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Colorado Springs Utilities
Customer & Corporate Services
Enhanced Service Engineering

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**Cc: Vince Guthrie**
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Re: Energy Audit Service: Fort Carson Heating Plant

On February 2 and 3, 2010, Colorado Springs Utilities visited your facility to suggest some ideas for energy savings / cost savings. This is a courtesy service of Colorado Springs Utilities, for you as our valued customer. Operations information came from Dan Robbins, which added to the report.

Financial detailed calculations outlining costs, benefits, and payback times (or rate of return) are very often required for customers to consider implementation. The information provided in this audit does not provide this level of detail. For added detail, especially for the capital improvement items, the Owner may wish to consider additional Energy Audit services through engineering firms in the community.

We hope this information is useful. If there are questions or comments, please feel free to contact Kellie Smith or myself.

Sincerely,

Steve Doty, PE CEM
Enhanced Service Engineering

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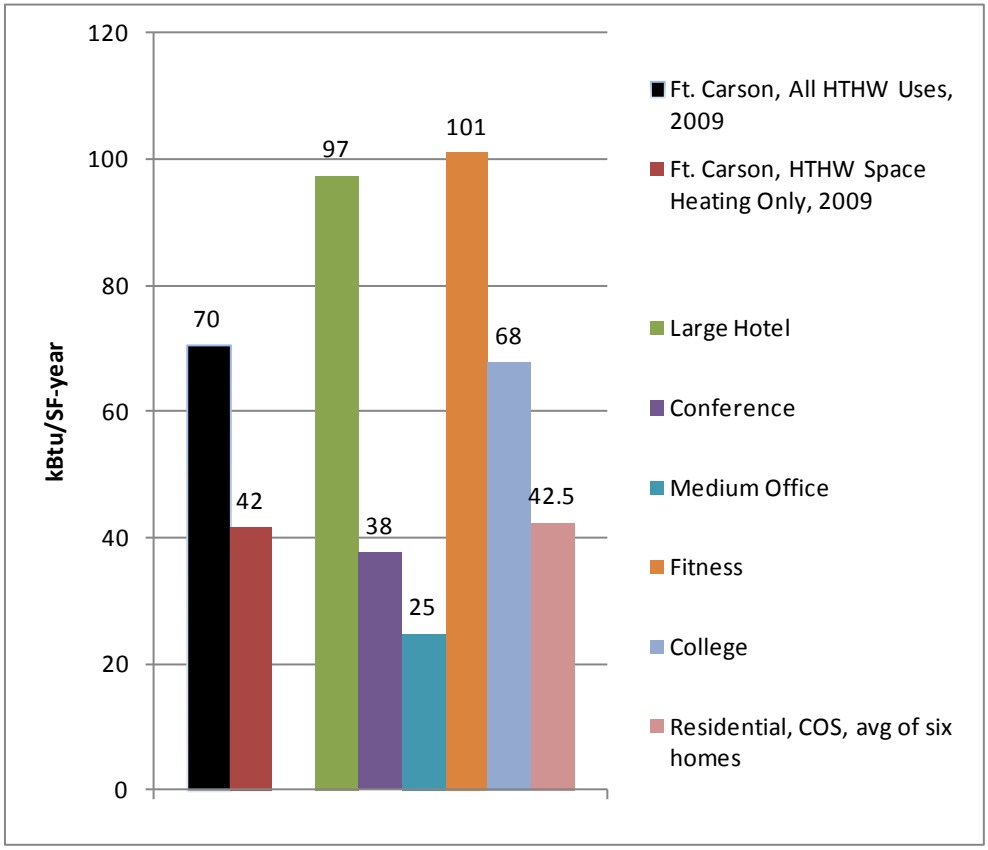
All utility-saving suggestions noted are optional. Nothing in this report is intended to supersede any law, regulation, code, local ordinance, or any Authority Having Jurisdiction, or impede with occupant comfort or facility operations. Safety, health and comfort are intended to take priority over utility conservation. If conflicts between this report and any other legal requirements exist, they are accidental and this report will defer to those requirements.

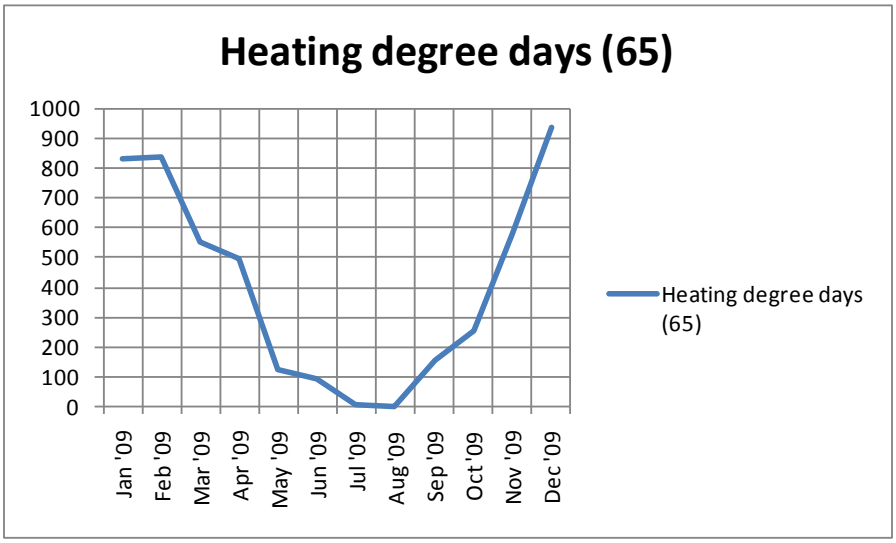
Energy savings are not guaranteed.

This information is provided in good faith, for use by the customer in conjunction with a qualified Contractor or Engineer.

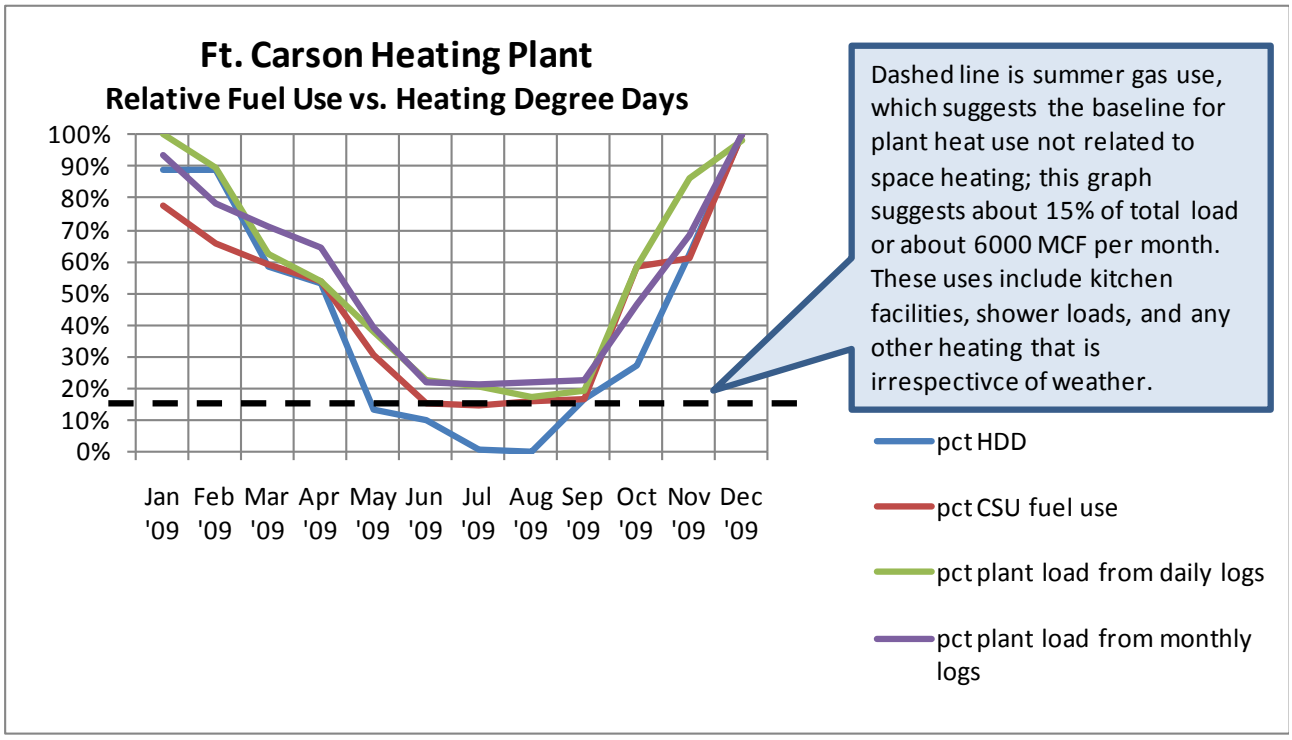
## SUMMARY:

Energy use for the building was compared against available benchmark information for similar facilities. See the figure below.






Heating degree days are a good overall representation of when space heating is needed, as well as for comparing year-to-year use or predicting fuel needs. Most, but not all, of the HTHW use is for heating.




Same chart, with fuel use and heating plant load superimposed. The area below the dotted line represents non-space heating loads. These are the loads that would need to e separately served to allow the HTHW system to be shut off in summer (currently it never shuts off). An intermediate recommendation that is more achievable is to replace the portion of the summer load that uses steam, allowing the system temperature to be lowered.

## Part 1 – IMPROVEMENT SUGGESTIONS

Opportunities for energy savings have been identified and are grouped as follows:

| | |
|---|---|
| **Low Cost** | Measures with low investment requirements, and usually correspondingly small returns. Characterized as the smaller easy items, with quickest paybacks |
| **Capital** | Measures requiring capital investment, but with proportionally greater returns. These are normally larger project items, with longer paybacks. |
| **Strategic** | Consideration of opportunities in future projects where energy savings alone is not the sole driving force. In many cases, strategic 'Energy-Wise' choices up front can build-in utility savings over the long run with little additional capital expense. |

**Notes:**

1. The customer should review each suggestion carefully to ensure it does not impact production or product quality.
2. Where manufacturer names or part numbers are shown, these are intended to illustrate the technology. Colorado Springs Utilities cannot endorse specific manufacturers.
3. Where demand savings are indicated, these normally will not show up for 12 months after the change is implemented due to the 12-month demand ratchet clause in the tariff.
4. Where payback data is shown, it is an order of magnitude estimate only, and should be verified by calculations and engineering analysis based on specific site conditions.
5. Where savings data are shown individually, they may not be additive. For example, if more efficient cooling equipment saves $1000 per month, and more efficient lighting saves $1000 per month, doing both would not save $2000 per month since the reduced light energy reduces the cooling load. Generally, de-rating individual measures by 30% will allow simple adding with little risk of over-stating the overlapping effect.
6. Implementing efficiency measures is optional, but encouraged. The check box column is provided in the table of suggestions to accommodate our customer survey of completed measures which normally occurs 1 year after issuing the report.

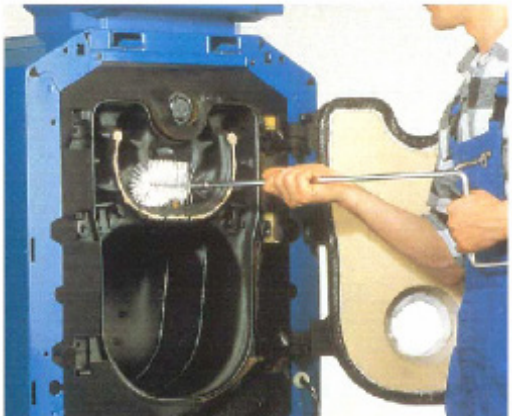
| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| **Energy End Use – Low Cost Measures.**<br>This energy survey was focused on the HTHW system; however the load it serves is the driver of most HTHW energy use and is the logical place to start. Energy conservation at the point of use will reflect upwards to the heating plant and reduce fuel use. The customer is encouraged to focus on both the HTHW system and the buildings for best results in reducing heating costs.<br><br>Most of these are low cost – capital items are notes with (**)<br><br>Example observations:<br>• Seal pipe entrances. For each new distribution pipe entrance, an aluminum box was installed to cover and protect the piping stub outs. These units were not sealed, nor were the core drilled holes in the walls into which they penetrated. Strong drafts of cold air were noticed at each mechanical room visited, creating heat loss.<br>• Insulate bare pipes, valves, and fittings were found in each mechanical room.<br>• Turn down heating. One barracks building common area was kept at 72 degF and was vacant.<br><br>Other considerations (topics only, not surveyed):<br>• **Low flow shower heads (1.0 or o1.25 gpm) to reduce water heating energy burden by half compared to standard 2.5 gpm heads.<br>• Automatic controls for standardized set points and night setback for common and individual HVAC zones.<br>• Reduced ventilation in unoccupied times or low occupancy times.<br>• Time switch function automatic controls for circulating pumps, domestic water circulators, air handler fans, and interlocked exhausters.<br>• Kitchen equipment and hood exhaust make-up systems operated when needed instead of all the time.<br>• **Heat recovery for large exhausters (e.g. 5kcfm or higher).<br>• **Pool covers.<br>• Insulate bare hot surfaces (piping, ducts, valves, fittings).<br>• Exterior door seals so no daylight is visible at the openings.<br>• Duct sealing for any ducts that travel outside the insulation envelope. | Low Cost | |
| **Stack Gas Economizer and Combustion Air Pre-Heat**<br>See sketch in **Appendix A**. This measure would install a pre-manufactured stack gas economizer (heat exchanger), and connect the heated water outlet to the existing plant Medium Temperature Hot Water system, in lieu of the heat exchangers, i.e. no longer use HTHW to heat the water used to preheat the air. Each system should have glycol to prevent freezing during idle periods in cold weather. There would be a pump per economizer, heating the air of that boiler, so the existing pumps will probably not be used. Also included in this measure is ductwork to connect the air inlet of boiler #3 to the old air intake serving it (move the lockers first); then all three boilers will benefit from the economizer preheat. Also included in this measure is adjusting the intake louvers to take air from outdoors only. In the half-half position, this 'vacuums' room heat into the boilers which may make sense if the room is too hot in summer, but in winter it results in cold spots in the building which are compensated for with heaters.<br><br>Basis of savings is preheating the air with waste heat rather than with output heat. | Capital | |

| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| Magnitude of savings is approximately 5% of fuel use for each boiler applied to.<br><br>Recovered waste heat would be used for preheating incoming combustion air, and for general space heating. The existing air pre-heaters are functional and were measured to raise the air temperature of boiler 1 by 60 degrees at 50% firing rate. Based on this, a minimum of 40 degF is anticipated (more is better, savings are proportional) with a 1.25% reduction in annual fuel use for each 40 degF rise. Economizers normally require at least 100 degF of approach to function, so 180 degF MTHW water can be expected with 280 degF flue gas, which is less than existing exit gas temperature and viable.<br><br>Operational note: There will be a practical limit on the amount of heat to extract, and that is the condensation point. Firing with natural gas allows stack gas temperature of around 220 degF with no condensation; however firing with oil, which happens occasionally, will produce condensation at this temperature and it is recommended to temporarily disable the economizer heat extraction when firing on oil.<br><br>Operational note: These coils should be cleaned annual as with any air coil, and more frequently if fouling occurs (there are no filters). Installation of 24”x24” access doors before and after each coil is recommended for cleaning. | | |

| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| **Waste Oil Boiler**<br>The military base has numerous vehicles with ongoing maintenance, and a continuous supply of waste oil, such as crank case oil and hydraulic oil. This waste oil can be recycled, but it can also be burned.<br><br>A HTHW unit capable of firing on waste oil was not found, but many examples of small packaged boilers designed for this are available. All such boilers need regular maintenance to clear off the soot from the tubes, so selecting one with maintenance in mind is recommended. Each of these includes swing-away design anticipating regular access for cleaning. In winter, cleaning once a month would be anticipated. | Capital | |

Water-tube style.
This manufacturer advertises a 30-minute cleaning procedure every 1000 hours of operation.

http://www.cleanburn.com/products/index.htm



Cast iron sectional style.
http://www.inov8-intl.com/pdf/bro_boiler.pdf

500,000 Btuh sizes are readily available, with some up to 1MMBtu or larger. The smaller package units seem more appropriate because of the ample provision for cleaning. Assuming 0.5 MMBtuh input, such a boiler would consume about 3.5-4.0 gallons of oil per hour and would be suitable for smaller facilities up to 15,000 SF per boiler. These could easily back feed hydronic heat loops in barracks or other buildings, with the HTHW systems left in place as backup.

The customer was unsure of the available amount of waste oil per year. Assuming the environmental permits are available to burn it a preliminary heat balance suggests that 25,000 **gallons of waste oil this has the potential to heat 40,000 SF of building for a year (1 typical barracks building)**.

Estimate is based on 2009 data that showed 70 kBtu/SF-year overall average fuel use, and an average of 125,000 Btu/gallon heat in waste oil.

| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| **Automatic Controls**<br>The plant is operated manually at this time. While heating can be maintained, there are opportunities for savings through optimization that can be achieved through automatic controls.<br><br>Caution: Before automation is considered, it should be understood that the automatic control system itself will require maintenance and attention. **Appendix B** shows how neglected instrumentation can lead to poor choices, and bad data input to an automatic control system creates improper outputs. Observations and interviews with plant personnel indicate that there is no maintenance of the measurement devices in place – without a change in procedure to include routine calibration and maintenance of automatic controls, automation is a poor choice. However, combined with the diligent efforts of an Instrumentation and Controls person, automation with applied optimization control routines is a good opportunity to produce savings. The following suggestions assume regular calibration and maintenance of automatic controls and related instruments.<br><br>1. <u>Optimal sequencing</u>: Each different machine has its own efficiency signature, where it's "sweet spot" is. By comparing the characteristic curves of each boiler, the control system can determine which unit is the smart choice for energy savings. A review of daily logs showed that this feature would be immediately useful. **See Appendix C**. For the months of March, April, and October, the heating demand was well within the limits of boiler #3, and yet boiler #1 was operated. Running a larger boiler than necessary increases part load losses. The rest of the months show the boiler run was the same as what an automatic controller would have chosen. Settings for the automatic choice were:<br>**→If a boiler is above 90% capacity, call for a larger boiler**<br><br>2. <u>Real-time plant efficiency calculation</u>: This measure requires a modification to the utility gas meters to include a "pulse board" that will provide a pulse output that represents flow rate. The fuel input, in proportion to the exported heat (loop flow and differential temperature) will yield an overall "big box" efficiency of the overall plant. This metric can be benchmarked year to year, but can also be useful for immediate (real time) feedback on whether variations in operation strategy have a positive impact on overall energy savings.<br>**NOTE:** CSU gas meter shop confirmed that there is already a pulse output from the meters.<br><br>3. <u>Variable speed drives:</u> If VSD control of pumps and fans are implemented, automatic controls would provide the regulation. For example, a variety of building differential pressure signals could be compared, to find the 'worst case' demand for water pressure and the pump speed would be modulated to meet that demand.<br><br>4. <u>Response to variable demand</u>: Many automatic control systems operate with a fixed set point, but this is done out of convenience and desire for simplicity. In truth, most processes in nature are not so static and squeezing the most out of energy dollars requires optimization which, in turn, requires flexibility. With attention to programming, the automation system can be used as a tool to achieve the last few percent of plant efficiency. Examples:<br>• Boiler supply temperature reset directly from building demand | Capital | |

| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| (control valve position or controller output as 'implied valve position') or indirectly from outside air. This is currently a manual set point.<br>• Loop pump pressure reset from building control valve position or percent plant load. This is currently set by a differential relief valve in the plant.<br><br>5. Interlocks and alarms: Key process alarms can be brought to the operator's attention sooner than periodic tours to the instrument board. The use of pre-alarms is especially useful since it can allow time for intervention and increase system reliability. For example, stack temperature is *getting warmer than normal* (pre-alarm). Interlocks for other processes can be automated through the control system, or can be hardwired. For example, if the stack gas heat recovery option is chosen, it should not be used when firing on oil. This fact can be committed to memory or procedure, or can be automated with an interlock.<br><br>In the consideration of a control system, there are some things to consider:<br>• Reliability requirements may help choose between commercial and industrial grade control systems.<br>• Software connectivity to plant equipment including boilers and any VFDs.<br>• Remote connectivity for access by operators or supervisors outside the plant.<br>• Local LAN or Ethernet/IP/Internet (web) style of communication. While very convenient and state-of-the-art, web style control systems may also create internet security concerns, so the IT department would need to comment.<br>• Access/password security level assignments – e.g. certain people only have access to certain features or adjustment points.<br>• Connectivity to other control systems in place.<br>• Abundant capability for trends, alarms, logs, reports; short term and long term.<br>• Loop control methods that include PID,<br>• Provisions for loop tuning, hold last value, monitor for "reliable" data.<br>• Graphical display.<br>• Control system architecture that will fail soft – e.g. any overarching control point would be applied in a supervisory capacity to a local controller, such that the failure of any one controller did not create a full plant shutdown. Override capability for all points in the event of controller malfunction would be an essential feature.<br>• Absence of "bells and whistles" points. Each "point" chosen for the system should have good merit.<br>• Service and support from the manufacturer.<br>• Training availability for operators.<br>• Cross training to avoid dependence of control knowledge on a single person. | | |
| **Mitigate Part Load Efficiency Losses**<br>This is a multi-part measure.<br><br>Distribution losses are an overhead energy cost tradeoff for the simplicity and convenience of central heating. Using interval utility data in "middle of the night in July", this has been estimated to be 24 therms per hour, 12% of annual HTHW energy use, and nearly 100% of energy use during summer at night. The heat lost to distribution in the four summer months is approximately **70,000 therms**, and there are many hours when the boilers operate simply to offset these piping losses. Losses were confirmed | Capital | |

| Suggested Measures | Type | Complete ✓ |
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| with field measurements that show steadily declining temperatures in the south loop, and are shown in **Appendix J.**<br><br>Part 1. Turn boilers off in summer. This is the direct approach, but would be costly since HTHW has been linked to more than just building heating. Heating valves for buildings are closed on a calendar basis, e.g. 15 Apr through - 15 Oct; however HTHW loads for domestic hot water for kitchens and showers remain even in summer, so the boilers must continue to run all year even at very low loads. Most buildings surveyed included hot water and very few of them had natural gas piped into the building, so this measure has a large practical barrier.<br><br>Part 1A. Reduce supply temperature in summer. Of the buildings that use HTHW for steam, only one requires steam in summer: Bldg 2061 / Dining Facility (18,000 SF). This measure calls for installing natural gas service and replacing the HTHW-to-steam generator in this building. With this off the HTHW system, the temperature of HTHW needed will be driven by shower loads which are 120 or 140 degF. This will allow the HTHW supply water temperature to be reset during summer months to 200 degF. Basis of savings is reduced distribution loss, lower stack temperature, and reduced boiler casing loss. Savings from this measure over four summer months would be approximately **35,000 therms**.<br><br>Assume 60 degF soil temperature and 340 degF supply temperature<br>(200-60) / (340-60) = 50% heat loss (loss is proportional to dT)<br><br>Part 2. Automatic control for boiler staging. Appendix D shows a sampling of hourly logs for each month, and a projection of what boiler "would run" if under automatic control. The basis for the switch is when the small boiler is at 90% of capacity. Graphs that show an hour a day switching are of no value, since starting and stopping large equipment frequently is not good practice. However, there is a definite advantage shown for March, April, May, October (**Appendix D**).<br><br>Part 3. Jockey Boiler. **Appendix D** shows that automatic control switching helps a little in summer months, but even the smaller boiler is grossly oversized for the low load. This creates disproportionate casing losses, which are 1-2% of the full firing rate at all times. This measure would install another, very small, HTHW boiler sized specifically for summer load so that it would run at 50% or higher load at all times and allow Boilers 1 and 3 to be turned off for summer months, **June through September**. Preliminary estimate suggests a jockey boiler size would be **10 MMBtuh** output capacity – the purple line on graphs for June through September show the improved percent loading by using a jockey boiler. **Appendix F** shows boiler efficiency loss from operating at low loads.<br><br>NOTE: With two new 10 MMBtuh Jockey boilers, instead of one, the combined capacity of boilers 3,4,5 would provide N=1 backup and **eliminate the need for replacing existing Boiler #1, a considerable cost savings.** Capacity of 3+4+5 = 44MMBtu which will back up boiler #2. Boiler #2, once functional, would be the winter base load unit. | | |

| Suggested Measures | Type | Complete ✓ |
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| Part 4. Parallel Positioning<br>Boilers 1 and 2 had a single point of control for fuel and air. This arrangement works reasonably well at higher loads, but characteristically will allow more excess air than necessary at part load. By controlling the air and fuel separately, the combustion efficiency (unrelated to casing losses) can be kept constant at all loads. A further benefit of parallel positioning is the ability to do "O2 Trim", discussed in another measure. | | |
| **O2 Trim**<br>Fuel combustion is never complete without some excess air, but too much excess air reduces efficiency. This is because the extra air passes through the combustion area, lowering the charge temperature, literally sweeping heat out the stack and increasing fuel use for the same amount of delivered heat. Readings taken at the boiler control panel showed O2 levels at 4% which matched daily logs (taken from the same instrument). This suggests O2 trim could produce meaningful savings, although with no calibration of boiler instruments reported the readings themselves may or may not be accurate.<br><br>A review of the manufacturer's burner performance and adjustment literature showed the characteristic single air-fuel control point best case at full fire and higher excess air and O2 values at low loads. Integral to the O2 trim recommendation is the splitting of air and fuel control actuators and new firing controls.<br><br>Boiler #1 is intended to be replaced soon and, if so, this measure may be better spent integrating the feature into the new boiler.<br><br>New boiler #2 does not have parallel positioning – since it is not yet running, changing the firing controls for parallel positioning and O2 trim is recommended.<br><br>Boiler #3 has independent control of air and fuel, so adding O2 trim will be easier than for the other two. | Capital | |
| **Primary/Secondary Pumping**<br>The system operates on a fixed pump speed (on-off), pumping through the boilers and the building in series. A differential pressure controller and bypass valve in the plant assure relatively constant flow through the boilers, as the two-way valves in the buildings close down and push back on the pumps.<br><br>This measure would modify the plant piping. **See Appendix E.** Each boiler would have a dedicated circulation pump, with backup, to provide a constant flow through the boiler. These would be the *primary* pumps. Constant flow is recommended in the boiler manufacturer's application literature. The loop would be served by distribution or *secondary* pumps, with variable flow. The primary pumps would be low head/low horsepower, and the secondary pumps would be higher head higher horsepower. The bypass valve would be removed. The basis of savings is reduced pump horsepower from no longer having to dissipate the excess head across the bypass valve and having appropriately sized pumps. Currently a pump large enough for a 40 MMBtuh boiler is used for the 24MMBtu boiler – roughly double the necessary pump energy.<br><br>Part of the pump electric savings is lost because of the fact that any waste pump energy ends up as heat in the water – thus the reduction of pump energy requires an equal and additive amount of additional heat input via burning fuel. But the environmental impact is | Capital | |

| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| positive since the electric energy saved equates to about 3 units of upstream energy expense and pollution.<br><br>NOTE 1: Conventional primary/secondary pumping was chosen over primary-only variable flow systems due to simplicity of operation and the ability to operate manually in the event of control failure.<br><br>NOTE 2: Since existing plant piping and pumps are near end of life, the cost of this measure should be considered normal replacement and not paid for on energy savings. It is simply a better way to rebuild the plant-end of the distribution system for the next life cycle.<br><br>NOTE 3: One advantage of the primary/secondary design is that the primary pump flow through the boiler is independent of changes in secondary flow (distribution). As a general note, if the primary/secondary system change is not implemented, then replacement pumps will need to be carefully selected to have sufficient rise in the pump curves to actuate the relief valve. Alternately, primary flow can be achieved using flow meters and control valves instead of differential pressure relief valves.<br><br>NOTE 4: Another advantage to the primary/secondary system is the flow isolation that will naturally occur for an "off" boiler simply by turning off the pump. Currently, large valves are manually closed whenever a boiler is stopped – this would not be needed with a primary/secondary system. | | |
| **Smaller Pump for Boiler #3**<br>If the system upgrades are not chosen, and constant flow primary pumping remains, then a smaller pump for Boiler #3 is recommended. The 75 Hp pumps are sized for the large boilers and are about double the necessary size for the small boiler. This would suggest two pumps for redundancy. Size would be approximately 30 hp. | Capital | |
| **Heat Nearby Buildings with Waste Heat**<br>Barracks buildings are similar to a hotel in that most of the building occupied areas are individual and have an outside wall. This fact plays into this measure.<br><br>This measure would consist of a new piping loop from the heating plant to selected barracks buildings close by, and converting those barracks buildings to individual water source heat pumps. A flue gas condensing heat exchanger at the heating plant would capture waste heat from the boiler stacks and provide a continuous supply of 70 degF water. Each room in the barracks buildings would have a high efficiency water source heat pump that would operate in heating mode with a COP of 5.0, **reducing the cost of heating the barracks by about 2/3.**<br><br>The key to this system is the availability of free heat. The condensing equipment would be large and located at ground level, but would prevent any condensation from draining into the main boilers. There would also be induced draft fans to control flue gas movement through the boiler and heat exchanger, and a circulating pump. Flue discharge temperature would be on the order of 100 degF compared to 300 degF currently.<br><br>The heat pumps could also provide cooling, if desired, and the only modification needed would be a cooling tower + plate frame heat exchanger, sized to provide a 7 degF | Capital | |

| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| approach with 61 degF WB entering air temperature, and a fan power budget of 0.05 kW/ton. Cooling units would operate at 0.7 kW/ton (EER-18). One manufacturer's performance data showing EER-18 and COP-5 at 70 degF water are shown in **Appendix G.**<br><br>Using a cold weather snap shot shows a maximum plant output of about 50MMBh (9am) which establishes the heating rate for the network of 19.7 Btuh per SF**. Using this figure, and an assumed recovery rate of stack waste heat, an estimate of buildings that could be heated with waste heat was derived.<br><br>Doing this measure in lieu of the stack gas recovery system would allow an estimated 15% recovered waste heat about **300,000 SF of barracks** to be heated.<br>For this scenario, a map section in **Appendix H** shows seven buildings that could be served from waste heat:<br>1667<br>1668<br>1663<br>1664<br>1665<br>1366<br>1367<br>These buildings appear identical (barracks) and are reported to be 40,639 SF each.<br><br>Doing this measure in addition to the stack gas recovery system would allow an estimated 10% recovered waste heat and about **200,000 SF of barracks** to be heated.<br>For this scenario, a map section in **Appendix H** shows the five closest buildings that could be served from waste heat:<br>1667<br>1668<br>1663<br>1664<br>1665<br><br>Most of the north loop is barracks buildings, but the total of all north loop buildings is over 800,000 SF which cannot be supported by this measure; thus a separate piping loop would be required. | | |

| Suggested Measures | Type | Complete ✓ |
|---|---|---|
| **Distribution Piping Maintenance**<br>The HTHW system is the proud owner of a new distribution system, which will make the HTHW system viable for another 30-50 years if properly cared for. The installed system was explained to be *Perma-Pipe Multi-Therm 500*, pictured below. The exterior layer of insulation is urethane foam, which cannot take the heat of the carrier pipe, so is isolated with a layer of high temp insulation and the corrugated spacer. The interior insulation may or may not be exactly what is installed, depending on what was specified, but what is significant is that this is a "drainable, dryable, pressure testable" pipe system. This measure suggests taking full advantage of these system properties.<br><br>If insulation becomes wet, the insulating properties are badly compromised. It is possible for the carrier pipe to leak or a fitting to leak – if this happens, a repair is needed but then there is wet insulation; the pipe-within-a-pipe system allows a path to drain the water – so the installation included prescribed sloping of pipes and "drip legs" to catch it; probably also drain valves to release it. So knowing the location of these low spots and checking them periodically is recommended. Note: water intrusion from a crack in the outer jacket cannot be vented.<br><br>A great way to detect leaks in the jacket steel pipe is to pressure test it. This was probably done during QC of the installation. This measure calls for periodic pressure testing to assure the system remains tight.<br><br> | Strategic | |
| **End of Life Replacement.**<br>Based on age, condition, and normal expected life, the balance of the HTHW system other than the new distribution system, appears due for replacement.<br><br>In the heating plant, this would include not only the boilers, but the main piping, valves, pumps, and controls as well.<br><br>In the buildings, this includes all the high temp interface points such as heat exchangers, control valves, monitoring equipment, piping and valves.<br><br>The equipment is functional, but repair costs will continue to escalate. A bigger concern is related to the piping and connections, and whether the age and slow erosion/corrosion removal of metal have created any weak spots that could result in failure from the high pressure. | Strategic | |

# SYSTEM DESCRIPTION AND OBSERVATIONS

**General:**
Outside air temperature varied from 15 degF to 40 degF during the two days.

**System Description:**
Heating for a large portion of the base buildings is provided by the central heating plant. This does not include housing, but includes barracks, gymnasium, dine, and administrative (office) buildings. The system is high temperature hot water (HTHW), operating in the range of 350 degrees F and 300 psi. B Boilers are forced draft water-tube type:
B1 – 40MMBtu output (1966) Union Iron Works (Riley Stoker)
B2 – 40MMBtu output (2008) English Boiler and Tube
B3 – 24MMBtu output (1966) Union Iron Works (Riley Stoker)

Distribution piping is direct buried and has been recently replaced under an Army Corps of Engineers project. The two "end pieces" of the system (the central plant and the building tie in equipment) is still of the original vintage, around 1966, putting the overall system age at 44 years. Primarily intended for heating, this system currently is kept running year-round to serve dining areas (cooking and hot water) and shower water heating. This results in very low load operation during summer months.

Distribution pumps are constant speed, equal size, and manually started one per boiler. Control valves surveyed are 2-way type that stop, not divert, the HTHW flow. When demand is low and most control valves are closed down, the flow is reduced and pumps move to different curve operating points; the associated pressure rise actuates the relief valve in the plant, set for 45 psid, to avoid excessive reduction of water flow in the boilers.

Distribution losses were measured and are noted in Appendix J. Utility bills were also used to calculate magnitude of these losses.

**System Condition:**
Distribution piping has been replaced in the last few years, and is in new condition. The interface piping and equipment at each building, consisting of interior piping, shutoff valves, controls, and heat exchangers is mostly original, with an estimated age of 44 years. The heating plant piping and equipment is mostly original, with an estimated age of 44 years. The exception to this is new boiler #2, although this boiler was reported to have had operational problems on startup two years ago and still is not operable.
Expected life of system piping and components varies depending on corrosion and erosion rates, but typical values are 50 years if well cared for. Heating plant pumps are in poor condition and should be a planned replacement expense soon.

**Controls:**
Each boiler has its own safety and firing controls from the manufacturer. Additionally, there is a display board for the key boiler readings and export values of flow and temperature for the HTHW water leaving the plant. Instrument calibration is lacking in the plant and accuracy of any of the readings is suspect. Staging of boilers and pumps is a manual decision by the operator on duty. Based on logs, it is common for boilers larger than necessary to be operated, which makes a case for automation; however automation will not cure system issues, so the combination of automatic controls and system / equipment improvements are noted in the recommendations section. Controls have been neglected of calibration and many of the readings appear to be grossly inaccurate. Sample discrepancies that support this statement are included in the report.

## Part 3 - OTHER OBSERVATIONS AND SUGGESTIONS

1. The design intent for winter heating is to have a redundant boiler – at this time, a failure of boiler #1 would result in a loss of system heating capacity since the smaller boiler #3 has significantly less heating capacity and cannot carry the cold weather load. Based on daily logs, about 35-40% of the existing load would need to be removed from the HTHW system for #3 to carry it in cold weather. The intended replacement for boiler #2 is reported to be dysfunctional and is not able to run; thus boiler #1 carries the winter load alone with only partial backup capacity. The sooner boiler #2 is repaired or replaced, the sooner the system reliability will be restored.

   In the meantime, contingency plans would be appropriate "just in case", such as:
   - Identifying non-critical loads to shut off to share remaining capacity. This could include double occupancy for private rooms, consolidating dining areas with modified shifts, sharing accommodations with other military facilities, or putting soldiers into hotels.
   - Catered food and no cooking on site.
   - Reduce demand by lowering indoor temperatures to 50 degrees, and possibly closing off outside air dampers temporarily.
   - Electric space heaters installed in ducts, and rooms, if the electric system can support it.
   - Portable heating provisions, such as trailer-mounted boilers, could supplement plant capacity. The easiest way to apply these units would be for specific buildings due to the very high system pressures of the HTHW system. However it would be possible, if not practical, to also inject portable capacity directly into the HTHW at one of the main valve pits outside the plant.
   - Portable low temperature hot water could also be distributed to the buildings via the chilled water piping network, except for the buildings that utilize a two-pipe system.

   Obviously, all these measures are undesirable and the preferred option is to get boiler #2 functional without delay. This is merely a reminder of the potential disruption.

   Also noted were boiler heat exchanger surface area specifications, noted here.

| Boiler | Rating | SF Total | SF Convection | SF Radiation | SF Economizer (not in total SF) |
|---|---|---|---|---|---|
| 1 | 40MM | 5223 | 4808 | 415 | Yes, ?? SF |
| 2 (new) | 40MM | 2801 | 2275 | 529 | ?? |
| 3 | 24MM | 2135 | 1715 | 420 | Yes, 980 SF |

2. Piping in the heating plant and the buildings is near the end of its expected useful life of 50 years. Budgeting to replace the pipe and valve infrastructure is suggested, and will establish the beginning of a new life cycle for the heating plant, since the distribution piping has been replaced already. In the meantime, replacing the root shutoff valves in the plant is suggested, since many of them are reported to not hold.

3. Make-up water to this sealed system is a steady 300-600 gallons per day. About 5% of the loss is coming from the heating plant boiler pumps which have rope packing and worn shafts (calculated with a wristwatch and observing the continuous leaks out of the packing). Approximate measurements of losses through the pump seals is shown here.

| | Approx Gallons per Day |
|---|---|
| HTHW Pump 1 | 5 |
| HTHW Pump 2 | 11 |
| HTHW Pump 3 | 1 |
| HTHW Pump 4 | 7 |
| TOTAL | 24 gallons per day |

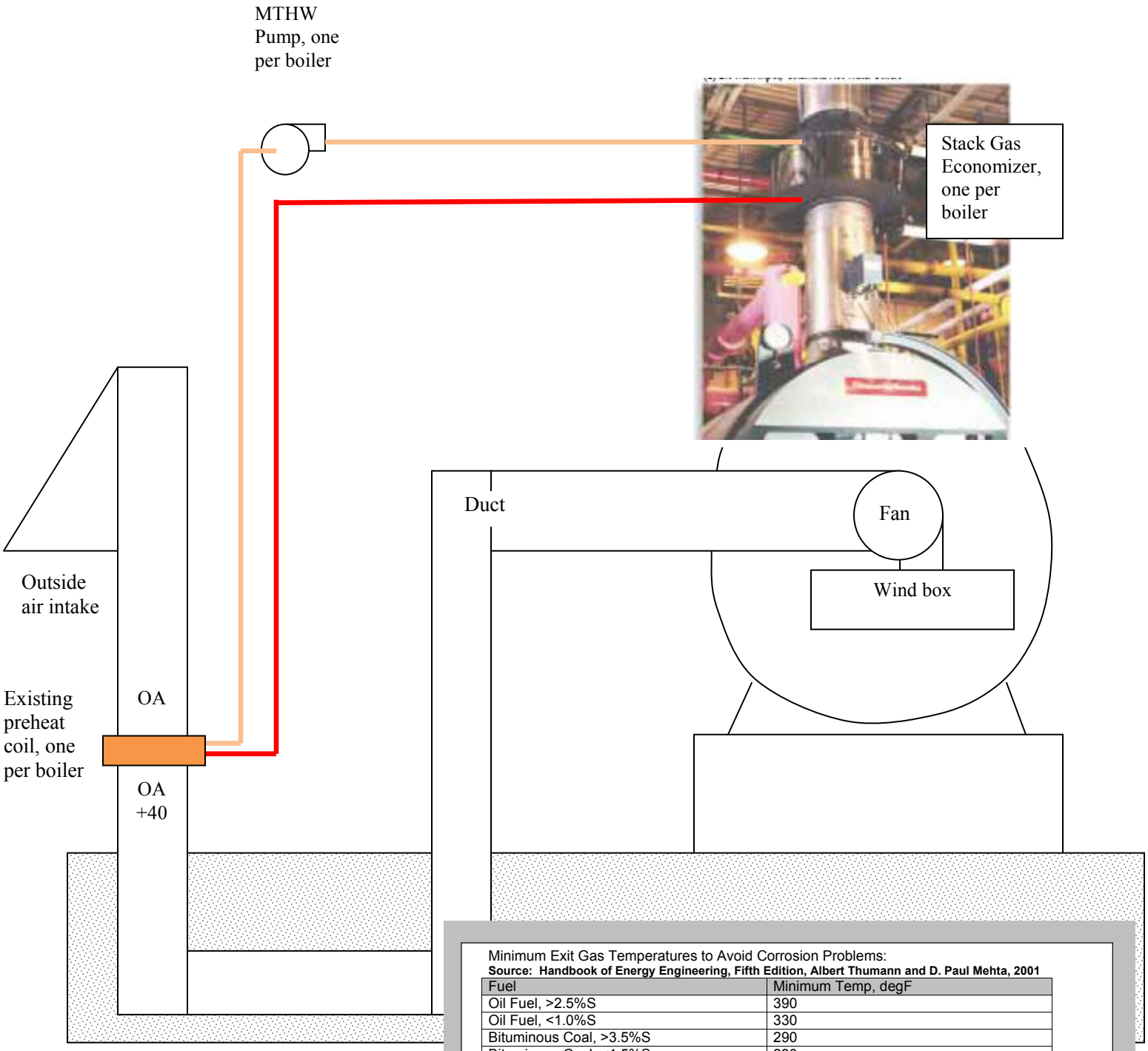
20 drops per ml, 20,000 drops per liter, 75,680 drops per gallon

The brief tour of 10-12 buildings where HTHW interfaced with building systems did not show any appreciable external leaks. A phone call to a stationary operator of a similar system indicated a typical make up rate of "max 75 gallons per day unless we have a leak." This suggests either underground leaks or tube leaks, either in the boilers or building heat exchangers. It is also possible that the make-up water meter is not reading correctly. This would be the easiest and first thing to check, especially due to the absence of instrument calibration.

## APPENDIX

| | |
|---|---|
| A | Stack Gas Economizer Diagram |
| B | Heating Plant Measurement Discrepancies |
| C | Representative Daily Logs (Hourly Readings) |
| D | Boiler Percent Loading Profile by Month |
| E | HTHW Pumping – Existing and Proposed |
| F | B oiler Efficiency Loss from Operating at Low Load |
| G | Water Source Heat Pump Efficiency Data |
| H | Low Temperature Waste Heat Loop Concept for Seven Buildings |
| J | HTHW South Loop Observed Supply Temperatures |

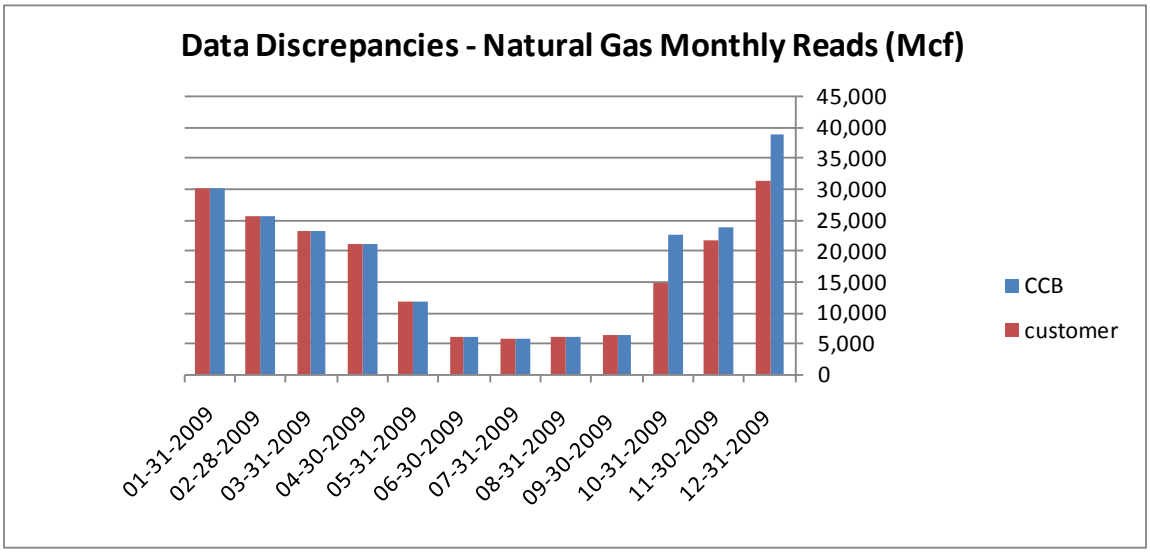
# Appendix A – Stack Gas Economizer Diagram




Minimum Exit Gas Temperatures to Avoid Corrosion Problems:
**Source: Handbook of Energy Engineering, Fifth Edition, Albert Thumann and D. Paul Mehta, 2001**

| Fuel | Minimum Temp, degF |
|---|---|
| Oil Fuel, >2.5%S | 390 |
| Oil Fuel, <1.0%S | 330 |
| Bituminous Coal, >3.5%S | 290 |
| Bituminous Coal, <1.5%S | 230 |
| Pulverized Anthracite | 220 |
| Natural Gas | 220 |
| | |

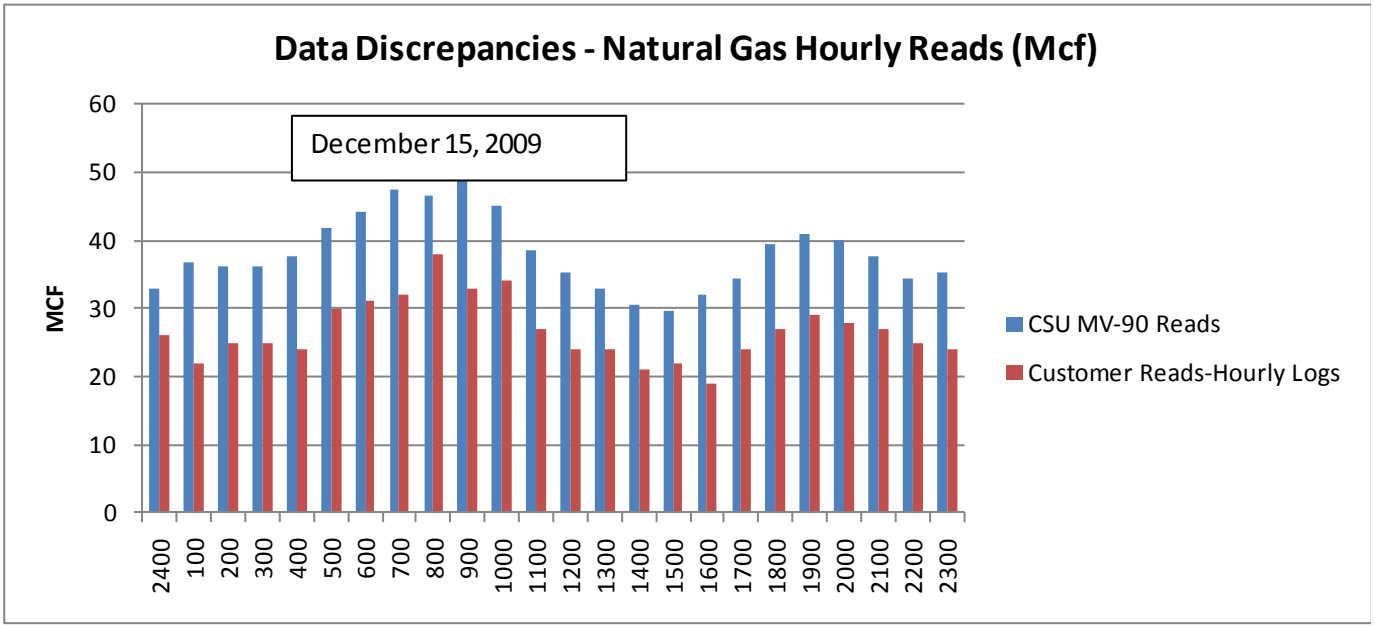
# Appendix B – Heating Plant Measurement Discrepancies

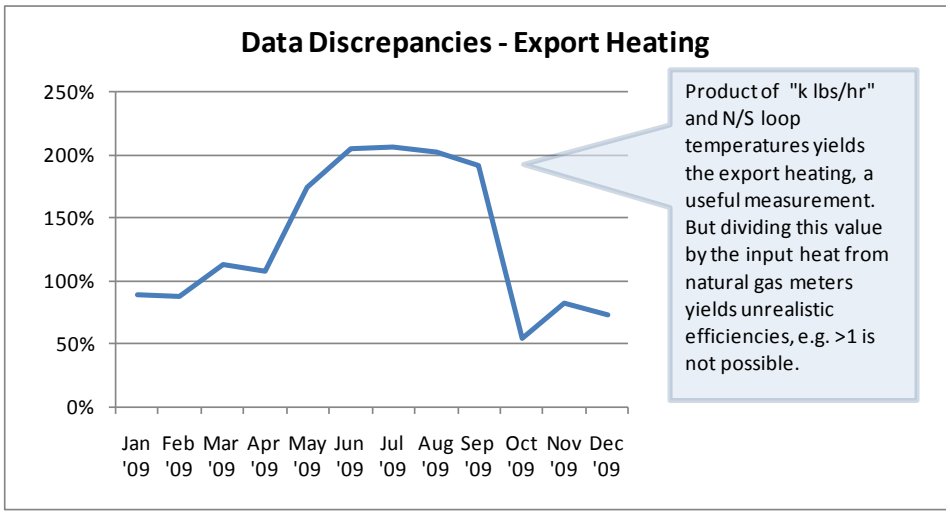



Sources of the discrepancies are unknown.

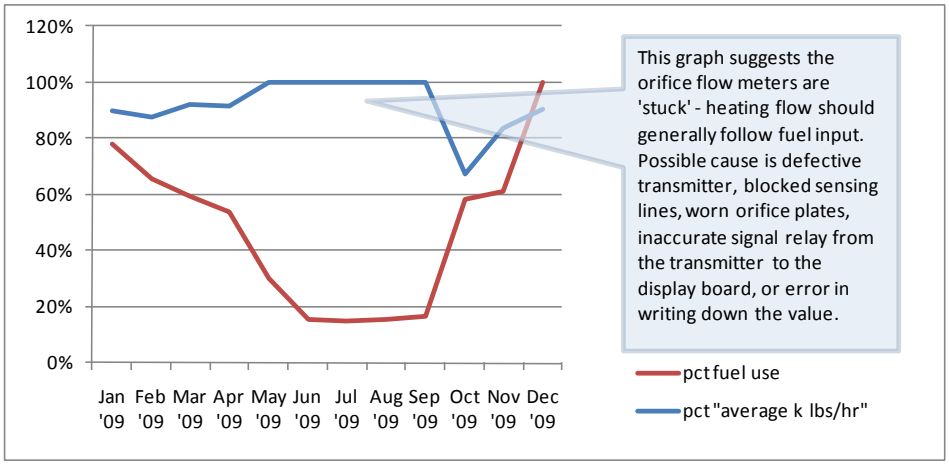
Monthly reads were occasionally off, but daily reads were consistently off.

CSU billing system meter reads were used in this report.






A likely cause of this error is the flow meters, shown in the next chart.




# Appendix B – Measurement Discrepancies (cont'd)

Other discrepancies.

A. The existing calculation for "Btus Produced" is intended to define output energy, but uses boiler gas use in the calculation which is an input value. While output is proportion to fuel input, this calculation ignores combustion efficiency and casing losses. The display unit takes gas flow for the boiler as an input and is manipulated in some fashion to display a number with the units of MMBtu (millions of Btus); the details of the conversion used to display MMBtu is not known: it could include an assumed heating value for the gas, an assumed fixed value of radiation losses, and/or an assumed value of combustion efficiency.

Boiler Btus Produced = Boiler Nat Gas MCF Input * Fx

Where:
Boiler Nat Gas MCF Input = the output of the gas flow meter on the boiler.
Fx = Some function or algorithm or signal conditioning step within the programmable display unit. Value is unknown.

A more appropriate calculation for boiler output would use water flow through the boiler with temperature rise to calculate the magnitude of heat leaving the boiler.

B. The existing calculation for "Generator Efficiency" is the output divided by input, which makes sense except for the fact that the output value used in the calculation is derived with the fuel input representing output; thus, in its present form, the efficiency calculation is of no value.

The efficiency calculation also uses inconsistent units. The output of "efficiency" is a percentage value of 100 or less, and is unitless, so dividing MMBtu by cf is invalid (not unitless). This may represent a short cut assumption that an MCF foot of gas at the CSU meter is "about 1MMBtu" but CSU gas supply is normalized to 12.07 psia and, at that pressure, has a heat content of about 802,000 Btu.

Generator Efficiency% = (Output / Input)
= 0.99 * (Boiler Btus Produced [item A]) / (CSU nat gas Mcf input)

With a few assumptions of the contents of Fx [item A] and correcting for the error in heat content for CSU gas at non-standard conditions, the unusually low values of calculated boiler percent efficiency can be reproduced. I do not believe the efficiency values are that low.

Example for Boiler #1:
Assume Boiler Output Fx includes a conversion of 1 MMBtu per MCF, a radiation loss of 2% [2% of 40 MMBtu capacity is 0.8 MMBtu], and a constant 82% combustion efficiency [constant is not a good assumption], the "output" Fx would be this factor:
Example Boiler Produced Calculation (with Fx) =(Boiler MCF (1 * 82%))-0.8
Then, for the boiler operating with 30 MCF of gas,
MMBtu calculation = Boiler Nat Gas cf Input * Fx
= (30 * 0.82)-0.8
= 23.8 MMBtu

Generator Efficiency% = (Boiler Btus Produced [item A]) / (CSU nat gas Mcf input)
= 0.99 * (23.8 / (30 / 0.802))
[dividing by 0.802 accounts for the extra MCF of flow at lower temperatures for the same amount of gas molecules.]
= 63%

Still neglecting combustion efficiency, this calculation would be closer to reality if BOTH of the gas flows were at the same pressure condition. The "per boiler" gas meter does not read out in gas MCF directly, so leaving item A alone, the corrected efficiency calculation would be:

Generator Efficiency% = (Boiler Btus Produced [item A]) / (CSU nat gas Mcf input, at STP)
= 23.8 / (CSU MCF*0.802)
[multiplying by 0.802 roughly corrects to STP]
[0.99 constant dropped]
= 23.8 / (30)
= 79%

This example explains a likely scenario of the calculation that exists in the boiler control panel "MMBtus produced" value, and the additional error introduced since the CSU meter is corrected to a non-standard value of natural gas density. The "MMBtus produced" calculation is a yardstick calculation only, and the efficiency calculation is circular and meaningless. The recommended approach is to begin with a measured value of boiler Btus out (using boiler water flow and temperature rise) and divide by fuel input in same units, measured at the respective boiler. The existing calculation can be improved by correcting for Btus per cubic foot for CSU meter readings, however the calculation is fully void if more than one boiler is running since the boiler heat output comes from gas measured "per boiler" and the boiler heat input comes from the CSU meter that supplies the entire plant.

# Appendix C – Representative Daily Logs (Hourly Readings)

January, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 1-15-09

| | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 24 | 250 | 290 | 339 | 275 | 432 | 2.6 | | | 318 | | | | | 31 |
| 0100 | 25 | 250 | 290 | 340 | 273 | 438 | 3.4 | | | 318 | | | | | 29 |
| 0200 | 19 | 250 | 285 | 342 | 292 | 432 | 2.2 | | | 318 | | | | | 29 |
| 0300 | 25 | 245 | 285 | 344 | 281 | 440 | 2.1 | | | 318 | | | | | 28 |
| 0400 | 26 | 245 | 280 | 342 | 278 | 438 | 2.8 | | | 318 | | | | | 28 |
| 0500 | 26 | 245 | 280 | 339 | 272 | 432 | 2.4 | | | 318 | | | | | 28 |
| 0600 | 27 | 240 | 280 | 336 | 267 | 430 | 4.2 | | | 320 | | | | | 29 |
| 0700 | 26 | 235 | 275 | 339 | 267 | 430 | 4.2 | | | 320 | | | | | 27 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 245 | 283 | 340 | 276 | 434 | 3.0 | | | 319 | | | | | 29 |
| 0800 | 26 | 235 | 275 | 339 | 259 | 436 | 3.6 | | | 325 | | | | | 28 |
| 0900 | 32 | 245 | 285 | 337 | 257 | 436 | 3.5 | | | 325 | | | | | 28 |
| 1000 | 32 | 245 | 285 | 340 | 270 | 430 | 3.4 | | | 320 | | | | | 34 |
| 1100 | 25 | 245 | 285 | 344 | 283 | 434 | 2.4 | | | 315 | | | | | 40 |
| 1200 | 18 | 245 | 285 | 339 | 288 | 426 | 3.4 | | | 315 | | | | | 45 |
| 1300 | 22 | 245 | 285 | 340 | 289 | 430 | 3.4 | | | 315 | | | | | 45 |
| 1400 | 18 | 240 | 280 | 336 | 284 | 428 | 3.6 | | | 315 | | | | | 44 |
| 1500 | 20 | 240 | 275 | 344 | 286 | 438 | 3.2 | | | 315 | | | | | 44 |
| ave | | 242 | 282 | 340 | 274 | 434 | 3.4 | | | 318 | | | | | 40 |
| 1600 | 23 | 235 | 275 | 342 | 280 | 428 | 2.4 | | | 315 | | | | | 40 |
| 1700 | 24 | 240 | 280 | 340 | 280 | 424 | 2.9 | | | 315 | | | | | 36 |
| 1800 | 25 | 240 | 280 | 340 | 225 | 428 | 2.6 | | | 315 | | | | | 35 |
| 1900 | 26 | 245 | 285 | 342 | 273 | 426 | 4.0 | | | 320 | | | | | 33 |
| 2000 | 24 | 245 | 285 | 337 | 273 | 434 | 2.8 | | | 315 | | | | | 32 |
| 2100 | 25 | 240 | 290 | 340 | 280 | 430 | 3.1 | | | 315 | | | | | 32 |
| 2200 | 23 | 240 | 280 | 340 | 283 | 428 | 2.2 | | | 315 | | | | | 33 |
| 2300 | 23 | 240 | 280 | 342 | 271 | 430 | 3.2 | | | 315 | | | | | 32 |
| ave. | | 241 | 281 | 340 | 278 | 429 | 3.0 | | | 316 | | | | | 34 |
| ave. | | 243 | 282 | 340 | 276 | 432 | 3.1 | | | 318 | | | | | 34 |
| Total generator BTU mil. | | | 200 | #1 | #3 | | | | 194 | | | | | | 193 |
| Total gas in m cu. Ft. | | | 357 | 35365 | | 491281 | 43382 | | 338 | 35559 | | 491452 | 43549 | | 357 |
| Total oil in gallons | | | | 35165 | 17230 | 491103 | 43209 | | | 35365 | 17230 | 491281 | 43382 | | |
| Generator efficiency in % | | | 57.5 | 200 | | 178 | 173 | | 57.9% | 194 | | 171 | 167 | | 54.6% |

15753 24 hour data

BTU Data

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | 35752 | | 17230 |
| Start | 35165 | | 17230 |
| Total | 587 | | Ø |
| 24 hr total | | | 587 |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 491633 | 43725 |
| Start | 491103 | 43209 |
| Total | 530 | 516 |
| Total gas used | | 1046 |
| Total oil used | | |

Generator efficiency % 56.7%

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | 8667370 | |
| Start | 8666980 | |
| Total | 390 | |

Outside temperature

| | |
|---|---|
| High temperature | 45 |
| Low temperature | 27 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

Total fuel on hand

| #1 | #3 | | |
|---|---|---|---|
| 35752 | 17230 | 491633 | 43725 |
| 35559 | 17230 | 491452 | 43549 |
| 193 | Ø | 181 | 176 |

February, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date 2-15-09

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % co2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 30 | 250 | 290 | 342 | 272 | 436 | 4.0 | | | 320 | | | | | 23 |
| 0100 | 24 | 250 | 290 | 337 | 268 | 432 | 4.6 | | | 320 | | | | | 23 |
| 0200 | 27 | 250 | 290 | 344 | 273 | 434 | 2.6 | | | 318 | | | | | 22 |
| 0300 | 26 | 250 | 285 | 337 | 268 | 434 | 3.4 | | | 318 | | | | | 22 |
| 0400 | 28 | 245 | 285 | 334 | 262 | 446 | 4.6 | | | 320 | | | | | 21 |
| 0500 | 28 | 245 | 285 | 339 | 275 | 436 | 2.5 | | | 318 | | | | | 21 |
| 0600 | 31 | 240 | 280 | 342 | 267 | 438 | 4.3 | | | 320 | | | | | 21 |
| 0700 | 24 | 240 | 280 | 336 | 257 | 436 | 4.0 | | | 320 | | | | | 20 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 246 | 286 | 339 | 268 | 437 | 3.8 | | | 319 | | | | | 22 |
| 0800 | 24 | 240 | 280 | 345 | 273 | 442 | 3.4 | | | 325 | | | | | 22 |
| 0900 | 28 | 240 | 280 | 340 | 263 | 428 | 4.4 | | | 320 | | | | | 29 |
| 1000 | 26 | 245 | 285 | 337 | 272 | 420 | 3.4 | | | 315 | | | | | 34 |
| 1100 | 26 | 245 | 285 | 339 | 273 | 422 | 3 | | | 315 | | | | | 37 |
| 1200 | 21 | 245 | 285 | 337 | 270 | 430 | 2.9 | | | 310 | | | | | 41 |
| 1300 | 25 | 245 | 285 | 337 | 276 | 422 | 3 | | | 310 | | | | | 42 |
| 1400 | 22 | 240 | 280 | 337 | 280 | 426 | 3.8 | | | 310 | | | | | 42 |
| 1500 | 24 | 240 | 280 | 344 | 278 | 420 | 2.8 | | | 315 | | | | | 43 |
| ave. | | 242 | 282 | 338 | 274 | 428 | 3.4 | | | 312 | | | | | 34 |
| 1600 | 25 | 240 | 280 | 337 | 284 | 414 | 3.4 | | | 315 | | | | | 43 |
| 1700 | 22 | 235 | 275 | 342 | 281 | 414 | 3.0 | | | 315 | | | | | 43 |
| 1800 | 22 | 235 | 275 | 340 | 281 | 422 | 3.2 | | | 315 | | | | | 39 |
| 1900 | 24 | 230 | 270 | 336 | 268 | 428 | 2.7 | | | 315 | | | | | 37 |
| 2000 | 23 | 230 | 270 | 340 | 275 | 418 | 3.7 | | | 315 | | | | | 37 |
| 2100 | 23 | 240 | 280 | 340 | 278 | 424 | 3.4 | | | 315 | | | | | 36 |
| 2200 | 25 | 240 | 280 | 337 | 280 | 416 | 3.7 | | | 315 | | | | | 34 |
| 2300 | 23 | 240 | 280 | 340 | 280 | 418 | 2.6 | | | 315 | | | | | 32 |
| ave. | | 236 | 276 | 339 | 278 | 419 | 3.2 | | | 315 | | | | | 37 |
| ave. | | 241 | 281 | 339 | 273 | 428 | 3.5 | | | 316 | | | | | 31 |
| Total generator BTU mil. | | | 212 | | | | | | 197 | | | | | | 179 |
| Total gas in m cu. Ft. | | | 380 | 51966 | | 506273 | | 57987 | 357 | 52163 | | 506454 | | 58163 | 314 |
| Total oil in gallons | | | | 51754 | | 506080 | | 57800 | | 51966 | | 506273 | | 57987 | |
| Generator efficiency in % | | | 56.3 | 217 | | 193 | | 187 | 55.7 | | | 181 | | 176 | 57.5 |
| Over for remarks | | | Operator | DH | | | | | Operator | | | [illegible] | | | Operator [illegible] |

16497 — 24 hour data

**BTU Data**

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | 2342 | | |
| Start | 51754 | | |
| Total | 588 | | |
| 24 hr total | | | 588 |

**Fuel Data**

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 613 | 9318 |
| Start | 506080 | 57800 |
| Total | 533 | 518 |
| Total gas used | | 1051 |
| Total oil used | | |
| Generator efficiency % | | 56.5 |

**Makeup Water**

| Water meter | 1 | 2 |
|---|---|---|
| Stop | 420 | |
| Start | 8080280 | |
| Total | 190 | |

**Outside temperature**

| | |
|---|---|
| High temperature | 43 |
| Low temperature | 20 |

**Oil meter**

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |
| Total fuel on hand | | | |

| | | | |
|---|---|---|---|
| 179 | | | |
| 314 | 342 | 613 | 218 |
| | 52163 | 506454 | 58163 |
| 57.5 | 179 | 159 | 155 |

March, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 3-15-09

| Time | Total BTU in mil. | Exp tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu Ft | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 16 | 240 | 280 | 328 | 280 | 432 | 4.0 | | | 300 | | | | | 40 |
| 0100 | 22 | 240 | 280 | 321 | 276 | 428 | 3.3 | | | 300 | | | | | 38 |
| 0200 | 18 | 240 | 280 | 328 | 280 | 434 | 2.2 | | | 300 | | | | | 37 |
| 0300 | 20 | 240 | 280 | 329 | 281 | 436 | 4.1 | | | 300 | | | | | 37 |
| 0400 | 24 | 240 | 280 | 328 | 278 | 434 | 3.6 | | | 300 | | | | | 36 |
| 0500 | 20 | 240 | 280 | 324 | 276 | 426 | 2.5 | | | 300 | | | | | 34 |
| 0600 | 16 | 235 | 275 | 324 | 273 | 432 | 3.2 | | | 300 | | | | | 34 |
| 0700 | 19 | 235 | 275 | 324 | 260 | 438 | 2.2 | | | 300 | | | | | 34 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 239 | 279 | 326 | 276 | 433 | 3.1 | | | 300 | | | | | 36 |
| 0800 | 20 | 240 | 275 | 326 | 276 | 430 | 2 | | | 300 | | | | | 35 |
| 0900 | 18 | 240 | 280 | 324 | 272 | 418 | 3 | | | 300 | | | | | 41 |
| 1000 | 17 | 240 | 275 | 332 | 280 | 420 | 2.6 | | | 300 | | | | | 50 |
| 1100 | 16 | 240 | 280 | 324 | 280 | 414 | 2.4 | | | 300 | | | | | 54 |
| 1200 | 18 | 245 | 280 | 332 | 278 | 416 | 2.8 | | | 300 | | | | | 57 |
| 1300 | 17 | 250 | 285 | 321 | 283 | 414 | 2.8 | | | 300 | | | | | 59 |
| 1400 | 17 | 250 | 285 | 329 | 283 | 416 | 3.4 | | | 300 | | | | | 62 |
| 1500 | 13 | 255 | 285 | 331 | 289 | 410 | 2.8 | | | 300 | | | | | 61 |
| ave. | | 243 | 282 | 327 | 280 | 418 | 2.8 | | | 300 | | | | | 52 |
| 1600 | 17 | 250 | 290 | 323 | 286 | 418 | 3.6 | | | 300 | | | | | 62 |
| 1700 | 14 | 255 | 295 | 324 | 294 | 416 | 3.6 | | | 300 | | | | | 63 |
| 1800 | 12 | 250 | 290 | 323 | 291 | 412 | 3.7 | | | 300 | | | | | 63 |
| 1900 | 12 | 250 | 290 | 323 | 289 | 420 | 3.5 | | | 300 | | | | | 60 |
| 2000 | 13 | 250 | 290 | 324 | 289 | 414 | 3.4 | | | 300 | | | | | 58 |
| 2100 | 14 | 245 | 285 | 324 | 286 | 416 | 2.6 | | | 300 | | | | | 55 |
| 2200 | 16 | 240 | 280 | 326 | 289 | 418 | 2.9 | | | 300 | | | | | 53 |
| 2300 | 14 | 240 | 280 | 324 | 284 | 416 | 2.9 | | | 300 | | | | | 49 |
| ave. | | 247 | 287 | 323 | 288 | 416 | 3.2 | | | 300 | | | | | 57 |
| ave. | | 243 | 283 | 325 | 281 | 422 | 3.0 | | | 300 | | | | | 48 |
| Total generator BTU mil. | | | 159 | #1 | | | | | 133 | | | | | | |
| Total gas in m cu. Ft. | | | 285 | 62683 | | | 517828 | 69250 | 237 | 62816 | | 517948 | | 69367 | |
| Total oil in gallons | | | | 62524 | | | 517683 | 69110 | | 62683 | | 517828 | | 69250 | |
| Generator efficiency in % | | | 56.3 | 159 | | | 145 | 140 | 58.3 | 133 | | 120 | | 117 | |
| Over for remarks | | | Operator | D.H | | | | | Operator | HJA | | | | | |

17038 — 24 hour data

BTU Data

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | 2925 | | |
| Start | 62524 | | |
| Total | 401 | | |
| 24 hr total | | | 401 |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 8044 | 461 |
| Start | 517683 | 69110 |
| Total | 361 | 251 |
| Total gas used | | 712 |
| Total oil used | | |

Generator efficiency % 56.8

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | | 0 |
| Start | | 8694440 |
| Total | | 0 |

Outside temperature

| | |
|---|---|
| High temperature | 63 |
| Low temperature | 34 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |
| Total fuel on hand | | | |

| | | | | |
|---|---|---|---|---|
| 109 | #1 | | | |
| 190 | 925 | 8044 | 461 | |
| | 62816 | 517948 | 69367 | |
| 57.9 | 109 | 96 | 94 | |
| Operator | Ron | | | |

April, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date 4-15-09

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 11 | 255 | 295 | 332 | 302 | 418 | 3.7 | | | 310 | | | | | 53 |
| 0100 | 14 | 250 | 290 | 337 | 305 | 404 | 3.4 | | | 315 | | | | | 52 |
| 0200 | 11 | 245 | 285 | 336 | 304 | 414 | 3.0 | | | 315 | | | | | 52 |
| 0300 | 10 | 240 | 280 | 334 | 304 | 402 | 3.5 | | | 310 | | | | | 50 |
| 0400 | 13 | 240 | 280 | 334 | 297 | 410 | 3.4 | | | 310 | | | | | 48 |
| 0500 | 12 | 245 | 285 | 339 | 300 | 412 | 2.9 | | | 310 | | | | | 46 |
| 0600 | 14 | 245 | 280 | 340 | 299 | 408 | 2.7 | | | 315 | | | | | 46 |
| 0700 | 19 | 250 | 290 | 340 | 292 | 408 | 2.1 | | | 315 | | | | | 45 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 245 | 284 | 337 | 299 | 410 | 3.0 | | | 313 | | | | | 49 |
| 0800 | 16 | 250 | 285 | 336 | 288 | 416 | 2.2 | | | 300 | | | | | 47 |
| 0900 | 21 | 260 | 295 | 332 | 253 | 415 | 3.4 | | | 300 | | | | | 49 |
| 1000 | 19 | 260 | 300 | 336 | 292 | 422 | 2.4 | | | 300 | | | | | 53 |
| 1100 | 13 | 260 | 300 | 331 | 296 | 410 | 4 | | | 300 | | | | | 62 |
| 1200 | 13 | 260 | 295 | 334 | 299 | 406 | 3.4 | | | 300 | | | | | 63 |
| 1300 | 12 | 260 | 295 | 334 | 302 | 415 | 3.2 | | | 310 | | | | | 65 |
| 1400 | 11 | 260 | 295 | 332 | 302 | 404 | 3.8 | | | 300 | | | | | 66 |
| 1500 | 11 | 260 | 295 | 332 | 304 | 406 | 4.2 | | | 310 | | | | | 68 |
| ave. | | 258 | 295 | 333 | 294 | 412 | 3.0 | | | 302 | | | | | 57 |
| 1600 | 12 | 255 | 295 | 337 | 307 | 404 | 3.4 | | | 315 | | | | | 68 |
| 1700 | 10 | 255 | 295 | 336 | 306 | 412 | 3.9 | | | 315 | | | | | 67 |
| 1800 | 12 | 255 | 295 | 330 | 300 | 406 | 4.4 | | | 310 | | | | | 67 |
| 1900 | 12 | 255 | 295 | 332 | 299 | 420 | 3.9 | | | 310 | | | | | 65 |
| 2000 | 15 | 260 | 300 | 334 | 300 | 426 | 3.9 | | | 310 | | | | | 62 |
| 2100 | 14 | 260 | 300 | 337 | 299 | 403 | 3.0 | | | 315 | | | | | 59 |
| 2200 | 14 | 260 | 300 | 337 | 296 | 414 | 2.6 | | | 315 | | | | | 57 |
| 2300 | 19 | 255 | 300 | 339 | 298 | 410 | 3.9 | | | 315 | | | | | 56 |
| ave. | | 257 | 299 | 335 | 301 | 412 | 3.6 | | | 313 | | | | | 63 |
| ave. | | 253 | 292 | 335 | 298 | 411 | 3.3 | | | 309 | | | | | 56 |
| Total generator BTU mil. | | | 114 | | | | | | 112 | | | | | | |
| Total gas in m cu. Ft. | | | 207 | 77.43 | | 530006 | 81117 | | 208 | 77.55 | | 530110 | 81217 | | |
| Total oil in gallons | | | | 76.29 | 22280 | 529992 | 81014 | | | 77.43 | | 530006 | 81117 | | |
| Generator efficiency in % | | | 55.6 | 114 | | 104 | 103 | | 55.1% | 112 | | 104 | 101 | | |

| 24 hour data | | | |
|---|---|---|---|
| 17563 | | | |
| BTU Data | | | |
| Intergr | 1 | 2 | 3 |
| Stop | 959 | | |
| Start | 76.29 | | 22280 |
| Total | 330 | | |
| 24 hr total | | | 330 |

| Fuel Data | | |
|---|---|---|
| Gas meter | 19 | 20 |
| Stop | 30200 | 306 |
| Start | 529992 | 81014 |
| Total | 298 | 298 |
| Total gas used | | 590 |
| Total oil used | | |
| Generator efficiency % | | 56.5 |

| Makeup Water | | |
|---|---|---|
| Water meter | 1 | 2 |
| Stop | 5370 | |
| Start | 8705100 | |
| Total | 270 | |

| Outside temperature | |
|---|---|
| High temperature | 68 |
| Low temperature | 45 |

| Oil meter | | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Stop | | | |
| Start | | | |
| Total | | | |
| Total fuel on hand | | | |
| 104 | #1 | | |
| 172 | 959 | 200 | 306 |
| | 77.7 | 529113 | 81218 |
| 59.0 | 104 | 90 | 98 |

May, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 5-15-2009

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 | | | Generator flue gas temp. | | | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | 2 | 3 | 1 | 2 | 3 | | | |
| 2400 | 11 | 241 | 280 | 322 | 284 | 484 | | | 4.1 | | | 293 | | | 65 |
| 0100 | 9 | 235 | 275 | 322 | 268 | 484 | | | 2.2 | | | 286 | | | 61 |
| 0200 | 10 | 234 | 275 | 322 | 268 | 484 | | | 1.9 | | | 285 | | | 60 |
| 0300 | 12 | 231 | 270 | 321 | 276 | 484 | | | 2.7 | | | 289 | | | 59 |
| 0400 | 10 | 229 | 265 | 322 | 275 | 484 | | | 3.1 | | | 288 | | | 58 |
| 0500 | 11 | 235 | 265 | 323 | 273 | 484 | | | 2.5 | | | 288 | | | 59 |
| 0600 | 12 | 235 | 275 | 322 | 268 | 484 | | | 2.5 | | | 286 | | | 59 |
| 0700 | 11 | 232 | 270 | 322 | 264 | 484 | | | 1.8 | | | 284 | | | 61 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 233 | 272 | 322 | 272 | 484 | | | 2.6 | | | 287 | | | 60 |
| 0800 | 13 | 234 | 275 | 325 | 264 | 484 | | | 3.0 | | | 297 | | | 64 |
| 0900 | 14 | 239 | 275 | 321 | 265 | 484 | | | 2.5 | | | 286 | | | 71 |
| 1000 | 12 | 240 | 280 | 322 | 277 | 484 | | | 2.6 | | | 291 | | | 73 |
| 1100 | 10 | 238 | 280 | 323 | 279 | 484 | | | 3.0 | | | 291 | | | 75 |
| 1200 | 11 | 240 | 280 | 322 | 276 | 484 | | | 2.9 | | | 289 | | | 77 |
| 1300 | 10 | 240 | 280 | 322 | 274 | 484 | | | 2.8 | | | 288 | | | 76 |
| 1400 | 10 | 240 | 280 | 323 | 284 | 484 | | | 4.8 | | | 294 | | | 74 |
| 1500 | 10 | 240 | 280 | 323 | 286 | 484 | | | 4.4 | | | 294 | | | 73 |
| ave. | | 239 | 279 | 323 | 276 | 484 | | | 3.1 | | | 290 | | | 73 |
| 1600 | 9 | 235 | 275 | 322 | 280 | 484 | | | 3 | | | 290 | | | 70 |
| 1700 | 9 | 235 | 275 | 322 | 274 | 484 | | | 3.1 | | | 290 | | | 68 |
| 1800 | 11 | 235 | 270 | 322 | 275 | 484 | | | 3.1 | | | 290 | | | 68 |
| 1900 | 11 | 230 | 270 | 321 | 280 | 484 | | | 3.1 | | | 290 | | | 68 |
| 2000 | 10 | 230 | 270 | 321 | 281 | 484 | | | 3.7 | | | 300 | | | 65 |
| 2100 | 11 | 230 | 270 | 321 | 286 | 484 | | | 4 | | | 300 | | | 64 |
| 2200 | 8 | 225 | 265 | 323 | 279 | 484 | | | 3.1 | | | 300 | | | 63 |
| 2300 | 8 | 230 | 265 | 322 | 272 | 484 | | | 2 | | | 300 | | | 61 |
| ave. | | 230 | 270 | 321 | 278 | 484 | | | 3.1 | | | 295 | | | 66 |
| ave. | | 234 | 273 | 322 | 275 | 484 | | | 2.9 | | | 290 | | | 66 |
| Total generator BTU mil. | | 88 | #3 | | | | | | 84 | #3 | | | | | |
| Total gas in m cu. Ft. | | 140 | 29474 | | 538397 | 89325 | | | 135 | 29560 | | 538465 | 89392 | | |
| Total oil in gallons | | | 29286 | | 538326 | 89256 | | | | 29474 | | 538397 | 89325 | | |
| Generator efficiency in % | | 63% | 88 | | 71 | 69 | | | 62.8% | 84 | | 68 | 67 | | |

24 hour data #3 - 21122

BTU Data

| Intergr. | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | 29641 |
| Start | | | 29386 |
| Total | | | 255 |
| 24 hr total | | | 255 |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 538532 | 89458 |
| Start | 538326 | 89256 |
| Total | 206 | 202 |
| Total gas used | | 408 |
| Total oil used | | |

Generator efficiency % 63.1%

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | | 8716970 |
| Start | | 8716460 |
| Total | | 510 |

Outside temperature

| | |
|---|---|
| High temperature | 75 |
| Low temperature | 58 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

Total fuel on hand

| | | | |
|---|---|---|---|
| 81 | | | |
| 133 | 29641 | 538532 | 89458 |
| | 29560 | 538465 | 89392 |
| 61.5% | 81 | 67 | 66 |

June, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date 6-5-09

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 6 | 245 | 285 | 317 | 294 | 484 | | | 6.5 | | | 285 | | | 60 |
| 0100 | 5 | 245 | 285 | 318 | 293 | 484 | | | 5.8 | | | 290 | | | 59 |
| 0200 | 4 | 240 | 285 | 318 | 295 | 484 | | | 5.5 | | | 285 | | | 59 |
| 0300 | 4 | 240 | 280 | 318 | 296 | 484 | | | 6.5 | | | 285 | | | 59 |
| 0400 | 4 | 235 | 280 | 318 | 296 | 484 | | | 6.3 | | | 290 | | | 58 |
| 0500 | 6 | 235 | 275 | 317 | 298 | 484 | | | 8.0 | | | 285 | | | 57 |
| 0600 | 4 | 230 | 270 | 318 | 291 | 484 | | | 5.0 | | | 280 | | | 57 |
| 0700 | 6 | 230 | 270 | 318 | 295 | 484 | | | 7.1 | | | 285 | | | 58 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 238 | 279 | 318 | 295 | 484 | | | 6.3 | | | 286 | | | 58 |
| 0800 | 7 | 225 | 270 | 319 | 288 | 484 | | | 5.0 | | | 285 | | | 64 |
| 0900 | 9 | 230 | 270 | 318 | 284 | 484 | | | 5.4 | | | 285 | | | 66 |
| 1000 | 8 | 230 | 275 | 316 | 278 | 484 | | | 3.6 | | | 276 | | | 66 |
| 1100 | 6 | 230 | 275 | 317 | 296 | 484 | | | 6.6 | | | 286 | | | 67 |
| 1200 | 5 | 230 | 275 | 316 | 288 | 484 | | | 4.6 | | | 280 | | | 68 |
| 1300 | 5 | 225 | 275 | 317 | 294 | 484 | | | 6.8 | | | 280 | | | 70 |
| 1400 | 5 | 225 | 270 | 318 | 291 | 484 | | | 4.5 | | | 285 | | | 73 |
| 1500 | 6 | 225 | 270 | 318 | 293 | 484 | | | 6.6 | | | 281 | | | 75 |
| ave. | | 227 | 273 | 317 | 289 | 484 | | | 5.3 | | | 281 | | | 68 |
| 1600 | 4 | 220 | 265 | 318 | 290 | 484 | | | 4.2 | | | 285 | | | 77 |
| 1700 | 6 | 245 | 285 | 318 | 292 | 484 | | | 9.2 | | | 290 | | | 74 |
| 1800 | 5 | 240 | 280 | 318 | 298 | 484 | | | 5.0 | | | 280 | | | 72 |
| 1900 | 7 | 240 | 280 | 317 | 288 | 484 | | | 4.5 | | | 280 | | | 72 |
| 2000 | 6 | 240 | 280 | 317 | 294 | 484 | | | 7.2 | | | 285 | | | 71 |
| 2100 | 6 | 240 | 280 | 317 | 297 | 484 | | | 5.3 | | | 285 | | | 70 |
| 2200 | 6 | 240 | 280 | 318 | 295 | 484 | | | 4.1 | | | 280 | | | 66 |
| 2300 | 6 | 240 | 280 | 318 | 288 | 484 | | | 4.2 | | | 280 | | | 64 |
| ave. | | 238 | 279 | 318 | 293 | 484 | | | 5.3 | | | 283 | | | 71 |
| ave. | | 234 | 277 | 318 | 292 | 484 | | | 5.6 | | | 283 | | | 66 |
| Total generator BTU mil. | | | 40 | | | | | | 48 | | | | | | |
| Total gas in m cu. Ft. | | | 58 | | 34554 | 542217 | 93137 | | 70 | | 34602 | 542252 | 93172 | | |
| Total oil in gallons | | | | | 34514 | 542189 | 93107 | | | | 34554 | 542217 | 93137 | | |
| Generator efficiency in % | | | 69.6 | | 40 | 28 | 30 | | 69.2% | | 48 | 35 | 35 | | |

24 hour data 21856

BTU Data

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | 650 |
| Start | | | 34514 |
| Total | | | 136 |
| 24 hr total | | | |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 287 | 207 |
| Start | 542189 | 93107 |
| Total | 98 | 100 |
| Total gas used | | 198 |
| Total oil used | | |

Generator efficiency % 69.3

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | 8000 | |
| Start | 8727660 | |
| Total | 340 | |

Outside temperature

| | |
|---|---|
| High temperature | 77 |
| Low temperature | 57 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |
| Total fuel on hand | | | |

48 #3

70 650 87 207

34602 542252 93172

69.2 48 35 35

July, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 1-1-2007

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outle temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 5 | 237 | 275 | 318 | 296 | 484 | | | 7.9 | | | 299 | | | 73 |
| 0100 | 5 | 236 | 275 | 317 | 296 | 484 | | | 9.0 | | | 301 | | | 73 |
| 0200 | 5 | 235 | 272 | 316 | 300 | 484 | | | 6.2 | | | 302 | | | 71 |
| 0300 | 5 | 231 | 270 | 317 | 298 | 484 | | | 8.7 | | | 301 | | | 69 |
| 0400 | 4 | 229 | 268 | 317 | 298 | 484 | | | 8.9 | | | 301 | | | 67 |
| 0500 | 4 | 227 | 265 | 317 | 299 | 484 | | | 9.4 | | | 301 | | | 67 |
| 0600 | 5 | 234 | 275 | 317 | 290 | 484 | | | 5.0 | | | 295 | | | 65 |
| 0700 | 6 | 233 | 275 | 318 | 288 | 484 | | | 4.7 | | | 294 | | | 69 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 233 | 272 | 317 | 296 | 484 | | | 8.0 | | | 299 | | | 69 |
| 0800 | 5 | 240 | 272 | 318 | 289 | 484 | | | 6.6 | | | 295 | | | 75 |
| 0900 | 8 | 235 | 272 | 318 | 281 | 484 | | | 5.1 | | | 290 | | | 77 |
| 1000 | 8 | 240 | 277 | 318 | 285 | 484 | | | 5.0 | | | 291 | | | 84 |
| 1100 | 6 | 240 | 275 | 317 | 290 | 484 | | | 5.4 | | | 295 | | | 86 |
| 1200 | 6 | 240 | 275 | 317 | 292 | 484 | | | 7.5 | | | 298 | | | 87 |
| 1300 | 5 | 237 | 275 | 317 | 296 | 484 | | | 7.7 | | | 298 | | | 88 |
| 1400 | 5 | 235 | 275 | 318 | 293 | 484 | | | 5.9 | | | 298 | | | 88 |
| 1500 | 5 | 234 | 272 | 316 | 299 | 484 | | | 10.0 | | | 302 | | | 88 |
| ave. | | 238 | 274 | 317 | 291 | 484 | | | 6.7 | | | 296 | | | 84 |
| 1600 | 4 | 230 | 270 | 318 | 295 | 484 | | | 6.4 | | | 300 | | | 89 |
| 1700 | 6 | 235 | 272 | 318 | 293 | 484 | | | 6 | | | 300 | | | 86 |
| 1800 | 6 | 235 | 275 | 316 | 291 | 484 | | | 5.1 | | | 300 | | | 86 |
| 1900 | 6 | 235 | 275 | 311 | 291 | 484 | | | 5.1 | | | 310 | | | 82 |
| 2000 | 7 | 235 | 275 | 317 | 292 | 484 | | | 5.1 | | | 310 | | | 79 |
| 2100 | 5 | 230 | 272 | 318 | 291 | 484 | | | 7.1 | | | 310 | | | 75 |
| 2200 | 5 | 230 | 270 | 318 | 295 | 484 | | | 8.7 | | | 310 | | | 71 |
| 2300 | 4 | 230 | 270 | 317 | 298 | 484 | | | 8. | | | 310 | | | 71 |
| ave. | | 232 | 272 | 317 | 294 | 484 | | | 6.5 | | | 306 | | | 79 |
| ave. | | 234 | 272 | 317 | 293 | 484 | | | 7.0 | | | 300 | | | 77 |
| Total generator BTU mil. | | | 39 #3 | | | | | | 47 | | | | | | |
| Total gas in m cu. Ft. | | | 55 | 886 | | 545258 | 96147 | | 66 | 38714 | | 545292 | 96179 | | |
| Total oil in gallons | | | | 3802 | | 545230 | 96120 | | | 38667 | | 545258 | 96147 | | |
| Generator efficiency in % | | | 70.9 | | | | 28 | 27 | 71.9 | 47 | | 34 | 32 | | |

24 hour data #3 - 22623

| BTU Data | | | |
|---|---|---|---|
| Intergr | 1 | 2 | 3 |
| Stop | | | 38758 |
| Start | | | 38628 |
| Total | | | 130 |
| 24 hr total | | | 130 |

| Fuel Data | | |
|---|---|---|
| Gas meter | 19 | 20 |
| Stop | 545324 | 96211 |
| Start | 545230 | 96120 |
| Total | 94 | 91 |
| Total gas used | | 185 |
| Total oil used | | |
| Generator efficiency % | | 70.9% |

| Makeup Water | | |
|---|---|---|
| Water meter | 1 | 2 |
| Stop | | 8741370 |
| Start | | 8741230 |
| Total | | 140 |

| Outside temperature | |
|---|---|
| High temperature | 89 |
| Low temperature | 65 |

| Oil meter | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

| Total fuel on hand | | | |
|---|---|---|---|
| 44 | BTU | #1 | #2 |
| 64 | 38758 | 545324 | 96211 |
| | 38714 | 545292 | 96179 |
| 69.4% | 44 | 32 | 32 |

August, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 8-15-09

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 5 | 240 | 280 | 318 | 298 | 484 | | | 8.1 | | | 299 | | | 69 |
| 0100 | 5 | 239 | 280 | 318 | 297 | 484 | | | 8.7 | | | 299 | | | 69 |
| 0200 | 5 | 237 | 275 | 317 | 297 | 484 | | | 8.0 | | | 300 | | | 68 |
| 0300 | 4 | 234 | 275 | 317 | 296 | 484 | | | 7.8 | | | 300 | | | 68 |
| 0400 | 5 | 237 | 270 | 317 | 298 | 484 | | | 7.6 | | | 299 | | | 67 |
| 0500 | 4 | 237 | 280 | 317 | 298 | 484 | | | 8.0 | | | 300 | | | 65 |
| 0600 | 5 | 235 | 275 | 317 | 298 | 484 | | | 9.8 | | | 301 | | | 63 |
| 0700 | 4 | 233 | 275 | 318 | 298 | 484 | | | 9.0 | | | 301 | | | 67 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 236 | 276 | 317 | 297 | 484 | | | 8.4 | | | 300 | | | 67 |
| 0800 | 4 | 233 | 270 | 317 | 293 | 484 | | | 6.2 | | | 298 | | | 70 |
| 0900 | 5 | 231 | 270 | 318 | 291 | 484 | | | 4.6 | | | 295 | | | 74 |
| 1000 | 5 | 231 | 270 | 318 | 292 | 484 | | | 6.3 | | | 296 | | | 77 |
| 1100 | 6 | 230 | 270 | 318 | 286 | 484 | | | 4.8 | | | 293 | | | 80 |
| 1200 | 6 | 232 | 270 | 317 | 292 | 484 | | | 6.3 | | | 297 | | | 83 |
| 1300 | 6 | 233 | 270 | 318 | 295 | 484 | | | 6.8 | | | 298 | | | 86 |
| 1400 | 6 | 233 | 275 | 317 | 292 | 484 | | | 5.6 | | | 296 | | | 86 |
| 1500 | 5 | 231 | 270 | 318 | 294 | 484 | | | 6.3 | | | 299 | | | 86 |
| ave | | 232 | 271 | 318 | 292 | 484 | | | 5.9 | | | 297 | | | 80 |
| 1600 | 6 | 230 | 270 | 318 | 291 | 484 | | | 6.0 | | | 298 | | | 86 |
| 1700 | 4 | 230 | 270 | 317 | 292 | 484 | | | 5.8 | | | 296 | | | 87 |
| 1800 | 6 | 230 | 270 | 317 | 292 | 484 | | | 6.5 | | | 296 | | | 87 |
| 1900 | 5 | 230 | 270 | 318 | 297 | 484 | | | 7.3 | | | 301 | | | 85 |
| 2000 | 5 | 250 | 290 | 317 | 294 | 484 | | | 6.6 | | | 299 | | | 82 |
| 2100 | 5 | 250 | 290 | 317 | 293 | 484 | | | 6.0 | | | 298 | | | 77 |
| 2200 | 6 | 250 | 290 | 318 | 291 | 484 | | | 5.6 | | | 295 | | | 77 |
| 2300 | 5 | 250 | 290 | 318 | 296 | 484 | | | 6.4 | | | 299 | | | 70 |
| ave. | | 240 | 280 | 317 | 293 | 484 | | | 6.2 | | | 297 | | | 81 |
| ave. | | 236 | 276 | 317 | 294 | 484 | | | 6.8 | | | 298 | | | 76 |
| Total generator BTU mil | | 36 | #3 | | | | | | 44 | #3 | | | | | |
| Total gas in m. cu. Ft. | | 49 | 42367 | | 548053 | 98903 | | | 64 | 42412 | 548085 | 98935 | | | |
| Total oil in gallons | | | 42331 | | 548028 | 98879 | | | | 42367 | 549053 | 98903 | | | |
| Generator efficiency in % | | 74.2 | 36 | | 25 | 24 | | | 69.4 | 44 | 32 | 32 | | | |
| Over for remarks | | | | | | | | | | | | | | | |

24 hour data #3-23306

BTU Data

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | 452 |
| Start | | | 42331 |
| Total | | | 121 |
| 24 hr total | | | |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 114 | 964 |
| Start | 548028 | 98879 |
| Total | 86 | 85 |
| Total gas used | | 171 |
| Total oil used | | |

Generator efficiency % 71.4

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | | 52410 |
| Start | | 8754750 |
| Total | | 490 |

Outside temperature

| | |
|---|---|
| High temperature | 87 |
| Low temperature | 63 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

Total fuel on hand

| | | | |
|---|---|---|---|
| 410 | #3 | | |
| 58 | 52 | 114 | 964 |
| | 42412 | 548085 | 98935 |
| 69.6 | 40 | 29 | 29 |

September, 2009

Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date 9-15-09

| Time | Total BTU in mil | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 6 | 245 | 285 | 318 | 295 | 484 | | | 6.5 | | | 285 | | | 67 |
| 0100 | 4 | 245 | 285 | 316 | 291 | 484 | | | 4.6 | | | 285 | | | 67 |
| 0200 | 4 | 240 | 285 | 316 | 295 | 484 | | | [illegible] | | | 285 | | | 66 |
| 0300 | 5 | 240 | 280 | 318 | 300 | 484 | | | 7.5 | | | 290 | | | 64 |
| 0400 | 4 | 240 | 280 | 316 | 297 | 484 | | | 7.4 | | | 290 | | | 62 |
| 0500 | 5 | 235 | 275 | 318 | 297 | 484 | | | 6.8 | | | 290 | | | 60 |
| 0600 | 4 | 230 | 275 | 317 | 296 | 484 | | | 6.5 | | | 290 | | | 59 |
| 0700 | 6 | 230 | 275 | 320 | 290 | 484 | | | 5.3 | | | 280 | | | 59 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 238 | 280 | 317 | 295 | 484 | | | 6.5 | | | 287 | | | 63 |
| 0800 | 6 | 225 | 275 | 320 | 292 | 484 | | | 5.1 | | | 293 | | | 61 |
| 0900 | 7 | 240 | 285 | 320 | 290 | 484 | | | 3.8 | | | 291 | | | 66 |
| 1000 | 6 | 240 | 275 | 315 | 293 | 484 | | | 4.2 | | | 295 | | | 72 |
| 1100 | 7 | 240 | 275 | 317 | 294 | 484 | | | 6.8 | | | 297 | | | 75 |
| 1200 | 6 | 240 | 280 | 317 | 297 | 484 | | | 8.4 | | | 301 | | | 76 |
| 1300 | 5 | 240 | 280 | 317 | 290 | 484 | | | 5.9 | | | 298 | | | 78 |
| 1400 | 4 | 240 | 280 | 317 | 297 | 484 | | | 7.6 | | | 300 | | | 79 |
| 1500 | 5 | 240 | 280 | 318 | 297 | 484 | | | 7.9 | | | 300 | | | 79 |
| ave. | | 238 | 279 | 317 | 294 | 484 | | | 6.2 | | | 297 | | | 73 |
| 1600 | 5 | 238 | 280 | 317 | 296 | 484 | | | 7.4 | | | 299 | | | 79 |
| 1700 | 4 | 235 | 280 | 317 | 296 | 484 | | | 7.5 | | | 290 | | | 79 |
| 1800 | 5 | 240 | 285 | 318 | 295 | 484 | | | 6.3 | | | 285 | | | 73 |
| 1900 | 5 | 240 | 285 | 318 | 293 | 484 | | | [illegible] | | | 285 | | | 72 |
| 2000 | 5 | 240 | 290 | 317 | 291 | 484 | | | 4.5 | | | 285 | | | 70 |
| 2100 | 6 | 240 | 290 | 318 | 296 | 484 | | | 7.3 | | | 290 | | | 68 |
| 2200 | 4 | 240 | 290 | 317 | 296 | 484 | | | 6.5 | | | 290 | | | 67 |
| 2300 | 5 | 240 | 285 | 317 | 296 | 484 | | | 7.0 | | | 290 | | | 65 |
| ave. | | 239 | 282 | 317 | 295 | 484 | | | 6.4 | | | 289 | | | 72 |
| ave. | | 238 | 281 | 317 | 295 | 484 | | | 6.4 | | | 291 | | | 69 |
| Total generator BTU mil. | | 38 | | | | | | | 45 | | | | | | |
| Total gas in m cu. Ft. | | | | | 46474 | 551159 | 101964 | | 70 | 46519 | 551192 | 101999 | | | |
| Total oil in gallons | | 58 | | | 46436 | 551129 | 101936 | | | 46474 | 551157 | 101964 | | | |
| Generator efficiency in % | | 66.17 | | | 38 | 30 | 28 | | 64.9% | 45 | 35 | 35 | | | |
| Over for remarks | | Operator | | | D H | | | | Operator | | | | | | |

24 hour data 240316

BTU Data

| intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | 558 |
| Start | | | 46436 |
| Total | | | 122 |
| 24 hr total | | | |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 223 | 2030 |
| Start | 551129 | 101936 |
| Total | 94 | 94 |
| Total gas used | | 188 |
| Total oil used | | |

Generator efficiency % 65.5

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | | 720 |
| Start | | 8768460 |
| Total | | 260 |

Outside temperature

| | |
|---|---|
| High temperature | 79 |
| Low temperature | 59 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

Total fuel on hand

| | | | |
|---|---|---|---|
| 39 | 63 | | |
| 62 | 58 | 223 | 2030 |
| | 46519 | 551192 | 101999 |
| 63.5 | 39 | 31 | 31 |
| Operator | | | |

October, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 10-15-200

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 16 | 240 | 275 | 334 | 297 | 416 | 4.4 | | | 310 | | | | | 54 |
| 0100 | 15 | 236 | 275 | 334 | 290 | 422 | 4.4 | | | 310 | | | | | 51 |
| 0200 | 16 | 234 | 270 | 334 | 291 | 414 | 5.0 | | | 310 | | | | | 50 |
| 0300 | 16 | 231 | 270 | 332 | 291 | 424 | 3.6 | | | 310 | | | | | 49 |
| 0400 | 16 | 229 | 270 | 336 | 294 | 419 | 3.4 | | | 310 | | | | | 49 |
| 0500 | 16 | 231 | 275 | 334 | 292 | 416 | 4.1 | | | 310 | | | | | 49 |
| 0600 | 17 | 231 | 275 | 342 | 284 | 418 | 4.2 | | | 315 | | | | | 48 |
| 0700 | 19 | 228 | 270 | 339 | 289 | 424 | 3.0 | | | 310 | | | | | 48 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 233 | 273 | 336 | 292 | 419 | 4.0 | | | 311 | | | | | 50 |
| 0800 | 21 | 235 | 270 | 332 | 280 | 428 | 5 | | | 300 | | | | | 49 |
| 0900 | 24 | 245 | 280 | 336 | 275 | 428 | 3.8 | | | 300 | | | | | 57 |
| 1000 | 20 | 255 | 290 | 336 | 288 | 422 | 4.8 | | | 310 | | | | | 61 |
| 1100 | 15 | 255 | 285 | 331 | 257 | 415 | 5.5 | | | 320 | | | | | 65 |
| 1200 | 15 | 255 | 290 | 339 | 300 | 410 | 4 | | | 300 | | | | | 67 |
| 1300 | 12 | 250 | 285 | 339 | 300 | 410 | 5 | | | 300 | | | | | 67 |
| 1400 | 13 | 250 | 285 | 337 | 301 | 415 | 4.2 | | | 310 | | | | | 69 |
| 1500 | 11 | 245 | 285 | 332 | 305 | 414 | 5.4 | | | 310 | | | | | 69 |
| ave. | | 250 | 283 | 334 | 296 | 416 | 5 | | | 305 | | | | | 62 |
| 1600 | 12 | 240 | 280 | 334 | 305 | 422 | 4.9 | | | 315 | | | | | 69 |
| 1700 | 12 | 241 | 295 | 336 | 307 | 422 | 5.1 | | | 315 | | | | | 69 |
| 1800 | 10 | 240 | 295 | 337 | 305 | 420 | 4.9 | | | 315 | | | | | 68 |
| 1900 | 14 | 250 | 290 | 334 | 304 | 423 | 5.4 | | | 315 | | | | | 64 |
| 2000 | 15 | 240 | 280 | 339 | 294 | 424 | 4.6 | | | 315 | | | | | 61 |
| 2100 | 15 | 240 | 280 | 336 | 291 | 416 | 5.1 | | | 315 | | | | | 59 |
| 2200 | 16 | 240 | 295 | 331 | 296 | 422 | 5.2 | | | 310 | | | | | 57 |
| 2300 | 15 | 240 | 280 | 337 | 291 | 428 | 5.0 | | | 315 | | | | | 56 |
| ave. | | 242 | 283 | 336 | 299 | 421 | 5.0 | | | 314 | | | | | 63 |
| ave. | | 242 | 280 | 335 | 296 | 419 | 4.9 | | | 310 | | | | | 58 |
| Total generator BTU mil. | | | 129 | #1 | | | | | 122 | | | | | | |
| Total gas in m cu. Ft. | | | 221 | 13258 | | | 557448 | 108102 | 213 | | 13360 | 557556 | | 108207 | |
| Total oil in gallons | | | | 13129 | | | 557336 | 107993 | | | 13258 | 557448 | | 108102 | |
| Generator efficiency in % | | | 58.9% | 129 | | | 112 | 109 | 57.8% | | 122 | 109 | | 105 | |

#1-17847

24 hour data

BTU Data

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | 13493 | | |
| Start | 13129 | | |
| Total | 364 | | |
| 24 hr total | | | 364 |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 557657 | 108306 |
| Start | 557336 | 107993 |
| Total | 321 | 313 |
| Total gas used | | 634 |
| Total oil used | | |

Generator efficiency % 57.9%

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | 8798430 | |
| Start | 8797800 | |
| Total | 630 | |

Outside temperature

| | |
|---|---|
| High temperature | 69 |
| Low temperature | 48 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

Total fuel on hand

| | | | |
|---|---|---|---|
| 113 | #1 | | |
| 200 | 13493 | 557657 | 108306 |
| | 13360 | 557556 | 108207 |
| 57.0% | 113 | 101 | 99 |

November, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 11-15-09

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % co2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 20 | 240 | 280 | 342 | 204 | 416 | 3.6 | | | 300 | | | | | 36 |
| 0100 | 21 | 240 | 280 | 340 | 261 | 418 | 4.0 | | | 300 | | | | | 35 |
| 0200 | 23 | 240 | 280 | 336 | 278 | 424 | 3.9 | | | 300 | | | | | 34 |
| 0300 | 22 | 240 | 280 | 342 | 278 | 438 | 3.4 | | | 300 | | | | | 32 |
| 0400 | 24 | 235 | 275 | 340 | 280 | 436 | 3.9 | | | 300 | | | | | 32 |
| 0500 | 23 | 235 | 275 | 339 | 275 | 422 | 3.8 | | | 300 | | | | | 32 |
| 0600 | 24 | 235 | 275 | 340 | 283 | 430 | 4.3 | | | 300 | | | | | 32 |
| 0700 | 22 | 235 | 275 | 340 | 280 | 420 | 3.2 | | | 300 | | | | | 32 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 237 | 277 | 339 | 261 | 424 | 3.7 | | | 300 | | | | | 33 |
| 0800 | 21 | 240 | 275 | 334 | 267 | 426 | 3.2 | | | 310 | | | | | 33 |
| 0900 | 22 | 240 | 275 | 336 | 272 | 430 | 3.8 | | | 315 | | | | | 32 |
| 1000 | 25 | 245 | 280 | 340 | 272 | 432 | 3.8 | | | 315 | | | | | 34 |
| 1100 | 26 | 245 | 280 | 337 | 272 | 432 | 3.8 | | | 315 | | | | | 30 |
| 1200 | 25 | 245 | 280 | 337 | 275 | 438 | 3.4 | | | 315 | | | | | 36 |
| 1300 | 25 | 250 | 280 | 337 | 280 | 434 | 3.8 | | | 315 | | | | | 36 |
| 1400 | 25 | 250 | 285 | 334 | 268 | 432 | 3.2 | | | 315 | | | | | 36 |
| 1500 | 24 | 250 | 285 | 342 | 278 | 446 | 2.8 | | | 315 | | | | | 35 |
| ave. | | 245 | 280 | 338 | 274 | 436 | 3.5 | | | 315 | | | | | 34 |
| 1600 | 26 | 245 | 280 | 341 | 280 | 448 | 4.5 | | | 315 | | | | | 35 |
| 1700 | 24 | 245 | 280 | 342 | 282 | 442 | 4.7 | | | 315 | | | | | 34 |
| 1800 | 20 | 245 | 280 | 341 | 272 | 434 | 4.9 | | | 315 | | | | | 34 |
| 1900 | 20 | 240 | 280 | 341 | 282 | 448 | 5.3 | | | 315 | | | | | 33 |
| 2000 | 19 | 240 | 280 | 339 | 287 | 432 | 5.9 | | | 315 | | | | | 33 |
| 2100 | 25 | 245 | 280 | 336 | 275 | 430 | 5.6 | | | 315 | | | | | 32 |
| 2200 | 24 | 240 | 280 | 334 | 282 | 434 | 5.4 | | | 315 | | | | | 29 |
| 2300 | 22 | 245 | 280 | 342 | 280 | 442 | 5.1 | | | 315 | | | | | 30 |
| ave. | | 243 | 280 | 340 | 280 | 439 | 5.2 | | | 315 | | | | | 32 |
| ave. | | 241 | 279 | 339 | 280 | 433 | 4.2 | | | 310 | | | | | 33 |
| Total generator BTU mil. | | | 180 | 26429 | 569267 | 119583 | | | 203 | 26632 | | | 569453 | 119764 | |
| Total gas in m cu. Ft. | | | 327 | 26249 | 569101 | 119422 | | | 367 | 26429 | | | 569267 | 119583 | |
| Total oil in gallons | | | | 180 | 166 | 161 | | | | 203 | | | 186 | 181 | |
| Generator efficiency in % | | | 55.0 | | | | | | 55.94 | | | | | | |
| Over for remarks | | | | | | | | | | | | | | | |

186136 — 24 hour data

BTU Data

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | 26824 | | |
| Start | 26249 | | |
| Total | 575 | | |
| 24 hr total | | | |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 569627 | 119933 |
| Start | 569101 | 119422 |
| Total | 526 | 511 |
| Total gas used | | 1037 |
| Total oil used | | |

Generator efficiency %

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | 8845607 | |
| Start | 8845800 | |
| Total | 193 | |

Outside temperature

| | | | |
|---|---|---|---|
| High temperature | | | 36 |
| Low temperature | | | 29 |

Oil meter

| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

Total fuel on hand

| | | | | |
|---|---|---|---|---|
| 192 | 26824 | 569627 | 119933 | |
| 343 | 26632 | 569453 | 119764 | |
| | 192 | 174 | 169 | |
| 56.5 | | | | |

December, 2009

Daily Heating Plant Log — Fort Carson — Heating Plant HTHW — Building 1860 — Date: 12-15-09

| Time | Total BTU in mil. | Exp. tank pressure | Gen Outlet pressure | Gen outlet temp. | Gen inlet temp. | Total flow m / lbs / hr | Generator flue gas % o2 1 | 2 | 3 | Generator flue gas temp. 1 | 2 | 3 | Gas in m cu. Ft. | Gallons of oil | Outside temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2400 | 26 | 245 | 285 | 344 | 283 | 428 | 3.6 | | | 318 | | | | | 31 |
| 0100 | 22 | 245 | 282 | 344 | 270 | 434 | 5.4 | | | 320 | | | | | 30 |
| 0200 | 23 | 245 | 282 | 352 | 283 | 422 | 4.1 | | | 320 | | | | | 30 |
| 0300 | 25 | 240 | 280 | 347 | 281 | 422 | 3.2 | | | 320 | | | | | 29 |
| 0400 | 24 | 240 | 275 | 342 | 276 | 430 | 3.2 | | | 318 | | | | | 29 |
| 0500 | 30 | 235 | 270 | 345 | 273 | 430 | 5.1 | | | 320 | | | | | 28 |
| 0600 | 31 | 235 | 270 | 345 | 259 | 438 | 4.0 | | | 325 | | | | | 28 |
| 0700 | 32 | 245 | 285 | 347 | 265 | 432 | 4.7 | | | 330 | | | | | 28 |
| extra | | | | | | | | | | | | | | | |
| ave. | | 241 | 279 | 346 | 274 | 430 | 4.2 | | | 321 | | | | | 29 |
| 0800 | 38 | 245 | 285 | 345 | 260 | 436 | 4.8 | | | 325 | | | | | 29 |
| 0900 | 33 | 255 | 290 | 345 | 256 | 442 | 4.2 | | | 325 | | | | | 33 |
| 1000 | 24 | 260 | 295 | 347 | 278 | 422 | 4.5 | | | 325 | | | | | 39 |
| 1100 | 27 | 260 | 295 | 344 | 278 | 436 | 3.0 | | | 315 | | | | | 42 |
| 1200 | 24 | 255 | 295 | 344 | 278 | 424 | 3.4 | | | 315 | | | | | 43 |
| 1300 | 24 | 250 | 290 | 344 | 289 | 432 | 4.1 | | | 315 | | | | | 45 |
| 1400 | 21 | 245 | 285 | 348 | 288 | 418 | 3.1 | | | 315 | | | | | 46 |
| 1500 | 22 | 240 | 280 | 344 | 291 | 414 | 4.2 | | | 315 | | | | | 46 |
| ave. | | 251 | 289 | 345 | 277 | 428 | 3.9 | | | 318 | | | | | 40 |
| 1600 | 19 | 240 | 280 | 347 | 278 | 420 | 2.7 | | | 315 | | | | | 46 |
| 1700 | 24 | 245 | 285 | 345 | 280 | 424 | 3.1 | | | 315 | | | | | 44 |
| 1800 | 27 | 245 | 285 | 344 | 272 | 438 | 5.0 | | | 320 | | | | | 39 |
| 1900 | 29 | 250 | 295 | 345 | 270 | 428 | 5.0 | | | 320 | | | | | 38 |
| 2000 | 28 | 255 | 295 | 352 | 281 | 422 | 2.7 | | | 320 | | | | | 38 |
| 2100 | 27 | 255 | 295 | 344 | 268 | 434 | 5.0 | | | 320 | | | | | 36 |
| 2200 | 25 | 255 | 295 | 345 | 283 | 422 | 2.7 | | | 320 | | | | | 36 |
| 2300 | 24 | 250 | 290 | 348 | 283 | 436 | 2.8 | | | 315 | | | | | 36 |
| ave. | | 249 | 290 | 346 | 277 | 428 | 3.6 | | | 318 | | | | | 39 |
| ave. | | 247 | 286 | 346 | 276 | 429 | 3.9 | | | 319 | | | | | 36 |
| Total generator BTU mil | | | 227 | #1 | #3 | | | | 204 | | | | | | |
| Total gas in m cu. Ft. | | | 404 | 43680 | | 586381 | 136156 | | 364 | 43884 | | 586566 | 136335 | | |
| Total oil in gallons | | | | 43453 | 51915 | 586176 | 135957 | | | 43680 | | 586381 | 136156 | | |
| Generator efficiency in % | | | 56.7 | 227 | | 205 | 199 | | 56.6% | 204 | | 185 | 179 | | |
| Over for remarks | | | Operator | D H | | | | | Operator | [illegible] | | | | | |

19311 — 24 hour data

BTU Data

| Intergr | 1 | 2 | 3 |
|---|---|---|---|
| Stop | 4091 | | |
| Start | 43453 | | 51915 |
| Total | 638 | | |
| 24 hr total | | | |

Fuel Data

| Gas meter | 19 | 20 |
|---|---|---|
| Stop | 753 | 6516 |
| Start | 586176 | 135957 |
| Total | 577 | 559 |
| Total gas used | | 1136 |
| Total oil used | | |

Generator efficiency % 56.7

Makeup Water

| Water meter | 1 | 2 |
|---|---|---|
| Stop | 38160 | |
| Start | 88298 10 | |
| Total | 350 | |

Outside temperature

| | |
|---|---|
| High temperature | 46 |
| Low temperature | 28 |

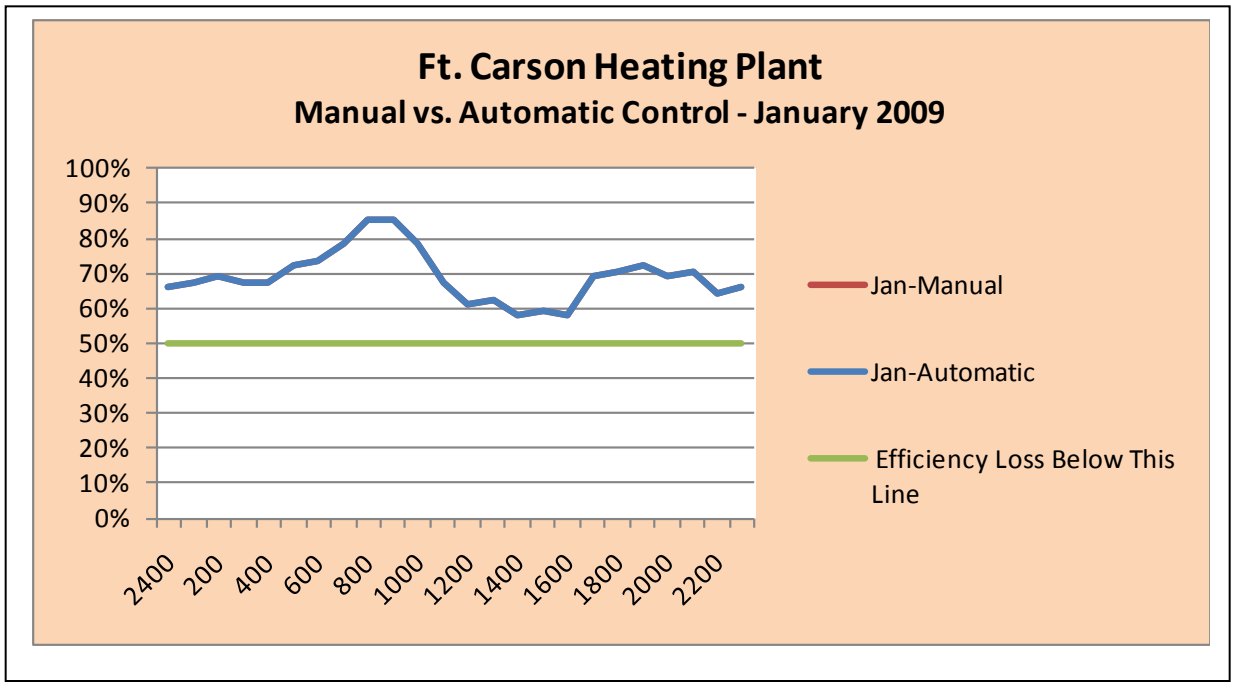
Oil meter

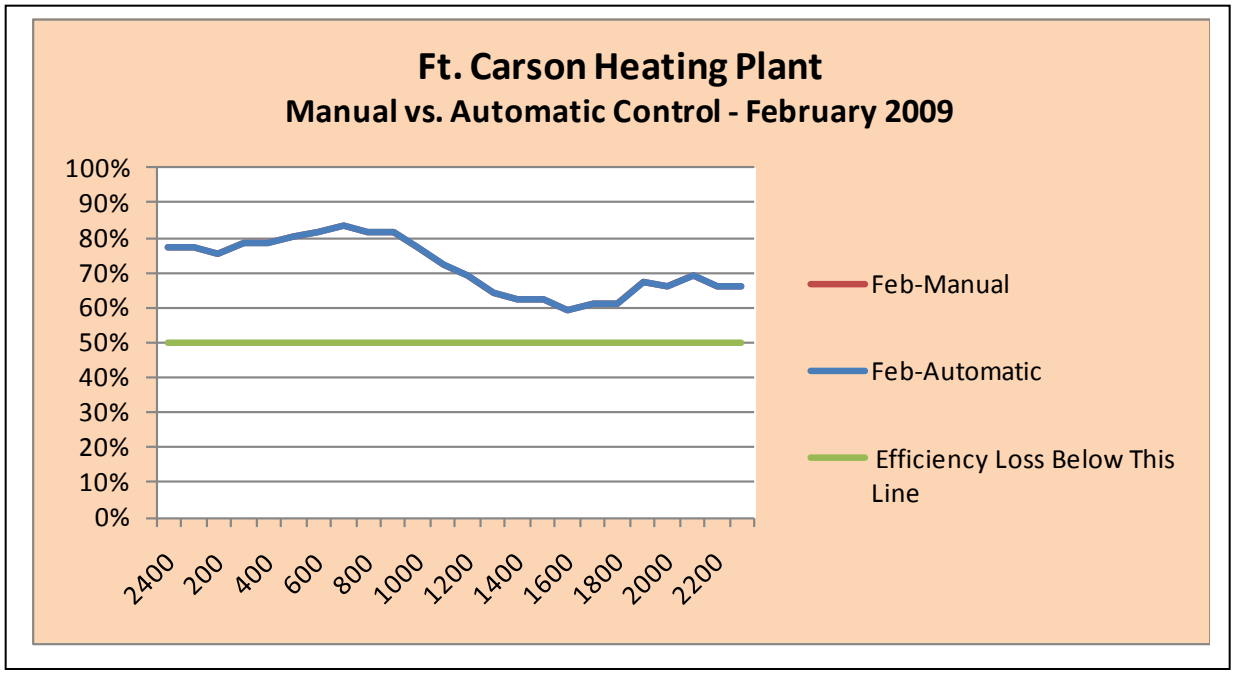
| | 1 | 2 | 3 |
|---|---|---|---|
| Stop | | | |
| Start | | | |
| Total | | | |

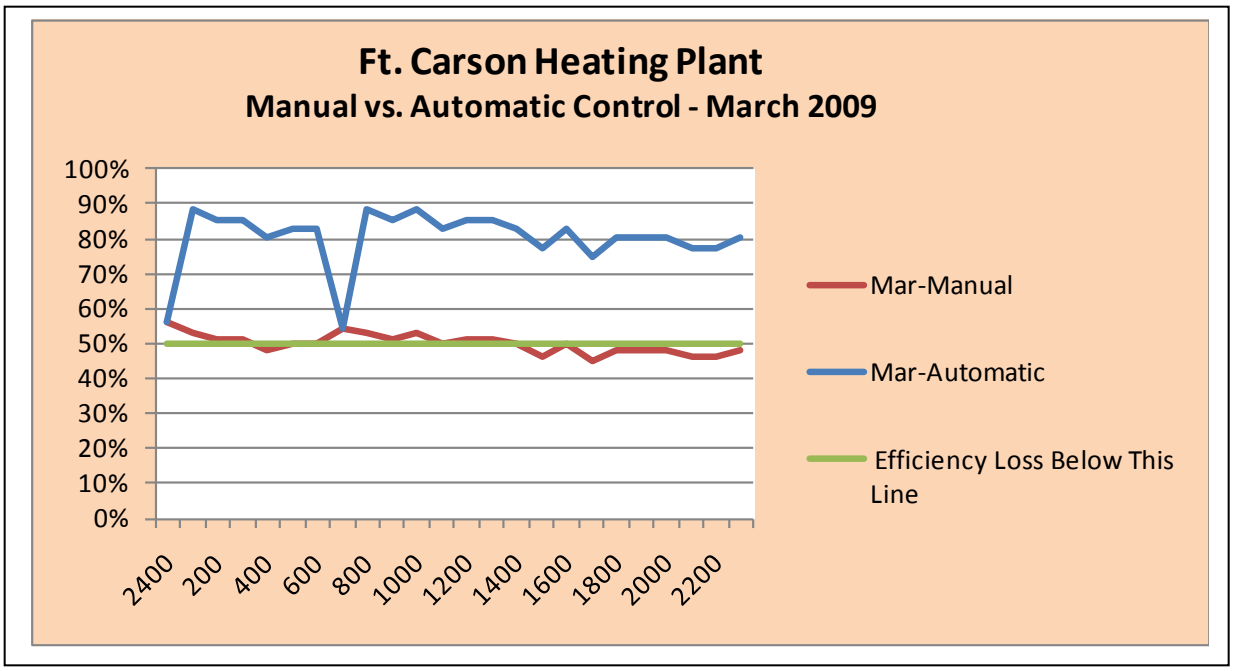
Total fuel on hand

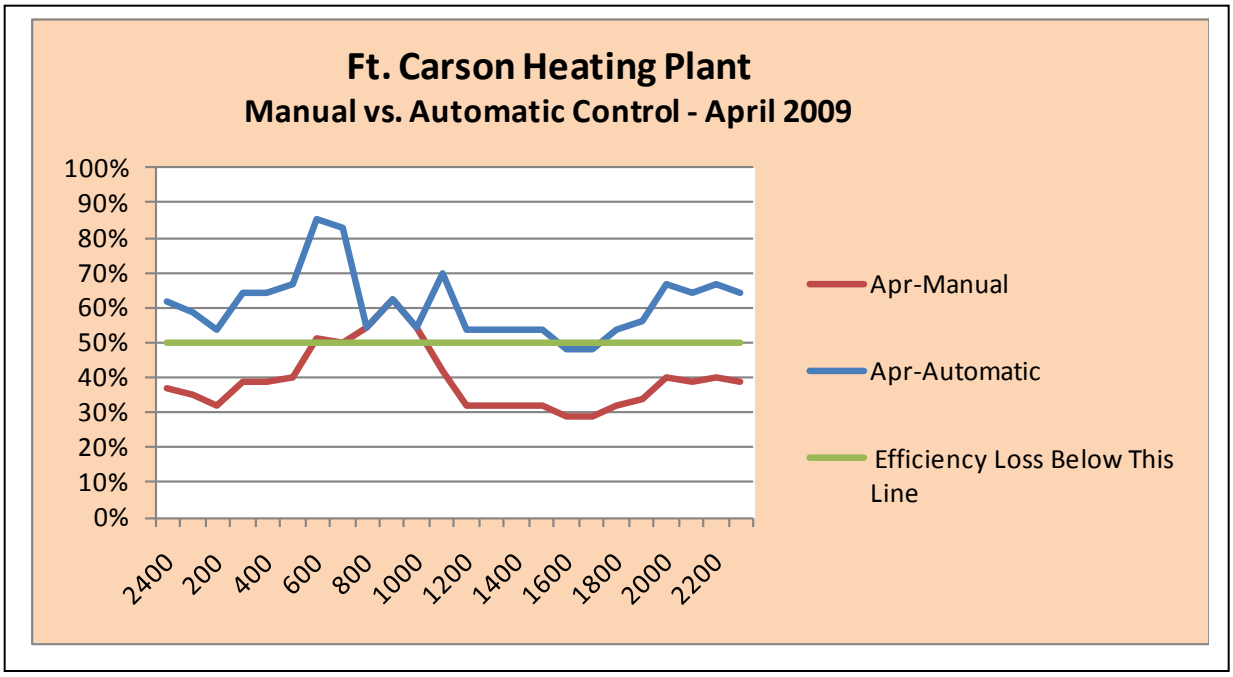
| | | | |
|---|---|---|---|
| 207 | #1 | | |
| 368 | 4091 | 753 | 516 |
| | 43884 | 586566 | 136335 |
| 56.8 | 207 | 187 | 181 |
| Operator | [illegible] | | |

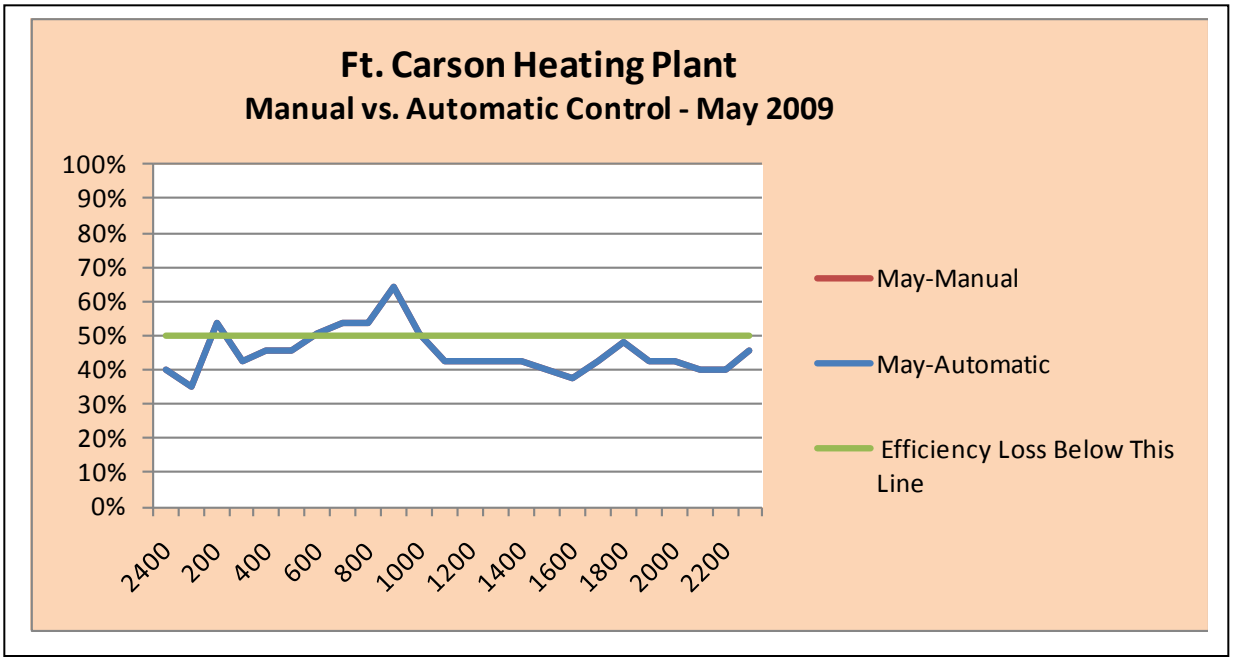
Appendix D – Boiler Percent Loading Profile by Month

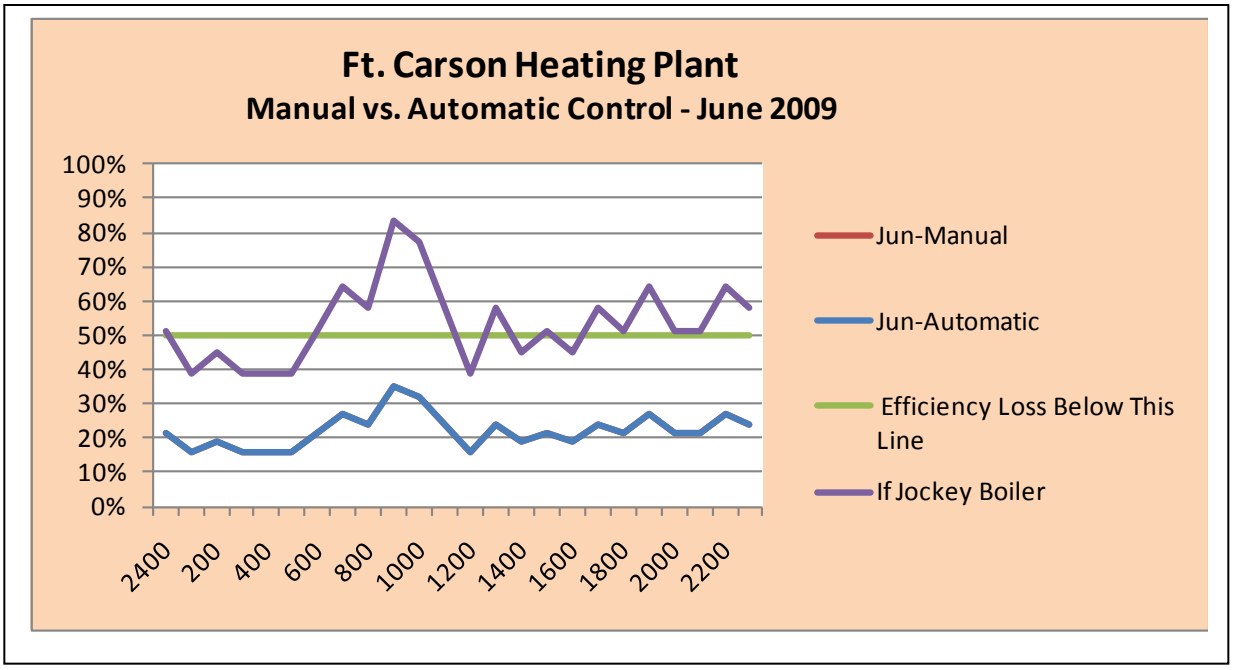


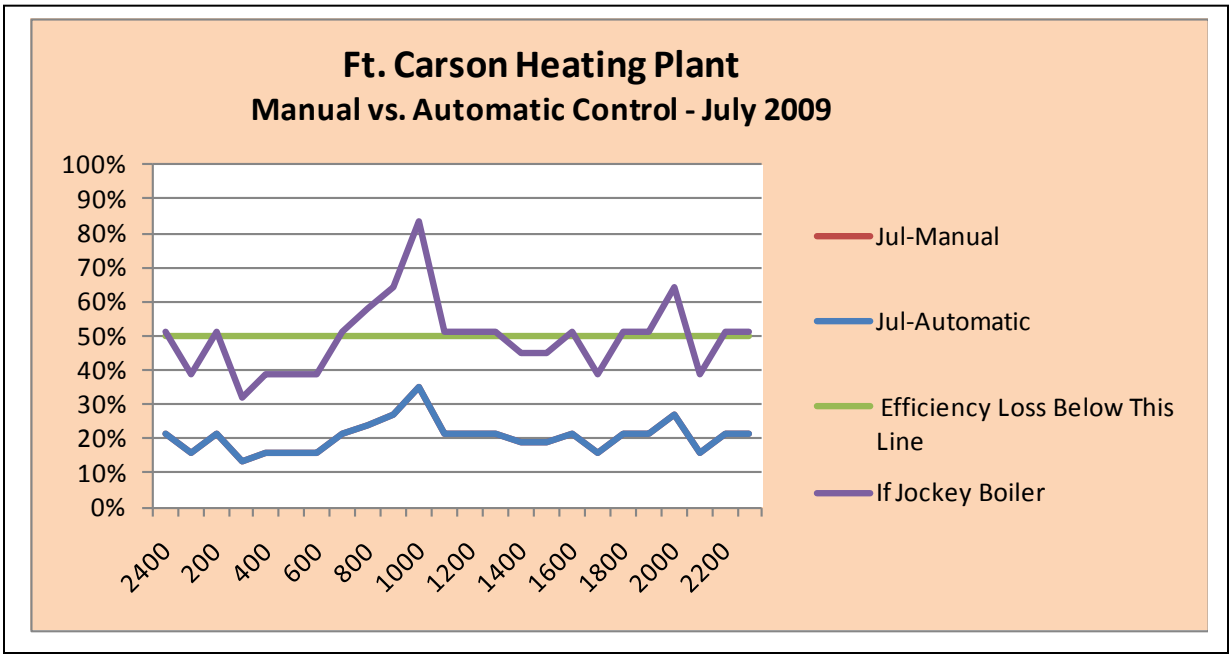



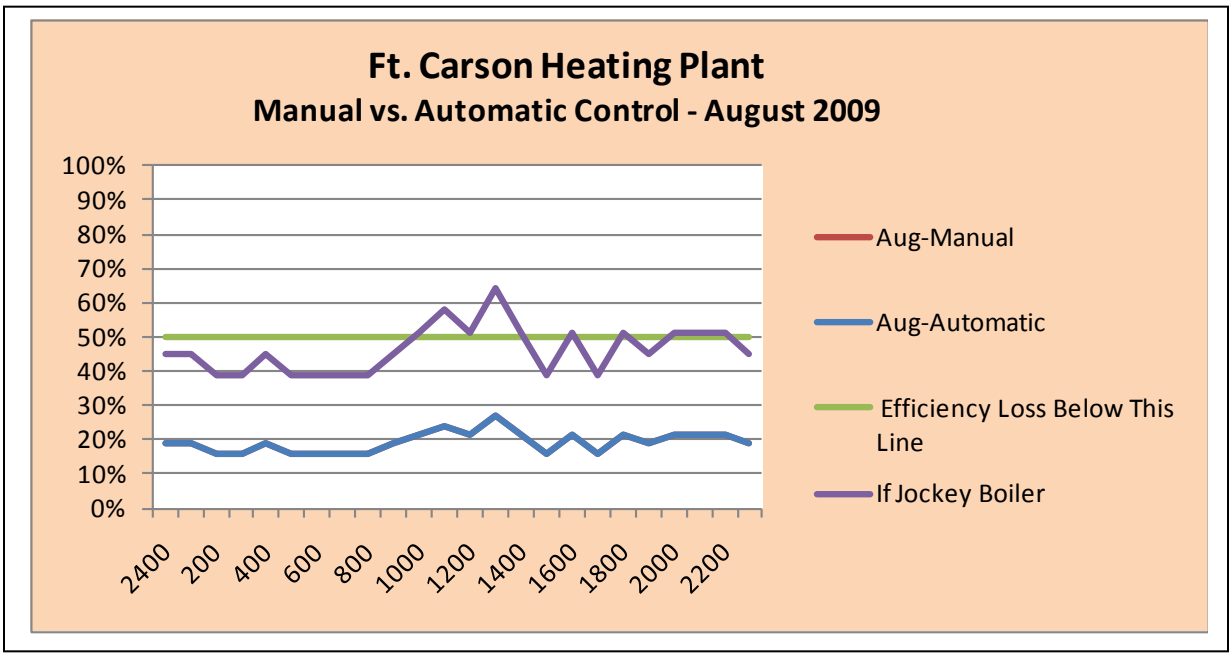

Ft. Carson Heating Plant
Manual vs. Automatic Control - March 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Mar-Manual
Mar-Automatic
Efficiency Loss Below This Line

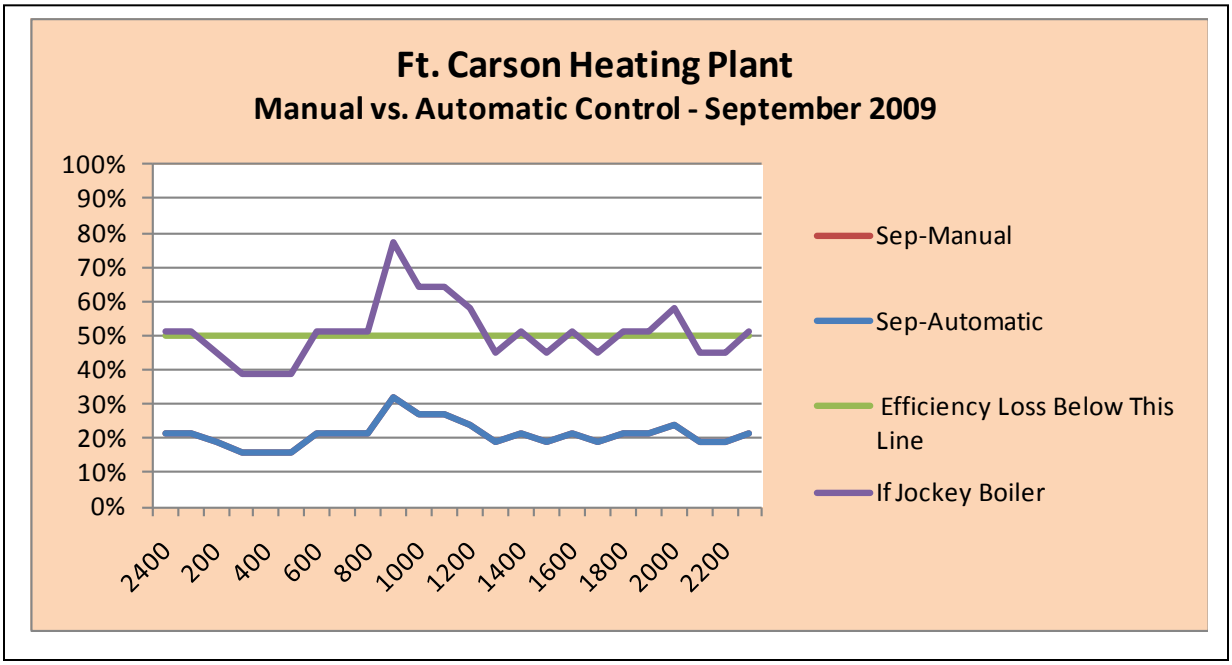

Ft. Carson Heating Plant
Manual vs. Automatic Control - April 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Apr-Manual
Apr-Automatic
Efficiency Loss Below This Line

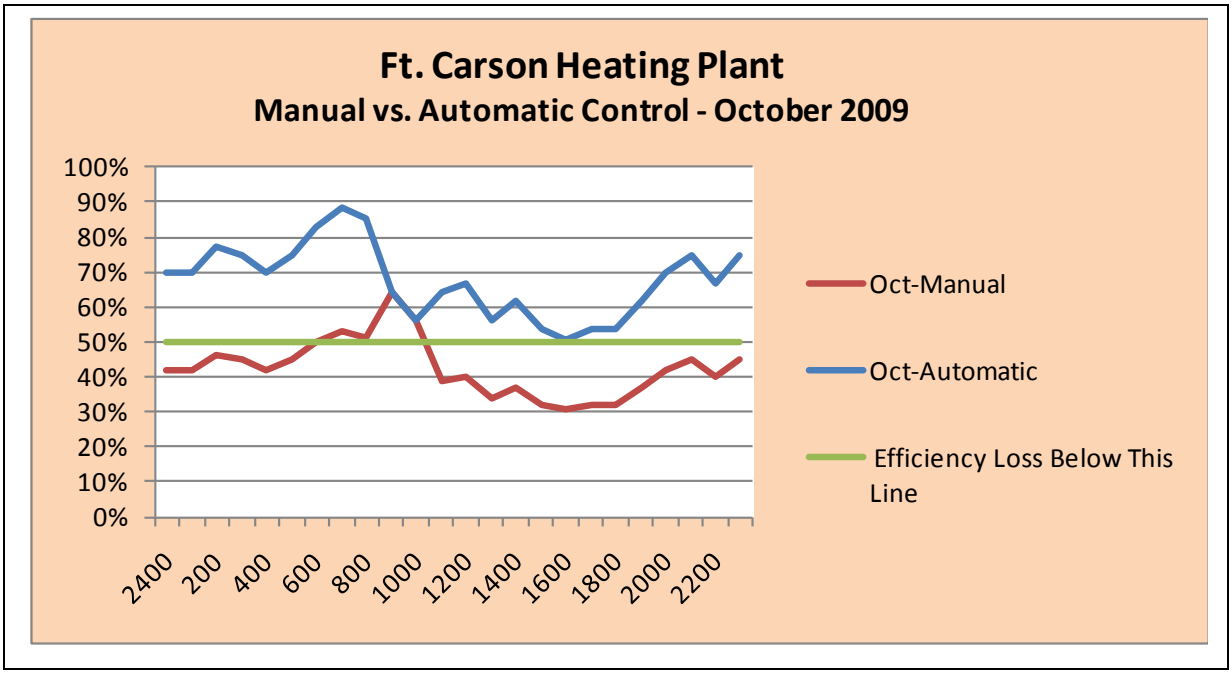

Ft. Carson Heating Plant
Manual vs. Automatic Control - May 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
May-Manual
May-Automatic
Efficiency Loss Below This Line

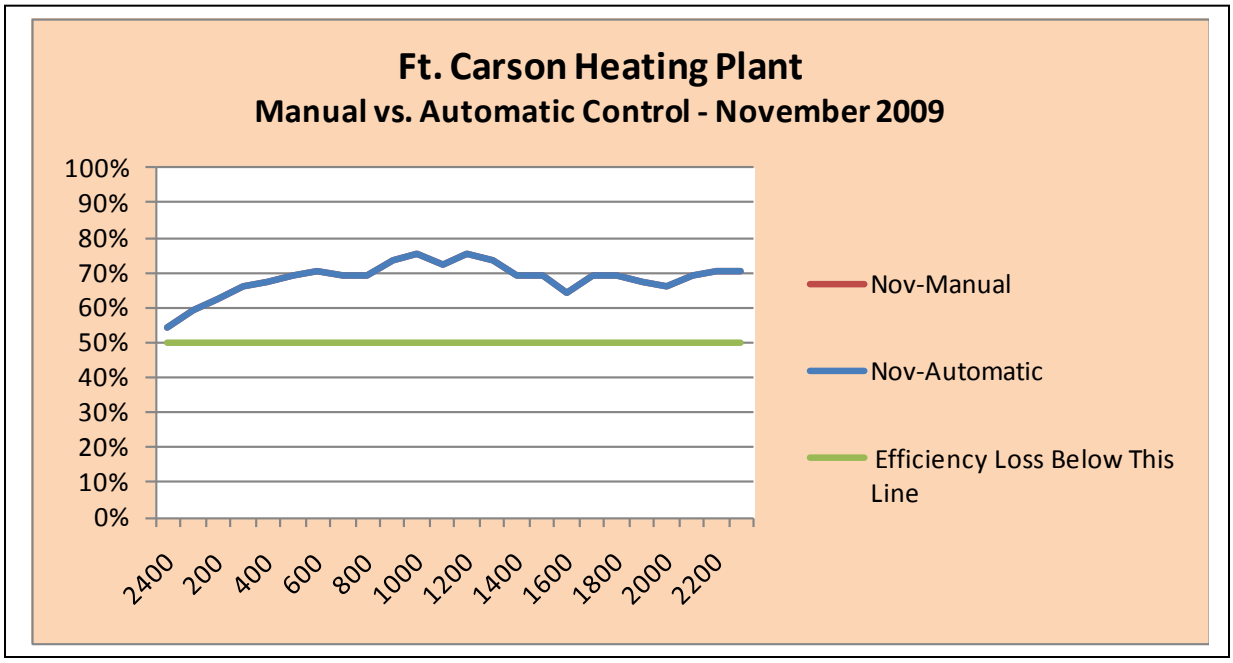

Ft. Carson Heating Plant
Manual vs. Automatic Control - June 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Jun-Manual
Jun-Automatic
Efficiency Loss Below This Line
If Jockey Boiler

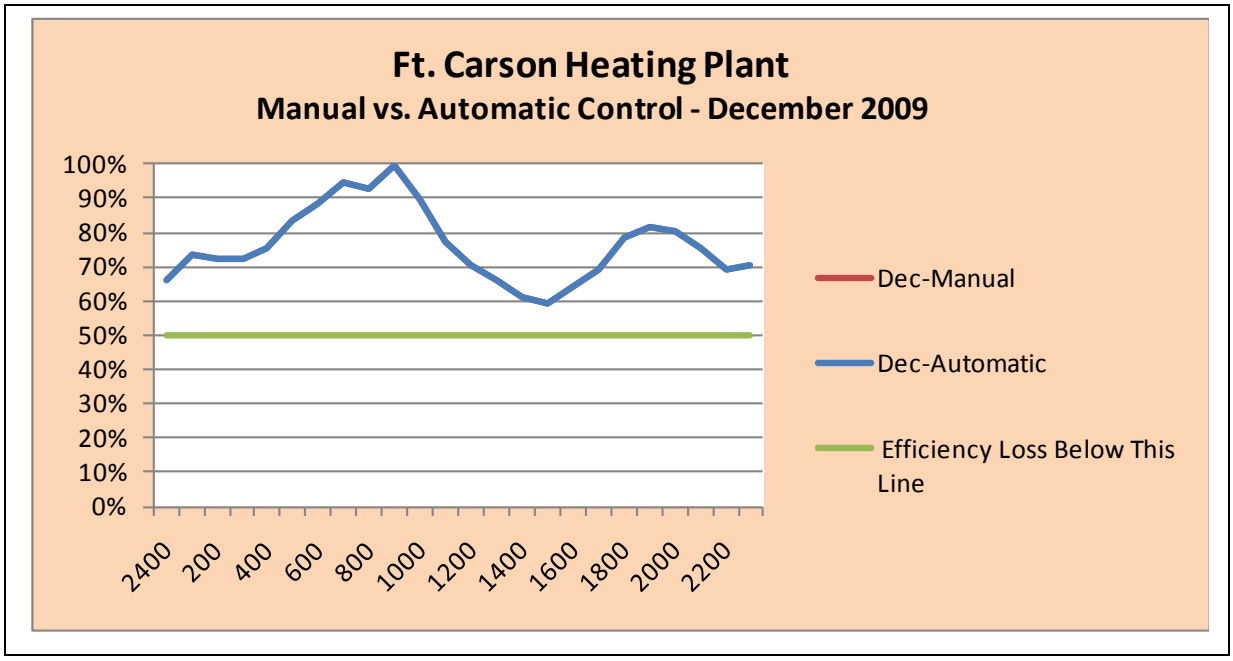

Ft. Carson Heating Plant
Manual vs. Automatic Control - July 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Jul-Manual
Jul-Automatic
Efficiency Loss Below This Line
If Jockey Boiler


Ft. Carson Heating Plant
Manual vs. Automatic Control - August 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Aug-Manual
Aug-Automatic
Efficiency Loss Below This Line
If Jockey Boiler

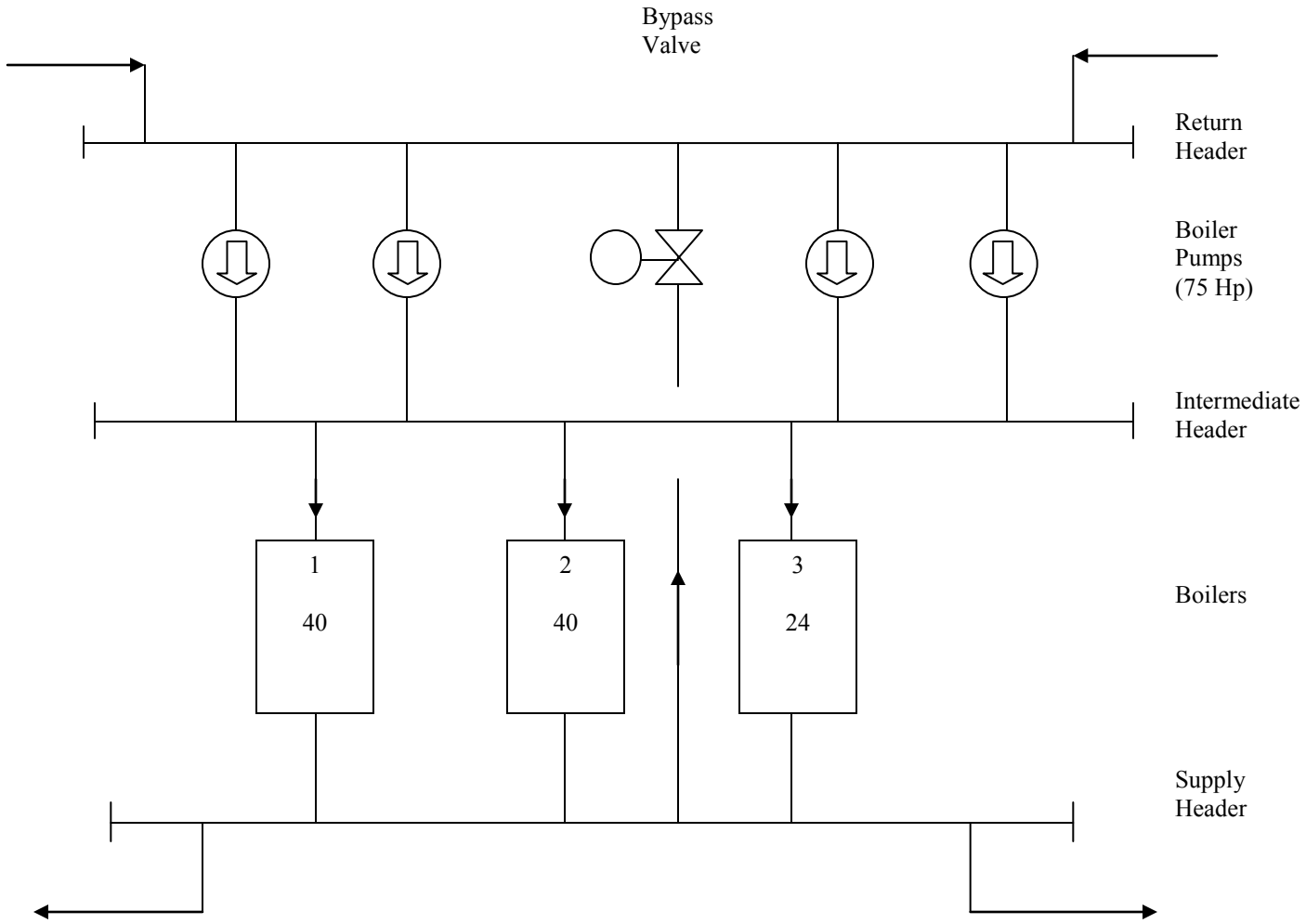

Ft. Carson Heating Plant
Manual vs. Automatic Control - September 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Sep-Manual
Sep-Automatic
Efficiency Loss Below This Line
If Jockey Boiler


Ft. Carson Heating Plant
Manual vs. Automatic Control - October 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Oct-Manual
Oct-Automatic
Efficiency Loss Below This Line

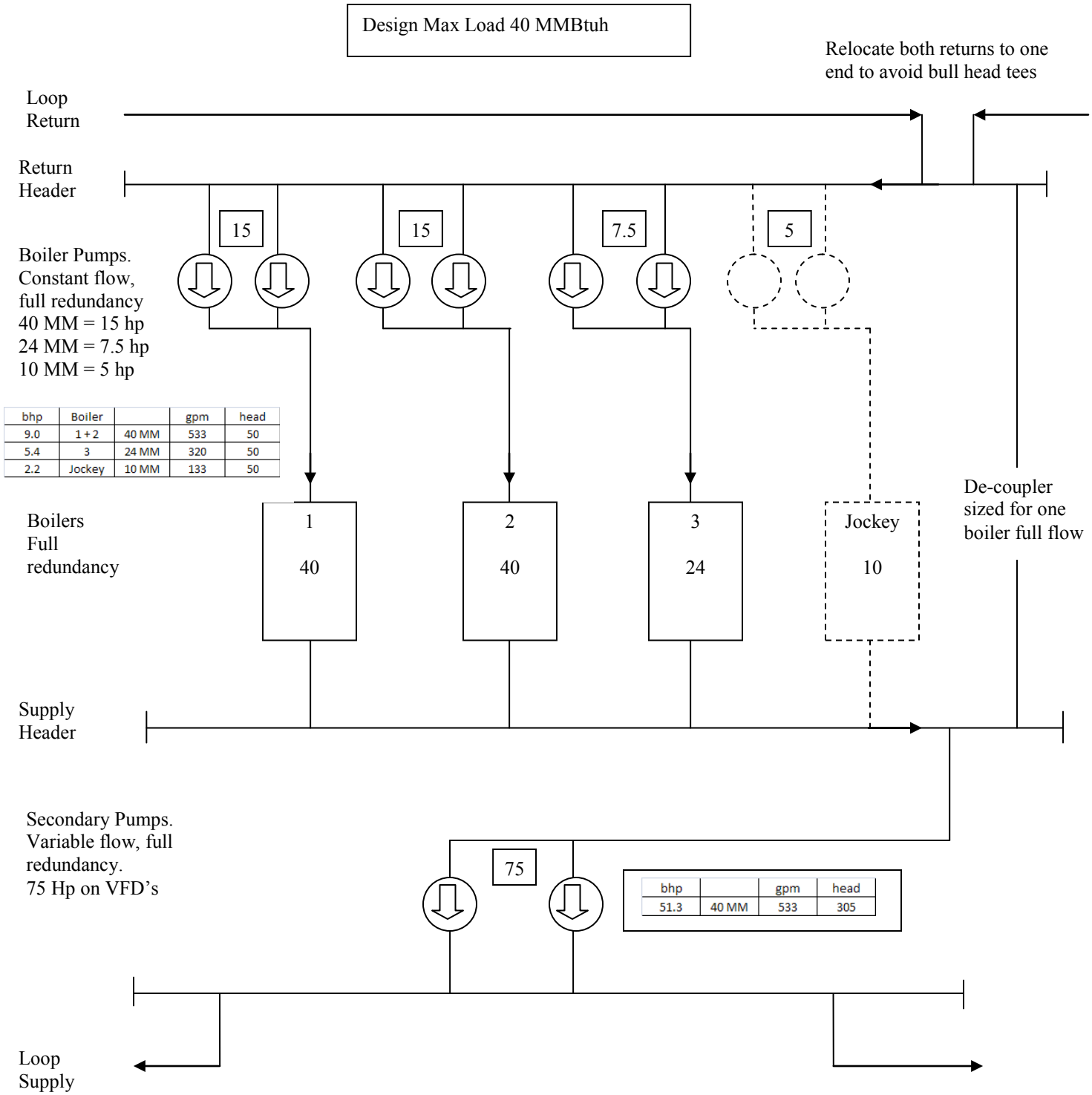

Ft. Carson Heating Plant
Manual vs. Automatic Control - November 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Nov-Manual
Nov-Automatic
Efficiency Loss Below This Line


Ft. Carson Heating Plant
Manual vs. Automatic Control - December 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2400
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Dec-Manual
Dec-Automatic
Efficiency Loss Below This Line

# Appendix E – HTHW Pumping Concept - Existing



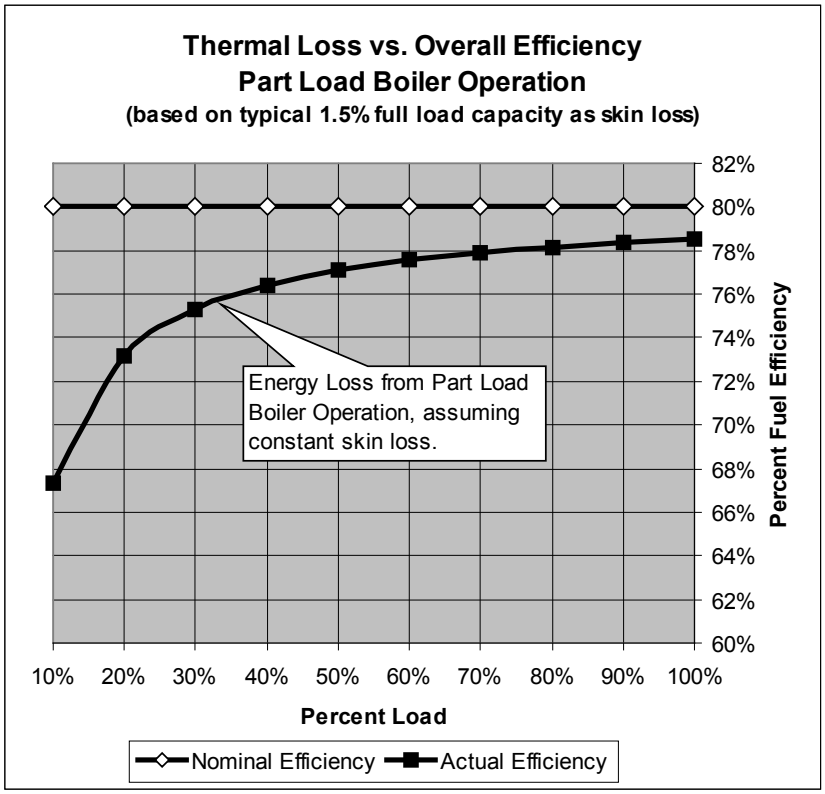
# Appendix E – HTHW Concept – Proposed (Primary/Secondary)

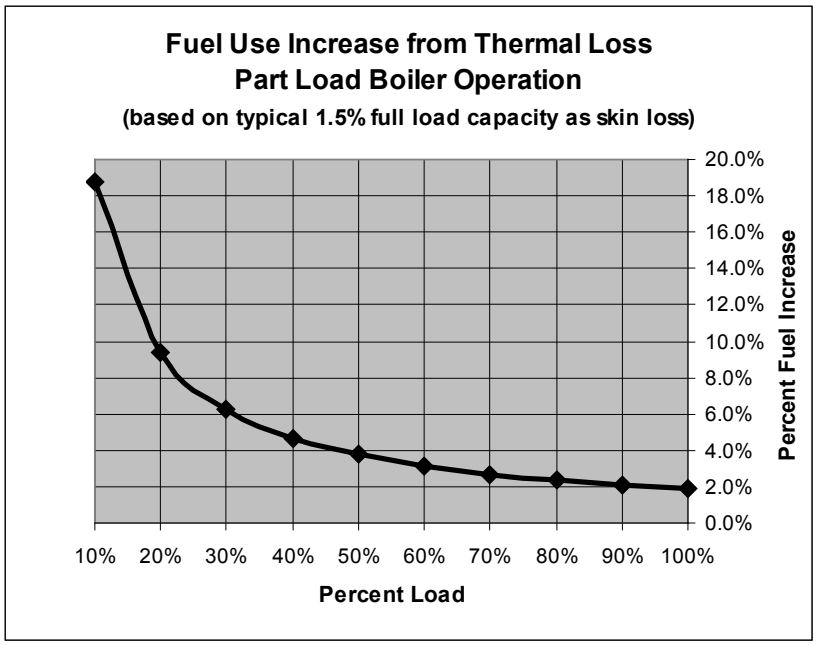



| bhp | Boiler | | gpm | head |
|---|---|---|---|---|
| 9.0 | 1 + 2 | 40 MM | 533 | 50 |
| 5.4 | 3 | 24 MM | 320 | 50 |
| 2.2 | Jockey | 10 MM | 133 | 50 |

| bhp | | gpm | head |
|---|---|---|---|
| 51.3 | 40 MM | 533 | 305 |

# Appendix F – Efficiency Loss from Operating a Boiler at Low Load




Source: Commercial Energy Auditing Reference Handbook, Fairmont Press.

# Appendix G – Water Source Heat Pump Efficiency Data

CLIMATEMASTER

## Performance Data
## TT H/V/D 038 (Full Load)

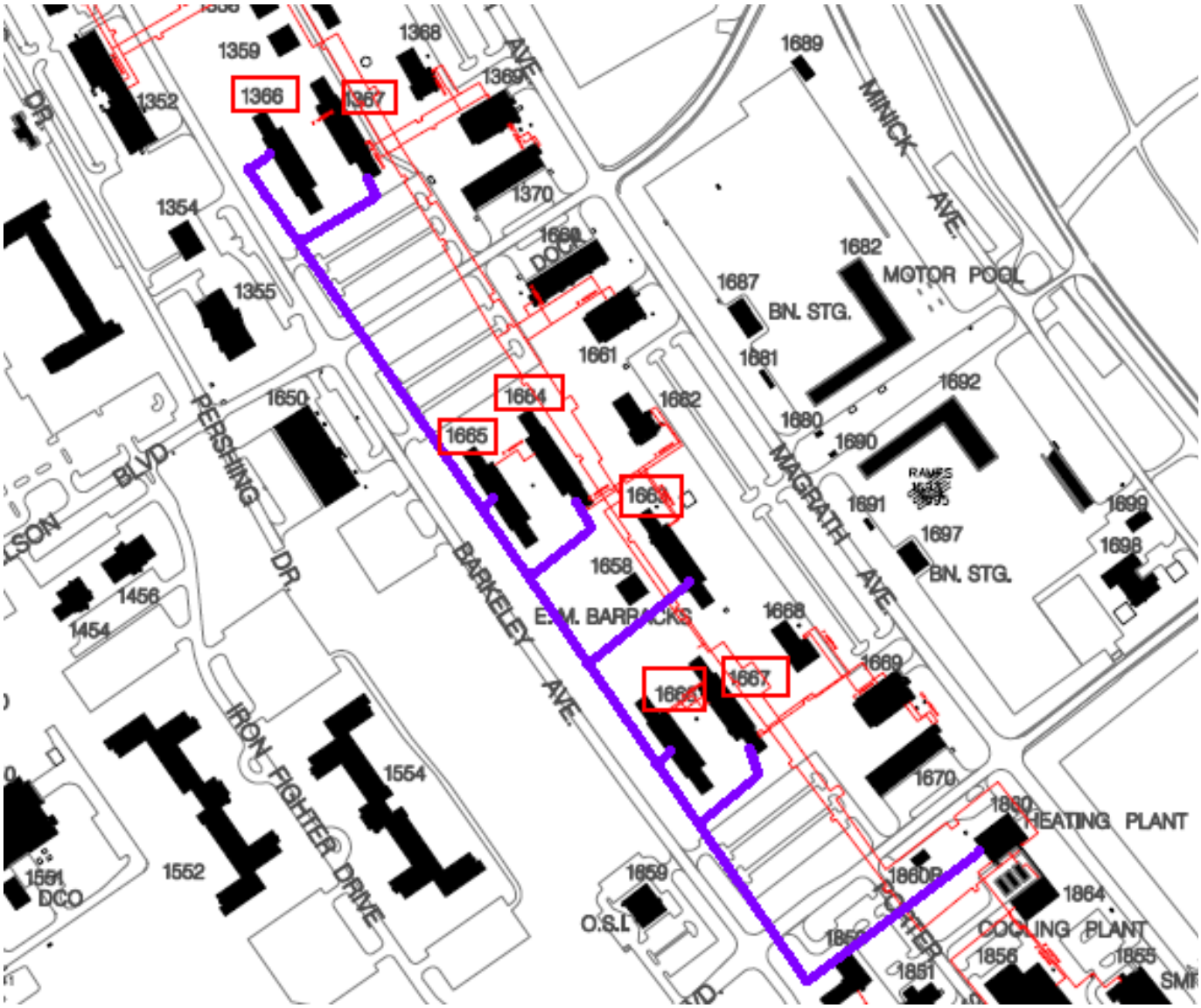
1250 CFM Nominal (Rated) Airflow Cooling, 1250 CFM Nominal (Rated) Airflow Heating

Performance capacities shown in thousands of Btuh

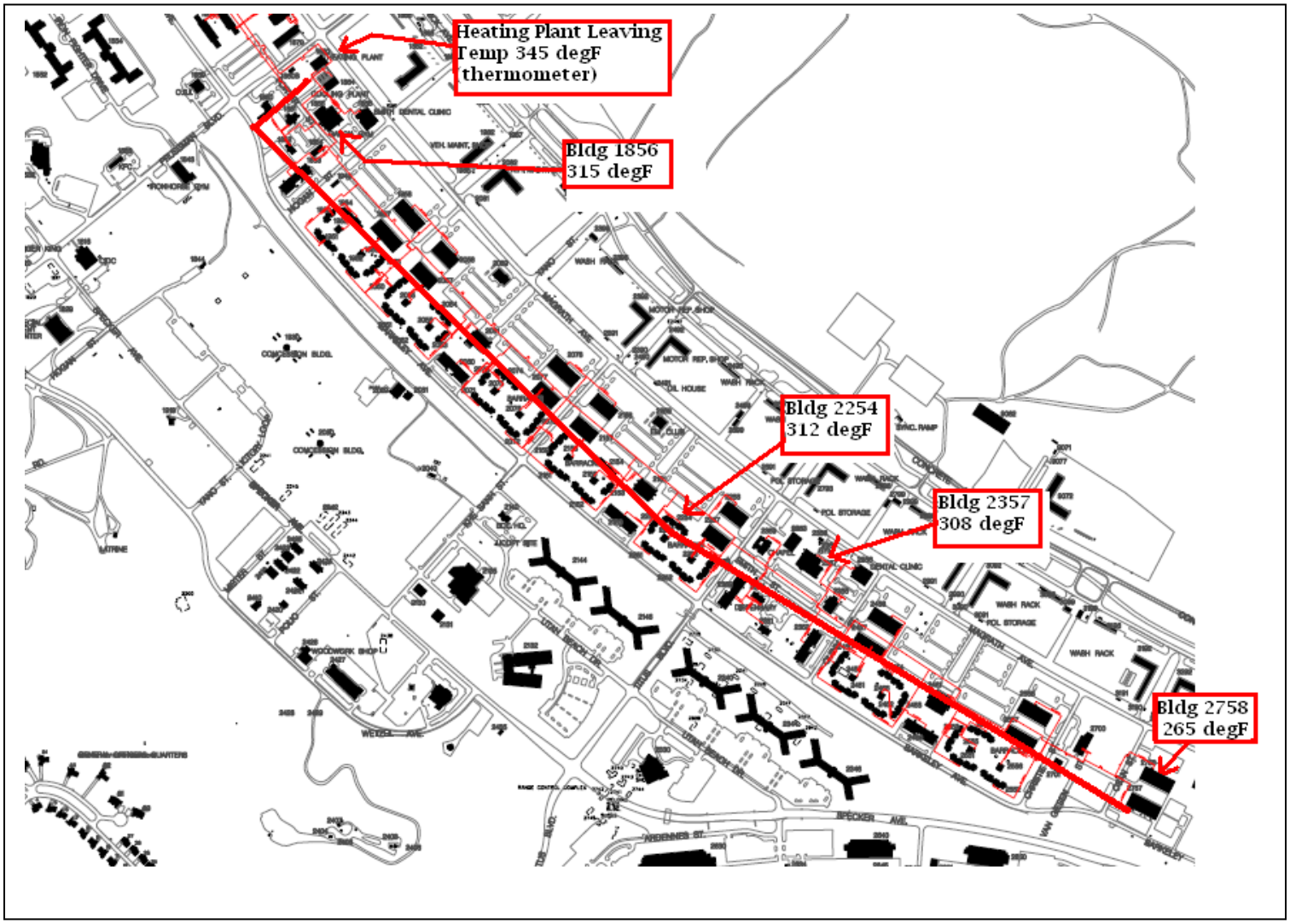
| EWT °F | GPM | WPD | | Cooling - EAT 80/67°F | | | | | | | Heating - EAT 70°F | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PSI | FT | Airflow CFM | TC | SC | Sens/Tot Ratio | kW | HR | EER | Airflow CFM | HC | kW | HE | LAT | COP |
| 20 | 9.0 | 5.9 | 13.7 | Operation not recommended | | | | | | | 1080 | 25.7 | 2.28 | 18.2 | 92.0 | 3.30 |
| | 9.0 | 5.9 | 13.7 | | | | | | | | 1250 | 26.2 | 2.18 | 18.8 | 89.4 | 3.51 |
| 30 | 4.5 | 1.7 | 3.9 | 1080 | 43.1 | 27.4 | 0.64 | 1.55 | 48.3 | 27.9 | 1080 | 27.9 | 2.32 | 20.2 | 93.9 | 3.52 |
| | 4.5 | 1.7 | 3.9 | 1250 | 44.1 | 30.1 | 0.68 | 1.61 | 49.6 | 27.3 | 1250 | 28.4 | 2.22 | 20.9 | 91.1 | 3.75 |
| | 6.8 | 3.3 | 7.7 | 1080 | 43.3 | 27.5 | 0.63 | 1.44 | 48.1 | 30.0 | 1080 | 29.2 | 2.35 | 21.4 | 95.0 | 3.64 |
| | 6.8 | 3.3 | 7.7 | 1250 | 44.3 | 30.1 | 0.68 | 1.51 | 49.4 | 29.4 | 1250 | 29.7 | 2.25 | 22.1 | 92.0 | 3.87 |
| | 9.0 | 5.7 | 13.1 | 1080 | 43.4 | 27.5 | 0.63 | 1.39 | 48.1 | 31.2 | 1080 | 29.9 | 2.36 | 22.0 | 95.6 | 3.71 |
| | 9.0 | 5.7 | 13.1 | 1250 | 44.4 | 30.1 | 0.68 | 1.45 | 49.4 | 30.6 | 1250 | 30.4 | 2.26 | 22.8 | 92.5 | 3.94 |
| 40 | 4.5 | 1.5 | 3.5 | 1080 | 42.3 | 27.5 | 0.65 | 1.69 | 48.0 | 25.0 | 1080 | 31.8 | 2.40 | 23.8 | 97.2 | 3.88 |
| | 4.5 | 1.5 | 3.5 | 1250 | 43.3 | 30.1 | 0.69 | 1.77 | 49.4 | 24.5 | 1250 | 32.4 | 2.30 | 24.6 | 94.0 | 4.12 |
| | 6.8 | 3.2 | 7.4 | 1080 | 42.9 | 27.6 | 0.64 | 1.59 | 48.2 | 27.1 | 1080 | 33.3 | 2.44 | 25.2 | 98.6 | 4.01 |
| | 6.8 | 3.2 | 7.4 | 1250 | 43.9 | 30.2 | 0.69 | 1.66 | 49.6 | 26.5 | 1250 | 33.9 | 2.34 | 26.0 | 95.1 | 4.26 |
| | 9.0 | 5.4 | 12.5 | 1080 | 43.1 | 27.6 | 0.64 | 1.53 | 48.3 | 28.1 | 1080 | 34.1 | 2.46 | 25.9 | 99.3 | 4.08 |
| | 9.0 | 5.4 | 12.5 | 1250 | 44.1 | 30.3 | 0.69 | 1.60 | 49.6 | 27.6 | 1250 | 34.8 | 2.35 | 26.8 | 95.8 | 4.33 |
| 50 | 4.5 | 1.3 | 3.1 | 1080 | 41.1 | 27.1 | 0.66 | 1.85 | 47.4 | 22.2 | 1080 | 35.7 | 2.49 | 27.4 | 100.6 | 4.20 |
| | 4.5 | 1.3 | 3.1 | 1250 | 42.1 | 29.7 | 0.70 | 1.93 | 48.7 | 21.8 | 1250 | 36.4 | 2.39 | 28.3 | 97.0 | 4.47 |
| | 6.8 | 3.1 | 7.2 | 1080 | 42.0 | 27.4 | 0.65 | 1.74 | 47.9 | 24.2 | 1080 | 37.5 | 2.54 | 29.0 | 102.2 | 4.34 |
| | 6.8 | 3.1 | 7.2 | 1250 | 43.0 | 30.0 | 0.70 | 1.81 | 49.2 | 23.7 | 1250 | 38.3 | 2.43 | 30.0 | 98.3 | 4.61 |
| | 9.0 | 5.2 | 12.0 | 1080 | 42.4 | 27.5 | 0.65 | 1.68 | 48.1 | 25.2 | 1080 | 38.5 | 2.56 | 29.9 | 103.0 | 4.41 |
| | 9.0 | 5.2 | 12.0 | 1250 | 43.4 | 30.1 | 0.69 | 1.75 | 49.4 | 24.8 | 1250 | 39.3 | 2.46 | 30.9 | 99.1 | 4.68 |
| 60 | 4.5 | 1.2 | 2.8 | 1080 | 39.6 | 26.4 | 0.67 | 2.02 | 46.4 | 19.6 | 1080 | 39.8 | 2.60 | 31.0 | 104.1 | 4.50 |
| | 4.5 | 1.2 | 2.8 | 1250 | 40.5 | 29.0 | 0.72 | 2.11 | 47.7 | 19.2 | 1250 | 40.6 | 2.49 | 32.1 | 100.1 | 4.78 |
| | 6.8 | 3.0 | 6.9 | 1080 | 40.7 | 26.9 | 0.66 | 1.90 | 47.1 | 21.4 | 1080 | 41.9 | 2.65 | 32.9 | 105.9 | 4.63 |
| | 6.8 | 3.0 | 6.9 | 1250 | 41.7 | 29.5 | 0.71 | 1.98 | 48.4 | 21.0 | 1250 | 42.7 | 2.54 | 34.1 | 101.6 | 4.92 |
| | 9.0 | 5.0 | 11.6 | 1080 | 41.2 | 27.1 | 0.66 | 1.84 | 47.4 | 22.4 | 1080 | 43.1 | 2.69 | 34.0 | 106.9 | 4.70 |
| | 9.0 | 5.0 | 11.6 | 1250 | 42.2 | 29.7 | 0.70 | 1.92 | 48.7 | 22.0 | 1250 | 43.9 | 2.58 | 35.1 | 102.5 | 5.00 |
| 70 | 4.5 | 1.1 | 2.5 | 1080 | 37.8 | 25.7 | 0.68 | 2.22 | 45.3 | 17.0 | 1080 | 44.0 | 2.71 | 34.8 | 107.7 | 4.75 |
| | 4.5 | 1.1 | 2.5 | 1250 | 38.7 | 28.2 | 0.73 | 2.32 | 46.6 | 16.7 | 1250 | 44.8 | 2.60 | 36.0 | 103.2 | 5.05 |
| | 6.8 | 2.9 | 6.7 | 1080 | 39.1 | 26.2 | 0.67 | 2.08 | 46.1 | 18.8 | 1080 | 46.4 | 2.79 | 36.9 | 109.8 | 4.88 |
| | 6.8 | 2.9 | 6.7 | 1250 | 40.0 | 28.8 | 0.72 | 2.17 | 47.4 | 18.4 | 1250 | 47.3 | 2.67 | 38.2 | 105.0 | 5.19 |
| | 9.0 | 4.8 | 11.0 | 1080 | 39.7 | 26.5 | 0.67 | 2.01 | 46.5 | 19.7 | 1080 | 47.8 | 2.83 | 38.2 | 111.0 | 4.95 |
| | 9.0 | 4.8 | 11.0 | 1250 | 40.6 | 29.0 | 0.72 | 2.10 | 47.8 | 19.3 | 1250 | 48.7 | 2.71 | 39.5 | 106.1 | 5.27 |
| | 4.5 | 1.0 | 2.3 | 1080 | 35.8 | 24.8 | 0.69 | 2.44 | 44.2 | 14.7 | 1080 | 48.3 | 2.84 | 38.6 | 111.4 | 4.98 |
| | 4.5 | 1.0 | 2.3 | 1250 | 36.7 | 27.2 | 0.74 | 2.55 | 45.4 | 14.4 | 1250 | 49.2 | 2.73 | 39.9 | 106.5 | 5.29 |

# Appendix H – Low Temperature Waste Heat Loop Concept for Seven Buildings

Buildings 1667, 1668, 1663, 1664, 1665, 1366, 1367 ~300,000 SF



# Appendix J – HTHW South Loop Observed Supply Temperatures




Heating plant temperature value came from a glass thermometer in the boiler outlet piping. All other readings came from a hand held infrared thermometer.