Manufacturing Project
Exceptional Calculation Methods
Methodology and Background for Process Hot Water and Steam Savings

Background

The manufacturing processes use a substantial amount of steam and hot water. The steam is supplied by (2) natural gas steam boilers, each with a net output capacity of 5,021 MBH at 82% AFUE.

P-502 is a schematic drawing of the process hot water flow and shows the connections for (3) sources of water heating along with (2) hot water storage tanks. The manufacturing process requires 10,000 gallons per hour of 70F water. This water is drawn from the 20,000 gallon storage tank in (2) 5,000 gallon "batches" at a peak flow of 500 gpm.

A 6,264 gallon storage tank can also be seen in P-502. This storage tank is an integral component of the process hot water heating system and allows the project to take advantage of three possible sources of water heating: heat recovery from the process air compressors, water-to-water groundsource heat pumps, and natural gas boilers. The system includes piping and controls such that these three sources of water heating can be used either independently or in conjunction with each other. While the tank temperature is set for 70F, the controls include a high limit shut-off set at 72F which locks out the heat recovery from the air compressors and heating from the water-to-water heat pumps. For the purposes of the Exceptional Calculation Method, only the 6,264 gallon storage tank is used in the calculations.

The primary source of process hot water heating is heat recovery from the air compressors. The project includes (3) air compressors: (1) 150 hp and (2) 100 hp units. The 150 hp air compressor operates whenever the manufacturing process is operating. In addition, (1) of the two 100 hp units operates in conjunction with the larger unit, while the other is a standby unit. The (2) smaller units will be used alternately. The heat rejected by the air compressors is run through a shell and tube heat exchanger to help heat the process hot water. Any excess heat not needed by the process water heating system is rejected to dry coolers, as seen in P-502.

The second source of process hot water heating is via (2) water-to-water groundsource heat pumps. This system is the second priority and is

The last stage of process hot water heating is from (5) natural gas hot water boilers, each with a net output capacity of 1,899 MBH at 95% AFUE. The boilers will only be used when the air compressors and water-to-water groundsource heat pump systems are off-line and/or the process hot water heating requirements exceed the available capacities of the other (2) systems.

Assumptions

For the purposes of the savings calculations, the following assumptions were made (please see the file "PI Process Water Exceptional Calculations 08-06-09.xlsx". The tab "Proc Schedules &

Drycooler Fans" includes the background setup information for the 6,264 gallon tank and the dry coolers.

Tank Assumptions

Tank Temperature = 70F

Operating Schedule:

Monday – Friday: 2 full shifts, 7am-3pm and 3pm – 11pm

Saturday – Sunday: 1 partial shift, 7am-3pm

Hourly flow:

Monday – Friday: 10,000 gallons in 2 separate 5,000 gallon batches at a flow rate of 500 gpm.

Saturday – Sunday: 5,000 gallons in (1) 5,000 gallon batch at a flow rate of 500 gpm

Entering water from York Water company:

Average temperature varies by month as seen in the file "York Water Company supply temperatures.pdf". Please note that York Water Company has 2 above ground supply tanks.

Dry Coolers Assumptions

There are 6 compressor fans which can be staged depending on the heat needed to be rejected from the process air compressors.

For the Baseline and Proposed buildings, the energy consumption of the dry coolers was calculated in Column O in tab "ECM Calculations" in "PI Process Water Exceptional Calculations 08-06-09.xlsx" based on all 6 compressor fans running at full heat rejection for all 16 hours Monday – Friday and all 8 hours Saturday – Sunday.

Baseline Modeling Methodology for the Process Steam

The steam boilers were modeled directly in eQuest with loads and schedules entered in the circulation loop as process loads. The steam boilers and process loads in both the Baseline and Proposed buildings were modeled identically using an 80% AFUE.

Baseline Modeling Methodology for the Process Hot Water

The process hot water boilers were initially modeled directly in eQuest with loads and schedules entered in the circulation loop as process loads as a quality control check of the base calculations in the file "PI Process Water Exceptional Calculations 08-06-09.xlsx" (Columns L-O). The process hot water boilers and process loads in both the Baseline and Proposed buildings were modeled identically using an 80% AFUE.

Please note that the Template uses the consumptions and costs as calculated in the Exceptional Calculations spreadsheet. Each calculation is performed for all 8,760 hours of the year.

Columns A-K in tab "ECM Calculations" calculate the required quantity of heat needed to raise the tank temperature to 70F. These calculations assume that the tank temperature is 70F at the beginning of each batch 5,000 gallon draw. Since the tank is 6,264 gallons, the remaining 1,264 gallons at 70F will be mixed with 5,000 gallons of water from York Water Company at the average monthly temperature, and a mixed water temperature is calculated. The hourly heat energy input required to raise the tank to 70F is then calculated.

Exceptional Calculation Measure #1, Increased Efficiency of Steam Boilers
This measure was modeled directly in eQuest by increasing the steam boiler efficiency from 80% AFUE to 82% AFUE. The DOE2 reports for this measure have been included in the "PI DOE2 repots.pdf" file.

Exceptional Calculation Measure #2, Increased Efficiency of Hot Water Boilers
This measure was calculated in the spreadsheet (Columns P-S) by increasing the hot water boiler efficiency from 80% AFUE to 95% AFUE.

Exceptional Calculation Measure #3, Heat Recovery from Air Compressors
Columns T-AC in tab “ECM Calculations” calculate the amount of heat recovery available from the process air compressors, the amount of heat recovery available, the additional energy consumption of the pump, the dry cooler consumption of any remaining heat to be rejected, and the boiler consumption if additional heat is required for the tank to reach 70F.

Exceptional Calculation Measure #4, Heat Supplied by Water-to-Water Heat Pumps
Columns AD-AN in tab “ECM Calculations” calculate the amount of heat supplied by (2) water-to-water heat pumps.

Manufacturing Facility

eQuest v3.6 Modeling Results Summary

Building Energy Summary

Design Run	PI-ASH 6-15-09 ASHRAE Baseline Building	PI-Prop 6-15-09 Proposed Design without Exceptional Calcualtion measures	PI-Prop-ECM 1 Proposed with increased Steam Boiler efficiency	PI-Prop-ECM 2 Proposed with increased Hot Water Boiler efficiency	PI-Prop-ECM 3 ECM-1 with Air Compressor Heat Recovery	PI-Prop-ECM 4 ECM-2 with W to W HP Process water heating
Estimated Operating Costs						
Electric	$1,595,632	$1,322,680	$1,322,680	$1,322,680	$1,318,879	$1,321,177
Gas	$1,365,426	$755,914	$745,425	$737,584	$720,833	$718,859
Total	**$2,961,058**	**$2,078,595**	**$2,068,105**	**$2,060,265**	**$2,039,712**	**$2,040,036**
Cost/SqFt	**$2.64**	**$1.86**	**$1.85**	**$1.84**	**$1.82**	**$1.82**
Cost Savings	**N/A**	**$882,463**	**$892,952**	**$900,793**	**$921,345**	**$921,021**
Savings Percentage	**N/A**	**29.8%**	**30.2%**	**30.4%**	**31.1%**	**31.1%**
LEED Points	**N/A**	**6**	**6**	**6**	**6**	**6**
Building Energy Use (MBtus)						
Electric	67,071.9	56,148.1	56,148.1	56,148.1	55,986.8	56,084.3
Gas	190,479.3	103,748.9	102,309.2	101,233.1	98,934.0	98,663.1
Total	**257,551.2**	**159,897.0**	**158,457.3**	**157,381.2**	**154,920.8**	**154,747.4**
Consumption						
Site (kBtu / SqFt / Yr)	257.6	159.9	158.5	157.4	154.9	154.7
Building Electric Use (kWh)						
Lights	6,678,338	4,765,559	4,765,559	4,765,559	4,765,559	4,765,559
Task Lights	0	0	0	0	0	0
Misc. Equip.	79,737	79,737	79,737	79,737	79,737	79,737
Space Heat	163,574	25,845	25,845	25,845	25,845	25,845
Space Cool	45,256	48,546	48,546	48,546	48,546	48,546
Heat Rejection	0	0	0	0	0	0
Pumps & Aux.	35,335	39,511	39,511	39,511	39,511	39,511
Ventilation Fans	1,278,650	337,148	337,148	337,148	337,148	337,148
Refrig Display	0	0	0	0	0	0
Ht Pump Supplement	32,478	19,668	19,668	19,668	19,668	19,668
Domestic Hot Water	48,556	48,104	48,104	48,104	48,104	48,104
Exterior Usage	501,231	298,380	298,380	298,380	298,380	298,380
Process Dry Coolers/Pumps	112,752	112,752	112,752	112,752	65,476	65,746
Air Compressors	814,687	814,687	814,687	814,687	814,687	814,687
Manufacturing Equipment	3,654,051	3,654,051	3,654,051	3,654,051	3,654,051	3,654,051
Process Pumps	6,207,259	6,207,259	6,207,259	6,207,259	6,207,259	6,207,259
WSHPs/Pumps	0	0	0	0	0	28,306
Total	**19,651,904**	**16,451,247**	**16,451,247**	**16,451,247**	**16,403,971**	**16,432,547**
Building Gas Use (Therms)						
Space Heat	1,232,005	365,547	365,547	365,547	365,547	365,547
Domestic Hot Water	4,725	3,879	3,879	3,879	3,879	3,879
Process Steam Boilers	599,907	599,907	585,510	585,510	585,510	585,510
Process Hot Water Boilers	68,156	68,156	68,156	57,395	34,404	31,695
Total	**1,904,793**	**1,037,489**	**1,023,092**	**1,012,331**	**989,340**	**986,631**
Sum of Building Space Peak Loads (without Ventilation)						
Heating (kBtu/h)	-21,092.3	-6055.0	-6055.0	-6055.0	-6055.0	-6055.0
Cooling (Tons)	1,190	531.1	531.1	531.1	531.1	531.1

Note: "MBtu" = 1,000,000,000 Btu

See the file " " for an explanation of the Exceptional Calculation Measures