Summary

Meline Engineering Corporation (MEC) investigated heating and cooling options for a proposed 90,000 square foot wool processing plant for Fibershed. Plant location is yet to be determined; Woodland, Marysville, Santa Rosa, and Firebaugh are possible sites.

Space cooling load, space heating loads, and scouring water heat loads were estimated and equipment alternatives were considered. Per Fibershed's request, both solar water heating and a ground-source heat pump system were investigated. In addition, a heat recovery alternative was considered.

Primary conclusions are as follows:

- ✓ A solar thermal system would be an excellent investment; it would supplement a standard boiler/chiller/tower system. An economical solar polymer array and storage system by Fafco would cost $48,500 and provide $11,000 dollars in operating savings per year.

- ✓ A ground-source system does not appear economical; cooling loads are so high that the system would almost always dump heat to the ground are rarely draw heat from the ground. A large ground loop would be required resulting in high first costs. Further, even a large loop could result in high returning water temperatures from the ground, resulting in very little increase in cooling efficiency versus standard systems.

- ✓ A heat recovery system provides similar operating savings to a solar system and may cost less to install than a standard boiler/chiller/tower system. The heat recovery system provides approximately $12,000 per year savings at virtually no additional cost.

- ✓ In the preliminary analysis provided here, the very large space cooling loads are a dominant factor. Further analysis should study cooling loads in detail. Design efforts should consider measures to lower cooling loads (improving the building envelope, investigating variable speed drives on equipment motors, considering heat recovery for ventilation air); a lowering of cooling loads will decrease both first and operating costs and may make the ground source alternative viable.

Loads Estimation

Scouring Hot Water Load – Loads below are based on

- 1.5 pounds of hot water per pound wool
- 1200 pounds wool per hour
- 140°F hot water delivery temperature and
- 60°F cold water temperature.

With these assumptions, the water heating rate is 1,200 MBH (1.2 million btu per hour), with a daily heating requirement of 96 therms.

Space Cooling Load – The cooling requirement for the facility is more challenging to pinpoint. 6 major contributions to the space cooling load were investigated: heat in through the building envelope, heat by lights, equipment heat, people heat, heat due to the introduction of ventilation air (a requirement to satisfy code and ensure indoor air quality) and hot water loads. Calculation results are summarized in the chart below followed by discussion of components.

Load	Tons Cooling Required	Notes
Envelope	30	*See glass values in appendix*
Lighting	20	*Watts/sf value?*
Equipment	115	*Loading and % duty needed*
People	12	200 workers
Ventilation	33	.15 cfm/sf
Hot Water	60	
Total	**270**	

The total of 270 tons is central to the analysis in this report; it is used to size equipment and estimate operating costs. A starting point for additional work would be to fine tune the above numbers. Notes on load components:

- Envelope Loads: Heat in through the envelope is estimated at 30 tons (where 1 ton is 12,000 btu/hr). This estimate was arrived at by modeling using EnergyPro, a certified program for California energy compliance calculations. For the building model, fairly standard construction was assumed (R-19 walls, R-30 roof, 2000 square feet of double pane – but not low-E – windows distributed around the building). This load could be lowered by at least 10 tons by upgrading the envelope.   A printout showing details of these and other loads is provided in the appendix.

- Lighting Loads: A standard lighting value is 0.9 Watts of lighting per square foot. Using this standard value results in a cooling requirement of ≈ 23 tons (cooling to remove heat from lights). A very moderate increase in efficiency could lower this load to 20 tons.

- Equipment Heat: Per the equipment list forwarded to MEC, motor loads will be substantial. Standard procedure for motors in a facility is to convert operating motor horsepower or kW to heat ; when a motor runs, eventually all the energy it consumes is converted to heat which must be removed from the space to maintain setpoint temperature.
  If a motor is turned off for portions of operating hours or if it operates at part load, heat load from a motor may be reduced from its maximum kW value; thus operating hours (or % duty) and loading are important to any effort to lower cooling loads estimates and cooling equipment size.

  For this analysis, information % duty and loading information were not available. To arrive at a cooling load estimate, kW for all listed equipment was added arriving at a total of 648 kW. For this study it was assumed that on average 62% of the motor load, giving motor heat cooling load of 115 tons.

If this project moves forward to design, the motor heat cooling load should be studied in detail, as motor heat is a substantial portion of the total load, affecting equipment sizes, first costs and estimated operating costs. It is suggested, as a start, that the seven Ring Spinning Frames be investigated, as each of these is stated to have a 55 kW motor, equivalent to almost 16 tons of load. MEC contacted NSC for help understand Ring Spinning Frame operation but has not received useful information yet.

- People Loads: Workers emit both sensible heat and latent heat (moisture). Standard values per person working in a manufacturing facility are 275 bth/occupant sensible heat and 475 bth/occupant moisture (latent) heat. Estimating 200 workers gives a combined sensible and latent load of approximately 12 tons (150,000 btu/hr).

- Ventilation Loads: In design, the required amount of fresh air to maintain indoor air quality would be dialed in. For this study, the standard value of .15 cubic feet per minute of outside air per square foot of floor space was used.

- Hot Water Loads: 30 gpm of hot water is to be used on the scouring line, with the water entering at 140°F. The water will cool with a significant portion of the heat from the water going to the space. In theory the water could cool to 73°F, the space temperature, resulting in 83 tons of heat to the scouring line space. We assumed in our calculations that the water exited at a slightly higher temperature, and so arrived at a cooling load of 60 tons due to hot water releasing heat.

Space Heating Load: A significant building heating load improves the economics of the ground-source heat pump alternative. Ground source systems work best when heat is both rejected to the ground (during the cooling season) and removed from the ground (for heating); the ground temperature remains moderate and heat pump cooling and heating occurs with good efficiency. The figures provided above indicate a significant amount of heat would be removed from the Wool Facility annually; would space heating requirements result in significant heat removal from the ground?

Space Heating Loads were calculated using EnergyPro, with a worst case heating load (25°F outside air, no equipment operating) of only 77 tons (see appendix for details)

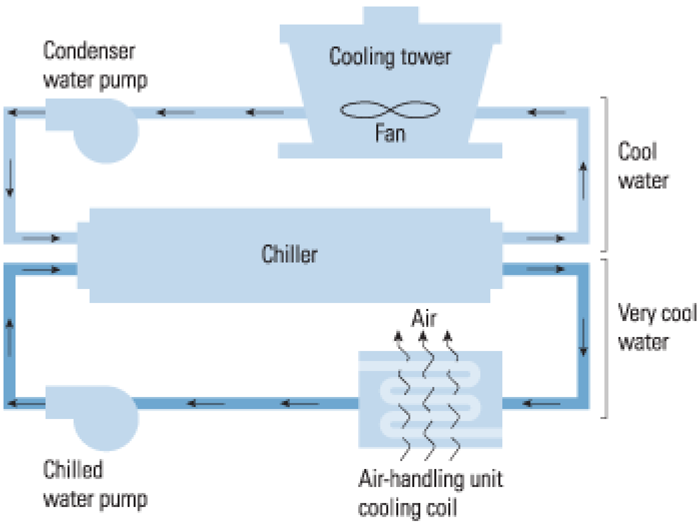
- 25 tons for heat loss through the envelope and
- 52 tons for ventilation air.

Comparing this heat requirement to the heat rejection by equipment alone (115 tons), we arrive at the conclusion that heat rarely will need to be supplied to the facility, perhaps only during morning warm-up in preparation for the arrival of workers. Once the facility is up and running, even on the coldest day, internal heat generation offsets heat losses. The buildings HVAC system will be in cooling mode almost all operational hours of the year.

Alternate Systems

Baseline: While there are many alternatives, a very common set-up for a building with a large heating and cooling load that often proves economical is boiler/chiller/tower system.

- A boiler for heating scouring water and - where necessary - providing space heat.
- A chiller for providing chilled water; the chilled water runs into the building and provide cooling to air running through air handlers or fan coils.
- A cooling tower for heat relief – heat pulled out of the chilled water by the chiller would then be rejected to a stream of water; this stream of water would flow to the tower where heat of rejection would be removed by evaporative cooling.



The above schematic does not include the boiler which would operate entirely separately. While chillers can be air-cooled, water-cooled chillers are more efficient, and for large facilities, the pay-off associated with a water-cooled chiller is short enough to warrant the scheme depicted above.

Alternatives to this baseline considered are

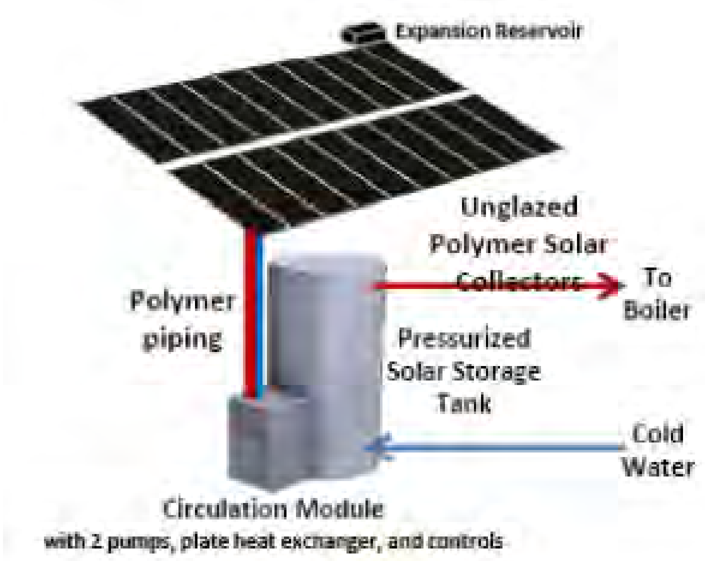
1. Warming the scouring water in part by a solar system
2. Replacing the chiller/cooling tower with a ground source heat pump system and using the ground-source system for heating as well as coling (heat rejected from the building to the ground is pulled out of the ground and used for scouring water).
3. A heat recovery system, where the chiller and tower are downsized and a heat recovery unit is added; the heat recovery unit takes as much heat rejected from the building as is economic and uses it to warm scouring water.

Alternative 1: Solar System

A solar system can be sized to displace a significant portion of the hot water load. It is important to understand, however, that the panel area required to pre-heat water (raise the temperature from 60°F0 to around 90°F) is much lower than the panel area required to go beyond pre-heat (say from 90°F to 120°F). As water temperatures get higher, panel heat loss to the surroundings increases, and so more area is required for high temperature increases than low temperature increase.

For this reason, economic analysis of solar thermal systems often yields a pre-heat - rather than a full-heat - recommendation. Pre-heat is achieved with a relatively small number of panels and pays off quickly.
A key choice in a solar thermal system is type of panel – plastic unglazed polymer panes, copper panels covered with glazing, or evacuated tubes. The previous choices are ordered by expense. Each type has advantages and disadvantages. MEC has experience with all types.

Knowing that economics would dictate the use of solar for pre-heat, an analysis of a solar thermal system using FAFCO unglazed polymer panels is provided. Polymer panels work well for pre-heat and a relatively inexpensive. A schematic of a possible arrangement is shown below:



A representative from FAFCO has presented the following figures to optimize the rebates and payback:

Square feet of solar collectors	3,846
Expected production (therms of natural gas offset per year)	13,846
Initial cost	$307,680
State rebate	($201,177)
Tax Credit	($31,951)
Tax Deduction (Depreciation)	($26,093)
Remainder	$48,459
Annual savings (assuming $0.80/therm NG)	($11,076)
Simple Payback (years)	4.4

In sum, $11,000 dollars in operating savings per year for an initial investment of $48,500. Details on the FAFCO system are provided in the appendix.

Alternative2: Ground-Source System

Some generalities on Ground-Source Heat Pump (GSHP) systems:

- ✓ A heat pump in heating mode draws energy from a source, increases the temperature of that energy, and then delivers that energy to a load (usually hot water or space heating).

- ✓ In cooling mode, the transfer is reversed – energy is removed from a load, usually to cool a building; the heat pump increases the temperature of that energy and then dumps it to a heat sink.

- ✓ For a ground-source system (see schematic on next page) the source during heating is the ground; the sink during cooling is also the ground.

- ✓ Heat pumps operate efficiently when the source/sink temperature is moderate. If a heat pump is in heating mode and the source is cold, efficiency will be low. If a heat pump is in cooling mode and the sink temperature is high, efficiency will be low.

- ✓ In an economical GSHP system, the ground remains at moderate temperature. Heat dumped to the ground during cooling is offset to a reasonable degree by energy removed to serve heating loads.

How can a ground source system pay-off in comparison with the standard boiler/chiller/tower? The main change in going to a GSHP is substituting the ground loop for the tower; with the ground loop being much more expensive. The tower, however, will provide the chiller approximately 85°F sink water, whereas the ground loop in an economical GSHP system will provide lower temperature sink water (the ground is usually cool). The heat pump therefore will cool more efficiently than the chiller in the boiler/chiller/tower system. This efficiency, along with the elimination of the expense of operating the cooling tower, results in lower operating costs and payback. A typical payback for an economical GSHP system is 10 years. Payback can vary greatly; a key parameter is the balance between heating and cooling requirements.

What about the heating/cooling balance for the proposed Fibershed Facility?

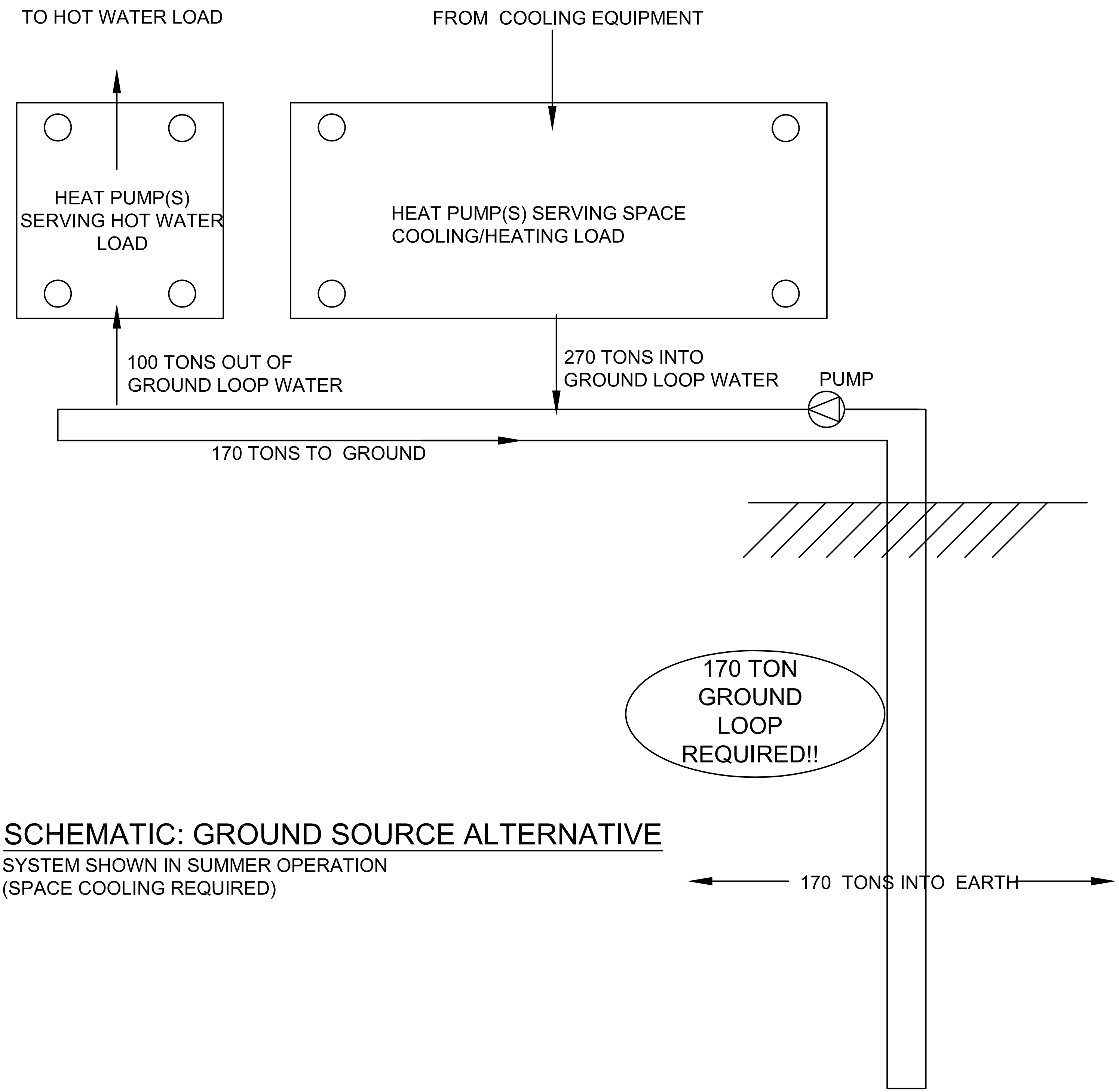
Summer operation

- ✓ Peak heating = 100 tons (scouring hot water)
- ✓ Peak simultaneous cooling = 270 tons.
- ✓ Heat to ground = 170 tons (some of heat into ground loop water is removed to heat scouring water)

Winter Operation

- ✓ Baseline heat to space from equipment, lights, people and hot water ≈200 tons
- ✓ Space heat load due to envelope losses and ventilation requirements ≈ 77 tons
- ✓ Maximum scouring hot water load = 100 tons.
- ✓ Net heat to ground = 200 – 77 – 100 = 33 tons.

The numbers above indicate that there will *almost never* be a period of the year where the system is primarily in heating mode; virtually during all operational hours – even on the coldest morning – heat will need to be dumped to the ground.



SCHEMATIC: GROUND SOURCE ALTERNATIVE

SYSTEM SHOWN IN SUMMER OPERATION
(SPACE COOLING REQUIRED)

As a result, even with sufficient piping in the ground allowing the heat dump to spread over a large volume, the ground does warm and the water returning from the ground reaches temperatures such that the heat pumps operating in cooling mode, are no more efficient than the chiller in the boiler/chiller/tower system. Here are estimates:

- ✓ Ground loop to be sized to handle 170 ton peak load with system almost always in cooling.
- ✓ 1 bore at 250 feet per ton cooling.
- ✓ So 170*250 = 42,500 feet of bore.
- ✓ Estimate $25 per foot bore for ground loop installation.
- ✓ Incremental cost of ground loop ≈42,500*$25 ≈$1 million.

Note that with this size ground loop and the system loading estimated above, the ground does warm up (net heat is to ground) for much of the year the return water from the ground loop would often be 85 to 90°F; the sink water temperature for the tower alternative (85 to 90°F from tower) and for the GSHP alternative (85 to 90°F from the ground) are similar. We have no significant increase in efficiency for a $1 million dollar investment.

Also note that both peak and typical cooling loads are key to the above analysis. If peak and typical cooling loads can be lowered significantly, the ground loop size becomes smaller and the GSHP alternative may become more viable.

Alternative 3: Heat Recovery Alternative

While Fibershed did not inquire about heat recovery, MEC believes this alternative may provide the greatest economic benefit and so a brief discussion is provided.

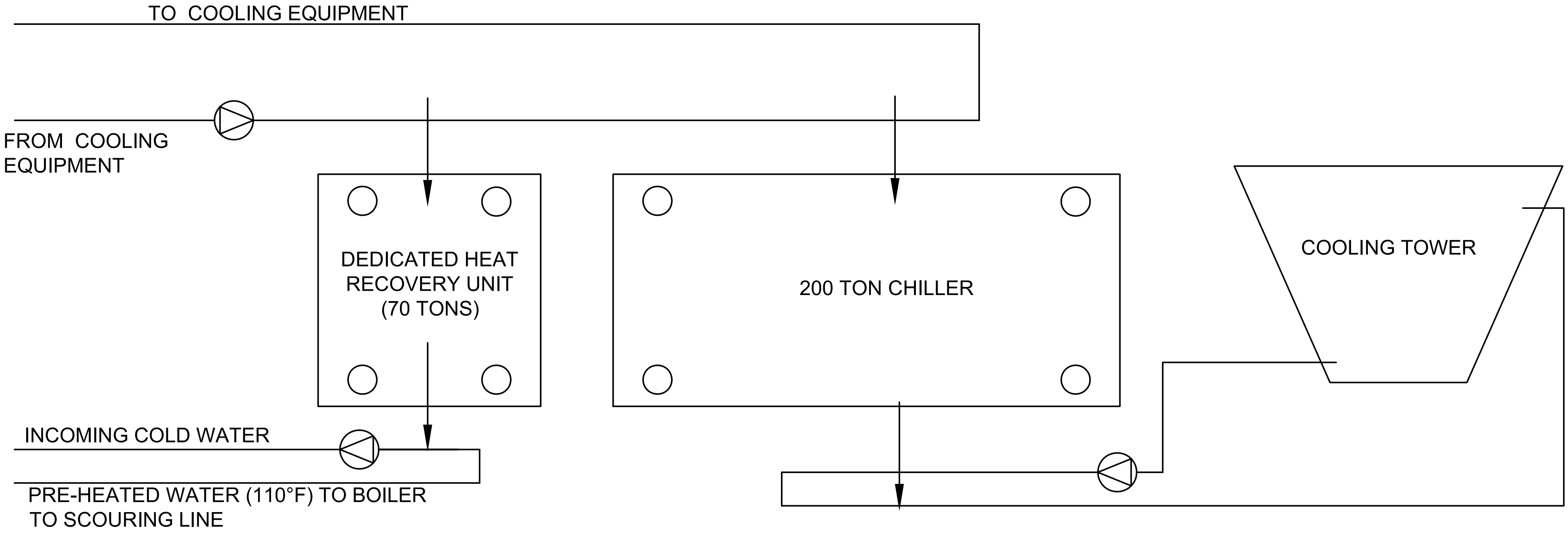
A heat recovery schematic is provided on the next page. The concept is simple.

- ✓ A heat recovery unit can simultaneously remove heat from return space cooling water and transfer this heat to incoming scouring line water. This transfer is at very low operating costs (two loads, heating and cooling, essentially served by one compressor circuit).
- ✓ Furthermore, since the scouring line load is steady, some cooling is always provided by the heat recovery unit and the chiller and cooling tower can be downsized.

So with this option, we have water heating and a portion of the cooling at low cost, and lower first cost for the downsized chiller and tower. These savings have to be weighed against the cost of a heat recovery unit which are complex devices.

To analyze this alternative, MEC worked with Air Treatment Corporation, a national manufacturer's representative which provides technical assistance for Multi-stack products. Multi-stack makes heat recovery units and chillers, so Air Treatment was able to gather both first cost and operating costs for the boiler/chiller/tower system and the heat recovery alternative, summarized below (only key cost differences provided).

HEAT RECOVERY SYSTEM SCHEMATIC



Boiler/Chiller/Tower First Costs
270 ton MagLev Chiller $175,000
270 ton FXT Cooling Tower: $21,500
IntegraClean Tower Water Cleaning: $20,000
-
Total Budget Equipment Cost : $216,500

Heat Recovery First Costs
200 ton MagLev Chiller $125,000
200 ton FXT Cooling Tower: $18,500
IntegraClean Tower Water Cleaning: $20,000
70 ton heat recovery unit: $50,000
Total Budget Equipment Cost : $213,00

The reduction in chiller and tower cost essentially pays for the heat recovery unit.

For operating costs, Air Treatment assumed “blended” gas cost of 60 cents per therm and “blended” electrical cost of 11 cents per kW-hr. Assuming operation of 8 hours per day 50 hours per year and domestic hot water pre-heat to 95°F water (as with the solar system, water could be heated to a higher temperature by the recovery system but the economics suffer), Air Treatment calculated approximately $12,000 annual operational savings.

Appendix:

1. Heating and Cooling Loads (from EnergyPro – envelope, lights, ventilation, workers).

2. 270 Ton Chiller and Cooling Tower – equipment specs

3. FAFCO Solar Thermal System Details

4. Heat Recovery Option – equipment specs.

From: **Marcus Romani** marcus@meline.com
Subject: cost data, notes for performa
Date: October 31, 2013 at 2:44 PM
To: Amber Bieg amberbieg@gmail.com
Cc: Dustin Kahn dustinkahn@gmail.com

Amber – Here are my recommendations for updating your performa:

1. **<u>Boiler/Chiller/Tower/Air Handlers Scenario</u>** - This would be a standard approach to conditioning a large facility.
   - Boilers for heating (hot water, steam, and heating hot water) and chiller for cooling; see my earlier report for a schematic and details.
   - There would be air handlers in the facility, probably one per zone (ie scouring, spinning, etc).
   - Each air handler would have a cooling coil and heating coil.
   - When cooling is required (most of the year), chilled water is pumped through the air handler, picking up heat from the indoor air.
   - Heat is relieved through the cooling tower.

   A. Estimate the first cost for the system above at $650,000 (equipment and install); perhaps high but I would rather be conservative.
      - Note that maximum total cooling tonnage given the revised equipment (in particular only 4 spinning frames) and occupants is around 200 tons (as opposed to 270 tons in earlier report).

   B. For operating costs, you have water heating in another section of your performa, so here I will estimate HVAC space conditioning costs alone.
      - This can be done on a kW/ton basis.
      - With a good chiller/tower system, estimate 1 kW/ton (includes pumps and air handlers).
      - 200 tons is the maximum, estimate an average 140 ton cooling requirement during operation.
      - So 1kW/ton*140 tons*4000 hours per year = 560,000 kW-hr per year for HVAC.

   C. For your office/facilities energy per year cell on the Energy tab, you also need to include lighting and some office equipment.
      - Lighting: 85000 sf * 0.9 W/sf = 76.5 kW * 4000 hours per year = 306,000 kW-hr. Add some energy consumption for office equipment, so 330,000 kW-hr.
      - So total for cell is 560,000 kW-hr + 330,000 kW-hr = 890,000 kW-hr.

   D. You were interested in operating costs in watts/sf. So 890,000 kW/hr/(4000 hours)/85,000sf = 2.62 watts/sf. You should be cautious about using this figure for different hours of operation and building sizes.
      - In general, if hours of operation go up, watts/sf will go down. More hours of operation at night when cooling requirements will be less.
      - In general, as facility size goes down, watts/sf will increase. For cooling there are efficiencies of scale.

2. **Pump and Dump** – In this scenario, instead of dumping building heat to water which circulates through a cooling tower, we pump water from the ground, dump heat to this water, perhaps use some of the pre-heated water for scouring, and re-inject the rest into the ground in a second injection well.

This actually looks very promising – you need a well anyway and the building heat dump could preheat some of the water going to the scouring line. The cooling efficiency would be good (better than with a chiller/tower).
Permitting may be a challenge.

A. For first cost, a quick estimate does not show that much difference from the $650,000. You need the wells and heat exchanger, but no cooling tower, and there other ways to lower first costs. I'd stay with same cost.

B. For operating costs, once again can use a kW/ton value.
   - I estimate 20% more efficient on average so 0.8 kW/ton total (cooling, pumps, air handler blowers, etc).
   - So 0.8 kW/ton*140 tons*4000 hours per year = 448,000 kW-hr per year for HVAC.
   - Lighting remains the same.
   - So total for cell is 448,000 kW-hr + 330,000 kW-hr = 778,000 kW-hr.
   - For watts/sf, 778,000/85000/4000 = 2.29 watts/sf. Again, use caution using this figure for different size facilities and hours of operation.

3. Solar:
- As noted yesterday, solar cannot cover 100% of water heating costs. Often ROI maxes out at 50% by solar.
- You can go higher, but its tough to go above 70% of solar. Solar cannot do steam.
- So in your performa, have 70% of the water heating by solar.
- Solar array size would need to be upsized significantly to get up to 70%. Ballpark the square foot requirement at 6,000 sf.
- Ballpark the solar system cost (after rebates, credits, etc.) at $100,000 – may need to go to flat-plate glazed collectors to get higher water temperatures.

Good luck with your presentation.

Marcus Romani
Meline Engineering Corporation
Ph: (916) 366-3458
Fax: (916) 366-3958

meline engineering
www.meline.com

Meline Engineering Corporation is a licensed mechanical engineering consulting firm located in Sacramento, CA. For the past 18 years, Meline Engineering Corporation has provided energy *efficient mechanical system designs for commercial and residential buildings and is considered the West Coast industry leader in designing geoexchange and related applications.*

Physical Address:
9343 Tech Center Drive, Suite 135, Sacramento, CA 95826. From highway 50 West, take the Bradshaw Road exit. From highway 50 East, take the South Watt Avenue exit. We are also conveniently located 1 block from the Tiber Lightrail Station.

HVAC SYSTEM HEATING AND COOLING LOADS SUMMARY

Project Name	Date
Fibershed	10/9/2013
System Name	**Floor Area**
System 1	90,895

ENGINEERING CHECKS	
Number of Systems	
Heating System	
Output per System	
Total Output (Btuh)	
Output (Btuh/sqft)	
Cooling System	
Output per System	
Total Output (Btuh)	
Total Output (Tons)	
Total Output (Btuh/sqft)	
Total Output (sqft/Ton)	
Air System	
CFM per System	
Airflow (cfm)	
Airflow (cfm/sqft)	
Airflow (cfm/Ton)	
Outside Air (%)	
Outside Air (cfm/sqft)	
Note: values above given at ARI conditions	

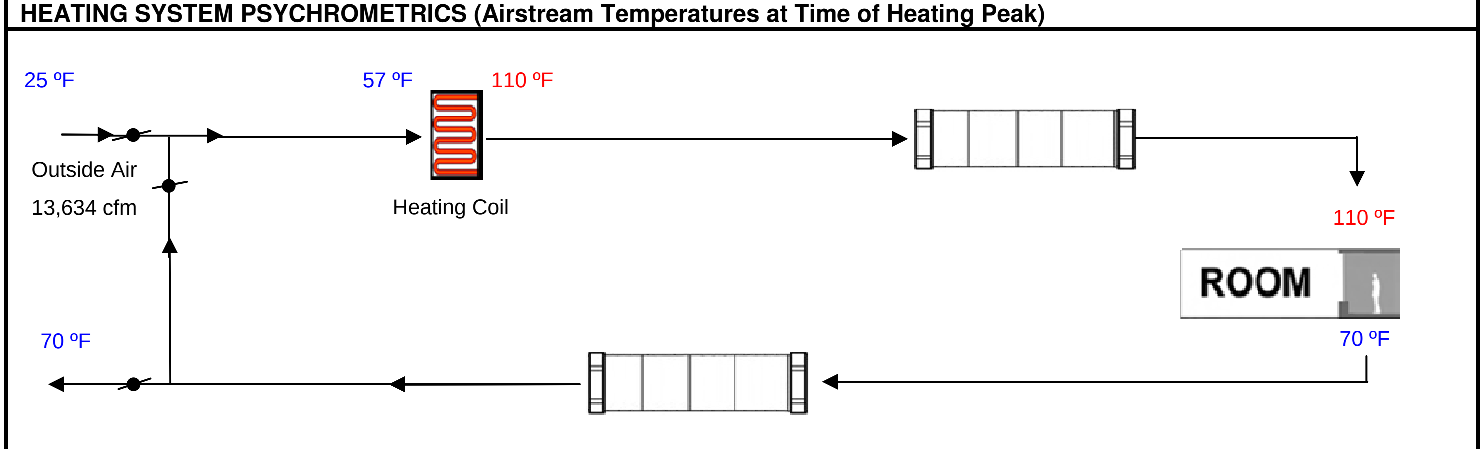
SYSTEM LOAD

	COIL COOLING PEAK			COIL HTG. PEAK	
	CFM	**Sensible**	**Latent**	**CFM**	**Sensible**
Total Room Loads	34,069	697,329	95,945	7,122	306,886
Return Vented Lighting		0			
Return Air Ducts		0			0
Return Fan		0			0
Ventilation	13,634	396,566	81,714	13,634	660,944
Supply Fan		0			0
Supply Air Ducts		0			0
TOTAL SYSTEM LOAD		1,093,896	177,658		967,830

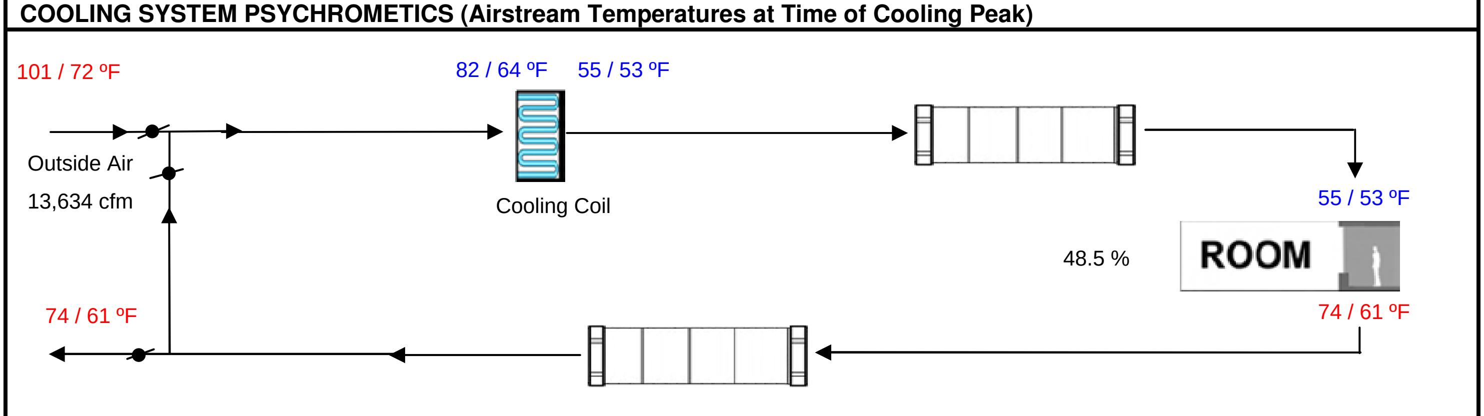
HVAC EQUIPMENT SELECTION

Total Adjusted System Output (Adjusted for Peak Design conditions)			
TIME OF SYSTEM PEAK		Jul 3 PM	Jan 1 AM

HEATING SYSTEM PSYCHROMETRICS (Airstream Temperatures at Time of Heating Peak)



COOLING SYSTEM PSYCHROMETICS (Airstream Temperatures at Time of Cooling Peak)



ROOM HEATING PEAK LOADS

Project Name	Date
Fibershed	*10/9/2013*

ROOM INFORMATION		DESIGN CONDITIONS	
Room Name	*Room 1*	**Time of Peak**	*Jan 1 AM*
Floor Area	*90,895.0 ft²*	**Outdoor Dry Bulb Temperature**	*25 ºF*
Indoor Dry Bulb Temperature	*70 ºF*		

Conduction	Area		U-Value		ΔT °F		Btu/hr
R-19 wall	*15,008.0*	x	*0.0740*	x	*45*	=	*49,977*
Double Metal Clear	*2,000.0*	x	*0.7100*	x	*45*	=	*63,900*
Wood Door	*240.0*	x	*0.5000*	x	*45*	=	*5,400*
R-30 Roof Rafter	*90,895.0*	x	*0.0360*	x	*45*	=	*147,250*
Slab-On-Grade	*perim = 1,212.0*	x	*0.7400*	x	*45*	=	*40,360*

Items shown with an asterisk (*) denote conduction through an interior surface to another room **Page Total** *306,886*

Infiltration: [*1.00* (Schedule Fraction) x *1.077* (Air Sensible) x *90,895* (Area) x *14.00* (Ceiling Height) x *0.000* (ACH) / 60] x *45* (ΔT) = *0*

TOTAL HOURLY HEAT LOSS FOR ROOM *306,886*

ROOM COOLING PEAK LOADS

Project Name	Date
Fibershed	*10/9/2013*

ROOM INFORMATION		DESIGN CONDITIONS	
Room Name	*Room 1*	**Time of Peak**	*Jul 3 PM*
Floor Area	*90,895.0 ft²*	**Outdoor Dry Bulb Temperature**	*101 ºF*
Indoor Dry Bulb Temperature	*74 ºF*	**Outdoor Wet Bulb Temperature**	*72 ºF*

Conduction	Area		U-Value		DETD[1]		Btu/hr
R-19 wall	*4,594.0*	X	*0.0740*	X	*31.5*	=	*10,692*
Double Metal Clear	*1,200.0*	X	*0.7100*	X	*17.2*	=	*14,664*
R-19 wall	*2,910.0*	X	*0.0740*	X	*43.9*	=	*9,448*
Double Metal Clear	*800.0*	X	*0.7100*	X	*17.2*	=	*9,776*
Wood Door	*120.0*	X	*0.5000*	X	*53.1*	=	*3,188*
R-19 wall	*4,594.0*	X	*0.0740*	X	*25.8*	=	*8,763*
R-19 wall	*2,910.0*	X	*0.0740*	X	*28.3*	=	*6,084*
Wood Door	*120.0*	X	*0.5000*	X	*30.0*	=	*1,799*
R-30 Roof Rafter	*90,895.0*	X	*0.0360*	X	*60.4*	=	*197,480*
					Page Total		*261,892*

1. Design Equivalent Temperature Difference (DETD)
Items shown with an asterisk (*) denote conduction through an interior surface to another room.

Solar Gain	Orientation	Area		SGF		SC		Weighting Factor		Btu/hr
Window	*(S)*	*600.0*	X	*69*	X	*0.813*	X	*0.888*	=	*29,693*
Window	*(W)*	*400.0*	X	*227*	X	*0.813*	X	*0.386*	=	*28,480*
Window	*(N)*	*600.0*	X	*43*	X	*0.813*	X	*0.797*	=	*16,684*
Window	*(E)*	*400.0*	X	*43*	X	*0.813*	X	*1.870*	=	*26,099*
			X		X		X		=	
			X		X		X		=	
			X		X		X		=	
			X		X		X		=	
			X		X		X		=	
								Page Total		*100,955*

Internal Gain	Sched. Frac.		Area		Heat Gain						Weighting Factor		Btu/hr
Lights	*1.00*	X	*90,895*	X	*0.900*	Watts/Sqft	X	*3.413*	Btu/Watt	X	*0.999*	=	*278,935*
Occupants	*1.00*	X	*90,895*	X	*275*	Btu/occ.	/	*450*	Sqft/occ.	X	*1.000*	=	*55,547*
Receptacle	*1.00*	X	*90,895*	X	*0.000*	Watts/Sqft	X	*3.413*	Btu/Watt	X	*1.000*	=	*0*
Process	*1.00*	X	*90,895*	X	*0.000*	Watts/Sqft	X	*3.413*	Btu/Watt	X	*1.000*	=	*0*
Process Lighting	*1.00*	X	*90,895*	X	*0.000*	Watts/Sqft	X	*3.413*	Btu/Watt	X	*0.000*	=	*0*

	Schedule Fraction		Air Sensible		Area		Ceiling Height		ACH			ΔT		
Infiltration:[	*1.00*	X	*1.077*	X	*90,895*	X	*14.00*	X	*0.00*	/ 60]	X	*27*	=	*0*

TOTAL HOURLY SENSIBLE HEAT GAIN FOR ROOM *697,329*

Latent Gain	Sched. Frac.		Area		Heat Gain						Btu/hr
Occupants	*1.00*	X	*90,895*	X	*475*	Btuh/occ.	/	*450*	Sqft/occ.	=	*95,945*
Receptacle	*1.00*	X	*90,895*	X	*0.000*	Watts/Sqft	X	*3.413*	Btu/Watt	=	*0*
Process	*1.00*	X	*90,895*	X	*0.000*	Watts/Sqft	X	*3.413*	Btu/Watt	=	*0*

	Schedule Fraction		Air Sensible		Area		Ceiling Height		ACH			ΔW		
Infiltration:[	*1.00*	X	*4,830*	X	*90,895*	X	*14.00*	X	*0.00*	/60]	X	*0.00000*	=	*0*

TOTAL HOURLY LATENT HEAT GAIN FOR ROOM *95,945*

270 ton chiller and tower information

MULTISTACK

Job Name	Wool Facility Flooded	Job Number	~~OPTION # 1~~
Location	Test	Quote Number	QLBRIMER10072013-1
Engineer	Meline	Representative	Logan Brimer
Contractor		Rep Office	Sacramento

Performance Data

Chiller Model Number	Frame Type	Rated Capacity
MS0292FC1M2W2H1CC88FM-R134A	Frame 1 2 TT-400	270.0

PERFORMANCE DATA										
				Evaporator			Condenser			
Load	Capacity	kW	kW/ton	Flow Rate (GPM)	Entering °F	ΔP (PSI)	Flow Rate (GPM)	Entering °F	Leaving °F	ΔP (PSI)
100%	270.0	156.3	0.579	648	54.0	6.5	757	85.0	95.0	5.8
90%	243.0	122.4	0.504	648	53.0	6.5	757	81.0	89.8	5.8
80%	216.0	95.0	0.440	648	52.0	6.5	757	77.0	84.7	5.8
75%	202.5	83.3	0.411	648	51.5	6.5	757	75.0	82.2	5.8
70%	189.0	72.7	0.384	648	51.0	6.5	757	73.0	79.6	5.8
60%	162.0	53.9	0.333	648	50.0	6.5	757	69.0	74.6	5.8
50%	135.0	38.3	0.284	648	49.0	6.5	757	65.0	69.6	5.8
40%	108.0	30.4	0.281	648	48.0	6.5	757	65.0	68.7	5.8
30%	81.0	21.5	0.265	648	47.0	6.5	757	65.0	67.8	5.8
25%	67.5	17.6	0.260	648	46.5	6.5	757	65.0	67.3	5.8
20%	54.0	14.3	0.264	648	46.0	6.5	757	65.0	66.8	5.8
10%										

With Tower Relief (per AHRI 550/590) | NPLV | 0.324

EVAPORATOR DESIGN DATA	(Based on Water)
Entering Temperature	54
Leaving Temperature	44
Design Flow	648
Design Pressure Drop	6.450 PSI / 14.900 ft
Minimum Flow	225
Minimum Pressure Drop	0.740 PSI / 1.709 ft
Number of Passes	2
Tube Type	3/4 diameter 0.025" Copper Enhanced
Fouling Factor	0.0001
Connection Size	8"
Connection Type	Grooved Coupling
Head Style	Dish
Head Mounting	Inlet: Right Outlet: Right

CONDENSER DESIGN DATA	(Based on Water)
Entering Temperature	85
Leaving Temperature	95
Design Flow	757
Design Pressure Drop	5.840 PSI / 13.490 ft
Minimum Flow	275
Minimum Pressure Drop	0.860 PSI / 1.987 ft
Number of Passes	2
Tube Type	3/4 diameter 0.025" Copper Enhanced
Fouling Factor	0.00025
Connection Size	8"
Connection Type	Grooved Coupling
Head Style	Dish
Head Mounting	Inlet: Right Outlet: Right

PHYSICAL DATA	
* Length (Shell Only)	120"
Width	37.25"
Height	78"
Estimated Shipping Weight	9040 lbs
Estimated Operating Weight	9840 lbs
Refrigerant Type	R-134A
Refrigerant Charge	608 lbs
Shell Configuration	Stacked

* See Head drawing for additional length for the heads

ELECTRICAL DATA	
Voltage	460-60-3
Power Input	156.27
Compressor(s) RLA	110.5
MCA	249
MOP	350

Version #: 1.0.4435.38010

Certified in accordance with the AHRI Water-Cooled Water Chilling Packages Using Vapor Compression Cycle Certification Program, which is based on AHRI Standard 550/590 (I-P). Certified units may be found in the AHRI Directory at www.ahridirectory.org

AHRI CERTIFIED

270 ton chiller and tower information

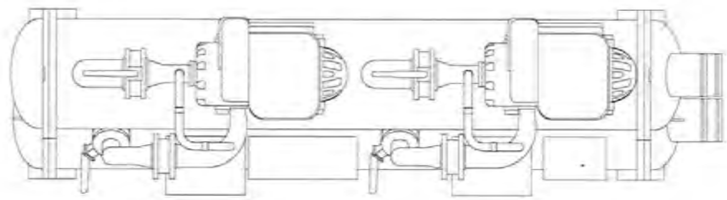
REISSUE	A
DATE 2/9/13	REVISION: UPDATED CHILLER WEIGHTS	BY: M.G.

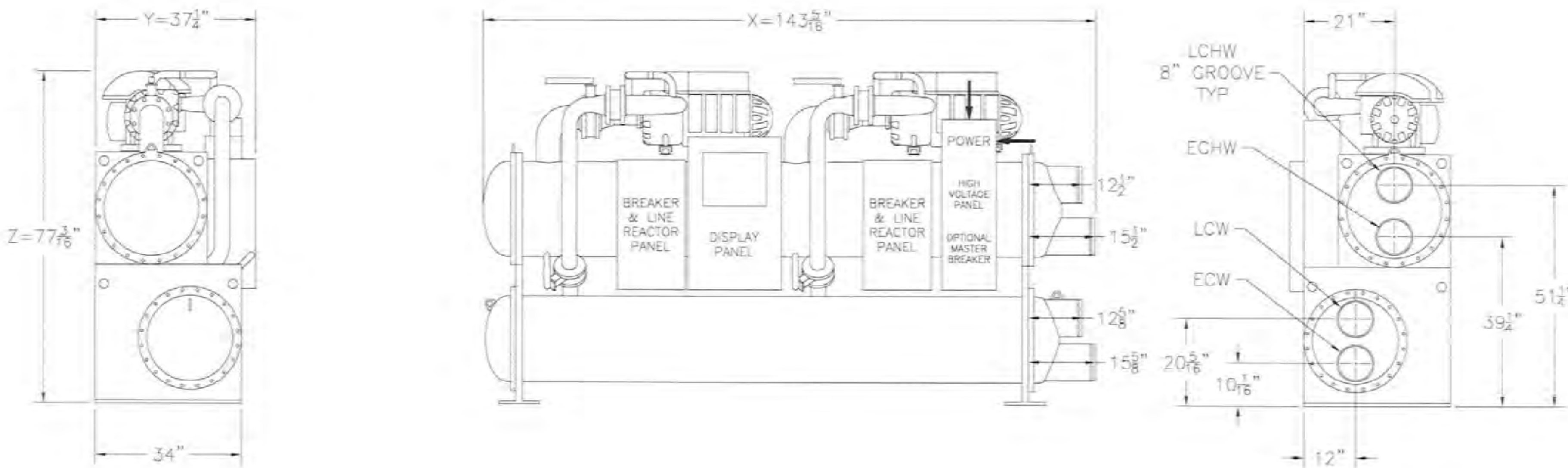
MULTISTACK
Sparta, Wisconsin 54656

LAYOUT
MS292FL
RH 2-PASS EVAP DOME HEAD
RH 2-PASS COND DOME HEAD

DRAWN BY: BJH DATE: 01.28.13
SCALE: NONE

WEIGHTS (LBS)		
EMPTY	SHIPPING	OPERATING
8440	9040	9840





THE CONTENT OF THIS DOCUMENT IS CONFIDENTIAL AND INTENDED SOLEY FOR THE GIFTED RECIPIENTS.
LAYOUT DRAWINGS ARE FOR REFERENCE ONLY. DIMENSIONS AND WEIGHTS ARE SUBJECT TO CHANGE UPON FINAL DESIGN.

D LAYOUT

270 ton chiller and tower information

Baltimore Aircoil Company, Inc.

Cooling Tower Selection Program

Version:	8.1.2 NA
Product data correct as of:	September 10, 2013

Project Name:	Wool Plant
Selection Name:	270 Ton Towe
Project State/Province:	
Project Country:	United States
Date:	October 07, 2013

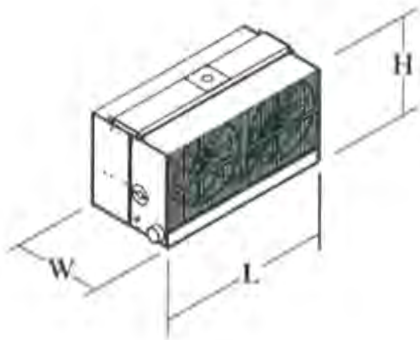
Model Information

Product Line:	FXT
Model:	FXT-216-JM
Number of Units:	1
Fan Type:	Standard Fan
Fan Motor:	Full Speed, 7.50 BHP
Total Standard Fan Power:	(1) 7.50 = 7.50 HP/Unit
Intake Option:	None
Internal Option:	None
Discharge Option:	None

Design Conditions

Flow Rate:	810.00 USGPM
Hot Water Temp.:	95.00 °F
Cold Water Temp.:	85.00 °F
Wet Bulb Temp.:	72.00 °F
Tower Pumping Head:	4.76 psi
Reserve Capability:	3.47%

Thermal performance at design conditions and standard total fan motor power is certified by the Cooling Technology Institute (CTI).



Engineering Data, per Unit

Unit Length:	12' 0.13"
Unit Width:	7' 3.38"
Unit Height:	11'
Air Flow:	51,469 CFM
Approximate Shipping Weight:	3,545 pounds
Heaviest Section:	3,545 pounds
Approximate Operating Weight:	9,405 pounds

Minimum Distance Required

From Solid Wall:	4.5 ft.
From 50% Open Wall:	3 ft.

Energy Rating:

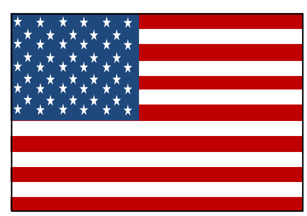
96.27 per ASHRAE 90.1, ASHRAE 189 and CA Title 24.

Note: These unit dimensions do not account for any options/accessories. Please contact your local BAC sales representative for dimensions of units with options/accessories.

FAFCO SOLAR WATER HEATING

Who we are

- **The oldest and largest solar water heating manufacturer in the U.S.**
- **We specialize in manufacturing polymer heat exchangers that cost effectively transfer diffuse energy to a load.**
- **We pioneered the use of polymer materials for solar pool heating.**
- ***Replaced expensive, difficult to install copper technology with inexpensive , customer friendly polymers.***
- **Nearly 2,000,000 panels generating over 3GW of power have been installed worldwide.**
- ***More than 200,000 satisfied customers.***



PROUDLY MANUFACTURING IN CALIFORNIA

Celebrating 43 Years 1969- 2013

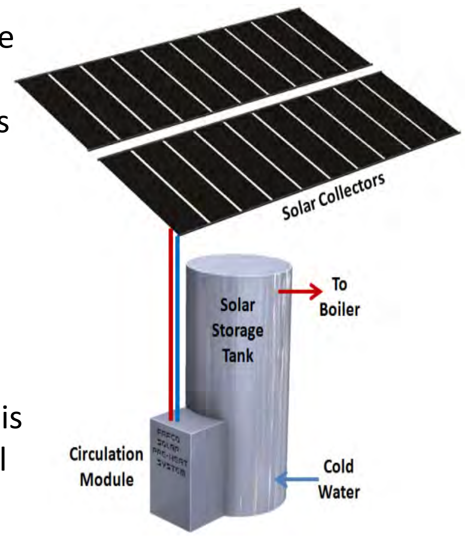
FAFCO SOLAR WATER HEATING

Solar Pre-heat Overview

FAFCO's industry-changing polymer solar thermal system is low cost and saves a significant amount of the energy typically required to heat water. It's one of the only solar systems that can have a payback less than 5 years. Our systems do the "heavy lifting" of handling water at ground temperature and increasing its temperature to 80, 90, or 100 degrees or more depending on the system and application.

Advantages

FAFCO's solar pre-heat system can be installed at a fraction of the cost of other types of systems due to the light weight (1 lb/sqft) solar collectors and pre-assembled system components. FAFCO's high performance unglazed polymer solar collectors rival the performance at pre-heating temperatures of glazed and evacuated tube collectors, but have the advantage that they cannot overheat. The piping and fittings are made of the same weather resistant polymer that enables FAFCO's solar collectors to last more than 30 years in the sun, proven by FAFCO systems installed in the 1970's that are still operating today! The system is fully automated with FAFCO's innovative computer based control and data logging system.



Comparison

	FAFCO	Glazed
Daily hot water consumption (gallons)	3,600	
Collector area (sqft)	1000	
Tank size (gallons)	1000	
Annual therms of natural gas offset	3000	4000
Installed price per sqft of collector	**$75**	**$150**
Initial system price	$75,000	$150,000
CSI Rebate	$43,560	$58,080
Federal ITC	$22,500	$45,000
System price after incentives	$8,940	$46,920
Price/therm of natural gas	$0.80	
Annual savings (w/o energy escalation)	$2,400	$3,200
Simple pay back	**4**	**15**

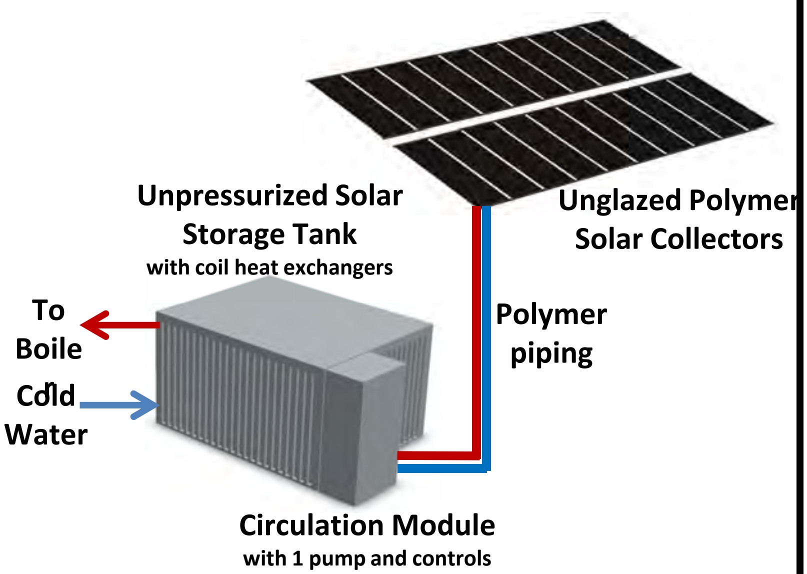
FAFCO®
SOLAR WATER HEATING

System Options

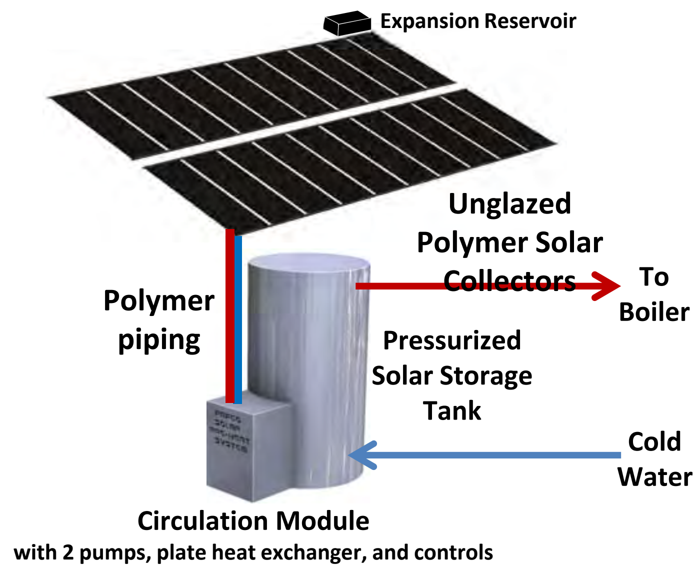
Universal Features

- Cost effective, high performing
- Lightweight (< 1 lb/sqft)
- Polymer piping, fittings, & components
- Cannot overheat and Freeze proof
- Designed with FAFCO's 40yr/2M collectors
- Simple installation
- 30+ year life
- Indirect system designs

Drainback



Anti-freeze



Advantages

Drainback

- Higher state rebate
- Uses water rather than antifreeze
- Collectors connect without equipment
- Less components and joints
- Uses FAFCO's IceStor tank design

Anti-freeze

- Collectors can mount flat on roof
- Piping does not need to be sloped
- Uses lower head pumps
- Uses a small efficient heat exchanger
- Smaller and taller tank

Considerations

Drainback

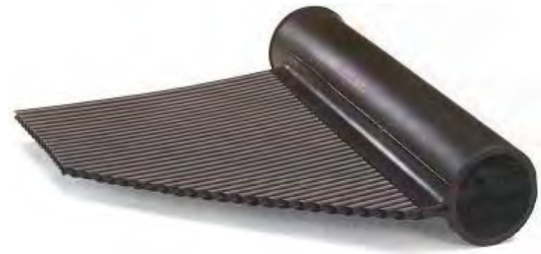
- Larger tank required
- Solar loop must gravity drain to tank
  - Collectors mounted at min 10 degrees (2/12)
  - Piping sloped ¼" per foot
- High head pump required
- Solar loop water quality must be maintained

Anti-freeze

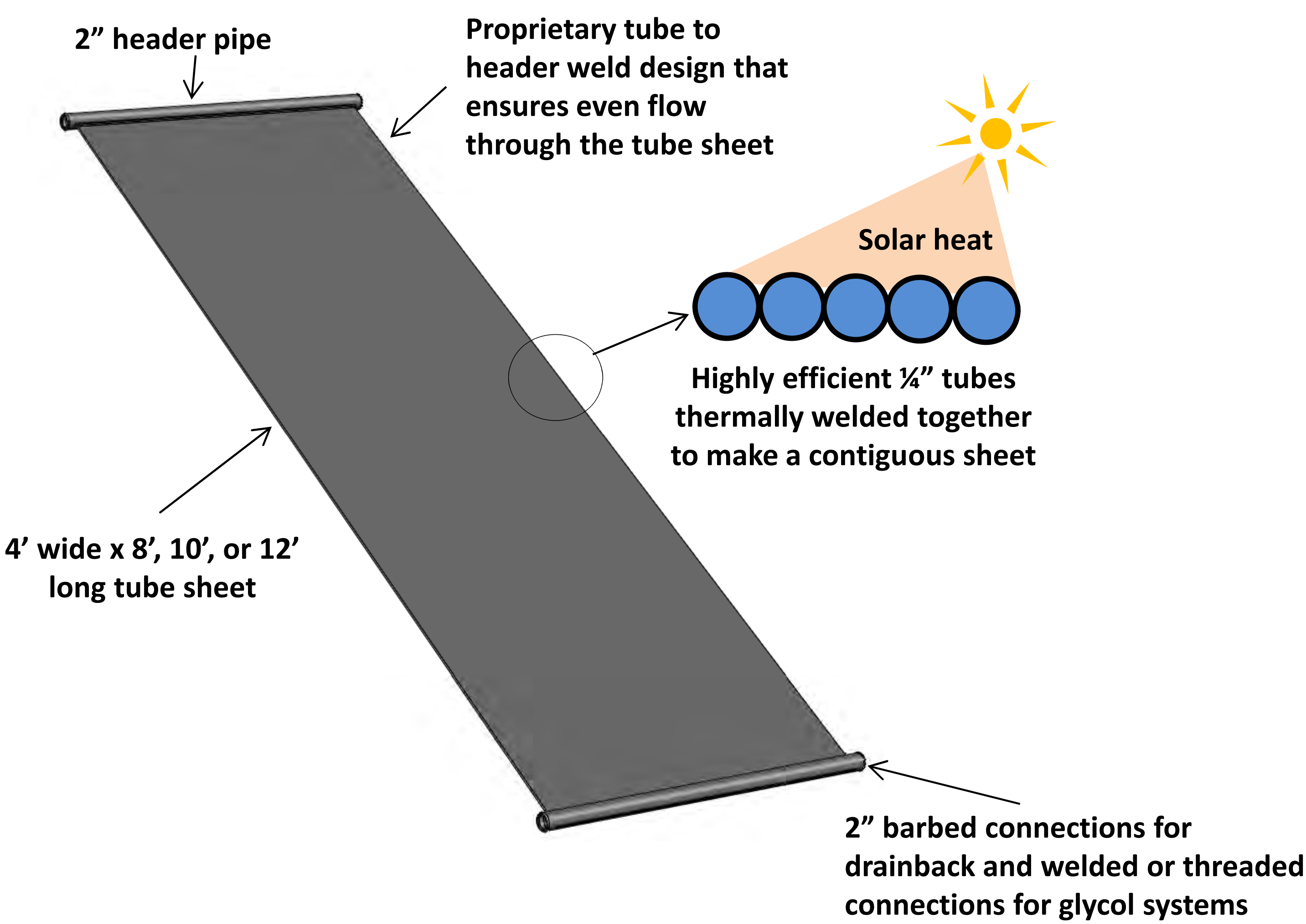
- More components and joints
- Collectors fusion welded together
- Anti-freeze must be maintained
-

Solar Collector

Features



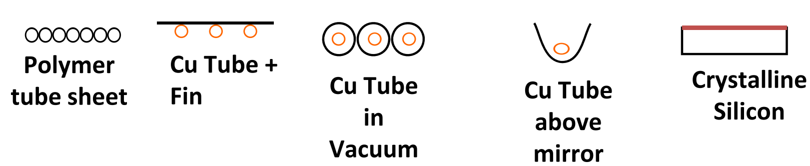
- Highest performing certified unglazed collector
- Commercial grade
- Based on FAFCO's 40yr/2M collector design
- Collectors in the field still operating after 30 years
- Custom polymer formulation modeled after 50 year overhead cable sheathing
- Innovative even flow to thousands of efficient small diameter tubes
- A variety of sizes available



Solar Technology Comparison

Solar technologies are becoming more and more cost effective, but many are focusing higher performance without reducing cost. The goal of energy saving technologies is to provide the most cost effective solution taking into account performance, installation cost, and fuel savings. The following example illustrates a comparison of various solar technologies:

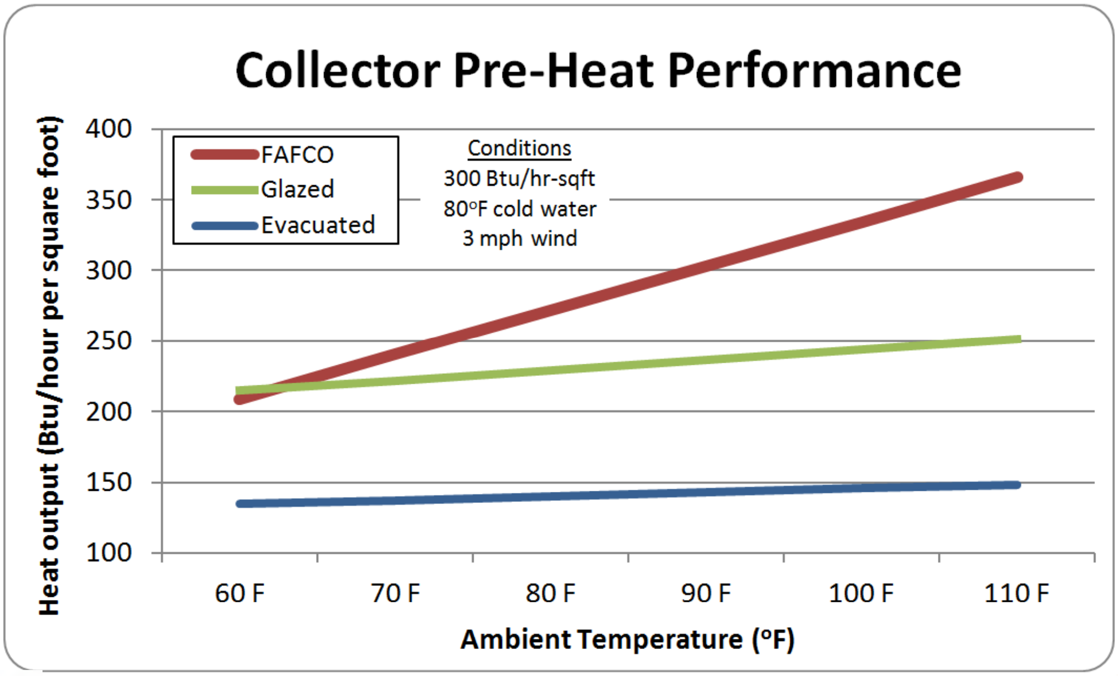
		FAFCO	Glazed (SS)	Evacuated Tube	Parabolic Trough	PV
Annual Therms of Natural Gas Saved		8000	12000	9000	14000	2500
Investment	Upfront	100000	200000	250000	300000	300000
	After 30% Tax Credit	70000	140000	175000	210000	210000
	After Pending State Rebate	16000	86000	105880	156000	140880
Life Cycle Savings	w/o energy escalation	$138,000	$172,000	$59,000	$154,000	-$75,880
	w/ energy escalation	$222,000	$298,000	$153,500	$301,000	-$49,630
	w/ ee & discount rate (aka NPV)	$391,080	$174,878	-$692,327	-$344,966	-$1,277,771
Simple Payback	Upfront	9.6	12.8	21.4	16.5	92.3
	After 30% Tax Credit	6.7	9.0	15.0	11.5	64.6
	After Pending State Rebate	1.5	5.5	9.0	8.6	43.3
ROI (based on price w/o state rebate)		17%	13%	6%	9%	-4%
Price per Therm		$ 0.44	$ 0.58	$ 0.97	$ 0.75	$ 4.20



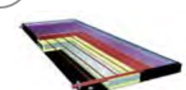
FAFCO®
SOLAR WATER HEATING

ST Technology Comparison

Performance



Functionality


Courtesy of SunEarth

Unglazed		Glass/Metal
Yes	Collectors are lightweight	No
Yes	Collectors are flexible	No
Yes	Collectors are highly durable	No
Yes	Lifetime corrosion resistance	No
Yes	No severe scalding potential due to temperatures above 150F	No
Yes	No product failure issues due to overheating	No
Yes	No Scale accumulation in collectors or heat exchanger due to high fluid temperature	No
Yes	Certified by SRCC for all PEX tube plumbing	No
Yes	Easy to repair or remove solar collectors	No
100%	Transmittance of solar energy	Less than 90%
Greater than 85%	Optical Efficiency	Less than 60%
Yes	Capable of excellent performance	Yes

Hot water assessment

To determine the exact State rebate amount, the CSI thermal program requires a metered hot water assessment on any projects, excluding new construction, that do not fit into their list of standard applications:
(apartments, dorms, hotels, retirement homes, office buildings, restaurants, schools, and coin-op laundries)

The CSI thermal program requires a hot water assessment submitted by a licensed P.E. . FAFCO can provide this service.

Options for metering are as follows:

1 ***Hot tap style meter with data logger***

2 ***Saddle fitting style meter with data logger***

3 ***Gas meter with data logger***

4 ***Ultrasonic (only if other options are not feasible)***

200 ton chiller + Heat Recovery Option: Equipment Specs

MULTISTACK

Job Name	200 Ton Flooded	Job Number	Option #2
Location	Test	Quote Number	QLBRIMER10072013-3
Engineer		Representative	Logan Brimer
Contractor		Rep Office	Sacramento

Performance Data

Chiller Model Number	Frame Type	Rated Capacity
MS0192FC1M2W2H1CC88FK-R134A	Frame 1 1 TT-500	193.0

PERFORMANCE DATA

				Evaporator			Condenser			
Load	Capacity	kW	kW/ton	Flow Rate (GPM)	Entering °F	ΔP (PSI)	Flow Rate (GPM)	Entering °F	Leaving °F	ΔP (PSI)
100%	193.0	114.0	0.590	463	54.0	7.5	543	85.0	95.0	7.3
90%	173.7	89.9	0.518	463	53.0	7.5	543	81.0	89.8	7.3
80%	154.4	69.6	0.451	463	52.0	7.5	543	77.0	84.7	7.3
75%	144.8	60.6	0.419	463	51.5	7.5	543	75.0	82.2	7.3
70%	135.1	52.5	0.389	463	51.0	7.5	543	73.0	79.6	7.3
60%	115.8	38.7	0.334	463	50.0	7.5	543	69.0	74.6	7.3
50%	96.5	26.7	0.276	463	49.0	7.5	543	65.0	69.6	7.3
40%	77.2	21.7	0.281	463	48.0	7.5	543	65.0	68.7	7.3
30%	57.9	17.5	0.302	463	47.0	7.5	543	65.0	67.8	7.3
25%	48.3	15.5	0.321	463	46.5	7.5	543	65.0	67.3	7.3
20%	38.6	13.4	0.348	463	46.0	7.5	543	65.0	66.9	7.3
10%										

With Tower Relief (per AHRI 550/590) NPLV 0.331

EVAPORATOR DESIGN DATA	(Based on Water)
Entering Temperature	54
Leaving Temperature	44
Design Flow	464
Design Pressure Drop	7.520 PSI / 17.371 ft
Minimum Flow	160
Minimum Pressure Drop	0.790 PSI / 1.825 ft
Number of Passes	2
Tube Type	3/4 diameter 0.025" Copper Enhanced
Fouling Factor	0.0001
Connection Size	5"
Connection Type	Grooved Coupling
Head Style	Dish
Head Mounting	Inlet: Right Outlet: Right

CONDENSER DESIGN DATA	(Based on Water)
Entering Temperature	85
Leaving Temperature	95
Design Flow	543
Design Pressure Drop	7.290 PSI / 16.840 ft
Minimum Flow	170
Minimum Pressure Drop	0.750 PSI / 1.733 ft
Number of Passes	2
Tube Type	3/4 diameter 0.025" Copper Enhanced
Fouling Factor	0.00025
Connection Size	6"
Connection Type	Grooved Coupling
Head Style	Dish
Head Mounting	Inlet: Right Outlet: Right

PHYSICAL DATA	
* Length (Shell Only)	120"
Width	34"
Height	78"
Estimated Shipping Weight	6640 lbs
Estimated Operating Weight	7150 lbs
Refrigerant Type	R-134A
Refrigerant Charge	401 lbs
Shell Configuration	Stacked

* See Head drawing for additional length for the heads

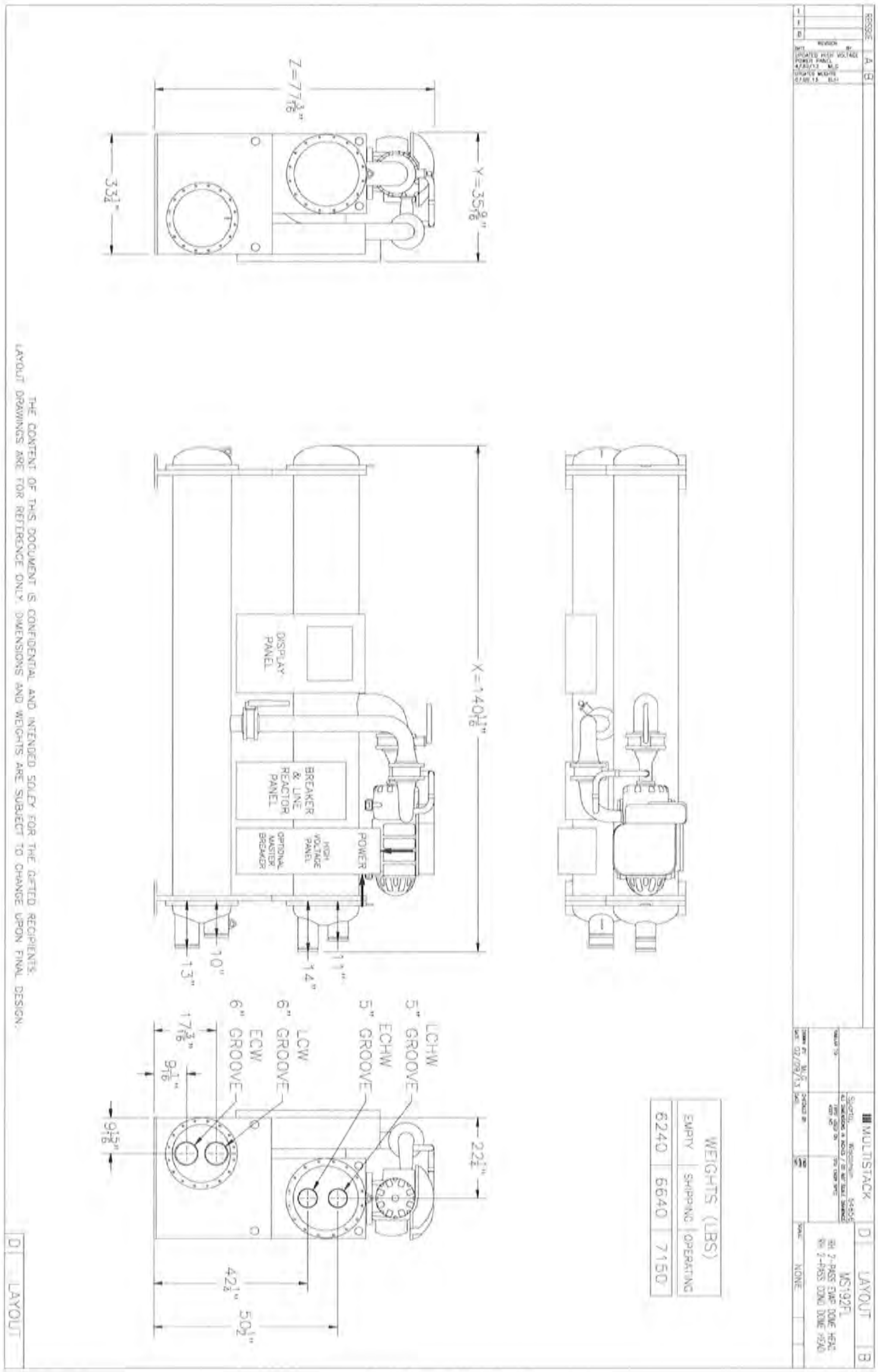
ELECTRICAL DATA	
Voltage	460-60-3
Power Input	113.96
Compressor(s) RLA	159.6
MCA	200
MOP	250

Version #: 1.0.4435.38010

Certified in accordance with the AHRI Water-Cooled Water Chilling Packages Using Vapor Compression Cycle Certification Program, which is based on AHRI Standard 550/590 (I-P). Certified units may be found in the AHRI Directory at www.ahridirectory.org

AHRI CERTIFIED

200 ton chiller + Heat Recovery Option: Equipment Specs



200 ton chiller + Heat Recovery Option: Equipment Specs

Baltimore Aircoil Company, Inc.

Cooling Tower Selection Program

Version:	8.1.2 NA
Product data correct as of:	September 10, 2013
Project Name:	Wool Plant
Selection Name:	200 Ton Tower
Project State/Province:	
Project Country:	United States
Date:	October 07, 2013

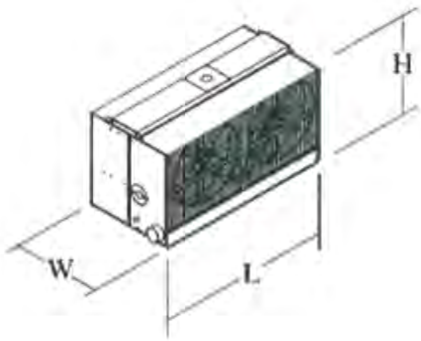
Model Information

Product Line:	FXT
Model:	FXT-160-HM
Number of Units:	1
Fan Type:	Standard Fan
Fan Motor:	Full Speed, 5.00 BHP
Total Standard Fan Power:	(1) 5.00 = 5.00 HP/Unit
Intake Option:	None
Internal Option:	None
Discharge Option:	None

Design Conditions

Flow Rate:	600.00 USGPM
Hot Water Temp.:	95.00 °F
Cold Water Temp.:	85.00 °F
Wet Bulb Temp.:	72.00 °F
Tower Pumping Head:	3.61 psi
Reserve Capability:	0.55%

Thermal performance at design conditions and standard total fan motor power is certified by the Cooling Technology Institute (CTI).



Engineering Data, per Unit

Unit Length:	12' 0.13"	
Unit Width:	7' 3.38"	
Unit Height:	8' 4.00"	
Air Flow:	41,402	CFM
Approximate Shipping Weight:	2,850	pounds
Heaviest Section:	2,850	pounds
Approximate Operating Weight:	8,000	pounds

Minimum Distance Required

From Solid Wall:	4.2 ft.
From 50% Open Wall:	3 ft.

Energy Rating:

103.40 per ASHRAE 90.1, ASHRAE 189 and CA Title 24

Note: These unit dimensions do not account for any options/accessories. Please contact your local BAC sales representative for dimensions of units with options/accessories.

200 ton chiller + Heat Recovery Option: Equipment Specs

MULTISTACK

Job Name	Test	Job Number	
Location	Test	Quote Number	QLBRIMER10072013-2
Engineer		Representative	Logan Brimer
Contractor		Rep Office	Sacramento

Mechanical Modules: (1) MS070XC1H1H2AAC-410A
Accessory Modules:

PERFORMANCE DATA												
							EVAPORATOR			CONDENSER		
Load	Capacity (Tons)	kW	THR (mbh)	kW/ton	EER	COP	Flow Rate (GPM)	Leaving °F	ΔP (ft)	Flow Rate (GPM)	Leaving °F	ΔP (ft)
100%	67.4	49.9	978.8	0.741	16.2	4.7	162	44.0	16.0	66	95	2.1
75%	51.3	37.4	742.6	0.729	16.5	4.8	162	44.0	16.0	66	95	2.1
50%	33.7	25.1	490.0	0.746	16.1	4.7	162	44.0	16.0	66	95	2.1
25%	17.3	13.2	252.3	0.767	15.6	4.6	162	44.0	16.0	66	95	2.1

Cooling COP	Heating COP	Heating and Cooling COP
4.7	5.8	10.5

No Tower Relief

NPLV	N/A

EVAPORATOR DESIGN DATA	(Based on Water)
Entering Temperature	54
Leaving Temperature	44
Design Flow (GPM)	162
Pressure Drop (Full Load)	6.91 PSI / 15.97 ft
Minimum Flow	162
System Min Flow For Bypass Sizing	162
Heat Exchanger Type	Brazed Plate
Fouling Factor	.0001
Header Size	6"
Header Connection Type	Grooved Coupling

CONDENSER DESIGN DATA	(Based on Water)
Entering Temperature	65
Leaving Temperature	95
Design Flow (GPM)	66
Pressure Drop (Full Load)	0.90 PSI / 2.08 ft
Minimum Flow	66
System Min Flow For Bypass Sizing	66
Heat Exchanger Type	Brazed Plate
Fouling Factor	.00025
Header Size	6"
Header Connection Type	Grooved Coupling

PHYSICAL DATA	Section 1	Section 2
Length (in.)	29.5	
Width (in.)	49.125	
Height (in.)	64	
Estimated Dry weight (lbs)	1900	
Estimated Operating weight (lbs)	2200	
Refrigerant Type	R-410A	
Refrigerant Charge (lbs per circuit)	24	

Dimensions are estimated and do not include J-Boxes

ELECTRICAL DATA (Direct Connect-Per Module)	MCA	MOP		
(1) MS070X	135	200		
Voltage	460/60/3			

CHILLER DATA	
Compressor Description	Scroll
Options	No Tower Relief
Compressor RLA	60

MOUNTING/LIFTING FRAME	
Materials	Option Not Selected
I-Beam Size	Option Not Selected
Bolt together frame - # of pieces	Option Not Selected
End Type	Option Not Selected

*Parallel feeds not required (Assumes no larger than 300 MCM/kcmil wire)

Version #: 1.0.4435.27651

Heat Reclaim unit operating with heat reclaim off and certified in accordance with the AHRI Water-Cooled Water Chilling Packages Using Vapor Compression Cycle Certification Program, which is based on AHRI Standard 550/590 (I-P). Certified units may be found in the AHRI Directory at www.ahridirectory.org

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200 ton chiller + Heat Recovery Option: Equipment Specs

note: only one of the modules below would be required