HVAC - Maintenance and Technologies

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BY

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Technology Test Centers (TTC)
Design and Engineering Services
Southern California Edison (SCE)
www.sce.com/rttc

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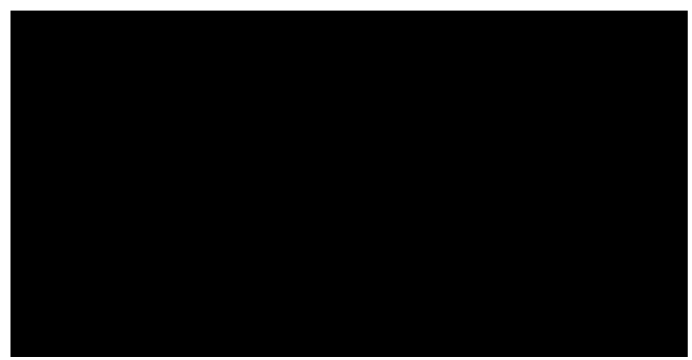
Outline

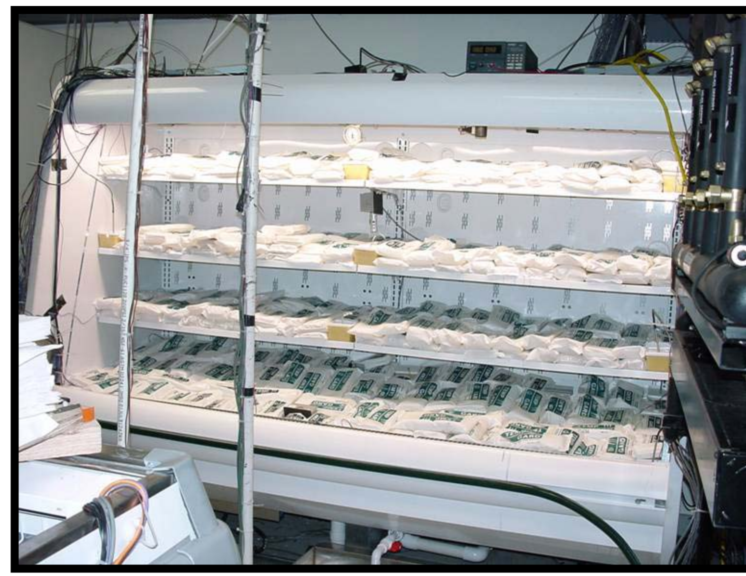
- Introduction to SCE's TTC
- Overview of energy challenges in California (CA)
- Role of HVAC in CA's energy and demand equations
- Factors affecting HVAC performance
  - Focus on SCE's research on maintenance faults
- Next generation of HVAC equipment
- HVAC technologies on SCE's TTC radar
- Black boxes – do they all work?

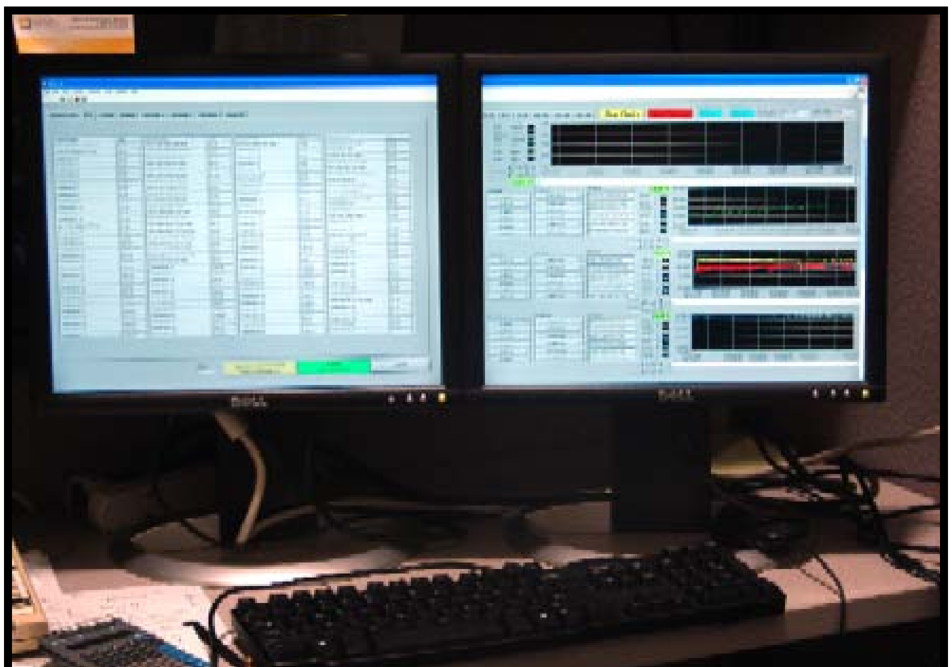
SCE's Technology Test Centers

- SCE applied research facilities located in Irwindale, CA comprised of 3 test beds:
  - Refrigeration
  - HVAC
  - Lighting
- Coming Soon! - A new ZNE lab

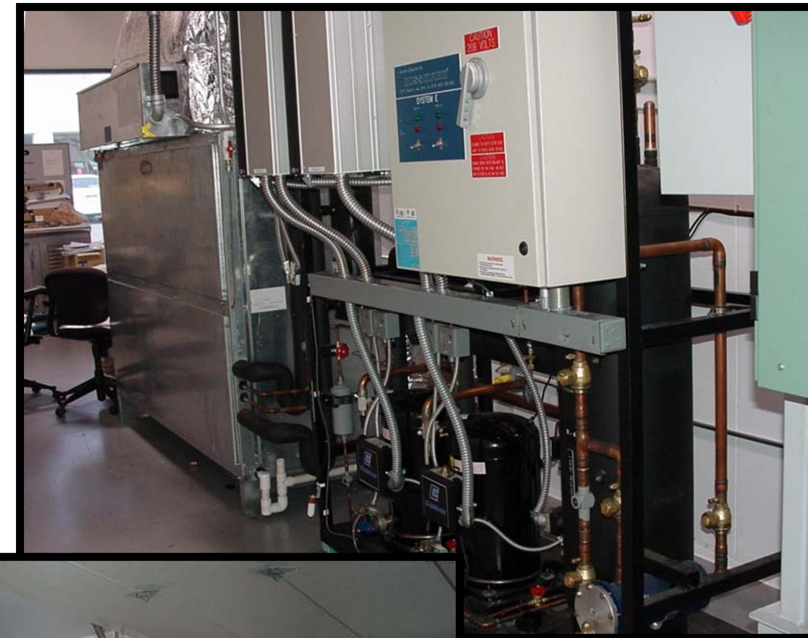


Refrigeration Testing

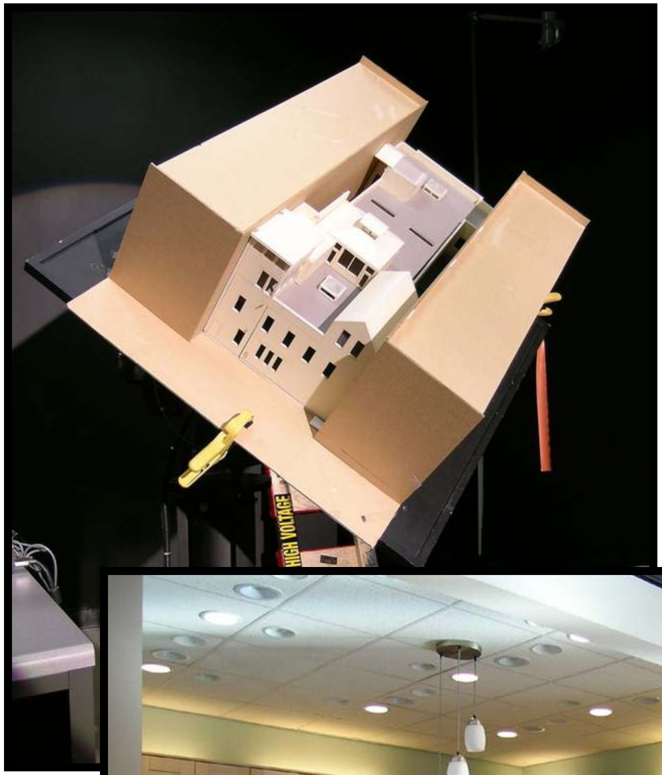


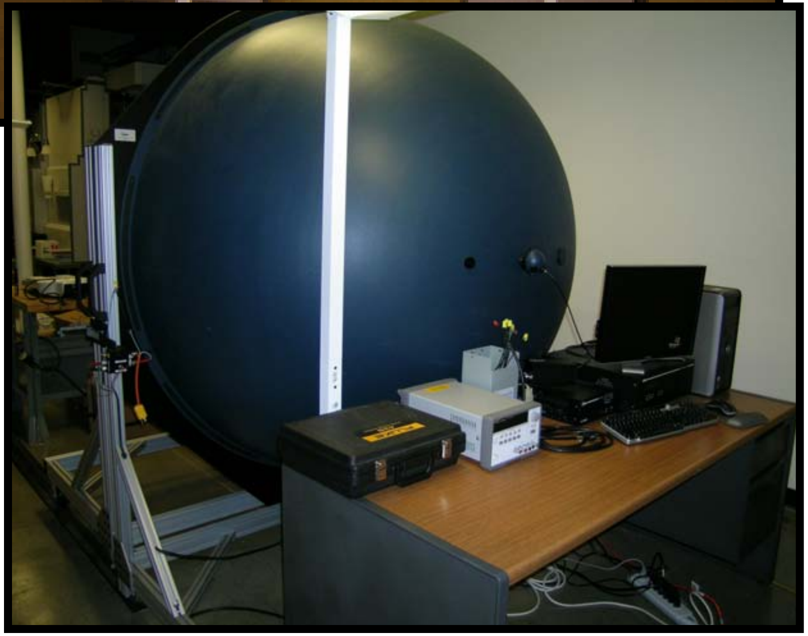


HVAC Testing



Lighting Testing

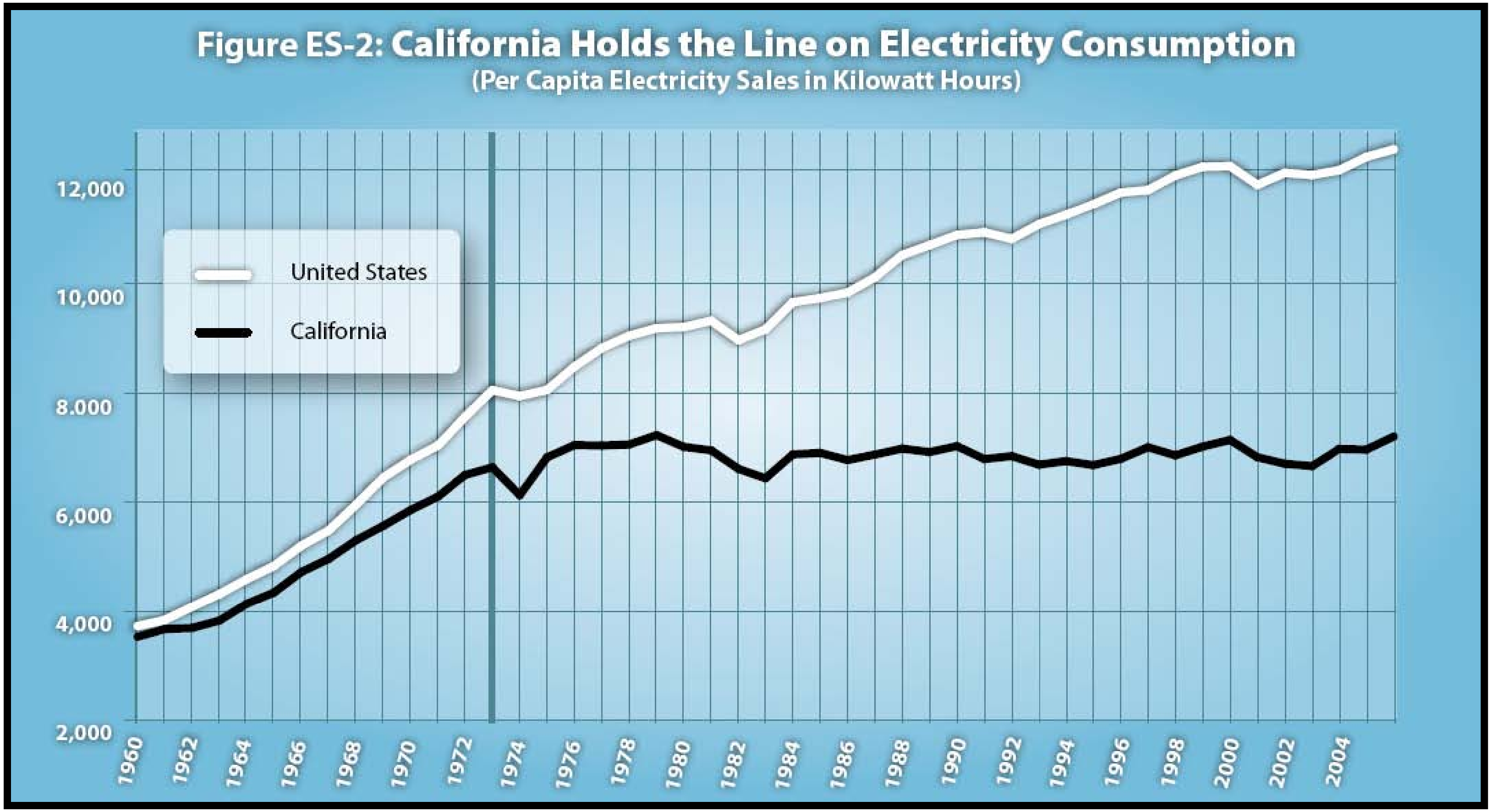




Future of Energy Efficiency in California

- Climate change initiatives are drivers
  - California Assembly Bill 32 (AB 32)
    - Greenhouse gas (GHG) be reduced to
      - 1990 levels by 2020
      - 80% below 1990 level by 2050
- DSM transition to IDSM and renewable generation
- By 2020 all new residential buildings and by 2030 all new construction commercial buildings must be Zero Net Energy (ZNE)
- HVAC systems to be tailored to California's hot and dry climate

California – A Leader in Energy Efficiency



Source: California Energy Commission (2007 Integrated Energy Policy Report, Page 3)

….but its still not enough.

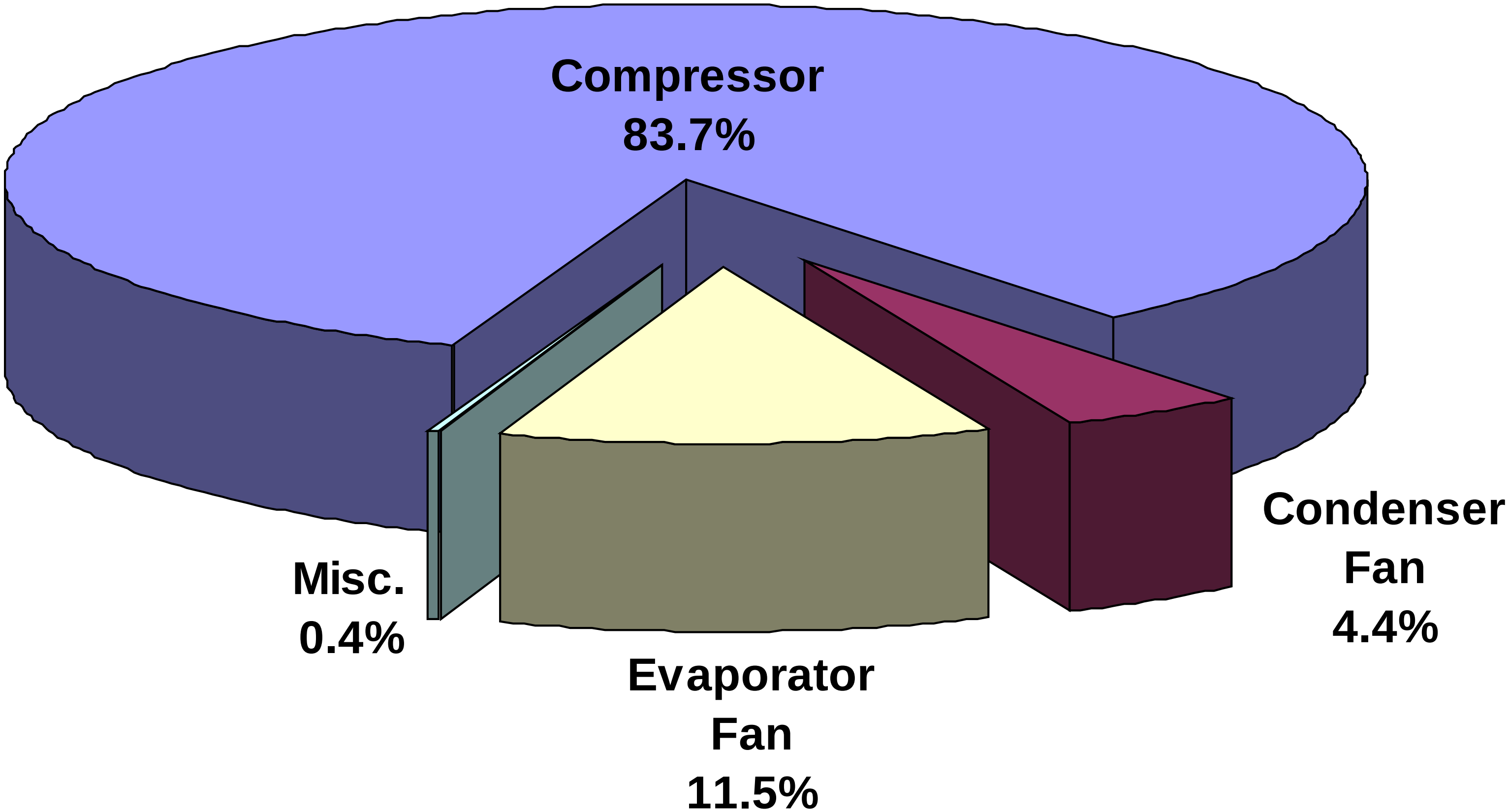
ZNE -A Key Step To Achieve GHG Goals

California and HVAC Facts...

- Peak electric demand nearly ~50,000 MW and is increasing ~1-3.5% annually
- Air conditioning constitutes ~30% of CA's peak electric load
- Air conditioner compressor consumes the most power
- Compressor power consumption increases when the ambient temperature is high
- Overlooked maintenance accounts for ~ 10% of A/C energy use
- Refrigerant leakage from A/C units is equivalent to 8.8 million metric tons of CO_2 per year

Typical RTU Power Demand

(SCE's test data measured for ARI 115°F ambient test – average of six units)

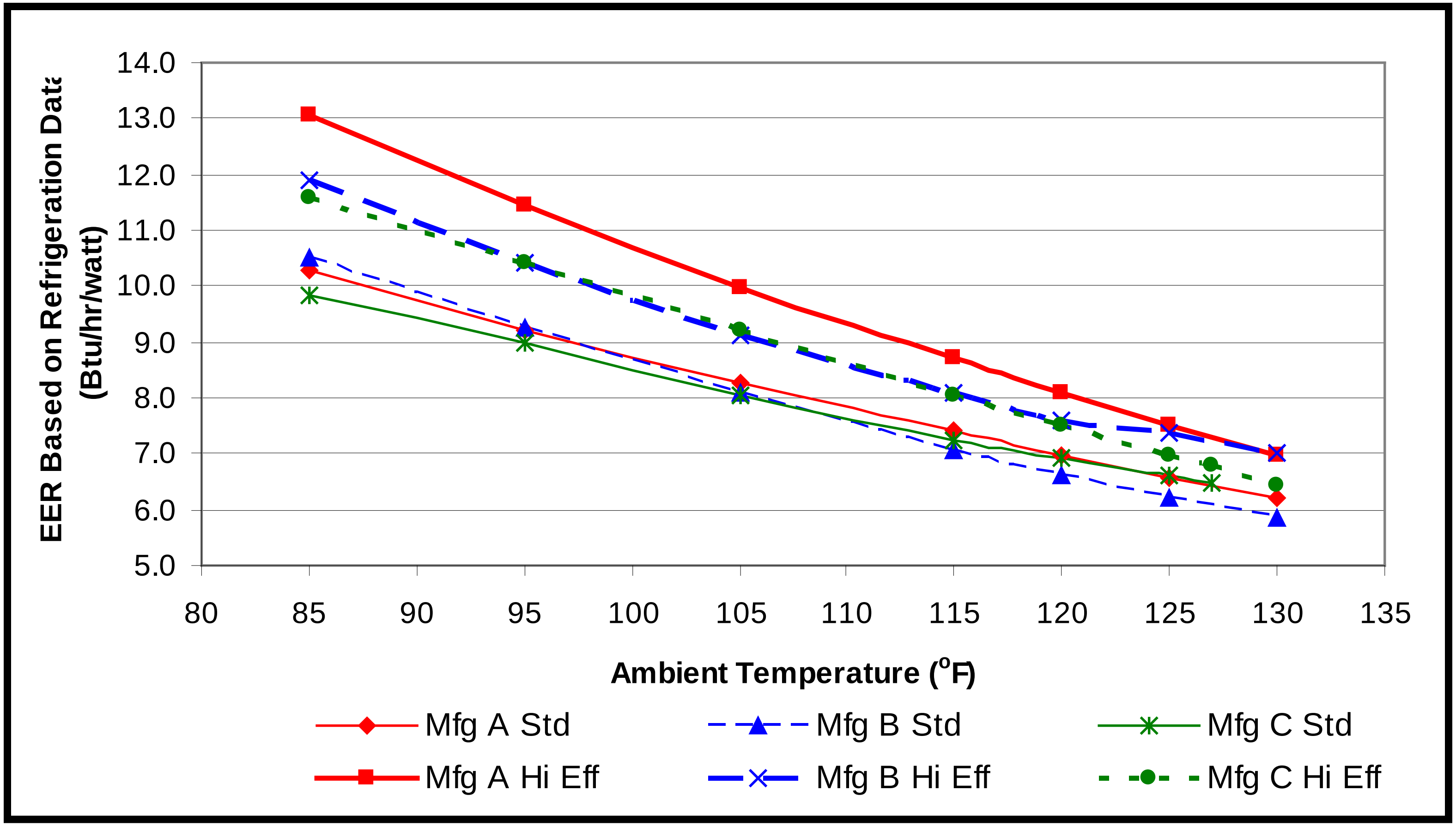


Key Parameters Affecting HVAC Performance

- Ambient Conditions
- Maintenance
- Effectiveness of energy efficiency features

Effects of High Ambient Temp on EER

(SCE's test results)



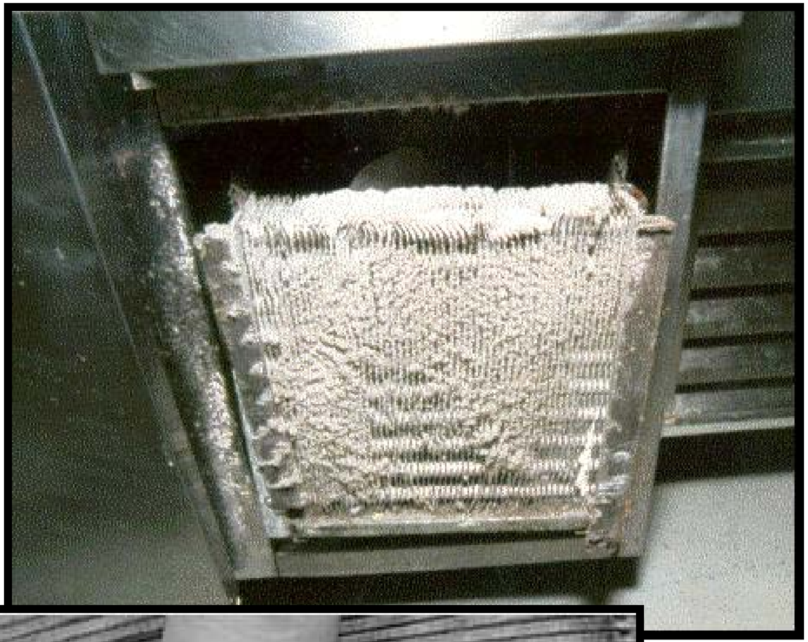
- At high ambient temperatures:
  - Compressor power increases
  - Cooling capacity decreases

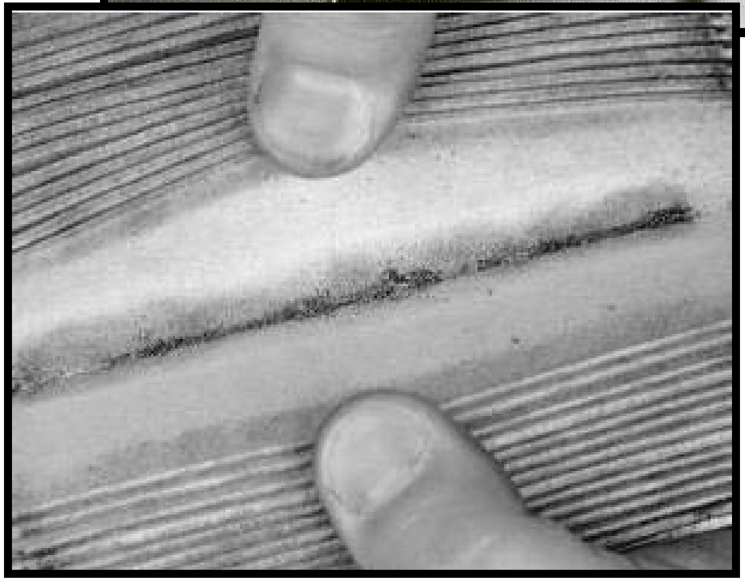
Effects of Overlooked Maintenance

(based on tests conducted at SCE's TTC)

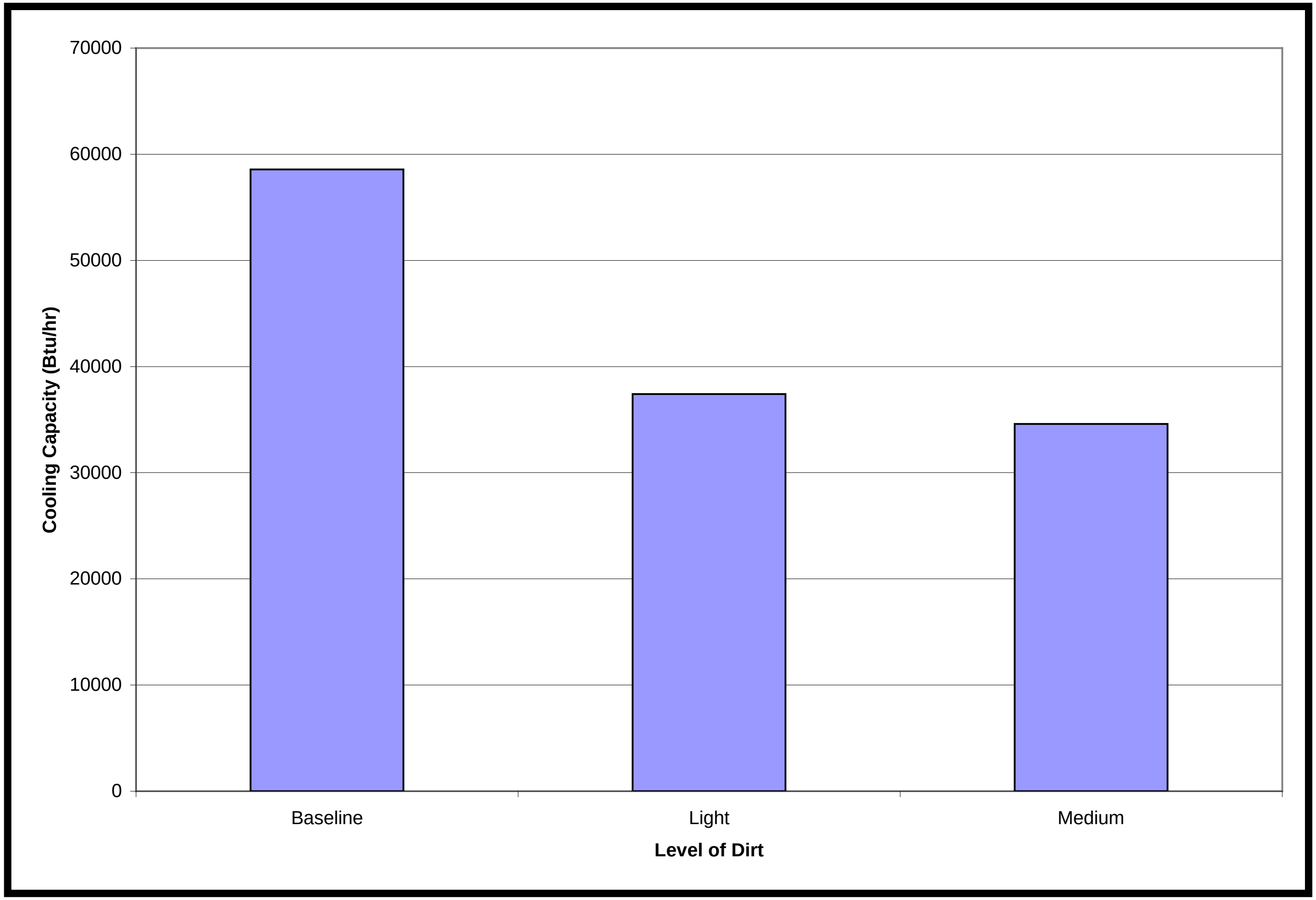
Common HVAC Faults

- Dirty evaporator coils
- Dirty air filters
- Dirty condenser coils
- Improper refrigerant charges
- Malfunctioning economizers
- Incorrect fan settings
- Refrigerant line cloggage



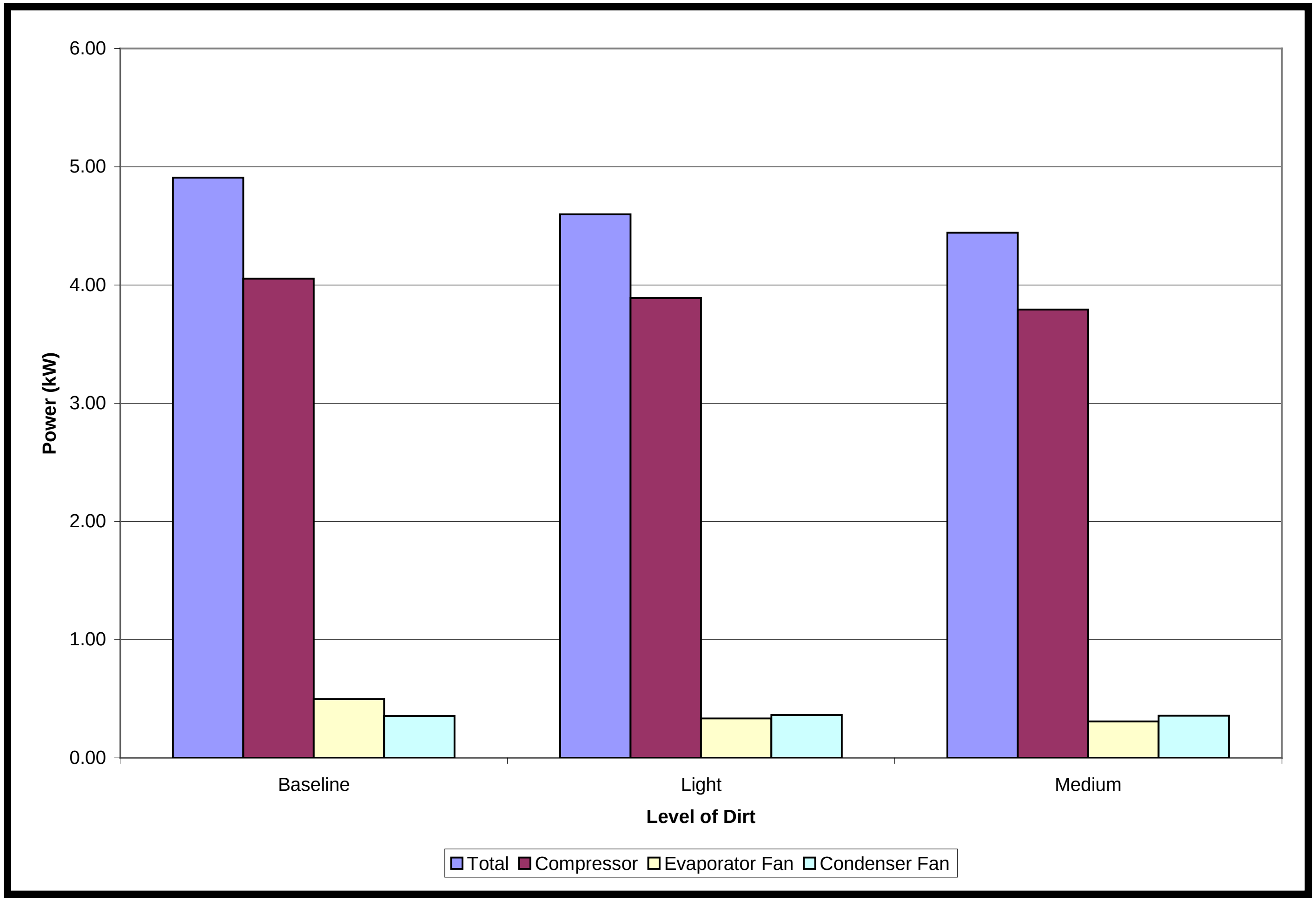


Dirty Evaporator Coil Impact on Cooling Capacity



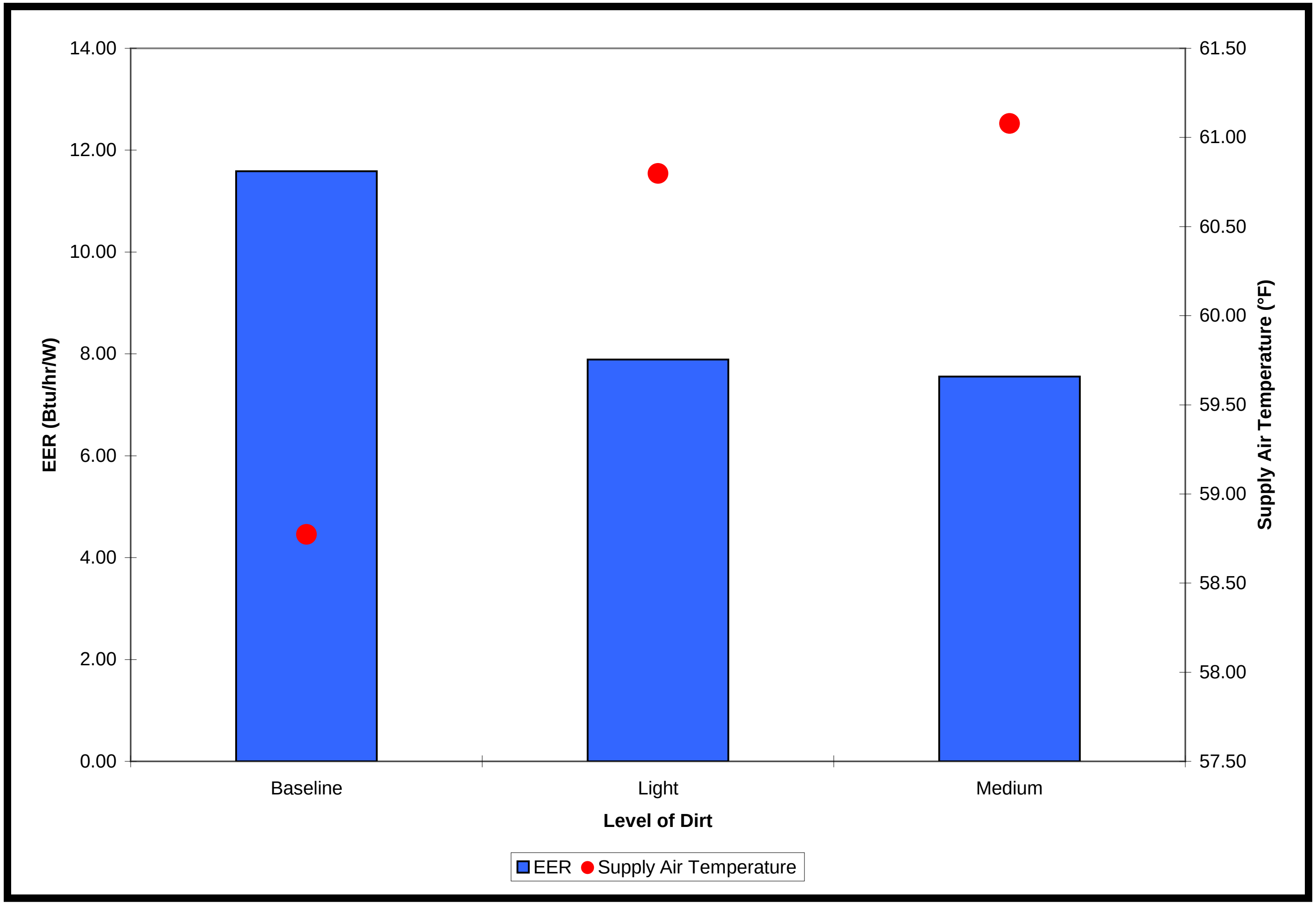
- Cooling capacity was degraded by as much as ~40%

Dirty Evaporator Coil Impact on Power



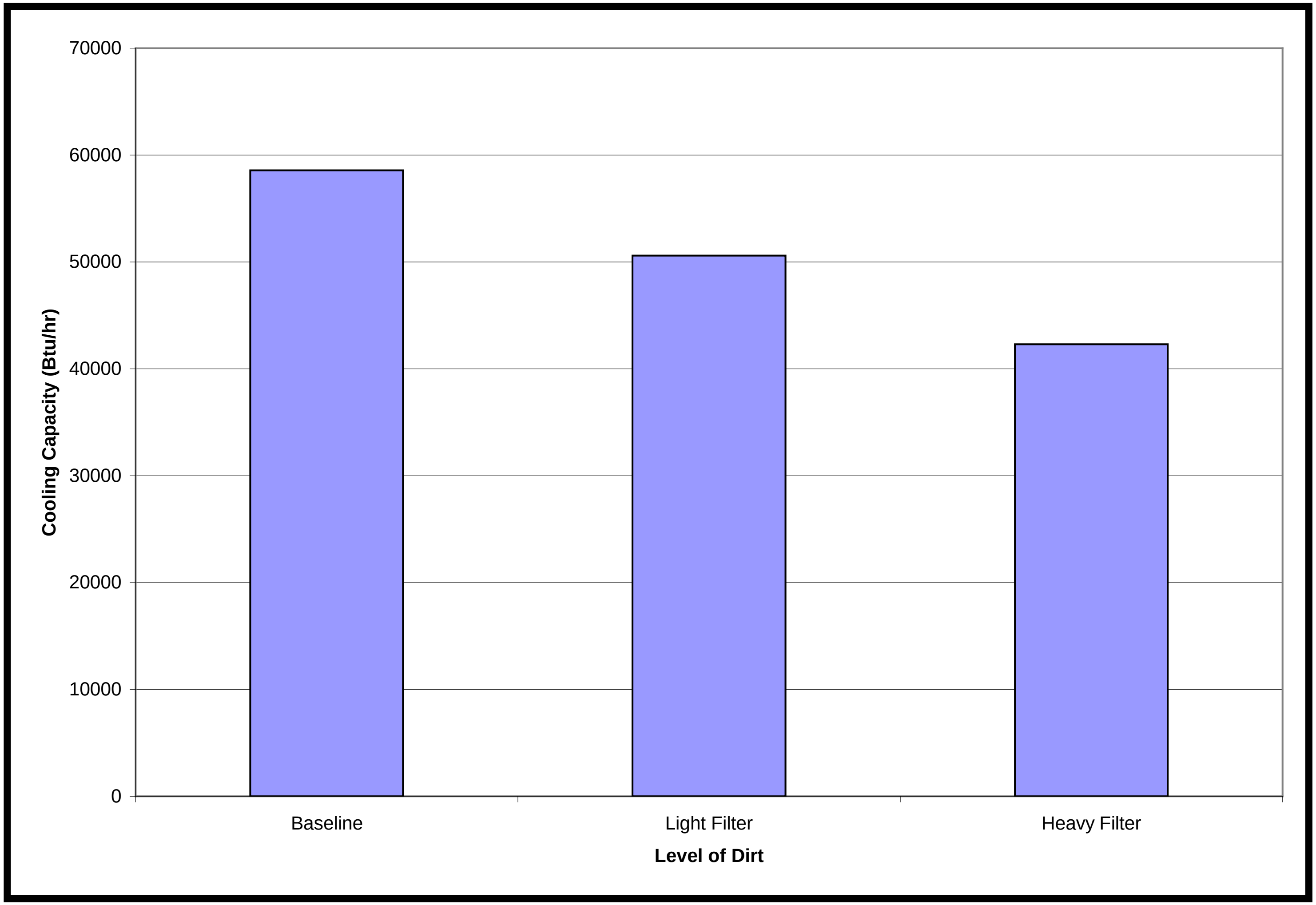
- Compressor power was reduced by as much as ~7%
- Evaporator fan power was reduced by as much as ~40%
  - Supply CFM was reduced by ~75% due to evaporator cloggage

Dirty Evaporator Coil Impact on Efficiency and Supply Air Temperature



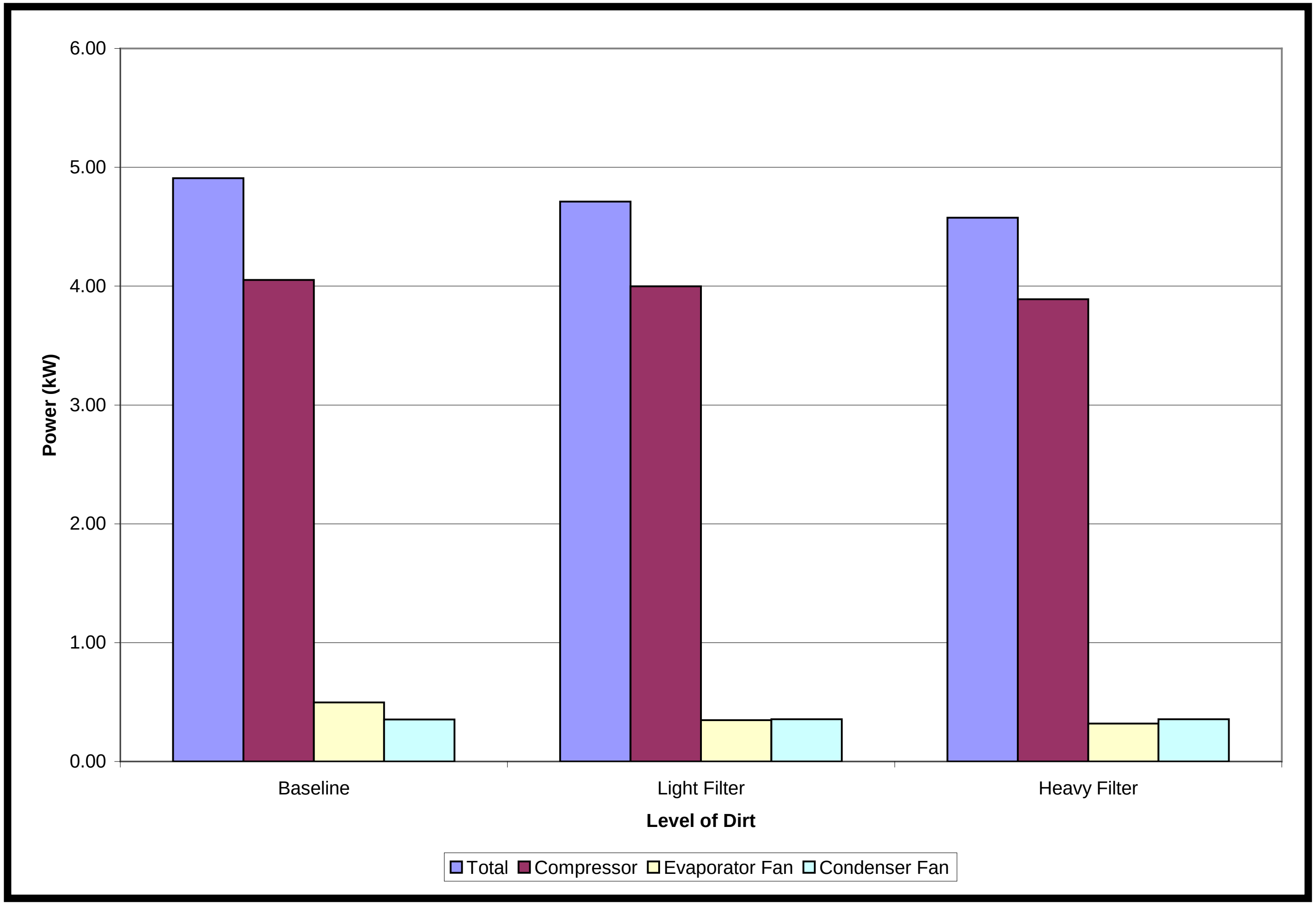
- EER was reduced by as much as ~35%
- Supply air temperature was increased by ~2ºF

Dirty Air Filter Impact on Cooling Capacity



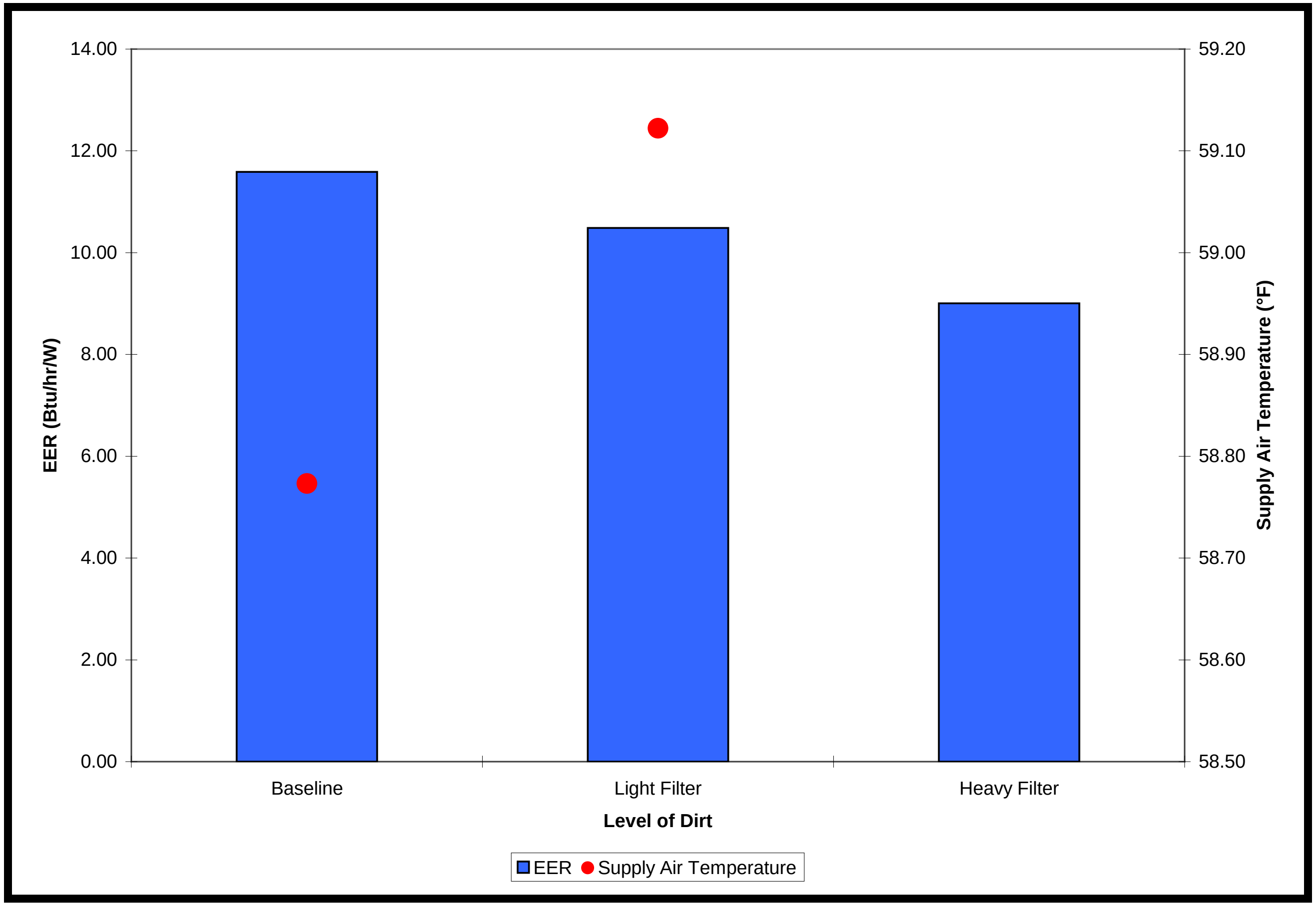
- Cooling capacity was degraded by as much as ~30%

Dirty Air Filter Impact on Power



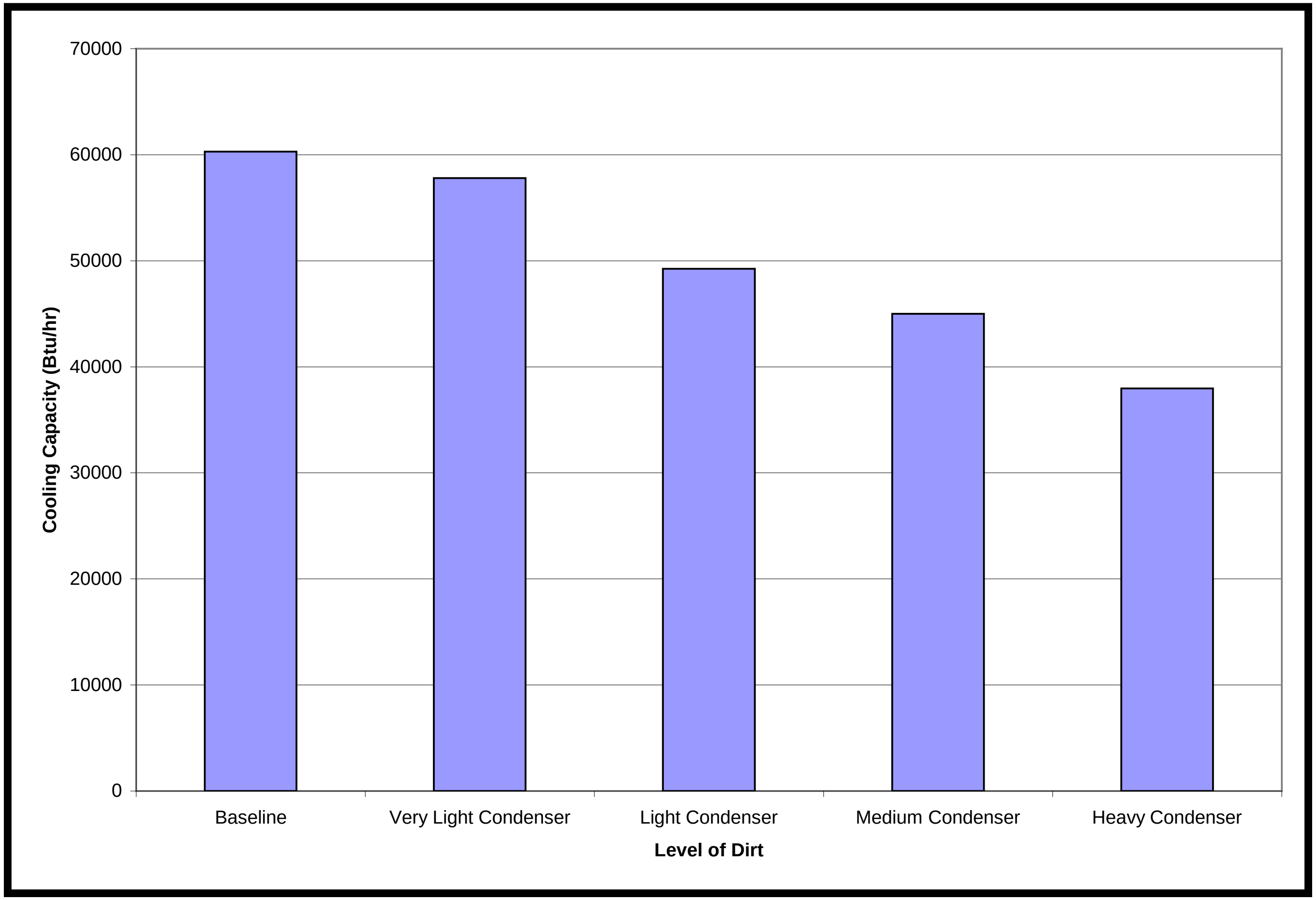
- Compressor power was reduced as much as ~4%
- Evaporator fan power was reduced by as much as ~35%
- Condenser fan power remained constant

Dirty Air Filter Impact on Efficiency and Supply Air Temperature



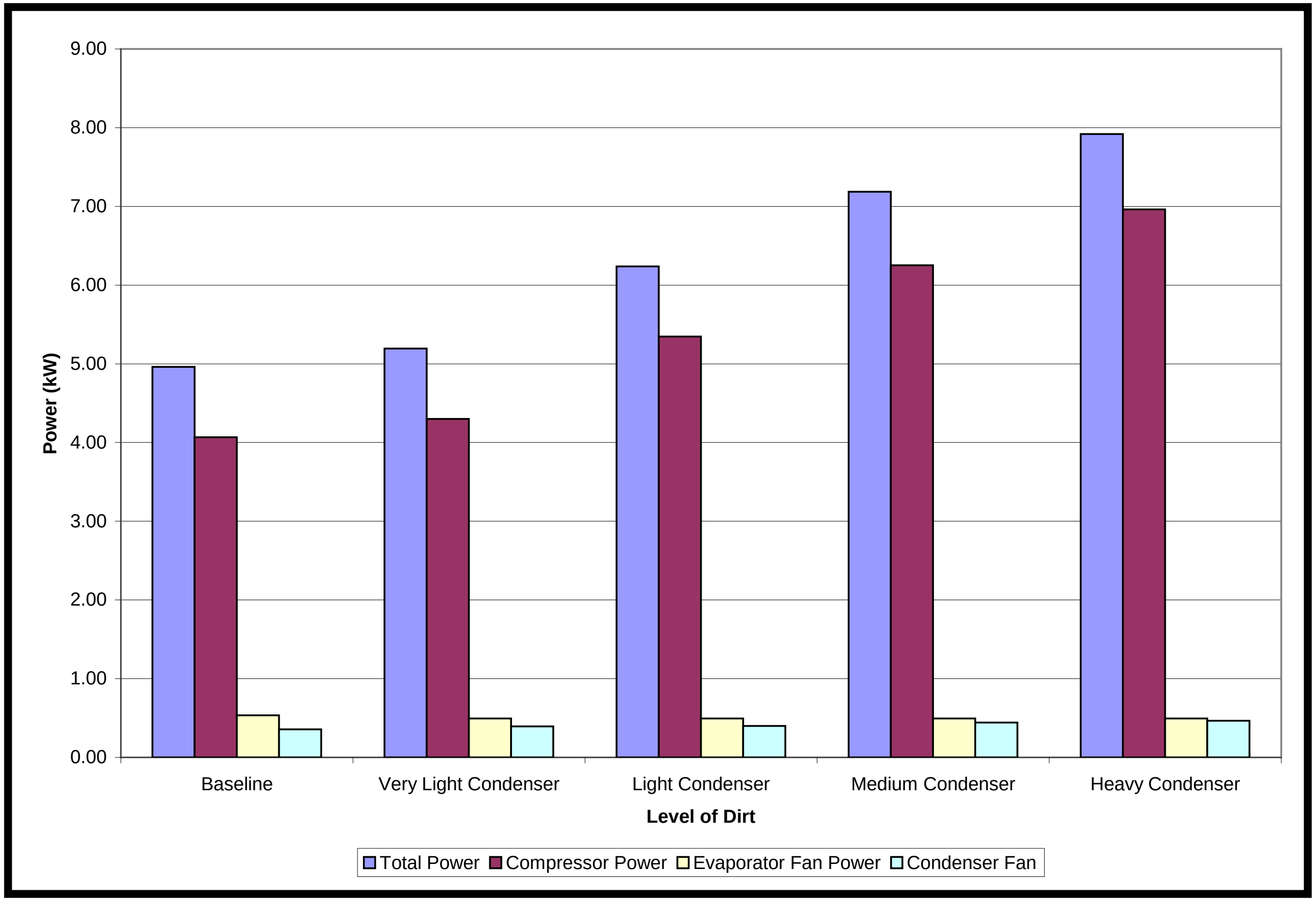
- EER was reduced by as much as ~20%
- SAT was increased ~0.5°F at the light condition, at grater levels of dirt this data determined to not be valid

Dirty Condenser Coil Impact on Cooling Capacity



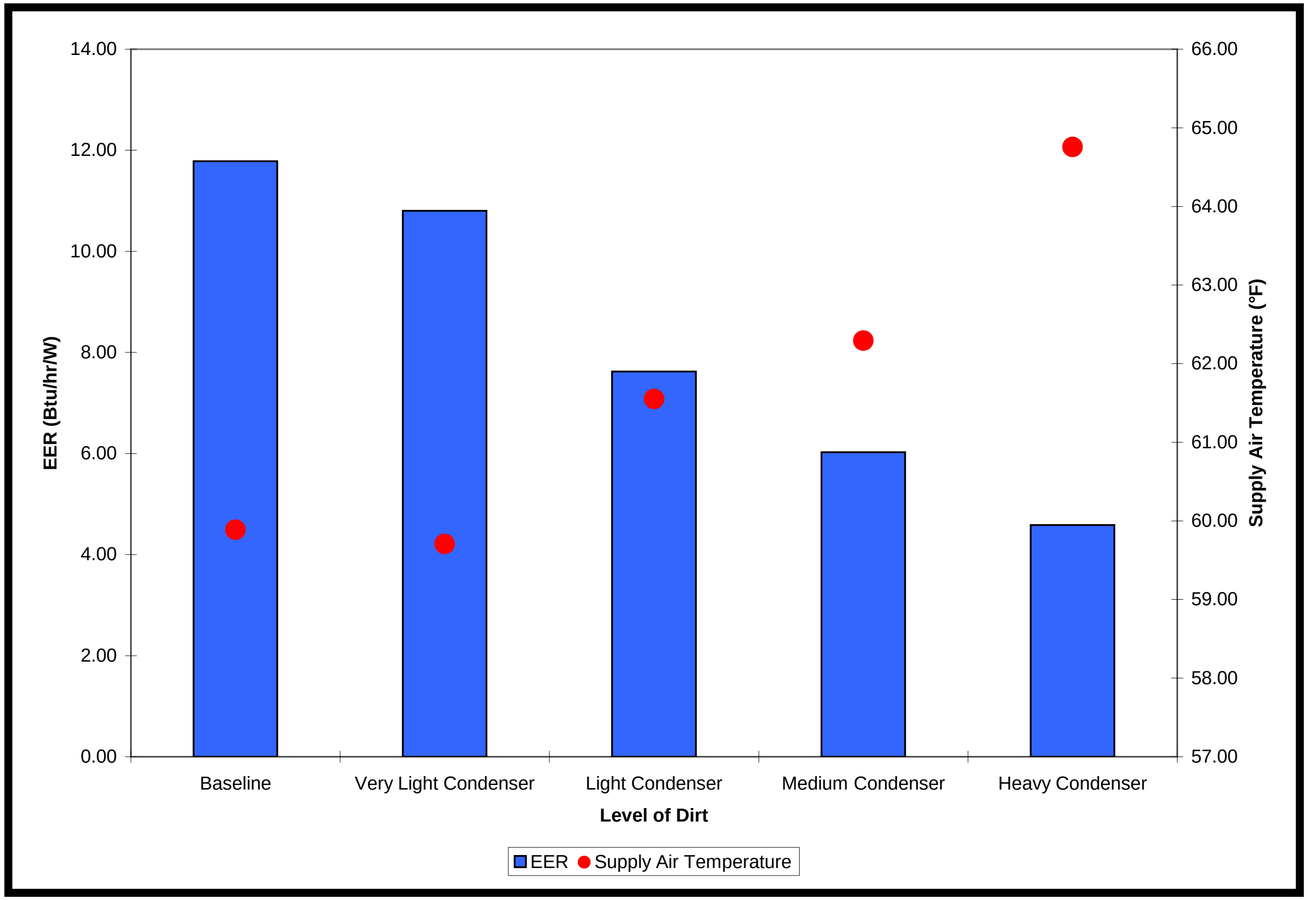
- Cooling capacity was degraded by as much as ~40%
  - An increase of ~60% in discharge pressure caused a decrease in refrigeration effect of ~30%, impacting capacity

Dirty Condenser Coil Impact on Power



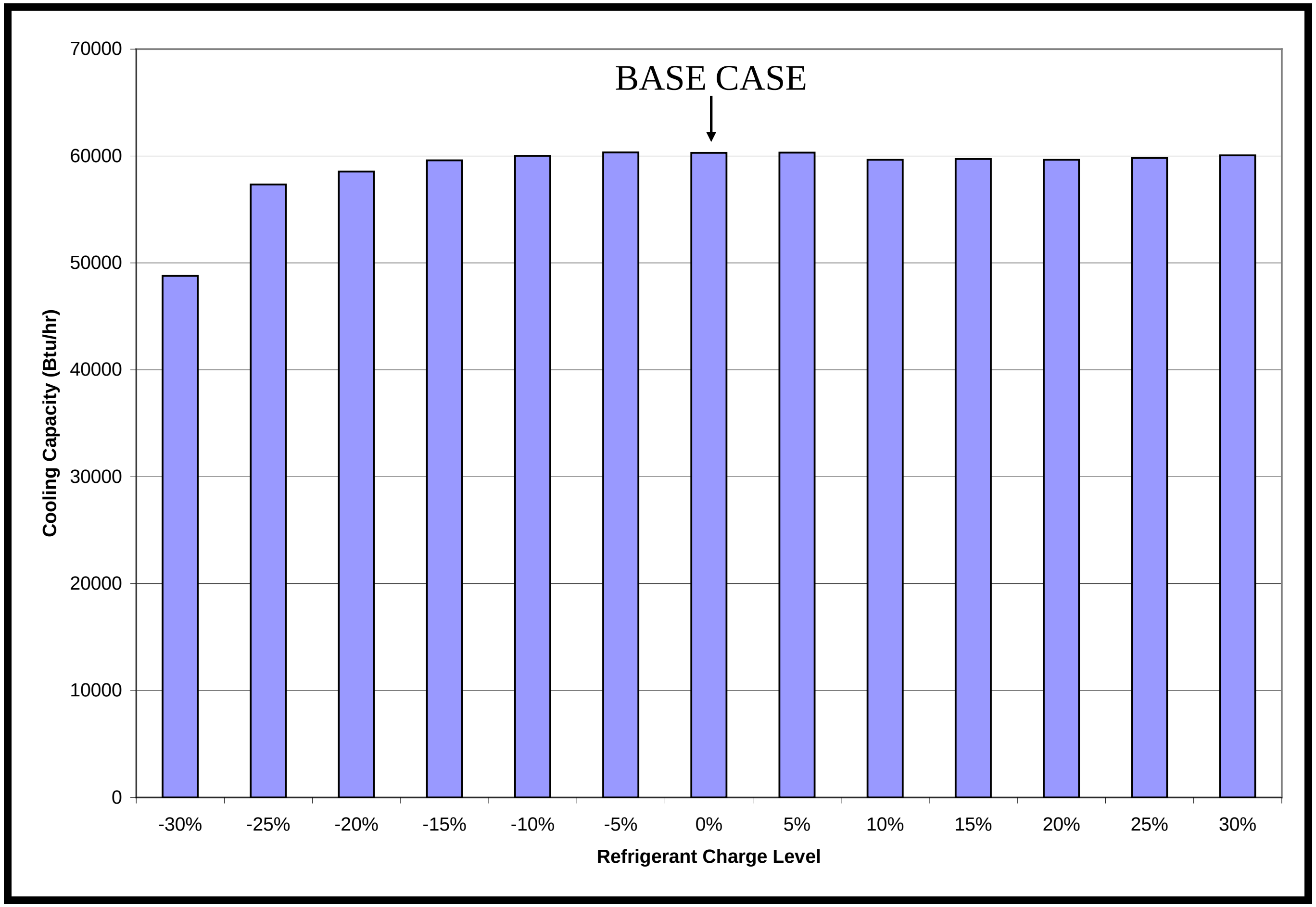
- Compressor power was increased by as much as ~70%
  - Compression ratio increased by ~60%
- Evaporator fan power remained constant
- Condenser fan was increased by as much as ~30%

Dirty Condenser Coil Impact on Efficiency and Supply Air Temperature



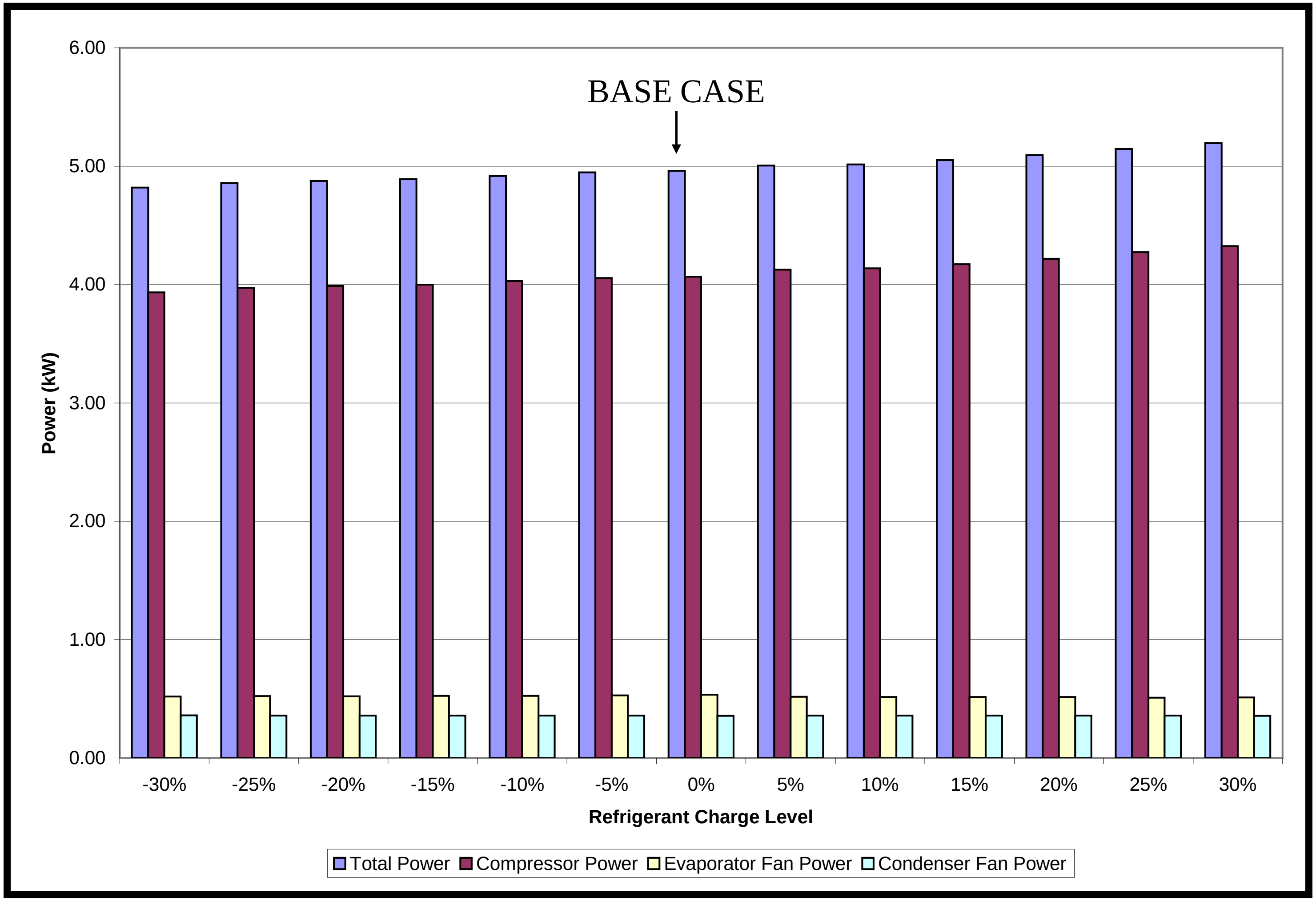
- EER was reduced by as much as ~60%
- Supply air temp increased by ~5°F

Improper Refrigerant Charge Impact on Cooling Capacity



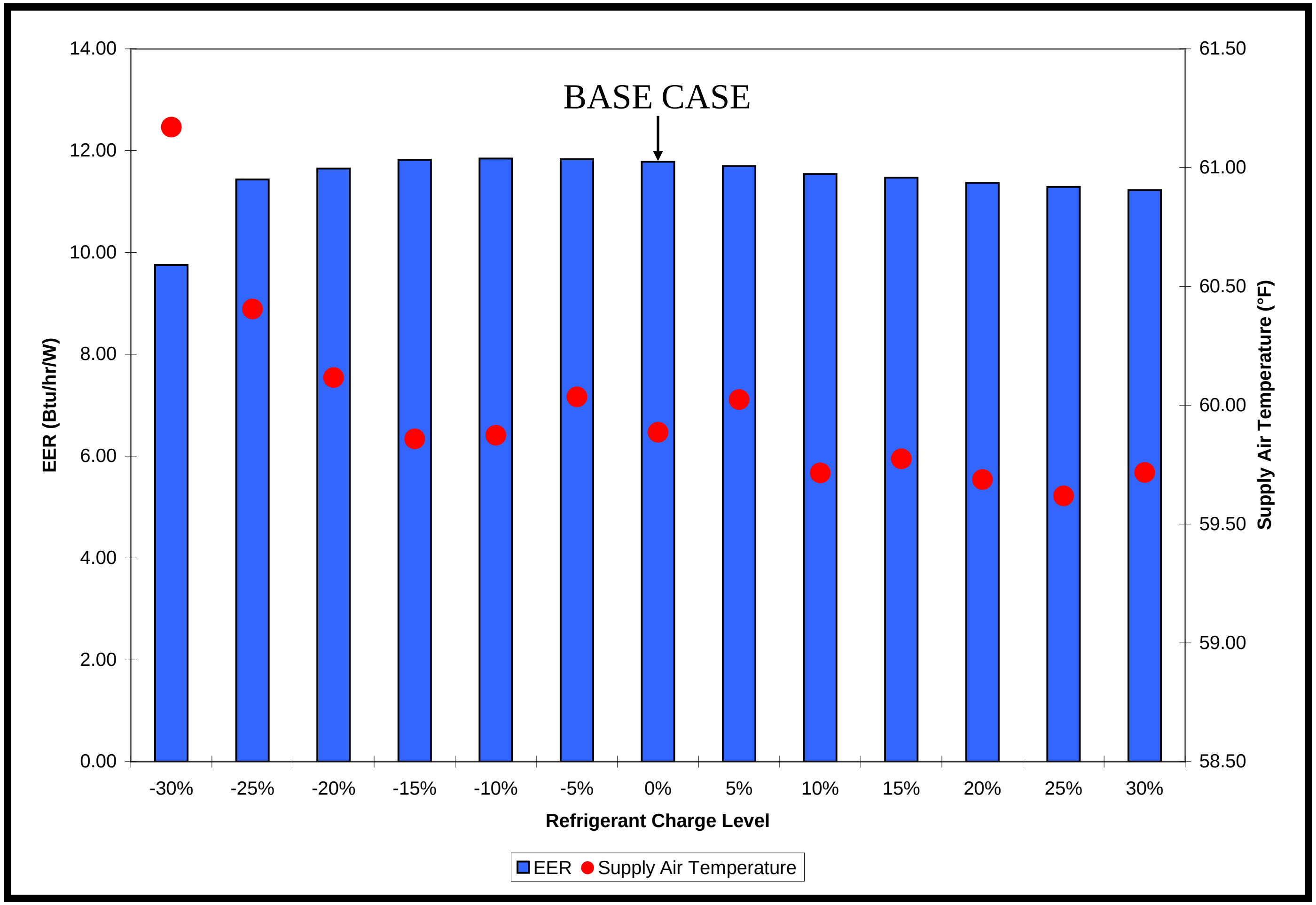
- Undercharged – cooling capacity was reduced by as much as ~20%
- Overcharged – there was negligible impact on cooling capacity

Improper Refrigerant Charge Impact on Power



- <u>Undercharged</u> – total unit power was *reduced* by as much as ~3%
- <u>Overcharged</u> – total unit power was *increased* by as much as ~5%

Improper Refrigerant Charge Impact on Efficiency and Supply Air Temperature



- <u>Undercharged</u> – reduced efficiency by ~20%, raised SAT by ~1°F
- <u>Overcharged</u> – negligible impact on both efficiency and SAT

Next Generation of HVAC Technologies

Characteristics of Next Generation HVAC Equipment

- High efficiency at peak design and under part load
- Climatic region sensitive design
- Robust integration capabilities with:
  - Building energy systems,
  - Building automation
  - Smart meter/grid
- Intelligent and demand response ready
- Environmentally friendly refrigerants
- Compliant with indoor air quality and human comfort
- Reliable
- Cost effective

Next Generation of A/C Units Features

- **Efficient**
  - Low temperature lift heat exchangers
  - Compressor-less: indirect/direct cooling systems
  - Desiccant dehumidification
  - Variable speed fan and compressor: match capacity and load
  - Efficient compressor and fan motors
  - Precise metering device: electronic expansion valve (EXV)
  - Hybrid Cooling: adiabatic + direct expansion (DX)
  - Indirect <u>or</u> direct evaporatively cooled condensers
  - Heat recovery

Next Generation of A/C Units Features (cont'd)

- **Intelligent**
  - 2-way connectivity
  - Smart user interface and energy advisory
  - *On-board fault detection and diagnostic*
  - Direct digital control
- **Indoor Air Quality**
  - Economizer integrated with Demand Controlled Ventilation
- **Low GWP Refrigerant**
  - Natural refrigerants
    - Hydrocarbons
    - CO2

Technologies on SCE’s Radar Screen

On-Board Fault Detection and Diagnostics

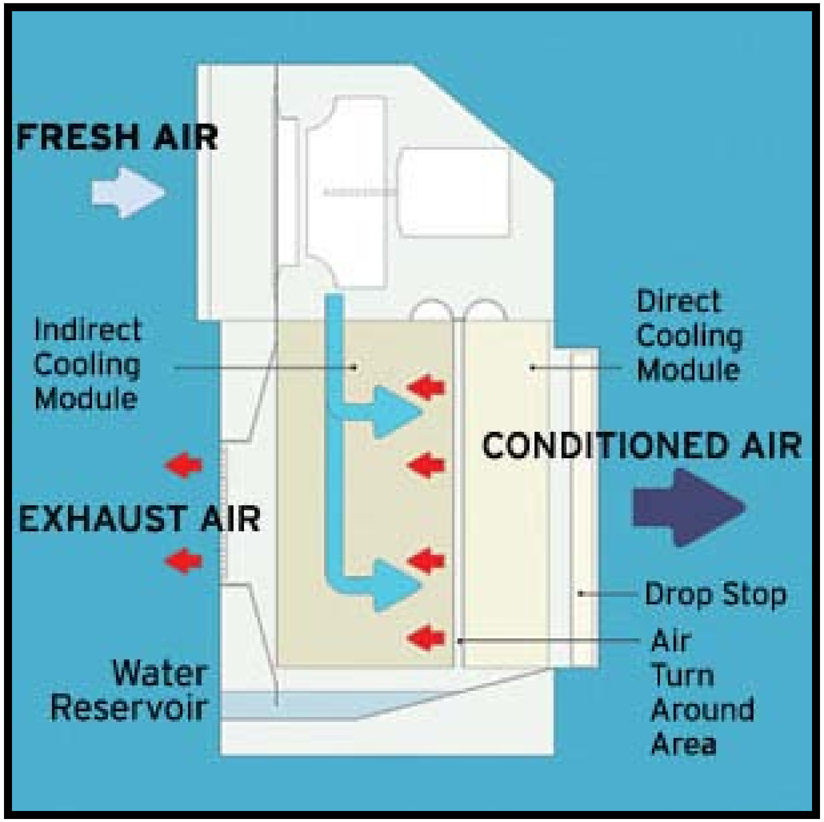
- Detect failed:
  - Compressor
  - Evaporator and condenser fan motors
  - Evaporator fan belt
- Detect degradation/maintenance faults:
  - Dirty air filter
  - Dirty evaporator and condenser coils
  - Dirty refrigerant filter
  - Failed relief damper
  - Air in refrigeration loop
  - Restriction in refrigeration loop
- Detect economizer damper operation
- Detect air temperature differential across evaporator
- Detect low/high refrigerant charge levels
- Detect faulty and failed sensors

Advanced Direct Evaporative Cooler

- Residential and light commercial
  ~ 4 Ton
- Suitable for hot/dry climates
- Electronically commutated motor (ECM)
- Efficient centrifugal fan
- Long life Chillcel™ pads
- Automatic motor speed adjustment:
  - Accommodate different ducting systems and back pressures
- Electronic water quality management system:
  - Before impurities build-up inside the cooler, they are automatically detected and replaced with clean water
- Quiet operation

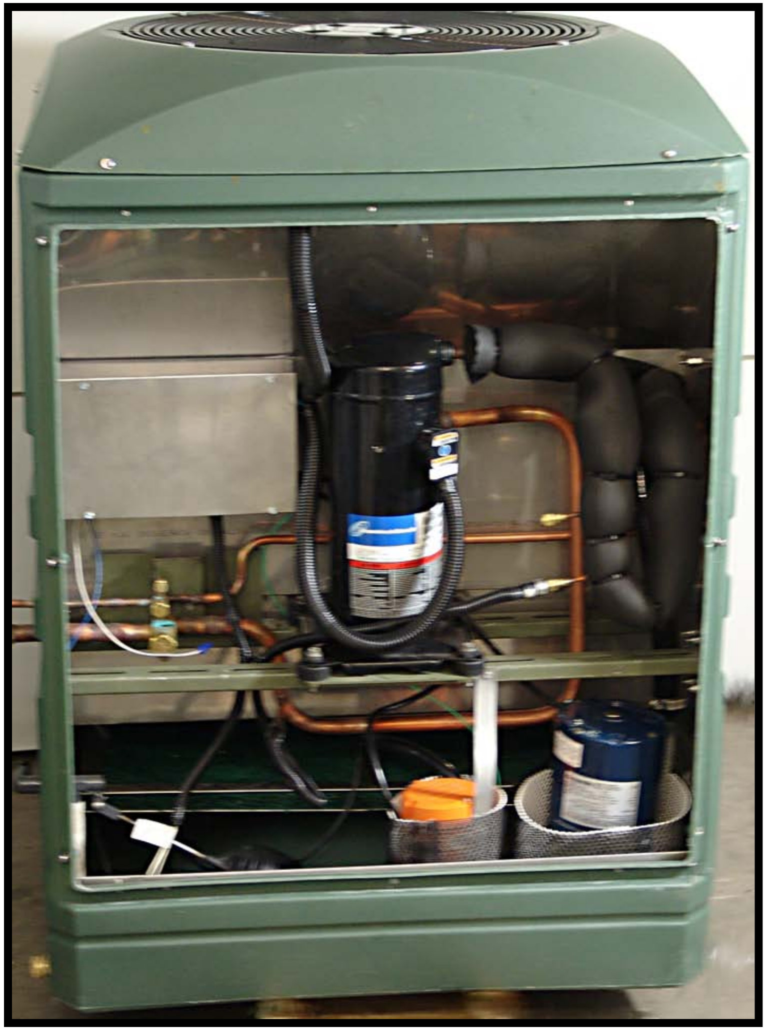
Advanced Indirect/Direct Evaporative Cooler

- Suitable for hot/dry climates
- > 40 SEER
- Counter-flow heat exchanger between:
  - Indirect: cool RA/hot OSA
  - Direct: Warm/dry OSA cools
  - ECM fan motors
- Compared to vapor compression A/C, a PIER Tech Brief says:
  - ~90% - energy savings
  - ~80% - demand savings



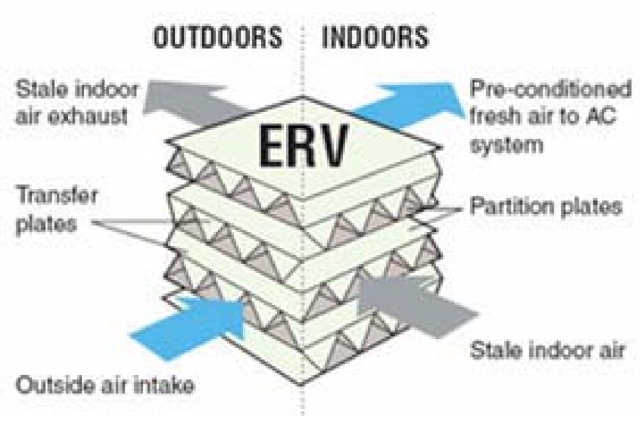
Evaporatively Cooled DX Split System

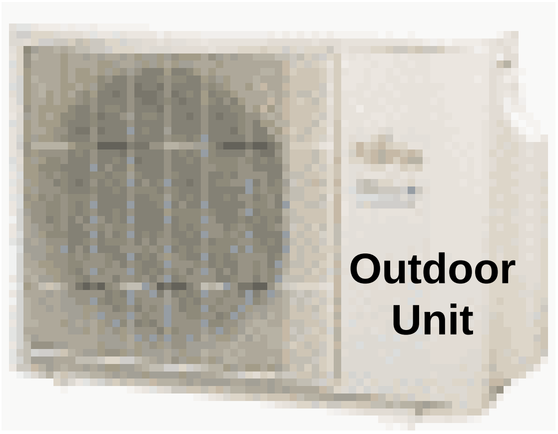
- Residential and light commercial
- Suitable for hot/dry climates
- High efficiency (EER = 14.5)
- ~ 40% downsized scroll compressor
- ECM condenser fan motor
- PSC indoor blower fan
- Operates at lower head pressures than a traditional air-cooled condenser
- Quiet operation
- SCE's Test Results-compared to an air-cooled unit, at 95°F (AHRI) showed:
  - Power reduction of ~50%
  - EER improvement of 3.5 Btu/hr/watts



Multi-Zone VRF A/C System

- Claimed system efficiency > 21 SEER
- One condensing unit can serve up to 16 zones
- Variable refrigerant flow zoning system
- Low fan energy
- Inverter controlled high efficiency blower fan
- Inverter controlled compressor optimizes part-load efficiency by matching capacity with cooling load
- Improved human comfort thru tight individual zone temperature control
- Conditions only the occupied spaces
- Zonal heat recovery
- Ducted or ductless indoor units
- Manage up to 2,000 indoor units from a single PC
- Energy recovery ventilators (ERV)
- Integration with building EMS



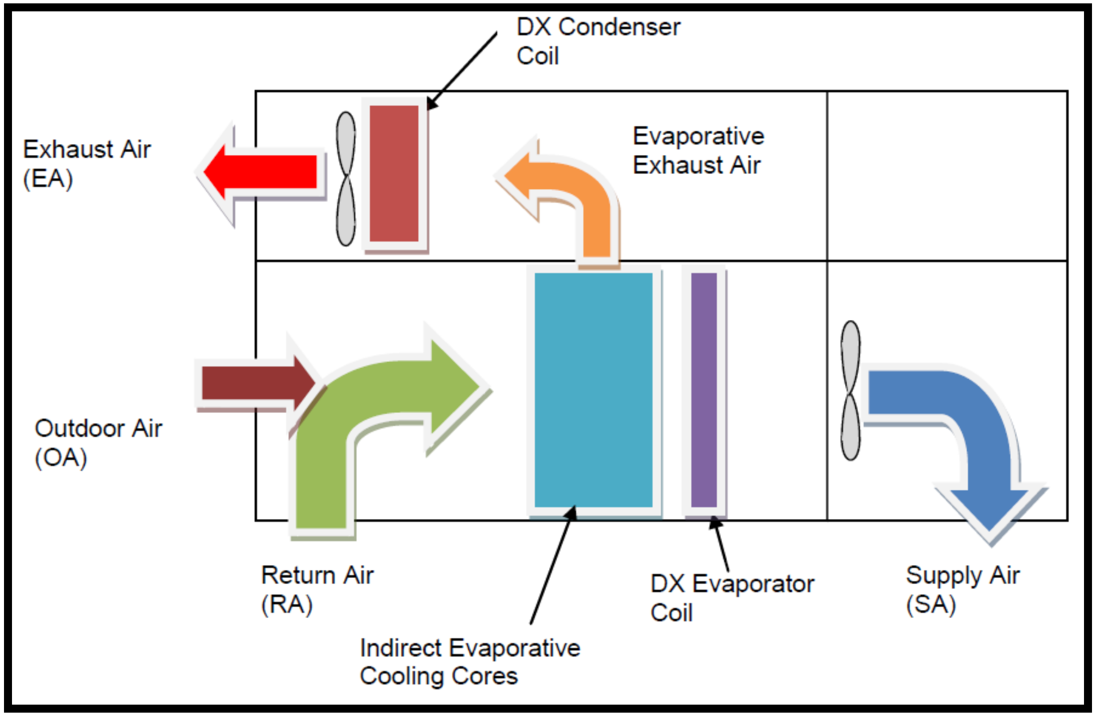


New Premium Efficiency Rooftop Units

- Energy Star & CEE Tier II qualified
  - Up to 17 SEER and 14.3 EER
- Multiple evenly sized high-efficiency scroll compressors
- Economizer
- Large heat exchanger
- VSD supply fan
- ECM fan motors
- Intelligent direct digital controls

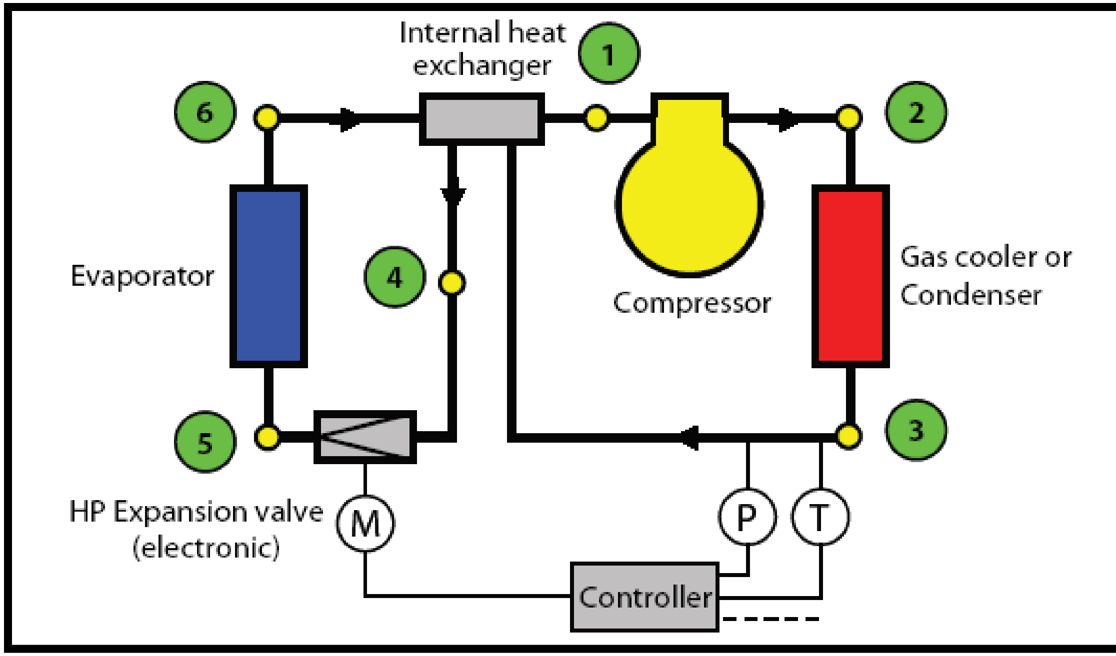
Hybrid Packaged Rooftop Unit

- Premium efficiency 5-ton packaged rooftop AC for residential/small commercial
- Up to 58% peak demand and 80% energy savings compared to 2010 DOE standards
- Winner of UC Davis Western Cooling Challenge
- Indirect evaporative cooling + DX cooling
- Evaporatively pre-cooled condenser
- ECM fan motors



CO_2 Heat Pump

- Refrigerant, CO_2: GWP = 1 ; ODP = 0
- Dual stage intercooler (DSI) circuit
- High efficiency heat exchangers
- EXV
- Hi efficiency compressor
- Hi efficiency fan motors
- COP - compared to R-22
  - Cooling: barely compatible
  - Heating: up to 14% higher

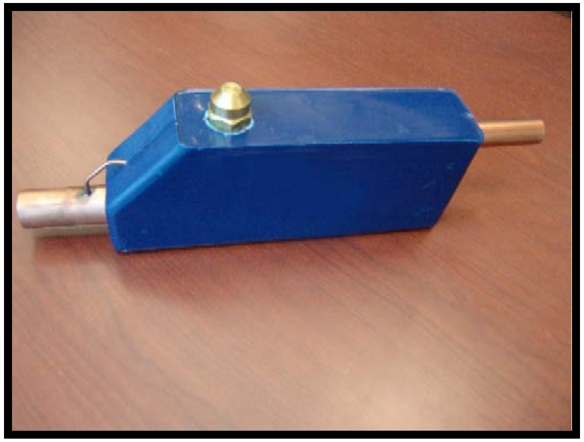


Radiant Cooling

- Uses chilled water as cooling fluid
- High EER
- No fan power/energy
- Higher energy and demand savings under low cooling load conditions
  - Cooling tower economizer mode with no chiller running

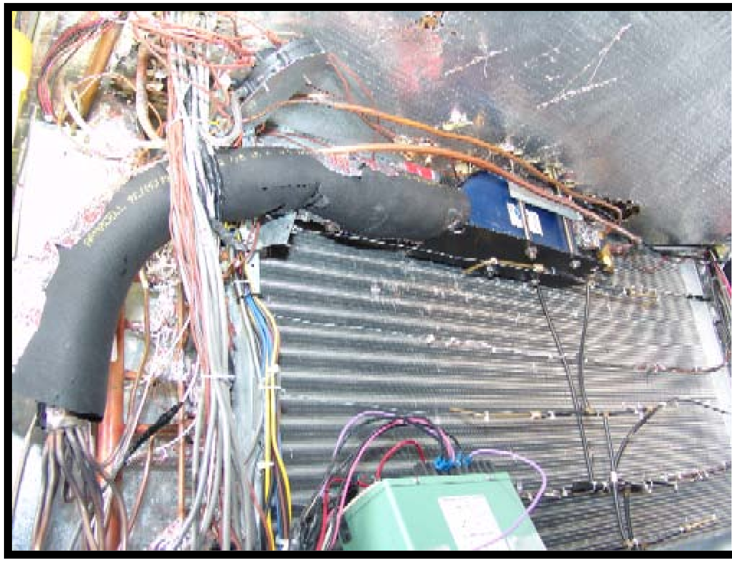
Not Every Black Box Works

Black Box 1
Annular Refrigerant Flow Device (ARFD)



What is it?

- A 2-way box between TXV and evaporator
- Installation and set up requires over hauling more than 10 areas of the unit first (e.g., superheat, over sized TXV, etc.)



Claims?

- Reduces energy usage by at least 15%
- Extends equipment life
- Reduces maintenance costs
- Maintains consistent temperatures

Black Box 1 – ARFD

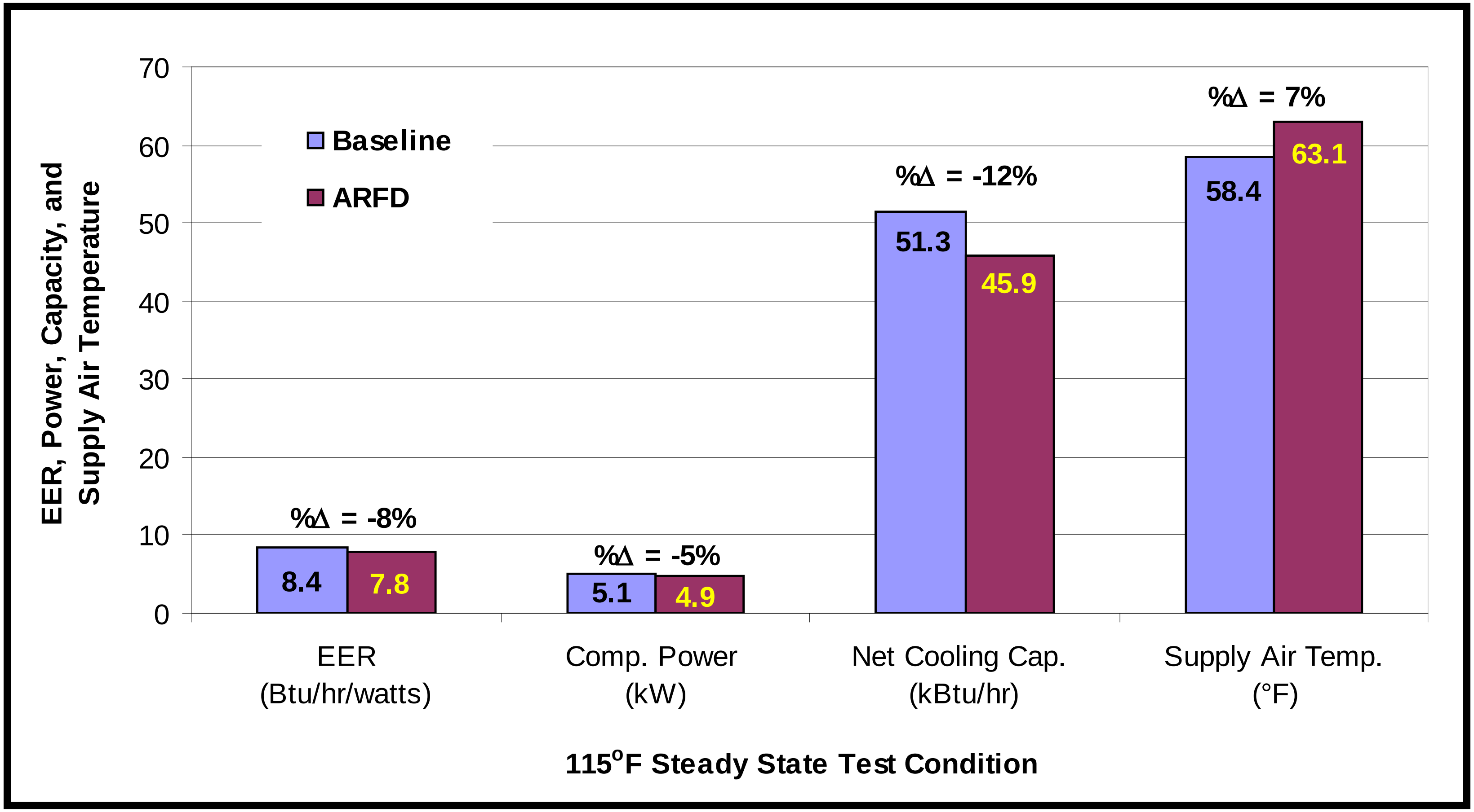
How does it work?

- It enhances heat transfer efficiency by changing the quality of refrigerant in evaporator (close to all liquid phase)

Applications?

- Commercial refrigeration and air conditioning systems

Black Box 1 (ARFD) – Laboratory Test Results



- Baseline – 5-ton RTU, SEER 14 and EER 12.5, nonadjustable TXV set to 10-15°F superheat
- With ARFD, EER of the unit was decreased for all AHRI test conditions

Black Box 2 – Refrigeration System Optimizer

What is it?

- An electrical device to optimize the compressor run time
- Installed on systems with **oversized** compressor capacity

Claim?

- Reduces energy usage of oversized compressor by at least 10%

Black Box 2

Black Box 2 (Refrigeration System Optimizer)

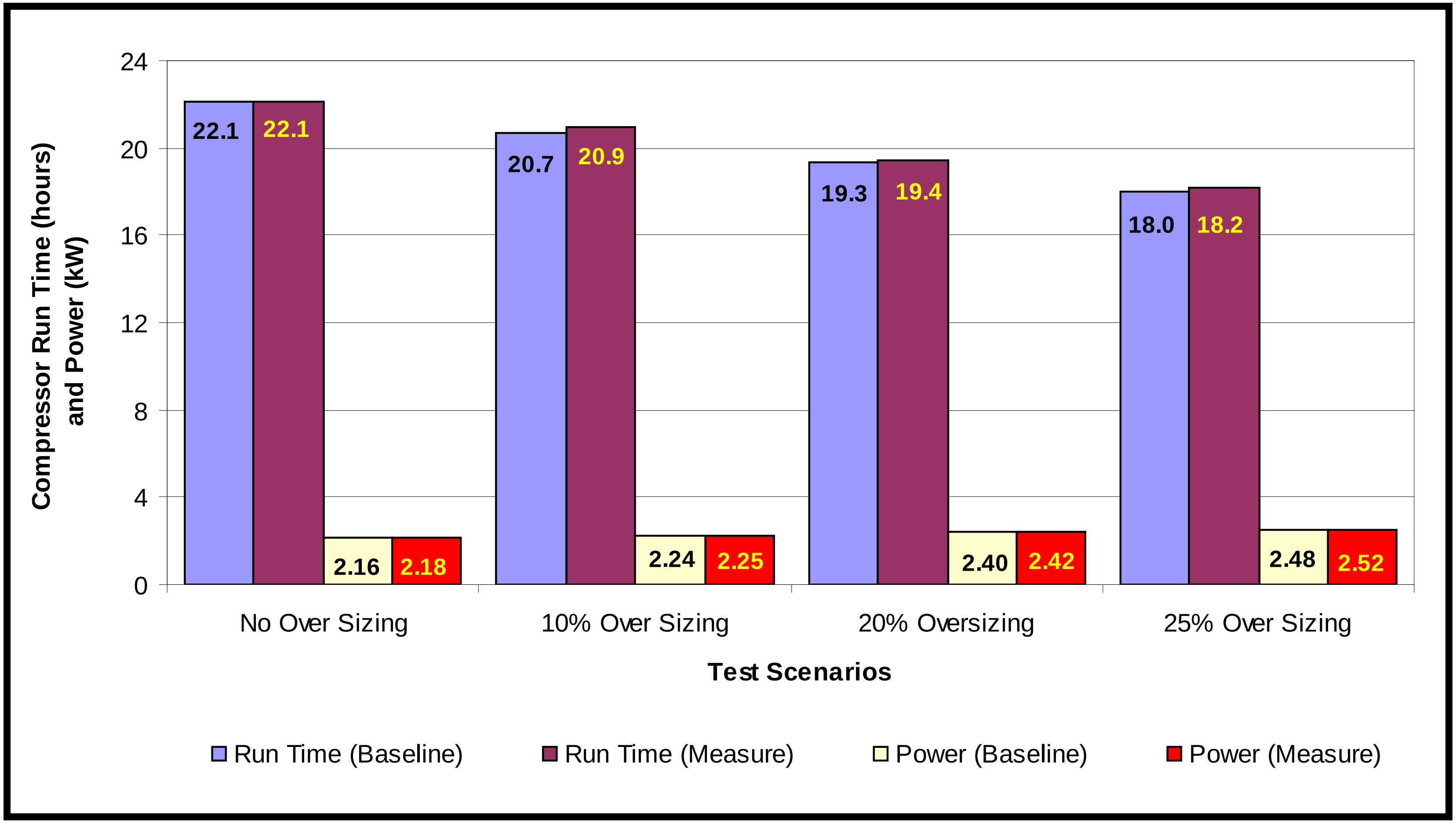
How does it work?

- It improves system performance by real-time “load-demand” analysis and control

Applications?

- Commercial refrigeration and air conditioning systems
- Residential refrigeration and air conditioning systems

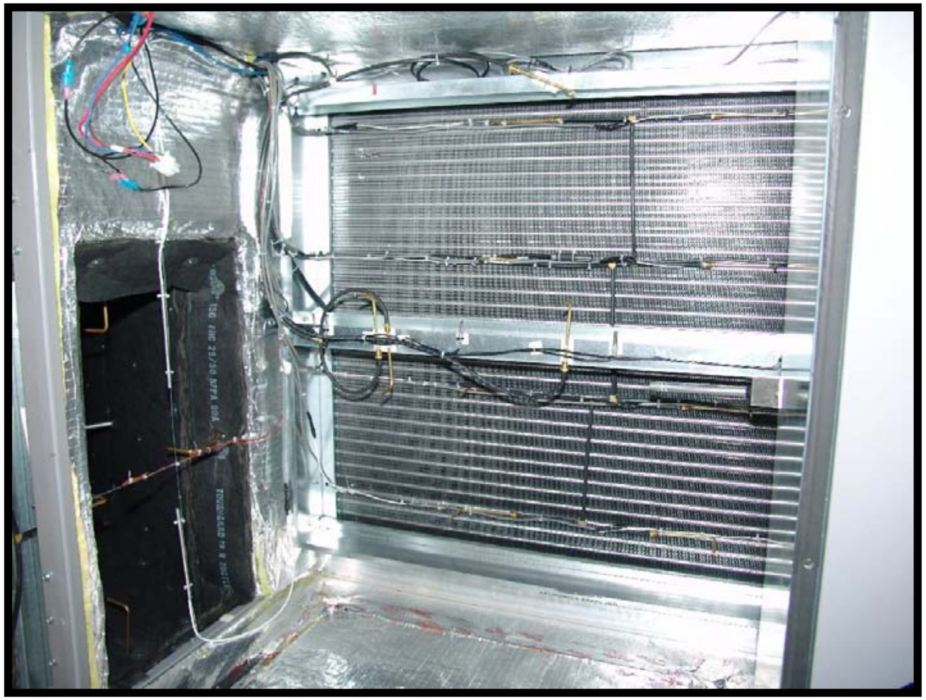
Black Box 2 (Refrigeration System Optimizer) Preliminary Laboratory Test Results



- For all scenarios, maximum product temperature was below 40°F

Appendix

Dirty Evaporator Coil



CLEAN COIL

DIRTY COIL

Dirty Air Filter

CLEAN FILTER

DIRTY FILTER

Dirty Condenser Coil

CLEAN COIL

Blocking Material

DIRTY COIL

Improper Refrigerant Charge

Nanofluids

- Nanofluids: new class of advanced heat-transfer fluids engineered to disperse nanoparticles smaller than 100 nm (nanometer) in conventional refrigerants
  - Improve heat transfer effectiveness of evaporator and condenser coils
  - No cloggage due to extremely small nano structure
- Technology still in the fundamental research stage