# How to Develop Cooling Tower Life Cycle Cost

## JMP Equipment Company

It is important that engineers be able to compare cooling towers (brands *and* configurations) in terms of both equipment and life cycle cost. At JMP we've developed a straightforward procedure that any engineer can follow to accurately determine the lifecycle cost of a cooling tower. This method, which uses IPLV (Integrated Part Load Value) for chillers per AHRI 550/590 – 2015, can be applied to virtually any brand or type of cooling tower.

It begins with a worksheet that looks like this:

**Cooling Tower Life Cycle Cost**

Conditions: _______nom tons / _______ gpm, _____ - _____ range @ ______w.b.

Full load motor HP =_______, kw =_______, Model _______

**Cooling Tower Energy Cost (per tower)**

| Load Tons | Flow GPM | O. Air wb | Cond. Water | Yearly Tons- Hrs | Hours Operation | Fan kw | Annual kw |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Yearly total kwh ________

**A** - Cooling tower yearly total kwH _______ x $.08/kwH x _______ years = $_______

**B -** Cooling tower pump energy cost

(FT) =

Vertical tower head or lift (Ft) = _______

+ Spray nozzle pressure (Ft) = _______

Total tower pump head (Ft) = _______

$$\frac{\text{GPM x Tower TDH x .746 x \$.08/kwH}}{\text{3960 x .75 x .90}}$$ x _______hrs x _______years = _______

**C-** Total cooling tower cost = $_______

**LFC Life Cycle Cost (A + B + C ) = $_______**

We begin by filling in some of the basic information about our selection. This includes the cooling tower model, tonnage, capacity and design condition values shown at the top part of the worksheet.

For the example we will use throughout this paper, we have chosen a 500-ton Model S3E-1020-07P Baltimore Aircoil water-cooled tower with 1500 gpm capacity. We chose 95 degree entering temperature, 85 degree leaving temperature, and 78 w.b. because these values are the basis of a nominal cooling tower ton according to CTI (Cooling Tower Institute). If your design conditions are different, you will want to adjust these values.

With this information we can fill in the top part of our worksheet. Notice that we have also assigned the fan motor with a horsepower of 40 HP. At full load, the kw of a 40 HP motor is calculated as follows:

***40HP x 0.746kw/hp = 29.84kw***

**Cooling Tower Life Cycle Cost**

Conditions: 500 nom tons / 1500 gpm, 95 - 85 range @ 78 w.b.

Full load motor HP = 40, kw = 29.84, Model S3E-1020-07P

**Life Expectancy**

Next, we need to determine the life expectancy of our tower. This will depend on the type of basin you choose. Based on JMP's experience, the following are reasonable life expectancy in years for various types of basins:

- Galvanized: 12 years
- Stainless-Steel: 20 years
- Fiberglass: 20 years
- Concrete basin: 30 years

For our example we've chosen a stainless-steel basin, which will provide approximately 20 years of service. This value has also been added to the worksheet.

**Cooling Tower Life Cycle Cost**

Conditions: 500 nom tons / 1500 gpm, 95 - 85 range @ 78 w.b.

Full load motor HP = 40, kw = 29.84, Model S3E-1020-07P

**Cooling Tower Energy Cost (per tower)**

| Load Tons | Flow GPM | O. Air wb | Cond. Water | Yearly Tons- Hrs | Hours Operation | Fan kw | Annual kw |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Yearly total kwh ________

**A** - Cooling tower yearly total kwH _______ x $.08/kwH x 20 years = $_______

## Condenser Water Pump Energy

One data point that is often overlooked in cooling tower life cycle analyses is the condenser water pump energy consumption. This value must incorporate head losses for BOTH:

(1) ***the vertical lift*** between the pump discharge and the point at which water enters the tower, and

(2) ***the spray nozzles*** that are used to distribute water to the fill IF the tower is a *counterflow* tower.

For this example we are assuming that this is a crossflow tower that relies solely on gravity for the flow of water from the hot water basin to the cold-water basin. We are using a lift value of 13.75 ft. and *zero* head pressure for nozzles since crossflow tower do not have spray nozzles.

### Cooling Tower Life Cycle Cost

Conditions: **500** nom tons / **1500** gpm, **95** - **85** range @ **78** w.b.

Full load motor HP = **40**, kw = **29.84**, Model **S3E-1020-07P**

**Cooling Tower Energy Cost (per tower)**

| Load Tons | Flow GPM | O. Air wb | Cond. Water | Yearly Tons- Hrs | Hours Operation | Fan kw | Annual kw |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Yearly total kwh ________

**A** - Cooling tower yearly total kwH _______ x $.08/kwH x **20** years = $_______

**B -** Cooling tower pump energy cost

(FT) = Vertical tower head or lift (Ft) = **13.75**
\+ Spray nozzle pressure (Ft) = **0**
Total tower pump head (Ft) = **13.75**

$$\frac{\text{GPM x Tower TDH x .746 x \$.08/kwH}}{3960 \times .75 \times .90}$$ x _______hrs x _______years = _______

**Note:** If you are using a *counterflow* cooling tower don't forget to include the head loss associated with the spray nozzles for your pump energy calculation, as this could add a considerable amount of energy costs which must be included in your life cycle calculation.

## Developing the Load Profile

All remaining values are dependent on the load profile we develop for the application.

You may wonder why we need a load profile to compare cooling towers. What's wrong with simply comparing cooling towers based on design conditions alone?

Most of us are well aware of the fact that cooling towers typically only operate at design conditions a few days out of the year. But that's just *part* of the reason we need to incorporate load profiles into our lifecycle analysis. How you choose to operate cooling towers ( e.g. how you size and stage them), along with the load profile of a given climate, has a *dramatic* impact on operational costs.

The life cycle method we propose captures these and other variables so that the engineer can make *completely* informed decisions with their clients. It begins with estimating the number of hours a cooling tower will operate at various load conditions. If you don't know your load profile (and don't anticipate taking the time to research it), we suggest using the IPLV (Integrated Part Load Value) for chillers per AHRI 550/590 – 2015. After all, if the chiller is operating, then the cooling tower is operating, too.

This standard anticipates that a chiller will typically operate at:

100% load for 1% of the year = **88** hours per year

75% load for 42% of the year = **3679** hours per year

50% load for 45% of the year = **3942** hours per year

25% for load 12% of the year = **1051** hours per year

The IPLV also suggests the following condenser water temperatures at various chiller loads. These values incorporate *resetting* the condenser water temperature (water going from the cooling tower to the chiller) as the load drops:

**85°F** condenser water temperature at 100% load

**75°F** condenser water temperature at 75% load

**65°F** condenser water temperature at 50% load

**65°F** condenser water temperature at 25% load

The above values apply to water-cooled chillers. However, AHRI also has IPLV values for air-cooled chillers and for evaporative cooling equipment:

**AHRI Standard 550/590-2015**

Table 3. - Entering Condenser Fluid Temperatures at Part Load
I-P System

| % Load | 2015 Standard | | |
|---|---|---|---|
| | **Water-Cooled - WC** °F Entering Condenser Water Temperature - ECWT | **Air-Cooled - AC** °F Entering Air Dry Bulb Temperature - EDB | Evaporative Cooled - EC °F Entering Air Wet Bulb Temperature - EWB |
| 100 % | 85 | 95 | 75 |
| 75 % | 75 | 80 | 68.75 |
| 50 % | 65 | 65 | 62.5 |
| 25 % | 65 | 55 | 56.25 |

Complete standard at www.ahrinet.org

Based on all of the above, we now have a lot more information that we can add into our life-cycle cost worksheet:

**Cooling Tower Energy Cost (per tower)**

| Load Tons | Flow GPM | O. Air wb | Cond. Water | Yearly Tons- Hrs | Hours Operation | Fan kw | Annual kw |
|---|---|---|---|---|---|---|---|
| 500 | 1500 | | 85 | | 88 | | |
| 375 | 1500 | | 75 | | 3679 | | |
| 250 | 1500 | | 65 | | 3942 | | |
| 125 | 1500 | | 65 | | 1051 | | |

Yearly total kwh ________

**A** - Cooling tower yearly total kwH _______ x $.08/kwH x __20__ years = $_______

**B -** Cooling tower pump energy cost

(FT) = Vertical tower head or lift (Ft) = __13.75__
\+ Spray nozzle pressure (Ft) = __0__
Total tower pump head (Ft) = __13.75__

$$\frac{\text{GPM x Tower TDH x .746 x \$.08/kwH}}{3960 \times .75 \times .90}$$ x _______hrs x __20__years = _______

**Determining Wet Bulb for Part Load Conditions**

The next step is filling in the wet bulb temperatures that correspond with the part load conditions we've identified. If you have done the legwork to determine wet bulb temperatures for your climate zone, feel free to use them. If not, we suggest you use the following wet bulb temperatures. These values are based on the ARI Air Cooled Dry Bulb Design Points:

Cooling Tower Utilization Profile

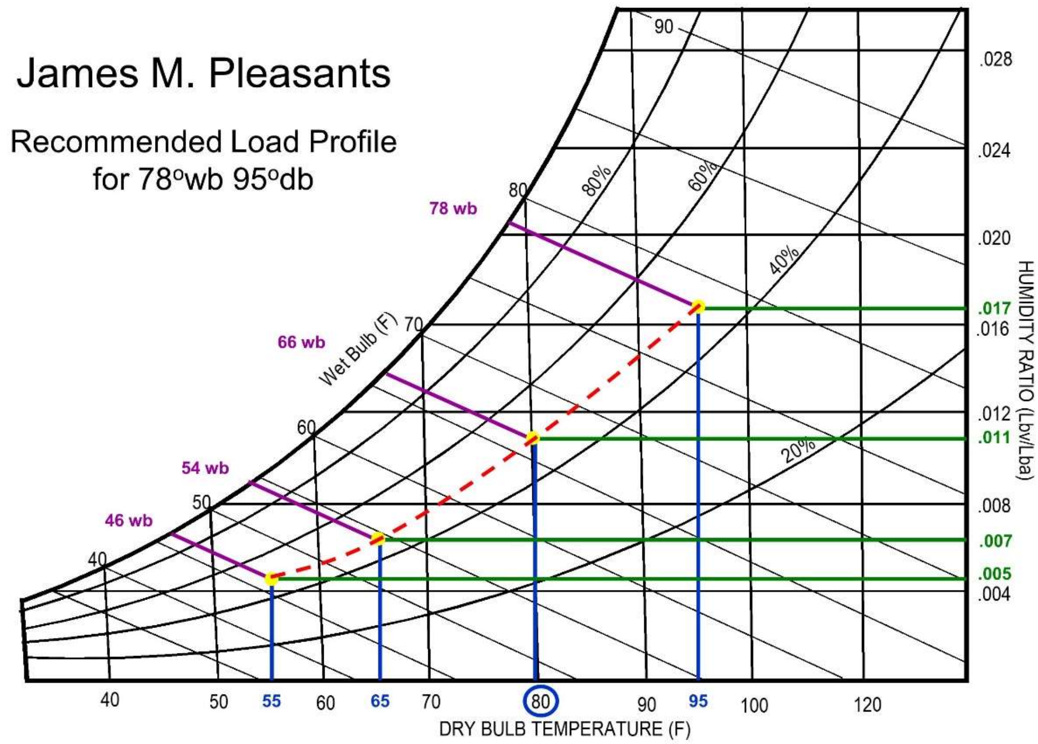
(Based on ARI Air Cooled Dry Bulb Design Points)

| Load % | Dry Bulb | Relative Humidity Curve | Entering Water (deg F) | Leaving Water (deg F) | Outdoor Air Wet Bulb (deg F) |
|---|---|---|---|---|---|
| 100 | 95 | 47% | 95 | 85 | 78 |
| 75 | 80 | 47% | 82.5 | 75 | 66 |
| 50 | 65 | 47% | 70 | 65 | 54 |
| 25 | 55 | 47% | 67.5 | 65 | 46 |

*Suggest Keeping the **Same Relative Humidity as 100% Design Point**

Example for **78°** Wet Bulb

As you can see, our load profile consists of the following dry bulb temperatures: 95°F, 80°F, 65°F and 55°F. The wet blub temperatures shown in blue have been derived from the psychrometric chart shown below and are based on the dry bulb temperatures profile at a recommended constant humidity of 47%.




Notice the dry bulb design points shown in blue on the horizontal axis of the psychrometric chart. To determine wet bulb temperatures at these design points, follow the (blue) vertical line from these four dry bulb values up to the curved (dotted red) line that represents a constant 47% relative humidity. From that point follow the purple diagonal line to the left where you find the wet bulb temperature that corresponds with these conditions:

| Dry Bulb and Corresponding Wet Bulb Temperatures at 47% rH | |
|---|---|
| 95°F | 78°F |
| 80°F | 66°F |
| 65°F | 54°F |
| 55°F | 46°F |

**Cold Air Holds Less Moisture!**

What happens to the humidity ratio (the amount of water that can be held in a single pound of air at a given temperature)? Looking at the psychrometric chart above, it is clear that as the dry bulb temperature goes down, so does the maximum amount of water the air can hold at saturation. This is not surprising. After all, most of us are aware that cold air holds less moisture. However, we often overlook the impact that this has on a cooling tower's ability to cool. Because cold air holds less moisture, it reduces the potential for evaporation. And since cooling towers cool by evaporation, their cooling capacity decreases with dry bulb.

| Why do You Need a Greater Approach at Lower Wet Bulbs? | | | | |
|---|---|---|---|---|
| % Load | 25 | 50 | 75 | 100 |
| Dry Bulb | 55°db | 65°db | 80°db | 95°db |
| **Wet Bulb at 47% RH** | **46°wb** | **54°wb** | **66°wb** | **78°wb** |
| 100% RH Grains | 46 grains | 63 grains | 97 grains | 147 grains |
| 47% RH Grains | 32 grains | 46 grains | 74 grains | 118 grains |
| Grains that can be Added per pound of Dry Air Flow | 14 grains | 17 grains | 23 grains | 29 grains |

The significance of this  is often underestimated in the role it plays in cooling tower operation. All too often the assumption is that the cooling tower approach will remain constant during times of cooler weather. But cooling towers are evaporative machines and if they can't evaporate moisture into the air then they can't cool. That's why we have to make sure that our load profile reflects the true evaporative capability of the machine under our design point conditions. Specifically, we have to be realistic with our approach and entering wet-bulb temperature. The lower the wet bulb (with a constant approach) the less evaporation we can achieve. The wet bulb temperatures that we propose reflect these realities and help ensure a fair and accurate lifecycle analysis.

So here's what our worksheet looks like now with our wet bulb temperatures applied. We've also done the math for our Yearly Ton Hours (Load Tonnage x Hours of Operation):

**Cooling Tower Energy Cost  (per tower)**

| Load Tons | Flow GPM | O. Air wb | Cond. Water | Yearly Tons- Hrs | Hours Operation | Fan kw | Annual kw |
|---|---|---|---|---|---|---|---|
| **500** | **1500** | **78** | **85** | **44,000** | **88** | | |
| **375** | **1500** | **66** | **75** | **1,454,625** | **3679** | | |
| **250** | **1500** | **54** | **65** | **985,500** | **3942** | | |
| **125** | **1500** | **46** | **65** | **131,375** | **1051** | | |

Yearly total kwh ________

**A** - Cooling tower yearly total kwH _______ x $.08/kwH x __**20**__ years = $_______

**B -** Cooling tower pump energy cost

(FT) =

Vertical tower head or lift (Ft) = __**13.75**__

\+ Spray nozzle pressure (Ft) = __**0**__

Total tower pump head (Ft) = __**13.75**__

$$\frac{\text{GPM x Tower TDH x .746 x \$.08/kwH}}{3960 \text{ x .75 x .90}}$$

x _______hrs x __**20**__years = _______

Now it is up to the vendor to determine the kW required to operate a given tower based on the data you've provided. With this information the vendor can give you the exact annual fan kW for the tower you've selected. You calculate the annual kw for the four load conditions and add them together to come up with the total annual kW consumption.

Using the same example we've referred to throughout this series, that yearly total adds up to 107,183 kwh.

| Load Tons | Flow GPM | O. Air wb | Cond. Water | Yearly Tons- Hrs | Hours Operation | Fan kw | Annual kw |
|---|---|---|---|---|---|---|---|
| 500 | 1500 | 78 | 85 | 44,000 | 88 | 24.81 | 2,183 |
| 375 | 1500 | 66 | 75 | 1,454,625 | 3679 | 17.97 | 66,111 |
| 250 | 1500 | 54 | 65 | 985,500 | 3942 | 9.74 | 38,395 |
| 125 | 1500 | 46 | 65 | 131,375 | 1051 | .47 | 494 |

Yearly total kwh **107,183**

Notice the significant reduction in kW as we go from full load to part load operation. This gives us important intel with respect to how we might stage cooling towers in order to improve lifecycle cost. With this approach, we can very easily compare the life cycle cost of a system that uses *multiple* cooling towers at *reduced* speeds versus the lifecycle cost of fewer towers operating at full speed.

**The Final Analysis**

All that's left now is some fairly simple math, applying whatever utility rate that is appropriate. In this case we're using $.08/kwH. We've also included the 13.75 tower pump head which we need to factor into pump kW. (Don't forget this step!)

## Cooling Tower Life Cycle Cost

Conditions: **500** nom tons / **1500** gpm, **95** - **85** range @ **78** w.b.

Full load motor HP = **40**, kw = **29.84**, Model **S3E-1020-07P**

**Cooling Tower Energy Cost (per tower)**

| Load Tons | Flow GPM | O. Air wb | Cond. Water | Yearly Tons- Hrs | Hours Operation | Fan kw | Annual kw |
|---|---|---|---|---|---|---|---|
| 500 | 1500 | 78 | 85 | 44,000 | 88 | 24.81 | 2,183 |
| 375 | 1500 | 66 | 75 | 1,454,625 | 3679 | 17.97 | 66,111 |
| 250 | 1500 | 54 | 65 | 985,500 | 3942 | 9.74 | 38,395 |
| 125 | 1500 | 46 | 65 | 131,375 | 1051 | .47 | 494 |

Yearly total kwh **107,183**

**A** - Cooling tower yearly total kwH **107,183** x $.08/kwH x **20** years = $**171,493**

**B -** Cooling tower pump energy cost

(FT) =

| | | |
|---|---|---|
| | Vertical tower head or lift | (Ft) = **13.75** |
| + | Spray nozzle pressure | (Ft) = **0** |
| | Total tower pump head | (Ft) = **13.75** |

$$\frac{1500 \text{ GPM} \times \text{Tower HD}(13.75) \times .746 \times \$.08/\text{kwH}}{3960 \times .75 \times .90} \times 8760 \text{ hrs} \times 20 \text{ years} = \$80{,}679$$

**C-** Total cooling tower cost = $**40,393**

**LFC Life Cycle Cost (A + B + C ) = $292,565**

So there you have it – a reliable life cycle cost analysis for given selection for a specific application! You can use this method to compare various brands, models and design configurations to help you make the best possible recommendations to your client.