirements for thermophilic digestion scenarios.

4.4 Heat Load Transfer

Each digester location should have a load circuit from the hydronic distribution system and a HEX to transfer an appropriate amount of heat from the distribution system into the associated digester. This allotment of heat includes a portion of the total raw sludge heating load, proportional to the amount of raw sludge loading allocated to the digester, and the amount of heat to offset radiation losses from the digester vessel.

Figure 4-6 indicates the estimated amount of heat for each 110-foot diameter digester with an active volume of 2.89 million gallons following an upgrade to a submerged fixed cover, operating in a mesophilic digestion scenario. The negligible effects of differing HRTs and of numbers of operating digesters are also indicated. Based on theoretical calculations, these heat transfer requirements appear to be close to the rated capacity of the existing HEXs when operated with 180°F water, as opposed to the 160°F water limit that has generally been used by the plant to date. Pilot testing of the capacity of the existing HEXs with higher hot water temperatures and/or increased sludge flow rates is recommended to confirm the capacity of the existing HEXs at higher water temperatures. Additional (or replaced) HEXs may be required for continued operation in the mesophilic mode when digester vessels are upgraded to submerged fixed cover design if actual HEX performance is less than theoretical or the plant cannot maintain 180°F during design loading conditions .

Figure 4-7 indicates the volumetric flow rate for hot water in an individual load circuit necessary to provide heat for the mesophilic digestion scenarios. These rates appear reasonably matched to the capacity of the existing load circuit pump and piping configurations, presuming that automatic flow balancing modifications, as discussed previously in this TM, are installed.

Figure 4-8 presents estimated per digester heat requirements for digesters associated with the first stage of thermophilic digestion in a thermophilic digestion scenario. The requirements are dramatically higher because the raw sludge heating load is distributed between fewer digesters that are allocated to the first stage of the multi-staged process. Accommodating these requirements would require a quadrupling of the HEX equipment, load circuit equipment, and circulating sludge pumping equipment at each of the first stage thermophilic digesters. Alternatively, a centrally located raw sludge pre-heating facility could be constructed upstream of the digesters, either as a sludge heat recovery or direct heating system. In this case, existing configurations of HEXs at the digesters would be sufficient to offset radiation losses from the thermophilic vessels.

Figure 4-9 describes corresponding hot water flow rates that would be required at each first stage thermophilic digester load circuit in a thermophilic digestion scenario. As indicated above, delivering these flows to HEX units at the digester locations would require additional load circuit capacity.

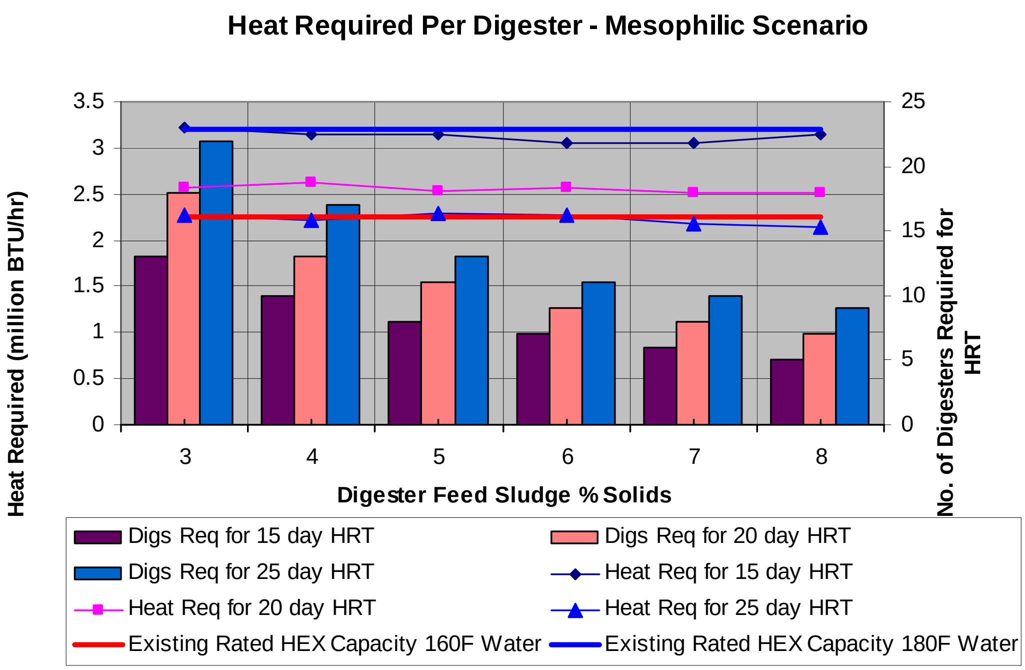

Figure 4-6. Estimated heat required per digester for mesophilic digestion scenarios

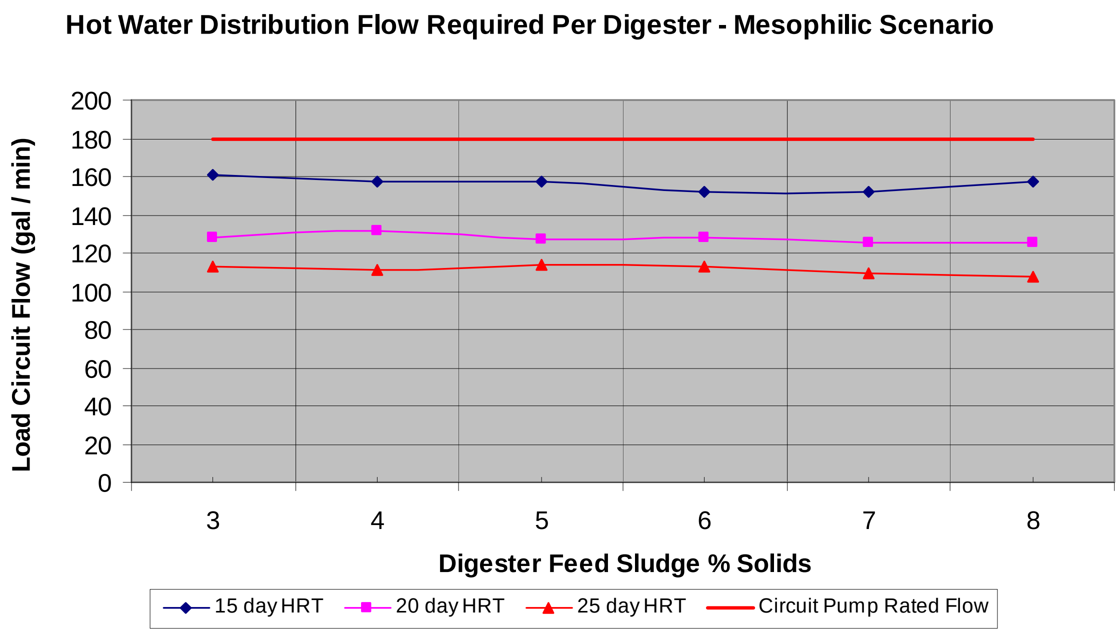

Figure 4-7. Estimated hot water flow required for individual load circuit in mesophilic digestion scenario.

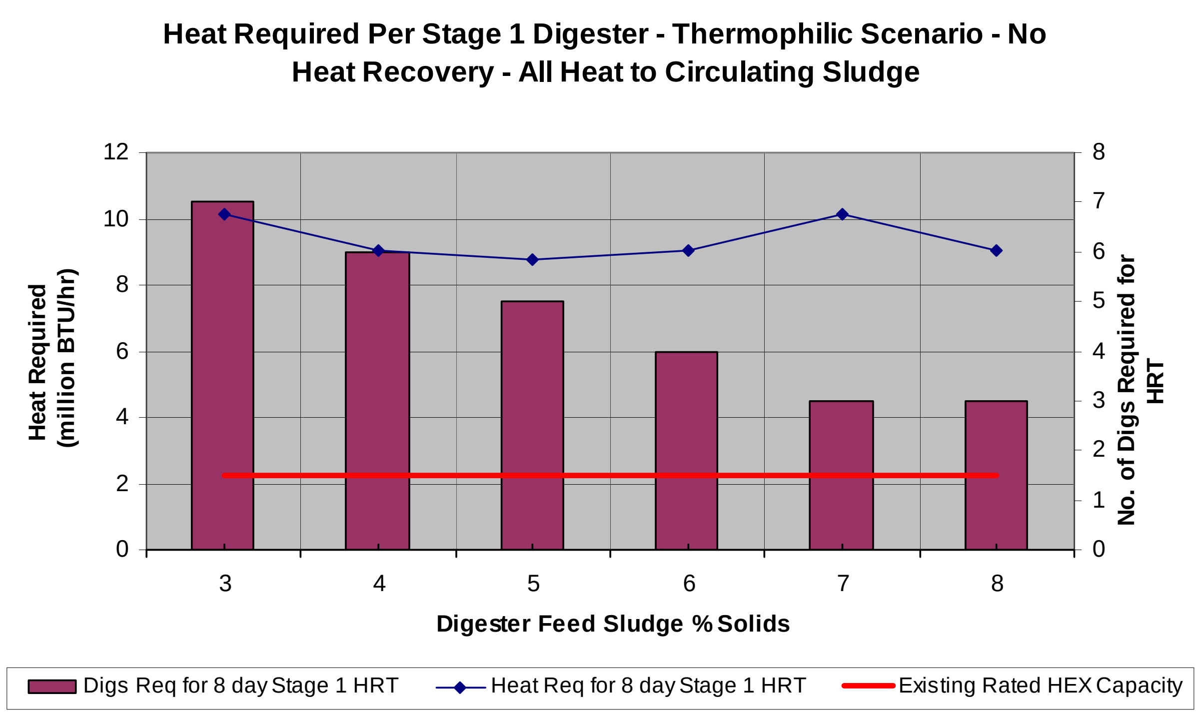

Figure 4-8. Estimated per digester heating requirements for first stage thermophilic digesters.

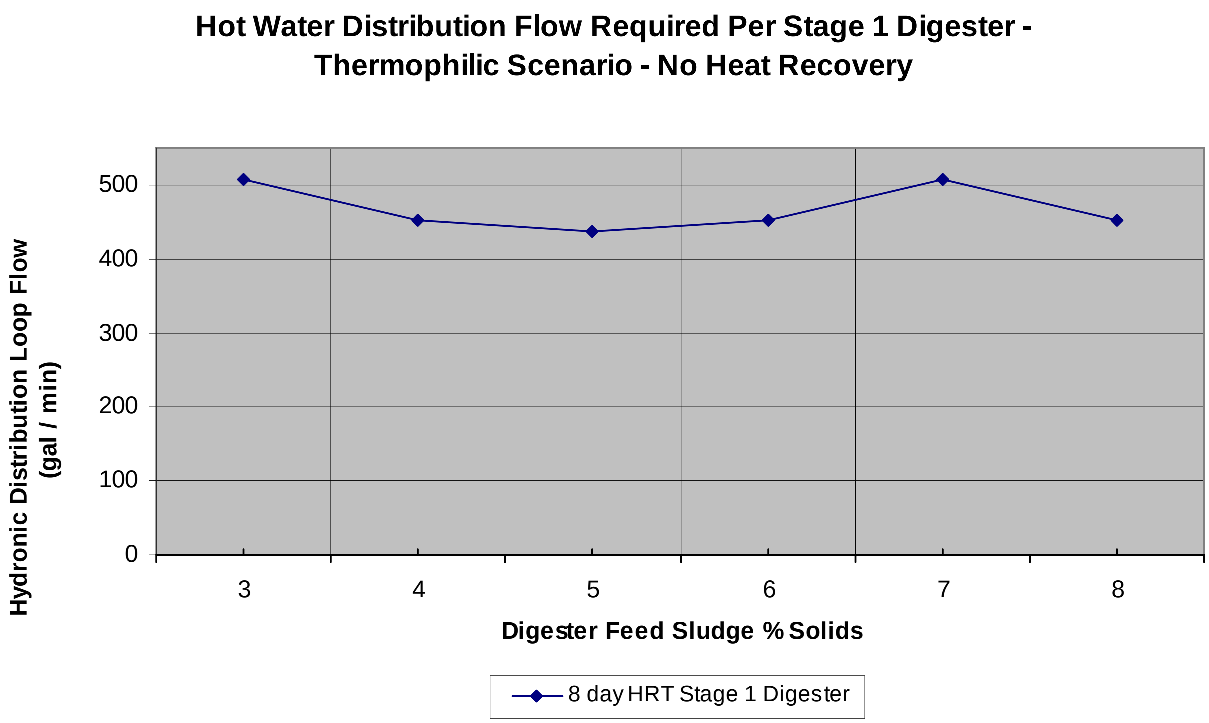

Figure 4-9. Estimated hot water flow required for individual load circuit in thermophilic digestion scenario.

5. HEAT DISTRIBUTION AND HEAT EXCHANGER EQUIPMENT ALTERNATIVES

5.1 Heat Production

The WPCP's substantial investment in combined heat and power generation equipment is such that there appears to be adequate heat production capacity for mesophilic digestion scenarios through the end of the planning period (year 2030).

If a decision is made to pursue thermophilic digestion alternatives, heat production capacity may require supplementation if there is no investment in recovery of heat from thermophilic digested sludge. If migration to thermophilic operation is contemplated in the future, an additional optimization study should be conducted to evaluate the tradeoff between taxing of heat production capacity versus investment in equipment to recover heat from thermophilic digested sludge.

5.2 Heat Distribution

A major conclusion of this technical memorandum is that the hydronic heat distribution system at the WPCP is operating impaired and modifications to the system should be made to improve the mesophilic digestion scenario operations. The principal modifications recommended are to:

- Install automatic flow control valves at each load circuit to create an automatic flow balancing system for the hydronic distribution loop;
- Replace the 3/4 inch flow restrictions in the common pipes at each load circuit with a 4-inch diameter pipe spool; and
- Replace the hydronic loop distribution pumps with units that are more closely matched to the pressure, flow, and heat delivery requirements of the networked system.

5.2.1 Mesophilic Scenario

Table 5-1 describes alternative approaches for achieving the goals listed above. For comparison to the estimated costs shown in Table 5-1, Table 5-2 provides an estimate of economic benefits associated with the improvements if they result in constant temperature maintenance and if constant temperature maintenance yields an improvement in digester volatile solids reduction by 0.5 volatile solids reduction (VSR) percent removal points. This is a reasonable assumption based on process modeling conducted and reported in TM 3.3B (Attachment B to TM 3.3). For almost every case, the benefits are significantly greater than the probable cost to execute these simple improvements.

Table 5-1. Alternative Approaches for Mesophilic Scenario Hydronic Distribution System Improvements			
Alternative	Description	Advantages	Disadvantages
1 - Good	• Pilot operated flow controller valves at each load circuit. • Constant flow-rate hydronic loop distribution pumps. • Estimated Cost - $15,000 per digester plus $100,000 for hydronic distribution pumps.	• Lowest cost. • Least amount of operator attention	• Little operational control for trimming distribution flow energy requirements in periods of lower heating demand. • Special effort required to set flow rate control valves operating point.
2 - Better	• SCADA operated flow controller valves with remote flow rate monitoring and control at each load circuit. • Constant flow-rate hydronic loop distribution pumps with SCADA monitoring of flow rate delivery. • Estimated Cost - $30,000 per digester plus $125,000 for hydronic distribution pumps.	• Real time ability to confirm flow balancing in the hydronic loop distribution system. • Limited ability to trim distribution flows within the acceptable operating range of the constant speed pumps.	• Higher cost. • Additional operator attention. • Higher maintenance valve actuators.
3 - Best	• SCADA operated flow controller valves with remote flow rate monitoring and control at each load circuit. • Variable flow-rate hydronic loop distribution pumps with SCADA based remote flow-rate monitoring and pump speed control. • Estimated Cost - $30,000 per digester plus $270,000 for hydronic distribution pumps.	• High level of system control and status monitoring. • Highest level of trim capability for optimizing distribution flow requirements to variable heating requirements.	• Highest cost • Highest complexity and maintenance.

Table 5-2. Simple Benefits if Hydronic Improvements Increase VSR by 0.5% Points			
	Design Year Load Case		
Alternative	No Import Materials	Design Import Materials	Maximum Import Materials
Additional Gas Production (cu. ft. / day)	23,000 – 24,000	56,000 – 57,000	62,000 – 67,000
Benefit of Additional Gas ($ / year)	$ 38,750	$93,000	$ 106,500
Benefit of Hydronic Pump Energy Savings ($ / year)	$27,500	$27,500	$27,500
Total Benefits	$66,250	$120,500	$134,500
30 Year Net Present Value of Benefits	$ 1,485,000	$ 2,700,000	$ 3,000,000

Notes:
1. Load cases described in TM 3.3
2. Gas benefits based on $ 0.70 100 cu. ft.
3. NPV – 2% Net Discount Rate.
4. See Section 2.1.2 for estimation of pump energy savings

5.2.2 Thermophilic Scenario

Thermophilic digestion scenarios would require additional upgrades and extensions of the hydronic distribution system. Table 5-3 describes how alternative thermophilic scenarios impact requirements to upgrade the heat distribution systems at the WPCP.

The descriptions in Table 5-3 are intended to provide a broad overview of the general approaches available for accomplishing staged thermophilic sludge digestion heating systems. The capital investments for achieving heat recovery are generally significant and ultimately need to be weighed against the competing costs of additional heating capacity and heat maintenance. A cost benefit analysis of that question is more appropriately evaluated after a decision to build staged thermophilic processes is made, based upon other considerations.

Table 5-3. Alternative Approaches for Thermophilic Scenario Hydronic Distribution System Improvements

Alternative	Description	Advantages	Disadvantages
1 – No Thermophilic Sludge Heat Recovery – Heat Raw Sludge via Circulating Sludge Loops in Thermophilic Digesters	• Significantly higher capacity heat distribution flow capacity. • Load circuits at thermophilic digesters upgraded to handle higher flow rates. • Second heat distribution system for sludge cooling at mesophilic digesters. Direct flow WPCP effluent or chilled water loop.	• All heat is transferred to circulating sludge loop with superior flow characteristics in HEX.	• Significant piping system upgrades required at each digester.
2 – No Thermophilic Sludge Heat Recovery – Pre-Heat Raw Sludge with HEXs ahead of Digesters	• Existing hydronic loop distribution system (with modifications discussed in Table 4-1) serves thermophilic digesters to make up for vessel radiation. • Second heat distribution system extension to location of pre-heating HEXs • Third heat distribution system for sludge cooling at mesophilic digesters. Direct flow from WPCP effluent or chilled water loop.	• Fewer piping upgrades required at existing digester locations.	• Does not avoid need for heat network wide heat distribution system to support sludge cooling. • Additional operation and maintenance requirements to support extension of heat distribution system for new sludge pre-heat HEX center.
3 – Thermophilic Sludge Heat Recovery	• Existing hydronic loop distribution system (with modifications discussed in Table 4-1) serves all digesters to make up for vessel radiation and supplemental raw sludge heating. • Sludge heat recovery center houses HEXs system that transfers heat from thermophilic sludge to pre-heat raw sludge. • Extension of heat distribution system to sludge heat recovery center in order to provide supplemental sludge pre-heating.	• Minimizes heat distribution system upgrades required at existing digester locations.	• Higher cost and risk for thermophilic sludge heat recovery heat distribution system.

5.3 Heat Exchangers and Heat Load Transfer

As discussed in Section 4.4 above, for mesophilic digestion scenarios with conversion to submerged fixed covers having higher active liquid volume per digester than existing digesters, the existing concentric tube heat exchangers (HEXs) appear to be marginally adequate under 15 day HRT load conditions (see Figure 4.6). Pilot testing of the capacity of the existing HEXs with higher hot water temperatures and/or increased sludge flow rates is recommended to confirm the capacity of the existing HEXs at higher water temperatures. Additional (or replaced) HEXs may be required for continued operation in the mesophilic mode when digester vessels are upgraded to submerged fixed cover design if actual HEX performance is less than theoretical or the plant cannot maintain 180°F during design loading conditions

For thermophilic digestion scenarios, new or additional HEXs will be required. The configuration and arrangements of new HEX units will be dependent on subsequent decisions to be made regarding sludge heat recovery possibilities and whether or not raw sludge heating is accomplished with pre-heating exchangers or with circulating sludge HEXs at each digester location.

6. DIGESTER FEED AND CIRCULATION PIPING SYSTEMS

6.1 Digester Feed

Currently, digester feed is accomplished by routing discharge from primary sludge pumps and thickened waste activated sludge pumps, in a common blended sludge piping (2–pipe network), to individual digesters on a timed sequential basis, one or two digesters at a time. Feeding more than one or two digesters at a time is not practical because the existing system has no means to control the division of flow received by simultaneously fed digesters. This feed method is somewhat suboptimal with respect to digestion performance, because the sludge quality to an individual digester may be variable and the load allocated to individual digesters can be variable, both resulting in uneven digestion rates and uneven and suboptimal gas production rates.

Figure 6-1 describes an optimal continuous digester feed system. It includes a blended sludge storage tank system to provide a more consistent quality of blended sludge throughout the operating day and the ability to blend in and pace the application rate of trucked-in FOG or other co-digestion wastes. The system would also include a blended sludge distribution system that could divide and distribute blended sludge flow rates equally (or in proper proportion to individual digester volume) to each operating digester in a given stage. This method of distribution and sludge application allows each digester to achieve a more steady state biological condition, optimizing sludge stabilization and digester gas production.

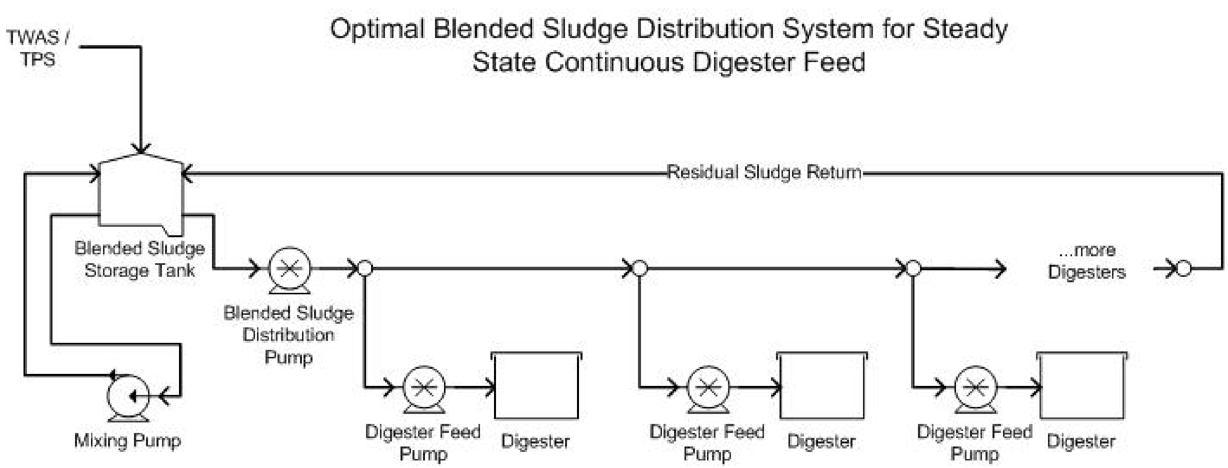

Figure 6-1. Schematic of continuous feed blended sludge distribution system

Figure 6-2 indicates the range of maximum month total sludge flow rates for various solids concentrations. In the existing sequential feed system, each digester would be fed approximately 750 to 1,500 gpm for a total of approximately 1 to 2 hours per day.

Figure 6-3 indicates the range of individual digester sludge feed rates that would be realized with a continuous feed system in a mesophilic scenario. Figure 6-4 illustrates the range of individual digester feed rates for stage 1 digesters in a thermophilic scenario. These rates would vary over a limited range on a 24/7 basis, allowing each digester to achieve steady state stabilization rates and gas production rates.

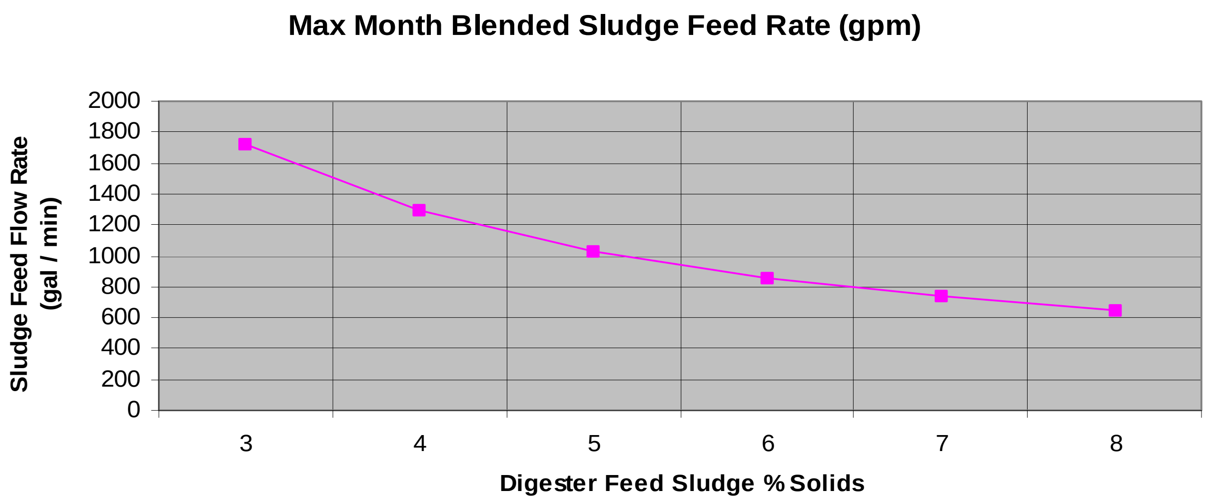

Figure 6-2. Estimated blended sludge total digester feed flow rates for mesophilic digestion scenarios.

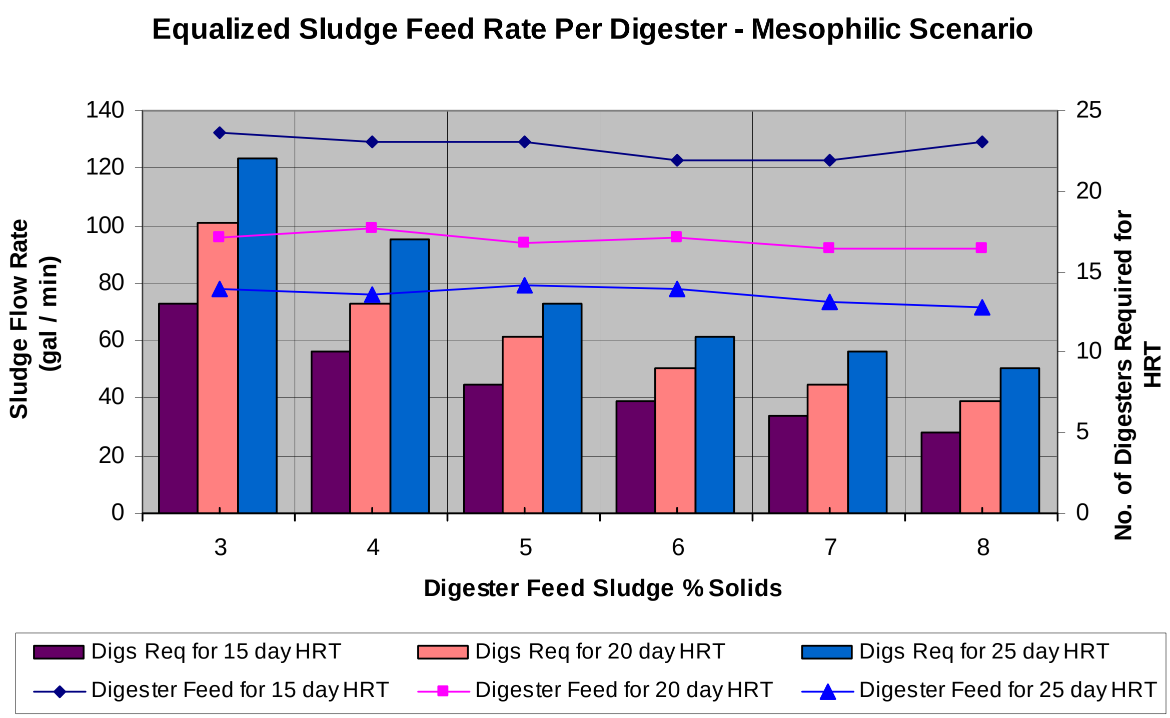

Figure 6-3. Estimated blended sludge feed rate per digester in mesophilic scenarios.

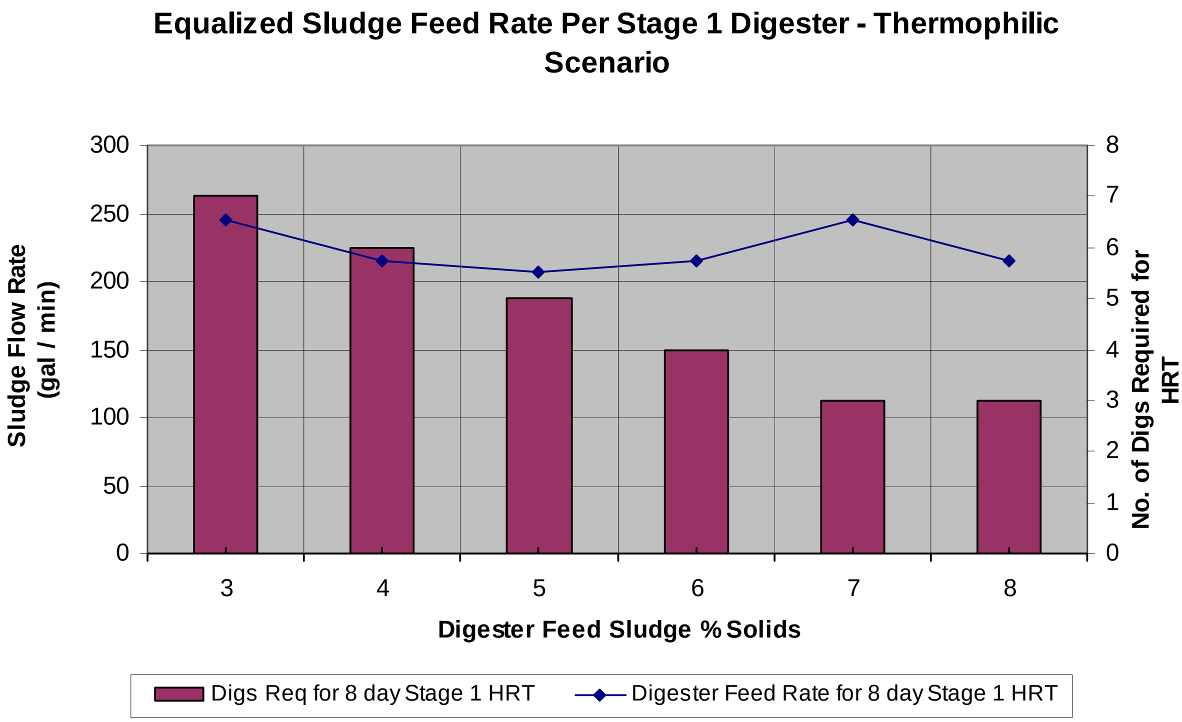

Figure 6-4. Estimated blended sludge feed rate per digester in thermophilic scenarios.

The blended sludge function can be accomplished by a blended sludge storage tank as shown above. Blending can also be accomplished by operation of sludge wasting from primary sedimentation and the secondary treatment system in a uniform manner that dampens load peaks throughout the day in conjunction with blending prior to potential co-thickening of the two sludge streams (see TM 7.1). Alternatively, a primary sludge equalization tank could be constructed prior to the co-thickening DAFTs to help relieve the primary sedimentation tanks from having to store primary solids prior to blending with secondary solids. Secondary solids are currently wasted relatively constantly throughout the day through automatic SRT control, so further pre-thickening storage of WAS to even out loads is not required. In addition, DAFT skimmer speed control, VFD speed control of feed pumps, and TSS meters can all be used to help even out feed rates. The optimum blending system will be determined during detailed design when the full compliment of project modifications is known. Continuous feeding will require dedicated sludge feed pumps for each digester.

We recommend implementing this type of feed system in order to optimize the overall digestion process. The estimated cost for providing two digester feed pumps at each digester is approximately $225,000 per digester. Further analysis during detailed design may identify other options for achieving continuous feed goals at lower cost.

6.2 Circulating Sludge System

Circulating sludge systems are required to convey heat into the digester vessels. Many times they are also a process piping location where raw sludge can be added to the digester vessel in a manner that quickly mixes the incoming flow with the heated contents of the digester vessel. The flow rate for circulating sludge is dictated by the amount of heat needing to be delivered to the digester and the allowable temperature rise, above digester temperature, thought reasonable for the circulating sludge stream. Figure 6-5 indicates estimated circulating sludge flow rates for the mesophilic digestion scenario. The figure indicates that current equipment capacity is sufficient for mesophilic operations.

Figure 6-6 indicates that thermophilic digestion scenarios will require an increase in circulation sludge capacity for first stage digesters that are used to heat raw sludge. As discussed previously, sludge heat recovery systems or upstream heating of raw sludge can significantly mitigate the need for capacity improvements at the digester locations.

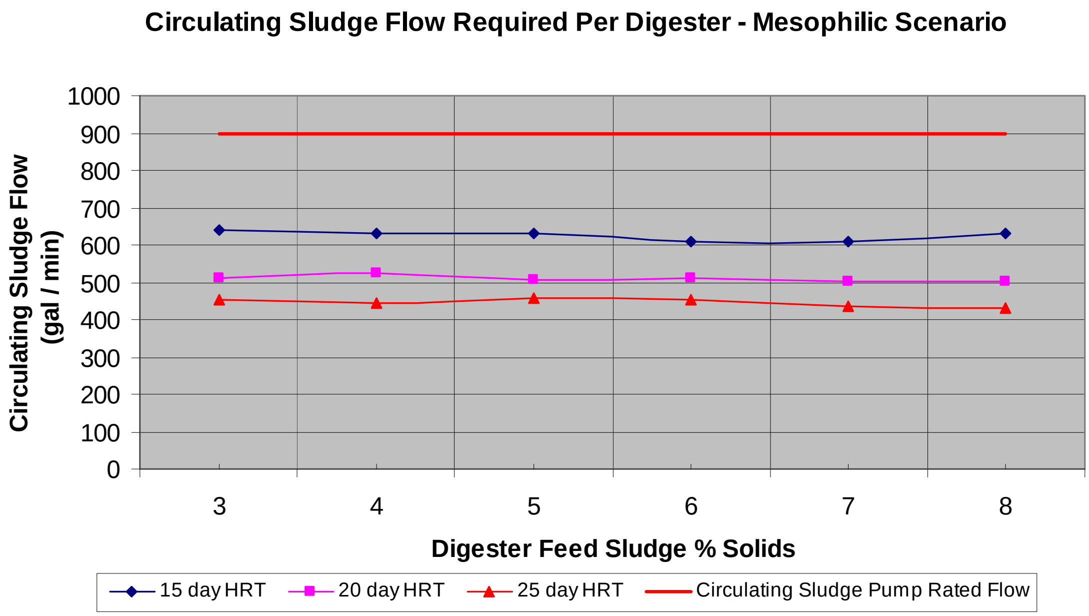

Figure 6-5. Circulating sludge flow requirements for mesophilic scenarios.

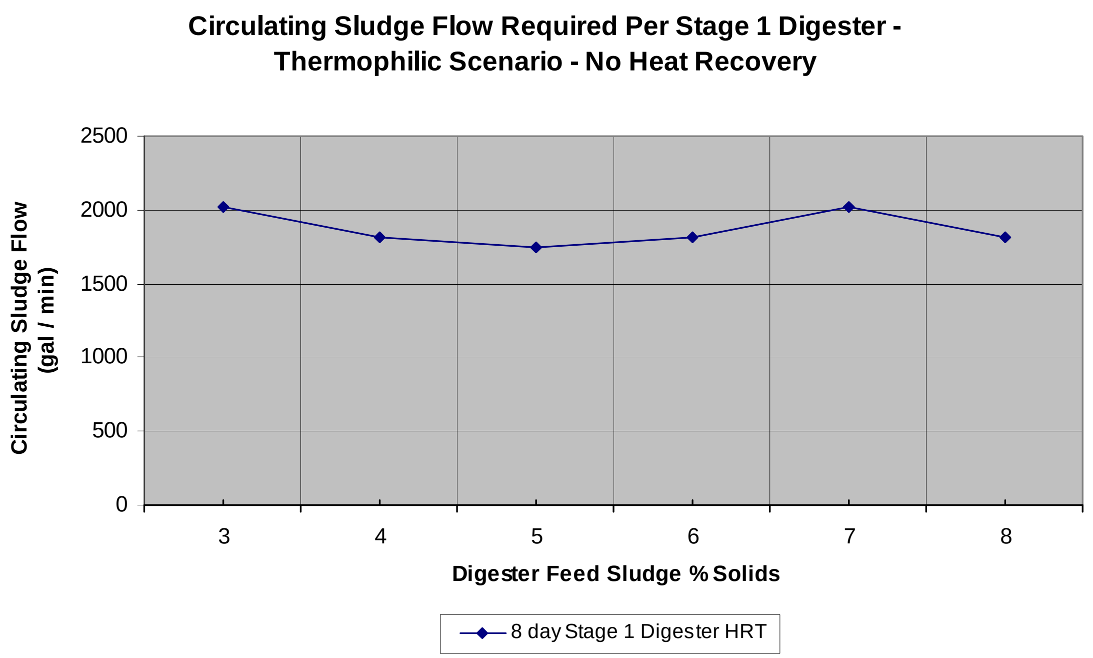

Figure 6-6. Circulating sludge flow required per stage 1 digester for thermophilic digestion scenarios.

6.3 Withdrawal and Drainage

Digester withdrawal and drainage is accommodated at several locations where digester transfer pumps are dedicated to serving a group of digesters. These pumps transfer digested sludge to the Digested Sludge Export Pump Station. We were not advised of any deficiencies in the digested sludge transfer pumps. WPCP staff did indicate that struvite accumulations in piping downstream of the Digested Sludge Export Pump Station caused deterioration of pumping capacity and that there was interest in a parallel pipeline to allow maintenance and to increase robustness of the process function. Recommendations on struvite control are discussed in TM 4.6. Alternatives for chemically controlling struvite are recommended. However if these alternatives do not prove cost effective in pilot testing, piping modifications are recommended for future upgrades.

If the WPCP installs the digester feed system recommended in this TM, there will have to be appropriate examination of the coordinated function of the digester withdrawal pumps to ensure that digester contents are managed without vessel overflows.

7. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

- The existing hydronic loop system that delivers heat exchange fluid (hot water) to the digesters operates in a hydraulically imbalanced manner. The hot water system does not provide the same heat to all digesters.
- Hydraulic imbalance causes difficulties in balancing heat delivery to individual digesters and precludes proper operation of the three-way control valves at each digester heat load circuit. Digester temperature is different between digesters.
- Installation of individual flow controllers at each digester load circuit are recommended to provide for automatic balancing of the hydronic system.
- Removal of flow restriction orifices in the "common" pipes of each load circuit is recommended.
- Continued mesophilic operation at 3.5 percent solids would require an upgrade to the capacity of the hot water distribution system. However, with mesophilic operation with a thicker feed sludge as is contemplated with co-thickening upgrades to the existing DAFTs, no distribution system capacity upgrades would be required.
- Hydronic loop distribution pumps are oversized – pressure is too high. Replacement of the three hydronic loop system distribution pumps is recommended to more closely match the pump pressure output with the pressure requirements of the hydronic distribution system. This replacement would result in overall energy savings for operation of the heating system.
- VSR improvement can be expected to pay for the above recommended low-cost heating system upgrades.
- Existing HEXs are in good condition and are a good and appropriate design.
- HEX capacity can be increased by increasing hot water temperatures.
- For mesophilic digestion with co-thickening, HWS and HEXs are marginally sufficient to serve future conditions at design loads. With increased vessel volumes with upgrades to submerged fixed covers, pilot testing of HEX capacity should be conducted with higher hot water temperatures and/or increased circulating sludge flow rates to confirm the capacity of the existing HEXs at higher water temperatures. Additional (or replaced) HEXs may be required for continued operation in the mesophilic mode when digester vessels are upgraded to submerged fixed cover design if actual HEX performance is less than theoretical or the plant cannot maintain 180°F during design loading conditions.
- Future requirements for heat production and heat transfer capacities will be strongly influenced by the future choice of digestion process configuration. A future move to staged thermophilic operation would require improvements to the overall heat production and distribution capacity at the WPCP and to the local HEX equipment for the specific digester vessels dedicated to thermophilic operation. The rehabilitation final design should consider and allocate space for future thermophilic HEXs, heat recovery HEXs, and potential additional heat distribution piping.
- Implementation of a continuous-feed, blended-sludge distribution system is recommended to optimize overall digestion performance and to produce a more consistent and robust rate of digester gas delivery to energy recovery systems. The blended sludge function can be accomplished by operation of sludge wasting from primary sedimentation and the secondary treatment systems in a uniform manner to dampen diurnal loads in conjunction with blending prior to potential co-thickening of the two sludge streams (see TM 7.1). Other control features such as DAFT skimmer speed control, VFDs on feed pumps, and TSS meters can be incorporated to help optimize and select the optimum continuous feed option. Dedicated sludge feed pumps for each digester for continuous feeding would require at an estimated cost of approximately $225,000 per digester. Other options should be explored during detailed design.

8. REFERENCES

CDM Engineers, May 28, 2009. Heat Balance Study Technical Memorandum.

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