Hydronics and Geothermal, Best Practices/Design

Jim Cusack

Went through first IGSHPA training in 2000
Worked as a geo contractor for 16 years
12 years as general manager and system designer
Been with Enertech since January 2015
Have been training contractors in GSHP’s for over 15 years
Not what we are looking for
A little cleaner and more serviceable system
What have the problems been?

- Design water temp won’t heat space.
  - Insulation generally is the culprit

- Heat pump is locking out on HP.
  - Waterflow, Waterflow, Waterflow!
  - To much load side antifreeze?
  - Controls, Controls, Controls!

- High bill complaints.
  - Low loop temps, could be a multitude of reasons!
  - Running system at max 105F temps all season.
  - Bad insulation of slab
  - Design of the system must meet the expectations of the customer, and it is your job to install and verify your system will do the job!
Questions to ask yourself?

• What will be my design max water temp?
• What will be my design min water temp?
• Will I have a supplemental or backup system?
  • If so, how will it be piped and controlled?
• What is the heat distribution system?
  • High mass floors - concrete
  • Low mass floors – staple up
  • Radiation – high or low temp
• Am I doing chilled water for cooling?
• Do I have areas that need antifreeze?
• Who is doing the insulation? What is it?
• What type of floor coverings do I have?
Proper design starts with Loads!

• Doing an accurate load calculation is priority number 1 including radiant design!

• This will dictate your tube spacing, supply water temp and flow rates of the system.

• Knowing the building materials, insulation values, floor coverings, etc. is critical.

• Jobsite verification of building materials and insulation practices (pictures, pictures)

• This all goes into a successful installation and a happy customer with low energy costs!
Tools for Starting the Layout

• Wrightsoft and Elite are just two of many organizations that offer a computer based Manual J program with radiant design suite

• LoopCAD is another very good radiant design software program
Wrightsoft Drawing of a Home

- This slide shows the home layout and size scaled in a drawing form for ease of equipment placing and designing.
- Scale is adjustable with in this software.
A Report Generated by Wright J

Over 30 reports for you or the homeowner

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### Project Information

For: Robert Brown

### Design Information

<table>
<thead>
<tr>
<th>Cuttable (**)</th>
<th>Hlg</th>
<th>Cig</th>
<th>Method</th>
<th>Infiltration</th>
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</tr>
<tr>
<td>74</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

### Infiltration

- Construction quality: Average
- Fireplace: 1 (Average)

### HEATING EQUIPMENT

<table>
<thead>
<tr>
<th>Value</th>
<th>Trade</th>
<th>Serial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Value</td>
<td>Serial</td>
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</tbody>
</table>

### COOLING EQUIPMENT

<table>
<thead>
<tr>
<th>Value</th>
<th>Trade</th>
<th>Serial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Value</td>
<td>Serial</td>
</tr>
</tbody>
</table>

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![Image of energy audit report](image_url)
Zoning Capability of software

• Once the Loads and zoning are completed, zones can be looked at for tube spacing and sizing of air handlers

• the software allows the ability to design the individual zones at different indoor design conditions

• (IE.) Garage design may be only 50 F’ instead of 72 F’ as the rest of the home
Calculating BTUH output Per Sq. Ft.

A quick overview of things to remember
Heat Loss for Specific Zone

3200 BTUH
Total Square Feet in Space

10 x 20 = 200 Sq.Ft.

3200 BTUH
Subtract Areas NOT Heated by Hydronics

3200 BTUH
10 x 20 = 200 Sq.Ft.
-50 Sq Ft. Cabinets
= 150 Sq.Ft. Heated floor
Divide the Heat Loss by the Sq. Ft.

3200 BTUH
10 x 20 = 200 Sq.Ft.
-50 Sq.Ft. Cabinets
= 150 Sq.Ft. Heated floor
3200 BTUH ÷ 150 =

21.33 BTUH Per Sq.Ft.
Insulation, Tube Spacing, Floor Coverings & R-Values
sites not well drained can conduct considerable heat away from the slab. Insulating the heated slab from unheated masses of earth will prevent heat loss.
Insulation, Insulation, & Insulation

NCFI CLOSED-CELL SPRAY POLYURETHANE FOAM UNDER ENTIRE SLAB (2 LB/CU FT MIN DENSITY)

BOND BREAK (SPF OR OTHER SUITABLE BOND BREAK/JOINT SEAL)

CONCRETE SLAB

GRAVEL LAYER (DRAINAGE PAD AND CAPILLARY BREAK)

CONCRETE FOUNDATION WALL
The bubble bursts

CMHC study compares underslab insulation materials

By Simon Blake

A new study on underslab insulation conducted by the Canadian Mortgage and Housing Corporation (CMHC) has confirmed what a lot of people in the industry know: those homes were equipped with different types of underslab insulation while another, for comparison, had no insulation.

The materials

The test used double-layer bubble-pack with an intermediate foil layer. Two other 1,200 sq. ft. floor slabs were insulated with 50 mm extruded polystyrene (XPS) and steel skinned 44 mm polyurethane panels (window cutouts from insulated doors). All four homes used in the test were located on the same block.

The deep-ground temperatures ranged from 12°C to 14°C

as an insulation material.

Perhaps the best material tested proved to be the double skinned 44 mm window cutouts, which are discarded as scrap by manufacturers of steel doors, said Fugler. “It’s a great idea and it is being used (for underslab insulation).”

This material achieved a thermal resistance (RSI) value of 2.56 (R-14.5) in the test. XPS followed at 2.13 (R-12.1) with bubble foil recording 0.40 (R-2.3). (It should be noted that the}

See 'Underslab Insulation' page 3
Studies have shown you can lose 15 to 35% of your heat capacity to uninsulated footings and foundation walls... no data on how much energy an exposed sewer pipe can rob from the floor
18 btu’s sq.ft 12” O.C. 6 loops
18 btu’s sq.ft 9” O.C. 7 loops
Critical to match up design information in the loop design software that was used in the Manual J.
110 degree ELT
<table>
<thead>
<tr>
<th>Heating</th>
<th>Cooling</th>
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<tbody>
<tr>
<td>Annual Heating Load: 89.6 MMBtu</td>
<td>Annual Cooling Load: 17.0 MMBtu</td>
</tr>
<tr>
<td>Electricity (Tetra): 9133 kWh</td>
<td>Electricity (Tetra): 830 kWh</td>
</tr>
<tr>
<td>Electricity (Auxiliary): 52 kWh</td>
<td>Average Efficiency: 20.8 EER</td>
</tr>
<tr>
<td>% by Tetra: 99.8 %</td>
<td>Annual Cost: $83</td>
</tr>
<tr>
<td>Average Efficiency: 2.86 COP</td>
<td>Hot Water: $307</td>
</tr>
<tr>
<td>Annual Cost: $919</td>
<td>Total: $1109</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hot Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual DHW Load: 19.4 MMBtu</td>
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<tr>
<td>Electricity: 3073 kWh</td>
</tr>
<tr>
<td>% by Tetra: 55.8 %</td>
</tr>
<tr>
<td>Average Efficiency: 1.85 COP</td>
</tr>
<tr>
<td>Annual Cost: $307</td>
</tr>
</tbody>
</table>

- **System 1 - Geo System**
- **Weather Data Location**: Minneapolis MN
- **Estimated Annual Operating Costs**
  - Heating: $919
  - Cooling: $83
  - Hot Water: $307
  - Total: $1109

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**2.86 COP**

**$919 Annual heating cost**

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Annual Conference, December 14-16, 2021 – Nashville, TN
95 degree ELT

Annual Conference, December 14-16, 2021 – Nashville, TN
### System 1 - Geo System

**Weather Data Location:** Minneapolis MN

#### Heating
- **Annual Heating Load:** 89.6 MMbtu
- **Electricity (Ticket):** 7325 kWh
- **Electricity (Auxiliary):** 33 kWh
- **% by Ticket:** 99.9%
- **Average Efficiency:** 3.57 COP
- **Annual Cost:** $736

#### Cooling
- **Annual Cooling Load:** 17.0 MMbtu
- **Electricity (Ticket):** 813 kWh
- **Average Efficiency:** 20.9 EER
- **Annual Cost:** $81

#### Hot Water
- **Annual DHW Load:** 19.4 MMbtu
- **Electricity:** 3067 kWh
- **% by Ticket:** 55.6%
- **Average Efficiency:** 1.94 COP
- **Annual Cost:** $309

#### Design Heating Load
- **Design Heating Load:** 54000 Btu/hr
  - **Indoor Design Temperature:** 70 °F
  - **Outdoor Design Temperature:** -12 °F
  - **Heating Electric Rate:** $0.10 /kwh
  - **Winter Peak Electrical Demand:** 7.36 kW

#### Design Cooling Load
- **Design Cooling Load:** 20000 Btu/hr
  - **Indoor Design Temperature:** 75 °F
  - **Outdoor Design Temperature:** 89 °F
  - **Cooling Electric Rate:** $0.10 /kwh
  - **Summer Peak Electric Demand:** 1.95 kW

#### TDC048 with hot water generator
- **Load Temp (Entering) Htg/Ctg:** 95/45 °F
- **Emergency Heat:** 16.02 kW
  - **Circulating Pump:** Magna 32-140
  - **Pump Watts High speed:** 133
  - **Low speed:** 114
  - **Annual Pump Operating Cost:** $32

#### Loop Type / Soil
- **One Vertical U-Tube, Polyethylene SDR-11 3/4” / Average Rock**
  - **Bore Depth:** 200 ft
  - **Total Bore / Pipe:** 844 / 1988 ft
  - **Minimum Loop Temp:** 40 °F
  - **Maximum Loop Temp:** 63 °F
  - **Average Heating Loop Temp:** 43.2 °F
  - **Average Cooling Loop Temp:** 55.8 °F

---

**Estimated Annual Operating Costs**
- **Heating:** $736
- **Cooling:** $81
- **Hot Water:** $309
- **Total:** $1126

---

**3.75 cop**

**$736 Annual heating cost**
4.17 COP
$629 annual heating cost
Design the GSHP system to utilize the lowest water temps possible for proper space heating and highest system efficiency!

Things to consider:
- Tube spacing/sizing
- Flow rates
- Insulation
- Floor coverings
Allowable Compressor Operation Temps

The illustration below shows the parameters which are safe for compressor operation. Based on the leaving load water of 120°F, the loop would have to maintain 35°F to operate within the acceptable operating conditions for the compressor. Once your loop temperatures drop below 35°F, the acceptable leaving load temperature drops below 120°F. If you are designing loops for 30°F, the recommended leaving load temperature is 110°F.
Setting Aquastat Temperature

105°F
Let’s Do it Right!

WarmBoard

Infloor Emission Plates

Insulation below Pex must be 4 times the R-Value of the surface above. Including subfloor
Floor Coverings Affect the Output

- Keeping R-values low is the ultimate goal for any designer.
- R-values work much like a glove on a hand where one may feel 105°F water in a pipe in their bare hand, however with a glove on the hand there is no heat felt while the BTU’s are present within the pipe they are not penetrating the gloves insulated properties.
Effects of Tube Spacing

Temperature Distribution Due to Wide Tube Spacing

TILED FLOOR*
AVERAGE FLOOR SURFACE TEMPERATURE 80 °F

84°
82° 82° 82° 82°
80° 78° 80° 78°
76° 76° 76° 76°

TILED FLOOR*
AVERAGE FLOOR SURFACE TEMPERATURE 80 °F

81° 81° 81° 81°
79° 79° 79° 79°
81° 81° 81° 81°

*AT APPROXIMATELY 18 BTU/H*FT) OUTPUT

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# R-Value of Floor Coverings

<table>
<thead>
<tr>
<th>R-Value</th>
<th>Flooring Coverings</th>
<th>Tuft/Emb/Sq in (inches)</th>
<th>Depth (inches)</th>
</tr>
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<tbody>
<tr>
<td>0.20</td>
<td>Bare floor</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.21</td>
<td>Linoleum or vinyl sheet goods</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.22</td>
<td>Ceramic tile</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.54</td>
<td>Hardwood</td>
<td>-</td>
<td>3/8</td>
</tr>
<tr>
<td>0.55</td>
<td>Nylon level loop</td>
<td>86</td>
<td>1/8</td>
</tr>
<tr>
<td>0.65</td>
<td>Nylon level loop</td>
<td>48</td>
<td>1/8</td>
</tr>
<tr>
<td>0.67</td>
<td>Nylon level loop</td>
<td>67</td>
<td>3/16</td>
</tr>
<tr>
<td>0.68</td>
<td>Nylon level loop</td>
<td>80</td>
<td>1/8</td>
</tr>
<tr>
<td>0.78</td>
<td>Acrylic level loop</td>
<td>80</td>
<td>3/16</td>
</tr>
<tr>
<td>0.93</td>
<td>Hardwood</td>
<td>-</td>
<td>3/4</td>
</tr>
<tr>
<td>0.95</td>
<td>Bonded polyurethane with foam</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1.03</td>
<td>Acrylic level loop with foam back</td>
<td>80</td>
<td>1/4</td>
</tr>
<tr>
<td>1.12</td>
<td>Nylon plush</td>
<td>88</td>
<td>1/4</td>
</tr>
<tr>
<td>1.33</td>
<td>Nylon high low tip sheared</td>
<td>55</td>
<td>varies</td>
</tr>
<tr>
<td>1.51</td>
<td>Nylon shag</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>1.66</td>
<td>Polyester high low tip sheared</td>
<td>54</td>
<td>varies</td>
</tr>
<tr>
<td>1.71</td>
<td>Acrylic plush</td>
<td>44</td>
<td>1/2</td>
</tr>
<tr>
<td>1.83</td>
<td>Nylon plush</td>
<td>80</td>
<td>7/8</td>
</tr>
<tr>
<td>1.90</td>
<td>Acrylic plush</td>
<td>58</td>
<td>11/16</td>
</tr>
<tr>
<td>1.96</td>
<td>Nylon Saxony</td>
<td>29</td>
<td>9/16</td>
</tr>
<tr>
<td>2.19</td>
<td>Wool plush</td>
<td>45</td>
<td>1/2</td>
</tr>
<tr>
<td>2.46</td>
<td>Nylon shag</td>
<td>22</td>
<td>1-1/4</td>
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</table>

<table>
<thead>
<tr>
<th>R-Value</th>
<th>Carpet pad underlayments</th>
<th>Depth (inches)</th>
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</thead>
<tbody>
<tr>
<td>0.31</td>
<td>Acoust-Mat</td>
<td>1/4</td>
</tr>
<tr>
<td>0.62</td>
<td>Slab rubber</td>
<td>-</td>
</tr>
<tr>
<td>0.78</td>
<td>Waffled sponge rubber</td>
<td>-</td>
</tr>
<tr>
<td>1.61</td>
<td>Prime urethane 2.2 lbs. density</td>
<td>3/8</td>
</tr>
<tr>
<td>1.71</td>
<td>Coated combined hair and jute 56 oz.</td>
<td>-</td>
</tr>
<tr>
<td>2.09</td>
<td>Bonded urethane 4 lbs. density</td>
<td>1/2</td>
</tr>
<tr>
<td>2.15</td>
<td>Prime urethane 2.2 lbs. density</td>
<td>1/2</td>
</tr>
</tbody>
</table>

Total R-Value: \(0.20 + 0.93 = 1.13\)
Leaving load temperatures And radiant output understanding R-values And tube spacing
Concrete — 4" Slab (9" on center)

65°F Room Setpoint Temperature

Floor Covering R-value ($R_v$)

- $R_v = 0$
- $R_v = 0.5$
- $R_v = 1.0$
- $R_v = 1.5$
- $R_v = 2.0$
- $R_v = 2.5$
- $R_v = 3.0$

BTU/h/ft²

Differential Temperature

10°F to 20°F

Supply Water Temperature

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Radiant Output Summary

• Water temperatures will have an affect on output capacities
• Even with a low 105 F’ water temperature 40 BTU’s per square foot of radiant heat can be realized offering competition with the fossil fuel outputs
• R- values kept low on radiant applications will allow for most economical installation and operation
Loop field information can be determined from the heat gain and heat loss. In this slide, you choose the City and State for an accurate loop field design.
Load Sheet Inputs

- Critical to match up design information in the loop design software that was used in the Manual J.
Loop Design Sheet

- GeoAnalyst will give you the bore hole needed for the chosen design conditions
- Best designs are 1 bore per ton and 1 ton capacity per bore
- GeoAnalyst can project the actual cost of operation for heating, cooling, and domestic hot water
- Remember garbage in is garbage out
Equipment Sizing

• Systems with out any auxiliary heat source will need to meet 100% by Geo for proper sizing of the system.

• Systems with auxiliary electric backup or gas backup (a gas boiler assisting a water-to-water system at water temperatures below 120°F) should have a % by Geo between 96.5 – 98.5% for efficient and economical sizing.

• Systems with auxiliary electric backup or gas backup (a gas boiler assisting a water-to-water system at water temperatures above 120°F) could have a % by Geo as low as 60%. Check gas prices for efficient and economical sizing.
Geo-Flo Website and calculator demo
Water Quality is Important!

• Water quality and flushing system is of utmost importance for pump life and system life.
• Some antifreeze companies require deionized or distilled water only! Anyone?
• Dissimilar metals is also a problem which causes corrosion!
Why is a Buffer Tank Needed? 
&
What Size is Required?
Load-side “Guidelines”

- **ALL** heat pump hydronic systems require a buffer tank (well almost ALL).
  - “Decouples” floor pumping and unit flow requirements and prevents short cycling.
  - Usually 1 gallon per 1,000 Btuh

- In most cases, controls are the most difficult part of the installation.
  - Know what you’re getting into!

- Design systems for max. water temps of 115F or less for compressor life and efficiency!
Buffer Tank Sizing

• The capacity of the heat pump can vary based on application

• The first stage capacity can be used for sizing the buffer tank
  • Single Stage (Full Capacity)
  • Two Stage (67% of Full Capacity)
  • Multiple Units (Largest Capacity Stage)

• Buffer tank and storage tank are different
  • Buffer tank setup only energizes the unit when a zone calls
  • Storage tank setup energizes to always maintain tank
Buffer Tank Sizing

• The capacity of the heat pump and depending on the control strategy and smallest zone will determine the amount of storage needed.

• Hot tank (storage tank) – single set point
  • Usually 10 gallons/ton or 1gal/1000btu’s

• On-Demand control – single set point
  • Usually 6 gallons/ton or 1gal/1500btu’s

• Combo units buffer should be smaller!

• Example = 5-ton (52MBH + hot tank)
  • 5-tons x 10gal/ton = 50gal or 52,000btu/1000= 52gal
### Buffer Tank Sizing Calculator

**Buffer Tank Sizing for heating only (no cooling):**

- **Min. heat pump run time (typically 8 minutes):**
  - 5.0 minutes
- **Heat pump minimum capacity at the lowest stage:**
  - 87.000 Btu/hr
- **Heat pump maximum capacity at the lowest stage:**
  - 150.000 Btu/hr
- **NPSH available:**
  - 0.00 gpm
- **NPSH head:**
  - 0.75 gpm
- **Sump**
  - Use Buffer tank sump for CSTR sizing
- **Minimum Buffer tank size:**
  - 30.0 gallons

**Buffer Tank Sizing for heating & cooling: 36.4 U.S. gallons**

- **Min. heat pump run time (typically 8 minutes):**
  - 5.0 minutes
- **Heat pump minimum capacity at the lowest stage:**
  - 87.000 Btu/hr
- **Heat pump maximum capacity at the lowest stage:**
  - 150.000 Btu/hr
- **Sump**
  - Use Buffer tank sump for CSTR sizing
- **Minimum Buffer tank size:**
  - 36.4 U.S. gallons

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Important: This calculator is designed for the specific heating and cooling load conditions specified. It is not intended for other applications or uses. Always consult a professional for any modifications or upgrades.
Buffer Tank Selection

• Please do not use a water heater for your buffer tank.
  • Especially do not use the water heater thermostat

• The buffer tank should have the proper port sizes for all four connections to provide the proper flow of heat throughout the whole system

• The selected tank should have a thermal well port.
  • Be sure and use the thermal mastic for good thermal contact of the sensor
Hydronic control strategies

- Hot tank / cold tank
  - tank maintains Temperature on setpoint delta T regardless of demand

- Demand control

- How to change hot deck to demand control
On Demand Control Strategy!

SINGLE STAGE COMBO UNIT WIRING DIAGRAM WITH ZONE VALVES AND ONE PUMP

NOTES:
1. P-2 PUMP SIZE BY # OF LOOPS
2. THERMOSTATS INFLOOR MOD#29016
3. AQUASTAT JOHNSON CONTROLS #A419
4. P-2 CIRC PUMP TO BE 115V
5. FLOW CENTER PARALLEL PUMPS
6. 230V WIRED FROM UNIT
7. NO DISCONNECTS NEEDED
8. IF PANEL IS IN MECH RM
9. INFLOOR ZONE MODULE #30056 (4XTRA)
10. PUMP RELAY INFLOOR MOD#30050
11. ZONE VALVES HONEYWELL #V8043F
12. TRANSFORMER TO BE 75VA MINIMUM
Hot/Chilled Water Hydronic Systems

- Water-Water Unit Applications
  - Pressurized piping systems
    - Bock (or other) or Hydro-Connect
  - Non-pressurized piping systems
    - HSS (or others)
- Controls (heating & cooling)
  - Tekmar Controls
  - HBX Controls
  - Hydro-Connect
  - Heat pump Manufacturers
  - Do it yourself (who knows)
Chilled Water vs. DX Cooling

- W2W units have lower EER’s than Water-Air heat pumps (due to EWT’s)
- Be careful of sensible cooling capacities of the air handler or water coils – do not size strictly based on tonnage
- All piping with chilled water needs to be insulated including pumps
- Buffer tank must be insulated and have an air seal to prevent condensation
- Advantage – one unit vs. two units
Sensible vs. Total Cooling

<table>
<thead>
<tr>
<th>Model</th>
<th>CFM</th>
<th>EWT °F</th>
<th>GPM</th>
<th>WPD Ft/Hd</th>
<th>TC Btuh</th>
<th>SC Btuh</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPH024</td>
<td>789</td>
<td>45</td>
<td>3.0</td>
<td>2.5</td>
<td>30,776</td>
<td>21,517</td>
</tr>
<tr>
<td>MPH036</td>
<td>1058</td>
<td>45</td>
<td>4.5</td>
<td>2.5</td>
<td>41,100</td>
<td>28,654</td>
</tr>
<tr>
<td>MPH048</td>
<td>1564</td>
<td>45</td>
<td>6.0</td>
<td>3.2</td>
<td>52,901</td>
<td>38,568</td>
</tr>
<tr>
<td>MPH060</td>
<td>1952</td>
<td>45</td>
<td>7.5</td>
<td>5.1</td>
<td>64,516</td>
<td>47,117</td>
</tr>
</tbody>
</table>

Chilled Water Cooling Capacity – 80/67°F EAT (DB/WB)
Other Applications

- Chilled water Cooling
- Pool & spa heating
- Domestic water heating
- Snow melt ????
- Process water chilling
- Ice storage or Ice arena’s
- Waste heat recovery
So, the Keys to Success Are…

• Design the system properly, not using Btu’s per sqft, but rather good design practices.

• Insulation is a huge factor along with thermal breaks, if you aren’t doing it, verify it is done right!(or you will be blamed for poor performance)

• Select the proper control strategy for the application, buy off the shelf vs. build your own so anyone can service and troubleshoot!

• Size your piping and pumps for proper flow.

• Remember good water/ fluid quality, It's important for system longevity.
Questions or Comments???

Thank You!!!