

Fort Yukon District Heating Plant Final Design Process

35 Percent Report

Completed by: Alaska Wood Energy Associates

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Section 1: Executive Summary

1.1 Goals and Objectives

The objective of this interim 35 percent report is to document the progress and findings at this stage of the project. The scope of the project is the final design of a (primarily) biomass-fired district heating plant (DH Plant) for Fort Yukon, Alaska. The proposed DH plant will utilize heat recovered from co-located engine generators which provide power to the village, energy from the surrounding wood resources, and some supplemental oil heat. The entire process includes both an investment grade feasibility study and a final design for the plant.

At 35 percent, the feasibility study is 95 percent complete. The study is complete based on current knowledge. Additional site work in the village and as well additional information that comes to light as the design is finalized is expected to result in minor changes to the savings and/or cost projections.

To date, design has advanced primarily as required to support the study. The design at the 35 percent point is characterized as schematic level design. Examples of the design work to date are scattered through the text and the appendices.

The work on this project is being done by a team, Alaska Wood Energy Associates. This team consists of people from a number of different companies, representing various skill and knowledge sets. The feasibility study is being performed by Greg Koontz of efour, PLLC, Seattle, WA. Overall design responsibility integrating the biomass and diesel power plants lies with Steve Stassel of AE&E, located in Anchorage. Steve has designed and overseen the installation of numerous power plants, tank farms, and heat recovery systems throughout rural and bush Alaska. Greg Koontz will also provide design services specific to the DH Plant.

Obviously, a primary concern for any biomass fired plant is availability of the wood resources. This issue is the responsibility of Bill Wall of Sustainability, Inc. The means and methods of procuring the wood and processing it have been document extensively elsewhere. For that reason, this report does not address supply, only storage and material handling.

The objective for the team at this point is to use the study to choose a path forward into final design and construction. This report documents the feasibility study and design to date, and the path that will be followed moving forward to final design.

1.2 Project Scale

In order to be successful, a DH Plant must achieve a certain economy of scale. The capital costs involved are quite large, and so the savings to the village must be on the same scale in order to make economic sense.

In Fort Yukon, many of the largest buildings in the village are clustered together, most of them on the same street. One of the primary cost elements in a DH Plant is the distribution piping, so the most economical approach is to serve the largest, most tightly clustered buildings. However, this strategy may not completely support future village plans, and may exclude some of the more significant buildings within the village. For that reason, the study looked at five different DH Plant scenarios for Fort Yukon. The five plants are labeled Base, Expanded 1 (Exp 1), Expanded 2 (Exp 2), Maximum 1 (Max 1), and Maximum 2 (Max 2). Maps of the village showing the included buildings and proposed piping routes for all five Plants can be found in Appendix D.

Figure 1 below shows the buildings which were included in the study. In addition to the buildings, there is one heating load that is not associated with a building. Because the soil temperatures in Fort Yukon are low, the village heats the domestic water system enough to ensure it does not

freeze. This system has supply and return piping. The heat is currently injected into the system at the pump house. This building is a significant distance from the main village buildings – so far that it is not possible to serve this heating load from the DH Plant load economically. The cost of the piping and the associated heat loss from the piping preclude serving the pump house directly. However, we believe we can intercept the domestic water return piping where it runs through our service area. Injecting heat into the return water means that when it gets to the pump house, it is ideally already at setpoint temperature, so the pump house boilers (oil-fired) simply do not run.

Additional field work in the village will be needed to determine exactly how this is achieved. Currently, the study includes this heat load. However, the model is constructed in such a way that the load can easily be “toggled off” (see Section 3 for more information on the model). In Figure 1, this load is labeled “City DHW Load”. Figure 1 not only shows all of the buildings considered, it indicates which buildings are included in each of the five Plant configurations.

Buildings included	On	Base	Exp 1	Exp 2	Max 1	Max 2
1 School	1	1	1	1	1	1
2 Gym	1	1	1	1	1	1
3 Store	1	1	1	1	1	1
4 Post Office	1	1	1	1	1	1
5 CATG Main Office	1	1	1	1	1	1
6 State Building	1	1	1	1	1	1
7 Shop (adj School)	1	1	1	1	1	1
8 District Office	1	1	1	1	1	1
9 Church	1	1	1	1	1	1
10 Yukon Flats	1	1	1	1	1	1
11 City Building	1		1		1	1
12 New CATG Clinic	1		1		1	1
13 Tribal Offices	1			1	1	1
14 Water Treat	1			1	1	1
15 Old CATG Clinic	1					1
16 City DHW Load	1	1	1	1	1	1
include Heat Recovery	1					

Figure 1, buildings included in study

1.3 Resource Assumptions

In Section 4, a sensitivity analysis shows how the project financials vary as the cost of the inputs vary. In order to compare all the Plants on an equal basis, some base level assumptions about these costs had to be made and used in the performance / financial model. The assumptions shown in Figure 2 are based on current of recent costs in the village, plus projections of the cost of obtaining wood chips.

Base Level Resource Assumptions			
electrical energy :	\$0.48 per kWh	3,412	BTU/kWh
No. 1 oil :	\$4.00 per gal	134,000	BTU/gal
wood chips :	\$175.00 per green ton	5,315	BTU/lb
unit costs			
electrical enegy :	\$140.68 per mmBTU		
No. 1 oil :	\$29.85 per mmBTU		
wood chips :	\$16.46 per mmBTU		

Figure 2, Base Level Resource Assumptions

1.4 35 percent Summary and Recommendations

A mathematical model was constructed to model the performance of the various Plants, and to compare the financial performance of the five options. This model is discussed in detail in Section 3, and a sample of the calculations involved is shown in Appendix G. To date, it is not known for sure how this project would be financed, so the financial model does not include the cost of money, nor does it include projections of future resource costs escalation.

At this point, the key financial metric is net simple payback (NSP) at current costs. Figure 3A shows an abbreviated summary of the results of the model using the Base Level resource assumptions (see Section 1.3 above). The complete overall Summary sheet and the individual Plant Summary sheets can be found in Appendix F.

Financial	Base	Exp 1	Exp 2	Max 1	Max 2
current annual cost to heat connected buildings :	\$431,228	\$547,228	\$481,376	\$597,376	\$621,376
proposed annual cost of oil, DH Plant :	\$16,152	\$40,285	\$21,481	\$48,248	\$292
proposed annual cost of wood chips, DH Plant :	\$157,393	\$236,122	\$192,243	\$269,201	\$316,395
proposed annual cost of electrical energy, DH Plant :	\$66,378	\$101,150	\$77,626	\$70,522	\$121,982
total annual proposed costs, DH Plant :	\$239,922	\$377,557	\$291,350	\$387,971	\$438,669
savings :	\$191,306	\$169,671	\$190,026	\$209,405	\$182,707
estimated total DH plant cost :	\$2,501,751	\$2,886,217	\$2,563,315	\$3,100,228	\$3,659,476
net simple payback :	13.1 yrs	17.0 yrs	13.5 yrs	14.8 yrs	20.0 yrs

Figure 3A, Abbreviated Financial Summary (oil at \$4.00/gal)

Section 4 includes a number of tables and graphs showing the sensitivity of the project financials to changes in the cost of the inputs. One conclusion that is drawn from those tables is that the project is extremely sensitive to the cost of oil, and less so to the cost of wood and electrical energy. The feasibility study (and Figure 3A) is based on the current lower price of oil in the village; it has been much higher within the past 12 months, and is expected to get more expensive in the near future. For that reason, Figure 3B is included, showing the same abbreviated data at an oil cost of \$6.00 per gallon. Oil has reached and exceeded this level within Fort Yukon in the past.

Financial	Base	Exp 1	Exp 2	Max 1	Max 2
current annual cost to heat connected buildings :	\$646,842	\$820,842	\$722,064	\$896,064	\$932,064
proposed annual cost of oil, DH Plant :	\$24,228	\$60,427	\$32,222	\$72,373	\$437
proposed annual cost of wood chips, DH Plant :	\$157,393	\$236,122	\$192,243	\$269,201	\$316,395
proposed annual cost of electrical energy, DH Plant :	\$66,378	\$101,150	\$77,626	\$70,522	\$121,982
total annual proposed costs, DH Plant :	\$247,998	\$397,699	\$302,091	\$412,096	\$438,815
savings :	\$398,844	\$423,143	\$419,973	\$483,968	\$493,249
estimated total DH plant cost :	\$2,501,751	\$2,886,217	\$2,563,315	\$3,100,228	\$3,659,476
net simple payback :	6.3 yrs	6.8 yrs	6.1 yrs	6.4 yrs	7.4 yrs

Figure 3B, Abbreviated Financial Summary (oil at \$6.00/gal)

As noted above, the project shows extreme sensitivity to the cost of oil – an increase of 50 percent in the cost of oil cuts the NSP by more than half.

Based on the design and study results to date, the team believes that the Maximum Plant 1 is the best option for Fort Yukon. This Plant includes nearly every major building in the village, and provides significant piping infrastructure upon which to build for future additions.

The Base Plant and the Expanded 2 Plant both have better NSP values than Maximum 1. That is because they serve only the core village buildings, which are closely grouped. Beyond this core, the marginal cost to add a building to the system in the future goes up significantly. Adding buildings (outside the core area served) in the future to either of these Plants would mean that these new buildings would bear the cost not only of the connection to the main piping, but the extension of the mains as well. This may well be so cost prohibitive (when considered as part of the “building” cost) that no new buildings would be added in future.

The key marginal cost of expanding a DH plant is the distribution piping. The team believes that Fort Yukon should leverage the savings associated with serving the core buildings (the Expanded 2 Plant) to expand the piping infrastructure as far as economical feasible. Extending the infrastructure all the way to the out to the Old CATG Clinic (Maximum 2) does not look like a good deal for the village (20.0 year NSP). However, the Maximum 1 Plant, by extending to the New CATG Clinic and the City Building, provides the village with ~ 1,500 feet of additional main supply and return piping for only a small increase in NSP.

Having the piping mains in place means that the marginal cost of adding a future building to the system along this route consists only of the building connection, making it more likely that buildings will be added. In fact, installing DH main along a route often serves as a guide for future expansion, since the parties involved know that can get heat at a lower price if they hook into the DH heating system.

The team therefore recommends that further design and development concentrate only on the Maximum Plant 1 option.

The estimated cost of this option is \$3,100,228 for the DH Plant. However, there are additional costs not directly associated with the DH Plant. As noted above, the plant utilizes heat recovered from engine generators producing power for the village.

The existing power plant, like the pump house, is too far away from the proposed DH Plant site to allow for piping between the two. However, the village is planning to build a new power plant in the near future. As the maps in Appendix D show, the proposed location is directly adjacent (or even in the same building as) the proposed DH Plant. Towards this end, the village has already initiated the purchase of a new engine generator (and may soon purchase a second new unit). This unit is not only more fuel efficient than the existing units by far, but because it has a marine water jacket, it recovers more useful heat. Therefore, it will be run as the Lead generator.

As a part of this project, it is the intent that this new power unit (or units) be temporarily located at or in the DH Plant in order to allow heat recovery until the new plant is built. At that point, the new generators would be moved a short distance into their permanent locations. The DH Plant could then recover heat off of any engine running, not just the new one(s).

This temporary installation and setup necessarily costs more than it would cost to place and install the generators only once, in their final locations. The team estimates that an allowance of \$250,000 would be sufficient to cover this additional expense.

We therefore recommend that the village commit to a cost of \$3,350,000 (rounded) for the new DH plant.

A further note on recovered heat; the electrical demand data used in this study came from calendar year 2007. It therefore does not include the increased demand due to the new large waste water pumping stations recently and currently being installed. Thus the amount of recovered heat available when the DH Plant is installed is expected to be significantly larger than the values used in this study. Since this heat is “free” (no marginal cost) to the DH Plant, this additional heat can only improve the economics of any DH Plant considered.

Section 2: Design Intent

2.1 Recovered Heat

Heat recovered from an engine generator and used in a DH Plant is “free” in the sense that there is no marginal cost increase to reject that heat to a heating loop compared to the rejecting it to the atmosphere. The heat comes primarily from the cooling jacket of the engine, and must be carried away from the unit to prevent it overheating. In the absence of a co-located heating plant, the heat is normally carried to a radiator, which cools the jacket water by rejecting the heat to the atmosphere.

As noted in Section 1, the intent in the short term is to temporarily co-locate at least one, or perhaps two new Caterpillar 3456 engine generator next to the DH Plant. The longer term plan is to relocate a completely new power plant adjacent the DH Plant. This new plant would likely use the 3456 engine exclusively.

The Caterpillar 3456 engine is proposed because it has a significantly better fuel consumption profile than any other similarly sized engine that Fort Yukon could buy. With the cost of fuel (No. 1 oil) so high in the village, the new engine generators pay for themselves very quickly. In addition, the 3456 can be fitted with a marine cooling jacket that allows the capture of significantly more heat than an engine without the jacket. Thus the 3456 in the proposed configuration minimizes fuel consumption and maximizes heat recovery.

Engine generators producing prime power are an ideal source of heat for any heating plant. They run continuously, and the quality (temperature) of the heat rejected is almost identical to the heat required by the Plant. Recovered heat is the lowest cost form of input energy to the DH Plant, thus it is always selected first and used to the fullest. As the design is “tweaked”, the proposed operations will be continually examined to see if more recovered heat can be used in place or wood or oil heat. Section 3 tabulates the effects of recovered heat on the proposed Plant energy input.

Section 2.5 below describes how the recovered heat will be integrated into the DH Plant; Appendix A provides detailed one-line diagrams and sequence of operations for the combined Plant. Finally, Appendix E includes typical design documents for tying into the power plant cooling circuits.

2.2 Wood Heat

As noted above, recovered heat can be considered the primary heat source, because it is always used first to meet the needs of the DH Plant. Wood heat is thus the secondary heat source. As with recovered heat, wood heat will always be used to the extent possible before using supplemental heat (oil, in this case). The village owns significant amounts of this resource in the surrounding lands, and the team believes it can be produced in a usable form (wood chips) at a price significantly below that of oil, on a BTU basis.

Solid fuel boilers require more infrastructure than oil-fired boilers. They require space for wood storage and processing as well as material handling equipment to get the chips into the boiler. Given the remoteness of Fort Yukon, the equipment installed must be reliable and well tested. It is also desirable that the boilers be standard units, “off the shelf” so to speak. Proprietary or customized equipment increases the chance that if equipment failure occurs, it will be expensive and/or time consuming to get it fixed.

The team proposes to use a German line of boilers and material handling equipment. Wiessmann (formerly Kob) equipment has been deployed in hundreds of installations all over Europe, and now is starting to be used in the US. The North American headquarters of

Wiessmann is in Vancouver, BC. The units have been modified to meet UL and ASME standards, and can thus be used in the US.

The Wiessmann boilers are standard products, which come in set sizes, and offer a range of options specifically designed for each boiler in the range. The model range proposed for Fort Yukon is the Pyrtec line. Figure 4 below shows a Pyrtec boiler:



Figure 4, Pyrtec Boiler

The Pyrtec range has a relatively wide range of capacities, from 1.3 mmBTU/h to 4.3 mmBTU/h. The boiler can be equipped with automatic start, automatic de-ashing, a cyclone to remove particulate, and soot blowers to keep the tubes clean, all well as a number of other options. All of this equipment is purpose-built for the boiler, and is off-the-shelf equipment.

Wiessmann also offers a variety of material handling equipment to get the chips into the boiler. The site selected for the DH Plant (see Appendix D) will require some gravel fill to get the DH Plant and power plant above flood level. The wood storage, on the other hand, does not necessarily have to be raised as high as the plants.

In addition to the DH Plant and power plant buildings (which may actually be in the same building, depending on timing), the team anticipates an on-site wood processing building; basically a large Quonset-style building. The current plan is to leave a gap between the processing building and the DH Plant. This section, built in the shape of a steep-walled "V" can be constructed when the adjacent building fill is installed. The V would be covered, and run the width of the buildings. At the bottom would be two linear augers, both running into the center of the V. In the center of the V, these augers would dump into the opening of a perpendicular auger that would run diagonally up the wall of the V and into the DH Plant, and ultimately dump into the metering box on the boiler(s). Gravity would keep the chips flowing into the two center augers. The design will be finalized as the details of the DH Plant design proceed; the intent is to keep the material handling as short and simple as possible, with a minimum of moving parts.

From the processing building, chips could either be pushed into the V with a small bobcat-style loader, or blown into the V (depending on chipper type) as it is chipped.

2.3 Supplemental Heat

There are two conditions under which the combination of recovered heat and wood heat might not be able to meet the DH Plant load. Biomass boilers cannot turn down much below 35 – 40 percent of their full load capacity (the study assumed 40 percent to be conservative). Depending on the boiler selected, therefore, there may be time when the Load is greater than the amount of recovered heat available, and yet less than the minimum load the biomass boiler can support.

This “middle” range of temperature conditions is fairly narrow, but it does exist. The second condition is if the sum of the biomass boiler output and the recovered heat is too low to meet the Load. This would only occur when it is very cold. For both of these situations, the DH Plant is equipped with a small oil-fired boiler.

Either one of these ranges can be eliminated, but generally not both. Making the biomass boiler bigger eliminates the use of oil at the high end of the load, but widens the gap between the recovered heat and the minimum boiler load. Choosing a smaller boiler can eliminate this “middle” gap, but at the expense of more oil required in very cold conditions.

As a result, choosing the biomass boiler is a balancing act. Using the model, one can immediately see the effect of boiler size on heat source. Choosing a bigger boiler reduces or eliminates oil consumption in the cold months, while increasing it in the shoulder months. A smaller boiler has the opposite effects. Using two boilers can eliminate or nearly eliminate oil use altogether; however, it adds significant first cost. In optimizing the DH Plant options using the model, only the Maximum 2 Plant actually lowered the net simple payback by using two boilers. By using one smaller boiler and one larger one, this Plant essentially eliminated all oil use.

It could be argued that no oil boiler need be included in the DH Plant. The means in which the DH Plant connects to the buildings (see Section 2.6 below) allows the end-user to extract all the available heat possible from the DH loop and still use their existing oil boilers to top up the heat if need be. This could be a viable proposition; the DH Plant could simply notify all the customers to enable their existing heating equipment when the temperature dropped below a given level.

However, it would not be nearly as convenient to cover the “middle” gap in heating that occurs when the Load exceeds the recovered heat, but is too small to allow a biomass boiler to be fired up. As noted in Section 3, the model predicts electrical demand (and thus available recovered heat) on an average basis. These profile curves predict monthly consumption very accurately using average demand data, but have little or nothing to say about the demand (and thus heat) at a given time on a given day. Thus the DH plant would always be in danger not meeting load in parts of the shoulder season, and further, could not accurately predict when it might happen.

If the DH Plant cannot predict these events, they cannot warn their end-users to have their equipment available and ready. The potential for the DH Plant under-supplying heat is significant.

Again, one could argue that this could be mitigated by selecting smaller biomass boilers for the DH Plant. However, that in essence shifts a significant (and unpredictable) amount of the annual cost of heating back onto the end-user. In essence, the DH Plant is building a plant that cannot meet then known loads, knowing that it will shift the burden in very cold weather to the end-user.

Because this would occur only in very cold periods, the consequences of a failed “handover” would be significant. This, plus the unpredictability inherent in such an operating scheme (operationally and financially) has lead the team to recommend that the DH Plant be able to deliver the full expected Load; in order to do this smoothly, a supplemental oil-fired boiler was included.

Because an oil-fired boiler can start and stop very quickly, without human intervention and with high reliability, it is ideal for the supplemental heat needed. Oil heat will always be added last, only when the other two sources cannot be used to maintain Load. See Appendix A for details of how the proposed oil-fired boiler fits into the operating sequence.

2.4 Distribution

- 2.4.1 Piping: The heat generated at the DH plant must be distributed to the various end-users. This is done by pumping hot water through distribution pipes to each building. Traditionally, the piping used in this part of Alaska is a rigid system of pre-insulated piping. A carrier pipe carries the fluid; this is standard steel piping. Rigid foam insulation surrounds the carrier, and insulation in turn is protected by an outer spiral-wound metal jacket. See Figure 5 below



Figure 5, traditional “arctic pipe”

This system provide superior heat loss characteristics (i.e. very low losses), but it is expensive, and installation must be very well planned. It is expensive primarily because the whole piping system is rigid. It must therefore be installed below the permafrost – in Fort Yukon this means 18 to 20 feet deep. The required trenching is expensive, requires large equipment, and takes time.

Installation must be well planned out because it is difficult to modify in the field. Cutting a piece to length means cutting through all three layers; it is difficult to get a clean cut and subsequent clean connection to the next piece. For that reason, the system is typically laid out in great detail in the plans, and each piece and each fitting made for a specific spot in the system. Thus any mistakes in fabrication or any damage to a piece in the field can take a long time to repair.

If the proposed Fort Yukon DH Plants had to rely on this traditional piping system, the payback would be significantly extended. Instead, the basis of design is a flexible, pre-insulated system that uses a plastic carrier pipe. The carrier piping is constructed of cross-linked polyester, or PEX. The piping comes on rolls that are dozens or hundreds of feet long. Standard easy to install fittings are used anywhere in the piping to connect end-to-end, tee, or elbow as required. The piping can be obtained as a single pipe within a pipe (outer layer), or even supply and return in one common outer layer pipe.

Figure 6 shows an example of a PEX system:



Figure 6, Pex piping

Because the system is flexible, it can be installed in the active layer of the soil – the proposed depth in Fort Yukon is 48 to 60 inches deep. Connections are simple, so the layout does not need to be planned in great detail. Because it comes in rolls, hundred of feet of piping can be laid out in very little time. Trenches are shallow and simpler to construct.

The most significant negative aspect of the PEX system as opposed to the traditional system is that the insulation is not as effective. Piping losses are greater with the PEX system, and piping losses can have a significant effect on ongoing operating costs. As shown in Section 3.2, however, much of the input energy into the DH Plant is “free” recovered energy. These operational savings can be leveraged on an ongoing basis to counteract the increased piping losses, allowing Fort Yukon to realize the first cost savings associated with the PEX system without the additional piping losses excessively damaging the project financials.

In the DH plant calculations, all segments of the piping were individually sized based on the expected peak flow rate. However, in order to standardize sizes and inventory, and simply the installation even further, only three sizes were included in the final design (and cost estimate). These are 2”, 4”, and (2) x 4”. The latter is not a size; the maximum size carrier pipe in the PEX system is 4”. When this is not enough, the intent is to use two parallel 4” pipes (2 x supply and 2 x return). The supply and return mains will be connected at intervals to equalize flow and pressure drop. This not only provides significant capacity for future expansion, it means that damage to one main need not shut down the whole system.

This would not be the first installation of the PEX system in rural Alaska; thousands of feet of this type piping were recently installed in McGrath in less than one week.

Pipe sizing calculations can be seen in Appendix G.

- 2.4.2 Pumping. The DH plant uses a primary/secondary system. This means that within the DH Plant is a small piping loop that includes all of the heat sources, as well as some thermal storage. The secondary loop is the distribution loop which includes all the buried piping, and the connections to the end-user buildings.

The primary loop piping is shown in detail in Appendix A, and the sequence of operations for the Plant is also contained in Appendix A (the controls points list for the Plants is in Appendix B).

The heat sources are connected to the primary loop in the order the heat is preferentially taken – the heat exchanger from the engine cooling loop is first, the biomass boiler(s)

second, and the oil-fired boiler last. Thus the biomass boiler adds heat only when the recovered heat cannot maintain setpoint, and the oil boiler in turn adds heat only if either/both of the other two sources cannot maintain setpoint.

The thermal storage is added to primary loop because the volume of water in the loop is quite small. Thus it reacts to added heat very quickly. A biomass boiler does not react to temperature changes quickly, the way a gas or oil fired boiler can. Thus the thermal storage slows down the response time of the primary loop, allowing the biomass boiler to operate more smoothly. Three sensors in the tank at different elevations give an advance notice of the trend that the temperature loop is taking.

The primary loop contains two small pumps, each constant volume and each sized for 100 percent of the pumping load.

The secondary loop, on the other hand, contains two much larger pumps, each variable speed (to save energy) and each sized for 100 percent of the pumping load. These pumps must pump all the way out to the farthest building and back. This system volume is quite large, and has no heat sources connected, so no thermal storage is used.

Between the primary and secondary loops is a heat exchanger. This transfers heat between the loops, but keeps them physically separate.

At the building connection(s), two way control valves are used to control the transfer of heat to the end-users. As the loads decrease, the valves modulate closed. This raises the differential pressure between the supply and return piping in the distribution loop. As this happens, the control system modulates the speed of the secondary pumps down (using the associated variable frequency drives), driving the system differential back down to its setpoint. An increase in Load likewise results in the pumps speeding up. Varying the speed of these large pumps in response to Load creates significant energy savings compared to constant speed pumps. In order to cover such large piping system, three differential pressure sensors are used at different locations – the system uses the lowest of the three signals to modulate the pump speed, ensuring that all parts of the system get adequate flow.

2.5 Recovered Heat Integration

Diagrammatically, the integration of recovered heat into the DH Plant is covered in detail in Appendix A and Appendix F. The concept is very simple. The cooling loop from the operating engine(s) producing power in the power plant is routed first to the DH Plant.

In the DH Plant, the hot cooling water flows through a heat exchanger. A three-way control valve on the cooling loop side of the exchanger controls how much heat is rejected to the primary DH loop. If the valve is wide open, all the flow goes through the heat exchanger.

A temperature sensor in the primary loop compares the supply temperature to the setpoint. If the supply temperature is below setpoint, the three-way valve will be wide open, extracting as much heat as possible from the cooling loop. If this is not enough heat for to meet the Load, additional wood or oil heat will be added to primary loop as required. If the Load is less than the available recovered heat, the three-way valve will modulate as required to maintain the loop at setpoint.

On the cooling loop side, the water leaving the DH Plant, having flowed either through the heat exchanger or through the valve bypass, will return to the power plant cooler than it left. It will then flow to the engine radiators. If it is already cooler the radiator setpoint temperature, then the radiator fans will not come on – the water continues back to the engine jacket to start the cycle

2.6 Building Integration

The valves that control the origin of the heat will be controlled by the existing building controls where they exist, or by a small dedicated control panel if needed. If this proves too costly for very small installations, the switchover can always be done with manual valves, but this relies on an operator being present.

Figure 7 below shows a typical installation for two oil fired boilers. In this scenario, each boiler is sized for 100 percent of the load; the boilers are manually alternated so that they get roughly equal run time. In all cases (figures 7, 8, and 9), light solid lines indicate existing equipment and piping, dark solid lines depict new equipment and piping, and light dashed lines show the water flow through the system. For convenience, it is assumed in all cases that Oil Fired Boiler – 1 is the active boiler, and boiler 2 would be isolated using the associated manual isolation valve. HWS is hot water supply to the building, HWR is hot water return from the building.

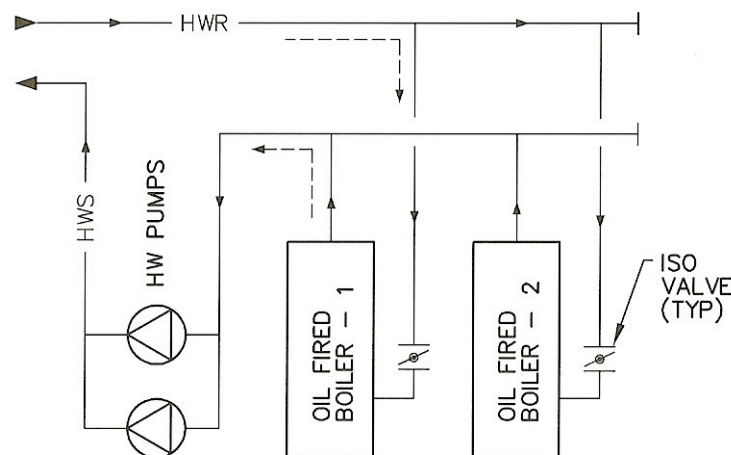


Figure 7, oil-fired heating plant

Alaska Wood Energy Associates

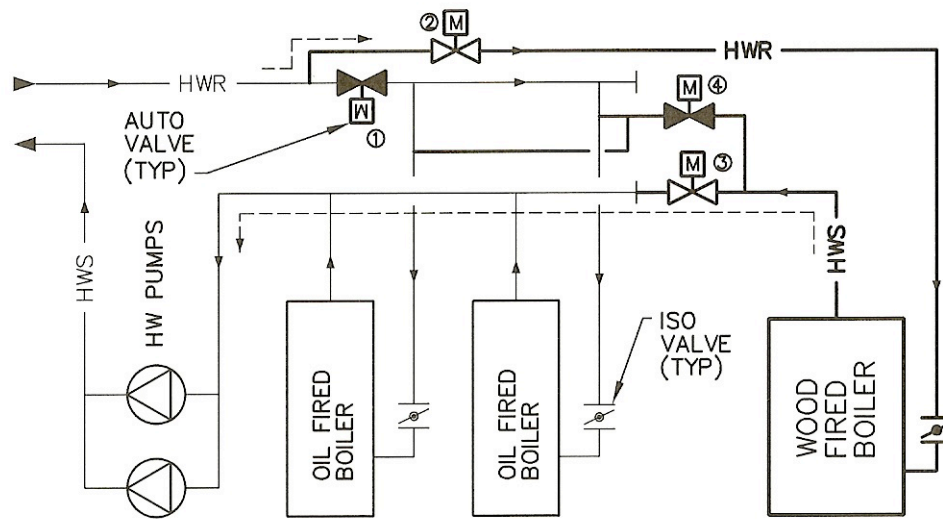


Figure 8, combined oil and DH Plant, all heat from DH

In the event that the DH plant cannot meet the building setpoint for any reason, the two systems can operate in series. The lack of adequate heat from the DH Plant could range from small to total (a plant failure), but the operation would remain the same – the oil-fired boiler would simply add enough heat to maintain setpoint, whether this is 1 percent or 100 percent of Load. This is shown in Figure 9.

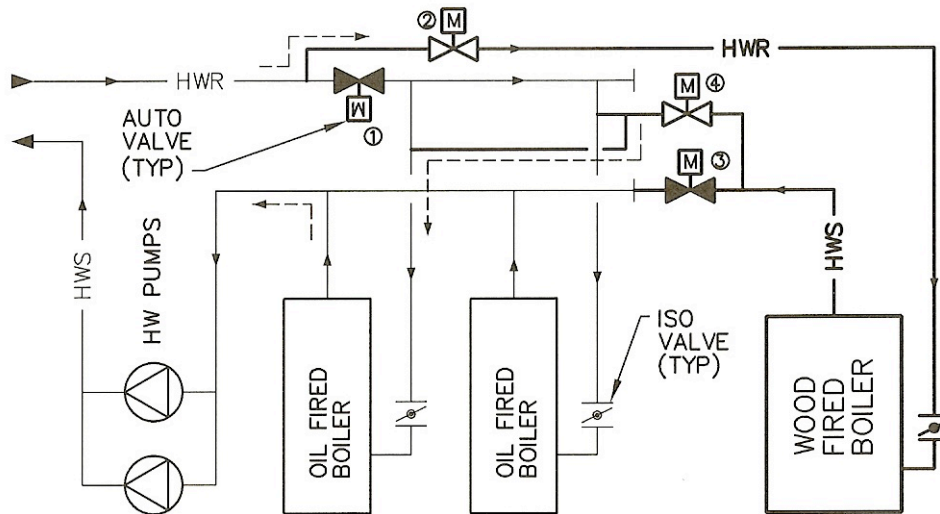


Figure9, combined oil and DH Plant, boiler heat in series with Plant heat

Section 3: Feasibility

3.1 Methodology

3.1.1 Limits. As with any performance evaluations, the quality and validity of the outputs and subsequent conclusions depends on the quality of the inputs and the methodology. Methodology is discussed in Section 3.1.2 below. The input data gathered for used in the analyses performed as a part of this study include:

- > Building specific data
- > Historical Fort Yukon PCE (electrical consumption) data
- > Proposed DH Plant equipment data
- > Annual oil consumption, by building
- > Annualized weather data (bin data) from the Fort Yukon airport
- > Site observations
- > Interviews with operating personnel
- > Interviews and meetings with Village and Corporation personnel
- > Village maps and plans
- > Interviews with Civil Engineers, contractors, and consultants with significant experience in the interior of Alaska
- > Pricing data from boiler manufacturers, piping suppliers and other AK vendors
- > Performance data from Wiessmann and Caterpillar
- > Input from other Alaska Wood Energy Associate team members

What was not performed a part of this analysis was detailed measurements of building heat loads and existing equipment performance. A building heating load profile is central to predicting annual fuel consumption (see 3.1.2 below). Ideally, this would be generated by directly measuring heating load throughout the year. At the same time, the actual operating efficiency of the existing boilers and distribution system would be measured. This would provide a highly detailed profile of heating load and the energy required to meet that load, for any condition throughout the year.

In practical terms, however, the required measurements are difficult to perform, and not cost-effective. The equipment needed to make these measurements is not present at any of the installations in the villages, and would have to be flown in and installed. The measurements would need to continue from winter to summer, to generate a complete load profile. The resulting incremental increase in the accuracy of the load profile cannot justify that level of cost. As Section 3.1.2 explains, even without the measurements, the data that were collected limit the load profiles to within a narrow range of values.

3.1.2 Methodology.

3.1.2.1 Energy Savings. The performance of the existing and proposed heating systems was modeled using a spreadsheet; the type of model used is known as a “bin model”. In this case, the bins are ranges of outside air temperatures (OATs). Temperature bins are used because heating load is very closely correlated to OAT. Each “bin” of OAT is 2 deg F wide – for instance, 40 – 42 deg F is a bin, with the midpoint temperature of 41 deg F. For each OAT bin, the heating load profile assigns a heating load to that temperature bin. The actual “bin data” is the number of hours per year that the outside air temperature falls into each specific bin.

Bin weather data is published for numerous sites, including many in Alaska. However, Fort Yukon is not one of those sites. Therefore, actual hourly temperature data from the Fort Yukon airport was used to construct a bin table for this site. The weather data came from calendar years 2007 and 2008, the last two complete years. The data were

combined to come up the average number of hours per year that the OAT in Fort Yukon falls into each bin. This was done on a monthly basis – for instance, the data in Figure 10 show the spread of temperatures in three different bins; 80 to 82 deg F, 40 to 42 deg F, and -20 to -22 deg F. The data show that on average, the OAT falls into the -20 to -22 deg F bin 6.5 hours in October, and 18.5 hours in January. If there are no hours within the given bin for a specific month, the cell remains blank; there are zero hours per year when the outside air temperature falls into the 80 to 82 deg F bin January, February, March, April, May, August, September, October, November, or December, for instance.

Bin hours, Fort Yukon Airport Data, average of 2007 / 08													
bin													
mid	744	672	744	720	744	720	744	744	720	744	720	744	
pt	31	28	31	30	31	30	31	31	30	31	30	31	
deg F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
81 :						14.0	9.5						23.5
41 :				24.0	29.0	2.0	0.5	17.0	36.5	0.5			109.5
(21) :	18.5	10.8	14.0							6.5	21.5	32.5	103.8

Figure 10, FY bin data

In the calculations performed within the model, individual calculations are completed in a series of tables that have the same format as the original bin temperature data (see Appendix G for extensive sample calculations). Figure 11 below shows a portion of a calculation used in this study.

Predicted heat load profile, biomass plant, kBTU/h													
bldgs	plant	piping		bin mid pt									
		losses	total		31	28	31	30	31	30	31	31	30
kBTU/h	kBTU/h	kBTU/h	kBTU/h	deg F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1,223	14	423	1,660	41 :				1,660	1,660	1,660	1,660	1,660	1,660
1,300	16	428	1,744	39 :				1,744	1,744	1,744	1,744	1,744	1,744
1,376	19	432	1,827	37 :				1,827	1,827		1,827	1,827	1,827
1,453	22	436	1,911	35 :			1,911	1,911	1,911			1,911	1,911
1,530	25	440	1,995	33 :			1,995	1,995	1,995			1,995	1,995

Figure 11, partial bin model

In the columns to the left, the building heat load, DH Plant heat load, and piping loss heat load are calculated; the fourth column shows the total load on the DH Plant. The next column shows the midpoint of the temperature bin represented. Proceeding to the right, the load is expressed in each month in which there are hours within the bin. For instance, in all five bins shown, there are no hours within that bin in January – so the load is not expressed anywhere in the January column shown. In June, only the top two bins shown have any hours, so the load is expressed only in those two bins. After all the loads are distributed across the table, the SUMPRODUCT function is used – that is, for each month, each load is multiplied by the number of hours within the associated bin, and all of those products are summed to calculate the total BTU of heat required that month.

Subsequent calculations are done to determine how much oil/wood/recovered heat is required to meet that load – one table for each energy source (complex rules determine which source is the primary, secondary, or tertiary source in each load condition). Once

the required oil (for instance) is calculated for each spot in the table, the SUMPRODUCT function sums up all the oil require for each month. This is the basic format of the calculations.

The basis of all calculations is the heating load profiles for each building included in the study. These load profiles reflect all the information available about the building, such as heating equipment capacity, operating data, historical oil consumption data, size and type of building, etc. As noted above, it is difficult to measure heat load directly, but simple to measure oil consumption. So the first profiles generated are oil consumption profiles. These profiles assign a specific oil consumption rate to each OAT bin. Using the calculation format above, the model calculates the amount of oil required to heat each building, and then compares that to known consumption – obviously, the model must be able to back-predict known consumption if it is to be used to predict future consumption.

Once the oil consumption profiles are verified, the oil consumption profile is converted to a space heating load profile, by multiplying BTU of input heat (oil) times the efficiency of the boiler/furnace to arrive at the actual heat to the space. Once these space load profiles are generated (see Figure 11 above), they are fixed.

No matter what heat source is used, or how great any parasitic or piping losses are, any proposed DH Plant must at the end of the day deliver that same amount of BTUs to the space as the current oil-fired appliance do. Once the space load profiles are established, the spreadsheet models the various DH Plants to determine how much energy they would consume to provide this required space heat. As noted above, in addition to producing a set amount of BTU for space heat, a DH Plant must produce enough BTUs to heat the plant itself (parasitic loss) and to overcome the heat lost from the distribution piping into the ground (piping losses). Finally, the model must calculate how much pumping (electrical) energy must be used to get the heat to the buildings. Once inside the buildings, the electrical energy used for pumping is the same for the existing systems as it would be with a DH Plant in place, so this energy is not calculated or accounted for in the model.

Additional key load profile assumptions:

- > Space heating load varies linearly with OAT (a 10 deg F drop in OAT results in twice the increase in load that a 5 deg F drop causes)
- > There is an OAT at which space heating stops – the OAT combined with the internal loads in the building (people, lights, equipment) are such that no additional heat is required; beyond this temperature, the only load is DHW. The model assumes no space heating above 60 deg F.
- > However, there is heating required above 60 deg F, for heating recirculating water in the village and domestic hot water in some of the buildings.

3.1.2.2 Recovered Heat. Just as with heating loads, a “recovered heat” profile is generated. This profile assigns a specific village power requirement to each temperature bin. This is less straightforward than assigning heat loads versus OAT, because the correlation between village power and OAT is not as strong – there is also a time-of-day component to power output. However, bin models predict long term average performance, not hour-by-hour performance. A bin model that predicts consumption accurately on a monthly basis is generally as specific as is required – most utilities bill and/or report consumption on a monthly basis

Plotting average monthly temperature versus monthly kWh for 2007 (the last calendar year for which complete PCE data were available when the plot was done) resulted in a scatter of data points. A best-fit curve could be constructed, and when used to predict demand kW at each OAT bin point, it would accurately predict annual electrical

consumption. However, it could not predict consumption monthly to within acceptable levels (some months were plus or minus 20 percent of more). However, it was noticed that the data points grouped themselves into two sets. Applying a separate curve to the two “sets” of points resulted in Figure 12 below:

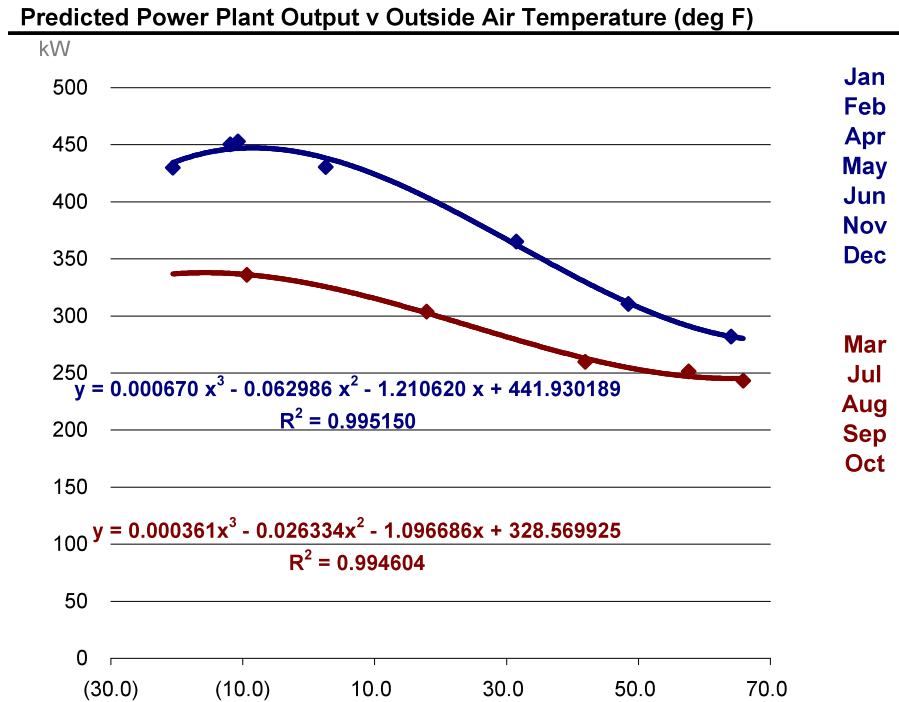


Figure 12, village demand v OAT

The top curve represents the data from the months shown in dark blue, the bottom curve the remaining months in maroon. It is not known why the correlation to OAT would change from month to month, but in general, the dark blue months are colder (except June) and the maroon months are warmer (except Mar). However, the R² correlations are extremely high (in excess of 99 percent). Using these curves to predict demand kW should produce valid results.

Figure 13 below shows the monthly results:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
PCE:	337,000	289,000	250,000	263,000	231,000	203,000	181,000	187,000	187,000	226,000	310,000	335,000	2,999,000
predicted:	332,164	303,905	255,490	260,598	235,760	206,866	184,489	186,007	190,868	224,718	309,951	331,882	3,022,697
delta:	4,836	(14,905)	(5,490)	2,402	(4,760)	(3,866)	(3,489)	993	(3,868)	1,282	49	3,118	(23,697)
delta:	0.015	(0.049)	(0.021)	0.009	(0.020)	(0.019)	(0.019)	0.005	(0.020)	0.006	0.000	0.009	(0.008)

Figure 13, correlation of predicted power to actual

The first line is the actual 2007 PCE data, kWh. The second line is the energy predicted by the model, applying the OAT bin data to the demand kW predicted by the two curves above. The third line is the delta (change in) on a unit basis, that is, in kWh. The final line is the delta as a fraction of the known PCE data. The table shows a deviation between actual and predicted of 0.8 percent (0.008) on an annual basis. More importantly, the magnitude of the largest monthly deviation is 4.9 percent (Feb), while the smallest is November, when the predicted value matches the actual value to within 49 kWh out of 310,000 (0.02 percent deviation).

These curves provided a means to accurately predict power demand as a function of temperature, but that is not the value needed for modeling DH Plant performance. What is needed is the amount of heat is available for heat recovery as a function of OAT. However, using the engine-generator manufacturer's data, a curve was constructed to calculate the available heat as a function of power output. So the bin model first generates a bin table of power demand for each bin by month, then a subsequent table calculates the heat recovery available for each bin by month. The model then calculates how much additional heat input in the form of wood or oil is required to meet the DH Plant load.

Figure 14 shows the relationship between kW demand and heat available for recovery; this is specific to the Cat 3456 generator on order by Fort Yukon (see Section 1):

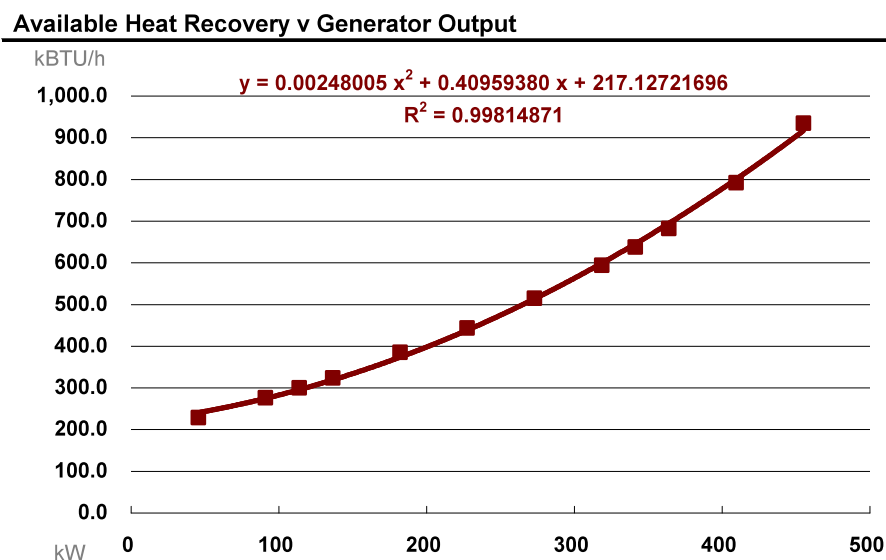


Figure 14, available heat recovery v power output

These three profiles, the “existing” oil consumption profiles, the building heat load profiles, and the profiles of heat available for recovery represent a baseline condition – the state of the things as they exists now in Fort Yukon. The model is set up to first model these elements, and then it can be modified to calculate the performance of the proposed DH Plants.

The following is the list of other calculations made in order to predict performance. Other than the calculations relating to the DH Plant piping (flow rates, distance, pipe size, etc), all of these calculation took the form of bin tables as described above (again, sample calculations can be found in Appendix G):

- > Proposed routing of DH pipe and associated lengths
- > Peak flow rate required by each building
- > Size of piping run-out to each building
- > Size of each segment of the piping mains (any pipe that serves more than one building)
- > Minimum and maximum heat loss in each segment and run-out and bin profile
- > DH Plant parasitic heating load profile

- > DH Plant heating load (building profile plus parasitic profile plus piping loss profile)
- > Useable recovered heat profile and bin calculation (month by month)
- > Wood energy input profile and bin calculation (month by month)
- > Oil energy input profile and bin calculation (month by month)
- > Pumping energy input profile and bin calculation (month by month)

3.1.2.3 Cost Estimates. The other component required to calculate the payback of any given scenario is the cost. One estimate was prepared for each proposed DH Plant (see Appendix C for a copy of the cost estimates). The current cost estimates contains the best knowledge of the team members regarding construction in Bush Alaska. As the final design proceeds, these costs estimates will be constantly updated to reflect the current design.

Ultimately, actual vendor quotes and contractor's estimates or bids will be used for the final cost estimates.

3.2 Results

Financial results are provided in Sections 1 and 4, and in Appendix F. This section details the engineering results of the performance model, specifically how each proposed DH plant performs in the complementary goals of displacing as much oil as possible, using as much "free" heat (recovered heat) as possible, and utilizing the village resources appropriately to reduce the village's energy dependence.

Figures 15 through 19 show the engineering/energy performance of the five proposed DH Plants. In all cases, the preferred option, Maximum Plant 1, is shaded.

Inputs	Base	Exp 1	Exp 2	Max 1	Max 2
current annual oil consumption, connected bldgs, gal :	107,807	136,807	120,344	149,344	155,344
proposed annual oil consumption, gal :	4,038	10,071	5,370	12,062	73
proposed annual wood consumption, green tons :	899	1,349	1,099	1,538	1,808
proposed annual electrical energy consumption, kWh :	138,287	210,730	161,721	146,920	254,130
fraction of oil displaced :	0.963	0.926	0.955	0.919	1.000

Figure 15, Plant Inputs

The amount of oil displaced ranges from 92 percent to 100 percent (actually slightly less, but even rounded to three places, it appears as 100 percent). The Max 2 Plant has the highest percentage of oil displaced; this is because it is the only plant with two biomass boilers, allowing it to cover both the very bottom of the range as well as the top. The other plants have only one boiler, and must thus use oil to fill the gaps when the recovered heat is not quite enough, and on the very coldest days when the biomass boiler capacity is not quite enough.

Figures 16 and 17 show the breakdown of heat sources for each DH Plant. Figure 16 shows the data in kBTU, while Figure 17 shows the same data in fractions.

Heat Sources, unit	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat from oil, kBTU :	449,103	1,120,118	597,292	1,341,548	8,106
annual heat recovered from Power Plant, kBTU :	5,285,120	5,513,598	5,407,258	5,524,605	5,559,001
annual heat from wood chips, kBTU :	8,030,058	12,046,738	9,808,062	13,734,424	16,142,238

Figure 16, Heat Sources (units)

Heat Sources, fraction	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat from oil :	0.033	0.060	0.038	0.065	0.000
annual heat recovered from Power Plant :	0.384	0.295	0.342	0.268	0.256
annual heat from wood chips :	0.583	0.645	0.620	0.667	0.744

Figure 17, Heat Sources (fractions)

The ability of each Plant to use recovered heat (as a fraction of total input heat) depends both on the size of the Plant and the boiler selection. In a smaller Plant, such as Base, the recovered heat naturally comprises more of the input energy, because the overall capacity of the Plant is much smaller than others. Exp 2 is only slightly larger than Base in terms of Load), so it also receives more than a third of its input energy from recovered heat.

Equally interesting is where the output heat goes. Figures 18 and 19 show this distribution, again in units of kBTU and then fractions of total. The DH Plant load (parasitic load) is a constant in all plant in kBTU terms, so naturally it drops as fraction of total as the Plant size gets bigger. Piping losses, on the other hand, vary in both absolute and relative terms, based on the length of size of the distribution piping required.

Heat Sinks, unit	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat to buildings, kBTU :	11,990,295	15,215,675	13,384,660	16,610,040	17,277,360
annual heat to piping losses, kBTU :	1,397,094	3,087,885	2,051,057	3,613,643	4,055,091
annual heat to plant, kBTU :	376,894	376,894	376,894	376,894	376,894

Figure 18, Heat Sinks (units)

Heat Sinks, fraction	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat to buildings :	0.871	0.815	0.846	0.806	0.796
annual heat to piping losses :	0.102	0.165	0.130	0.175	0.187
annual heat to plant :	0.027	0.020	0.024	0.018	0.017

Figure 19, Heat Sinks (fractions)

Piping losses are an important criterion for evaluating the plants. This heat, unlike the DH Plant load, is a complete loss. In essence, it can be thought of as the Plant efficiency, much like a boiler has an efficiency. It is calculated the same way – heat delivered divided by input heat. The Exp 2 Plant, for instance, would have a “heat delivery” efficiency of $(1.0 - 0.175) = 0.825 = 82.5$ percent. In a stand-alone DH Plant, that 17.5 percent loss would have to be paid for in fuel costs. However, because the proposed plants all use recovered heat from the co-located engine generator, this mitigates much of the impact of the losses. Note that in all cases, the percent of input heat from recovered heat is greater than the losses. The recovered heat is thus a major factor in the cost effectiveness of any of these Plants.

This data is all included in the Summary sheets in Appendix F.

Section 4: Financial Metrics, Sensitivity Analysis

4.1 Financial Metrics

The date, the funding mechanism(s) for the project have not been determined. For that reason, the current financial model does not include the effects of the cost of money, or required rates of return on investment.

The intent is that some or all the money come in the form of grants, which would carry no future obligation as debt and/or equity would do.

Until the funding mechanism is known, the financial model uses the simplest of key metrics – the net simple payback of the project. This is simply defined here as the cost of the project in dollars divided by the savings (over the current means of the heating) in dollars per year (year 1), resulting in a NSP in years. Figures 3A and 3B in the Section 1 show the NSP of the various DH Plants under two sets of assumptions. Appendix F shows the entire Summary sheets for the overall project, and for each individual DH Plant

4.2 Sensitivity Analysis

The base level resource assumptions are tabulated in Section 1.3 (abbreviated) and in Appendix F (in full). Figure 2 from Section 1.3, reproduced here, shows the base level cost and unit heat content assumptions.

Base Level Resource Assumptions			
electrical energy :	\$0.48 per kWh	3,412 BTU/kWh	
No. 1 oil :	\$4.00 per gal	134,000 BTU/gal	
wood chips :	\$175.00 per green ton	5,315 BTU/lb	
unit costs			
electrical enegy :	\$140.68 per mmBTU		
No. 1 oil :	\$29.85 per mmBTU		
wood chips :	\$16.46 per mmBTU		

Figure 2, Base Level Resource Assumptions (reproduced from Section 1.3)

As shown, there are three primary energy inputs to the DH Plant(s), electrical energy, No. 1 oil, and wood chips. Currently, there is only one primary energy input in the village (for heating), No. 1 oil. In the sensitivity tables and graphs that follow, two input costs are held constant, and one of the three is varied. This provides insight into how sensitive the project is to shifts in cost of the major cost component, input energy. In Figure 20, the cost of electrical energy is varied as the cost of oil and wood are held constant.

electrical unit cost	Net Simple Payback in Years			(basis of study in Bold)	
	Base	Exp 1	Exp 2	Max 1	Max 2
\$0.36 :	12.0	14.8	12.2	13.7	17.2
\$0.48 :	13.1	17.0	13.5	14.8	20.0
\$0.60 :	14.3	20.0	15.0	16.2	24.0
\$0.72 :	15.8	24.2	17.0	17.8	30.1
\$0.84 :	17.7	30.8	19.4	19.8	40.1

cost of oil is constant at \$4.00/gal
cost of wood is constant at \$175/green ton

Figure 20, sensitivity table, electrical energy

As the table shows, the net simple payback of the project is not especially sensitive to the cost of electrical energy – a 75 percent increase in the cost of the energy causes the NSP to increase by only about 35 percent.

This can be seen graphically in Figure 21; the slope of the lines are not particularly steep (see Figure 23). It can also be seen that the slope is increasing as the cost of energy increases; thus less dramatic increases in electrical costs have even smaller effects on project financials.

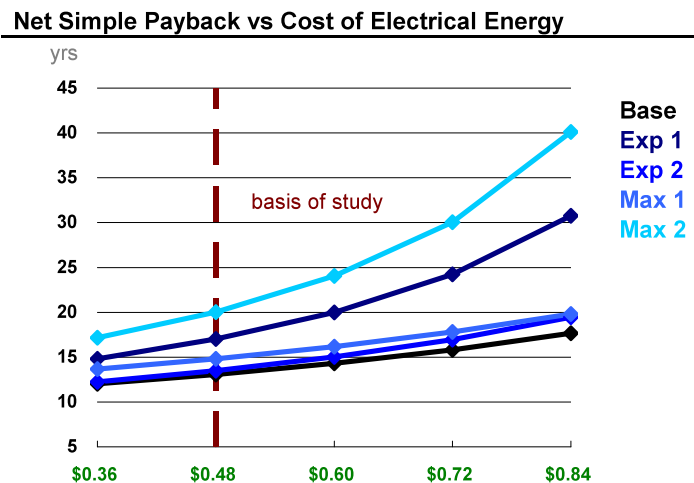


Figure 21, sensitivity graph, electrical energy

Figures 22 and 23 below show the effects of changes in cost of No. 1 oil. These effects are significantly greater than those associated with the cost of electricity. This is because oil is the primary energy input in the “existing” case (i.e. the current means of heating the village).

oil unit cost	Net Simple Payback in Years					(basis of study in Bold)
	Base	Exp 1	Exp 2	Max 1	Max 2	
\$3.00 :	28.6	67.2	34.2	43.0	133.4	
\$4.00 :	13.1	17.0	13.5	14.8	20.0	
\$5.00 :	8.5	9.7	8.4	8.9	10.8	
\$6.00 :	6.3	6.8	6.1	6.4	7.4	
\$7.00 :	5.0	5.2	4.8	5.0	5.6	
\$8.00 :	4.1	4.3	3.9	4.1	4.6	

cost of wood is constant at \$175/green ton
cost of electrical energy is constant at \$0.48/kWh

Figure 22, sensitivity table, oil energy

The financial effect of changes in the price of oil is the opposite of those associated with changes in the cost of electricity or wood; because oil is the sole source of energy in the “existing” case (and only a very small input to the DH Plants), an increase in the cost of oil increases the value of the project.

This can be seen in Figure 23 – the slope of the curves is opposite that of the curves in Figures 21 and 25. Note that because of the greater sensitivity of the NSP to the cost of oil, the scale of the Y axis had to be expanded. This allows the effect of a drop in oil cost to be shown, but it also masks the significance of increases in oil cost, by flattening out the slope of the curves to the right of the Base Level case. Figure 23, however, shows that an increase in the cost of oil by 50

percent represents a drop of more than 50 percent in NSP. A doubling of the oil cost decreases the NSP by close to 75 percent. The most significant effect, however, is a decrease in the price of oil from \$4.00 per gallon (Base Level) to \$3.00 per gallon; the NSP increases 300 percent or more. Resource prices can be volatile, however, the long term price of oil in the village is expected to rise. Therefore, the team believes the Base Level price of \$4.00 per gallon to be conservative, and a reasonable Base Level to use for this analysis.

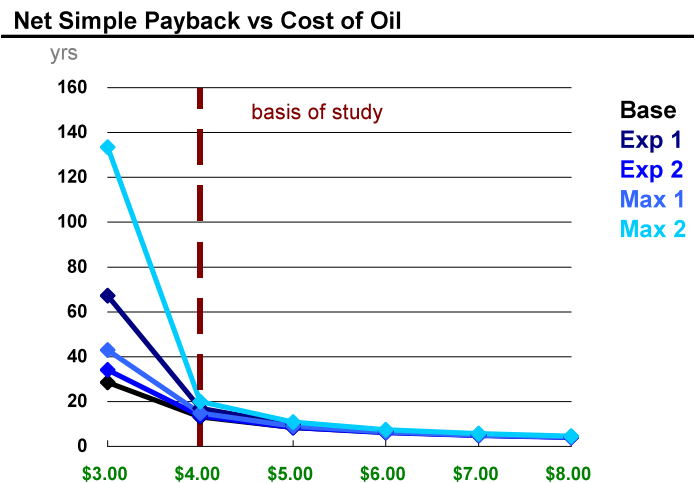


Figure 23, sensitivity graph, oil energy

Figures 24 and 25 show the effects of changes in the price of wood chips. The magnitude of these effects is almost identical to the effect of the price changes for electrical energy.

wood unit cost	Net Simple Payback in Years				
	Base	Exp 1	Exp 2	Max 1	Max 2
\$125.00 :	10.6	12.2	10.5	10.8	13.4
\$150.00 :	11.7	14.2	11.8	12.5	16.1
\$175.00 :	13.1	17.0	13.5	14.8	20.0
\$200.00 :	14.8	21.2	15.8	18.1	26.6
\$225.00 :	17.1	28.2	19.0	23.4	39.6

cost of oil is constant at \$4.00/gal

cost of electrical energy is constant at \$0.48/kWh

Figure 24, sensitivity table, wood energy

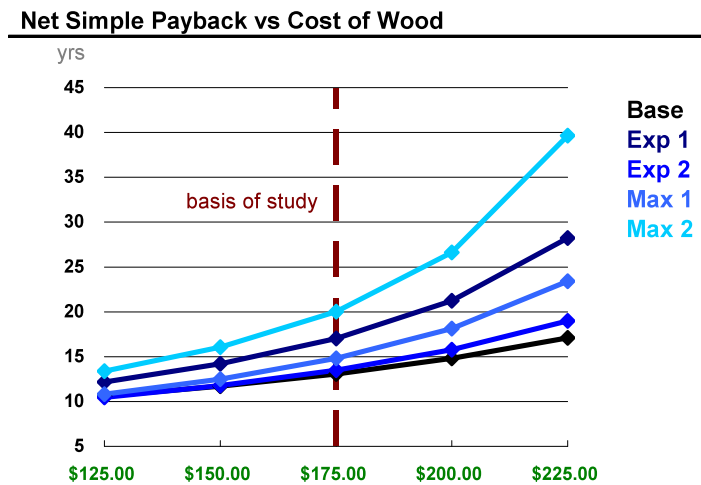
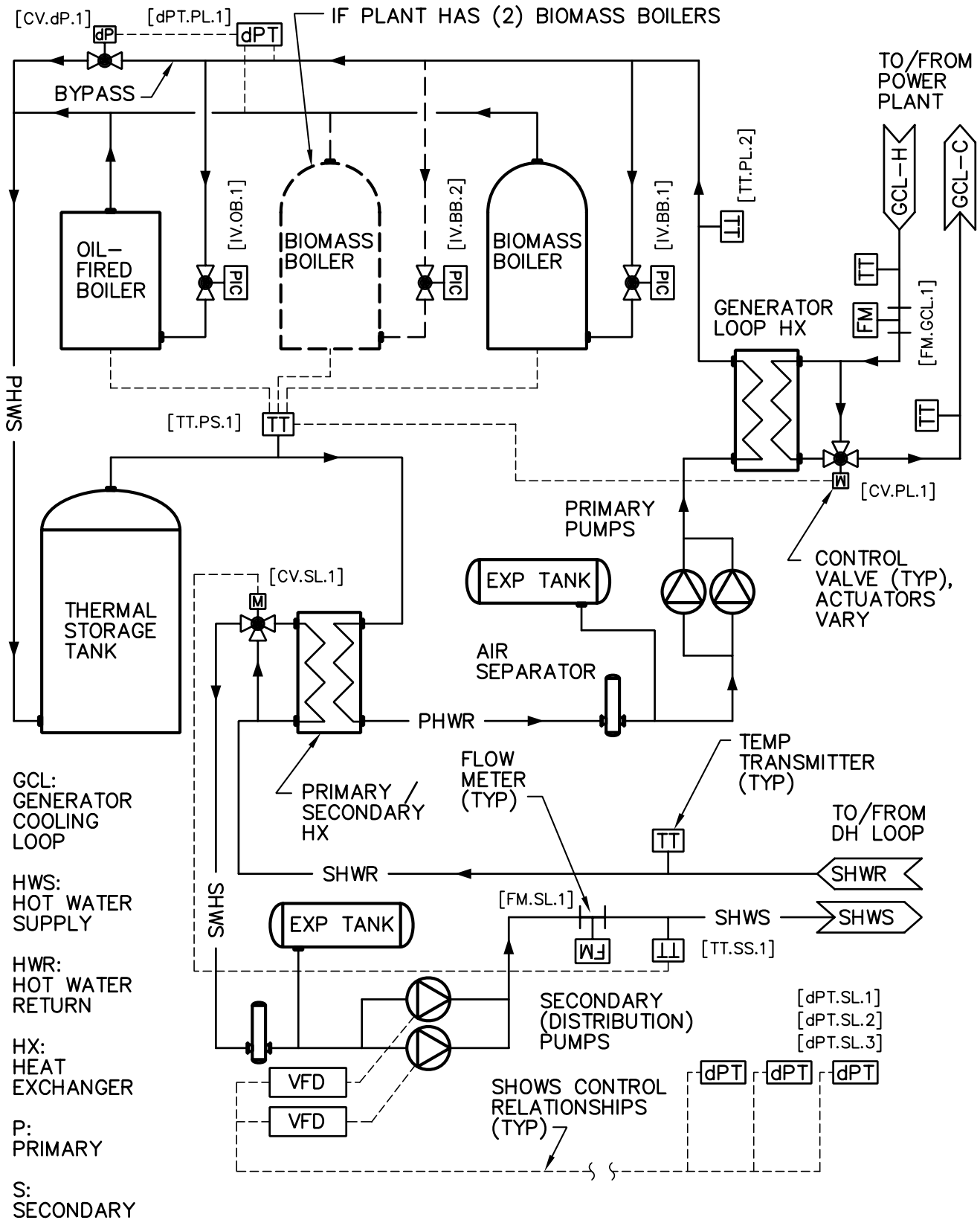


Figure 25, sensitivity graph, wood energy

Another assumption contained within the Base Level resource assumptions is the heat content of the wood chips. However, the sensitivity of the project to the heat content of the chips is essentially the same as that of the cost of wood chips – if the chips have less unit heat, one would simply have to buy more of them. Thus a drop in heat content has a one-to-one relationship with the cost of wood, and has the same effect on the project as an increase in wood chips costs.

Appendix A:

One-line Diagram and Sequence of Operations for Proposed DH Plants:



HEAT RECOVERY / DH PLANT INTERFACE

NTS

Sequence of Operations:

I Abbreviations:

BB:	Biomass Boiler
CGL:	Generator Cooling Loop
CV:	Control Valve
dP:	delta P (the change in Pressure)
FM:	Flow Meter:
IV:	Isolation Valve (motor actuated valves, used only for isolating equipment)
OB:	Oil Boiler
PL:	Primary Loop
PS:	Primary Supply
SL:	Secondary Loop
SS:	Secondary Supply
TT	Temperature Transmitter

II Heat Transfer

Heat transfer in BTUs is measured at two points; in the generator cooling loop, and the in the secondary, or distribution loop. The measurement is made by multiplying the difference between the supply and return temperatures times the mass rate of the system. The mass rate itself is calculated – the flow meters [FM.GCL.1] and [FM.SL.1] measure volumetric flow rate, which is then converted into mass rate via an internal calculation.

Heat transfer from the generator cooling loop is measured for accounting purposes. Depending on the final ownership of the district heating plant (DH Plant) and the Power Plant (P Plant), it may necessary that these BTUs be tracked.

Heat Transfer into the secondary loop is tracked for control purposes (see below) and also as a diagnostic. The heat transfer to each client is measured and recorded for billing/tracking purposed. The difference between the measured heat rate that leaves the DH plant, and the sum of the client heat rates is the system losses. These losses consist primarily of heat lost from the piping into the ground. By tracking this differential, the DH Plant operators can see if significant increases in losses occur, and so knowing, can track down the reason for the increase.

III Secondary (distribution) Loop

- A. Flow Control: There are three delta P transmitters ([dPT.SL.1, 2, and 3]) located within the secondary (distribution) piping. These transmitters measure the pressure differential between the secondary supply piping and the secondary return piping. The control system modulates the Lead Secondary Pump speed via the variable frequency drive (VFD) to maintain the supply-return dP setpoint, based on the lowest of the three dP values received from the transmitters.
- B. Pump Lead/Lag: Each pump is designed for 100 percent of the required flow. The operating pump is designated the Lead pump, the backup is the Lag pump. The Lead and Lag pump designations shall switch on the first of each calendar month, as noon on that day.

In the event of a Lead pump failure, the Lag pump shall immediately become the Lead pump, and the failed pump, the Lag pump. After a failure, the scheduled monthly Lead / Lag designation switch shall be suspended until the operator re-enables the switch. This is to prevent the system from trying to switch operations to a failed pump.

C Temperature Control:

1. Setpoint: Secondary Loop Setpoint is reset based on outside air temperature. Above 50 deg F OAT, setpoint shall be 140 deg F. Below 20 deg F, setpoint shall be 185 deg F. Between the 20 and 50 deg F, the setpoint shall vary linearly between the endpoint values.
2. Control: The control valve [CV.SL.1] located at the primary / secondary heat exchanger (HX) modulates to maintain the secondary loop heating water supply setpoint, as measured at [TT.SS.1].

IV Primary (plant) Loop

- A. Flow Control: The primary pumps are constant speed. However, there is a bypass between primary supply and return that controls flow from supply to return. The control valve [CV.dP.1] modulates to maintain the supply-return differential pressure setpoint, measured at [dPT.PL.1].
- B. Pump Lead/Lag: Each pump is designed for 100 percent of the required flow. The operating pump is designated the Lead pump, the backup is the Lag pump. The Lead and Lag pump designations shall switch on the first of each calendar month, as noon on that day.

In the event of a Lead pump failure, the Lag pump shall immediately become the Lead pump, and the failed pump, the Lag pump. After a failure, the scheduled monthly Lead / Lag designation switch shall be suspended until the operator re-enables the switch. This is to prevent the system from trying to switch operations to a failed pump.

C. Temperature Control:

1. The primary loop setpoint is set at 5.0 deg F higher than the secondary loop setpoint.
2. The primary loop temperature is measured by the transmitter [TT.PL.1], which is located downstream of the thermal storage tank. The signals from this transmitter are used to control both the control valve at the generator cooling loop HX and the firing rates of all of the boilers.
3. The primary purpose of the thermal storage tank is to provide a “thermal flywheel” for what is a very small system in terms of the amount of water in the system.
 - a. In a system with a minimal amount of water, temperature control is difficult, because a small input of heat can result in a large change in temperature.
 - b. The thermal storage tank provide extra volume (mass), which helps dampen the speed of temperature changes, and makes control easier.
 - c. However, because the transmitter that provide temperature control is downstream of the tank, there is a lag between an input of heat, and the resulting rise in temperature at [TT.PL.1]. To help make the control more accurate, there are three temperature transmitters in the tank at different elevations within the tank (not shown on drawing).

- d. This means the temperature controls must be set to react slowly, but because of the transmitters within the tank, it means that the controls can see how the system temperature is trending.
 - 1) This is an ideal scheme for the biomass boilers, which want use the knowledge of how the tank temperatures are trending to make slow and small changes in firing rate.
 - 2) During the commissioning process, the control valve on the HX [CV.PL.1] will be tuned to match the control speed to the reaction of the system.
 - 3) Also during commissioning, the rate at which control signal are sent to the oil-fired boiler will be tuned to match the system response.

D. Temperature and Flow Control, as load increases:

- 1. General: In this Section, BB max equals the maximum output of the biomass boilers. If there is only one, then BB max equals the capacity of that boiler. If there are two, then BB max equals the sum of the two boiler capacities. BB min equals the minimum turndown capacity of the smallest biomass boiler in the plant (there may be one or two). This is estimated at 40 percent of the rated capacity of the smallest biomass boiler. HR is the available heat recovery from the generator cooling loop.
- 2. Case 1: Load is less than available heat recovery (HR).
 - a. Control valve [CV.PL.1] modulates to maintain primary loop setpoint. As long as Load remain less than HR, no other action is required. When the Load exceeds the available heat recovery, the loop temperature measured at [TT.PS.1] will fall below setpoint.
 - b. In all cases, all primary flow goes through the generator loop HX. In this case, because the recovered heat can meet the Plant Load, all of the water flows through the downstream bypass from supply to return. The valve [CV.dP.1] modulates to maintain dP setpoint.
 - c. Because the primary pump flow is constant, and the flow through the HX does not vary, this valve holds a constant position once it has reached setpoint.
- 3. Case 2: Load is greater than HR, Load is less than BB min.
 - a. In this Case, the operator cannot meet the Load with only the recovered heat, and he cannot start a biomass boiler. Because the Load is less than BB min, the biomass boiler would not be able to remain on, and would attempt to cycle, which is not recommended. Therefore, the control system starts up the oil boiler. The system uses two pieces of information to determine the Case:
 - 1) Heat recovery alone cannot meet load: this is known because the temperature at [TT.PL.2] is less than the primary loop setpoint.
 - 2) The Load is less than BB min: The DH plant heat load is calculated as described above in Section II, and is found to be less than BB min.
 - b. Because the generator loop HX is upstream of the oil boiler, and in series with it, the system first takes all the available heat recovery; it fires the oil boiler only as required to maintain loop setpoint. This maximized the use of recovered heat.
 - c. In order to start up the oil boiler, the associated isolation valve [IV.OB.1] must be opened.

- 1) Each of the boiler isolation valves are two position valves (open or closed) and each is flow limited – that means the flow through the valve is a constant when it is open.
 - 2) Each of the two (or three) boilers has a set flow rate, each of which is individually less than the total primary flow. The sum of these flow rates equals the primary flow.
 - 3) The result of this is that except in the Case where all available boilers are operating, some water must flow through the bypass.
 - 4) When a valve opens, the supply/return dP in the bypass drops as some of the flow is diverted through a boiler, and into the supply piping.
 - 5) The bypass valve [CV.dP.1] modulates further closes to maintain the dP setpoint.
 - 6) Flow is now split between the operating boiler and the bypass.
 - 7) This pressure modulation and control occurs in this and all subsequent Cases; this description will not be repeated in further Case outlines.
4. Case 3: Load is greater than HR, Load is greater than BB min.
- a. At this point, the system opens [IV.BB.1] and starts the first (smallest, if there are two) biomass boiler.
 - b. When this biomass boiler is established, the system shuts down the oil fired boiler, and closes [IV.OB.1].
 - c. This is the only case in which not all of the available heat recovery is used. The system selects for wood over oil, so once the Load is great enough to operate a biomass boiler, the following occurs:
 - 1) The control valve [CV.GCL.1] slowly closes.
 - 2) This ensures that the first biomass boiler sees the entire Load.
 - 3) Using the control system, the biomass boiler is held at the minimum sustainable firing rate (minimum turndown).
 - 4) As the Load increases, the boiler is held at minimum, and [CV.PL.1] modulates to maintain primary loop setpoint. This ensures that the maximum amount of recovered heat is used.
 - 5) As Load increases further, the point will be reached when the Load is now greater than HR plus the BB min.
5. Case 4: Load is greater than HR, Load is greater than (HR + BB min).
- a. The control [CV.PL.1] is wide open, and all possible heat is being recovered.
 - b. The biomass boiler controls are released from their hold at minimum. The boiler is now allowed to modulate the firing rate to maintain primary loop setpoint.
 - c. If there is only one biomass boiler, then the boiler modulates the firing rate until the rate reaches maximum. If the primary loop temperature then falls below setpoint, the next Case is reached.
 - d. If there are two biomass boilers:
 - 1) The smaller boiler modulates to or near to full fire as Load increases.
 - 2) The larger boiler is then brought on, and the smaller one shut down.

- 3) As Load increases, and the larger boiler modulates to or near to full fire, the smaller boiler is brought on. Both boilers modulate in unison (same percent firing rate, not same BTU output).
 - 4) When the boilers reach maximum firing rate, and the primary loop temperature drops below setpoint, the next case is reached.
6. Case 5: Load is greater than HR, Load is greater than (HR + BB max).
 - a. The control [CV.PL.1] is wide open, and all possible heat is being recovered.
 - b. The biomass boiler(s) are at maximum firing rate.
 - c. The oil fired boiler is brought on to make up the difference between the Load and recovered heat plus the biomass boiler heat. Recovered heat and biomass heat are maximized, oil heat is minimized.

Appendix B:

Control Points List for Proposed DH Plants:

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Points List
C:\Documents and Settings\lgk\Desktop\wFort Yukon\L3 Ph II\FY L3 I 1 ver 11.xls

Points List

(same for all 5 proposed plants)

DH Plant			15 AO	31 AI	7 BO	22 BI
main HX in and out	temp	:		4		
HR HX in and out	temp	:		4		
main HX control valve	position	:	1			
HR HX control valve	position	:	1			
main HX flow meter	flow	:		1		
HR HX flow meter	flow	:		1		
primary loop supply	temp	:		1		
primary pump	status	:				2
primary pump	stop/start	:			2	
secondary pump VFD	status	:				2
secondary pump VFD	enable	:			2	
secondary pump VFD	speed	:	2			
secondary pump VFD	alarm	:				2
secondary pump VFD	amps	:		2		
secondary piping system	delta P	:		3		
secondary loop supply	temp	:		1		
boiler in outlet	temp	:		3		
boiler discharge setpoint	temp	:	3			
boiler	enable	:			3	
boiler	status	:				3
boiler iso valves	position	:	3			
stack gas	temp	:		3		
storage tank	temp	:		4		
emergency generator	status	:				1
tank	low level	:				1
tank	low low	:				1
fuel oil pumpset	alarm	:				1
fuel oil pumpset	enable	:	1			
plant	oa temp	:		2		
plant	sp temp	:		2		
UH	enable	:	4			
UH	status	:				4
heat trace	status	:				5

Appendix C:

Cost Estimates for Proposed DH Plants:

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Cost Est

C:\Documents and Settings\gk\Desktop\w\Fort Yukon\L3 Ph II\FY L3 I 1 ver 11.xls

description	units	Unit costs			Number					Extended Cost				
		labor	labor	material	Base	Exp 1	Exp 2	Max 1	Max 2	Base	Exp 1	Exp 2	Max 1	Max 2
boilers	:													
Wiessmann model 390	ea			\$276,250					1.0					\$276,250
Wiessmann model 530	ea			\$295,000	1.0					\$295,000				
Wiessmann model 720	ea			\$313,750			1.0					\$313,750		
Wiessmann model 950	ea			\$332,500		1.0		1.0	1.0		\$332,500		\$332,500	\$332,500
Wiessmann model 1250	ea			\$351,250										
install model 390 on site	ea	200.0	\$16,000	\$15,000					1.0					\$31,000
install model 530 on site	ea	200.0	\$16,000	\$15,001	1.0					\$31,001				
install model 720 on site	ea	240.0	\$19,200	\$15,002			1.0					\$34,202		
install model 950 on site	ea	240.0	\$19,200	\$15,003		1.0		1.0	1.0		\$34,203		\$34,203	\$34,203
install model 1250 on site	ea	240.0	\$19,200	\$15,004										
shipping	ea			\$20,000	1.0	1.0	1.0	1.0	2.0	\$20,000	\$20,000	\$20,000	\$20,000	\$40,000
mech room	:													
main heat exchanger, flat plate	ea	30.0	\$2,400	\$29,900	1.0	1.0	1.0	1.0	1.0	\$32,300	\$32,300	\$32,300	\$32,300	\$32,300
generator loop heat exchanger	ea	30.0	\$2,400	\$29,900	1.0	1.0	1.0	1.0	1.0	\$32,300	\$32,300	\$32,300	\$32,300	\$32,300
7.5 HP Pump	ea	10.0	\$800	\$3,536	2.0	2.0	2.0			\$8,672	\$8,672	\$8,672		
10 HP Pump	ea	14.1	\$1,129	\$4,053				2.0	2.0				\$10,365	\$10,365
15 HP Pump	ea	14.1	\$1,129	\$4,053										
20 HP Pump	ea	16.0	\$1,280	\$4,312	2.0					\$11,184				
25 HP Pump	ea	15.6	\$1,246	\$7,250										
30 HP Pump	ea	17.3	\$1,388	\$8,140			2.0					\$19,056		
40 HP Pump	ea	20.0	\$1,600	\$9,475										
50 HP Pump	ea	22.5	\$1,803	\$11,900		2.0					\$27,406			
60 HP Pump	ea	24.7	\$1,980	\$13,620				2.0					\$31,200	
75 HP Pump	ea	28.1	\$2,246	\$16,200					2.0					\$36,891
4 inch pump set (valves, etc)	ea	36.5	\$2,918	\$3,106										
6 inch pump set (valves, etc)	ea	52.0	\$4,163	\$4,294	4.0	4.0	4.0	4.0	4.0	\$33,829	\$33,829	\$33,829	\$33,829	\$33,829
20 HP VFD	per HP			\$150	2.0					\$6,000				
25 HP VFD	per HP			\$150										
30 HP VFD	per HP			\$150			2.0					\$9,000		
40 HP VFD	per HP			\$150										
50 HP VFD	per HP			\$150		2.0					\$15,000			
60 HP VFD	per HP			\$150				2.0					\$18,000	
75 HP VFD	per HP			\$150					2.0					\$22,500
additional piping	ls	320.0	\$25,600	\$25,000	1.0	1.0	1.0	1.0	1.0	\$50,600	\$50,600	\$50,600	\$50,600	\$50,600
oil fired boiler, 750 kBTU/h	ea	78.0	\$6,244	\$8,193	1.0	1.0	1.0	1.0	1.0	\$14,437	\$14,437	\$14,437	\$14,437	\$14,437

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Cost Est

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description	units	Unit costs			Number					Extended Cost				
		labor	labor	material	Base	Exp 1	Exp 2	Max 1	Max 2	Base	Exp 1	Exp 2	Max 1	Max 2
2-position isolation valves, 6"	ea	8.0	\$640	\$3,278	2.0	2.0	2.0	2.0	3.0	\$7,836	\$7,836	\$7,836	\$7,836	\$11,754
control valves, 6"	ea	8.0	\$640	\$5,600	2.0	2.0	2.0	2.0	2.0	\$12,480	\$12,480	\$12,480	\$12,480	\$12,480
6" flow meter	ea	6.9	\$549	\$4,500	2.0	2.0	2.0	2.0	2.0	\$10,097	\$10,097	\$10,097	\$10,097	\$10,097
electrical	ls			\$30,000	1.0	1.0	1.0	1.0	1.0	\$30,000	\$30,000	\$30,000	\$30,000	\$30,000
lights	sf			\$10	480.0	480.0	480.0	480.0	480.0	\$4,800	\$4,800	\$4,800	\$4,800	\$4,800
control points, binary	ea			\$600	29.0	29.0	29.0	29.0	29.0	\$17,400	\$17,400	\$17,400	\$17,400	\$17,400
control points, analog	ea			\$900	46.0	46.0	46.0	46.0	46.0	\$41,400	\$41,400	\$41,400	\$41,400	\$41,400
controls, panels	ea	16.0	\$1,280	\$8,000	2.0	2.0	2.0	2.0	2.0	\$18,560	\$18,560	\$18,560	\$18,560	\$18,560
controls, HMI	ea			\$1,500	2.0	2.0	2.0	2.0	2.0	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000
controls, programming	ls	250.0	\$20,000		1.0	1.0	1.0	1.0	1.0	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000
thermal storage tank, 6000 gal	ea	60.0	\$4,800	\$21,965	1.0	1.0	1.0	1.0	1.0	\$26,765	\$26,765	\$26,765	\$26,765	\$26,765
expansion tank, primary loop, 80g	ea	2.3	\$183	\$817	1.0	1.0	1.0	1.0	1.0	\$999	\$999	\$999	\$999	\$999
expansion tank, primary loop, 400g	ea	5.7	\$457	\$3,939	3.0	3.0	3.0	3.0	3.0	\$13,188	\$13,188	\$13,188	\$13,188	\$13,188
building	sf			\$100	900.0	900.0	900.0	900.0	900.0	\$90,000	\$90,000	\$90,000	\$90,000	\$90,000
remainder of plant														
plant stack, 50 ft	lf	0.8	\$60	\$158	50.0	50.0	50.0	50.0	50.0	\$10,900	\$10,900	\$10,900	\$10,900	\$10,900
stack fittings	ea	0.8	\$64	\$250	6.0	6.0	6.0	6.0	9.0	\$1,884	\$1,884	\$1,884	\$1,884	\$2,826
emergency generator, 100 kW	ea			\$50,000	1.0	1.0	1.0	1.0	1.0	\$50,000	\$50,000	\$50,000	\$50,000	\$50,000
fuel oil tank, DW, AG, 2000 gal	ea	7.7	\$617	\$7,590	1.0	1.0	1.0	1.0	1.0	\$8,207	\$8,207	\$8,207	\$8,207	\$8,207
tank accessories	ls	48.0	\$3,840	\$3,500	1.0	1.0	1.0	1.0	1.0	\$7,340	\$7,340	\$7,340	\$7,340	\$7,340
FO pump set	ea	2.7	\$213	\$1,200	1.0	1.0	1.0	1.0	1.0	\$1,413	\$1,413	\$1,413	\$1,413	\$1,413
electrical	ea			\$7,500	1.0	1.0	1.0	1.0	1.0	\$7,500	\$7,500	\$7,500	\$7,500	\$7,500
lights	sf			\$10	1,200	1,200	1,200	1,200	1,200	\$12,000	\$12,000	\$12,000	\$12,000	\$12,000
material handling	ls			\$80,000	1.0	1.0	1.0	1.0	1.0	\$80,000	\$80,000	\$80,000	\$80,000	\$80,000
distribution														
2" pex pipe, installed in place	lf			\$38	3,164	3,068	4,312	4,802	7,522	\$118,650	\$115,050	\$161,700	\$180,075	\$282,075
4" pex pipe, installed in place	lf			\$60		7,376	3,016	6,516	6,516		\$442,560	\$180,960	\$390,960	\$390,960
(2) 4" pex pipe, installed in place	lf			\$112	3,110	870	870	1,730	1,730	\$348,320	\$97,440	\$97,440	\$193,760	\$193,760
building connections	ea			\$21,500	11.0	13.0	13.0	15.0	16.0	\$236,500	\$279,500	\$279,500	\$322,500	\$344,000
future connections	ea			\$1,500	7.0	8.0	7.0	9.0	7.0	\$10,500	\$12,000	\$10,500	\$13,500	\$10,500
DH site														
wood processing building	sf			\$40	1,200	1,200	1,200	1,200	1,200	\$48,000	\$48,000	\$48,000	\$48,000	\$48,000
fill	cu yd			\$2.5	10,000	10,000	10,000	10,000	10,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

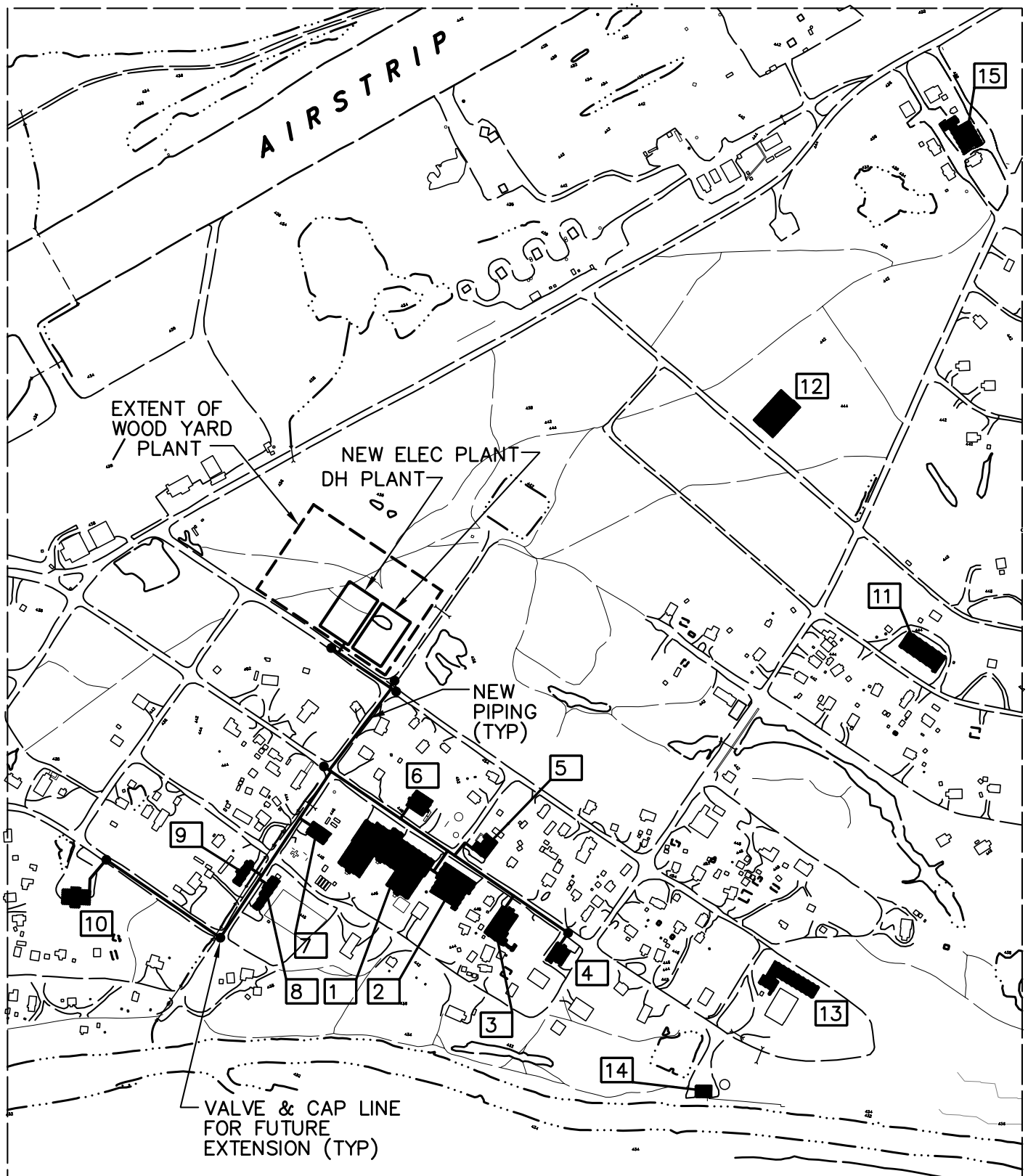
Cost Est

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description	units	Unit costs			Number					Extended Cost				
		labor	labor	material	Base	Exp 1	Exp 2	Max 1	Max 2	Base	Exp 1	Exp 2	Max 1	Max 2
General Conditions	:													
mob and demob	ls			\$40,000	1.0	1.0	1.0	1.0	1.0	\$40,000	\$40,000	\$40,000	\$40,000	\$40,000
small tools	ls			\$42,000	1.0	1.0	1.0	1.0	1.0	\$42,000	\$42,000	\$42,000	\$42,000	\$42,000
temp facilities	ls			\$25,000	1.0	1.0	1.0	1.0	1.0	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000
					construction subtotal					\$1,905,062	\$2,203,566	\$1,954,015	\$2,366,298	\$2,829,099
					subcontractor mark-ups (mech is general)									
					electrical contractor mark-up 0.125					\$15,788	\$16,288	\$16,288	\$16,788	\$17,038
					controls contractor mark-up 0.125					\$22,222	\$24,347	\$23,597	\$25,722	\$27,274
					site contractor 0.125					\$97,059	\$125,944	\$99,075	\$145,037	\$160,474
					subtotal					\$135,068	\$166,578	\$138,959	\$187,546	\$204,786
					total construction					\$2,040,130	\$2,370,144	\$2,092,974	\$2,553,844	\$3,033,885
					design / construction admin (% of cons)									
					final design/study					\$125,000	\$125,000	\$125,000	\$125,000	\$125,000
					bid assistance 0.005					\$10,201	\$11,851	\$10,465	\$12,769	\$15,169
					construction admin 0.035					\$71,405	\$82,955	\$73,254	\$89,385	\$106,186
					commissioning/start up 0.025					\$51,003	\$59,254	\$52,324	\$63,846	\$75,847
					contingency 0.100					\$204,013	\$237,014	\$209,297	\$255,384	\$303,388
					subtotal					\$461,621	\$516,074	\$470,341	\$546,384	\$625,591
					total					\$2,501,751	\$2,886,217	\$2,563,315	\$3,100,228	\$3,659,476

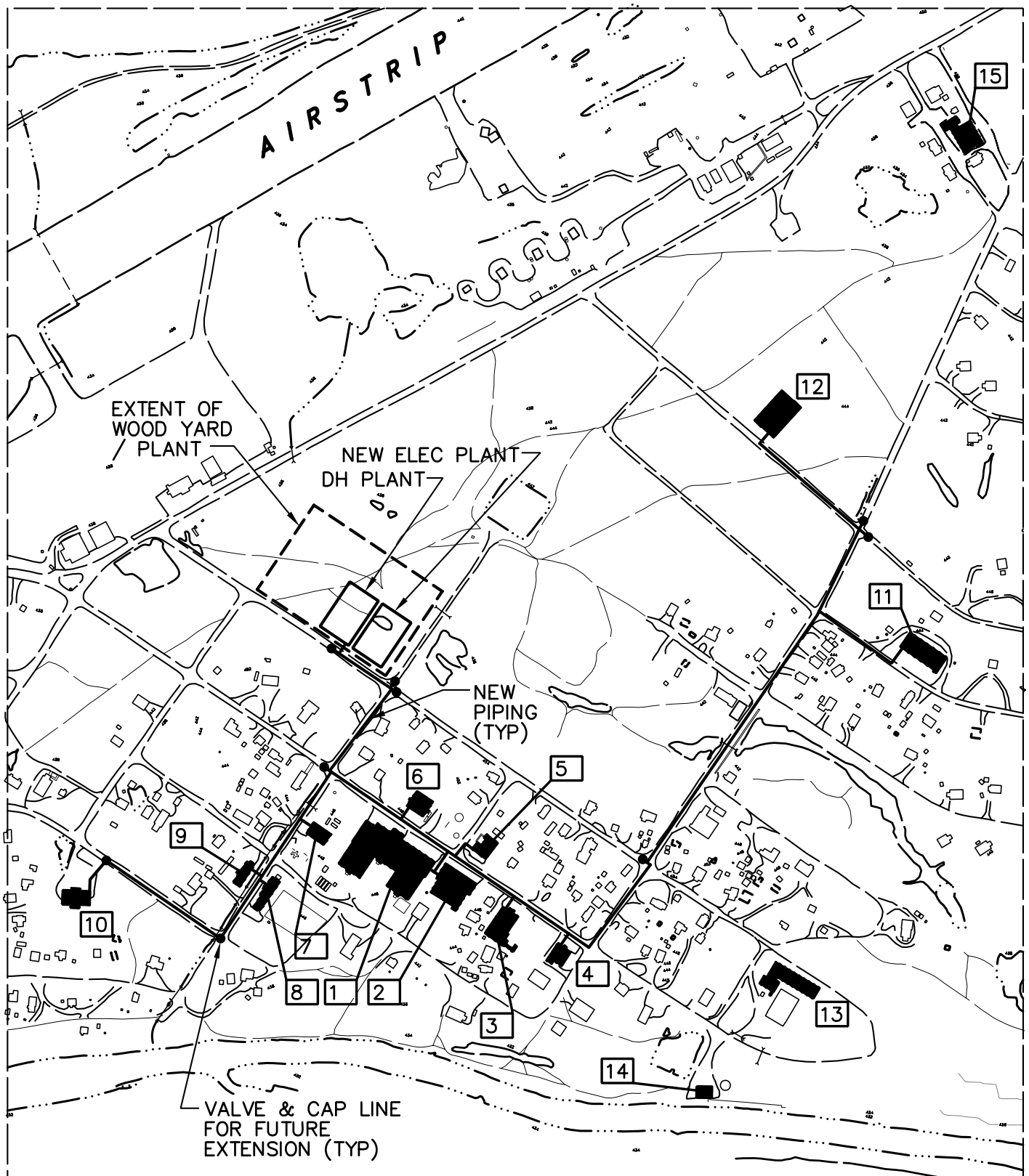
Appendix D:

Maps of Proposed DH Plants:



BASE PLANT
NTS

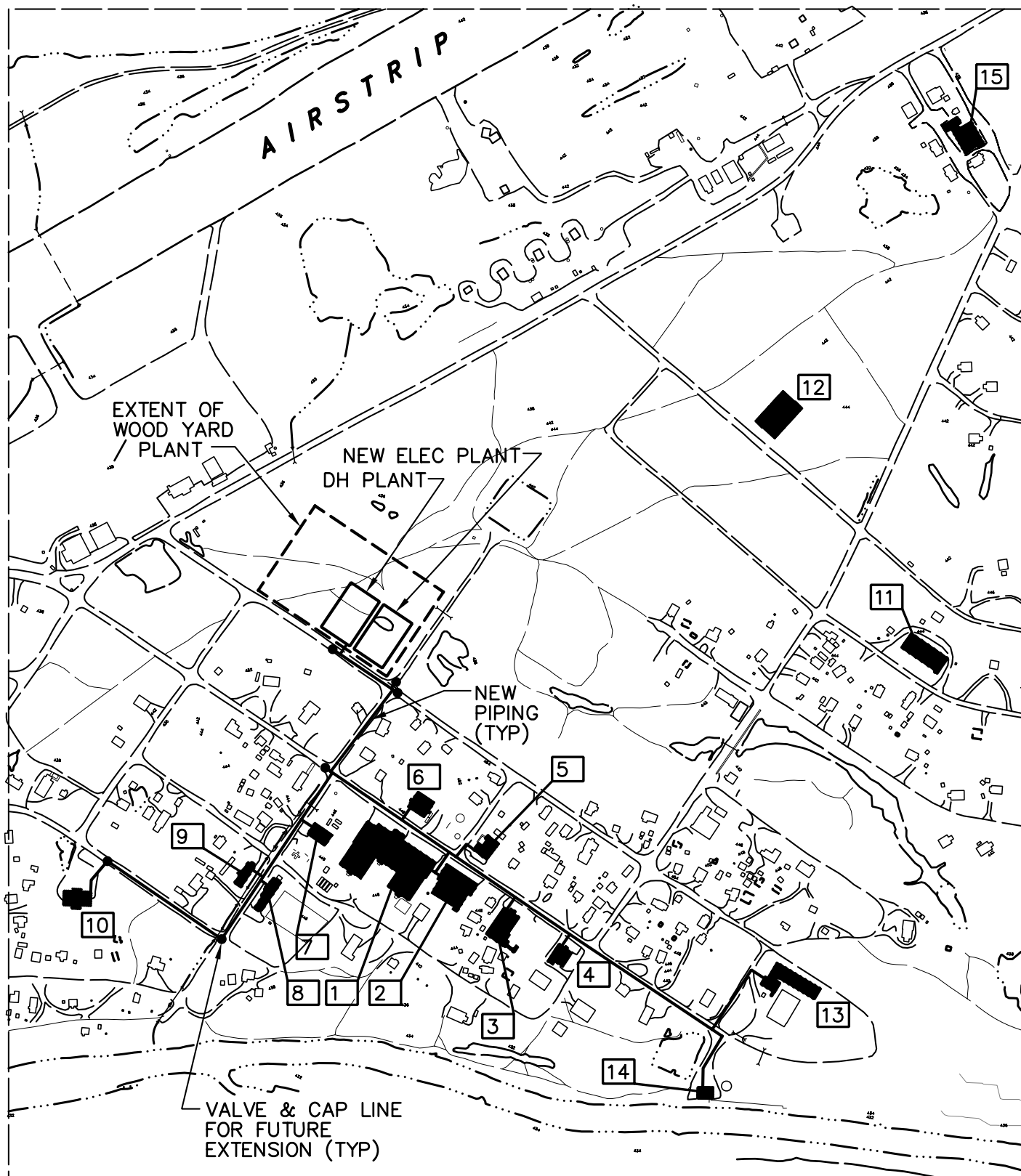




EXP PLANT 1
NTS

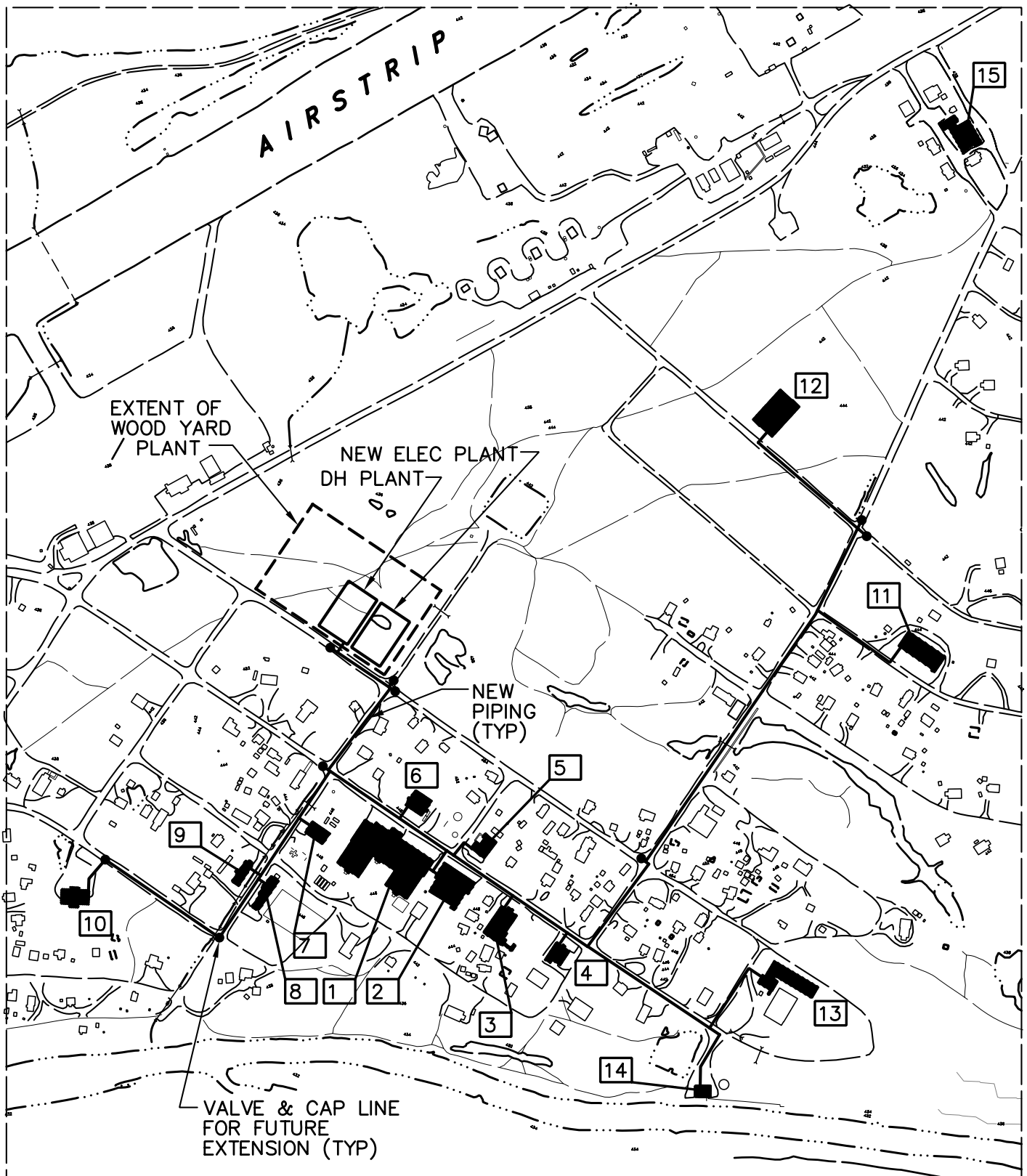


- | | | |
|----------------|--------------------|---------------------|
| 1. SCHOOL | 6. STATE BLDG | 11. CITY BLDG |
| 2. GYM | 7. SHOP | 12. NEW CATG CLINIC |
| 3. STORE | 8. DISTRICT OFFICE | 13. TRIBAL OFFICES |
| 4. POST OFFICE | 9. CHURCH | 14. WATER TREAT |
| 5. CATG OFFICE | 10. YUKON FLATS | 15. OLD CATG CLINIC |



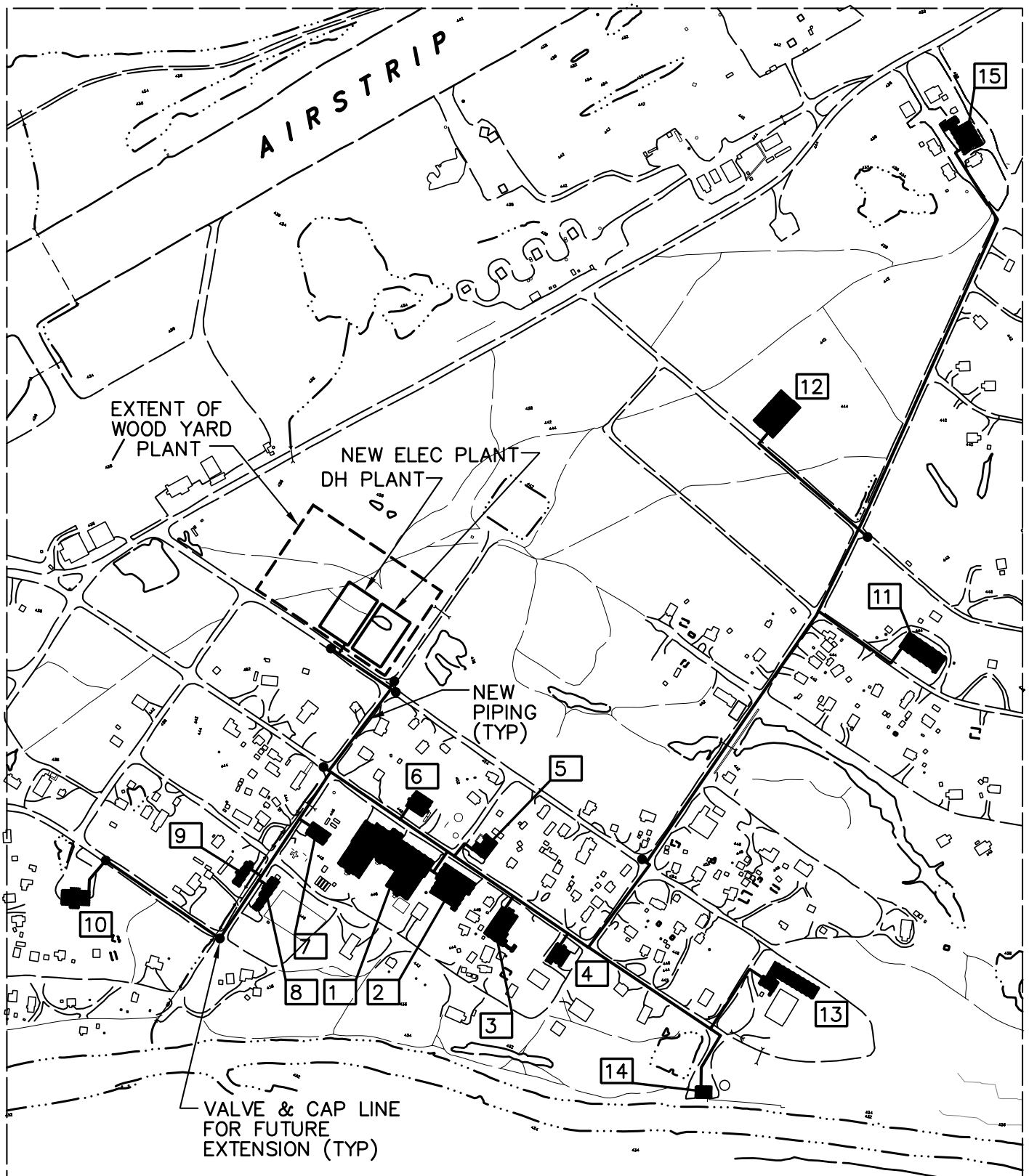
EXP PLANT 2
NTS





MAX PLANT 1
NTS





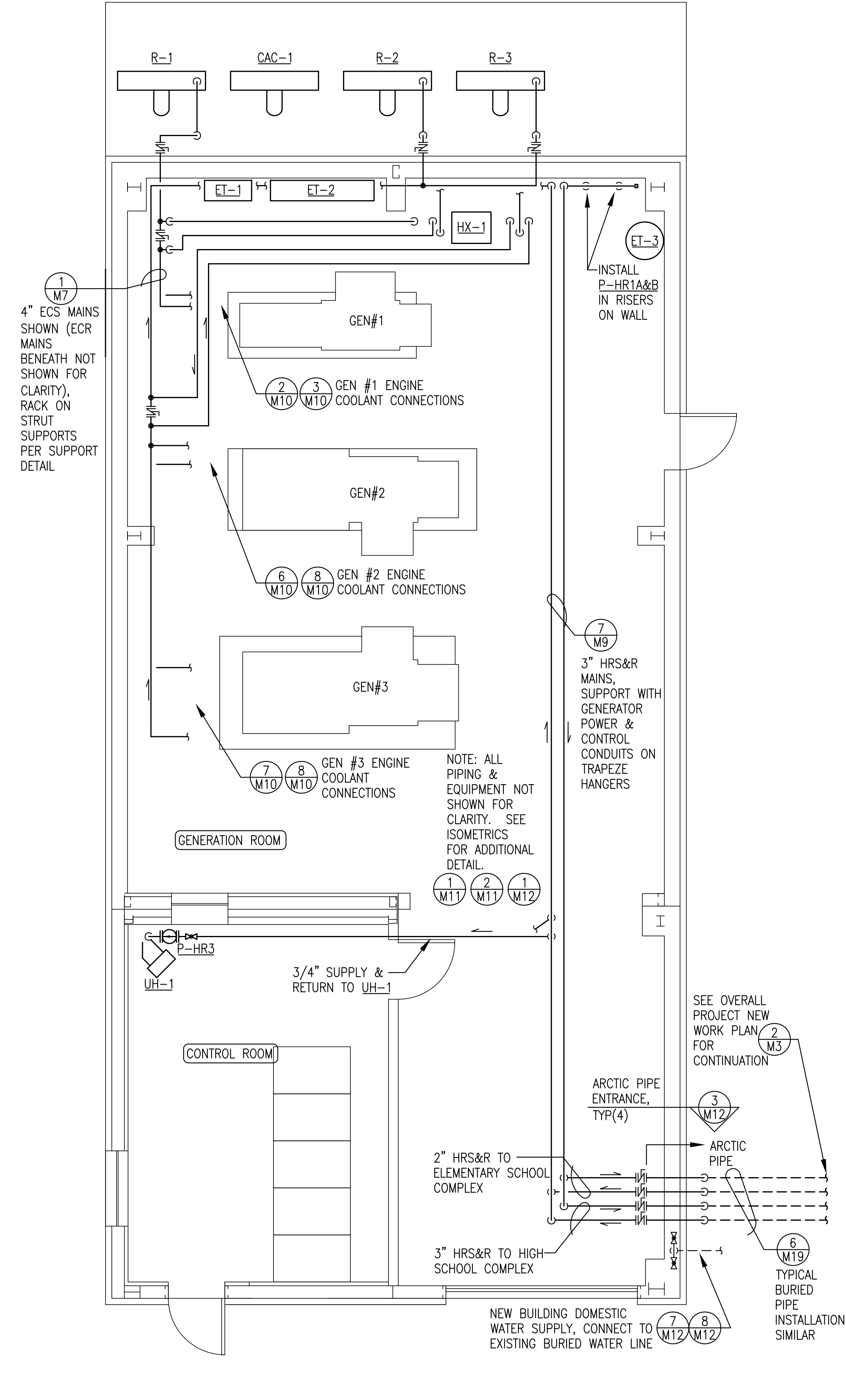
MAX PLANT 2
NTS



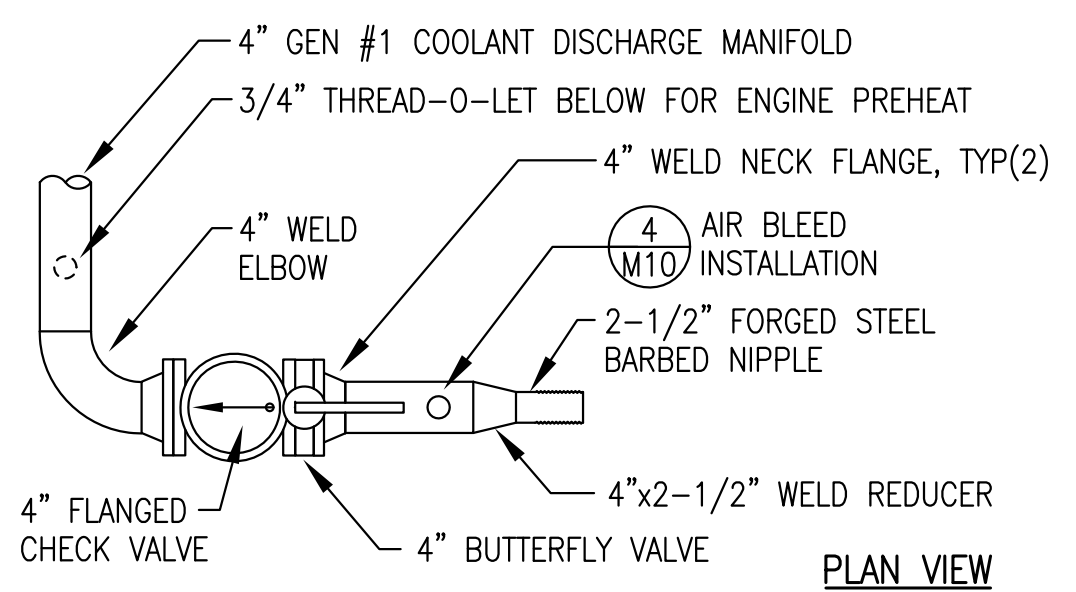
Appendix E:

Typical Design Documents, Heat Recovery from Engine Generators:

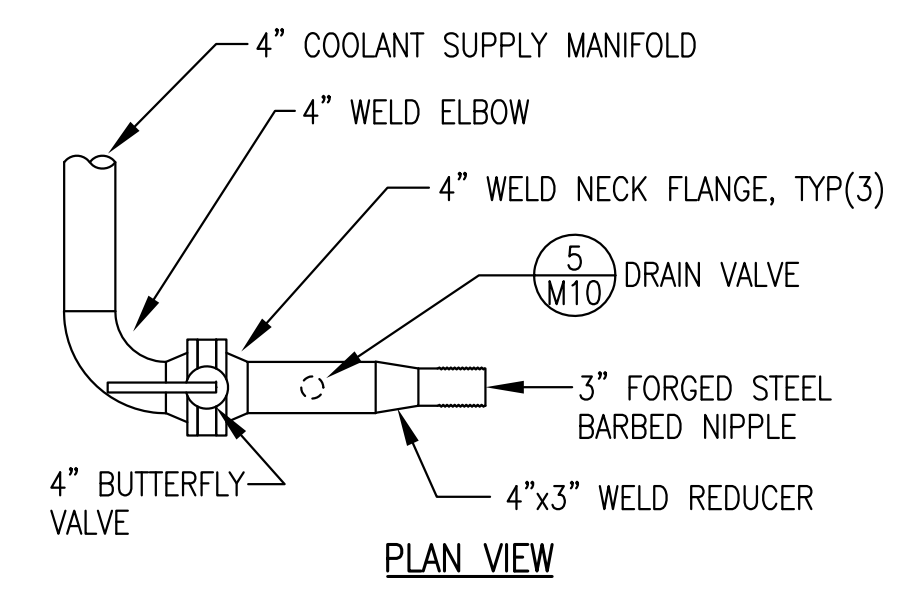
(These plans are from a previous job, but the methodology will be the same)



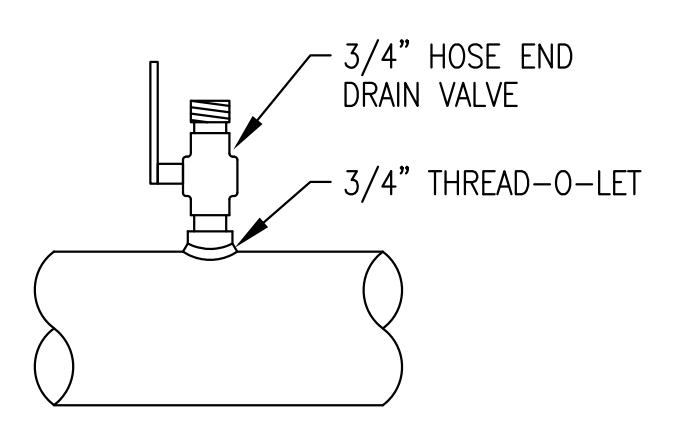
1 ENGINE COOLANT AND HEAT RECOVERY PIPING PLAN
M10 1/4"=1'



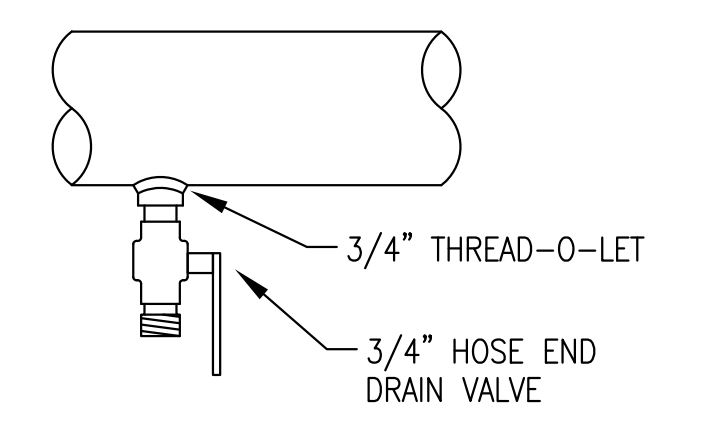
2 GENERATOR #1 DISCHARGE CONNECTION
M10 NO SCALE



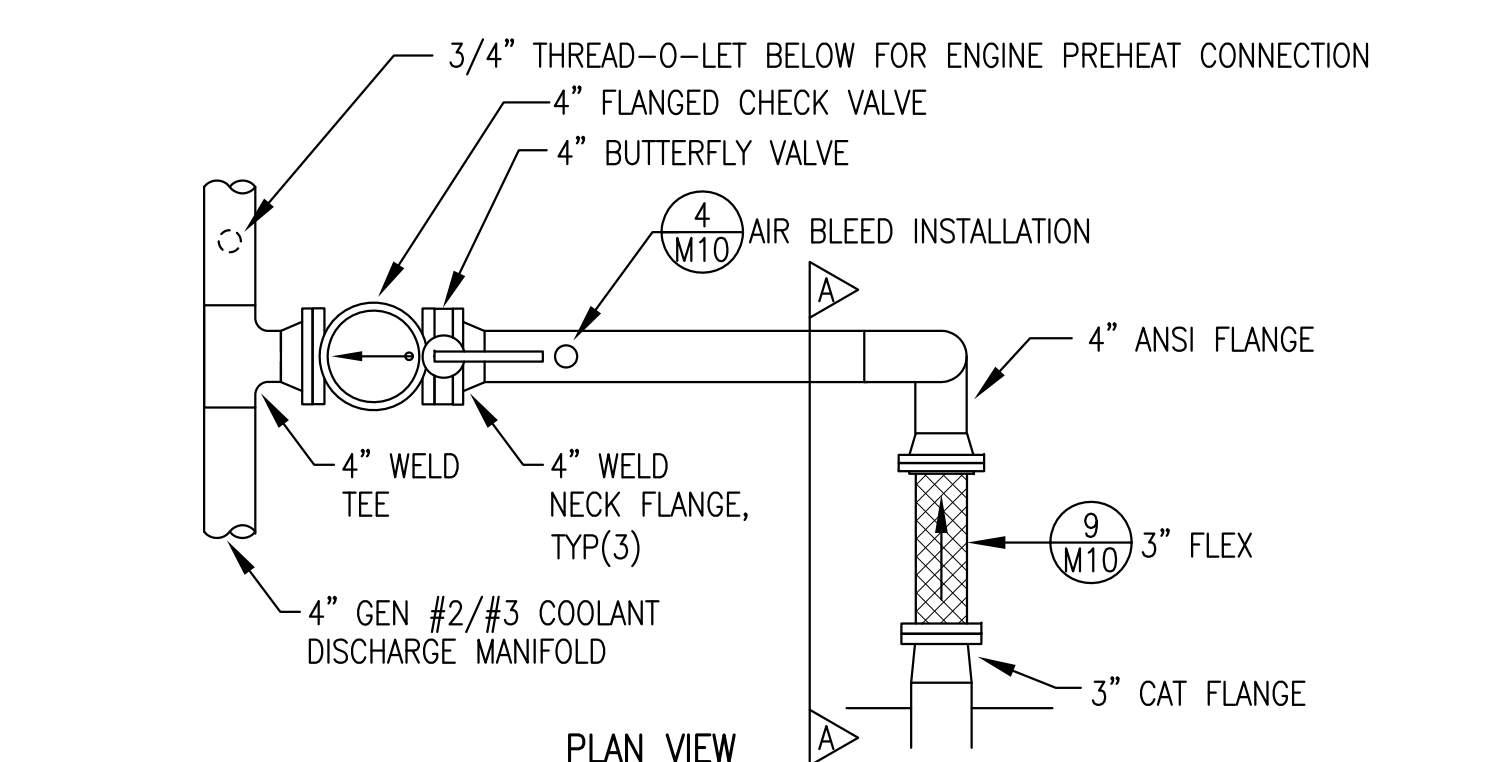
3 GENERATOR #1 INLET CONNECTION
M10 NO SCALE



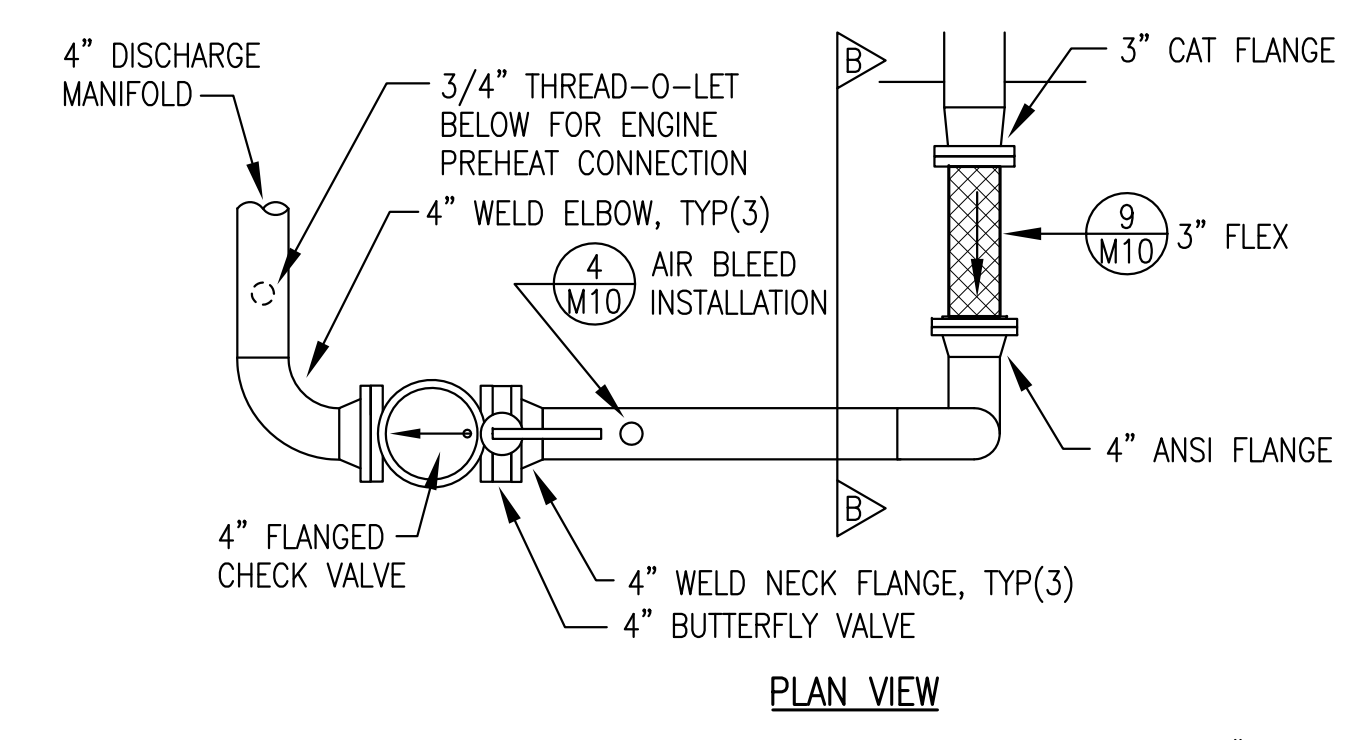
4 AIR BLEED INSTALLATION
M10 NO SCALE



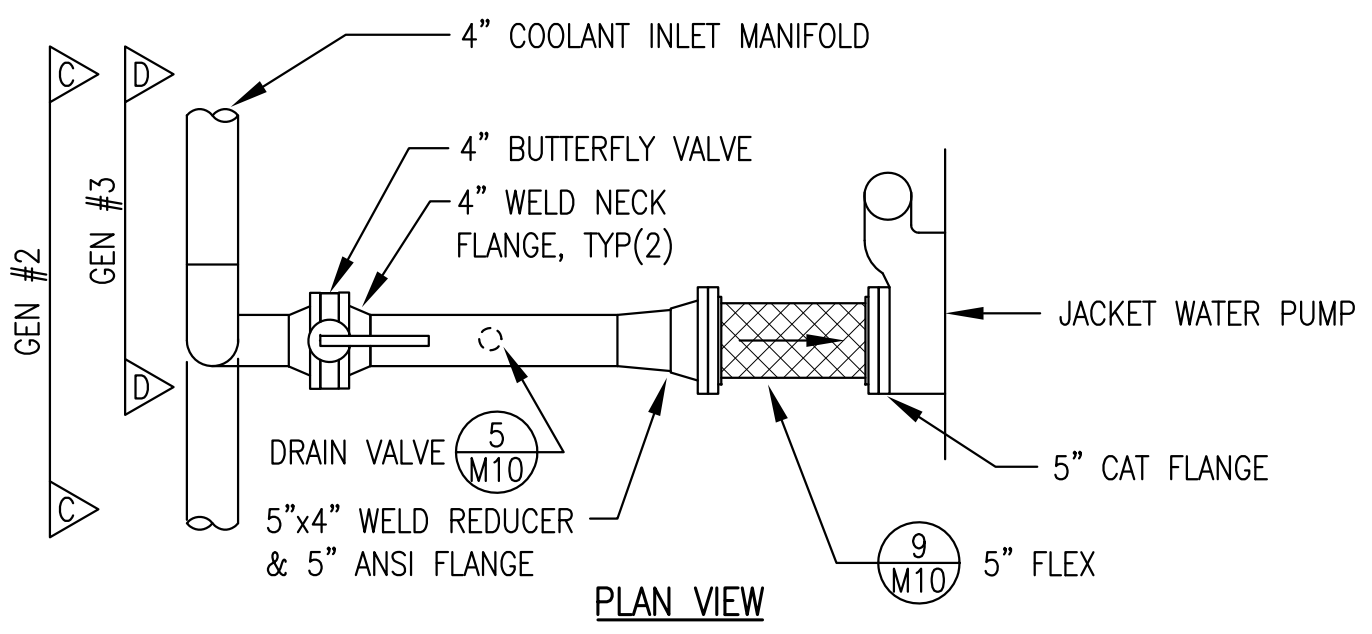
5 DRAIN INSTALLATION
M10 NO SCALE



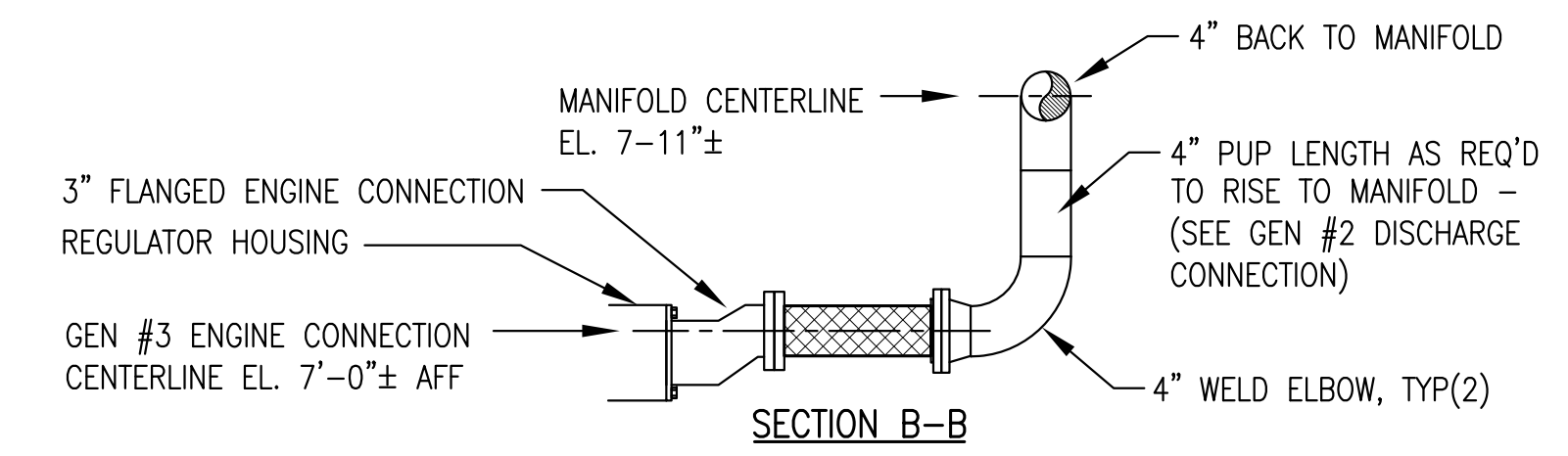
6 GENERATOR #2 DISCHARGE CONNECTION
M10 NO SCALE



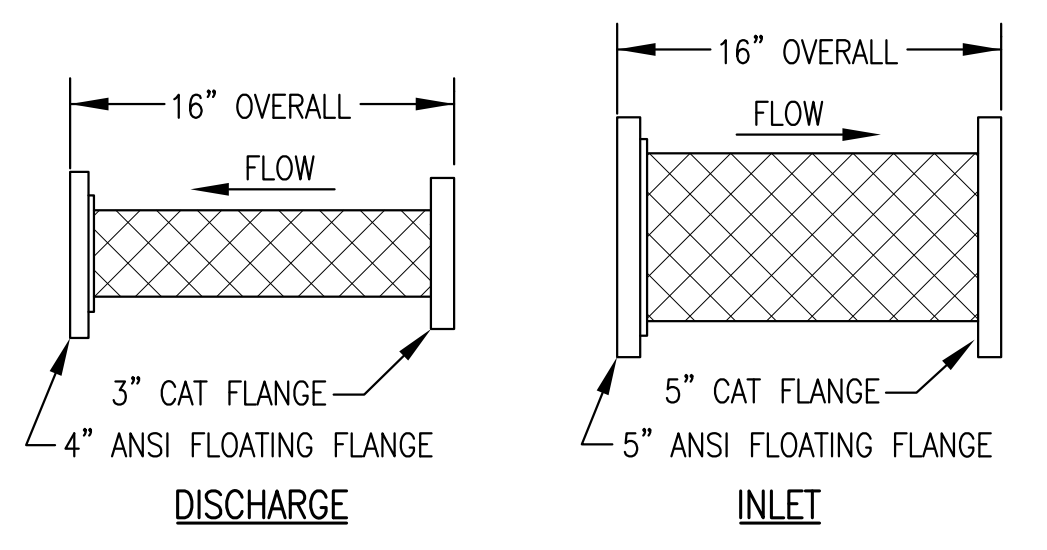
7 GENERATOR #3 DISCHARGE CONNECTION
M10 NO SCALE



8 GENERATOR #2 & #3 INLET CONNECTION
M10 NO SCALE



9 GEN #2 & #3 COOLANT FLEX CONNECTORS
M10 NO SCALE

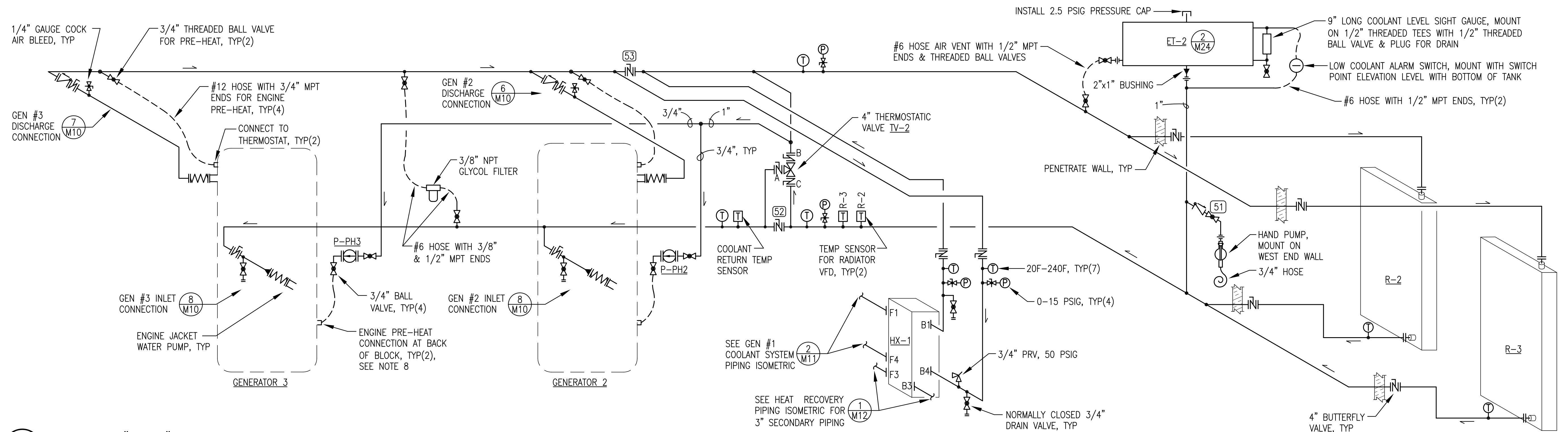


- NOTES:
- 1) FURNISH 2 EACH 3"x4" DISCHARGE FLEX CONNECTORS AND 2 EACH 5" INLET FLEX CONNECTORS.
 - 2) FABRICATE FROM TYPE 321 STAINLESS STEEL CORRUGATED HOSE WITH TYPE 304 STAINLESS STEEL WIRE DOUBLE BRAIDED OUTER SHIELD.
 - 3) PROVIDE WITH DROP-IN STAINLESS STEEL FLOW LINER IN DIRECTION SHOWN.
 - 4) FURNISH WITH CERTIFICATION OF MINIMUM 125 PSIG PRESSURE TEST.

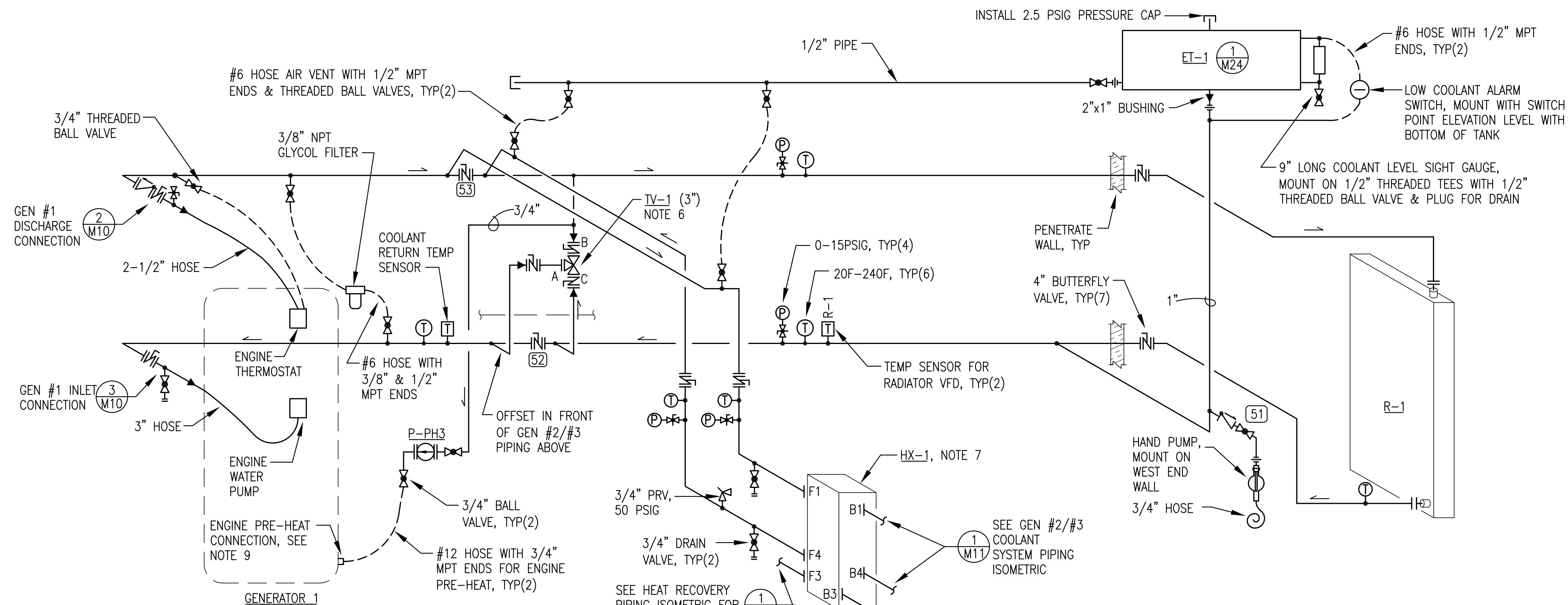
ISSUED FOR
CONSTRUCTION
MARCH 2008



State of Alaska Department of Community and Economic Development AIDEA/AEA Rural Energy Group 813 West Northern Lights Blvd. Anchorage, Alaska 99503 ALASKA ENERGY AUTHORITY			
PROJECT: ANGOON POWER SYSTEM UPGRADE			
TITLE: COOLANT & HEAT RECOVERY PIPING PLANS AND DETAILS			
ALASKA ENERGY AND ENGINEERING, INC P.O. BOX 111405 ANCHORAGE, ALASKA 99511-1405 PHONE (907) 349-0100			
DRAWN BY: JTD	SCALE: AS NOTED	FILE NAME: ANGPPM10	SHEET: M10 OF 24
DESIGNED BY: BCG	DATE: 3/4/08	PROJECT NUMBER: 04-02-9820	



1 GENERATOR #2 & #3 COOLANT SYSTEM PIPING ISOMETRIC
M11 NO SCALE

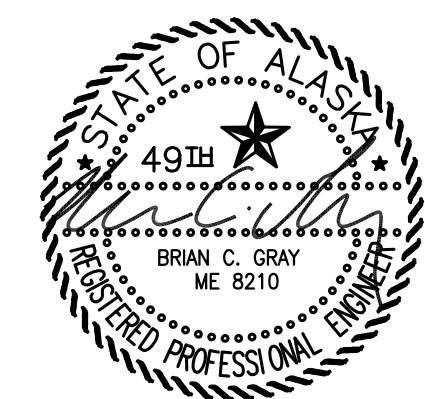


2 GENERATOR #1 COOLANT SYSTEM PIPING ISOMETRIC
M11 NO SCALE

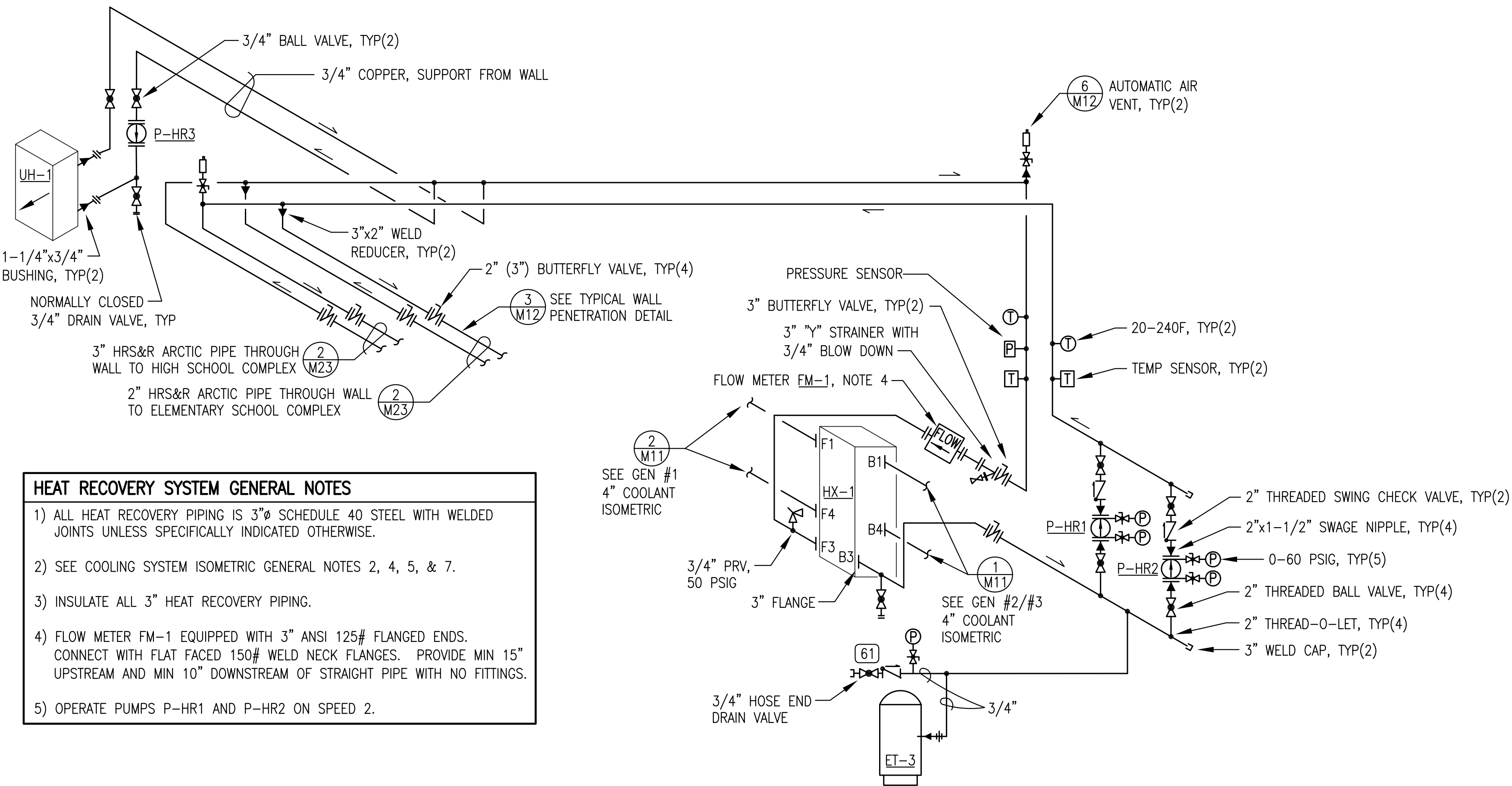
COOLING SYSTEM GENERAL NOTES

- ALL COOLANT PIPING IS 4"Ø SCHEDULE 40 STEEL WITH WELDED JOINTS UNLESS SPECIFICALLY INDICATED OTHERWISE. ALL PIPING SMALLER THAN 3"Ø IS SCHEDULE 40 STEEL WITH THREADED OR SOCKET WELD JOINTS UNLESS SPECIFICALLY INDICATED AS COPPER.
- ALL FLANGES ANSI 150# PATTERN SLIP-ON STYLE EXCEPT WHERE SPECIFICALLY INDICATED AS WELD NECK (ENGINE BRANCH CONNECTION TEES ONLY).
- INSULATE ALL INTERIOR 4" COOLANT PIPING MAINS AND 3" HEAT RECOVERY PIPING MAINS. ALL OTHER PIPING NOT INSULATED. CLEAN AND PAINT EXTERIOR OF ALL UNINSULATED PIPING, SEE SPECIFICATIONS.
- ON ALL SMALL DIAMETER HOSES INSTALL 37" JIC FEMALE SWIVEL FITTINGS WITH MALE FLARE MPT CONNECTORS, SIZE AS INDICATED.
- UNLESS SPECIFIED OTHERWISE MAKE ALL CONNECTIONS FOR INSTRUMENTATION, VENTS, PRE-HEAT LINES, GLYCOL FILTER LINES AND BLEED LINES WITH 3/4" THREAD-O-LET AND THREADED BUSHING AS REQUIRED.
- THERMOSTATIC VALVE TV-1 IS 3". INSTALL 4x3 CONCENTRIC WELD REDUCERS AND 3" BUTTERFLY VALVES AS SHOWN.
- FASTEN HEAT EXCHANGER HX-1 TO FLOOR SLAB WITH THREE EACH 5/8"x8" LONG STUD ANCHORS SET IN EPOXY. NOTE THAT ALL CONNECTIONS ARE STUDDED PORTS FOR ANSI 150# FLANGE CONNECTION: 3" SIZE FOR HEAT RECOVERY PORTS B3 & F3; 4" SIZE FOR COOLANT PORTS B1, F1, B4, & F4.
- REMOVE EXISTING ELECTRIC ENGINE BLOCK HEATERS AND DISCONNECT EXISTING SUPPLY AND RETURN HOSES FROM ENGINE BLOCK. PLUG ONE ENGINE BLOCK CONNECTION AND CONNECT NEW PREHEAT HOSE TO OTHER.
- CONNECT NEW PREHEAT HOSE TO FACTORY CONNECTION POINT FOR OPTIONAL ELECTRIC BLOCK HEATER.
- UPON COMPLETION OF FABRICATION FLUSH INTERIOR OF PIPING TO REMOVE ALL DEBRIS AND RESIDUE PRIOR TO FILLING SYSTEM.

ISSUED FOR
CONSTRUCTION
MARCH 2008

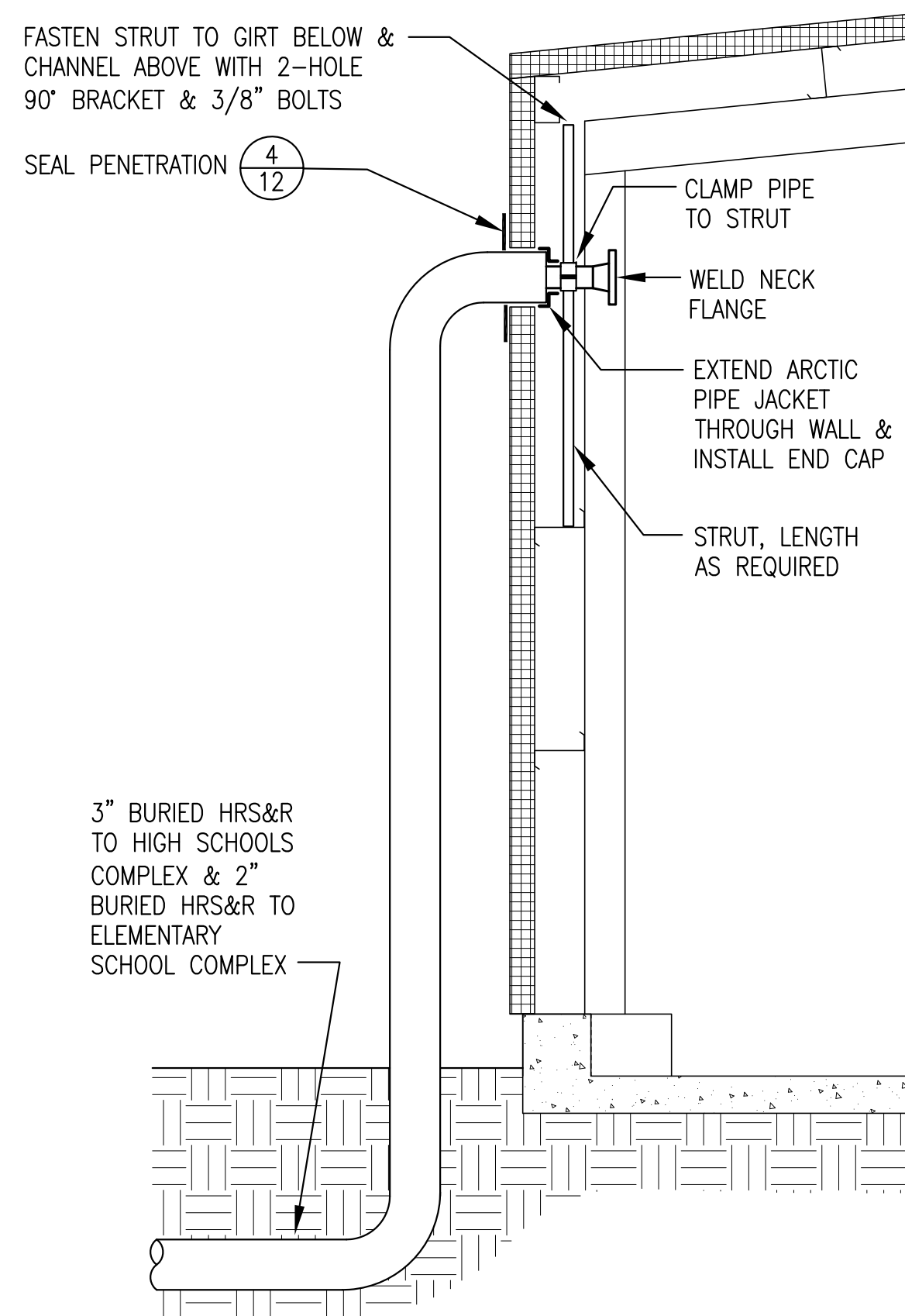
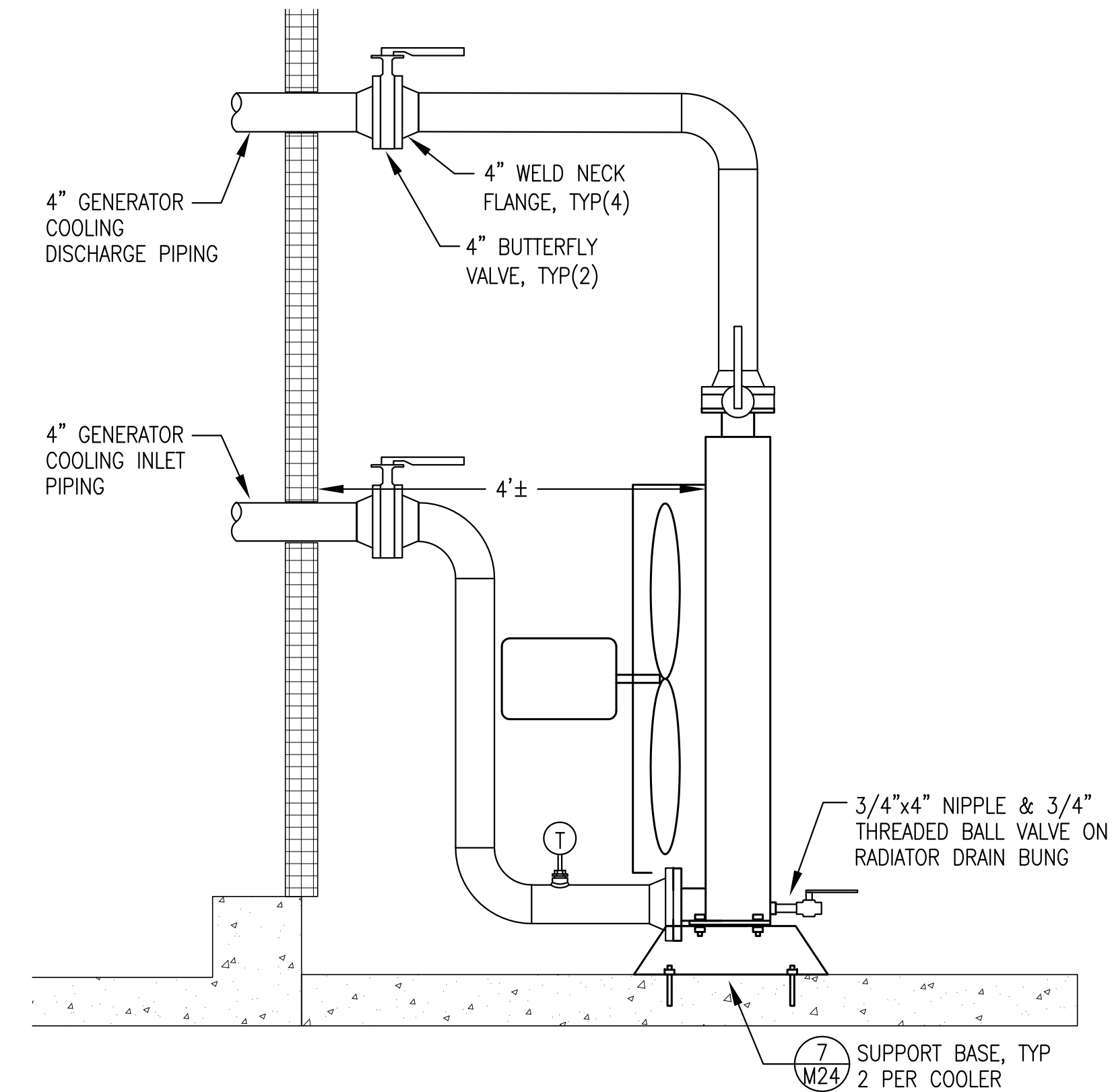


State of Alaska Department of Community and Economic Development AIDEA/AEA Rural Energy Group 813 West Northern Lights Blvd. Anchorage, Alaska 99503 ALASKA ENERGY AUTHORITY			
PROJECT: ANGOON POWER SYSTEM UPGRADE			
TITLE: COOLANT PIPING ISOMETRICS			
ALASKA ENERGY AND ENGINEERING, INC P.O. BOX 111405 ANCHORAGE, ALASKA 99511-1405 PHONE (907) 349-0100			
DRAWN BY: JTD	SCALE: NO SCALE	FILE NAME: ANGPPM11	SHEET: M11 OF 24
DESIGNED BY: BCG	DATE: 3/4/08	PROJECT NUMBER: 04-02-9820	

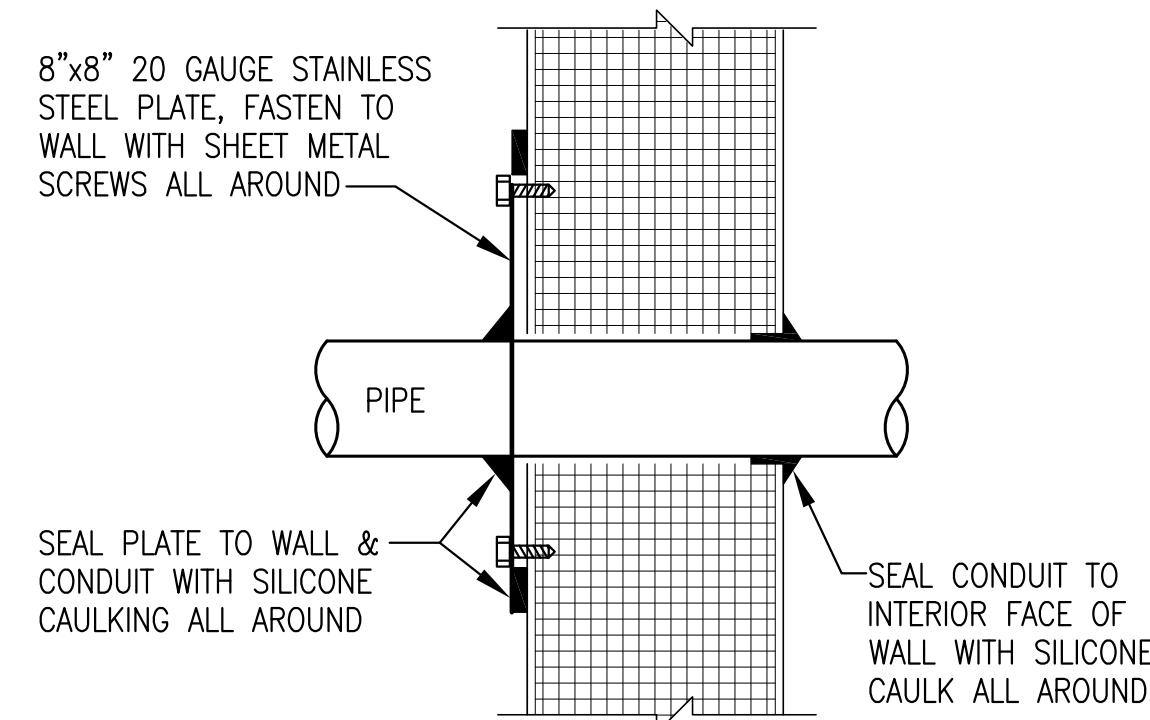


1 HEAT RECOVERY SYSTEM ISOMETRIC
NO SCALE

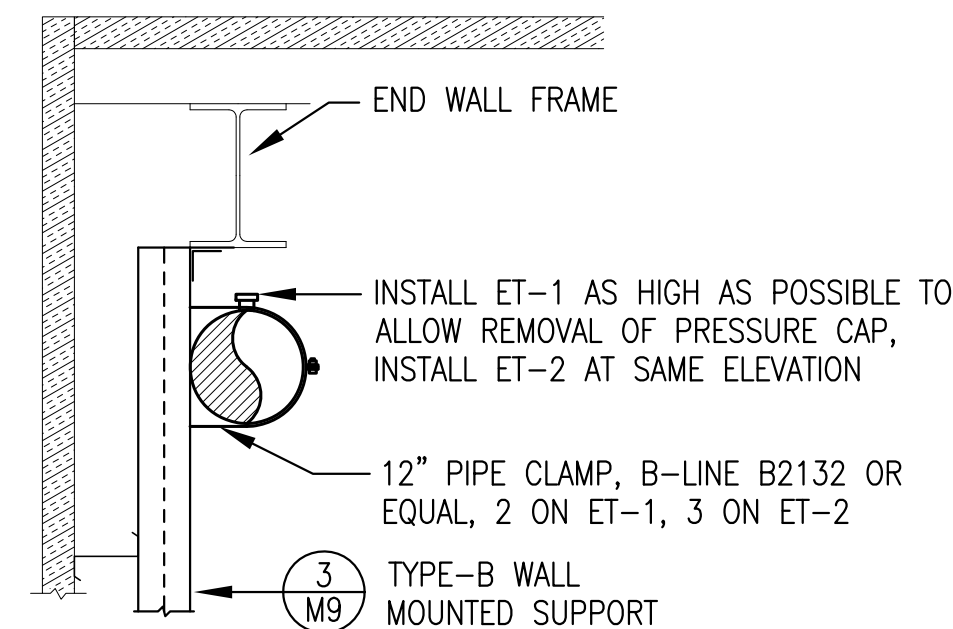
2 RADIATOR R-2 & R-3 INSTALLATION (R-1 SIMILAR)
3/4"=1'



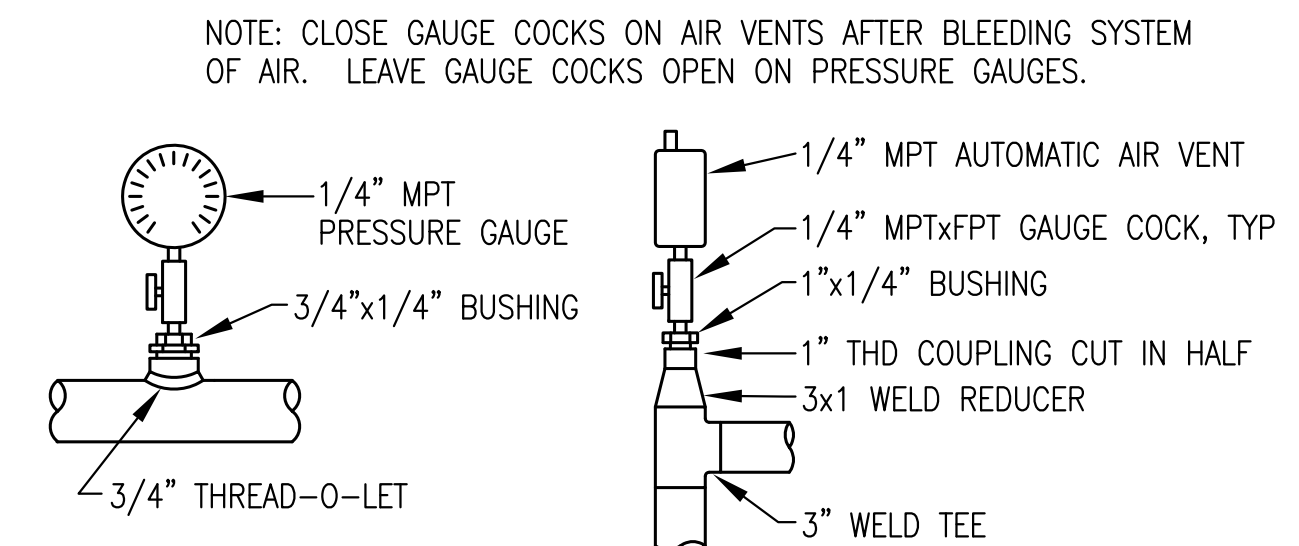
3 POWER PLANT ARCTIC PIPE BUILDING ENTRANCE
NO SCALE



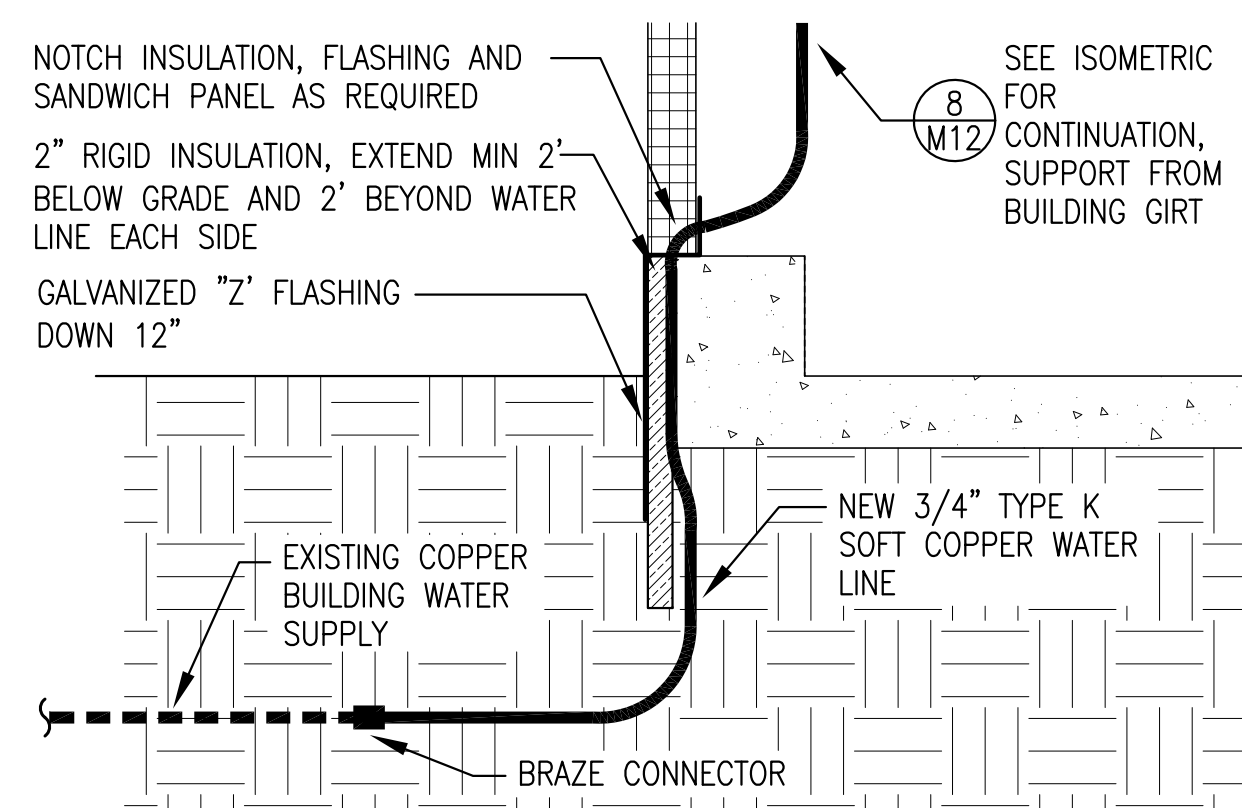
4 TYPICAL WALL PENETRATION
NO SCALE



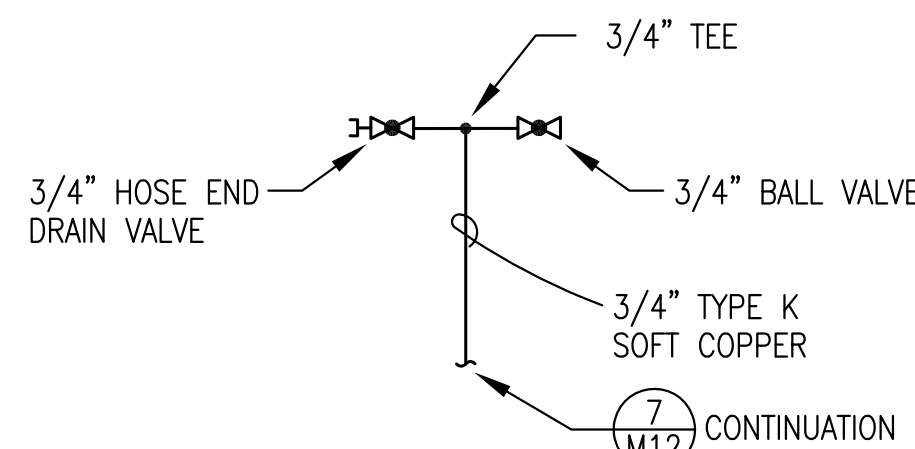
5 ET-1/ ET-2 INSTALLATION & SUPPORT
NO SCALE



6 TYPICAL AIR VENT & PRESSURE GAUGE
NO SCALE

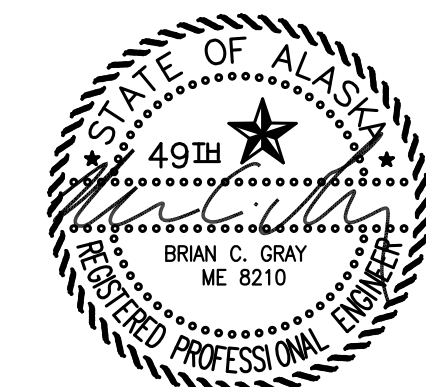


7 WATER SUPPLY BUILDING ENTRANCE
NO SCALE



8 WATER SUPPLY ISOMETRIC
NO SCALE

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CONSTRUCTION
MARCH 2008



State of Alaska Department of Community and Economic Development AIDEA/AEA Rural Energy Group 813 West Northern Lights Blvd. Anchorage, Alaska 99503 ALASKA ENERGY AUTHORITY			
PROJECT: ANGOON POWER SYSTEM UPGRADE			
TITLE: HEAT RECOVERY PIPING ISOMETRICS & DETAILS			
ALASKA ENERGY AND ENGINEERING, INC P.O. BOX 111405 ANCHORAGE, ALASKA 99511-1405 PHONE (907) 349-0100			
DRAWN BY: JTD	SCALE: AS NOTED	FILE NAME: ANGPPM12	SHEET: M12 OF 24
DESIGNED BY: BCG	DATE: 3/4/08	PROJECT NUMBER: 04-02-9820	

Appendix F:

Main Summary, DH Plant Summary Sheets, and Key Inputs:

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Summary
C:\Documents and Settings\gk\Desktop\w\Fort Yukon\L3 Ph I\FY L3 I 1 ver 11.xls

Summary

Buildings included	On	Inputs	(dark text are user inputs)		
1 School	1	cost of oil :	\$4.00	per gallon	
2 Gym	1	cost of electricity :	\$0.48	per kWh	
3 Store	1	cost of wood :	\$175.00	per GT	
4 Post Office	1				
5 CATG Main Office	1	MC of wood at use :	0.25	MC	
6 State Building	1	unit heat content :	5,315	BTU/lb	
7 Shop (adj School)	1				
8 District Office	1	soil conditions :	(for heat loss calcs, select only one)		
9 Church	1	dry :			
10 Yukon Flats	1	med :	1		
11 City Building	1	moist :			
12 New CATG Clinic	1				
13 Tribal Offices	1	Biomass Boilers :	B-1 model	B-2 Model	choices
14 Water Treat	1	Base Plant :	530		390
15 Old CATG Clinic	1	Expanded Plant 1 :	950		530
16 City DHW Load	1	Expanded Plant 2 :	720		720
		Maximum Plant 1 :	950		950
include Heat Recovery	1	Maximum Plant 2 :	390	950	1,250

Results

(see Individual Plant Summary sheets for more details)

Financial	Base	Exp 1	Exp 2	Max 1	Max 2
current annual cost to heat connected buildings :	\$431,228	\$547,228	\$481,376	\$597,376	\$621,376
proposed annual cost of oil, DH Plant :	\$16,152	\$40,285	\$21,481	\$48,248	\$292
proposed annual cost of wood chips, DH Plant :	\$157,393	\$236,122	\$192,243	\$269,201	\$316,395
proposed annual cost of electrical energy, DH Plant :	\$66,378	\$101,150	\$77,626	\$70,522	\$121,982
total annual proposed costs, DH Plant :	\$239,922	\$377,557	\$291,350	\$387,971	\$438,669
savings :	\$191,306	\$169,671	\$190,026	\$209,405	\$182,707
estimated total DH plant cost :	\$2,501,751	\$2,886,217	\$2,563,315	\$3,100,228	\$3,659,476
net simple payback :	13.1 yrs	17.0 yrs	13.5 yrs	14.8 yrs	20.0 yrs
Inputs	Base	Exp 1	Exp 2	Max 1	Max 2
current annual oil consumption, connected bldgs, gal :	107,807	136,807	120,344	149,344	155,344
proposed annual oil consumption, gal :	4,038	10,071	5,370	12,062	73
proposed annual wood consumption, green tons :	899	1,349	1,099	1,538	1,808
proposed annual electrical energy consumption, kWh :	138,287	210,730	161,721	146,920	254,130
fraction of oil displaced :	0.963	0.926	0.955	0.919	1.000
Heat Sources, unit	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat from oil, kBTU :	449,103	1,120,118	597,292	1,341,548	8,106
annual heat recovered from Power Plant, kBTU :	5,285,120	5,513,598	5,407,258	5,524,605	5,559,001
annual heat from wood chips, kBTU :	8,030,058	12,046,738	9,808,062	13,734,424	16,142,238
Heat Sources, fraction	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat from oil :	0.033	0.060	0.038	0.065	0.000
annual heat recovered from Power Plant :	0.384	0.295	0.342	0.268	0.256
annual heat from wood chips :	0.583	0.645	0.620	0.667	0.744
Heat Sinks, unit	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat to buildings, kBTU :	11,990,295	15,215,675	13,384,660	16,610,040	17,277,360
annual heat to piping losses, kBTU :	1,397,094	3,087,885	2,051,057	3,613,643	4,055,091
annual heat to plant, kBTU :	376,894	376,894	376,894	376,894	376,894
Heat Sinks, fraction	Base	Exp 1	Exp 2	Max 1	Max 2
annual heat to buildings :	0.871	0.815	0.846	0.806	0.796
annual heat to piping losses :	0.102	0.165	0.130	0.175	0.187
annual heat to plant :	0.027	0.020	0.024	0.018	0.017

Summary

Base DH Plant

Buildings included		DH Plant	
1	School	maximum plant load:	3,827 kBTU/h
2	Gym	coincident heat recovery available:	971 kBTU/h
3	Store	fraction of heat from HR at peak:	0.254
4	Post Office		
5	CATG Main Office	est minimum boiler capacity:	2,856 kBTU/h
6	State Building	est minimum boiler capacity:	837 kW(th)
7	Shop (adj School)		
8	District Office	use Weissmann model:	530 (from Summary)
9	Church	maximum capacity:	1,808
10	Yukon Flats	minimum capacity:	723
11	City Building		
12	New CATG Clinic	predicted plant flow rate:	320 gpm
13	Tribal Offices	pipe length to design load:	2,726 ft
14	Water Treat	estimated secondary pump head:	162 ft
15	Old CATG Clinic	estimated pump efficiency:	0.740
16	City DHW Load	peak secondary pump power:	13.2 kW
		estimated primary pump head:	50 ft
		peak primary pump power:	4.1 kW
		estimated plant parasitic power:	7.5 kW

Results

DH Plant runs : 1 1 1 1 1 1 1 1 1 1 1 1 1 1															
Current		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	
oil gal :		15,023	14,275	13,609	7,444	4,676	2,587	2,612	3,720	5,563	10,561	12,386	15,350	107,807	
cost \$:		60,094	57,101	54,437	29,774	18,704	10,350	10,446	14,882	22,250	42,243	49,546	61,401	\$431,228	
Predicted		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	fraction
oil gal :		621	1,221	526	10	88	106	285	296	83	133	55	614	4,038	
cost \$:		2,485	4,883	2,103	42	353	422	1,141	1,183	331	534	221	2,455	\$16,152	0.067
wood tons :		127	116	131	62	40	7	5	25	52	100	104	132	899	
cost \$:		22,275	20,314	22,982	10,852	6,942	1,141	829	4,344	9,075	17,465	18,150	23,023	\$157,393	0.656
electricity kWh :		12,841	12,100	12,191	10,723	11,067	10,710	11,067	11,067	10,710	11,372	11,441	12,998	138,287	
cost \$:		6,164	5,808	5,852	5,147	5,312	5,141	5,312	5,312	5,141	5,458	5,492	6,239	\$66,378	0.277
total cost		30,923	31,005	30,937	16,041	12,607	6,705	7,282	10,839	14,547	23,457	23,862	31,717	\$239,922	1.000
savings		29,170	26,096	23,500	13,733	6,097	3,645	3,164	4,042	7,703	18,786	25,684	29,684	\$191,306	
														estimated construction cost :	\$2,501,751
														net simple payback :	13.08 yrs
Heat Sources		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
from oil kBTU :		69,093	135,785	58,470	1,163	9,809	11,744	31,720	32,886	9,196	14,839	6,133	68,267	449,103	0.033
from HR kBTU :		666,938	603,907	471,513	404,616	267,090	311,805	313,257	263,465	262,122	430,261	621,274	668,872	5,285,120	0.384
from wood kBTU :		1,136,444	1,036,387	1,172,542	553,653	354,187	58,229	42,316	221,640	463,007	891,050	926,004	1,174,598	8,030,058	0.583
(assumes plant runs all year)														total :	13,764,282
Heat Sinks		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
to load kBTU :		1,670,907	1,587,696	1,513,625	827,867	520,076	287,780	290,463	413,784	618,667	1,174,561	1,377,626	1,707,242	11,990,295	0.871
to piping kBTU :		137,366	126,271	132,961	110,832	104,784	93,715	96,640	101,550	104,897	123,464	126,230	138,384	1,397,094	0.102
to plant kBTU :		64,203	62,113	55,939	20,733	6,225	282	190	2,658	10,760	38,125	49,555	66,112	376,894	0.027
(assumes plant runs all year)														total :	13,764,282
														gallons of oil displaced :	103,769
														fraction of oil displaced :	0.963

Summary

Expanded DH Plant 1

Buildings included	DH Plant
1 School	maximum plant load: 5,091 kBTU/h
2 Gym	coincident heat recovery available: 971 kBTU/h
3 Store	fraction of heat from HR at peak: 0.191
4 Post Office	
5 CATG Main Office	est minimum boiler capacity: 4,120 kBTU/h
6 State Building	est minimum boiler capacity: 1,208 kW(th)
7 Shop (adj School)	
8 District Office	use Weissmann model: 950 (from Summary)
9 Church	maximum capacity: 3,241
10 Yukon Flats	minimum capacity: 1,297
11 City Building	
12 New CATG Clinic	predicted plant flow rate: 420 gpm
13 Tribal Offices	pipe length to design load: 6,986 ft
14 Water Treat	estimated secondary pump head: 322 ft
15 Old CATG Clinic	estimated pump efficiency: 0.740
16 City DHW Load	peak secondary pump power: 34.4 kW
	estimated primary pump head: 50 ft
	peak primary pump power: 5.3 kW
	estimated plant parasitic power: 7.5 kW

Results

DH Plant runs :	1	1	1	1	1	1	1	1	1	1	1	1		
Current	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	
oil gal :	19,256	18,312	17,414	9,391	5,780	3,098	3,122	4,537	6,941	13,442	15,831	19,682	136,807	
cost \$:	77,025	73,248	69,655	37,565	23,120	12,391	12,490	18,150	27,765	53,768	63,324	78,727	\$547,228	
Predicted	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	fraction
oil gal :	245	551	69	396	1,669	1,403	1,854	2,378	1,350			157	10,071	
cost \$:	979	2,203	277	1,584	6,678	5,610	7,417	9,510	5,398			629	\$40,285	0.107
wood tons :	203	192	202	99	40	1	1	17	66	155	165	210	1,349	
cost \$:	35,582	33,583	35,435	17,263	6,952	191	114	2,901	11,521	27,044	28,792	36,743	\$236,122	0.625
electricity kWh :	21,010	20,295	19,237	15,493	15,958	15,443	15,958	15,958	15,443	16,868	17,635	21,433	210,730	
cost \$:	10,085	9,742	9,234	7,437	7,660	7,413	7,660	7,660	7,413	8,097	8,465	10,288	\$101,150	0.268
total cost	46,645	45,527	44,946	26,284	21,290	13,214	15,191	20,071	24,332	35,141	37,256	47,660	\$377,557	1.000
savings	30,379	27,721	24,710	11,281	1,830	(822)	(2,701)	(1,922)	3,432	18,628	26,068	31,067	\$169,671	
													estimated construction cost :	\$2,886,217
													net simple payback :	17.01 yrs
Heat Sources	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
from oil kBTU	27,216	61,248	7,690	44,036	185,673	155,997	206,221	264,437	150,103			17,498	1,120,118	0.060
from HR kBTU	666,922	603,246	471,012	385,387	340,305	386,234	349,012	319,295	276,689	426,275	620,348	668,872	5,513,598	0.295
from wood kBTU	1,815,348	1,713,380	1,807,874	880,754	354,696	9,724	5,835	148,023	587,811	1,379,757	1,468,922	1,874,613	12,046,738	0.645
(assumes plant runs all year)													total :	18,680,453
Heat Sinks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
to load kBTU	2,141,675	2,036,674	1,936,765	1,044,481	642,852	344,541	347,283	504,650	771,997	1,495,025	1,760,719	2,189,014	15,215,675	0.815
to piping kBTU	303,609	279,086	293,872	244,964	231,597	207,132	213,595	224,447	231,846	272,883	278,996	305,858	3,087,885	0.165
to plant kBTU	64,203	62,113	55,939	20,733	6,225	282	190	2,658	10,760	38,125	49,555	66,112	376,894	0.020
(assumes plant runs all year)													total :	18,680,453
													gallons of oil displaced :	126,736
													fraction of oil displaced :	0.926

Summary

Expanded DH Plant 2

Buildings included	DH Plant
1 School	maximum plant load: 4,306 kBTU/h
2 Gym	coincident heat recovery available: 971 kBTU/h
3 Store	fraction of heat from HR at peak: 0.226
4 Post Office	
5 CATG Main Office	est minimum boiler capacity: 3,335 kBTU/h
6 State Building	est minimum boiler capacity: 977 kW(th)
7 Shop (adj School)	
8 District Office	use Weissmann model: 720 (from Summary)
9 Church	maximum capacity: 2,457
10 Yukon Flats	minimum capacity: 983
11 City Building	
12 New CATG Clinic	predicted plant flow rate: 360 gpm
13 Tribal Offices	pipe length to design load: 4,180 ft
14 Water Treat	estimated secondary pump head: 217 ft
15 Old CATG Clinic	estimated pump efficiency: 0.740
16 City DHW Load	peak secondary pump power: 19.9 kW
	estimated primary pump head: 50 ft
	peak primary pump power: 4.6 kW
	estimated plant parasitic power: 7.5 kW

Results

DH Plant runs :		1	1	1	1	1	1	1	1	1	1	1			
Current		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	
oil	gal	16,699	15,862	15,137	8,324	5,272	2,972	3,003	4,217	6,246	11,770	13,783	17,059	120,344	
cost	\$	66,795	63,448	60,547	33,294	21,088	11,887	12,012	16,870	24,985	47,079	55,131	68,238	\$481,376	
Predicted		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	fraction
oil	gal	325	690	140	83	611	635	1,044	1,092	498	14		237	5,370	
cost	\$	1,300	2,761	558	334	2,446	2,541	4,175	4,369	1,993	55		950	\$21,481	0.074
wood	tons	159	149	162	80	42	3	2	24	61	123	128	165	1,099	
cost	\$	27,833	26,097	28,379	14,043	7,417	501	308	4,205	10,611	21,525	22,485	28,839	\$192,243	0.660
electricity	kWh	15,432	14,682	14,447	12,296	12,682	12,273	12,682	12,682	12,273	13,166	13,437	15,669	161,721	
cost	\$	7,407	7,047	6,935	5,902	6,087	5,891	6,087	6,087	5,891	6,320	6,450	7,521	\$77,626	0.266
total cost	\$	36,540	35,906	35,872	20,279	15,950	8,933	10,571	14,661	18,495	27,900	28,935	37,310	\$291,350	1.000
savings	\$	30,254	27,543	24,675	13,015	5,138	2,955	1,441	2,209	6,491	19,179	26,197	30,928	\$190,026	
													estimated construction cost	\$2,563,315	
													net simple payback	13.49 yrs	
Heat Sources		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
from oil	kBTU	36,153	76,781	15,526	9,278	68,009	70,645	116,096	121,467	55,402	1,522		26,413	597,292	0.038
from HR	kBTU	666,925	603,446	471,264	383,449	300,020	372,198	344,249	284,791	262,708	428,698	620,638	668,872	5,407,258	0.342
from wood	kBTU	1,420,012	1,331,442	1,447,860	716,467	378,393	25,549	15,722	214,550	541,371	1,098,196	1,147,162	1,471,338	9,808,062	0.620
(assumes plant runs all year)													total	15,812,611	
Heat Sinks		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
to load	kBTU	1,857,222	1,764,179	1,683,513	925,749	586,365	330,527	334,002	469,066	694,722	1,309,035	1,532,929	1,897,353	13,384,660	0.846
to piping	kBTU	201,665	185,377	195,198	162,712	153,833	137,583	141,876	149,084	153,998	181,256	185,317	203,159	2,051,057	0.130
to plant	kBTU	64,203	62,113	55,939	20,733	6,225	282	190	2,658	10,760	38,125	49,555	66,112	376,894	0.024
(assumes plant runs all year)													total	15,812,611	
													gallons of oil displaced	114,974	
													fraction of oil displaced	0.955	

Summary

Max DH Plant 1

Buildings included	DH Plant
1 School	maximum plant load: 5,551 kBTU/h
2 Gym	coincident heat recovery available: 971 kBTU/h
3 Store	fraction of heat from HR at peak: 0.175
4 Post Office	
5 CATG Main Office	est minimum boiler capacity: 4,580 kBTU/h
6 State Building	est minimum boiler capacity: 1,342 kW(th)
7 Shop (adj School)	
8 District Office	use Weissmann model: 950 (from Summary)
9 Church	maximum capacity: 3,241
10 Yukon Flats	minimum capacity: 1,297
11 City Building	
12 New CATG Clinic	predicted plant flow rate: 460 gpm
13 Tribal Offices	pipe length to design load: 6,986 ft
14 Water Treat	estimated secondary pump head: 322 ft
15 Old CATG Clinic	estimated pump efficiency: 0.740
16 City DHW Load	peak secondary pump power: 37.7 kW
	estimated primary pump head: 50 ft
	peak primary pump power: 5.9 kW
	estimated plant parasitic power: 7.5 kW

Results

DH Plant runs :	1	1	1	1	1	1	1	1	1	1	1	1		
Current	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	
oil gal :	20,931	19,899	18,941	10,271	6,376	3,482	3,514	5,034	7,625	14,651	17,227	21,391	149,344	
cost \$:	83,726	79,596	75,765	41,085	25,504	13,929	14,056	20,138	30,500	58,605	68,909	85,565	\$597,376	
Predicted	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	fraction
oil gal :	643	1,320	320	165	1,412	1,965	2,474	2,215	928	52	6	562	12,062	
cost \$:	2,571	5,281	1,278	659	5,650	7,862	9,897	8,859	3,712	208	24	2,249	\$48,248	0.124
wood tons :	225	207	224	112	56	4	2	32	83	174	187	232	1,538	
cost \$:	39,379	36,276	39,188	19,669	9,823	661	407	5,574	14,498	30,395	32,724	40,608	\$269,201	0.694
electricity kWh :	21,474	12,100	12,191	10,723	11,067	10,710	11,067	11,067	10,710	11,372	11,441	12,998	146,920	
cost \$:	10,308	5,808	5,852	5,147	5,312	5,141	5,312	5,312	5,141	5,458	5,492	6,239	\$70,522	0.182
total cost	52,257	47,365	46,318	25,475	20,785	13,664	15,616	19,745	23,351	36,061	38,240	49,096	\$387,971	1.000
savings	31,468	32,231	29,447	15,610	4,719	265	(1,560)	393	7,149	22,544	30,669	36,469	\$209,405	
													estimated construction cost :	\$3,100,228
													net simple payback :	14.80 yrs
Heat Sources	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
from oil kBTU :	71,473	146,825	35,544	18,320	157,091	218,602	275,182	246,327	103,201	5,770	678	62,533	1,341,548	0.065
from HR kBTU :	666,938	604,264	471,607	427,964	328,157	377,656	345,047	294,556	287,238	430,481	621,825	668,872	5,524,605	0.268
from wood kBTU :	2,009,085	1,850,786	1,999,349	1,003,484	501,146	33,711	20,745	284,369	739,694	1,550,717	1,669,573	2,071,765	13,734,424	0.667
(assumes plant runs all year)													total :	20,600,577
Heat Sinks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
to load kBTU :	2,327,990	2,213,157	2,106,653	1,142,363	709,140	387,288	390,822	559,932	848,051	1,629,499	1,916,021	2,379,124	16,610,040	0.806
to piping kBTU :	355,303	326,605	343,909	286,673	271,029	242,399	249,963	262,662	271,321	319,345	326,500	357,935	3,613,643	0.175
to plant kBTU :	64,203	62,113	55,939	20,733	6,225	282	190	2,658	10,760	38,125	49,555	66,112	376,894	0.018
(assumes plant runs all year)													total :	20,600,577
													gallons of oil displaced :	137,282
													fraction of oil displaced :	0.919

Summary

Max DH Plant 2

Buildings included	DH Plant
1 School	maximum plant load: 5,844 kBTU/h
2 Gym	coincident heat recovery available: 971 kBTU/h
3 Store	fraction of heat from HR at peak: 0.166
4 Post Office	
5 CATG Main Office	est minimum boiler capacity: 4,873 kBTU/h
6 State Building	est minimum boiler capacity: 1,428 kW(th)
7 Shop (adj School)	
8 District Office	use Weissmann model: 390 950 (from Summary)
9 Church	maximum capacity: 1,331 3,241
10 Yukon Flats	minimum capacity: 532 1,297
11 City Building	
12 New CATG Clinic	predicted plant flow rate: 480 gpm
13 Tribal Offices	pipe length to design load: 8,626 ft
14 Water Treat	estimated secondary pump head: 384 ft
15 Old CATG Clinic	estimated pump efficiency: 0.740
16 City DHW Load	peak secondary pump power: 46.8 kW
	estimated primary pump head: 50 ft
	peak primary pump power: 6.1 kW
	estimated plant parasitic power: 7.5 kW

Results

DH Plant runs :	1	1	1	1	1	1	1	1	1	1	1	1		
Current	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	
oil gal :	21,855	20,783	19,765	10,662	6,568	3,537	3,567	5,159	7,883	15,259	17,969	22,338	155,344	
cost \$:	87,420	83,133	79,059	42,649	26,270	14,148	14,267	20,636	31,532	61,034	71,875	89,352	\$621,376	
Predicted	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	fraction
oil gal :	7	56										10	73	
cost \$:	30	222										39	\$292	0.001
wood tons :	249	239	243	114	71	45	48	62	94	186	201	256	1,808	
cost \$:	43,628	41,743	42,504	20,035	12,349	7,930	8,373	10,912	16,467	32,585	35,136	44,733	\$316,395	0.721
electricity kWh :	25,972	25,247	23,521	18,312	18,837	18,230	18,837	18,837	18,230	20,153	21,401	26,551	254,130	
cost \$:	12,466	12,119	11,290	8,790	9,042	8,750	9,042	9,042	8,750	9,674	10,273	12,745	\$121,982	0.278
total cost	56,124	54,084	53,794	28,825	21,391	16,681	17,415	19,954	25,218	42,259	45,408	57,517	\$438,669	1.000
savings	31,296	29,049	25,266	13,824	4,879	(2,533)	(3,148)	682	6,314	18,776	26,466	31,835	\$182,707	
													estimated construction cost :	\$3,659,476
													net simple payback :	20.03 yrs
Heat Sources	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
from oil kBTU :	825	6,185										1,096	8,106	0.000
from HR kBTU :	666,938	604,264	471,607	506,112	410,761	261,079	250,184	314,479	351,815	431,066	621,825	668,872	5,559,001	0.256
from wood kBTU :	2,225,872	2,129,680	2,168,496	1,022,179	630,047	404,599	427,197	556,699	840,157	1,662,478	1,792,595	2,282,238	16,142,238	0.744
(assumes plant runs all year)													total :	21,709,345
Heat Sinks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		fraction
to load kBTU :	2,430,725	2,311,512	2,198,243	1,185,866	730,445	393,384	396,692	573,770	876,745	1,697,063	1,998,480	2,484,434	17,277,360	0.796
to piping kBTU :	398,707	366,503	385,921	321,693	304,139	272,011	280,499	294,750	304,466	358,357	366,385	401,661	4,055,091	0.187
to plant kBTU :	64,203	62,113	55,939	20,733	6,225	282	190	2,658	10,760	38,125	49,555	66,112	376,894	0.017
(assumes plant runs all year)													total :	21,709,345
													gallons of oil displaced :	155,271
													fraction of oil displaced :	1.000

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Inputs
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Global Inputs

Fort Yukon

fuel :			
cost of oil :	\$4.00	per gallon	assumption
heat content of oil :	134,000	BTU/gal	ASHRAE
:			
cost of chips :	\$175.00	per green ton	assumption
heat content of wood chips, dry :	8,300	BTU/lb	assumption
average moistue content when used, MC :	0.250		assumption
average fuel temp :	45	deg F	assumption
heat content of chips at MC :	5,315	BTU/lb	calc
:			
electricity :	\$0.48	per kWh	
:			
Boiler efficiency :			
Wiessmann chip-fired :	0.840		assumption
minimum turndown :	0.400		assumption
No 1 oil-fired :	0.830		assumption
:			
fluid :			
fraction of glycol (propelyne) :	0.00		standard in the area
density at 180 deg F :	60.790	lb/ft^3	tables
heat capacity at 180 deg F :	1.000	BTU/lb*deg F	tables
density specific heat product :	487.6	BTU/hr/gpm/deg F	calc
:			
at peak load :			
HWS :	190	deg F	assumption
HWR :	165	deg F	assumption
building delta T :	25	deg F	assumption
:			
ground temp, active layer (insulpex) :	0	deg F	Dwayne Miller
:			
at min load :			
HWS :	150	deg F	assumption
HWR :	125	deg F	assumption
building delta T :	25	deg F	assumption
:			
ground temp, active layer (insulpex) :	45	deg F	Dwayne Miller
:			
soil conditions for piping heat loss :			
dry :	0		
medium :	1		
moist :	0		
:			
piping :			
sizing criteria for pipe sizing :	2.50	ft drop per 100 ft	average
heat exchanger pressure drop :	18.48	ft each	assumption
control valves :	11.55	each	assumption
eq length multiplier :	1.50		assumption
estimated pump efficiency, all pumps :	0.74		assumption
minimum pump turndown :	0.50		assumption
:			
plant parasitic power :			
estimated plant power for lights, etc :	7.5	kW	assumption

Appendix G:

Sample Calculations:

Appendix G, part 1:

Sample Calculations: Power Load Profile and Heat Available for Heat Recovery

Bin hours, Fort Yukon Airport Data, average of 2007 / 08															
bin	744	672	744	720	744	720	744	744	720	744	720	744	8,760		
mid	31	28	31	30	31	30	31	31	30	31	30	31	365		
pt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total		
deg F															
85 :						1.5							1.5		
83 :						2.0	2.0						4.0		
81 :						14.0	9.5						23.5		
79 :						22.5	18.5	1.5					42.5		
77 :						14.0	16.5	1.0					31.5		
75 :						27.5	40.5	1.5					69.5		
73 :					11.0	26.5	38.5	10.0					86.0		
71 :						9.0	37.0	41.5	14.5				102.0		
69 :						17.0	56.5	53.5	30.0	1.0			158.0		
67 :						15.5	50.5	49.0	23.5	4.5			143.0		
65 :						13.5	63.5	56.0	36.0	12.0			181.0		
63 :						19.5	68.5	67.5	40.0	15.0			210.5		
61 :						25.5	53.0	69.0	43.5	20.0			211.0		
59 :						18.0	42.0	41.0	46.5	8.5			156.0		
57 :				1.5	38.5	63.5	73.0	77.0	14.0				267.5		
55 :				7.0	50.5	53.5	60.5	64.0	17.5				253.0		
53 :				4.5	36.5	43.5	49.0	49.5	19.0				202.0		
51 :				10.5	57.5	30.0	23.0	50.5	35.5				207.0		
49 :				8.5	47.0	24.5	19.5	37.0	39.0				175.5		
47 :				20.5	52.5	11.5	5.5	48.0	39.0				177.0		
45 :				26.5	59.0	7.0	6.0	56.0	53.5				208.0		
43 :				30.0	44.0	4.0	3.0	34.0	53.5				168.5		
41 :				24.0	29.0	2.0	0.5	17.0	36.5	0.5			109.5		
39 :				38.5	49.5	1.5	0.5	29.5	64.0	2.0			185.5		
37 :				41.5	38.0		0.5	15.5	52.0	2.5			150.0		
35 :			2.0	45.0	34.0			7.5	41.5	3.5			133.5		
33 :			2.0	65.0	29.5			4.0	48.5	16.0			165.0		
31 :			0.5	48.5	26.5			2.0	31.0	23.5			132.0		
29 :		2.4	0.5	63.5	13.5			3.0	36.0	27.5	3.5		149.9		
27 :		5.8	3.0	50.0	7.0			1.5	31.5	47.5	9.5		155.8		
25 :	0.5	3.9	2.5	39.0	1.5				22.0	52.0	2.5		123.9		
23 :	0.5	1.4	3.5	19.0					6.5	37.0	2.0		69.9		
21 :	0.5	5.3	8.5	40.5	1.0				9.5	63.5	3.5		132.3		
19 :	1.0	3.4	8.5	34.5					4.5	60.5	6.0	1.5	119.9		
17 :	1.0	4.3	19.0	23.5					2.0	46.5	28.0	8.0	132.3		
15 :	8.5	10.1	21.5	15.0					2.0	69.0	48.0	8.5	182.6		
13 :	15.0	11.2	27.5	10.5					0.5	43.0	32.5	4.5	144.7		
11 :	8.0	10.2	24.0	10.5						28.5	41.5	8.0	130.7		
9 :	19.5	14.7	36.0	12.5						23.5	53.5	14.0	173.7		
7 :	14.0	18.7	35.5	12.5						27.5	31.0	18.5	157.7		
5 :	7.0	17.2	21.0	3.5						10.5	32.0	7.0	98.2		
3 :	31.0	27.6	45.0	7.0						20.0	61.0	20.5	212.1		
1 :	52.0	29.5	44.5	1.5						23.5	69.5	38.0	258.5		
(1) :	17.0	19.6	32.0	1.5						7.5	26.0	9.5	113.1		
(3) :	44.0	22.1	32.5	3.0						8.5	30.5	30.0	170.6		
(5) :	69.0	32.8	49.0	1.0						8.0	37.5	49.5	246.8		
(7) :	44.0	25.5	40.0							9.0	28.0	44.0	190.5		
(9) :	43.5	30.4	38.5							8.5	30.0	33.0	183.9		
(11) :	54.0	20.1	49.5							13.0	21.5	42.5	200.6		
(13) :	20.5	7.9	25.5							9.0	11.5	30.0	104.4		
(15) :	41.0	22.6	32.5							10.0	10.0	44.0	160.1		
(17) :	38.5	18.7	23.0							10.5	12.5	52.0	155.2		
(19) :	34.5	12.2	26.5							8.0	20.5	45.5	147.2		
(21) :	18.5	10.8	14.0							6.5	21.5	32.5	103.8		
(23) :	23.0	19.2	15.5							5.5	33.5	34.0	130.7		
(25) :	11.5	21.5	7.0							5.5	11.0	21.0	77.5		
(27) :	13.5	24.1	8.5							3.0	2.0	24.5	75.6		
(29) :	12.0	24.7	11.0							3.5		26.5	77.7		
(31) :	8.0	16.3	5.0									18.5	47.8		
(33) :	9.0	19.7	3.5									12.0	44.2		
(35) :	13.5	21.8	4.5									13.5	53.3		
(37) :	8.5	11.8	4.0									10.5	34.8		
(39) :	6.5	17.3	3.0									5.5	32.3		
(41) :	7.0	15.3	5.0									12.0	39.3		
(43) :	6.0	11.9	3.5									10.5	31.9		
(45) :	16.0	11.4	4.0									5.0	36.4		
(47) :	10.5	13.9	1.5										25.9		
(49) :	4.5	8.9										0.5	13.9		
(51) :	3.0	9.4											12.4		
(53) :	4.5	7.9										2.5	14.9		
(55) :	4.0	11.7										6.0	21.7		
(57) :		10.6										0.5	11.1		
(59) :		5.8											5.8		

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

power
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x^3	0.0	0.0														
x^2	(0.1)	(0.0)														
x	(1.2)	(1.1)														
c	441.9	328.6														annual kWh
		MWh	333	301	249	264	236	208	185	188	192	229	313	333	3,029,360	
Ja, Fe, Ap, My, Jn, Nv	Mr, Jl, Au, Se Oc	bin mid pt	Predicted demand, kW													
De		F	31	28	31	30	31	30	31	31	30	31	30	31	365	
kW	kW	deg F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total	
295.4	266.8	85	:					295							295	
290.6	262.5	83	:					291	263						553	
286.7	258.8	81	:					287	259						545	
283.5	255.6	79	:					284	256	256					795	
281.1	252.8	77	:					281	253	253					787	
279.5	250.5	75	:					279	250	250					780	
278.5	248.6	73	:				279	279	249	249					1,054	
278.3	247.2	71	:				278	278	247	247					1,051	
278.6	246.1	69	:				279	279	246	246	246				1,296	
279.6	245.5	67	:				280	280	245	245	245				1,296	
281.1	245.2	65	:				281	281	245	245	245				1,298	
283.2	245.2	63	:				283	283	245	245	245				1,302	
285.8	245.6	61	:				286	286	246	246	246				1,308	
288.9	246.3	59	:				289	289	246	246	246				1,317	
292.4	247.4	57	:			292	292	292	247	247	247				1,619	
296.3	248.7	55	:			296	296	296	249	249	249				1,635	
300.6	250.2	53	:			301	301	301	250	250	250				1,652	
305.2	252.0	51	:			305	305	305	252	252	252				1,672	
310.2	254.1	49	:			310	310	310	254	254	254				1,693	
315.5	256.3	47	:			315	315	315	256	256	256				1,715	
321.0	258.8	45	:			321	321	321	259	259	259				1,739	
326.7	261.4	43	:			327	327	327	261	261	261				1,764	
332.6	264.2	41	:			333	333	333	264	264	264	264			2,055	
338.7	267.2	39	:			339	339	339	267	267	267	267			2,085	
344.8	270.2	37	:			345	345		270	270	270	270			1,771	
351.1	273.4	35	:		273	351	351			273	273	273			1,796	
357.5	276.7	33	:		277	357	357			277	277	277			1,822	
363.8	280.0	31	:		280	364	364			280	280	280			1,848	
370.2	283.4	29	:	370	283	370	370			283	283	283	370		2,614	
376.5	286.9	27	:	377	287	377	377			287	287	287	377		2,654	
382.8	290.3	25	:	383	383	290	383	383			290	290	383		2,785	
388.9	293.8	23	:	389	389	294	389			294	294	389			2,437	
394.9	297.3	21	:	395	395	297	395	395			297	297	395		2,866	
400.8	300.7	19	:	401	401	301	401			301	301	401	401		2,906	
406.4	304.1	17	:	406	406	304	406			304	304	406	406		2,944	
411.9	307.4	15	:	412	412	307	412				307	307	412	412	2,982	
417.0	310.7	13	:	417	417	311	417				311	311	417	417	3,017	
421.9	313.8	11	:	422	422	314	422					314	422	422	2,737	
426.4	316.8	9	:	426	426	317	426					317	426	426	2,766	
430.6	319.7	7	:	431	431	320	431					320	431	431	2,792	
434.4	322.5	5	:	434	434	322	434					322	434	434	2,817	
437.7	325.1	3	:	438	438	325	438					325	438	438	2,839	
440.7	327.4	1	:	441	441	327	441					327	441	441	2,858	
443.1	329.6	(1)	:	443	443	330	443					330	443	443	2,875	
445.0	331.6	(3)	:	445	445	332	445					332	445	445	2,888	
446.3	333.3	(5)	:	446	446	333	446					333	446	446	2,898	
447.1	334.8	(7)	:	447	447	335						335	447	447	2,458	
447.2	336.0	(9)	:	447	447	336						336	447	447	2,461	
446.7	337.0	(11)	:	447	447	337						337	447	447	2,461	
447.9	337.6	(13)	:	448	448	338						338	448	448	2,467	
449.1	337.9	(15)	:	449	449	338						338	449	449	2,472	
450.3	337.8	(17)	:	450	450	338						338	450	450	2,477	
451.4	346.7	(19)	:	451	451	347						347	451	451	2,499	
452.6	355.7	(21)	:	453	453	356						356	453	453	2,522	
453.8	364.6	(23)	:	454	454	365						365	454	454	2,544	
455.0	373.5	(25)	:	455	455	373						373	455	455	2,567	
456.2	382.4	(27)	:	456	456	382						382	456	456	2,589	
457.3	391.3	(29)	:	457	457	391						391		457	2,155	
458.5	400.2	(31)	:	459	459	400							459		1,776	
459.7	409.1	(33)	:	460	460	409								460	1,788	
460.9	418.0	(35)	:	461	461	418								461	1,801	
462.0	427.0	(37)	:	462	462	427								462	1,813	
463.2	435.9	(39)	:	463	463	436								463	1,826	
464.4	444.8	(41)	:	464	464	445								464	1,838	
465.6	453.7	(43)	:	466	466	454								466	1,850	
466.8	462.6	(45)	:	467	467	463								467	1,863	
467.9	471.5	(47)	:	468	468	472									1,407	
469.1	480.4	(49)	:	469	469									469	1,407	
470.3	489.3	(51)	:	470	470										941	
471.5	498.3	(53)	:	471	471									471	1,414	
472.6	507.2	(55)	:	473	473									473	1,418	
473.8	516.1	(57)	:	474										474	948	
475.0	525.0	(59)	:	475											475	

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

x^3
x^2 0.0000
x 0.0407
c 4.2052

annual
gal
209,549

gal 23,348 21,142 17,026 18,145 16,106 14,173 12,699 12,895 13,116 15,630 21,861 23,408

Predicted fuel demand, gph, Cat 3456 - Low BSFC

bin															
mid pt	31	28	31	30	31	30	31	31	30	31	30	31	30	31	365
deg F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		total	
85 :						20.1								20	
83 :						19.8	18.0							38	
81 :						19.6	17.7							37	
79 :						19.4	17.5	17.5						54	
77 :						19.2	17.4	17.4						54	
75 :						19.1	17.2	17.2						54	
73 :					19.0	19.0	17.1	17.1						72	
71 :					19.0	19.0	17.0	17.0						72	
69 :					19.0	19.0	16.9	16.9	16.9					89	
67 :					19.1	19.1	16.9	16.9	16.9					89	
65 :					19.2	19.2	16.9	16.9	16.9					89	
63 :					19.3	19.3	16.9	16.9	16.9					89	
61 :					19.5	19.5	16.9	16.9	16.9					90	
59 :					19.7	19.7	17.0	17.0	17.0					90	
57 :				19.9	19.9	19.9	17.0	17.0	17.0					111	
55 :				20.2	20.2	20.2	17.1	17.1	17.1					112	
53 :				20.5	20.5	20.5	17.2	17.2	17.2					113	
51 :				20.8	20.8	20.8	17.3	17.3	17.3					114	
49 :				21.1	21.1	21.1	17.4	17.4	17.4					116	
47 :				21.5	21.5	21.5	17.6	17.6	17.6					117	
45 :				21.9	21.9	21.9	17.7	17.7	17.7					119	
43 :				22.3	22.3	22.3	17.9	17.9	17.9					121	
41 :				22.7	22.7	22.7	18.1	18.1	18.1	18.1				140	
39 :				23.1	23.1	23.1	18.3	18.3	18.3	18.3				143	
37 :				23.6	23.6		18.5	18.5	18.5	18.5				121	
35 :			18.7	24.0	24.0			18.7	18.7	18.7				123	
33 :			18.9	24.5	24.5			18.9	18.9	18.9				125	
31 :			19.1	25.0	25.0			19.1	19.1	19.1				126	
29 :		25.4	19.3	25.4	25.4			19.3	19.3	19.3	25.4			179	
27 :		25.9	19.6	25.9	25.9			19.6	19.6	19.6	25.9			182	
25 :	26.4	26.4	19.8	26.4	26.4				19.8	19.8	26.4			191	
23 :	26.8	26.8	20.0	26.8					20.0	20.0	26.8			167	
21 :	27.3	27.3	20.3	27.3	27.3				20.3	20.3	27.3			197	
19 :	27.7	27.7	20.5	27.7					20.5	20.5	27.7	27.7		200	
17 :	28.2	28.2	20.7	28.2					20.7	20.7	28.2	28.2		203	
15 :	28.6	28.6	21.0	28.6					21.0	21.0	28.6	28.6		206	
13 :	29.0	29.0	21.2	29.0					21.2	21.2	29.0	29.0		208	
11 :	29.4	29.4	21.4	29.4						21.4	29.4	29.4		190	
9 :	29.7	29.7	21.6	29.7						21.6	29.7	29.7		192	
7 :	30.1	30.1	21.8	30.1						21.8	30.1	30.1		194	
5 :	30.4	30.4	22.0	30.4						22.0	30.4	30.4		196	
3 :	30.6	30.6	22.2	30.6						22.2	30.6	30.6		197	
1 :	30.9	30.9	22.3	30.9						22.3	30.9	30.9		199	
(1) :	31.0	31.0	22.5	31.0						22.5	31.0	31.0		200	
(3) :	31.2	31.2	22.6	31.2						22.6	31.2	31.2		201	
(5) :	31.3	31.3	22.8	31.3						22.8	31.3	31.3		202	
(7) :	31.4	31.4	22.9							22.9	31.4	31.4		171	
(9) :	31.4	31.4	22.9							22.9	31.4	31.4		171	
(11) :	31.3	31.3	23.0							23.0	31.3	31.3		171	
(13) :	31.4	31.4	23.1							23.1	31.4	31.4		172	
(15) :	31.5	31.5	23.1							23.1	31.5	31.5		172	
(17) :	31.6	31.6	23.1							23.1	31.6	31.6		173	
(19) :	31.7	31.7	23.7							23.7	31.7	31.7		174	
(21) :	31.8	31.8	24.4							24.4	31.8	31.8		176	
(23) :	31.9	31.9	25.0							25.0	31.9	31.9		178	
(25) :	32.0	32.0	25.7							25.7	32.0	32.0		179	
(27) :	32.1	32.1	26.3							26.3	32.1	32.1		181	
(29) :	32.2	32.2	27.0							27.0		32.2		151	
(31) :	32.3	32.3	27.7									32.3		125	
(33) :	32.4	32.4	28.4									32.4		126	
(35) :	32.5	32.5	29.1									32.5		127	
(37) :	32.6	32.6	29.8									32.6		128	
(39) :	32.7	32.7	30.5									32.7		129	
(41) :	32.8	32.8	31.2									32.8		130	
(43) :	32.9	32.9	31.9									32.9		131	
(45) :	33.0	33.0	32.6									33.0		132	
(47) :	33.1	33.1	33.4											100	
(49) :	33.2	33.2											33.2	100	
(51) :	33.3	33.3												67	
(53) :	33.4	33.4										33.4		100	
(55) :	33.5	33.5										33.5		100	
(57) :		33.6										33.6		67	
(59) :		33.7												34	

x^3
x^2 0.00
x 0.41
c 217.13

1 heat recovery available?

max kw HR available 285

annual
kBTU

mmBTU 667 604 472 506 445 390 351 356 362 431 622 669 5,874,367

Predicted heat available for heat recovery, KBTU/h															
bin mid pt	31 Jan	28 Feb	31 Mar	30 Apr	31 May	30 Jun	31 Jul	31 Aug	30 Sep	31 Oct	30 Nov	31 Dec	365 total		
deg F															
85 :						555							555		
83 :						546	496						1,041		
81 :						538	489						1,028		
79 :						533	484	484					1,500		
77 :						528	479	479					1,487		
75 :						525	475	475					1,476		
73 :					524	524	472	472					1,992		
71 :					523	523	470	470					1,986		
69 :					524	524	468	468	468				2,452		
67 :					526	526	467	467	467				2,452		
65 :					528	528	467	467	467				2,456		
63 :					532	532	467	467	467				2,464		
61 :					537	537	467	467	467				2,476		
59 :					542	542	469	469	469				2,490		
57 :				549	549	549	470	470	470				3,057		
55 :				556	556	556	472	472	472				3,086		
53 :				564	564	564	475	475	475				3,118		
51 :				573	573	573	478	478	478				3,153		
49 :				583	583	583	481	481	481				3,192		
47 :				593	593	593	485	485	485				3,235		
45 :				604	604	604	489	489	489				3,280		
43 :				616	616	616	494	494	494				3,328		
41 :				628	628	628	498	498	498	498			3,877		
39 :				640	640	640	504	504	504	504			3,935		
37 :				653	653		509	509	509	509			3,342		
35 :			514	667	667			514	514	514			3,391		
33 :			520	680	680			520	520	520			3,442		
31 :			526	694	694			526	526	526			3,494		
29 :		709	532	709	709			532	532	532	709		4,964		
27 :		723	539	723	723			539	539	539	723		5,047		
25 :	737	737	545	737	737				545	545	737		5,322		
23 :	752	752	552	752					552	552	752		4,661		
21 :	766	766	558	766	766				558	558	766		5,503		
19 :	780	780	565	780					565	565	780	780	5,592		
17 :	793	793	571	793					571	571	793	793	5,679		
15 :	807	807	577	807					577	577	807	807	5,765		
13 :	819	819	584	819					584	584	819	819	5,847		
11 :	831	831	590	831						590	831	831	5,336		
9 :	843	843	596	843						596	843	843	5,405		
7 :	853	853	602	853						602	853	853	5,470		
5 :	863	863	607	863						607	863	863	5,529		
3 :	872	872	612	872						612	872	872	5,583		
1 :	879	879	617	879						617	879	879	5,630		
(1) :	885	885	622	885						622	885	885	5,671		
(3) :	890	890	626	890						626	890	890	5,704		
(5) :	894	894	629	894						629	894	894	5,728		
(7) :	896	896	632							632	896	896	4,849		
(9) :	896	896	635							635	896	896	4,855		
(11) :	895	895	637							637	895	895	4,854		
(13) :	898	898	638							638	898	898	4,869		
(15) :	901	901	639							639	901	901	4,882		
(17) :	904	904	639							639	904	904	4,895		
(19) :	907	907	657							657	907	907	4,945		
(21) :	911	911	677							677	911	911	4,995		
(23) :	914	914	696							696	914	914	5,047		
(25) :	917	917	716							716	917	917	5,100		
(27) :	920	920	736							736	920	920	5,153		
(29) :	923	923	757							757		923	4,284		
(31) :	926	926	778									926	3,557		
(33) :	929	929	800									929	3,588		
(35) :	933	933	822									933	3,620		
(37) :	936	936	844									936	3,652		
(39) :	939	939	867									939	3,684		
(41) :	942	942	890									942	3,717		
(43) :	945	945	913									945	3,750		
(45) :	949	949	937									949	3,783		
(47) :	952	952	962										2,865		
(49) :	955	955									955		2,865		
(51) :	958	958											1,917		
(53) :	962	962										962	2,885		
(55) :	965	965										965	2,894		
(57) :		968										968	1,936		
(59) :		971											971		

Appendix G, part 2:

Sample Calculations: Calculation of Current Oil Heating Consumption Requirements

Bin hours, Fort Yukon Airport Data, average of 2007 / 08															
bin	744	672	744	720	744	720	744	744	720	744	720	744	8,760		
mid	31	28	31	30	31	30	31	31	30	31	30	31	365		
pt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total		
deg F															
85 :						1.5							1.5		
83 :						2.0	2.0						4.0		
81 :						14.0	9.5						23.5		
79 :						22.5	18.5	1.5					42.5		
77 :						14.0	16.5	1.0					31.5		
75 :						27.5	40.5	1.5					69.5		
73 :					11.0	26.5	38.5	10.0					86.0		
71 :						9.0	37.0	41.5	14.5				102.0		
69 :						17.0	56.5	53.5	30.0	1.0			158.0		
67 :						15.5	50.5	49.0	23.5	4.5			143.0		
65 :						13.5	63.5	56.0	36.0	12.0			181.0		
63 :						19.5	68.5	67.5	40.0	15.0			210.5		
61 :						25.5	53.0	69.0	43.5	20.0			211.0		
59 :						18.0	42.0	41.0	46.5	8.5			156.0		
57 :				1.5	38.5	63.5	73.0	77.0	14.0				267.5		
55 :				7.0	50.5	53.5	60.5	64.0	17.5				253.0		
53 :				4.5	36.5	43.5	49.0	49.5	19.0				202.0		
51 :				10.5	57.5	30.0	23.0	50.5	35.5				207.0		
49 :				8.5	47.0	24.5	19.5	37.0	39.0				175.5		
47 :				20.5	52.5	11.5	5.5	48.0	39.0				177.0		
45 :				26.5	59.0	7.0	6.0	56.0	53.5				208.0		
43 :				30.0	44.0	4.0	3.0	34.0	53.5				168.5		
41 :				24.0	29.0	2.0	0.5	17.0	36.5	0.5			109.5		
39 :				38.5	49.5	1.5	0.5	29.5	64.0	2.0			185.5		
37 :				41.5	38.0		0.5	15.5	52.0	2.5			150.0		
35 :			2.0	45.0	34.0			7.5	41.5	3.5			133.5		
33 :			2.0	65.0	29.5			4.0	48.5	16.0			165.0		
31 :			0.5	48.5	26.5			2.0	31.0	23.5			132.0		
29 :		2.4	0.5	63.5	13.5			3.0	36.0	27.5	3.5		149.9		
27 :		5.8	3.0	50.0	7.0			1.5	31.5	47.5	9.5		155.8		
25 :	0.5	3.9	2.5	39.0	1.5				22.0	52.0	2.5		123.9		
23 :	0.5	1.4	3.5	19.0					6.5	37.0	2.0		69.9		
21 :	0.5	5.3	8.5	40.5	1.0				9.5	63.5	3.5		132.3		
19 :	1.0	3.4	8.5	34.5					4.5	60.5	6.0	1.5	119.9		
17 :	1.0	4.3	19.0	23.5					2.0	46.5	28.0	8.0	132.3		
15 :	8.5	10.1	21.5	15.0					2.0	69.0	48.0	8.5	182.6		
13 :	15.0	11.2	27.5	10.5					0.5	43.0	32.5	4.5	144.7		
11 :	8.0	10.2	24.0	10.5						28.5	41.5	8.0	130.7		
9 :	19.5	14.7	36.0	12.5						23.5	53.5	14.0	173.7		
7 :	14.0	18.7	35.5	12.5						27.5	31.0	18.5	157.7		
5 :	7.0	17.2	21.0	3.5						10.5	32.0	7.0	98.2		
3 :	31.0	27.6	45.0	7.0						20.0	61.0	20.5	212.1		
1 :	52.0	29.5	44.5	1.5						23.5	69.5	38.0	258.5		
(1) :	17.0	19.6	32.0	1.5						7.5	26.0	9.5	113.1		
(3) :	44.0	22.1	32.5	3.0						8.5	30.5	30.0	170.6		
(5) :	69.0	32.8	49.0	1.0						8.0	37.5	49.5	246.8		
(7) :	44.0	25.5	40.0							9.0	28.0	44.0	190.5		
(9) :	43.5	30.4	38.5							8.5	30.0	33.0	183.9		
(11) :	54.0	20.1	49.5							13.0	21.5	42.5	200.6		
(13) :	20.5	7.9	25.5							9.0	11.5	30.0	104.4		
(15) :	41.0	22.6	32.5							10.0	10.0	44.0	160.1		
(17) :	38.5	18.7	23.0							10.5	12.5	52.0	155.2		
(19) :	34.5	12.2	26.5							8.0	20.5	45.5	147.2		
(21) :	18.5	10.8	14.0							6.5	21.5	32.5	103.8		
(23) :	23.0	19.2	15.5							5.5	33.5	34.0	130.7		
(25) :	11.5	21.5	7.0							5.5	11.0	21.0	77.5		
(27) :	13.5	24.1	8.5							3.0	2.0	24.5	75.6		
(29) :	12.0	24.7	11.0							3.5		26.5	77.7		
(31) :	8.0	16.3	5.0									18.5	47.8		
(33) :	9.0	19.7	3.5									12.0	44.2		
(35) :	13.5	21.8	4.5									13.5	53.3		
(37) :	8.5	11.8	4.0									10.5	34.8		
(39) :	6.5	17.3	3.0									5.5	32.3		
(41) :	7.0	15.3	5.0									12.0	39.3		
(43) :	6.0	11.9	3.5									10.5	31.9		
(45) :	16.0	11.4	4.0									5.0	36.4		
(47) :	10.5	13.9	1.5										25.9		
(49) :	4.5	8.9										0.5	13.9		
(51) :	3.0	9.4											12.4		
(53) :	4.5	7.9										2.5	14.9		
(55) :	4.0	11.7										6.0	21.7		
(57) :		10.6										0.5	11.1		
(59) :		5.8											5.8		

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

	1		1		1		1		1		1		1		1		1
max kBTU/h	598.4		447.0		580.9		145.2		93.2		250.5		348.6		232.4		
	17,000	17,000	13,000	13,000	16,000	16,000	4,000	4,000	2,567	2,567	6,900	6,900	9,600	9,600	6,400	6,400	
	use max	5.1 15.6	use max	3.8 4.2	use max	5.1	use max	1.3 4.0	use max	0.8 4.0	use max	2.2	use max	3.0	use max	2.0	
bin	School		Gym		Main Off		State Bldg		Shop		District + Ch		Store		Post Office		
mid																	
pt		0.050		0.065		0.030		0.030		0.030		0.030		0.030		0.030	
deg F	Sp	DHW	Sp	DHW	Sp	DHW	Sp	DHW	Sp	DHW	Sp	DHW	Sp	DHW	Sp	DHW	
85						0.15		0.04		0.02		0.07		0.09		0.06	
83						0.15		0.04		0.02		0.07		0.09		0.06	
81						0.15		0.04		0.02		0.07		0.09		0.06	
79						0.15		0.04		0.02		0.07		0.09		0.06	
77						0.15		0.04		0.02		0.07		0.09		0.06	
75						0.15		0.04		0.02		0.07		0.09		0.06	
73						0.15		0.04		0.02		0.07		0.09		0.06	
71		0.26		0.25		0.15		0.04		0.02		0.07		0.09		0.06	
69		0.26		0.25		0.15		0.04		0.02		0.07		0.09		0.06	
67		0.26		0.25		0.15		0.04		0.02		0.07		0.09		0.06	
65		0.26		0.25		0.15		0.04		0.02		0.07		0.09		0.06	
63		0.26		0.25		0.15		0.04		0.02		0.07		0.09		0.06	
61		0.26		0.25		0.15		0.04		0.02		0.07		0.09		0.06	
59	0.09	0.26	0.06	0.25	0.08	0.15	0.02	0.04	0.01	0.02	0.04	0.07	0.05	0.09	0.03	0.06	
57	0.17	0.26	0.13	0.25	0.17	0.15	0.04	0.04	0.03	0.02	0.07	0.07	0.10	0.09	0.07	0.06	
55	0.26	0.26	0.19	0.25	0.25	0.15	0.06	0.04	0.04	0.02	0.11	0.07	0.15	0.09	0.10	0.06	
53	0.34	0.26	0.25	0.25	0.34	0.15	0.08	0.04	0.05	0.02	0.15	0.07	0.20	0.09	0.14	0.06	
51	0.43	0.26	0.31	0.25	0.42	0.15	0.11	0.04	0.07	0.02	0.18	0.07	0.25	0.09	0.17	0.06	
49	0.51	0.26	0.38	0.25	0.51	0.15	0.13	0.04	0.08	0.02	0.22	0.07	0.30	0.09	0.20	0.06	
47	0.60	0.26	0.44	0.25	0.59	0.15	0.15	0.04	0.09	0.02	0.26	0.07	0.35	0.09	0.24	0.06	
45	0.68	0.26	0.50	0.25	0.68	0.15	0.17	0.04	0.11	0.02	0.29	0.07	0.41	0.09	0.27	0.06	
43	0.77	0.26	0.57	0.25	0.76	0.15	0.19	0.04	0.12	0.02	0.33	0.07	0.46	0.09	0.30	0.06	
41	0.85	0.26	0.63	0.25	0.85	0.15	0.21	0.04	0.14	0.02	0.36	0.07	0.51	0.09	0.34	0.06	
39	0.94	0.26	0.69	0.25	0.93	0.15	0.23	0.04	0.15	0.02	0.40	0.07	0.56	0.09	0.37	0.06	
37	1.02	0.26	0.75	0.25	1.01	0.15	0.25	0.04	0.16	0.02	0.44	0.07	0.61	0.09	0.41	0.06	
35	1.11	0.26	0.82	0.25	1.10	0.15	0.27	0.04	0.18	0.02	0.47	0.07	0.66	0.09	0.44	0.06	
33	1.20	0.26	0.88	0.25	1.18	0.15	0.30	0.04	0.19	0.02	0.51	0.07	0.71	0.09	0.47	0.06	
31	1.28	0.26	0.94	0.25	1.27	0.15	0.32	0.04	0.20	0.02	0.55	0.07	0.76	0.09	0.51	0.06	
29	1.37	0.26	1.01	0.25	1.35	0.15	0.34	0.04	0.22	0.02	0.58	0.07	0.81	0.09	0.54	0.06	
27	1.45	0.26	1.07	0.25	1.44	0.15	0.36	0.04	0.23	0.02	0.62	0.07	0.86	0.09	0.57	0.06	
25	1.54	0.26	1.13	0.25	1.52	0.15	0.38	0.04	0.24	0.02	0.66	0.07	0.91	0.09	0.61	0.06	
23	1.62	0.26	1.19	0.25	1.61	0.15	0.40	0.04	0.26	0.02	0.69	0.07	0.96	0.09	0.64	0.06	
21	1.71	0.26	1.26	0.25	1.69	0.15	0.42	0.04	0.27	0.02	0.73	0.07	1.01	0.09	0.68	0.06	
19	1.79	0.26	1.32	0.25	1.77	0.15	0.44	0.04	0.28	0.02	0.77	0.07	1.06	0.09	0.71	0.06	
17	1.88	0.26	1.38	0.25	1.86	0.15	0.46	0.04	0.30	0.02	0.80	0.07	1.12	0.09	0.74	0.06	
15	1.96	0.26	1.45	0.25	1.94	0.15	0.49	0.04	0.31	0.02	0.84	0.07	1.17	0.09	0.78	0.06	
13	2.05	0.26	1.51	0.25	2.03	0.15	0.51	0.04	0.33	0.02	0.87	0.07	1.22	0.09	0.81	0.06	
11	2.14	0.26	1.57	0.25	2.11	0.15	0.53	0.04	0.34	0.02	0.91	0.07	1.27	0.09	0.85	0.06	
9	2.22	0.26	1.64	0.25	2.20	0.15	0.55	0.04	0.35	0.02	0.95	0.07	1.32	0.09	0.88	0.06	
7	2.31	0.26	1.70	0.25	2.28	0.15	0.57	0.04	0.37	0.02	0.98	0.07	1.37	0.09	0.91	0.06	
5	2.39	0.26	1.76	0.25	2.37	0.15	0.59	0.04	0.38	0.02	1.02	0.07	1.42	0.09	0.95	0.06	
3	2.48	0.26	1.82	0.25	2.45	0.15	0.61	0.04	0.39	0.02	1.06	0.07	1.47	0.09	0.98	0.06	
1	2.56	0.26	1.89	0.25	2.54	0.15	0.63	0.04	0.41	0.02	1.09	0.07	1.52	0.09	1.01	0.06	
(1)	2.65	0.26	1.95	0.25	2.62	0.15	0.66	0.04	0.42	0.02	1.13	0.07	1.57	0.09	1.05	0.06	
(3)	2.73	0.26	2.01	0.25	2.70	0.15	0.68	0.04	0.43	0.02	1.17	0.07	1.62	0.09	1.08	0.06	
(5)	2.82	0.26	2.08	0.25	2.79	0.15	0.70	0.04	0.45	0.02	1.20	0.07	1.67	0.09	1.12	0.06	
(7)	2.90	0.26	2.14	0.25	2.87	0.15	0.72	0.04	0.46	0.02	1.24	0.07	1.72	0.09	1.15	0.06	
(9)	2.99	0.26	2.20	0.25	2.96	0.15	0.74	0.04	0.47	0.02	1.28	0.07	1.77	0.09	1.18	0.06	
(11)	3.07	0.26	2.26	0.25	3.04	0.15	0.76	0.04	0.49	0.02	1.31	0.07	1.83	0.09	1.22	0.06	
(13)	3.16	0.26	2.33	0.25	3.13	0.15	0.78	0.04	0.50	0.02	1.35	0.07	1.88	0.09	1.25	0.06	
(15)	3.25	0.26	2.39	0.25	3.21	0.15	0.80	0.04	0.52	0.02	1.39	0.07	1.93	0.09	1.28	0.06	
(17)	3.33	0.26	2.45	0.25	3.30	0.15	0.82	0.04	0.53	0.02	1.42	0.07	1.98	0.09	1.32	0.06	
(19)	3.42	0.26	2.52	0.25	3.38	0.15	0.85	0.04	0.54	0.02	1.46	0.07	2.03	0.09	1.35	0.06	
(21)	3.50	0.26	2.58	0.25	3.47	0.15	0.87	0.04	0.56	0.02	1.49	0.07	2.08	0.09	1.39	0.06	
(23)	3.59	0.26	2.64	0.25	3.55	0.15	0.89	0.04	0.57	0.02	1.53	0.07	2.13	0.09	1.42	0.06	
(25)	3.67	0.26	2.70	0.25	3.63	0.15	0.91	0.04	0.58	0.02	1.57	0.07	2.18	0.09	1.45	0.06	
(27)	3.76	0.26	2.77	0.25	3.72	0.15	0.93	0.04	0.60	0.02	1.60	0.07	2.23	0.09	1.49	0.06	
(29)	3.84	0.26	2.83	0.25	3.80	0.15	0.95	0.04	0.61	0.02	1.64	0.07	2.28	0.09	1.52	0.06	
(31)	3.93	0.26	2.89	0.25	3.89	0.15	0.97	0.04	0.62	0.02	1.68	0.07	2.33	0.09	1.56	0.06	
(33)	4.01	0.26	2.96	0.25	3.97	0.15	0.99	0.04	0.64	0.02	1.71	0.07	2.38	0.09	1.59	0.06	
(35)	4.10	0.26	3.02	0.25	4.06	0.15	1.01	0.04	0.65	0.02	1.75	0.07	2.43	0.09	1.62	0.06	
(37)	4.18	0.26	3.08	0.25	4.14	0.15	1.04	0.04	0.66	0.02	1.79	0.07	2.48	0.09	1.66	0.06	
(39)	4.27	0.26	3.14	0.25	4.23	0.15	1.06	0.04	0.68	0.02	1.82	0.07	2.54	0.09	1.69	0.06	
(41)	4.36	0.26	3.21	0.25	4.31	0.15	1.08	0.04	0.69	0.02	1.86	0.07	2.59	0.09	1.72	0.06	
(43)	4.44	0.26	3.27	0.25	4.39	0.15	1.10	0.04	0.71	0.02	1.90	0.07	2.64	0.09	1.76	0.06	
(45)	4.53	0.26	3.33	0.25	4.48	0.15	1.12	0.04	0.72	0.02	1.93	0.07	2.69	0.09	1.79	0.06	
(47)	4.61	0.26	3.40	0.25	4.56	0.15	1.14	0.04	0.73	0.02	1.97	0.07	2.74	0.09	1.83	0.06	
(49)	4.70	0.26	3.46	0.25	4.65	0.15	1.16	0.04	0.75	0.02	2.00	0.07	2.79	0.09	1.86	0.06	
(51)	4.78	0.26	3.52	0.25	4.73	0.15	1.18	0.04	0.76	0.02	2.04	0.07	2.84	0.09	1.89	0.06	
(53)	4.87	0.26	3.58	0.25	4.82	0.15	1.20	0.04	0.77	0.02	2.08	0.07	2.89	0.09	1.93	0.06	
(55)	4.95	0.26	3.65	0.25	4.90	0.15	1.23	0.04	0.79	0.02	2.11	0.07	2.94	0.09	1.96	0.06	
(57)	5.04	0.26	3.71	0.25	4.99	0.15	1.25	0.04	0.80	0.02	2.15	0.07	2.99	0.09	1.99	0.06	
(59)	5.12	0.26	3.77	0.25	5.07	0.15	1.27	0.04	0.81	0.02	2.19	0.07	3.04	0.09	2.03	0.06	

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

		1		1		1		1		1		1		1		1
		102.1		462.6		684.3		315.6		299.5		224.0		275.0		
		4,964	4,964	24,090	24,090	20,000	20,000	9,000	9,000	8,250	8,250	6,000	6,000	7,573	7,573	
		use	0.5	use	4.2	use	5.8	use	2.7	use	2.6	use	2.0	use	2.4	
		max	2.0	max	5.5	max	9.6	max		max	2.6	max		max		
		Water Treat		Pumphouse		New Clinic		City Bldg		Yukon Flats		Old Clinic		Tribal Office		
bin																
mid																
pt		0.750	0.400		0.065		0.050		0.030		0.015		0.030			
deg F	Sp	DHW	DWH		Sp	DHW	Sp	DHW	Sp	DHW	Sp	DHW	Sp	DHW	total	
85		0.39	1.66		0.38		0.14		0.08		0.03		0.07		3.18	
83		0.39	1.70		0.38		0.14		0.08		0.03		0.07		3.21	
81		0.39	1.73		0.38		0.14		0.08		0.03		0.07		3.25	
79		0.39	1.77		0.38		0.14		0.08		0.03		0.07		3.28	
77		0.39	1.80		0.38		0.14		0.08		0.03		0.07		3.32	
75		0.39	1.84		0.38		0.14		0.08		0.03		0.07		3.35	
73		0.39	1.87		0.38		0.14		0.08		0.03		0.07		3.39	
71		0.39	1.91		0.38		0.14		0.08		0.03		0.07		3.92	
69		0.39	1.94		0.38		0.14		0.08		0.03		0.07		3.96	
67		0.39	1.98		0.38		0.14		0.08		0.03		0.07		3.99	
65		0.39	2.01		0.38		0.14		0.08		0.03		0.07		4.03	
63		0.39	2.04		0.38		0.14		0.08		0.03		0.07		4.06	
61		0.39	2.08		0.38		0.14		0.08		0.03		0.07		4.10	
59	0.01	0.39	2.11		0.10	0.38	0.05	0.14	0.04	0.08	0.03	0.03	0.04	0.07	4.79	
57	0.02	0.39	2.15		0.19	0.38	0.09	0.14	0.09	0.08	0.07	0.03	0.08	0.07	5.48	
55	0.03	0.39	2.18		0.29	0.38	0.14	0.14	0.13	0.08	0.10	0.03	0.12	0.07	6.17	
53	0.03	0.39	2.22		0.39	0.38	0.18	0.14	0.17	0.08	0.13	0.03	0.16	0.07	6.86	
51	0.04	0.39	2.25		0.48	0.38	0.23	0.14	0.22	0.08	0.17	0.03	0.20	0.07	7.55	
49	0.05	0.39	2.29		0.58	0.38	0.27	0.14	0.26	0.08	0.20	0.03	0.24	0.07	8.24	
47	0.06	0.39	2.32		0.67	0.38	0.32	0.14	0.31	0.08	0.23	0.03	0.28	0.07	8.93	
45	0.07	0.39	2.36		0.77	0.38	0.36	0.14	0.35	0.08	0.26	0.03	0.32	0.07	9.62	
43	0.08	0.39	2.39		0.87	0.38	0.41	0.14	0.39	0.08	0.30	0.03	0.36	0.07	10.31	
41	0.09	0.39	2.43		0.96	0.38	0.45	0.14	0.44	0.08	0.33	0.03	0.40	0.07	11.00	
39	0.10	0.39	2.46		1.06	0.38	0.50	0.14	0.48	0.08	0.36	0.03	0.44	0.07	11.69	
37	0.10	0.39	2.50		1.16	0.38	0.54	0.14	0.52	0.08	0.40	0.03	0.48	0.07	12.38	
35	0.11	0.39	2.53		1.25	0.38	0.59	0.14	0.57	0.08	0.43	0.03	0.52	0.07	13.07	
33	0.12	0.39	2.56		1.35	0.38	0.63	0.14	0.61	0.08	0.46	0.03	0.56	0.07	13.76	
31	0.13	0.39	2.60		1.44	0.38	0.68	0.14	0.65	0.08	0.50	0.03	0.60	0.07	14.45	
29	0.14	0.39	2.63		1.54	0.38	0.72	0.14	0.70	0.08	0.53	0.03	0.64	0.07	15.14	
27	0.15	0.39	2.67		1.64	0.38	0.77	0.14	0.74	0.08	0.56	0.03	0.68	0.07	15.83	
25	0.16	0.39	2.70		1.73	0.38	0.81	0.14	0.78	0.08	0.60	0.03	0.72	0.07	16.52	
23	0.17	0.39	2.74		1.83	0.38	0.86	0.14	0.83	0.08	0.63	0.03	0.76	0.07	17.21	
21	0.17	0.39	2.77		1.93	0.38	0.90	0.14	0.87	0.08	0.66	0.03	0.80	0.07	17.89	
19	0.18	0.39	2.81		2.02	0.38	0.95	0.14	0.92	0.08	0.69	0.03	0.84	0.07	18.58	
17	0.19	0.39	2.84		2.12	0.38	0.99	0.14	0.96	0.08	0.73	0.03	0.88	0.07	19.27	
15	0.20	0.39	2.88		2.21	0.38	1.04	0.14	1.00	0.08	0.76	0.03	0.92	0.07	19.96	
13	0.21	0.39	2.91		2.31	0.38	1.08	0.14	1.05	0.08	0.79	0.03	0.96	0.07	20.65	
11	0.22	0.39	2.95		2.41	0.38	1.13	0.14	1.09	0.08	0.83	0.03	1.00	0.07	21.34	
9	0.23	0.39	2.98		2.50	0.38	1.17	0.14	1.13	0.08	0.86	0.03	1.04	0.07	22.03	
7	0.24	0.39	3.02		2.60	0.38	1.22	0.14	1.18	0.08	0.89	0.03	1.08	0.07	22.72	
5	0.24	0.39	3.05		2.70	0.38	1.26	0.14	1.22	0.08	0.93	0.03	1.12	0.07	23.41	
3	0.25	0.39	3.08		2.79	0.38	1.31	0.14	1.26	0.08	0.96	0.03	1.16	0.07	24.10	
1	0.26	0.39	3.12		2.89	0.38	1.35	0.14	1.31	0.08	0.99	0.03	1.20	0.07	24.79	
(1)	0.27	0.39	3.15		2.99	0.38	1.40	0.14	1.35	0.08	1.03	0.03	1.24	0.07	25.48	
(3)	0.28	0.39	3.19		3.08	0.38	1.44	0.14	1.39	0.08	1.06	0.03	1.28	0.07	26.17	
(5)	0.29	0.39	3.22		3.18	0.38	1.49	0.14	1.44	0.08	1.09	0.03	1.32	0.07	26.86	
(7)	0.30	0.39	3.26		3.27	0.38	1.53	0.14	1.48	0.08	1.12	0.03	1.36	0.07	27.55	
(9)	0.31	0.39	3.29		3.37	0.38	1.58	0.14	1.53	0.08	1.16	0.03	1.40	0.07	28.24	
(11)	0.31	0.39	3.33		3.47	0.38	1.62	0.14	1.57	0.08	1.19	0.03	1.44	0.07	28.93	
(13)	0.32	0.39	3.36		3.56	0.38	1.67	0.14	1.61	0.08	1.22	0.03	1.48	0.07	29.62	
(15)	0.33	0.39	3.40		3.66	0.38	1.71	0.14	1.66	0.08	1.26	0.03	1.52	0.07	30.31	
(17)	0.34	0.39	3.43		3.76	0.38	1.76	0.14	1.70	0.08	1.29	0.03	1.56	0.07	31.00	
(19)	0.35	0.39	3.47		3.85	0.38	1.80	0.14	1.74	0.08	1.32	0.03	1.60	0.07	31.69	
(21)	0.36	0.39	3.50		3.95	0.38	1.85	0.14	1.79	0.08	1.36	0.03	1.64	0.07	32.38	
(23)	0.37	0.39	3.54		4.04	0.38	1.89	0.14	1.83	0.08	1.39	0.03	1.68	0.07	33.07	
(25)	0.38	0.39	3.57		4.14	0.38	1.94	0.14	1.87	0.08	1.42	0.03	1.72	0.07	33.76	
(27)	0.38	0.39	3.60		4.24	0.38	1.98	0.14	1.92	0.08	1.46	0.03	1.76	0.07	34.45	
(29)	0.39	0.39	3.64		4.33	0.38	2.03	0.14	1.96	0.08	1.49	0.03	1.80	0.07	35.14	
(31)	0.40	0.39	3.67		4.43	0.38	2.07	0.14	2.00	0.08	1.52	0.03	1.84	0.07	35.83	
(33)	0.41	0.39	3.71		4.53	0.38	2.12	0.14	2.05	0.08	1.55	0.03	1.88	0.07	36.52	
(35)	0.42	0.39	3.74		4.62	0.38	2.16	0.14	2.09	0.08	1.59	0.03	1.92	0.07	37.21	
(37)	0.43	0.39	3.78		4.72	0.38	2.21	0.14	2.14	0.08	1.62	0.03	1.96	0.07	37.90	
(39)	0.44	0.39	3.81		4.81	0.38	2.25	0.14	2.18	0.08	1.65	0.03	2.00	0.07	38.59	
(41)	0.45	0.39	3.85		4.91	0.38	2.30	0.14	2.22	0.08	1.69	0.03	2.04	0.07	39.28	
(43)	0.45	0.39	3.88		5.01	0.38	2.34	0.14	2.27	0.08	1.72	0.03	2.08	0.07	39.97	
(45)	0.46	0.39	3.92		5.10	0.38	2.39	0.14	2.31	0.08	1.75	0.03	2.12	0.07	40.66	
(47)	0.47	0.39	3.95		5.20	0.38	2.43	0.14	2.35	0.08	1.79	0.03	2.16	0.07	41.35	
(49)	0.48	0.39	3.99		5.30	0.38	2.48	0.14	2.40	0.08	1.82	0.03	2.20	0.07	42.04	
(51)	0.49	0.39	4.02		5.39	0.38	2.52	0.14	2.44	0.08	1.85	0.03	2.24	0.07	42.73	
(53)	0.50	0.39	4.06		5.49	0.38	2.57	0.14	2.48	0.08	1.89	0.03	2.28	0.07	43.42	
(55)	0.51	0.39	4.09		5.58	0.38	2.61	0.14	2.53	0.08	1.92	0.03	2.32	0.07	44.11	
(57)	0.52	0.39	4.12		5.68	0.38	2.66	0.14	2.57	0.08	1.95	0.03	2.36	0.07	44.80	
(59)	0.52	0.39	4.16		5.78	0.38	2.70	0.14	2.61	0.08	1.98	0.03	2.40	0.07	45.49	

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

														annual gal
gal	21,855	20,783	19,765	10,662	6,568	3,537	3,567	5,159	7,883	15,259	17,969	22,338		155,344
Predicted fuel demand, gph, heating														
bin mid pt	31	28	31	30	31	30	31	31	30	31	30	31	30	365
gph	deg F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
3.18	85 :						3.2							3
3.21	83 :						3.2	3.2						6
3.25	81 :						3.2	3.2						6
3.28	79 :						3.3	3.3	3.3					10
3.32	77 :						3.3	3.3	3.3					10
3.35	75 :						3.4	3.4	3.4					10
3.39	73 :					3.4	3.4	3.4	3.4					14
3.92	71 :					3.9	3.9	3.9	3.9					16
3.96	69 :					4.0	4.0	4.0	4.0	4.0				20
3.99	67 :					4.0	4.0	4.0	4.0	4.0				20
4.03	65 :					4.0	4.0	4.0	4.0	4.0				20
4.06	63 :					4.1	4.1	4.1	4.1	4.1				20
4.10	61 :					4.1	4.1	4.1	4.1	4.1				20
4.79	59 :					4.8	4.8	4.8	4.8	4.8				24
5.48	57 :				5.5	5.5	5.5	5.5	5.5	5.5				33
6.17	55 :				6.2	6.2	6.2	6.2	6.2	6.2				37
6.86	53 :				6.9	6.9	6.9	6.9	6.9	6.9				41
7.55	51 :				7.5	7.5	7.5	7.5	7.5	7.5				45
8.24	49 :				8.2	8.2	8.2	8.2	8.2	8.2				49
8.93	47 :				8.9	8.9	8.9	8.9	8.9	8.9				54
9.62	45 :				9.6	9.6	9.6	9.6	9.6	9.6				58
10.31	43 :				10.3	10.3	10.3	10.3	10.3	10.3				62
11.00	41 :				11.0	11.0	11.0	11.0	11.0	11.0				77
11.69	39 :				11.7	11.7	11.7	11.7	11.7	11.7				82
12.38	37 :				12.4	12.4	12.4	12.4	12.4	12.4				74
13.07	35 :			13.1	13.1	13.1			13.1	13.1	13.1			78
13.76	33 :			13.8	13.8	13.8			13.8	13.8	13.8			83
14.45	31 :			14.4	14.4	14.4			14.4	14.4	14.4			87
15.14	29 :		15.1	15.1	15.1	15.1			15.1	15.1	15.1	15.1		121
15.83	27 :		15.8	15.8	15.8	15.8			15.8	15.8	15.8	15.8		127
16.52	25 :	16.5	16.5	16.5	16.5	16.5				16.5	16.5	16.5		132
17.21	23 :	17.2	17.2	17.2	17.2					17.2	17.2	17.2		120
17.89	21 :	17.9	17.9	17.9	17.9	17.9				17.9	17.9	17.9		143
18.58	19 :	18.6	18.6	18.6	18.6					18.6	18.6	18.6	18.6	149
19.27	17 :	19.3	19.3	19.3	19.3					19.3	19.3	19.3	19.3	154
19.96	15 :	20.0	20.0	20.0	20.0					20.0	20.0	20.0	20.0	160
20.65	13 :	20.7	20.7	20.7	20.7					20.7	20.7	20.7	20.7	165
21.34	11 :	21.3	21.3	21.3	21.3						21.3	21.3	21.3	149
22.03	9 :	22.0	22.0	22.0	22.0						22.0	22.0	22.0	154
22.72	7 :	22.7	22.7	22.7	22.7						22.7	22.7	22.7	159
23.41	5 :	23.4	23.4	23.4	23.4						23.4	23.4	23.4	164
24.10	3 :	24.1	24.1	24.1	24.1						24.1	24.1	24.1	169
24.79	1 :	24.8	24.8	24.8	24.8						24.8	24.8	24.8	174
25.48	(1) :	25.5	25.5	25.5	25.5						25.5	25.5	25.5	178
26.17	(3) :	26.2	26.2	26.2	26.2						26.2	26.2	26.2	183
26.86	(5) :	26.9	26.9	26.9	26.9						26.9	26.9	26.9	188
27.55	(7) :	27.6	27.6	27.6							27.6	27.6	27.6	165
28.24	(9) :	28.2	28.2	28.2							28.2	28.2	28.2	169
28.93	(11) :	28.9	28.9	28.9							28.9	28.9	28.9	174
29.62	(13) :	29.6	29.6	29.6							29.6	29.6	29.6	178
30.31	(15) :	30.3	30.3	30.3							30.3	30.3	30.3	182
31.00	(17) :	31.0	31.0	31.0							31.0	31.0	31.0	186
31.69	(19) :	31.7	31.7	31.7							31.7	31.7	31.7	190
32.38	(21) :	32.4	32.4	32.4							32.4	32.4	32.4	194
33.07	(23) :	33.1	33.1	33.1							33.1	33.1	33.1	198
33.76	(25) :	33.8	33.8	33.8							33.8	33.8	33.8	203
34.45	(27) :	34.5	34.5	34.5							34.5	34.5	34.5	207
35.14	(29) :	35.1	35.1	35.1							35.1		35.1	176
35.83	(31) :	35.8	35.8	35.8									35.8	143
36.52	(33) :	36.5	36.5	36.5									36.5	146
37.21	(35) :	37.2	37.2	37.2									37.2	149
37.90	(37) :	37.9	37.9	37.9									37.9	152
38.59	(39) :	38.6	38.6	38.6									38.6	154
39.28	(41) :	39.3	39.3	39.3									39.3	157
39.97	(43) :	40.0	40.0	40.0									40.0	160
40.66	(45) :	40.7	40.7	40.7									40.7	163
41.35	(47) :	41.4	41.4	41.4										124
42.04	(49) :	42.0	42.0										42.0	126
42.73	(51) :	42.7	42.7											85
43.42	(53) :	43.4	43.4										43.4	130
44.11	(55) :	44.1	44.1										44.1	132
44.80	(57) :	44.8											44.8	90
45.49	(59) :	45.5												45

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

oil heat
C:\Documents and Settings\lg\Desktop\lw\Fort Yukon\L3 Ph I\FY L3 I 1 ver 11.xls

134,000 BTU/gal
0.830 eff

annual
kBtu

2,431 2,312 2,198 1,186 730 393 397 574 877 1,697 1,998 2,484 17,277,360

Predicted heat load profile, buildings, kBtu/h

bin mid pt	31	28	31	30	31	30	31	31	30	31	30	31	30	31	365
kBTU/h	deg F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		kW
353.7	85						354								103.7
357.6	83						358	358							104.8
361.4	81						361	361							105.9
365.3	79						365	365	365						107.1
369.1	77						369	369	369						108.2
373.0	75						373	373	373						109.3
376.8	73					377	377	377	377						110.4
436.5	71					436	436	436	436						127.9
440.3	69					440	440	440	440	440					129.1
444.2	67					444	444	444	444	444					130.2
448.0	65					448	448	448	448	448					131.3
451.9	63					452	452	452	452	452					132.4
455.7	61					456	456	456	456	456					133.6
532.5	59					532	532	532	532	532					156.1
609.2	57				609	609	609	609	609	609					178.5
685.9	55				686	686	686	686	686	686					201.0
762.7	53				763	763	763	763	763	763					223.5
839.4	51				839	839	839	839	839	839					246.0
916.1	49				916	916	916	916	916	916					268.5
992.8	47				993	993	993	993	993	993					291.0
1,069.6	45				1,070	1,070	1,070	1,070	1,070	1,070					313.5
1,146.3	43				1,146	1,146	1,146	1,146	1,146	1,146					336.0
1,223.0	41				1,223	1,223	1,223	1,223	1,223	1,223	1,223				358.4
1,299.7	39				1,300	1,300	1,300	1,300	1,300	1,300	1,300				380.9
1,376.5	37				1,376	1,376	1,376	1,376	1,376	1,376	1,376				403.4
1,453.2	35			1,453	1,453	1,453		1,453	1,453	1,453	1,453				425.9
1,529.9	33			1,530	1,530	1,530		1,530	1,530	1,530	1,530				448.4
1,606.6	31			1,607	1,607	1,607		1,607	1,607	1,607	1,607				470.9
1,683.4	29		1,683	1,683	1,683	1,683		1,683	1,683	1,683	1,683	1,683			493.4
1,760.1	27		1,760	1,760	1,760	1,760		1,760	1,760	1,760	1,760	1,760			515.9
1,836.8	25	1,837	1,837	1,837	1,837	1,837		1,837	1,837	1,837	1,837	1,837			538.3
1,913.6	23	1,914	1,914	1,914	1,914			1,914	1,914	1,914	1,914				560.8
1,990.3	21	1,990	1,990	1,990	1,990	1,990		1,990	1,990	1,990	1,990				583.3
2,067.0	19	2,067	2,067	2,067	2,067			2,067	2,067	2,067	2,067	2,067			605.8
2,143.7	17	2,144	2,144	2,144	2,144			2,144	2,144	2,144	2,144	2,144			628.3
2,220.5	15	2,220	2,220	2,220	2,220			2,220	2,220	2,220	2,220	2,220			650.8
2,297.2	13	2,297	2,297	2,297	2,297			2,297	2,297	2,297	2,297	2,297			673.3
2,373.9	11	2,374	2,374	2,374	2,374			2,374	2,374	2,374	2,374	2,374			695.8
2,450.6	9	2,451	2,451	2,451	2,451			2,451	2,451	2,451	2,451	2,451			718.2
2,527.4	7	2,527	2,527	2,527	2,527			2,527	2,527	2,527	2,527	2,527			740.7
2,604.1	5	2,604	2,604	2,604	2,604			2,604	2,604	2,604	2,604	2,604			763.2
2,680.8	3	2,681	2,681	2,681	2,681			2,681	2,681	2,681	2,681	2,681			785.7
2,757.6	1	2,758	2,758	2,758	2,758			2,758	2,758	2,758	2,758	2,758			808.2
2,834.3	(1)	2,834	2,834	2,834	2,834			2,834	2,834	2,834	2,834	2,834			830.7
2,911.0	(3)	2,911	2,911	2,911	2,911			2,911	2,911	2,911	2,911	2,911			853.2
2,987.7	(5)	2,988	2,988	2,988	2,988			2,988	2,988	2,988	2,988	2,988			875.7
3,064.5	(7)	3,064	3,064	3,064				3,064	3,064	3,064	3,064	3,064			898.1
3,141.2	(9)	3,141	3,141	3,141				3,141	3,141	3,141	3,141	3,141			920.6
3,217.9	(11)	3,218	3,218	3,218				3,218	3,218	3,218	3,218	3,218			943.1
3,294.6	(13)	3,295	3,295	3,295				3,295	3,295	3,295	3,295	3,295			965.6
3,371.4	(15)	3,371	3,371	3,371				3,371	3,371	3,371	3,371	3,371			988.1
3,448.1	(17)	3,448	3,448	3,448				3,448	3,448	3,448	3,448	3,448			1,010.6
3,524.8	(19)	3,525	3,525	3,525				3,525	3,525	3,525	3,525	3,525			1,033.1
3,601.5	(21)	3,602	3,602	3,602				3,602	3,602	3,602	3,602	3,602			1,055.6
3,678.3	(23)	3,678	3,678	3,678				3,678	3,678	3,678	3,678	3,678			1,078.0
3,755.0	(25)	3,755	3,755	3,755				3,755	3,755	3,755	3,755	3,755			1,100.5
3,831.7	(27)	3,832	3,832	3,832				3,832	3,832	3,832	3,832	3,832			1,123.0
3,908.5	(29)	3,908	3,908	3,908				3,908			3,908	3,908			1,145.5
3,985.2	(31)	3,985	3,985	3,985							3,985	3,985			1,168.0
4,061.9	(33)	4,062	4,062	4,062							4,062	4,062			1,190.5
4,138.6	(35)	4,139	4,139	4,139							4,139	4,139			1,213.0
4,215.4	(37)	4,215	4,215	4,215							4,215	4,215			1,235.5
4,292.1	(39)	4,292	4,292	4,292							4,292	4,292			1,257.9
4,368.8	(41)	4,369	4,369	4,369							4,369	4,369			1,280.4
4,445.5	(43)	4,446	4,446	4,446							4,446	4,446			1,302.9
4,522.3	(45)	4,522	4,522	4,522							4,522	4,522			1,325.4
4,599.0	(47)	4,599	4,599	4,599											1,347.9
4,675.7	(49)	4,676	4,676	4,676							4,676	4,676			1,370.4
4,752.5	(51)	4,752	4,752												1,392.9
4,829.2	(53)	4,829	4,829								4,829	4,829			1,415.4
4,905.9	(55)	4,906	4,906								4,906	4,906			1,437.8
4,982.6	(57)	4,983									4,983	4,983			1,460.3
5,059.4	(59)	5,059													1,482.8

Appendix G, part 3:

Sample Calculations: Pipe Sizing and Routing Diagram

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

p dwg
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[illegible]

Appendix G, part 4:

Sample Calculations: Pipe Sizing and Heat Loss Calculations:

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

p Tables
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	Base	Exp 1	Exp 2	Max 1	Max 2
2.0	3,164	3,068	4,312	4,802	7,522
4.0	3,110	7,376	3,016	6,516	6,516
8.0		870	870	1,730	1,730

use sizes: 2.0
4.0
8.0

Segments, length, ft					
	Base	Exp 1	Exp 2	Max 1	Max 2
a :	435	435	435	435	435
b :	98	98	98	98	98
c :	90	90	90	90	90
d :	228	228	228	228	228
e :	260	260	260	260	260
f :	170	170	170	170	170
g :	100	100	100	100	100
h :	60	60	60	60	60
i :	200	200	200	200	200
j :	188	188	188	188	188
k :		95	95	95	95
l :		1,255		1,255	1,255
m :		290		290	290
n :			442	442	442
sub	1,829	3,469	2,366	3,911	3,911

Size, calculated, NPS					
	Base	Exp 1	Exp 2	Max 1	Max 2
a :	4.0	8.0	8.0	8.0	8.0
b :	3.0	3.0	3.0	3.0	3.0
c :	2.5	2.5	2.5	2.5	2.5
d :	2.5	2.5	2.5	2.5	2.5
e :	4.0	4.0	4.0	8.0	8.0
f :	4.0	4.0	4.0	8.0	8.0
g :	3.0	3.0	3.0	3.0	3.0
h :	3.0	4.0	4.0	4.0	4.0
i :	2.0	4.0	3.0	4.0	4.0
j :	2.0	4.0	2.5	4.0	4.0
k :		3.0	2.0	4.0	4.0
l :		3.0		3.0	4.0
m :		2.5		2.5	3.0
n :			2.0	2.0	2.0

Size, BOD, NPS					
	Base	Exp 1	Exp 2	Max 1	Max 2
a :	4.0	8.0	8.0	8.0	8.0
b :	4.0	4.0	4.0	4.0	4.0
c :	4.0	4.0	4.0	4.0	4.0
d :	4.0	4.0	4.0	4.0	4.0
e :	4.0	4.0	4.0	8.0	8.0
f :	4.0	4.0	4.0	8.0	8.0
g :	4.0	4.0	4.0	4.0	4.0
h :	4.0	4.0	4.0	4.0	4.0
i :	2.0	4.0	4.0	4.0	4.0
j :	2.0	4.0	4.0	4.0	4.0
k :		4.0	2.0	4.0	4.0
l :		4.0		4.0	4.0
m :		4.0		4.0	4.0
n :			2.0	2.0	2.0

Run-outs, length, ft					
	Base	Exp 1	Exp 2	Max 1	Max 2
1 :	24	24	24	24	24
2 :	24	24	24	24	24
3 :	50	50	50	50	50
4 :	50	50	50	50	50
5 :	90	90	90	90	90
6 :	45	45	45	45	45
7 :	35	35	35	35	35
8 :	35	35	35	35	35
9 :	35	35	35	35	35
10 :	900	900	900	900	900
11 :		340		340	340
12 :		540		540	540
13 :			240	240	240
14 :			185	185	185
15 :					1,360
PH :	20	20	20	20	20
sub	1,308	2,188	1,733	2,613	3,973
total	3,137	5,657	4,099	6,524	7,884

Size, calculated, NPS					
	Base	Exp 1	Exp 2	Max 1	Max 2
1 :	2.5	2.5	2.5	2.5	2.5
2 :	2.0	2.0	2.0	2.0	2.0
3 :	2.0	2.0	2.0	2.0	2.0
4 :	2.0	2.0	2.0	2.0	2.0
5 :	2.5	2.5	2.5	2.5	2.5
6 :	1.5	1.5	1.5	1.5	1.5
7 :	1.5	1.5	1.5	1.5	1.5
8 :	2.0	2.0	2.0	2.0	2.0
9 :	1.5	1.5	1.5	1.5	1.5
10 :	2.0	2.0	2.0	2.0	2.0
11 :		2.0		2.0	2.0
12 :		2.5		2.5	2.5
13 :			2.0	2.0	2.0
14 :			1.5	1.5	1.5
15 :					1.5
PH :	2.0	2.0	2.0	2.0	2.0

Size, BOD, NPS					
	Base	Exp 1	Exp 2	Max 1	Max 2
1 :	4.0	4.0	4.0	4.0	4.0
2 :	2.0	2.0	2.0	2.0	2.0
3 :	2.0	2.0	2.0	2.0	2.0
4 :	2.0	2.0	2.0	2.0	2.0
5 :	4.0	4.0	4.0	4.0	4.0
6 :	2.0	2.0	2.0	2.0	2.0
7 :	2.0	2.0	2.0	2.0	2.0
8 :	2.0	2.0	2.0	2.0	2.0
9 :	2.0	2.0	2.0	2.0	2.0
10 :	2.0	2.0	2.0	2.0	2.0
11 :		2.0		2.0	2.0
12 :		4.0		4.0	4.0
13 :			2.0	2.0	2.0
14 :			2.0	2.0	2.0
15 :					2.0
PH :	2.0	2.0	2.0	2.0	2.0

Fort Yukon Biomass DH Plant

Fort Yukon Alaska

p Tables

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bury depth, in 51
T(avg): 177.5
min soil T: 0.0
use Cond: med

R	dry	med	moist
2.0	13.413	6.990	6.562
4.0	9.784	3.993	3.607
8.0	4.892	1.997	1.804

T(avg): 137.5
max soil T: 45.0

Max Heat Loss, kBTU/h

	Base	Exp 1	Exp 2	Max 1	Max 2
a :	38.7	77.3	77.3	77.3	77.3
b :	8.7	8.7	8.7	8.7	8.7
c :	8.0	8.0	8.0	8.0	8.0
d :	20.3	20.3	20.3	20.3	20.3
e :	23.1	23.1	23.1	46.2	46.2
f :	15.1	15.1	15.1	30.2	30.2
g :	8.9	8.9	8.9	8.9	8.9
h :	5.3	5.3	5.3	5.3	5.3
i :	10.2	17.8	17.8	17.8	17.8
j :	9.5	16.7	16.7	16.7	16.7
k :		8.4	4.8	8.4	8.4
l :		111.6		111.6	111.6
m :		25.8		25.8	25.8
n :			22.4	22.4	22.4
sub	147.8	347.1	228.6	407.8	407.8

Max Heat Loss, kBTU/h

	Base	Exp 1	Exp 2	Max 1	Max 2
1 :	2.1	2.1	2.1	2.1	2.1
2 :	1.2	1.2	1.2	1.2	1.2
3 :	2.5	2.5	2.5	2.5	2.5
4 :	2.5	2.5	2.5	2.5	2.5
5 :	8.0	8.0	8.0	8.0	8.0
6 :	2.3	2.3	2.3	2.3	2.3
7 :	1.8	1.8	1.8	1.8	1.8
8 :	1.8	1.8	1.8	1.8	1.8
9 :	1.8	1.8	1.8	1.8	1.8
10 :	45.7	45.7	45.7	45.7	45.7
11 :		17.3		17.3	17.3
12 :		48.0		48.0	48.0
13 :			12.2	12.2	12.2
14 :			9.4	9.4	9.4
15 :					69.1
PH :	1.0	1.0	1.0	1.0	1.0
sub	70.8	136.1	92.4	157.6	226.7
total	218.6	483.1	320.9	565.4	634.5

Min Heat Loss, kBTU/h

	Base	Exp 1	Exp 2	Max 1	Max 2
a :	20.2	40.3	40.3	40.3	40.3
b :	4.5	4.5	4.5	4.5	4.5
c :	4.2	4.2	4.2	4.2	4.2
d :	10.6	10.6	10.6	10.6	10.6
e :	12.0	12.0	12.0	24.1	24.1
f :	7.9	7.9	7.9	15.8	15.8
g :	4.6	4.6	4.6	4.6	4.6
h :	2.8	2.8	2.8	2.8	2.8
i :	5.3	9.3	9.3	9.3	9.3
j :	5.0	8.7	8.7	8.7	8.7
k :		4.4	2.5	4.4	4.4
l :		58.1		58.1	58.1
m :		13.4		13.4	13.4
n :			11.7	11.7	11.7
sub	77.0	180.9	119.1	212.5	212.5

Min Heat Loss, kBTU/h

	Base	Exp 1	Exp 2	Max 1	Max 2
1 :	1.1	1.1	1.1	1.1	1.1
2 :	0.6	0.6	0.6	0.6	0.6
3 :	1.3	1.3	1.3	1.3	1.3
4 :	1.3	1.3	1.3	1.3	1.3
5 :	4.2	4.2	4.2	4.2	4.2
6 :	1.2	1.2	1.2	1.2	1.2
7 :	0.9	0.9	0.9	0.9	0.9
8 :	0.9	0.9	0.9	0.9	0.9
9 :	0.9	0.9	0.9	0.9	0.9
10 :	23.8	23.8	23.8	23.8	23.8
11 :		9.0		9.0	9.0
12 :		25.0		25.0	25.0
13 :			6.4	6.4	6.4
14 :			4.9	4.9	4.9
15 :					36.0
PH :	0.5	0.5	0.5	0.5	0.5
sub	36.9	70.9	48.1	82.1	118.1
total	113.9	251.8	167.2	294.6	330.6

Appendix G, part 5:

Sample Calculations: Calculation of Heat Sources (recovered heat, wood, oil), and associated fuel consumption (wood, oil, and electrical energy)

NOTE: Only the chosen plant, Maximum Plant 1, is shown – there are four more sets of these calculations for the other four plants studied.

Max Plant 1

Bin hours, Fort Yukon Airport Data, average of 2007 / 08															
bin	744	672	744	720	744	720	744	744	720	744	720	744	8,760		
mid	31	28	31	30	31	30	31	31	30	31	30	31	365		
pt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total		
deg F															
85 :						1.5							1.5		
83 :						2.0	2.0						4.0		
81 :						14.0	9.5						23.5		
79 :						22.5	18.5	1.5					42.5		
77 :						14.0	16.5	1.0					31.5		
75 :						27.5	40.5	1.5					69.5		
73 :					11.0	26.5	38.5	10.0					86.0		
71 :						9.0	37.0	41.5	14.5				102.0		
69 :						17.0	56.5	53.5	30.0	1.0			158.0		
67 :						15.5	50.5	49.0	23.5	4.5			143.0		
65 :						13.5	63.5	56.0	36.0	12.0			181.0		
63 :						19.5	68.5	67.5	40.0	15.0			210.5		
61 :						25.5	53.0	69.0	43.5	20.0			211.0		
59 :						18.0	42.0	41.0	46.5	8.5			156.0		
57 :				1.5	38.5	63.5	73.0	77.0	14.0				267.5		
55 :				7.0	50.5	53.5	60.5	64.0	17.5				253.0		
53 :				4.5	36.5	43.5	49.0	49.5	19.0				202.0		
51 :				10.5	57.5	30.0	23.0	50.5	35.5				207.0		
49 :				8.5	47.0	24.5	19.5	37.0	39.0				175.5		
47 :				20.5	52.5	11.5	5.5	48.0	39.0				177.0		
45 :				26.5	59.0	7.0	6.0	56.0	53.5				208.0		
43 :				30.0	44.0	4.0	3.0	34.0	53.5				168.5		
41 :				24.0	29.0	2.0	0.5	17.0	36.5	0.5			109.5		
39 :				38.5	49.5	1.5	0.5	29.5	64.0	2.0			185.5		
37 :				41.5	38.0		0.5	15.5	52.0	2.5			150.0		
35 :			2.0	45.0	34.0			7.5	41.5	3.5			133.5		
33 :			2.0	65.0	29.5			4.0	48.5	16.0			165.0		
31 :			0.5	48.5	26.5			2.0	31.0	23.5			132.0		
29 :		2.4	0.5	63.5	13.5			3.0	36.0	27.5	3.5		149.9		
27 :		5.8	3.0	50.0	7.0			1.5	31.5	47.5	9.5		155.8		
25 :	0.5	3.9	2.5	39.0	1.5				22.0	52.0	2.5		123.9		
23 :	0.5	1.4	3.5	19.0					6.5	37.0	2.0		69.9		
21 :	0.5	5.3	8.5	40.5	1.0				9.5	63.5	3.5		132.3		
19 :	1.0	3.4	8.5	34.5					4.5	60.5	6.0	1.5	119.9		
17 :	1.0	4.3	19.0	23.5					2.0	46.5	28.0	8.0	132.3		
15 :	8.5	10.1	21.5	15.0					2.0	69.0	48.0	8.5	182.6		
13 :	15.0	11.2	27.5	10.5					0.5	43.0	32.5	4.5	144.7		
11 :	8.0	10.2	24.0	10.5						28.5	41.5	8.0	130.7		
9 :	19.5	14.7	36.0	12.5						23.5	53.5	14.0	173.7		
7 :	14.0	18.7	35.5	12.5						27.5	31.0	18.5	157.7		
5 :	7.0	17.2	21.0	3.5						10.5	32.0	7.0	98.2		
3 :	31.0	27.6	45.0	7.0						20.0	61.0	20.5	212.1		
1 :	52.0	29.5	44.5	1.5						23.5	69.5	38.0	258.5		
(1) :	17.0	19.6	32.0	1.5						7.5	26.0	9.5	113.1		
(3) :	44.0	22.1	32.5	3.0						8.5	30.5	30.0	170.6		
(5) :	69.0	32.8	49.0	1.0						8.0	37.5	49.5	246.8		
(7) :	44.0	25.5	40.0							9.0	28.0	44.0	190.5		
(9) :	43.5	30.4	38.5							8.5	30.0	33.0	183.9		
(11) :	54.0	20.1	49.5							13.0	21.5	42.5	200.6		
(13) :	20.5	7.9	25.5							9.0	11.5	30.0	104.4		
(15) :	41.0	22.6	32.5							10.0	10.0	44.0	160.1		
(17) :	38.5	18.7	23.0							10.5	12.5	52.0	155.2		
(19) :	34.5	12.2	26.5							8.0	20.5	45.5	147.2		
(21) :	18.5	10.8	14.0							6.5	21.5	32.5	103.8		
(23) :	23.0	19.2	15.5							5.5	33.5	34.0	130.7		
(25) :	11.5	21.5	7.0							5.5	11.0	21.0	77.5		
(27) :	13.5	24.1	8.5							3.0	2.0	24.5	75.6		
(29) :	12.0	24.7	11.0							3.5		26.5	77.7		
(31) :	8.0	16.3	5.0									18.5	47.8		
(33) :	9.0	19.7	3.5									12.0	44.2		
(35) :	13.5	21.8	4.5									13.5	53.3		
(37) :	8.5	11.8	4.0									10.5	34.8		
(39) :	6.5	17.3	3.0									5.5	32.3		
(41) :	7.0	15.3	5.0									12.0	39.3		
(43) :	6.0	11.9	3.5									10.5	31.9		
(45) :	16.0	11.4	4.0									5.0	36.4		
(47) :	10.5	13.9	1.5										25.9		
(49) :	4.5	8.9										0.5	13.9		
(51) :	3.0	9.4											12.4		
(53) :	4.5	7.9										2.5	14.9		
(55) :	4.0	11.7										6.0	21.7		
(57) :		10.6										0.5	11.1		
(59) :		5.8											5.8		

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Max Plant 1

min																	annual
max	150																kBTU
at	49	mmBTU	2,747	2,602	2,507	1,450	986	630	641	825	1,130	1,987	2,292	2,803	20,600,577		

Predicted heat load profile, biomass plant, kBTU/h

bldgs	plant	losses	total	bin mid pt	31	28	31	30	31	30	31	31	30	31	30	31	365
kBTU/h	kBTU/h	kBTU/h	kBTU/h	deg F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
350		295	645	85						645							645
354		298	653	83						653	653						1,305
358		302	660	81						660	660						1,321
362		306	668	79						668	668	668					2,004
366		310	676	77						676	676	676					2,027
370		313	683	75						683	683	683					2,049
374		317	691	73					691	691	691	691					2,763
433		321	754	71					754	754	754	754					3,017
437		325	762	69					762	762	762	762	762				3,809
441		328	769	67					769	769	769	769	769				3,847
445		332	777	65					777	777	777	777	777				3,885
449		336	785	63					785	785	785	785	785				3,923
452		340	792	61					792	792	792	792	792				3,961
525		344	869	59					869	869	869	869	869				4,345
599		347	946	57				946	946	946	946	946	946				5,675
672		351	1,023	55				1,023	1,023	1,023	1,023	1,023	1,023				6,136
745		355	1,099	53				1,099	1,099	1,099	1,099	1,099	1,099				6,597
818		359	1,176	51				1,176	1,176	1,176	1,176	1,176	1,176				7,057
891	3	362	1,256	49				1,256	1,256	1,256	1,256	1,256	1,256				7,535
964	5	366	1,335	47				1,335	1,335	1,335	1,335	1,335	1,335				8,012
1,037	8	370	1,415	45				1,415	1,415	1,415	1,415	1,415	1,415				8,489
1,110	11	374	1,494	43				1,494	1,494	1,494	1,494	1,494	1,494				8,966
1,183	14	377	1,574	41				1,574	1,574	1,574	1,574	1,574	1,574				11,018
1,256	16	381	1,653	39				1,653	1,653	1,653	1,653	1,653	1,653				11,574
1,329	19	385	1,733	37				1,733	1,733	1,733	1,733	1,733	1,733				10,398
1,402	22	389	1,813	35			1,813	1,813	1,813		1,813	1,813	1,813				10,875
1,475	25	392	1,892	33			1,892	1,892	1,892		1,892	1,892	1,892				11,352
1,548	27	396	1,972	31			1,972	1,972	1,972		1,972	1,972	1,972				11,830
1,621	30	400	2,051	29		2,051	2,051	2,051	2,051		2,051	2,051	2,051	2,051			16,409
1,694	33	404	2,131	27		2,131	2,131	2,131	2,131		2,131	2,131	2,131	2,131			17,045
1,767	35	407	2,210	25	2,210	2,210	2,210	2,210	2,210				2,210	2,210	2,210		17,682
1,840	38	411	2,290	23	2,290	2,290	2,290	2,290					2,290	2,290	2,290		16,028
1,913	41	415	2,369	21	2,369	2,369	2,369	2,369	2,369				2,369	2,369	2,369		18,954
1,986	44	419	2,449	19	2,449	2,449	2,449	2,449					2,449	2,449	2,449	2,449	19,591
2,060	46	423	2,528	17	2,528	2,528	2,528	2,528					2,528	2,528	2,528	2,528	20,227
2,133	49	426	2,608	15	2,608	2,608	2,608	2,608					2,608	2,608	2,608	2,608	20,863
2,206	52	430	2,687	13	2,687	2,687	2,687	2,687					2,687	2,687	2,687	2,687	21,500
2,279	55	434	2,767	11	2,767	2,767	2,767	2,767					2,767	2,767	2,767		19,369
2,352	57	438	2,847	9	2,847	2,847	2,847	2,847					2,847	2,847	2,847		19,926
2,425	60	441	2,926	7	2,926	2,926	2,926	2,926					2,926	2,926	2,926		20,482
2,498	63	445	3,006	5	3,006	3,006	3,006	3,006					3,006	3,006	3,006		21,039
2,571	65	449	3,085	3	3,085	3,085	3,085	3,085					3,085	3,085	3,085		21,596
2,644	68	453	3,165	1	3,165	3,165	3,165	3,165					3,165	3,165	3,165		22,153
2,717	71	456	3,244	(1)	3,244	3,244	3,244	3,244					3,244	3,244	3,244		22,709
2,790	74	460	3,324	(3)	3,324	3,324	3,324	3,324					3,324	3,324	3,324		23,266
2,863	76	464	3,403	(5)	3,403	3,403	3,403	3,403					3,403	3,403	3,403		23,823
2,936	79	468	3,483	(7)	3,483	3,483	3,483						3,483	3,483	3,483		20,897
3,009	82	471	3,562	(9)	3,562	3,562	3,562						3,562	3,562	3,562		21,374
3,082	85	475	3,642	(11)	3,642	3,642	3,642						3,642	3,642	3,642		21,851
3,155	87	479	3,721	(13)	3,721	3,721	3,721						3,721	3,721	3,721		22,328
3,228	90	483	3,801	(15)	3,801	3,801	3,801						3,801	3,801	3,801		22,806
3,301	93	486	3,880	(17)	3,880	3,880	3,880						3,880	3,880	3,880		23,283
3,374	95	490	3,960	(19)	3,960	3,960	3,960						3,960	3,960	3,960		23,760
3,447	98	494	4,040	(21)	4,040	4,040	4,040						4,040	4,040	4,040		24,237
3,520	101	498	4,119	(23)	4,119	4,119	4,119						4,119	4,119	4,119		24,715
3,594	104	501	4,199	(25)	4,199	4,199	4,199						4,199	4,199	4,199		25,192
3,667	106	505	4,278	(27)	4,278	4,278	4,278						4,278	4,278	4,278		25,669
3,740	109	509	4,358	(29)	4,358	4,358	4,358						4,358		4,358		21,789
3,813	112	513	4,437	(31)	4,437	4,437	4,437								4,437		17,749
3,886	115	517	4,517	(33)	4,517	4,517	4,517								4,517		18,067
3,959	117	520	4,596	(35)	4,596	4,596	4,596								4,596		18,385
4,032	120	524	4,676	(37)	4,676	4,676	4,676								4,676		18,703
4,105	123	528	4,755	(39)	4,755	4,755	4,755								4,755		19,022
4,178	125	532	4,835	(41)	4,835	4,835	4,835								4,835		19,340
4,251	128	535	4,914	(43)	4,914	4,914	4,914								4,914		19,658
4,324	131	539	4,994	(45)	4,994	4,994	4,994								4,994		19,976
4,397	134	543	5,074	(47)	5,074	5,074	5,074										15,221
4,470	136	547	5,153	(49)	5,153	5,153									5,153		15,459
4,543	139	550	5,233	(51)	5,233	5,233											10,465
4,616	142	554	5,312	(53)	5,312	5,312									5,312		15,936
4,689	145	558	5,392	(55)	5,392	5,392									5,392		16,175
4,762	147	562	5,471	(57)	5,471										5,471		10,942
4,835	150	565	5,551	(59)	5,551												5,551

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Max Plant 1														max kW	1,627
5,315 BTU/lb														max HR kW	285
0.840 eff															1,342
														annual	
														tons	
308 291 281 162 110 71 72 92 127 223 257 314															2,307
Predicted wood consumption, lb/hr (no HR)															
bin	mid	pt													365
lb/hr	deg F		31	28	31	30	31	30	31	31	30	31	30	31	kW
144.5	85	:						144							189.1
146.2	83	:						146	146						191.3
147.9	81	:						148	148						193.5
149.6	79	:						150	150	150					195.7
151.3	77	:						151	151	151					198.0
153.0	75	:						153	153	153					200.2
154.7	73	:				155	155	155	155						202.4
168.9	71	:				169	169	169	169						221.0
170.6	69	:				171	171	171	171	171					223.3
172.3	67	:				172	172	172	172	172					225.5
174.0	65	:				174	174	174	174	174					227.7
175.8	63	:				176	176	176	176	176					229.9
177.5	61	:				177	177	177	177	177					232.2
194.7	59	:				195	195	195	195	195					254.7
211.9	57	:			212	212	212	212	212	212					277.2
229.1	55	:			229	229	229	229	229	229					299.7
246.3	53	:			246	246	246	246	246	246					322.2
263.5	51	:			263	263	263	263	263	263					344.7
281.3	49	:			281	281	281	281	281	281					368.0
299.1	47	:			299	299	299	299	299	299					391.4
316.9	45	:			317	317	317	317	317	317					414.7
334.8	43	:			335	335	335	335	335	335					438.0
352.6	41	:			353	353	353	353	353	353	353				461.3
370.4	39	:			370	370	370	370	370	370	370				484.6
388.2	37	:			388	388		388	388	388	388				507.9
406.0	35	:			406	406	406		406	406	406				531.2
423.8	33	:			424	424	424		424	424	424				554.5
441.7	31	:			442	442	442		442	442	442				577.8
459.5	29	:		459	459	459	459		459	459	459	459			601.2
477.3	27	:		477	477	477	477		477	477	477	477			624.5
495.1	25	:	495	495	495	495	495		495	495	495	495			647.8
512.9	23	:	513	513	513	513			513	513	513	513			671.1
530.7	21	:	531	531	531	531	531		531	531	531	531			694.4
548.6	19	:	549	549	549	549			549	549	549	549	549		717.7
566.4	17	:	566	566	566	566			566	566	566	566	566		741.0
584.2	15	:	584	584	584	584			584	584	584	584	584		764.3
602.0	13	:	602	602	602	602			602	602	602	602	602		787.6
619.8	11	:	620	620	620	620			620	620	620	620	620		811.0
637.6	9	:	638	638	638	638			638	638	638	638	638		834.3
655.5	7	:	655	655	655	655			655	655	655	655	655		857.6
673.3	5	:	673	673	673	673			673	673	673	673	673		880.9
691.1	3	:	691	691	691	691			691	691	691	691	691		904.2
708.9	1	:	709	709	709	709			709	709	709	709	709		927.5
726.7	(1)	:	727	727	727	727			727	727	727	727	727		950.8
744.5	(3)	:	745	745	745	745			745	745	745	745	745		974.1
762.4	(5)	:	762	762	762	762			762	762	762	762	762		997.4
780.2	(7)	:	780	780	780				780	780	780	780	780		1,020.8
798.0	(9)	:	798	798	798				798	798	798	798	798		1,044.1
815.8	(11)	:	816	816	816				816	816	816	816	816		1,067.4
833.6	(13)	:	834	834	834				834	834	834	834	834		1,090.7
851.4	(15)	:	851	851	851				851	851	851	851	851		1,114.0
869.2	(17)	:	869	869	869				869	869	869	869	869		1,137.3
887.1	(19)	:	887	887	887				887	887	887	887	887		1,160.6
904.9	(21)	:	905	905	905				905	905	905	905	905		1,183.9
922.7	(23)	:	923	923	923				923	923	923	923	923		1,207.2
940.5	(25)	:	941	941	941				941	941	941	941	941		1,230.5
958.3	(27)	:	958	958	958				958	958	958	958	958		1,253.9
976.1	(29)	:	976	976	976				976		976		976		1,277.2
994.0	(31)	:	994	994	994						994		994		1,300.5
1,011.8	(33)	:	1,012	1,012	1,012						1,012		1,012		1,323.8
1,029.6	(35)	:	1,030	1,030	1,030						1,030		1,030		1,347.1
1,047.4	(37)	:	1,047	1,047	1,047						1,047		1,047		1,370.4
1,065.2	(39)	:	1,065	1,065	1,065						1,065		1,065		1,393.7
1,083.0	(41)	:	1,083	1,083	1,083						1,083		1,083		1,417.0
1,100.9	(43)	:	1,101	1,101	1,101						1,101		1,101		1,440.3
1,118.7	(45)	:	1,119	1,119	1,119						1,119		1,119		1,463.7
1,136.5	(47)	:	1,136	1,136	1,136										1,487.0
1,154.3	(49)	:	1,154	1,154								1,154			1,510.3
1,172.1	(51)	:	1,172	1,172											1,533.6
1,189.9	(53)	:	1,190	1,190									1,190		1,556.9
1,207.8	(55)	:	1,208	1,208									1,208		1,580.2
1,225.6	(57)	:	1,226										1,226		1,603.5
1,243.4	(59)	:	1,243												1,626.8

Max Plant 1											Boiler max boiler min		3,241 1,297	kBTU 5,524,605
mmBTU	667	604	472	428	328	378	345	295	287	430	622	669		
Load to HR, kBTU/h														
bin mid pt deg F	J	F	M	A	M	J	J	A	S	O	N	D	total	
85 :						555							:	
83 :						546	496						:	
81 :						538	489						:	
79 :						533	484	484					:	
77 :						528	479	479					:	
75 :						525	475	475					:	
73 :					524	524	472	472					:	
71 :					523	523	470	470					:	
69 :					524	524	468	468	468				:	
67 :					526	526	467	467	467				:	
65 :					528	528	467	467	467				:	
63 :					532	532	467	467	467				:	
61 :					537	537	467	467	467				:	
59 :					542	542	469	469	469				:	
57 :				549	549	549	470	470	470				:	
55 :				556	556	556	472	472	472				:	
53 :				564	564	564	475	475	475				:	
51 :				573	573	573	478	478	478				:	
49 :				583	583	583	481	481	481				:	
47 :				39	39	39	39	39	39				:	
45 :				118	118	118	118	118	118				:	
43 :				198	198	198	198	198	198				:	
41 :				277	277	277	277	277	277	277			:	
39 :				357	357	357	357	357	357	357			:	
37 :				436	436		436	436	436	436			:	
35 :			514	516	516			514	514	514			:	
33 :			520	596	596			520	520	520			:	
31 :			526	675	675			526	526	526			:	
29 :		709	532	709	709			532	532	532	709		:	
27 :		723	539	723	723			539	539	539	723		:	
25 :	737	737	545	737	737				545	545	737		:	
23 :	752	752	552	752					552	552	752		:	
21 :	766	766	558	766	766				558	558	766		:	
19 :	780	780	565	780					565	565	780	780	:	
17 :	793	793	571	793					571	571	793	793	:	
15 :	807	807	577	807					577	577	807	807	:	
13 :	819	819	584	819					584	584	819	819	:	
11 :	831	831	590	831						590	831	831	:	
9 :	843	843	596	843						596	843	843	:	
7 :	853	853	602	853						602	853	853	:	
5 :	863	863	607	863						607	863	863	:	
3 :	872	872	612	872						612	872	872	:	
1 :	879	879	617	879						617	879	879	:	
(1) :	885	885	622	885						622	885	885	:	
(3) :	890	890	626	890						626	890	890	:	
(5) :	894	894	629	894						629	894	894	:	
(7) :	896	896	632							632	896	896	:	
(9) :	896	896	635							635	896	896	:	
(11) :	895	895	637							637	895	895	:	
(13) :	898	898	638							638	898	898	:	
(15) :	901	901	639							639	901	901	:	
(17) :	904	904	639							639	904	904	:	
(19) :	907	907	657							657	907	907	:	
(21) :	911	911	677							677	911	911	:	
(23) :	914	914	696							696	914	914	:	
(25) :	917	917	716							716	917	917	:	
(27) :	920	920	736							736	920	920	:	
(29) :	923	923	757							757		923	:	
(31) :	926	926	778									926	:	
(33) :	929	929	800									929	:	
(35) :	933	933	822									933	:	
(37) :	936	936	844									936	:	
(39) :	939	939	867									939	:	
(41) :	942	942	890									942	:	
(43) :	945	945	913									945	:	
(45) :	949	949	937									949	:	
(47) :	952	952	962										:	
(49) :	955	955										955	:	
(51) :	958	958											:	
(53) :	962	962										962	:	
(55) :	965	965										965	:	
(57) :		968										968	:	
(59) :		971											:	

Max Plant 1											Boiler max boiler min		3,241 1,297	kBTU 1,341,548
mmBTU	71	147	36	18	157	219	275	246	103	6	1	63		
Load to oil, kBTU/h														
bin mid pt deg F	J	F	M	A	M	J	J	A	S	O	N	D	total	
85 :						90							:	
83 :						107	157						:	
81 :						122	171						:	
79 :						135	184	184					:	
77 :						147	196	196					:	
75 :						158	208	208					:	
73 :					167	167	218	218					:	
71 :					231	231	284	284					:	
69 :					238	238	294	294	294				:	
67 :					244	244	302	302	302				:	
65 :					249	249	310	310	310				:	
63 :					253	253	318	318	318				:	
61 :					255	255	325	325	325				:	
59 :					327	327	400	400	400				:	
57 :				397	397	397	476	476	476				:	
55 :				466	466	466	550	550	550				:	
53 :				535	535	535	625	625	625				:	
51 :				603	603	603	698	698	698				:	
49 :				673	673	673	774	774	774				:	
47 :													:	
45 :													:	
43 :													:	
41 :													:	
39 :													:	
37 :													:	
35 :													:	
33 :													:	
31 :													:	
29 :													:	
27 :													:	
25 :													:	
23 :													:	
21 :													:	
19 :													:	
17 :													:	
15 :													:	
13 :													:	
11 :													:	
9 :													:	
7 :													:	
5 :													:	
3 :													:	
1 :													:	
(1) :													:	
(3) :													:	
(5) :													:	
(7) :													:	
(9) :													:	
(11) :													:	
(13) :													:	
(15) :													:	
(17) :				1						1			:	
(19) :				61						61			:	
(21) :				122						122			:	
(23) :				182						182			:	
(25) :	40	40	241							241	40	40	:	
(27) :	117	117	300							300	117	117	:	
(29) :	193	193	359							359		193	:	
(31) :	270	270	418									270	:	
(33) :	346	346	476									346	:	
(35) :	422	422	533									422	:	
(37) :	499	499	590									499	:	
(39) :	575	575	647									575	:	
(41) :	651	651	704									651	:	
(43) :	728	728	760									728	:	
(45) :	804	804	815									804	:	
(47) :	880	880	870										:	
(49) :	957	957										957	:	
(51) :	1,033	1,033											:	
(53) :	1,109	1,109										1,109	:	
(55) :	1,186	1,186										1,186	:	
(57) :		1,262										1,262	:	
(59) :		1,338											:	

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

Max Plant 1													Boiler max	3,241	kBTU	
													boiler min	1,297		
total	2,747	2,602	2,507	1,450	986	630	641	825	1,130	1,987	2,292	2,803	20,600,577			
HR	667	604	472	428	328	378	345	295	287	430	622	669	5,524,605			
oil	71	147	36	18	157	219	275	246	103	6	1	63	1,341,548			
mmBTU	2,009	1,851	1,999	1,003	501	34	21	284	740	1,551	1,670	2,072	13,734,424			
Load to wood													20,600,577			
bin													checksum			
mid																
pt																
deg F	J	F	M	A	M	J	J	A	S	O	N	D	total			
85 :													:			
83 :													:			
81 :													:			
79 :													:			
77 :													:			
75 :													:			
73 :													:			
71 :													:			
69 :													:			
67 :													:			
65 :													:			
63 :													:			
61 :													:			
59 :													:			
57 :													:			
55 :													:			
53 :													:			
51 :													:			
49 :													:			
47 :				1,297	1,297	1,297	1,297	1,297	1,297				:			
45 :				1,297	1,297	1,297	1,297	1,297	1,297				:			
43 :				1,297	1,297	1,297	1,297	1,297	1,297				:			
41 :				1,297	1,297	1,297	1,297	1,297	1,297	1,297			:			
39 :				1,297	1,297	1,297	1,297	1,297	1,297	1,297			:			
37 :				1,297	1,297		1,297	1,297	1,297	1,297			:			
35 :			1,298	1,297	1,297			1,298	1,298	1,298			:			
33 :				1,372	1,297	1,297		1,372	1,372	1,372			:			
31 :				1,445	1,297	1,297		1,445	1,445	1,445			:			
29 :		1,343	1,519	1,343	1,343			1,519	1,519	1,519	1,343		:			
27 :		1,408	1,592	1,408	1,408			1,592	1,592	1,592	1,408		:			
25 :	1,473	1,473	1,665	1,473	1,473				1,665	1,665	1,473		:			
23 :	1,538	1,538	1,738	1,538					1,738	1,738	1,538		:			
21 :	1,604	1,604	1,811	1,604	1,604				1,811	1,811	1,604		:			
19 :	1,669	1,669	1,884	1,669					1,884	1,884	1,669	1,669	:			
17 :	1,735	1,735	1,957	1,735					1,957	1,957	1,735	1,735	:			
15 :	1,801	1,801	2,030	1,801					2,030	2,030	1,801	1,801	:			
13 :	1,868	1,868	2,104	1,868					2,104	2,104	1,868	1,868	:			
11 :	1,936	1,936	2,177	1,936						2,177	1,936	1,936	:			
9 :	2,004	2,004	2,251	2,004						2,251	2,004	2,004	:			
7 :	2,073	2,073	2,324	2,073						2,324	2,073	2,073	:			
5 :	2,143	2,143	2,398	2,143						2,398	2,143	2,143	:			
3 :	2,213	2,213	2,473	2,213						2,473	2,213	2,213	:			
1 :	2,285	2,285	2,547	2,285						2,547	2,285	2,285	:			
(1) :	2,359	2,359	2,623	2,359						2,623	2,359	2,359	:			
(3) :	2,433	2,433	2,698	2,433						2,698	2,433	2,433	:			
(5) :	2,509	2,509	2,774	2,509						2,774	2,509	2,509	:			
(7) :	2,587	2,587	2,850							2,850	2,587	2,587	:			
(9) :	2,666	2,666	2,928							2,928	2,666	2,666	:			
(11) :	2,747	2,747	3,005							3,005	2,747	2,747	:			
(13) :	2,823	2,823	3,083							3,083	2,823	2,823	:			
(15) :	2,900	2,900	3,162							3,162	2,900	2,900	:			
(17) :	2,976	2,976	3,241							3,241	2,976	2,976	:			
(19) :	3,053	3,053	3,241							3,241	3,053	3,053	:			
(21) :	3,129	3,129	3,241							3,241	3,129	3,129	:			
(23) :	3,205	3,205	3,241							3,241	3,205	3,205	:			
(25) :	3,241	3,241	3,241							3,241	3,241	3,241	:			
(27) :	3,241	3,241	3,241							3,241	3,241	3,241	:			
(29) :	3,241	3,241	3,241							3,241		3,241	:			
(31) :	3,241	3,241	3,241									3,241	:			
(33) :	3,241	3,241	3,241									3,241	:			
(35) :	3,241	3,241	3,241									3,241	:			
(37) :	3,241	3,241	3,241									3,241	:			
(39) :	3,241	3,241	3,241									3,241	:			
(41) :	3,241	3,241	3,241									3,241	:			
(43) :	3,241	3,241	3,241									3,241	:			
(45) :	3,241	3,241	3,241									3,241	:			
(47) :	3,241	3,241	3,241										:			
(49) :	3,241	3,241										3,241	:			
(51) :	3,241	3,241											:			
(53) :	3,241	3,241										3,241	:			
(55) :	3,241	3,241										3,241	:			
(57) :		3,241										3,241	:			
(59) :		3,241											:			

Fort Yukon Biomass DH Plant
Fort Yukon Alaska

min pump speed : 0.50
VFD exp : 2.00
primary pump kW : 5.85
secondary pump kW : 37.70
parasitic power : 7.50

Max Plant 1

Annual
kWh
219,858

mWh 21 21 20 16 17 16 17 17 16 18 18 22

electrical load

% cap	V load kW	C load kW	bin mid pt deg F													total
				J	F	M	A	M	J	J	A	S	O	N	D	
0.50	9.4	13.4	85						23							:
0.50	9.4	13.4	83						23	23						:
0.50	9.4	13.4	81						23	23						:
0.50	9.4	13.4	79						23	23	23					:
0.50	9.4	13.4	77						23	23	23					:
0.50	9.4	13.4	75						23	23	23					:
0.50	9.4	13.4	73					23	23	23	23					:
0.50	9.4	13.4	71					23	23	23	23					:
0.50	9.4	13.4	69					23	23	23	23	23				:
0.50	9.4	13.4	67					23	23	23	23	23				:
0.50	9.4	13.4	65					23	23	23	23	23				:
0.50	9.4	13.4	63					23	23	23	23	23				:
0.50	9.4	13.4	61					23	23	23	23	23				:
0.50	9.4	13.4	59					23	23	23	23	23				:
0.50	9.4	13.4	57				23	23	23	23	23	23				:
0.50	9.4	13.4	55				23	23	23	23	23	23				:
0.50	9.4	13.4	53				23	23	23	23	23	23				:
0.50	9.4	13.4	51				23	23	23	23	23	23				:
0.50	9.4	13.4	49				23	23	23	23	23	23				:
0.50	9.4	13.4	47				23	23	23	23	23	23				:
0.50	9.4	13.4	45				23	23	23	23	23	23				:
0.50	9.4	13.4	43				23	23	23	23	23	23				:
0.50	9.4	13.4	41				23	23	23	23	23	23	23			:
0.50	9.4	13.4	39				23	23	23	23	23	23	23			:
0.50	9.4	13.4	37				23	23		23	23	23	23			:
0.50	9.4	13.4	35			23	23	23			23	23	23			:
0.50	9.4	13.4	33			23	23	23			23	23	23			:
0.50	9.4	13.4	31			23	23	23			23	23	23			:
0.50	9.4	13.4	29			23	23	23			23	23	23	23		:
0.50	9.4	13.4	27		23	23	23	23			23	23	23	23		:
0.50	9.4	13.4	25	23	23	23	23	23				23	23	23		:
0.50	9.4	13.4	23	23	23	23	23					23	23	23		:
0.50	9.4	13.4	21	23	23	23	23	23				23	23	23		:
0.50	9.4	13.4	19	23	23	23	23					23	23	23	23	:
0.50	9.4	13.4	17	23	23	23	23					23	23	23	23	:
0.50	9.4	13.4	15	23	23	23	23					23	23	23	23	:
0.50	9.4	13.4	13	23	23	23	23					23	23	23	23	:
0.50	9.4	13.4	11	23	23	23	23						23	23	23	:
0.50	9.4	13.4	9	23	23	23	23						23	23	23	:
0.50	9.4	13.4	7	23	23	23	23						23	23	23	:
0.51	9.9	13.4	5	23	23	23	23							23	23	:
0.53	10.5	13.4	3	24	24	24	24							24	24	:
0.54	11.0	13.4	1	24	24	24	24							24	24	:
0.55	11.6	13.4	(1)	25	25	25	25							25	25	:
0.57	12.2	13.4	(3)	26	26	26	26							26	26	:
0.58	12.8	13.4	(5)	26	26	26	26							26	26	:
0.60	13.4	13.4	(7)	27	27	27								27	27	:
0.61	14.0	13.4	(9)	27	27	27								27	27	:
0.62	14.6	13.4	(11)	28	28	28								28	28	:
0.64	15.2	13.4	(13)	29	29	29								29	29	:
0.65	15.9	13.4	(15)	29	29	29								29	29	:
0.66	16.6	13.4	(17)	30	30	30								30	30	:
0.68	17.3	13.4	(19)	31	31	31								31	31	:
0.69	18.0	13.4	(21)	31	31	31								31	31	:
0.70	18.7	13.4	(23)	32	32	32								32	32	:
0.72	19.4	13.4	(25)	33	33	33								33	33	:
0.73	20.2	13.4	(27)	34	34	34								34	34	:
0.74	20.9	13.4	(29)	34	34	34								34	34	:
0.76	21.7	13.4	(31)	35	35	35									35	:
0.77	22.5	13.4	(33)	36	36	36									36	:
0.79	23.3	13.4	(35)	37	37	37									37	:
0.80	24.1	13.4	(37)	37	37	37									37	:
0.81	24.9	13.4	(39)	38	38	38									38	:
0.83	25.7	13.4	(41)	39	39	39									39	:
0.84	26.6	13.4	(43)	40	40	40									40	:
0.85	27.5	13.4	(45)	41	41	41									41	:
0.87	28.3	13.4	(47)	42	42	42										:
0.88	29.2	13.4	(49)	43	43										43	:
0.89	30.1	13.4	(51)	44	44											:
0.91	31.1	13.4	(53)	44	44										44	:
0.92	32.0	13.4	(55)	45	45										45	:
0.94	33.0	13.4	(57)	46											46	:
0.95	33.9	13.4	(59)	47												: