

# Chillers

## ENERGY SAVING FACT SHEET

### Introduction

Central building cooling options include water chillers and direct-expansion (DX) A/C units. Chillers use a refrigeration cycle to cool water to 42° F to 55° F for pumping to chilled water cooling coils. Air is then blown over the chilled water cooling coils to provide cool air to the conditioned space. DX systems also use a refrigeration cycle, but distribute refrigerant directly to DX cooling coils – some are packaged in a single housing, others are split (evaporator coil remote to condenser and compressor). High-efficiency chillers can produce chilled water using less than 0.50 kW per ton of cooling capacity. A refrigeration system must also reject the heat that it removes using a cooling tower for water cooling the condenser (most efficient) or using fans for air cooling the hot refrigerant of the condenser coil.

### Chiller Performance Ratings

There are many chiller manufacturers of several compressor types and condenser cooling configurations.<sup>1</sup> These manufacturers have websites that are very educational to chiller operation in general and specific marketing uniqueness of their equipment. The important thing for chiller operation is to know how the unit is performing relative to optimum design efficiency after the initial installation, where efficiency is dependent on chiller service duty and maintained equipment performance worthiness. The **Air-Conditioning and Refrigeration Institute (ARI)** certifies chiller performance both for capacity (tons) and power input according to very detailed procedure to ensure manufacturer's performance statements are verified through actual running under partial load and full load conditions. As seen below there is a kw/ton range from a partial loaded condition to a full loaded condition that would be expected during installed operation. It is possible

### Chiller Performance Facts

Chillers consume more than 50% of electrical energy during seasonal periods of building use.

More than 120,000 chillers in the U.S. are expending more than 30% in additional energy through operational inefficiencies. (Estimated by DOE survey)

Water cooled condenser water (cooling tower) temperature decrease of 1°F can increase efficiency of the chiller compressor by 1% to 2 % in most situations; however, there is a limit and optimum lower condenser temperature for a given partial loading of the chiller compressor.

A neglected or poorly maintained cooling tower can reduce chiller efficiency by 10% to 35% and a dirty coil condenser of an air cooled chiller as much as 5% to 15%

Chemical cleaning of the inside of the condenser and evaporator heat transfer surfaces can result in a 5% to 10% energy savings – kw/ton

Air-cooled chillers are less efficient than water-cooled chillers but cost less as well.

to determine, with today's chiller machines this instantaneous input (kw)/(ton) output relationship. Most have a control panel that looks at all of the motor drives connected kw for comparison with the evaporator chilled water flow and temperature. However, if this panel is not available, the following formula represents the readings that must be taken to approximate the kw/ton values for comparison with the previous ARI certification data. This will determine operating cost and efficiency and also represents a logged report.

### Efficiency Recommendations ARI Standard 550/590

#### Air Cooled Chillers

| Compressor Type & Capacity    | Part Load Optimized       |                              | Full Load Optimized            |                                   |
|-------------------------------|---------------------------|------------------------------|--------------------------------|-----------------------------------|
|                               | Recommended IPLV (kw/ton) | Best Available IPLV (kw/ton) | Recommended Full Load (kw/ton) | Best Available Full load (kw/ton) |
| Scroll (30 – 60 tons)         | 0.86 or less              | 0.83                         | 1.23 or less                   | 1.10                              |
| Reciprocating (30 – 150 tons) | 0.90 or less              | 0.80                         | 1.23 or less                   | 1.00                              |
| Screw (70 – 200 tons)         | 0.98 or less              | 0.83                         | 1.23 or less                   | 0.94                              |

#### Water Cooled Chillers

| Compressor Type & Capacity     | Part Load Optimized       |                              | Full Load Optimized            |                                   |
|--------------------------------|---------------------------|------------------------------|--------------------------------|-----------------------------------|
|                                | Recommended IPLV (kw/ton) | Best Available IPLV (kw/ton) | Recommended Full Load (kw/ton) | Best Available Full load (kw/ton) |
| Centrifugal (150 – 299 tons)   | 0.52 or less              | 0.47                         | 0.59 or less                   | 0.50                              |
| Centrifugal (300 – 2,000 tons) | 0.45 or less              | 0.38                         | 0.56 or less                   | 0.47                              |
| Rotary Screw greater 150 tons  | 0.49 or less              | 0.46                         | 0.64 or less                   | 0.58                              |

## Chiller Performance Measurements

### Input (Energy Consumed - KW)

- (KW1) Compressor Drive Motor - Amps @ Volts, or KW
  - (KW2) Condenser Water Pump Drive Motor - Amps @ Volts or KW
  - (KW3) Cooling Tower Fan Drive Motor - Amps @ Volts or KW
  - (KW4) Chiller Control System Feeder Circuit - Amps @ Volts or KW
  - (KW5) Transmission Oil Pump Motor and Oil Heater - Amps @ Volts or KW
- (Note: Chilled water pump drive motor is not considered apart of the power input)

### Output (Cooling Capacity Delivered - Tons)

- (TS) Chilled Water Supply Temperature - °F
- (TR) Chilled Water Return Temperature - °F
- (FCW) Chilled Water Flow Rate Gallons/Minute - GPM

Chiller Performance = Total KW Input/Tons Output (at one particular operating point)

= KW1 + KW2 + KW3 + KW4 + KW5/ Tons Capacity, where:

Tons Capacity = Fcw (gal/min) x 8.34 lb/gal x (Cp) 1 Btu/lb. °F x (TR - TS) x 60 mins./hr  
divided by 12,000 Btu/hr/Ton

The above formulas are for a chiller that has a cooling tower providing condenser cooling. KW3 would be the total KW of the multiple fan motors that are running for an air cooled condenser system. Obviously, if there is a single circuit supply to the chiller unit then all of the individual motors are collectively represented by a single amp and voltage measurement.

## Cost Savings Potential at Different Performance Levels

The following chart is an example of how much electricity expense can vary over a summer season of operation at different chiller performance levels. This chart is based on a 100 ton chiller running 24-hours each day, 180 days/year, at the efficiency as shown below. (average annual electricity cost of \$0.086/kwh)

## References & Resources:

1. Manufacturers; Trane, York, Carrier, McQuay,
2. ASHRAE Journal / [www.ashrae.org/](http://www.ashrae.org/)
3. Air-Conditioning and Refrigeration Institute (ARI) , [www.ahrinet.org](http://www.ahrinet.org)

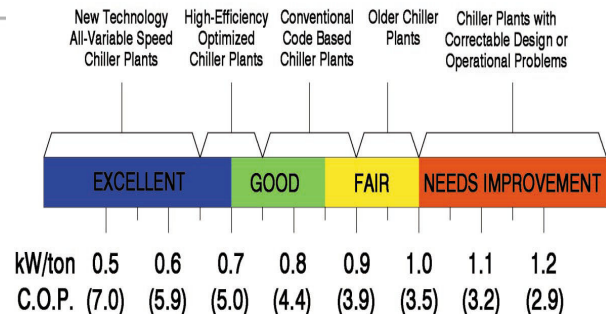
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Revised by Waste Reduction Partners— 05/2010

## Chiller Operating Cost Annual Operating Cost - 100 Ton Chiller

| Part Load Condition | Cost To Operate |
|---------------------|-----------------|
| 0.5 kw/ton          | \$18,600        |
| 0.6 kw/ton          | \$22,300        |
| 0.7 kw/ton          | \$26,000        |
| 0.8 kw/ton          | \$29,700        |
| 0.9 kw/ton          | \$33,400        |
| 1.0 kw/ton          | \$37,100        |
| 1.1 kw/ton          | \$40,900        |
| 1.2 kw/ton          | \$44,600        |
| 1.3 kw/ton          | \$48,300        |

As shown below, any chiller plant that operates continuously above about 1.2 kw/ton (air cooled condenser) or 0.64 kw/ton (water cooled condenser), there is a need for improvement. This usually involves a service representative to evaluate the loading, operating conditions (log sheets), and maintenance service records for revealing the deficiency.



**AVERAGE ANNUAL CHILLER PLANT EFFICIENCY IN KW/TON (C.O.P.)**  
(Input energy includes chillers, condenser pumps and tower fans)

Based on electrically driven centrifugal chiller plants in comfort conditioning applications with 42°F (5.6°C) nominal chilled water supply temperature and open cooling towers sized for 85°F (29.4°C) maximum entering condenser water temperature. Local Climate adjustment for North American climates is +/- 0.05 kW/ton