Automation and Energy Efficiency of Industrial Refrigeration Systems

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Introduction

Management thinker Peter Drucker was often quoted as saying that "**you can't** manage what **you can't measure**." Drucker means that **you can't** know whether or not **you** are successful unless success is defined and tracked.

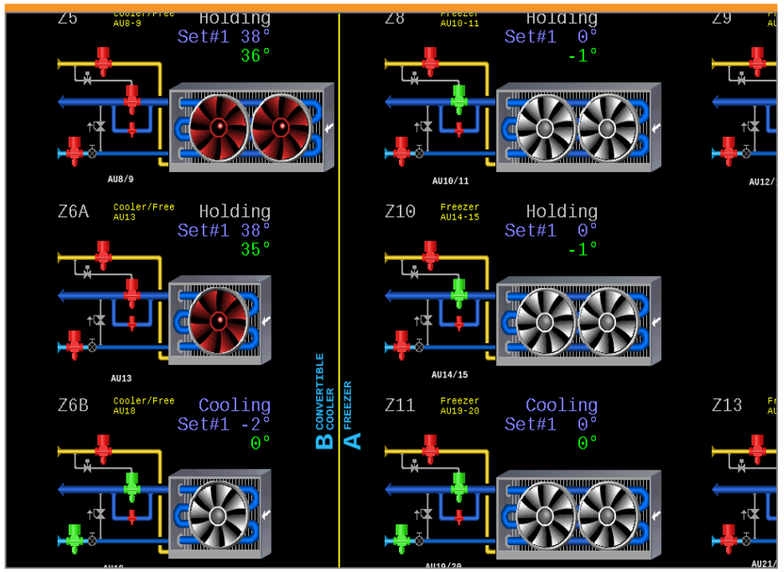
Refrigeration Basics 101: "You can't **control** what you can't **measure**."

Objective

- Objective: Extend the shelf life of a product!

- Action: Reduce and maintain the temperature of the product.

- Execution: Control the setpoint.



Temperature Control

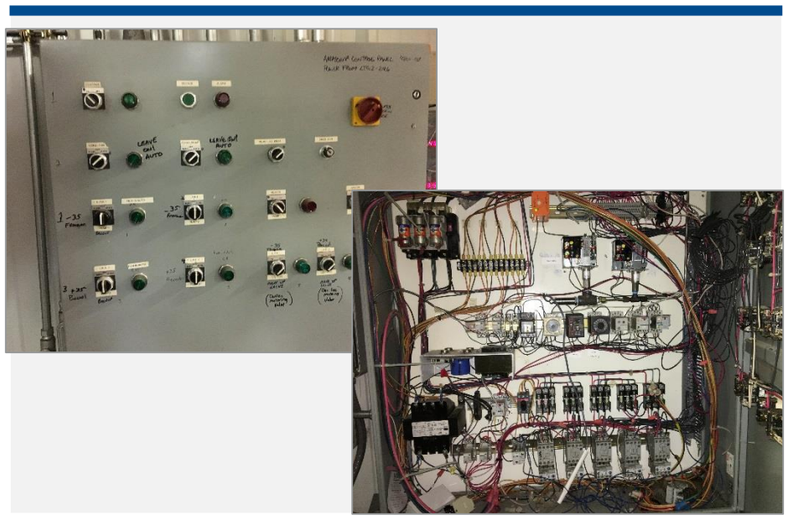
- Temperature control — if it was just that simple.
- Industrial refrigeration systems are:
  - A fundamental necessity for feeding today’s population!
  - Custom in design; no two systems are identical
  - High level of complexity — rely on engineers, contractors and trained operators to design, build and maintain
  - Large energy users — 20–60% of energy is used for food processing facility, and up to +80% for warehousing
  - High first cost capital
  - High risk — life safety, product integrity

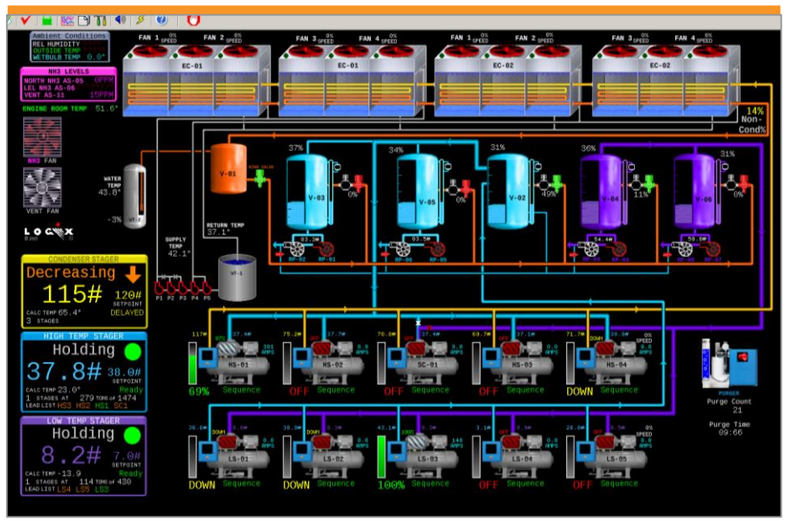
Industrial Refrigeration Control System Expectations

1. **Safety — life safety is paramount!**
   - Code compliance: ammonia, carbon dioxide, halocarbons, etc.
   - Alarming and emergency actions
   - Operator training
2. **Performance and reliability**
   - Deliver reliable heat transfer, as the refrigeration system was designed to do
   - React to alarms expeditiously and effectively
3. **Energy efficiency**
   - Deliver refrigeration as efficiently as possible

Controls Introduction

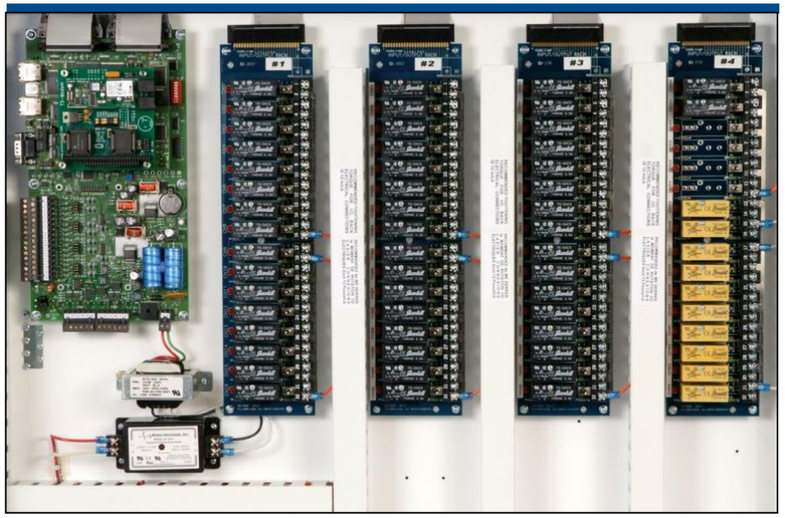
- Basic Control
  - Pressure switches, relays, thermostats, defrost clocks, switches, etc.
  - Requires continuous monitoring
  - Safety risks
  - Inefficient
- Local Control
  - Individual equipment controls: individual equipment controllers, i.e., compressor micros, electronic level control, etc.
  - Improved safety
  - Some efficiency capabilities
- Full Automation
  - Holistic approach
  - High level of safety
  - Precise control
  - Energy-efficiency capable
  - Monitoring, data logging, alarming and notification

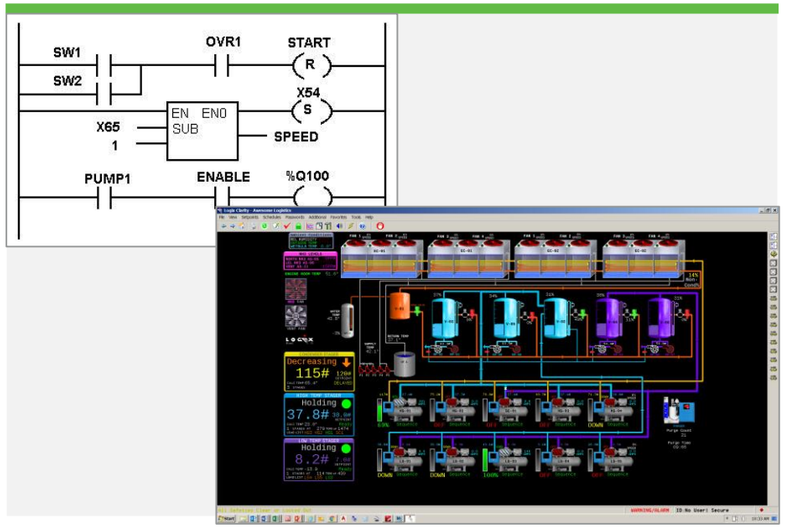


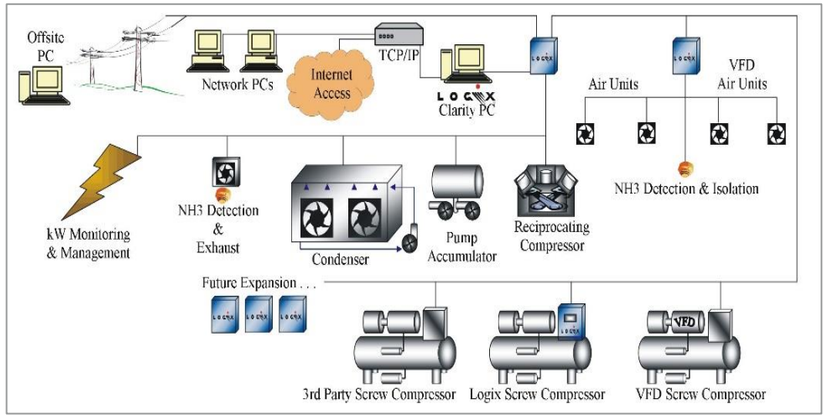


Automatic Control System Components

- Hardware
  - Controller — brains
  - Relays — digital signal
  - Switches — digital signal
  - Sensors — analog signal
  - Transducers — analog signal
- Software
  - Refrigeration control logic
    - Relay logic
    - Ladder Logix
    - Hard coding
  - Human-Machine Interface (HMI)
- Communications
  - Instruments to the controller
  - Controller to the HMI
  - Controller to third party devices
  - HMI to the facility network and internet







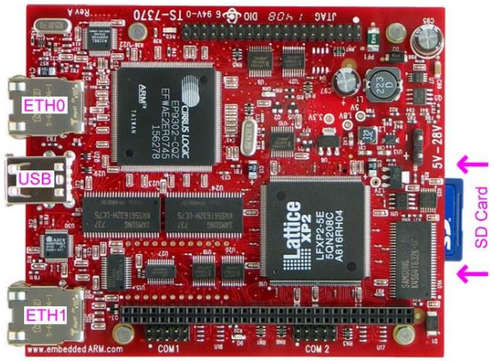
Hardware

Programmable Logic Controller

- Programmable Logic Controller (PLC)
- Originally used simple ladder logic to replace relays
- Software capability has steadily grown
- Jack of all trades: a good solution for many applications, but not great for any one

Micro Controller

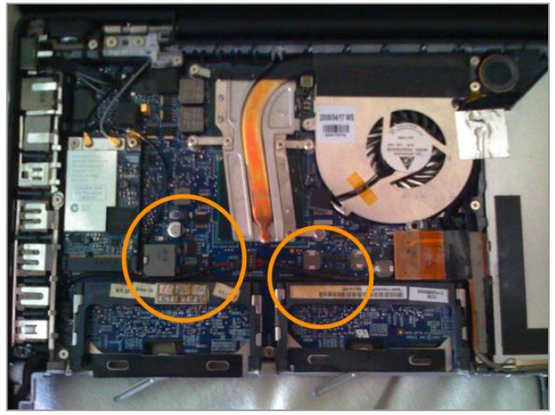
- Solid-state reliability
- Mission-specific application
- Allows sophisticated control programming



TS-7370 Axiom II CPU

Desktop Computer Control

- Inexpensive
- Desktop PCs are not industrial grade
- Subject to component failures
- Subject to Windows operating issues, viruses, etc.



Commercial Refrigeration Controls

- Commercial-grade = commercial result
- Limited feature set
- Limited capabilities and expandability

Control Software

- The satisfactory and safe control of your system is heavily dependent upon the logic developed and embedded into the controller.

- Programming should include the basic control strategies:
  - Standard refrigeration equipment control, i.e., evaporator defrost scheduling, vessel control, etc.
  - Ammonia detection and response
  - Built-in energy efficiency strategies
  - Alternate control strategies
  - Emergency shutdown and startup strategies

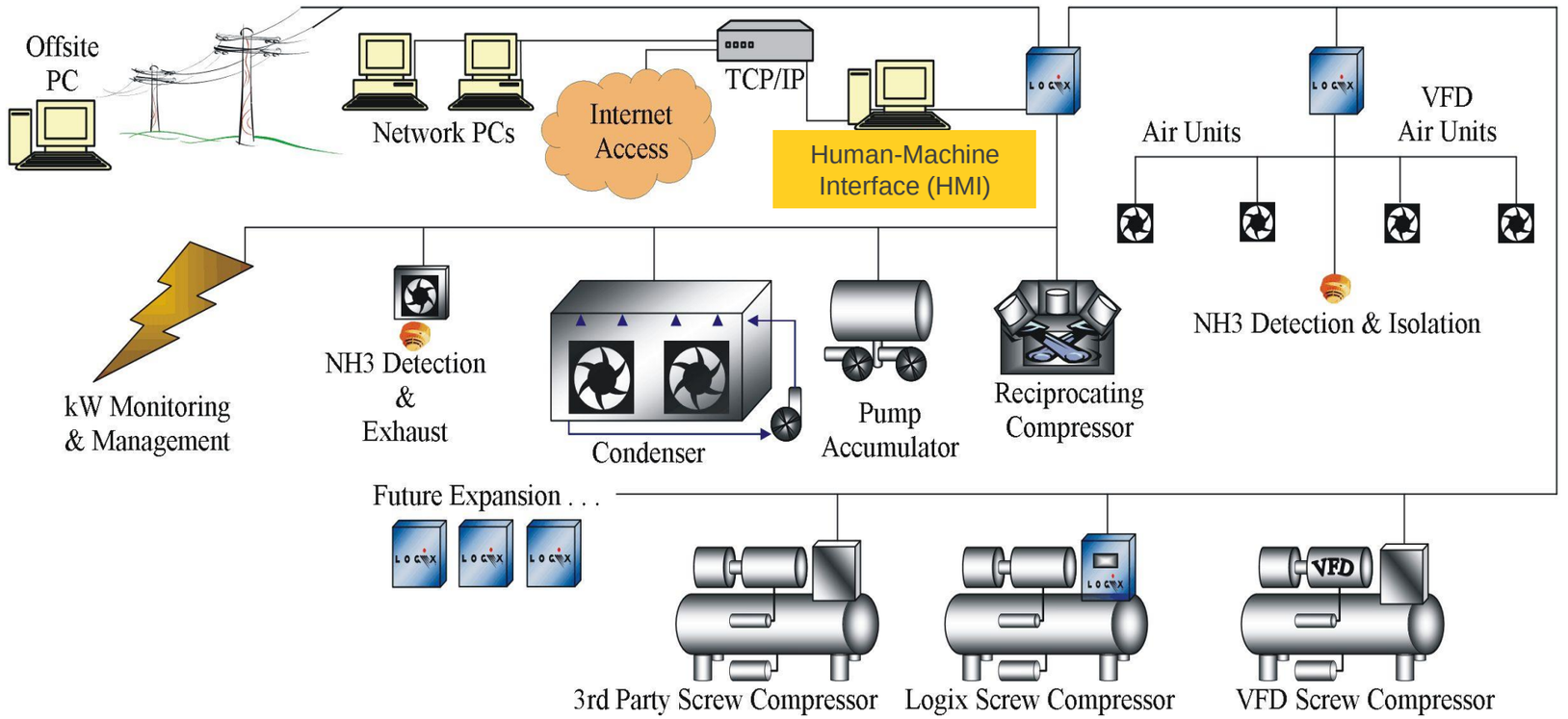
- Key points to consider when implementing a control system:
  - Develop functional description of the logic
  - Factory testing of the program with the hardware
  - Field testing prior to startup

HMI Software

- The HMI is the window to your refrigeration system
  - Easy to navigate
  - Multi-level password protection
  - Displays all settings, setpoints, conditions and states
  - Ability to log all access and setpoint changes made to the system
  - Backup data capability
  - Remote access
  - Remote alarm notification

Network Communications

- Keep the refrigeration system on its own communication network
- Integrate with third party microprocessors, i.e., compressors, spiral freezers and other equipment
- Server supports computer networking, internet access, email alarm messaging
- Phone and text remote alarm notification
- Incorporates refrigerant gas detection and response



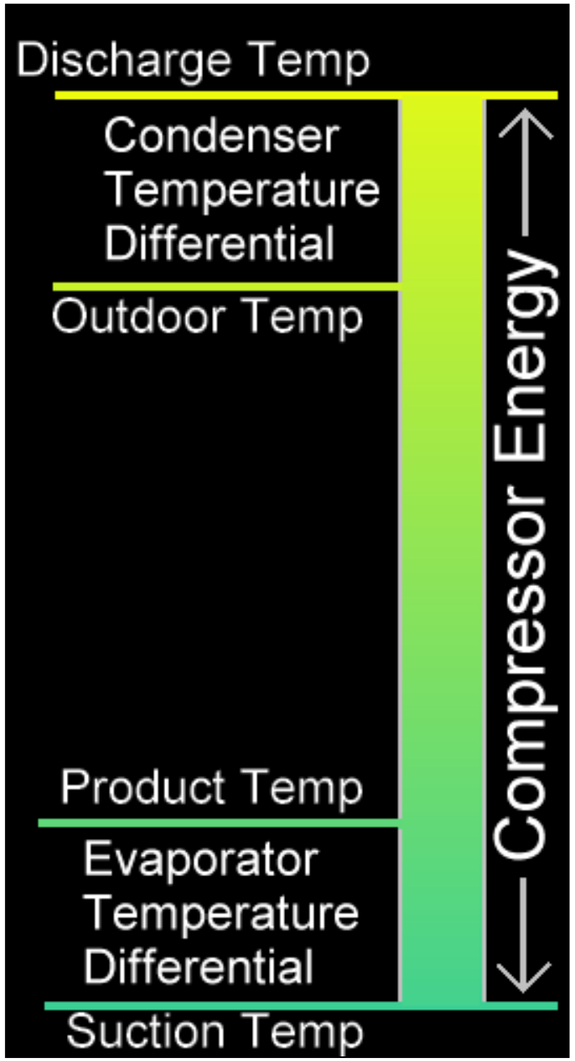
Energy Efficiency

- Automation and energy efficiency go hand in hand
  - Refrigeration systems are always in a state of flux; conditions and loads are always changing
  - Automation and energy-efficiency control strategies will reduce energy usage

Energy-Efficiency Strategies

Compressor Control

- Compressors are the biggest energy consumer in the refrigeration system.

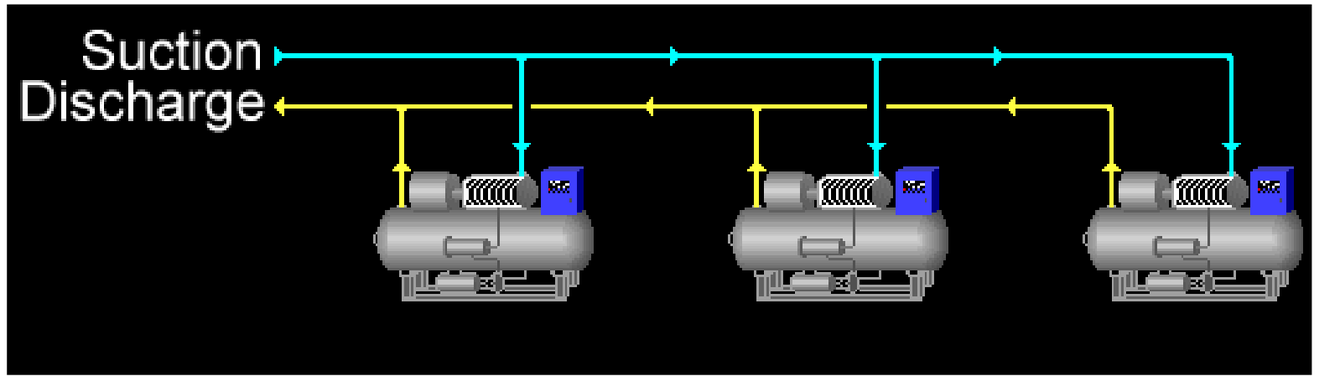


Energy-Efficiency Strategies *(cont'd.)*

Compressor Sequencing

- Staging is a coordinated control to a single objective.
- Avoid running multiple compressors at partial load.
- Keep compressors operating at 100% slide valve, and assign one compressor to be in trim mode.
- Shield compressors from erratic loads.

Screw Compressors Without Trim Control

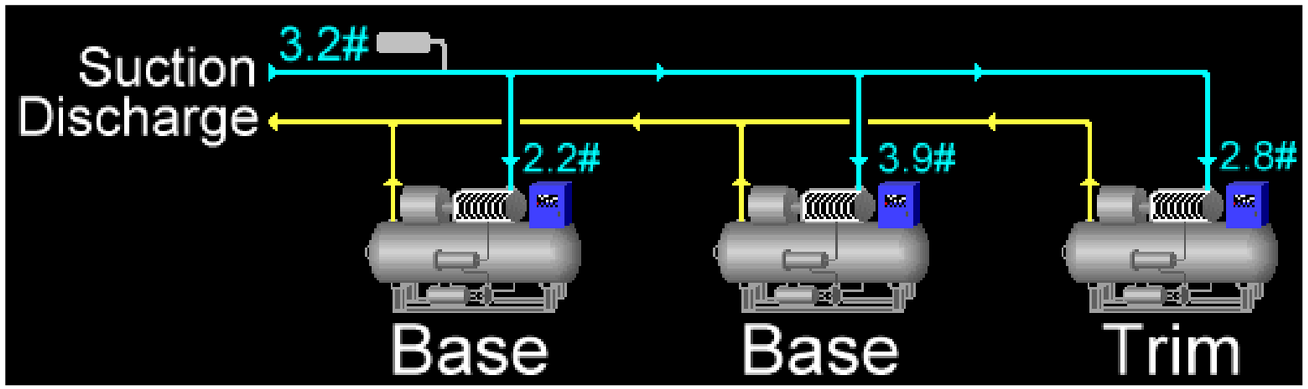


Slide valve = 4%
Motor amps = 38%

Slide valve = 24%
Motor amps = 49%

Slide valve = 44%
Motor amps = 62%

Screw Compressors With Trim Control



Slide valve = 0%
Motor amps =0%

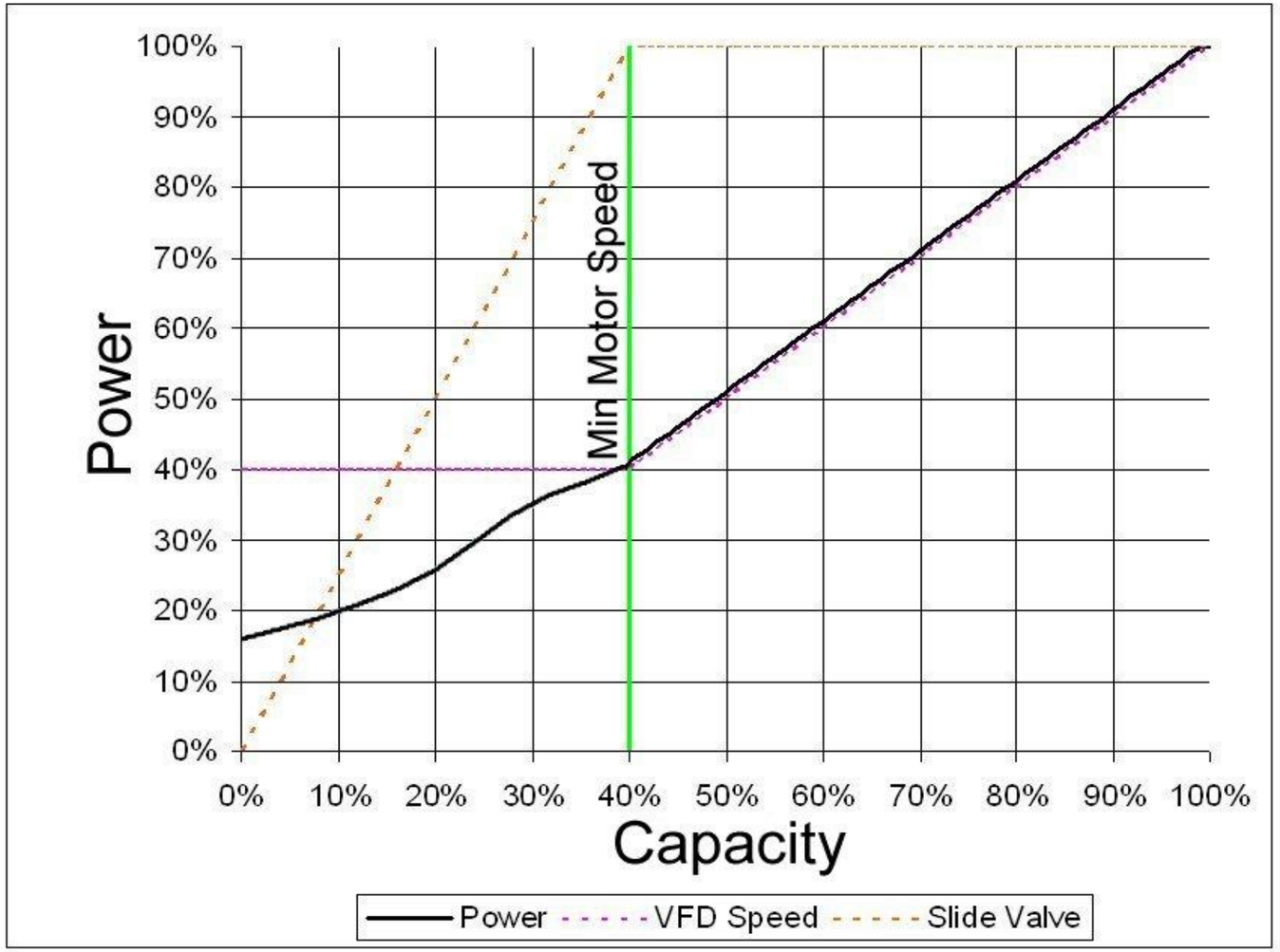
Slide valve = 100%
Motor amps = 100%

Slide valve = 44%
Motor amps = 62%

Energy-Efficiency Strategies *(cont'd.)*

Screw Compressor With Variable-Speed Drive

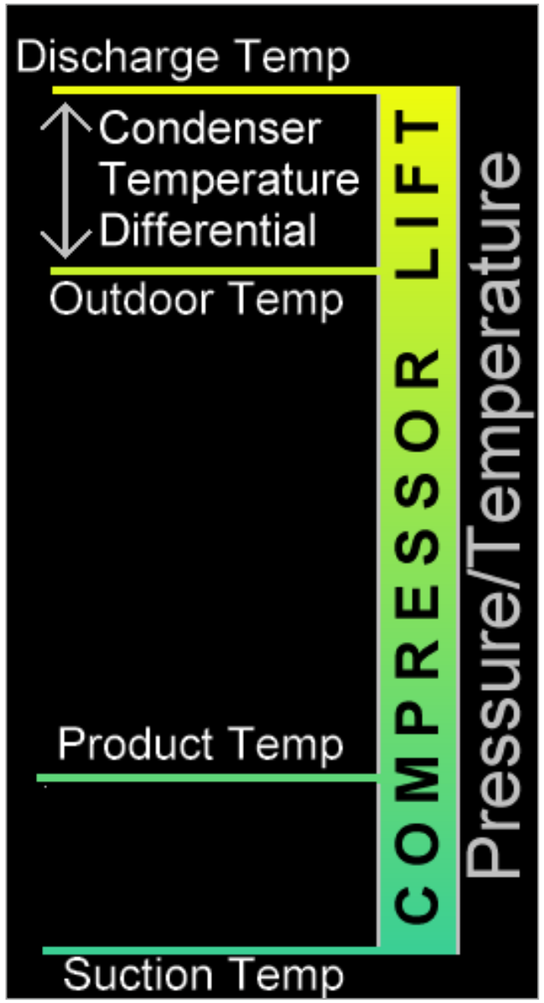
- Costly; should require a financial analysis prior to deciding.
- Payback can range from 3 to 15+ years
- VFD should be only added to a trim compressor in each suction group.
- Minimum speed limitation (~40–50%)
- Pick the largest HP compressor to provide a large throttling range.
- Retrofitting issues to existing compressors; consult the compressor package manufacturer.



Energy-Efficiency Strategies *(cont'd.)*

Condenser Control

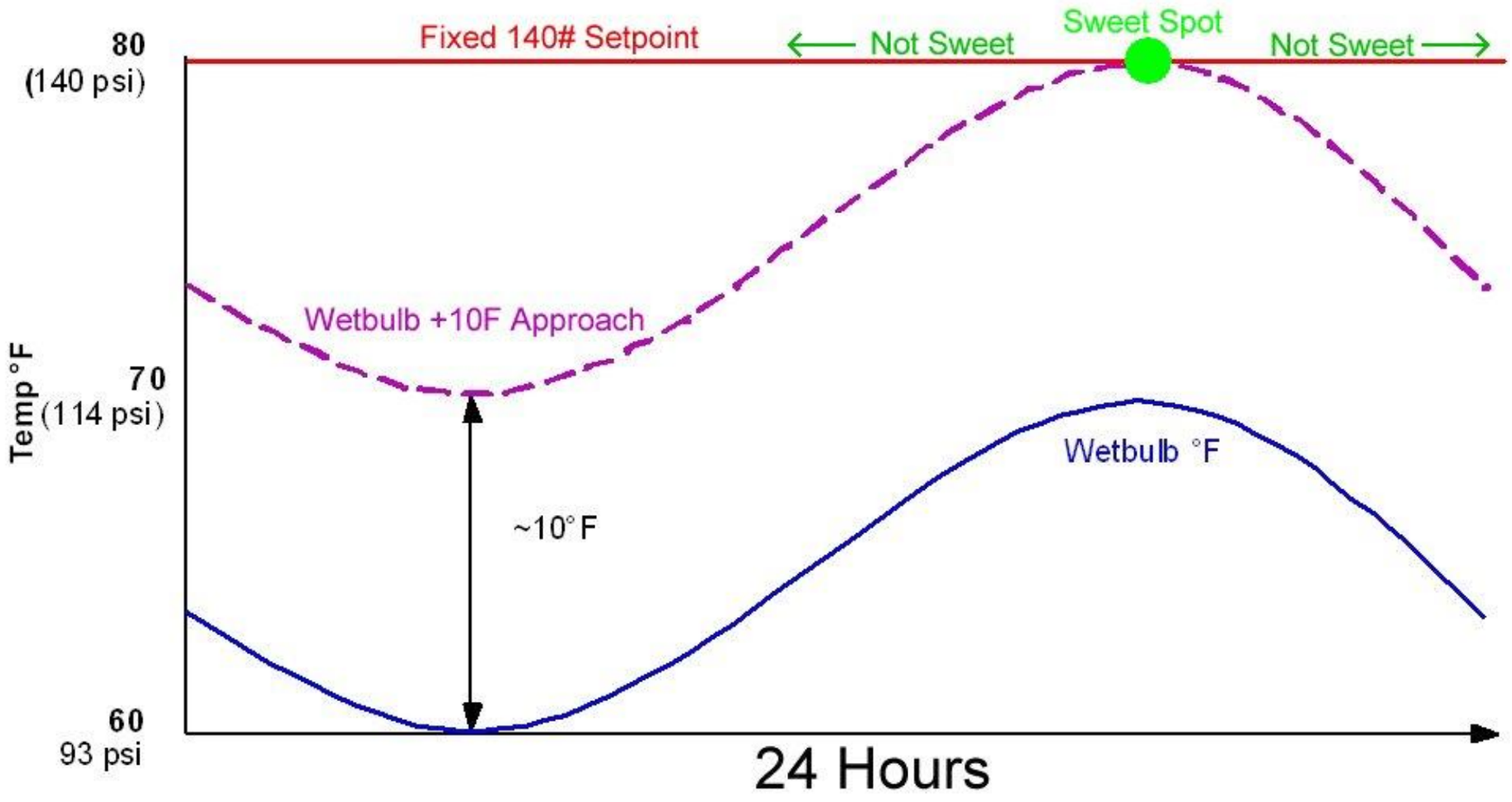
- Wet bulb is the atmosphere's true ability to absorb heat.
- Continually float staging setpoint to wet bulb.
- Avoid fan-only or pump-only operation.
- VFD fans provide a huge opportunity and control.
- Determine system minimum head pressure.



Energy-Efficiency Strategies *(cont'd.)*

Floating Head Pressure

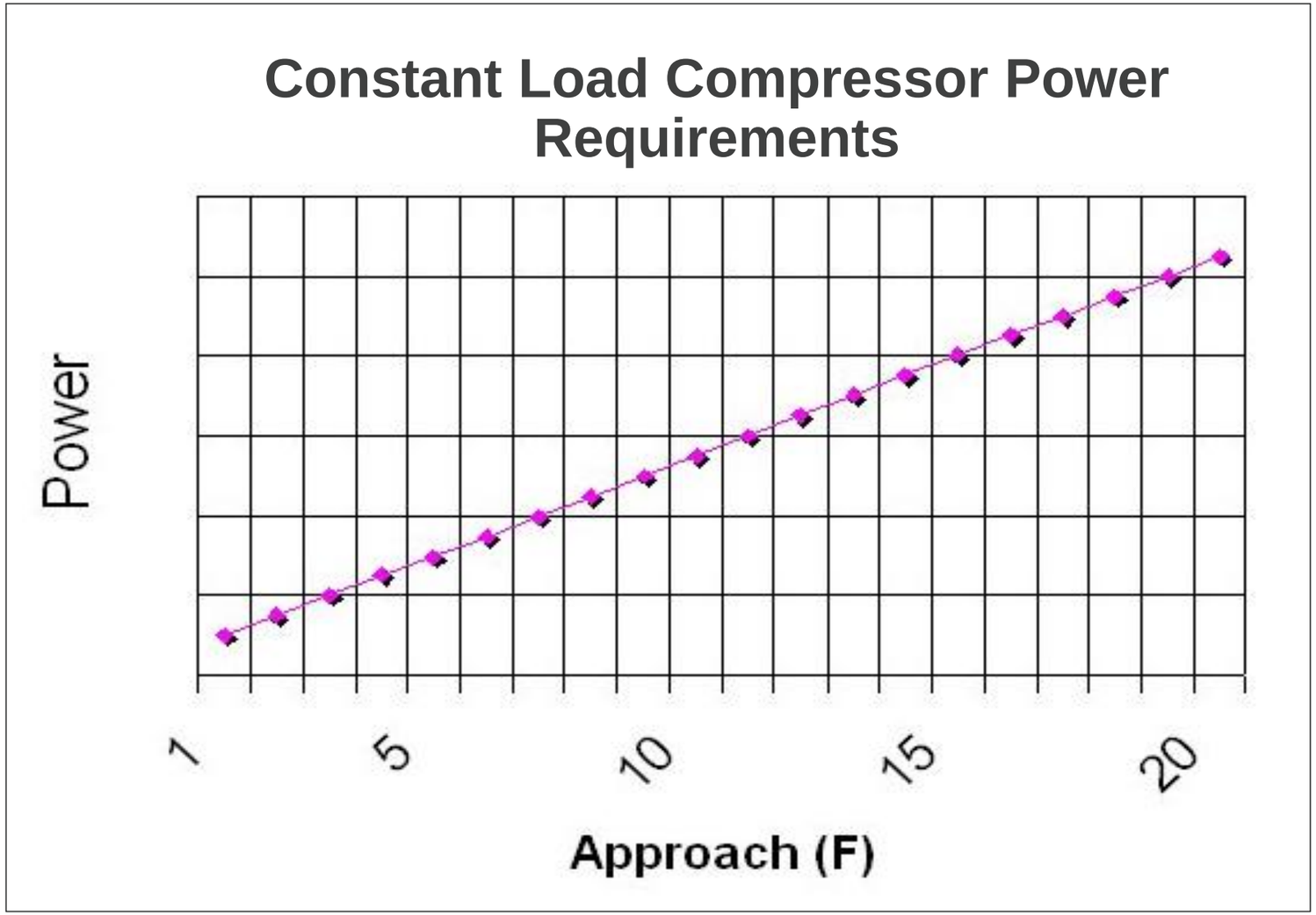
- Allow the head pressure to float with the outdoor wet bulb temperature.



Energy-Efficiency Strategies *(cont'd.)*

Floating Head Pressure

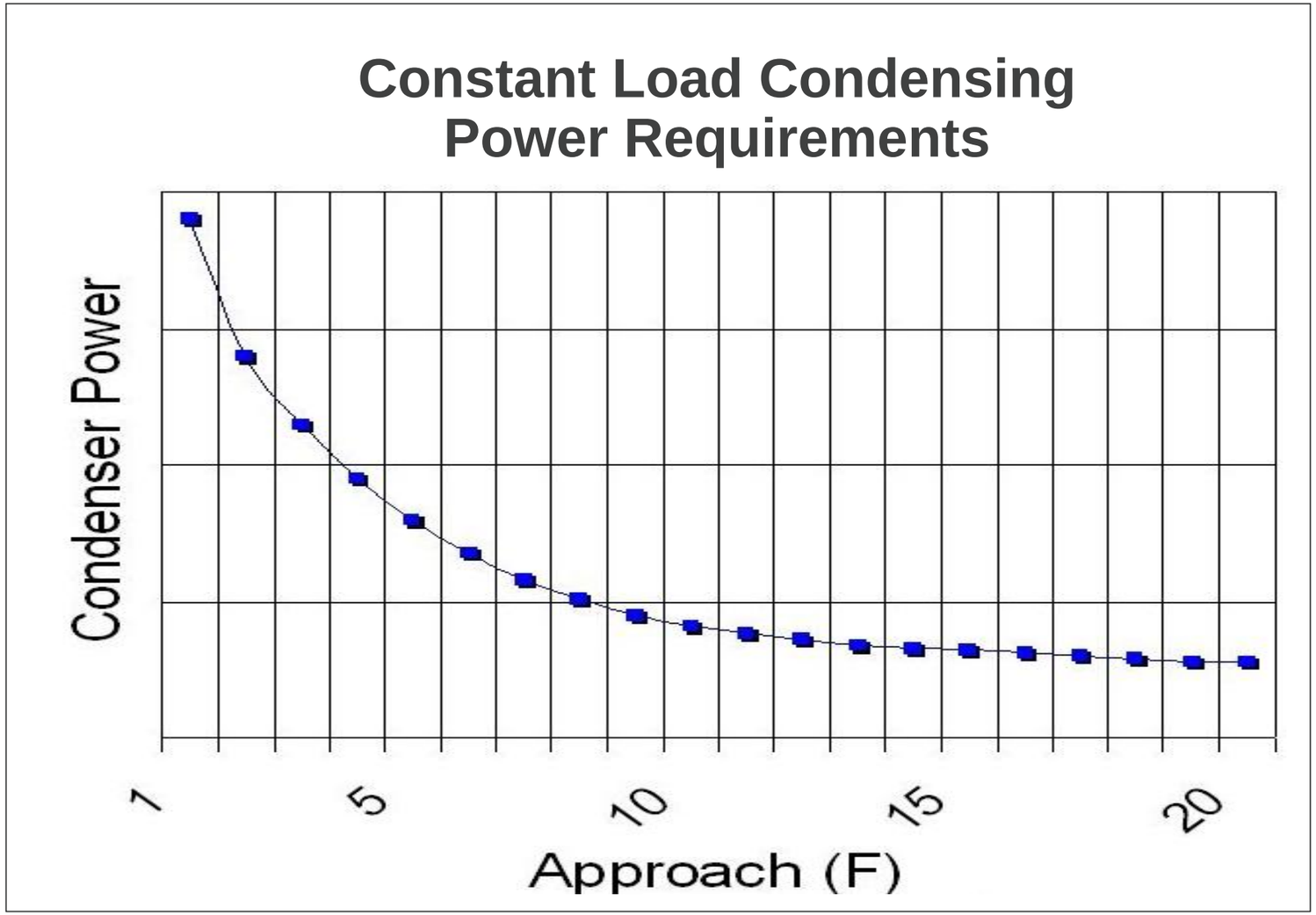
- As the approach temperature increases, the compressor power increases.



Energy-Efficiency Strategies *(cont'd.)*

Floating Head Pressure

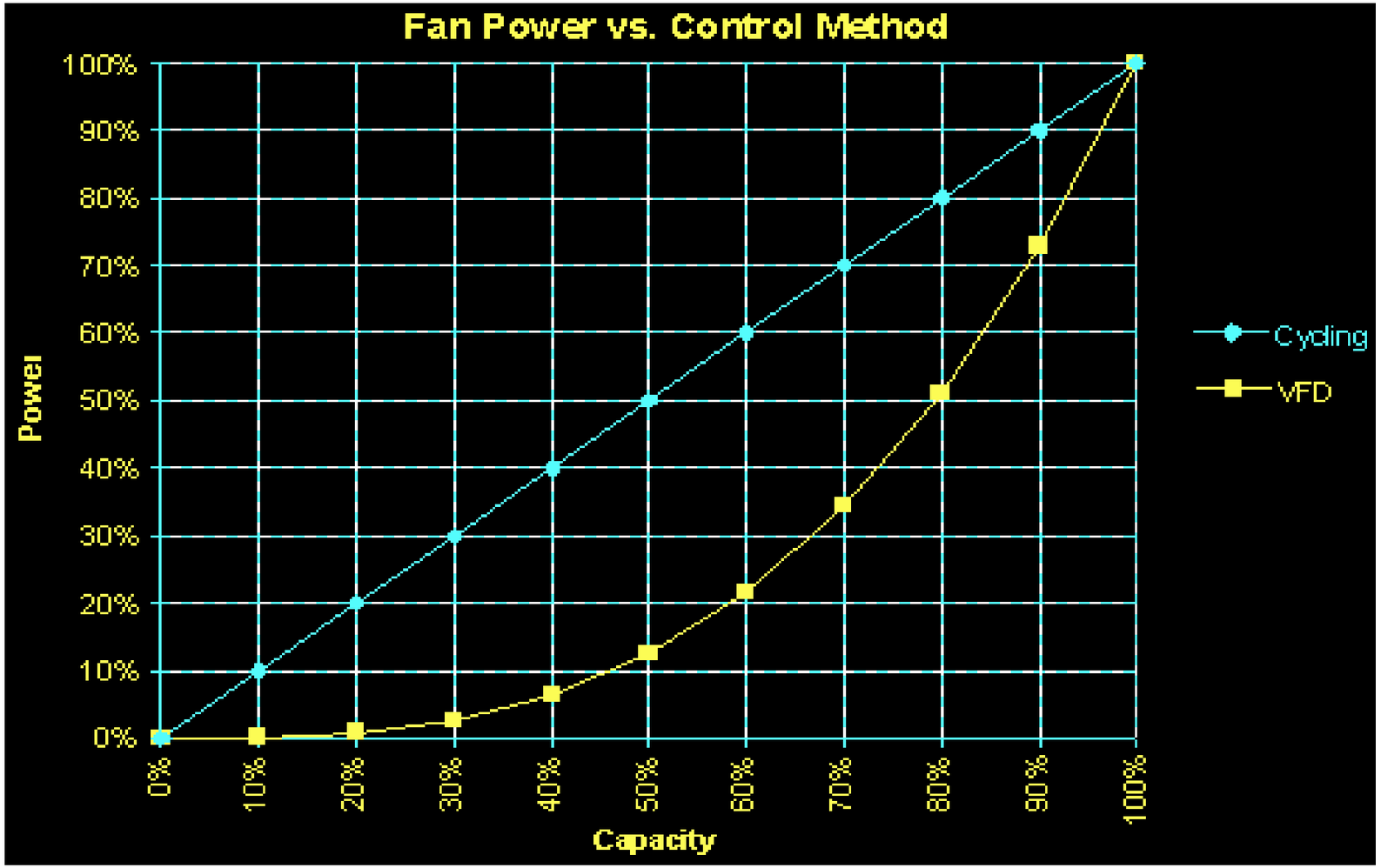
- As the approach temperature increases, the condenser becomes more efficient.



Energy-Efficiency Strategies *(cont'd.)*

Air Units

- Fan cycling
- Fan VFDs
- Defrost control



Types of Incentive Programs

- New Construction
  - Designing and executing a new construction project that exceeds a minimum baseline or government code, i.e., California's Title 24 energy-efficiency standards
- Retrofitting Existing Systems
  - Replacing older, less efficient equipment with higher efficiency — compressors, condensers, etc.
  - Adding variable-speed drives
  - Adding improved control strategies
- Retro-Commissioning
  - Retro-commissioning is fine-tuning existing buildings and systems in order to make them operate optimally and more efficiently through scheduling, sequencing, controls programming and optimizing setpoints.

Utility Incentive Programs

- Demand Response
  - Control system should have demand response capability
  - Auto DR
  - Load shedding
  - Permanent load shift

Summary

- Benefits of Enhanced Automation
  - High visibility and control for the operators
  - Improved temperature control — maintain product stability and quality
  - Alarming and notification — keep on top of operating issues
  - Life safety — minimize the risk of operating a refrigeration system
  - Energy saving and cost reduction — proven savings
  - Data logging and trending — you can’t control what you can’t measure
  - Improve equipment life — avoid driving with your brakes on
  - Reallocate labor — reduce babysitting your refrigeration system

Thank You!

Questions?