Designing Ultra-Efficient Building Cooling Systems

Design to Apply Effective Optimization Technologies To Chiller Plants and Air Systems

ASHRAE
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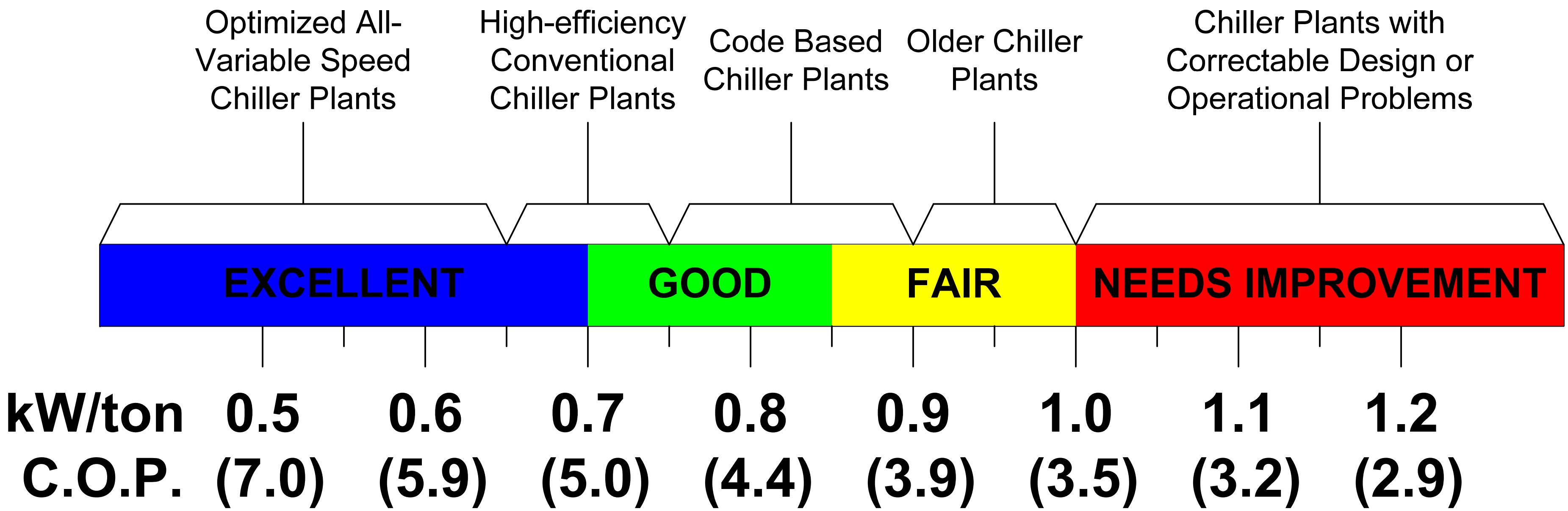
Chiller Plant Energy Use Spectrum



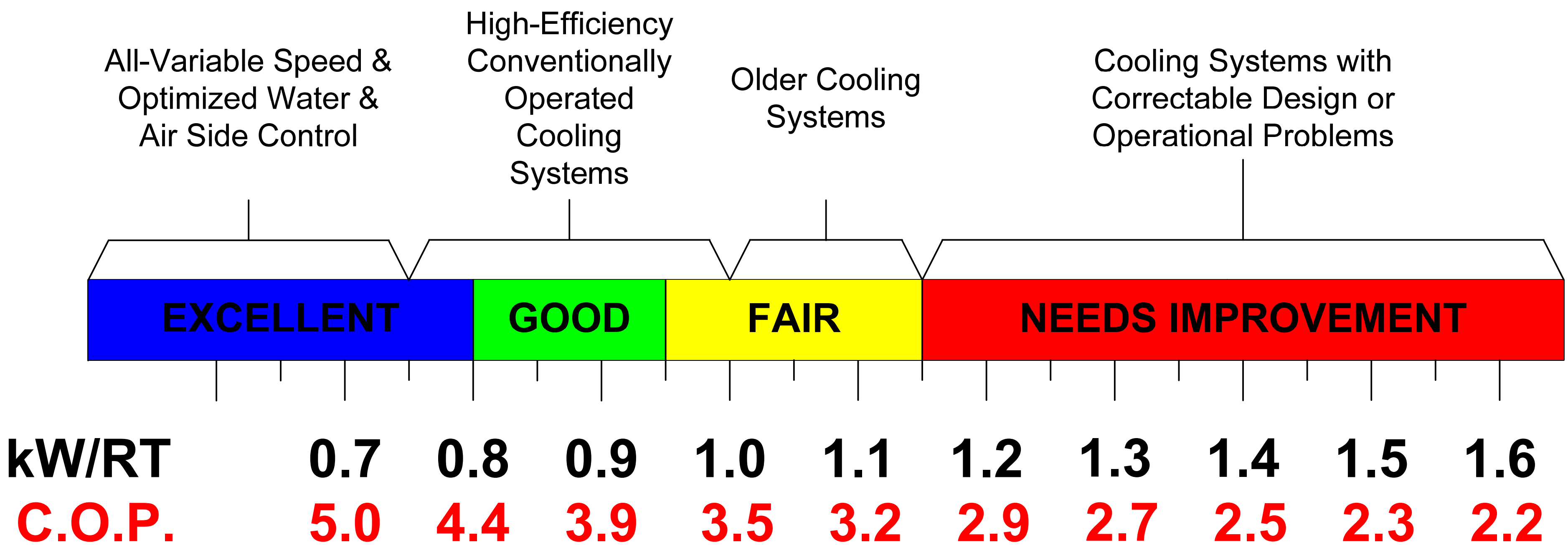
AVERAGE ANNUAL CHILLER PLANT EFFICIENCY IN KW/TON (C.O.P.)

(Input energy includes chillers, condenser pumps, tower fans and chilled water pumping)

Based on electrically driven centrifugal chiller plants in comfort conditioning applications with 42F (5.6C) nominal chilled water supply temperature and open cooling towers sized for 85F (29.4C) maximum entering condenser water temperature.

Local Climate adjustment for North American climates is +/- 0.05 kW/ton

Chiller Plant & Air System Energy Use Spectrum



AVERAGE ANNUAL COOLING SYSTEM EFFICIENCY IN KW/TON (C.O.P.)

***(Cooling RT includes all space and ventilation air cooling.
Input energy includes chillers, tower fans, pumping and fan power for comfort & ventilation air conditioning when mechanical cooliing is required)***

Based on VAV air system with 55F (12.8C) Minimum Supply Air Temperature

Presentation Agenda

1. **The Nature of Cooling Loads:**
   Expected load profiles in typical HVAC applications – Why variable speed is so well suited.

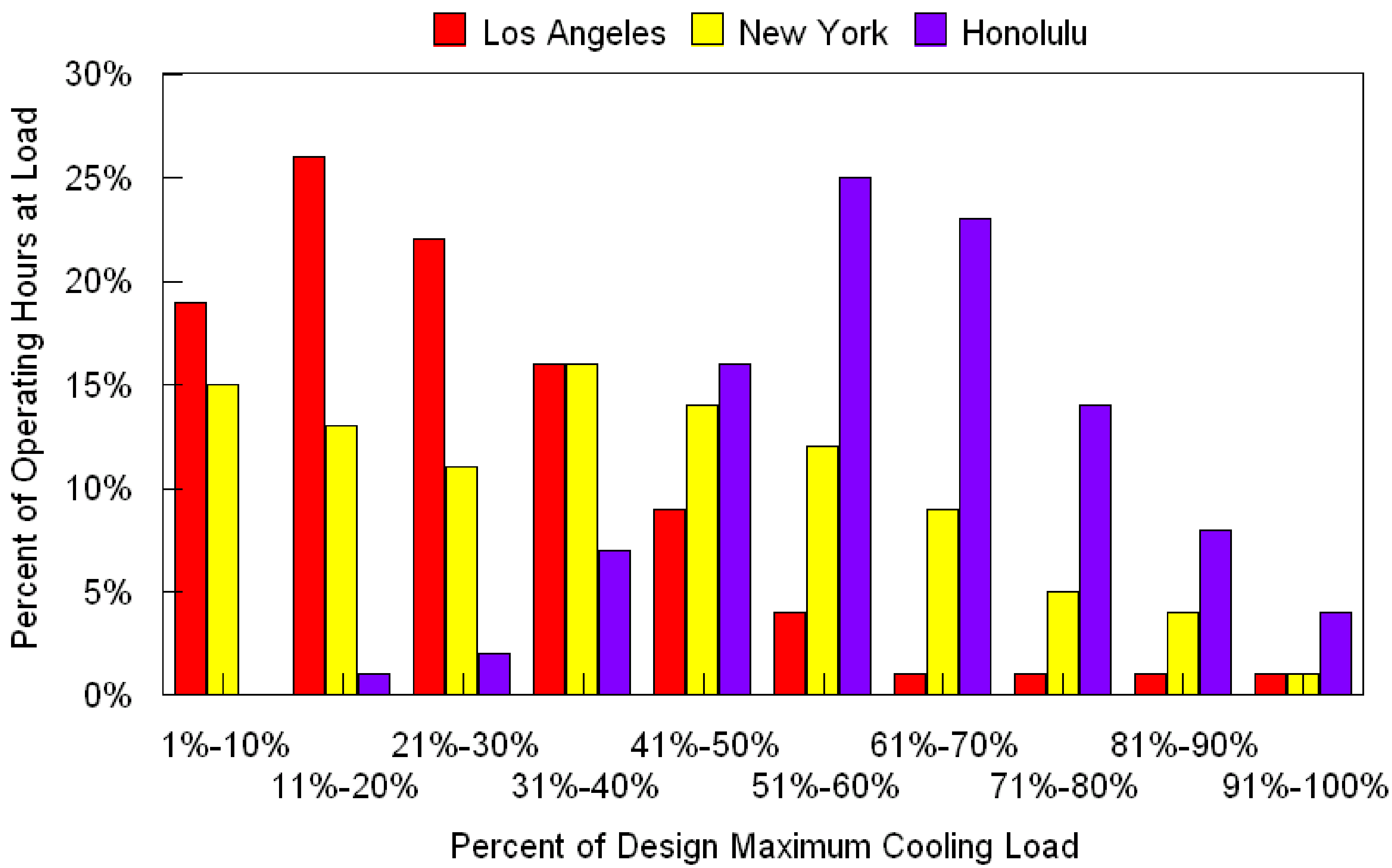
2. **The Equal Marginal Performance Principle & Relational Control:**
   Limitations of PID control, and newer control technologies that leverage the full advantage of variable speed using network control.

3. **Interfacing Chilled Water Plants with Air Side Systems:**
   Saving energy by optimizing air supply and chilled water supply temperatures.

4. **Design Rules for Optimized Systems:** What are the basics for ensuring ultra-efficient operation will be achieved.

5. **Discussion & Questions:**

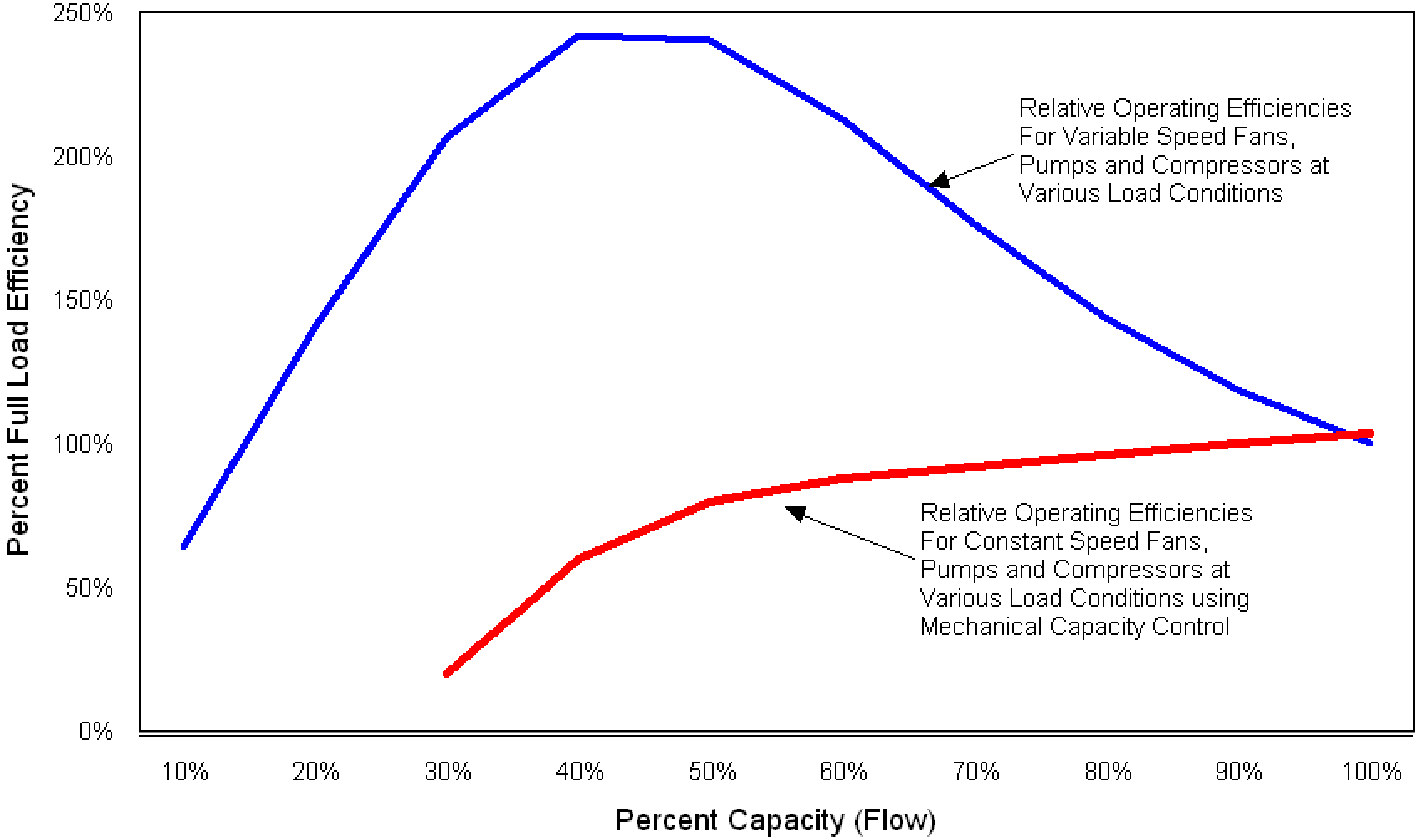
Characteristics of Comfort Cooling Loads for Climate Types



This chart shows typical building cooling load profiles for the three climate types: **Temperate** (Los Angeles); **Transitional** (New York); and **Tropical** (Honolulu).

Constant & Variable Speed Part Load Operating Efficiencies Comparison

For Fans, Pumps and Compressors



Variable speed offers large increases in “flow” efficiencies when components operate at part loads, but only if they are controlled to fit the affinity laws of fans, pumps or compressors

Variable Speed Laws
For Fans, Pumps & Chiller Compressors

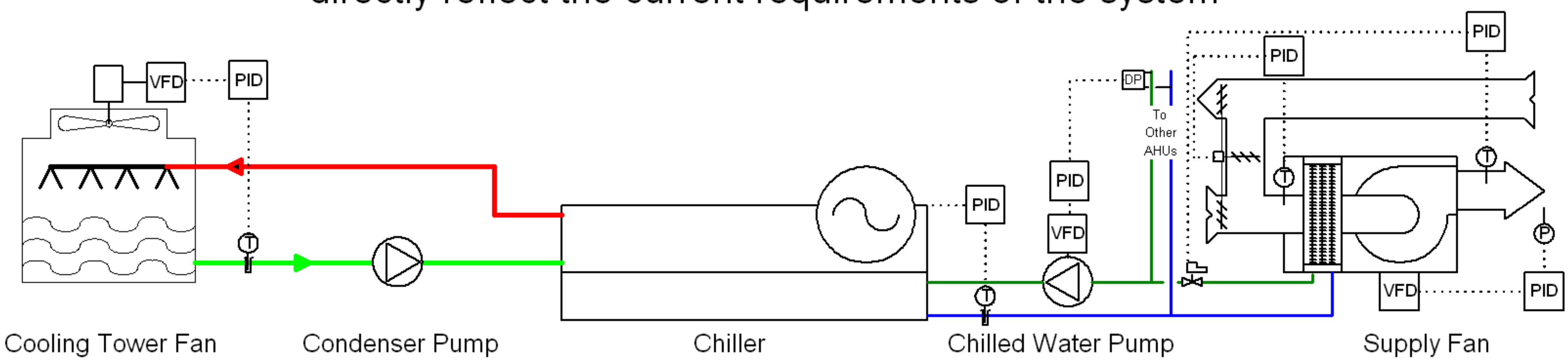
- **Flow** (Capacity) is proportional to the **speed**
- **Head** is proportional to the **speed squared**
- **Power** required is proportional to the **speed cubed**

Important Considerations when applying variable speed to HVAC system components:

1. The flow efficiency of variable speed equipment can improve significantly as capacity falls below 100%.
2. But to achieve this improvement, the head requirement of the fan, pump or compressor must be reduced at lower loads with the square of the flow.

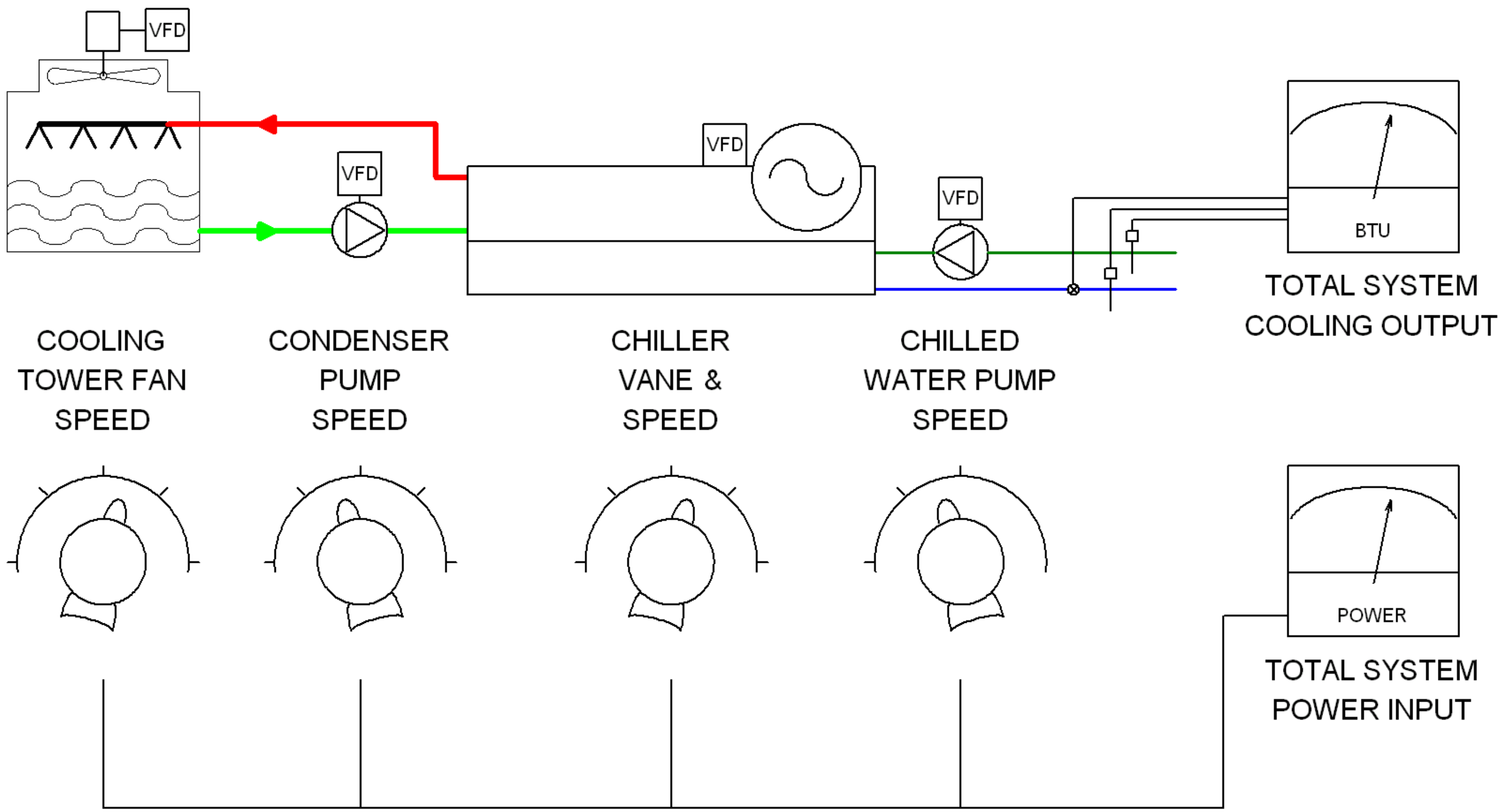
Conventional HVAC Cooling System Control

Under PID control, each system component is operated independently to maintain an intermediate setpoint (usually temperature or pressure) - that does not necessarily directly reflect the current requirements of the system



PID provides a primitive means of modulation control. Controllability and stability are almost always issues with PID control. Energy optimization over any range of conditions requires a separate step that adds to controllability and stability issues. Furthermore energy optimization opportunities are constrained by precision and accuracy of intermediate temperature and pressure instrumentation .

The
"Equal Marginal Performance Principle"



The Equal Marginal Performance Principle

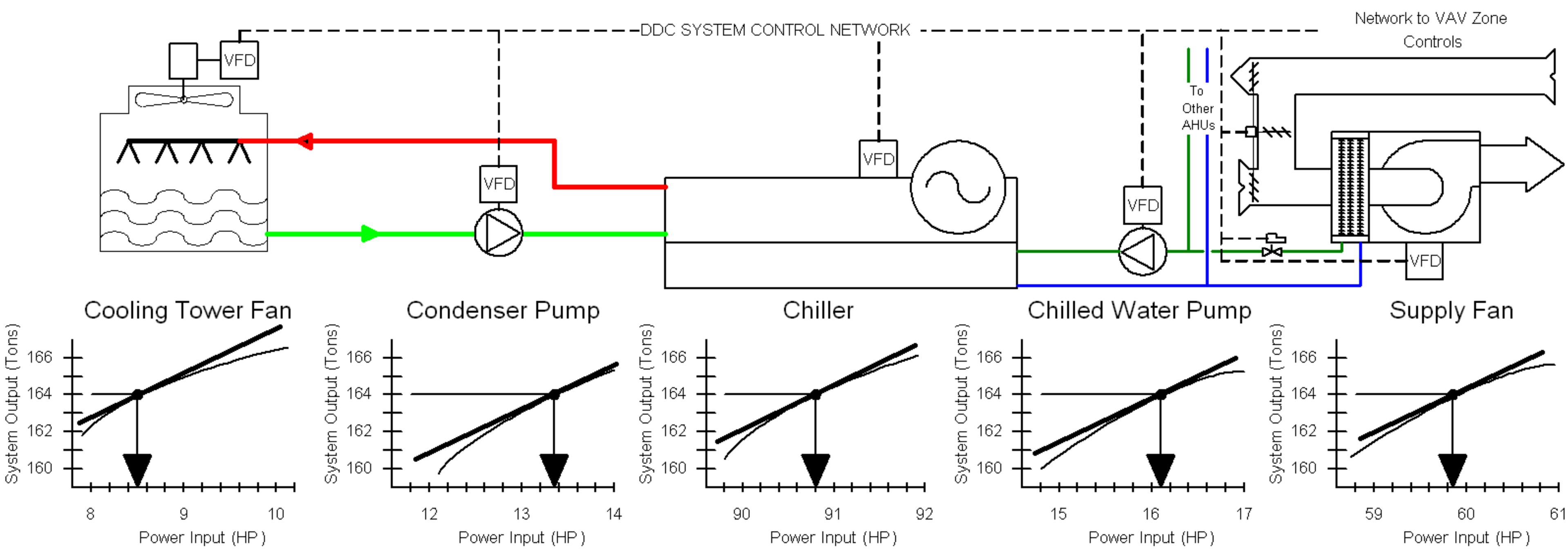
The Equal Marginal Performance Principle states that the energy performance of any system operating with multiple modulating components is optimized in so far as energy is concerned only if the same ***marginal*** (or incremental) amount of power applied to any of the system's components will yield the same ***marginal*** (or incremental) output from the system.

Demand Based Control

Demand Based Control is a method of relational control developed for systems that incorporate multiple modulating components to achieve a desired result or condition. It can replace or be overlaid on the independent stand alone PID loops that typically operate each component independently.

Demand Based Control

Demand based control is a relational method of control that has been developed from the Equal Marginal Performance Principle. Demand based control operates individual components based on relative power input rather than to maintain an intermediate temperature or pressure setpoints.

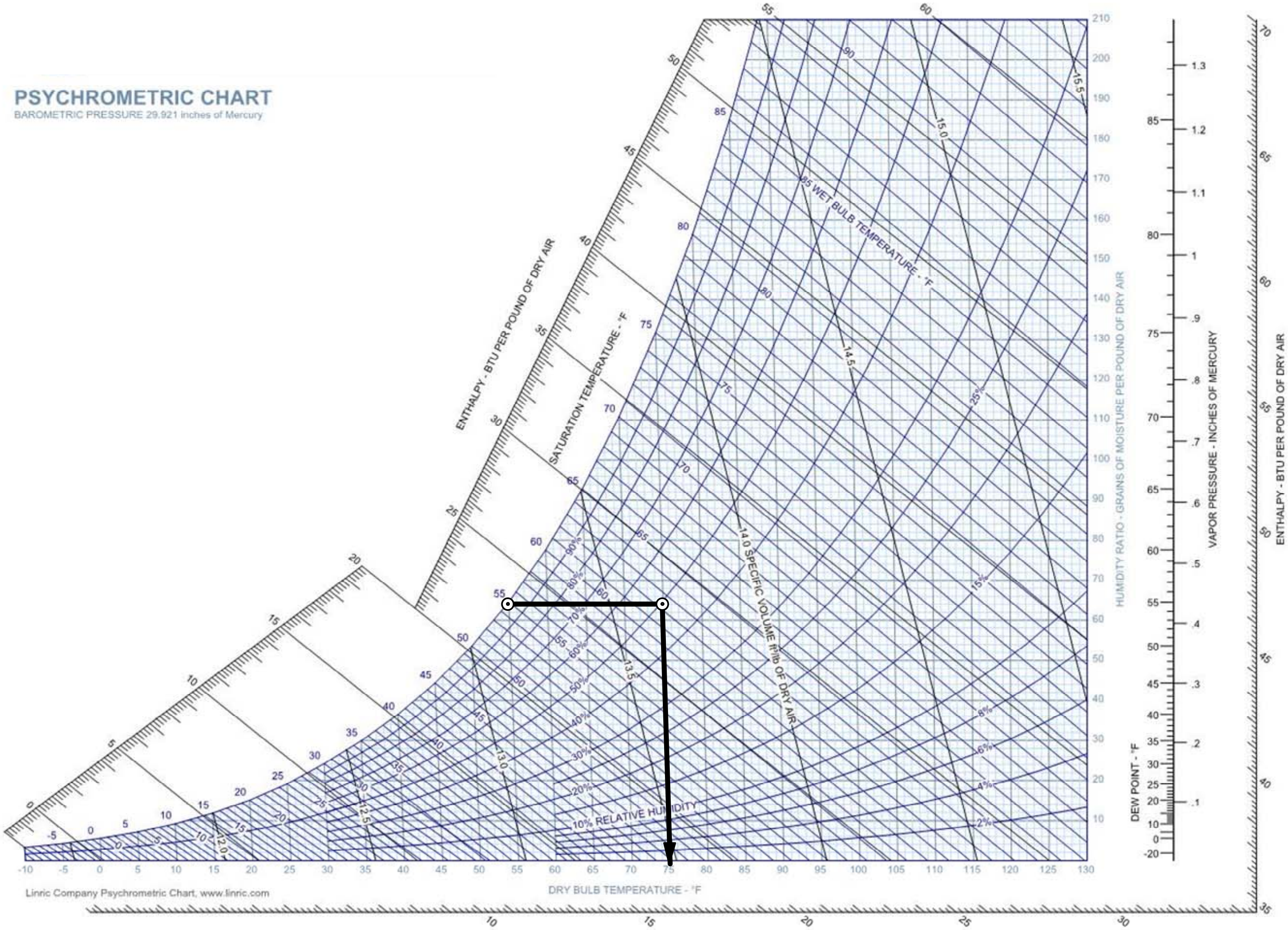


Because continuous error correction is not an essential element of demand based control, operating stability is almost never an issue. The above system is optimized at the relative power settings shown by the arrows because, in accordance with the Equal Marginal Performance Principle, the marginal performance (slope of the curve of total system output per unit input for the component) is the same for all system components.

Design Considerations for Operating Chilled Water Systems with Relational Control

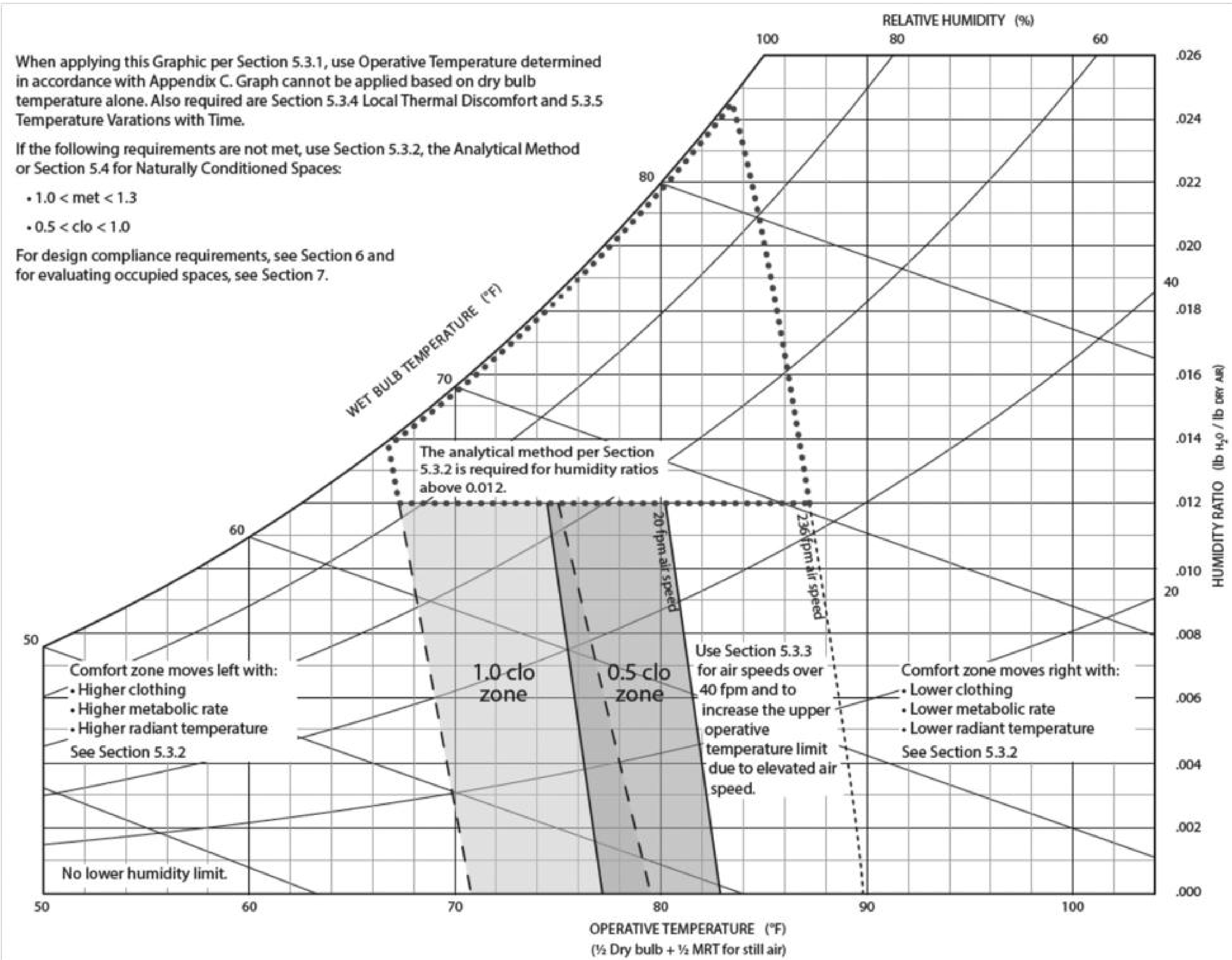
- Configure all-variable equipment. Size equipment to be identical in size, capacity, and operating characteristics if possible.
- Employ headered arrangements so that combinations of on-line pumps, chillers and towers can be varied.
- Ensure chillers and Towers allow at least 50% turndown in condenser water flow with complete fill coverage.
- Select close SAT/CHWT approach and low pressure distribution with larger control valves for low power pumping.
- Select optimization strategies that operate equipment in accordance with power based relationships while ensuring all temperature and flow limiting constraints are maintained.
- Incorporate ongoing performance monitoring, fault detection and operations support requirements into construction documents to ensure ultra-efficient energy performance is maintained over time.

What is The Optimal Supply Air Temperature?



Space Conditions for Achieving Comfort

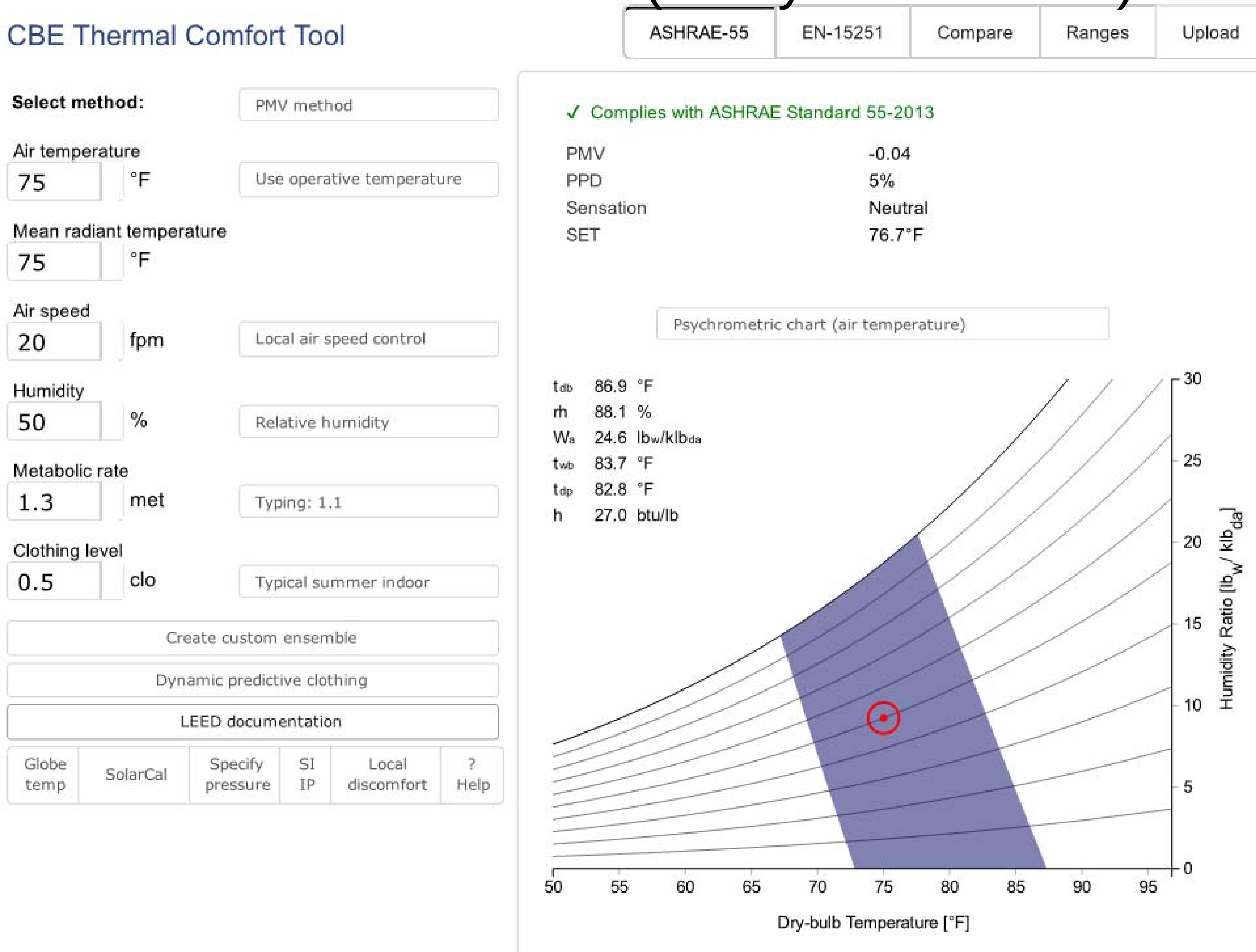
ASHRAE Graphical Method



ASHRAE Standard 55 Figure 5.3.1

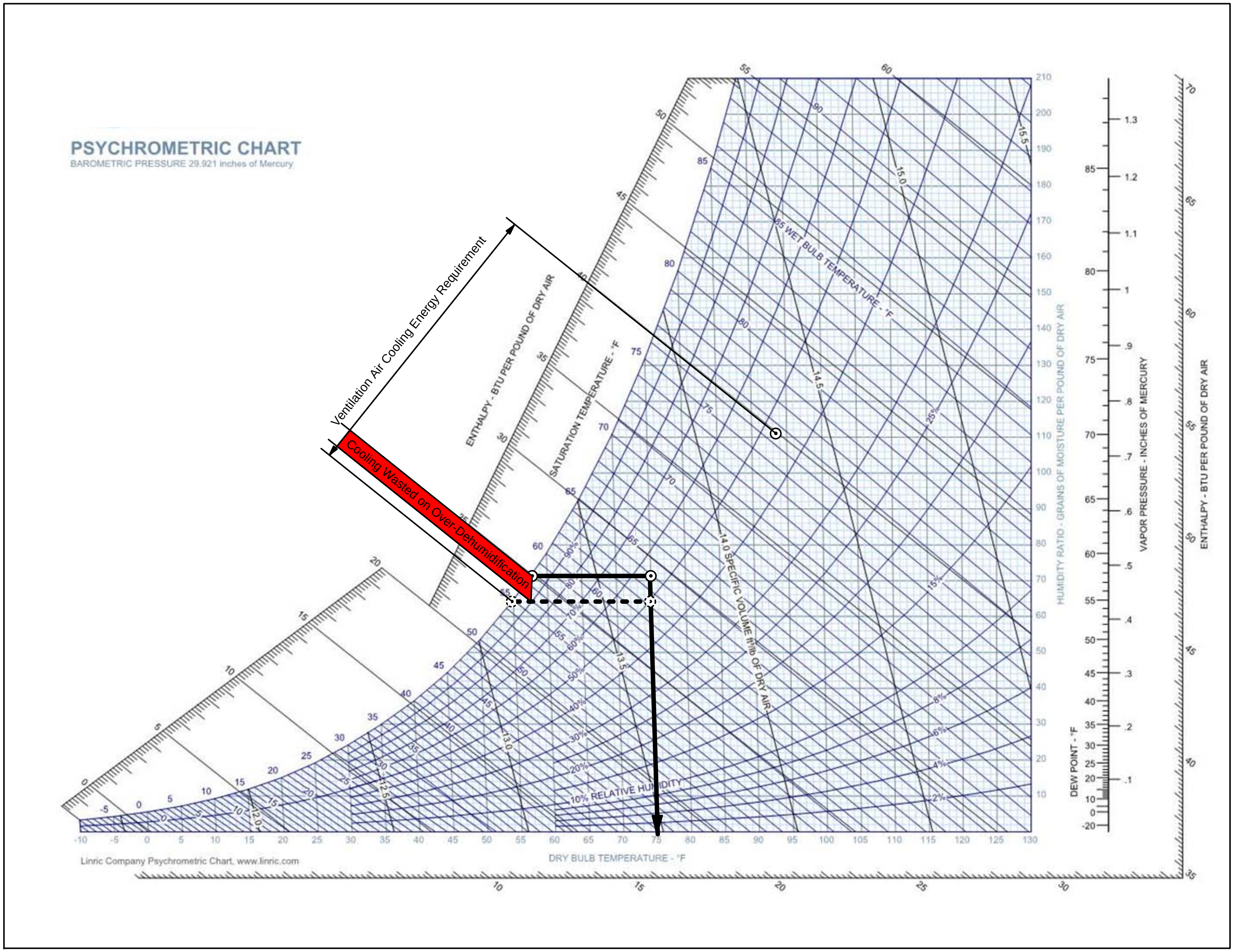
Space Conditions for Achieving Comfort

ASHRAE Comfort Tool (Analytical Method)



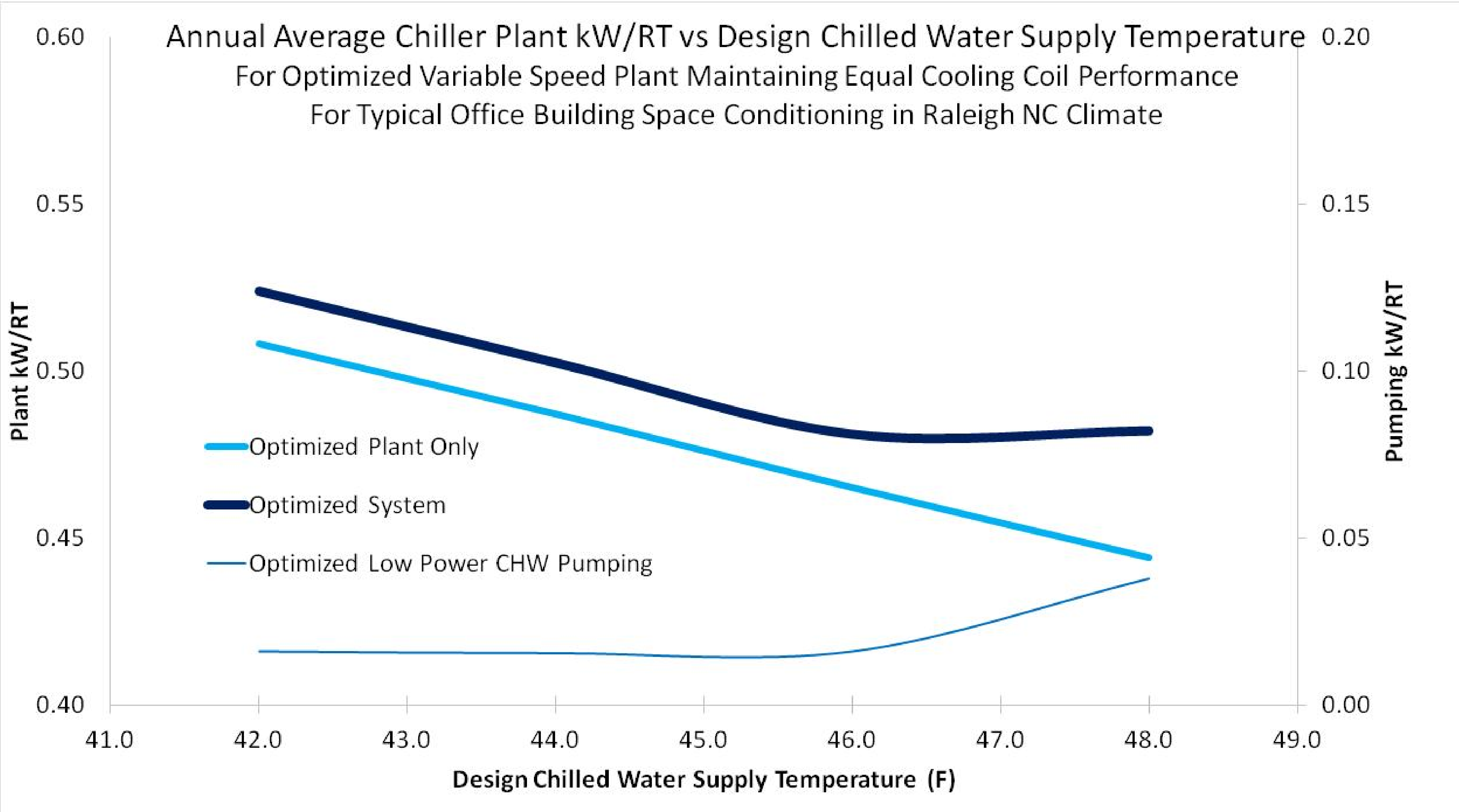
http://comfort.cbe.berkeley.edu/

What is Optimal Supply Air Temperature



Chiller Plant Average Annual Efficiencies vs. Design Chilled Water Supply Temperature

55ºF SAT Cooling Coil With Adjustable Chilled Water Temperature



Implementing Ultra-Efficient Optimized Control for Building Cooling Systems:

WHY?

- Achieves unparalleled high operating efficiencies
- Stable, ultra-efficient control with fault detection capabilities

HOW?

- Network driven control coordinates all equipment for optimum efficiency in response to system loads.
- Optimization contractor or partner is responsible for maintaining system efficiency by supporting operations staff

Design/Implementation Strategies for Performance Focused Technologies

1. Develop realistic “comfort map” using ASHRAE 55 and include RH control in system design.
2. Design to meet peak maximum loading but also to operate most efficiently at expected operating conditions.
3. Design and select cooling system configuration so that it can operate efficiently at the highest air and water temperatures possible to meet space conditions.

Achieving Ultra-Efficient All-Variable Speed Cooling Systems

1. Configure all-variable speed plant design and specify Optimization requirements to achieve ultra-efficient performance
2. Adapt new ***design & implementation procedures*** and optimization specialist to ensure ***performance focused*** design, construction and operations are supported.
3. Embed the requirement to monitor ***system performance*** over time to ensure success is achieved and maintained over time.

SUMMARY

- Ultra-efficient all-variable speed cooling systems are configured similarly to conventional systems.
- Network based control optimization can yield ultra-efficient and stable control for all-variable speed systems.
- Implementing ultra-efficient systems successfully requires new design procedures and practices that emphasize optimization throughout the design & implementation process, and incorporates monitoring and support services for operations staff to maintain energy performance over time.

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QUESTIONS & DISCUSSION

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