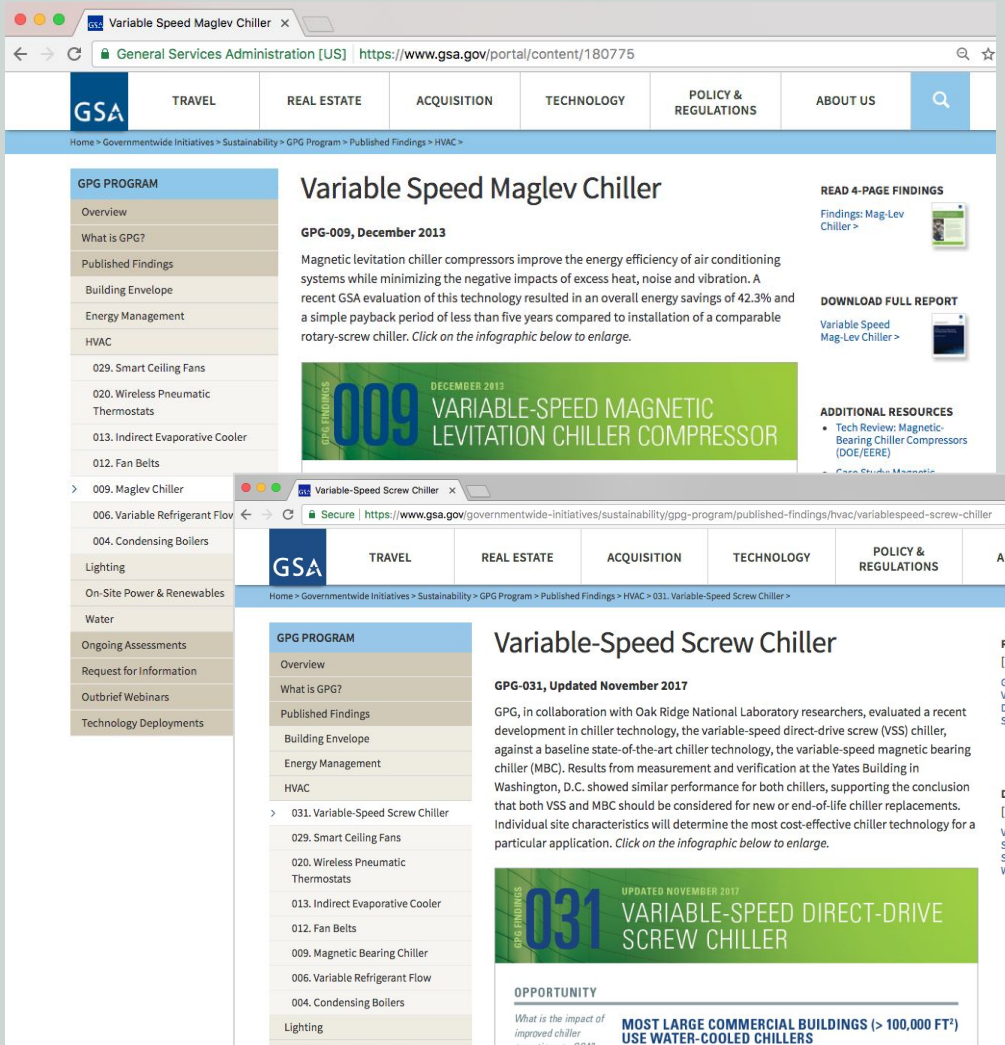
GPG Outbrief 09

Next-Generation Chillers

Emerging Technologies, GPG Program | U.S. General Services Administration | January 18, 2018

Reports Online

- Infographic
- 4-page Findings
- Full Report
- Additional Resources



Upcoming GPG Outbriefs - Thursdays, 12 PM ET

February 8	Plug Load Control
March 22	Honeycomb Solar Thermal Collector
April 19	Electrochromic Windows

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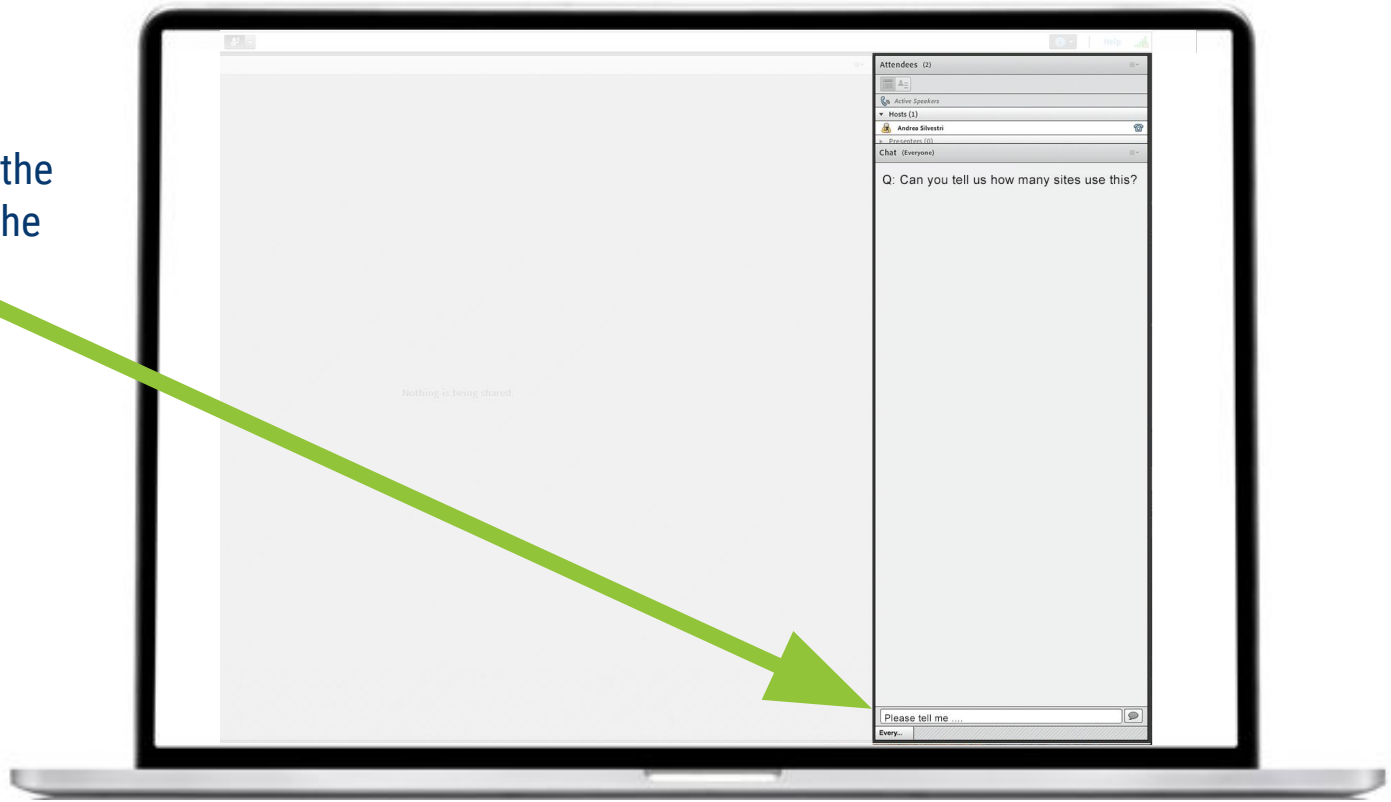

Next-Generation Chillers

Michael Lowell
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720.641.8891

Webinar Agenda

- Overview of GPG (5 minutes)
  Kevin Powell, Program Manager, Emerging Technologies
- Variable-Speed Magnetic Bearing Chiller (10 minutes)
  Jeromy Jenks, Pacific Northwest National Laboratory
- On-the-ground Feedback (10 minutes)
  Juan Griego, GSA Region 7
- Variable-Speed Screw Chiller (10 minutes)
  Dan Howett, Oak Ridge National Laboratory
- On-the-ground Feedback (10 minutes)
  Kenneth Thompson, Glenn Stewart, Randy Burgess, GSA Yates Building
- Best Practices (10 minutes)
  Dan Howett, Oak Ridge National Laboratory
- Q & A (15 minutes)

Introduction

Kevin Powell
Program Manager, Emerging Technologies
kevin.powell@gsa.gov
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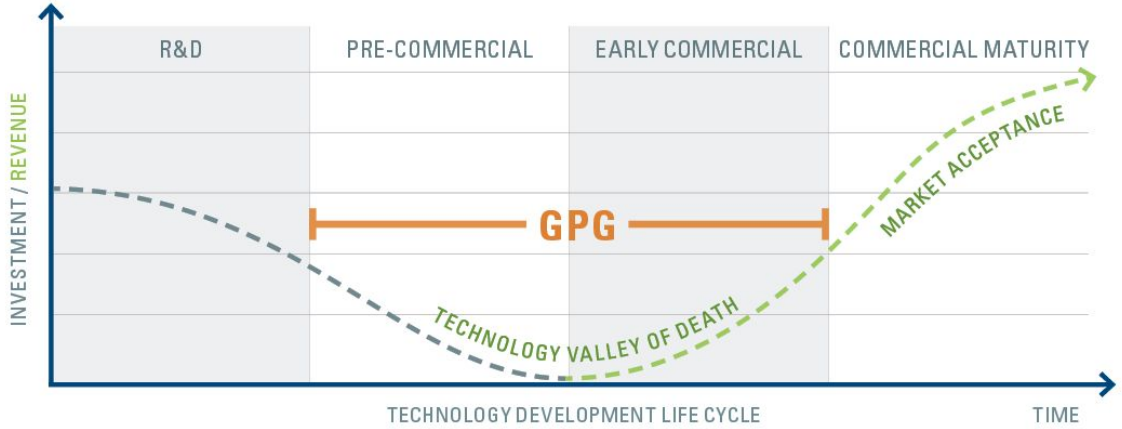
Emerging Technologies' two programs — GSA Proving Ground (GPG) and Pilot to Portfolio (P2P) — enable GSA to make sound investment decisions in next generation building technologies based on their real world performance

Leading by Example

GSA's Proving Ground accelerates market acceptance by objectively assessing innovative building technologies in real-world environments, and deploying those that deliver. To date, GSA has installed 9 technologies across more than 200 buildings. In aggregate, these technologies are delivering $7.4 Million in annual O&M savings.



GPG Process

Identify promising technologies at the edge of commercialization

Pilot technology installations within GSA's real estate portfolio

Partner with Department of Energy national laboratories to objectively evaluate real-world performance

Recommend technologies with broad deployment potential for GSA

Measurement & Verification - Maglev Chiller

Jeromy Jenks
Senior Thermal Systems Engineer
EED/Computational Fluids & Mechanics
Pacific Northwest National Laboratory

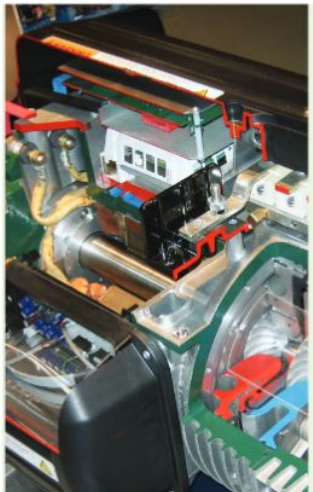
GPG-009

Variable Speed Magnetic Bearing Chiller

GSA Public Buildings Service

GPG-009 | OCTOBER 2013

MAGNETIC LEVITATION CHILLER COMPRESSOR



Magnetic Levitation Chiller Compressor Reduces Space Cooling Energy Consumption

In the U.S., space cooling accounts for 9.6% of energy consumption in office buildings. Because space cooling is primarily driven by electricity—a higher cost energy source—it can account for an even greater percentage of a facility's annual energy bill.[1] Chillers, used frequently in larger facilities, provide cooling in 31% of office building floor space within U.S. commercial buildings.[2]

GSA's Green Proving Ground (GPG) recently evaluated the effect of new, more efficient chiller compressor technology on energy cost and consumption by assessing a magnetic levitation ("maglev") chiller compressor at the George Howard, Jr. Federal Building and U.S. Courthouse in Pine Bluff, Arkansas. This new chiller compressor technology offers quieter, more efficient cooling at lower partial loads than positive displacement chillers, due to its ability to reduce friction, operate at variable speeds,

Opportunity

10%

OF ENERGY

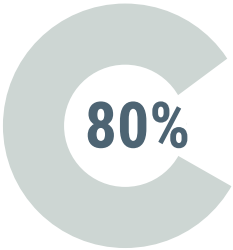
GOES TO SPACE COOLING

32%

OF COMMERCIAL BUILDINGS

RELY ON CHILLERS TO PROVIDE THIS COOLING

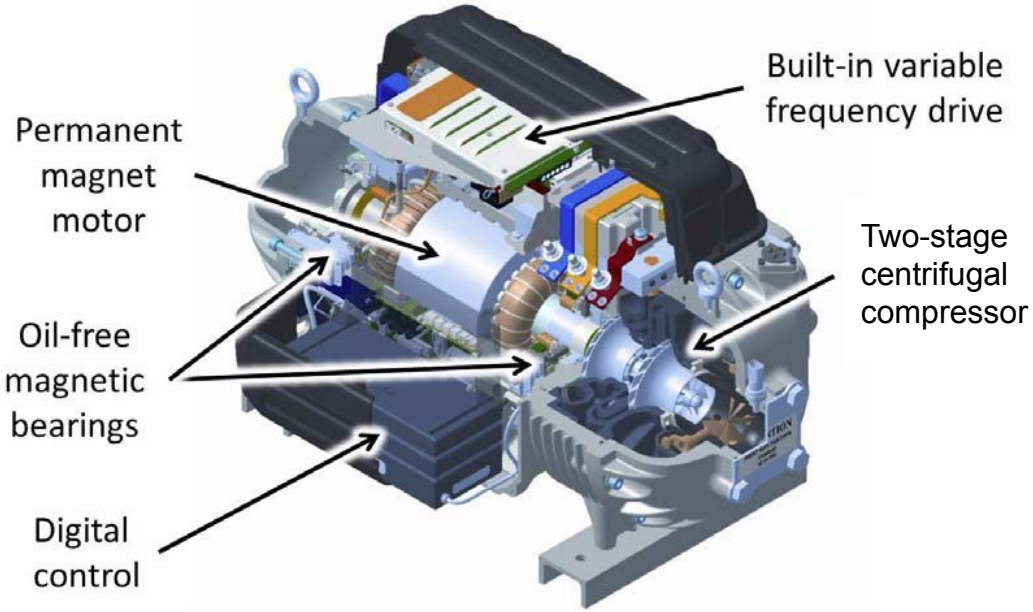
GSA Opportunity

GSA FLOOR SPACE	BUILDINGS >100,000 SF
 80% Large Buildings	Most Use Water-Cooled Chillers

GPG-009. Variable Speed Magnetic Bearing Chiller

Improves Efficiency when Operating Under Small and Partial Loads

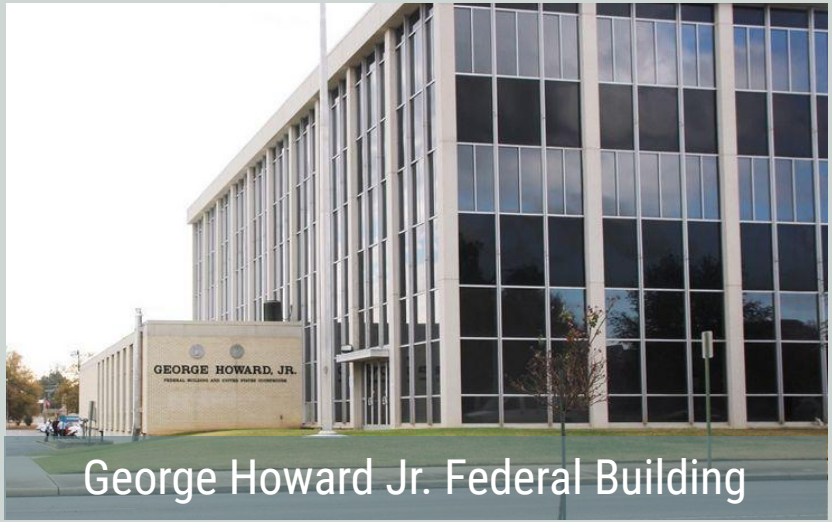
Uses magnetic levitation to eliminate heat, noise and vibration associated with standard chillers.



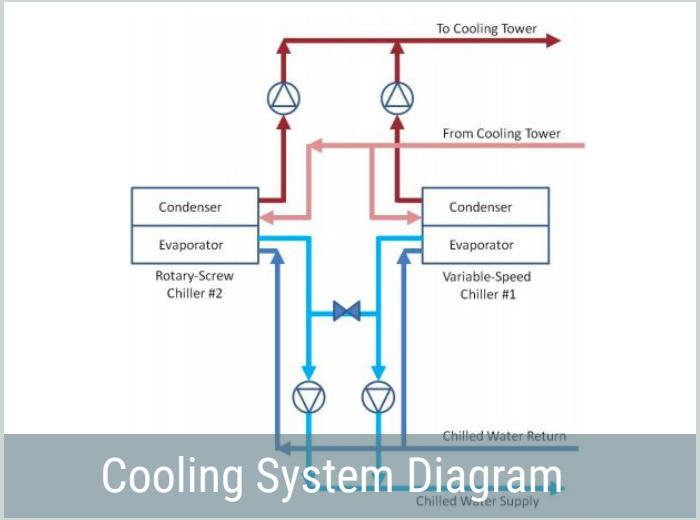
Measurement & Verification

Experts monitored performance of old and new chillers over a six-month period

George Howard, Jr. Federal Building—a four-story, 108,000 square foot courthouse and office building



George Howard Jr. Federal Building



Cooling System Diagram

Basecase at the George Howard Federal Building, Pine Bluff AR

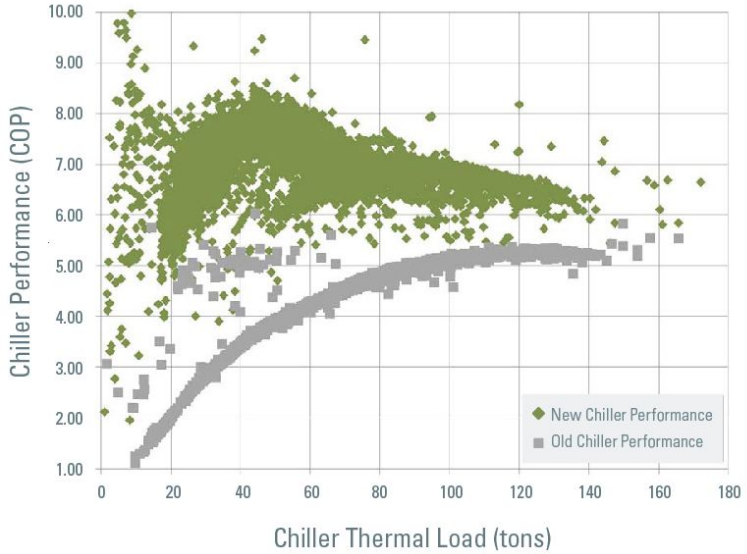
- 150-ton rotary-screw chiller installed in 1993
  (Before variable-speed chillers, smaller chillers needed to be rotary screw)
- Rotary-screw compressor used R-22 refrigerant; MBC used R-134A.

Description	Original Chiller	New Chiller
Nominal Capacity	150-tons cooling	150-tons cooling
Minimum Circuit Rating	460-volt, 185-amp, 3-phase	460-volt, 166-amp, 3-phase
Maximum Circuit Rating	480-volt, 300-amp, 3-phase	480-volt, 225-amp, 3-phase
Compressor Rating	1 unit 460 volt 148 run-load amps (RLA)	2 units 460 volt 72 RLA (each)
Oil Tank Heater	2 units 115 volts 2 RLA	Not applicable
Refrigerant	R-22 330 pounds	R-134A 531 pounds
Oil	35 pints	Not applicable

Efficiency of Magnetic Bearing Chiller (MBC) Increases at Low Load

MBC chiller efficiency is highest at low loads (27 to 33% of nominal full load)

Incumbent chiller efficiency continuously decreases as chiller load is reduced



42%

ENERGY SAVINGS

AS COOLING LOADS DECREASE, EFFICIENCY INCREASES

Cost-Effectiveness

$9,097 energy cost reduction per year

at the George Howard Jr. Federal Building @ $0.073/kWh

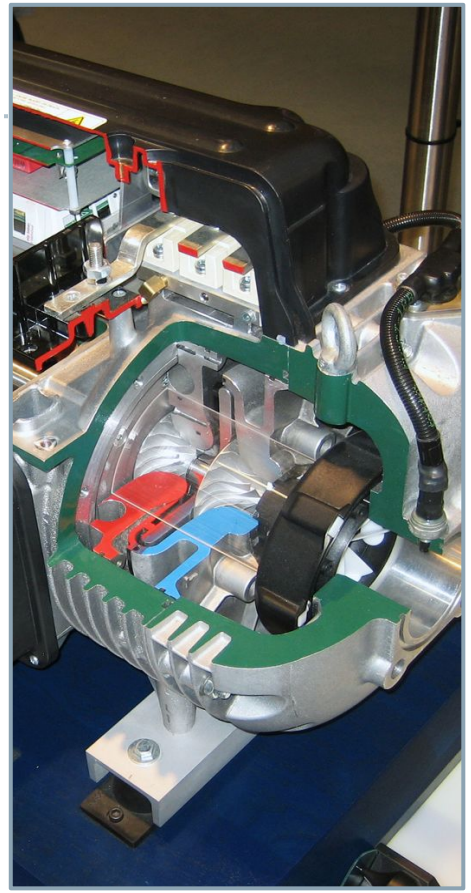
Less than 5 year incremental payback

at end-of-life replacement after normalizing for payment structure & utility costs and as compared to new FEMP-designated rotary screw chiller

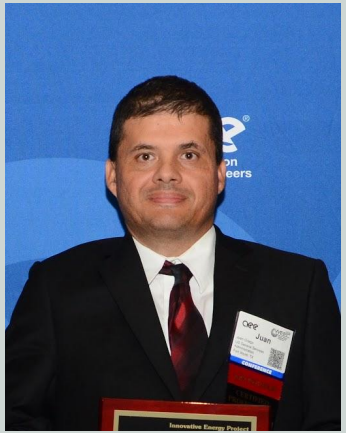
Operations & Maintenance

Magnetic bearing compressor benefits:

- Smaller and lighter than similar capacity compressors.
- Quiet, frictionless chillers placed closer to occupant spaces.
- More efficient cooling at lower partial loads.



GSA Feedback



Juan Griego
Energy Engineer
GSA Region 7

Additional GSA Deployments MBC Chiller

R1: 4 deployed
R2: 6 deployed
R4: 46 deployed
R5: 50 deployed
R6: 20 deployed
R7: 68 deployed, 4 pending
R8: 1 deployed, 3 pending
R9: 5 deployed
R10: 6 deployed
NCR: 4 deployed
210 total

GSA Region 7 Experience

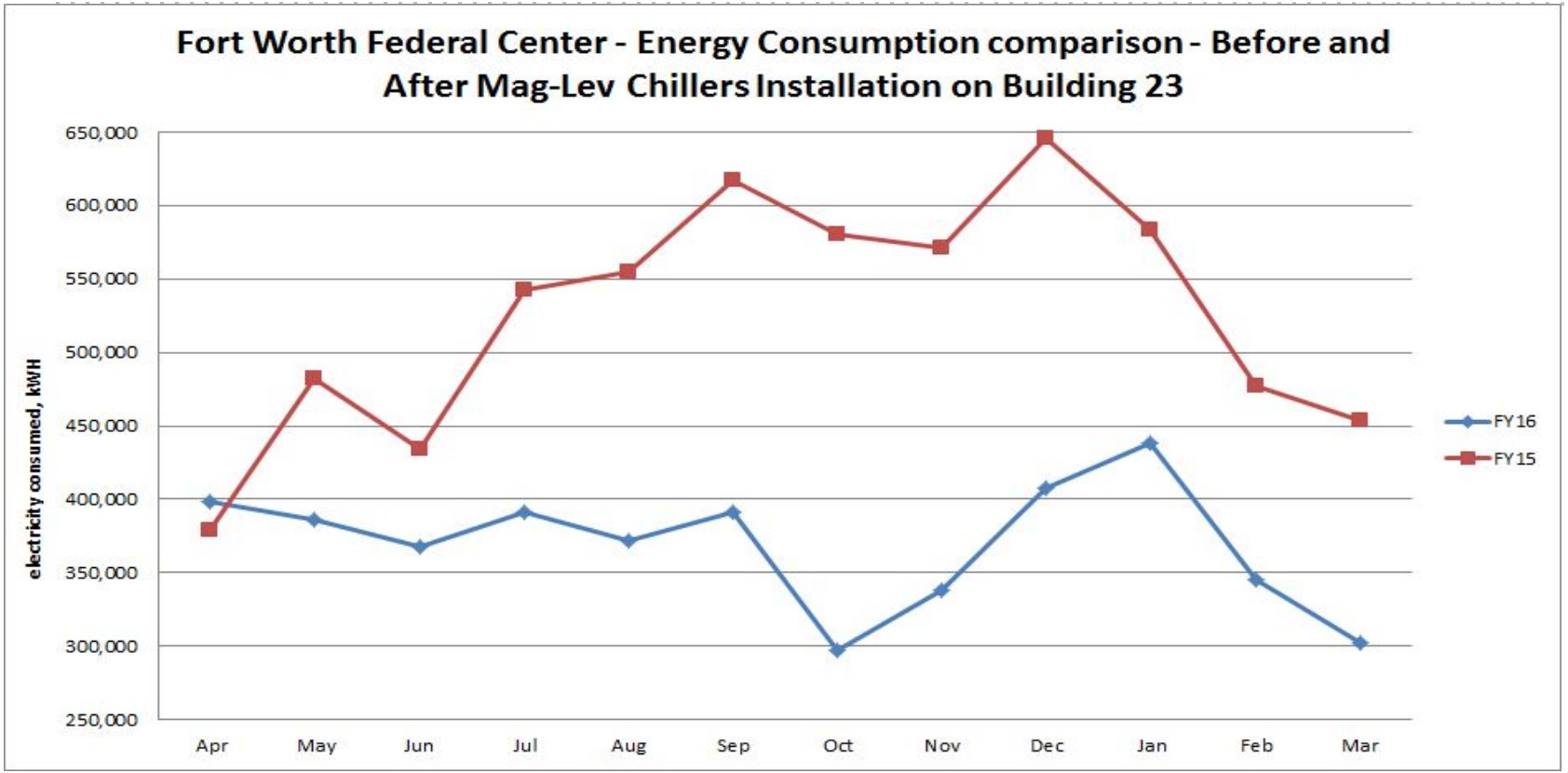
⅓ of R7 Chiller Inventory is MBC

- Range of tonnage
  - From 60-ton with 1 compressor to 750-ton with 4 compressors
  - Majority water-cooled, a few air-cooled
- IPLV values (in kW/tons) for water-cooled MBC typically range from 0.3 to 0.35
- Recommended IPLV values of various water-cooled chillers
  - Rotary screw (greater than 150 tons) - 0.49 or less
  - Centrifugal (150-299 tons) - 0.52 or less
  - Centrifugal (300-2000 tons) - 0.45 or less

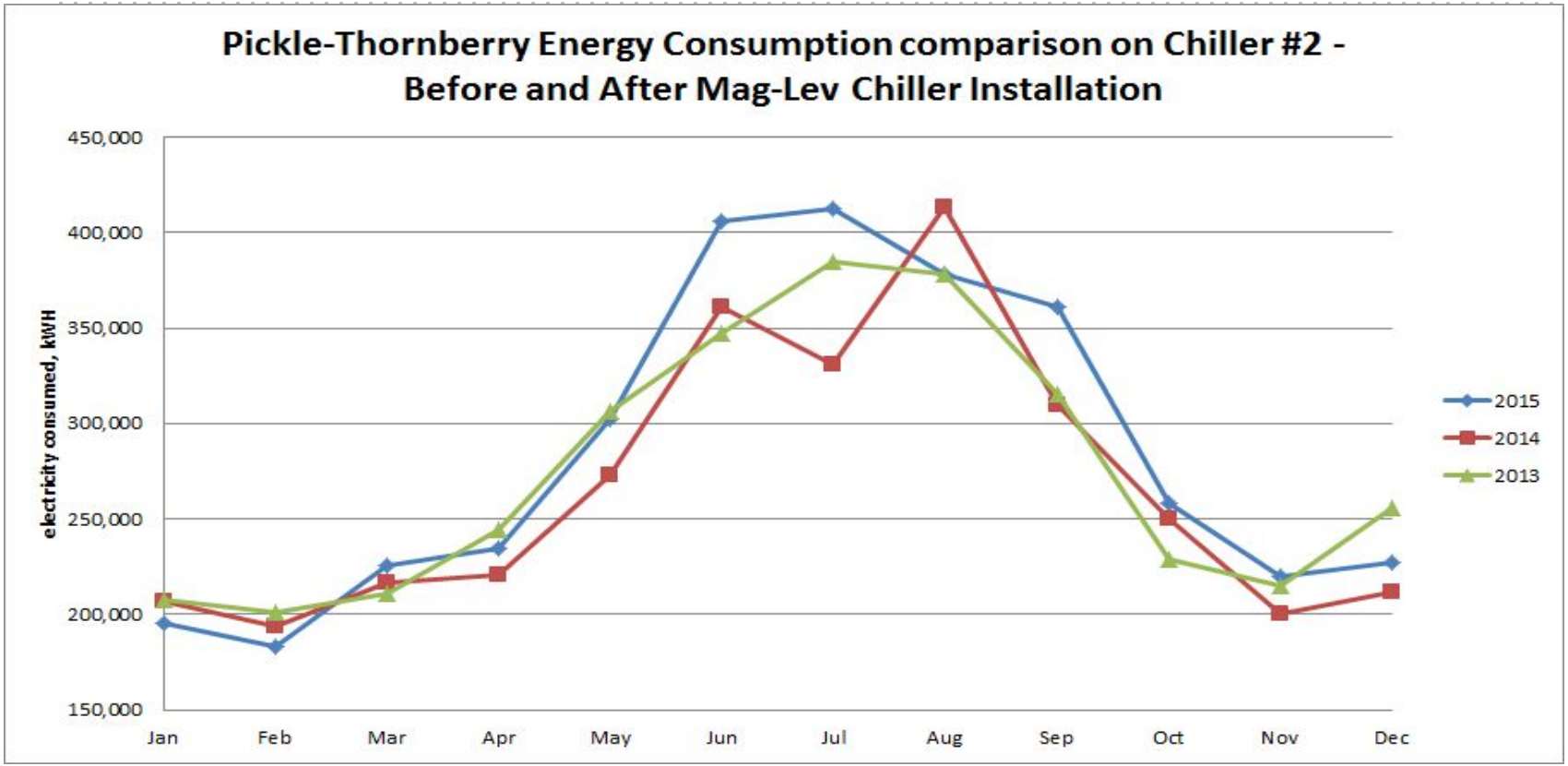
Lessons Learned

- MBC chiller needs to be operated differently, most efficient at lower partial loads, stage chillers to get maximum efficiency.
- Essential that O&M contractor is trained.
- In most cases, chiller-replacement projects are incentive-eligible

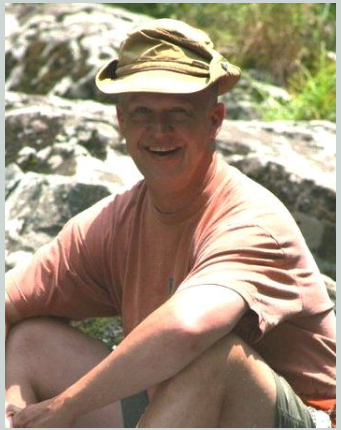
Examples from the Field — Whole Building Energy Use



Examples from the Field : Whole Building Energy Use



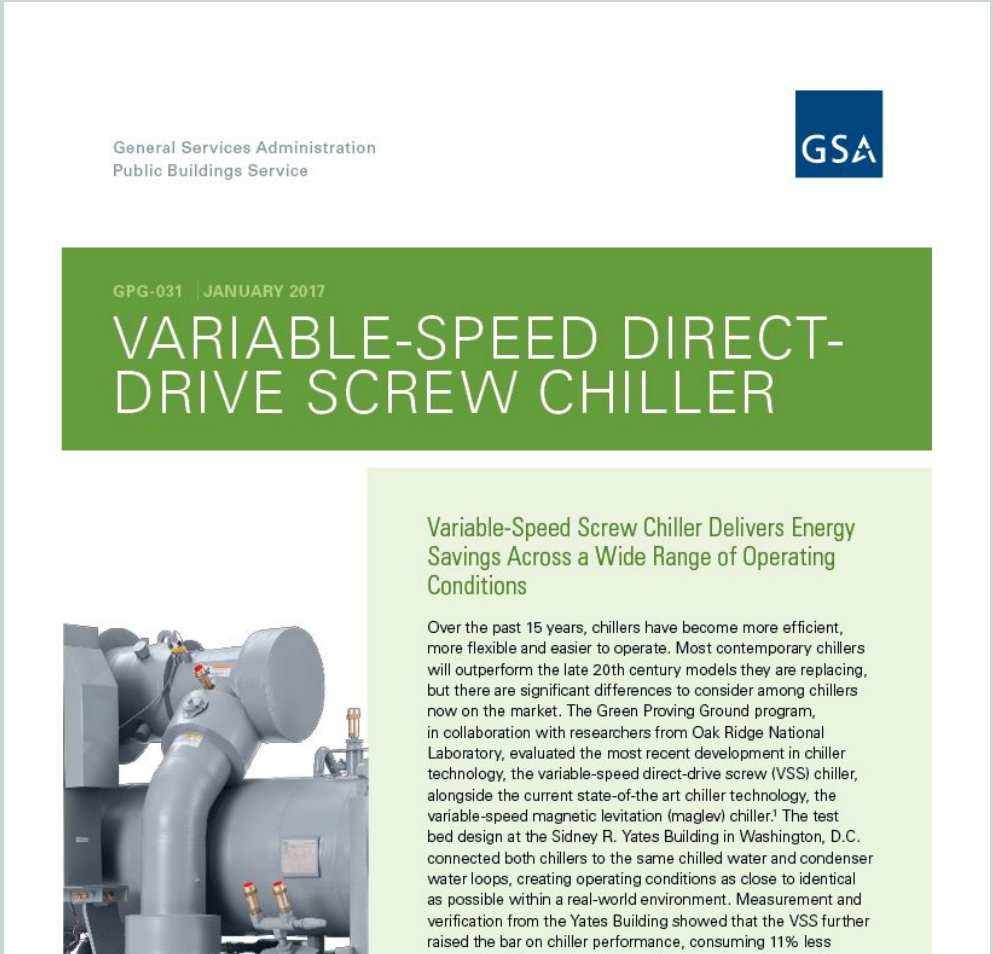
Measurement & Verification



Daniel Howett
R&D Staff
Oak Ridge National Laboratory

GPG-031

Variable-Speed Direct-Drive Screw Chiller



General Services Administration
Public Buildings Service

GSA

GPG-031 | JANUARY 2017

VARIABLE-SPEED DIRECT-DRIVE SCREW CHILLER

Variable-Speed Screw Chiller Delivers Energy Savings Across a Wide Range of Operating Conditions

Over the past 15 years, chillers have become more efficient, more flexible and easier to operate. Most contemporary chillers will outperform the late 20th century models they are replacing, but there are significant differences to consider among chillers now on the market. The Green Proving Ground program, in collaboration with researchers from Oak Ridge National Laboratory, evaluated the most recent development in chiller technology, the variable-speed direct-drive screw (VSS) chiller, alongside the current state-of-the art chiller technology, the variable-speed magnetic levitation (maglev) chiller.[1] The test bed design at the Sidney R. Yates Building in Washington, D.C. connected both chillers to the same chilled water and condenser water loops, creating operating conditions as close to identical as possible within a real-world environment. Measurement and verification from the Yates Building showed that the VSS further raised the bar on chiller performance, consuming 11% less

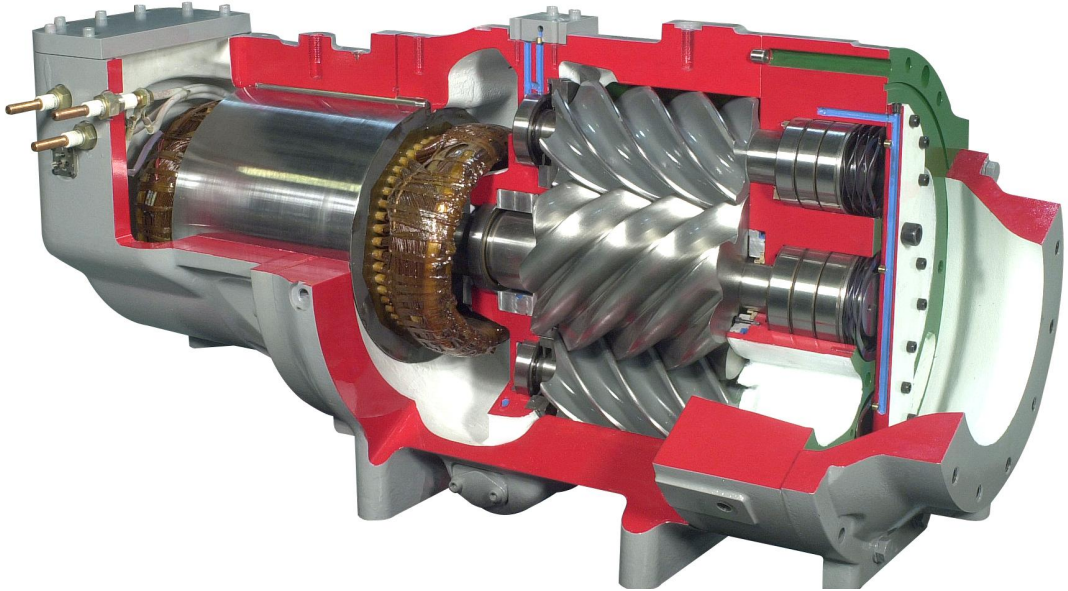
Report Reissued after Third-Party Review

- Report originally released in December 2016. In February 2017 Daikin (MBC Vendor) and Danfoss (OEM of MBC compressor) submitted letters raising concern about the accuracy of the published findings.
- GPG commissioned both internal and third-party review to validate the substance of these concerns. As an outcome of this review, language in the report has been clarified to better characterize test bed design, chiller selection, and measurement uncertainty. The report's substance and overall conclusions are unchanged.
- At the suggestion of NREL, who conducted the third party review, data from the site was analyzed using a second method. This alternative method (average hourly power demand —measured in kilowatts—was correlated to average hourly outside air temperature) corroborated the original data analysis.

GPG-031. Variable-Speed Direct-Drive Chiller

Capacity Controlled by Motor Speed Alone

Three screw rotors and a variable-speed motor are the only major moving parts.



Measurement & Verification

Both Connected to the Same Chilled and Condenser Water Loops

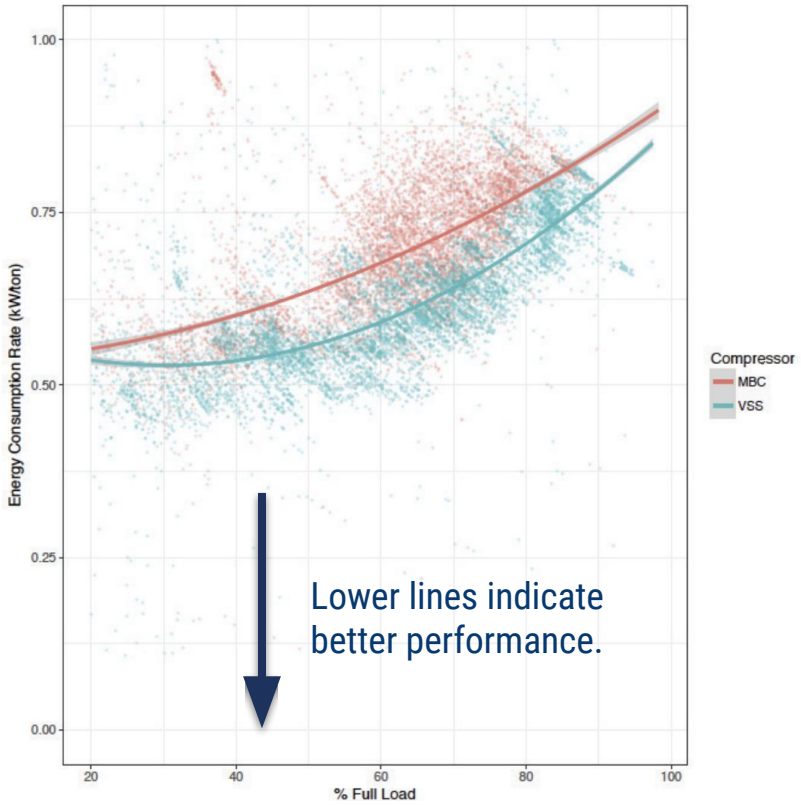
Real-world operating conditions as identical as possible in the Sidney R. Yates Building, Washington, D.C.

Carrier VSS

Daikin MBC

Technology for test-bed measurement and verification provided by Carrier and Daikin/Danfoss

Chiller Energy Use

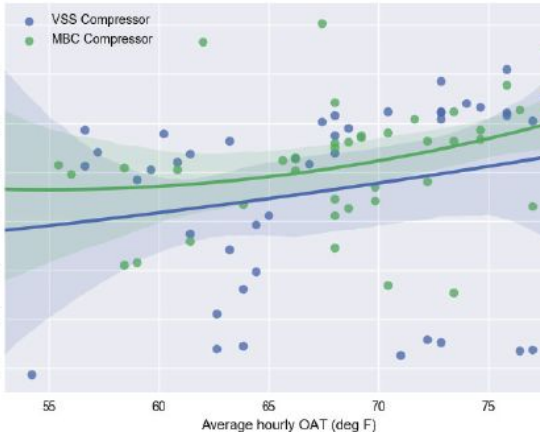


Chillers Have Comparable Energy Use

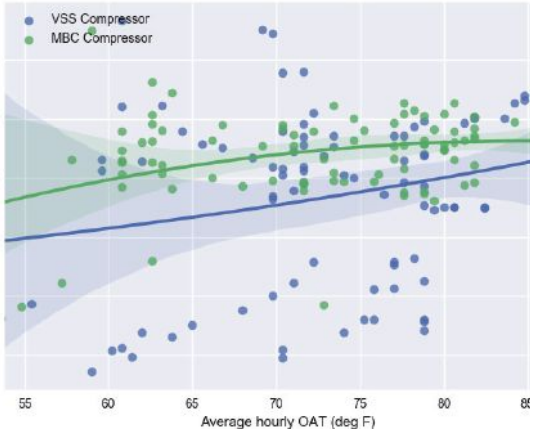
VSS 11% Lower Energy Consumption Rate at Test Bed

Savings could range from +24% to -4% due to measurement uncertainty

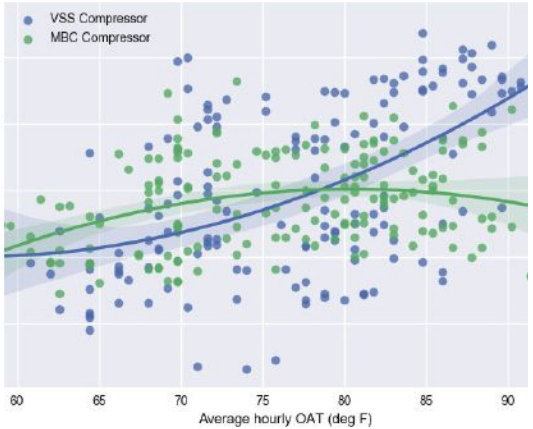
Average hourly —energy consumption vs outside air temperature



Energy consumed (in kilowatt-hours) per hour when condenser EWT is between **67.5°F and 72.5°F**



Energy consumed (in kilowatt-hours) per hour when condenser EWT is between **72.5°F and 77.5°F**



Energy consumed (in kilowatt-hours) per hour when condenser EWT is between **77.5°F and 82.5°F**

Operating Conditions

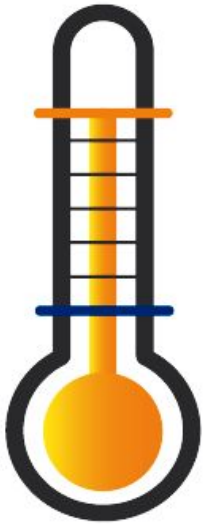
VSS able to handle swings in condenser water temperature outside the design parameters

Vendor states that MBC can be built to accept wider range of temperatures

VSS Entering Condenser Water Temperatures

July 2016, 95°

March 2016, 55°



Noise Ratings

78–83 Decibels for Both VSS and MBC

Sound level comparable to a vacuum cleaner, conversation is possible in the mechanical room.

VSS

Load	DBA
100	83
75	83
50	77
25	77

MBC

Load	DBA
100	83.5
75	82.5
50	81
25	77

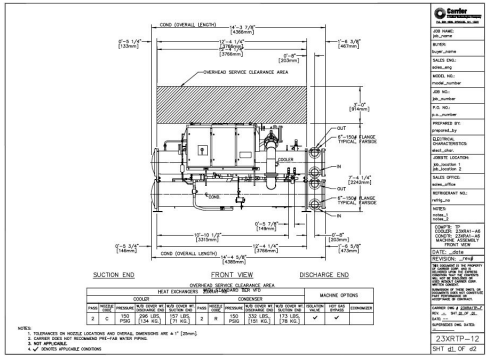
Yates Test Bed – 275 Ton Load Specified

VSS
275 ton chiller

14.4 ft length

18,857 lbs.

Budget Price: $119,000[1]



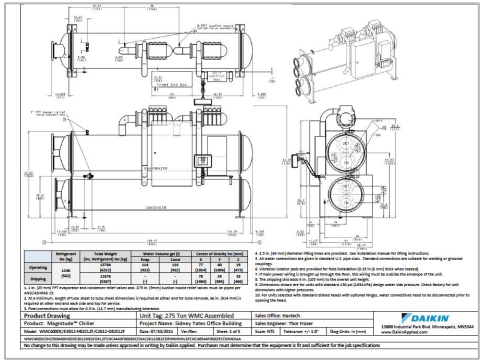
[1]Budget price was verified by using a third-party to "ghost shop" the vendor.

MBC
400 ton shell/2-200 ton compressors[2]

14.1 ft length

13,800 lbs.

Purchase Price: $185,000



[2]During design phase, vendor confirmed that this configuration was "selected for the most efficient" at a 275-ton capacity.

Deployment Opportunity

Consider VSS and MBC for End-of-Life Replacement for Water-Cooled Chillers

While VSS and MBC both provide improved operating performance compared to chillers meeting minimum FEMP performance criteria, the VSS chiller's ability to tolerate swings in condenser water temperature make it more robust and especially attractive for mission critical applications like data centers.

Facility Manager Feedback

Kenneth Thompson
Supervisory Property Manager
Yates Federal Building
NCR

Glenn Stewart
Chief Engineer
NCR

Randy Burgess
Engineer
NCR

Facility Manager Feedback - Yates Test Bed

Thumbs Up to Both Chillers

- VSS runs more in shoulder season accepts lower condenser water temperatures — 55°F for VSS, 65°F for MBC.
- You can shut down one of the compressors on the MBC.
- VSS chiller is a little noisier at low loads.

Facility Manager Feedback - Yates Test Bed

VSS Best for Our Unique Set-Up

- Cooling tower sump is 25-feet in the ground with no heater.

BEST PRACTICES

Best Practices for Chillers

Chiller Plant Design and Commissioning

Employ a mechanical engineer to do a thorough economic and technical analysis for all facets of the chiller plant design. Consider the control optimization system for chiller plants that GPG evaluated in September 2016 (GPG #028) in the chiller plant analysis.

Peak Cooling Load

When replacing an old chiller, perform a new heat gain/loss calculation to size the new chiller correctly.

Best Practices for Chillers

Cooling Load Profile

If the building spends most of the time at partial loads, prioritize the energy consumption rate (kW/ton) at part load. If a facility operates 24/7/365 with a fairly high and constant internal load focus on a chiller's efficiency at maximum capacity.

Load	VSS Rated kW/ton	MBC Rated kW/ton
100	0.615	0.543
75	0.414	0.412
50	0.278	0.295
25	0.303	0.265

Best Practices for Chillers

Condenser Water Supply Temperature

Centrifugal compressors are custom designed to meet site-specific condenser water temperatures. For effective performance of MBC centrifugal chillers, water temperature must be considered during design.

The variable-speed screw compressor is a universal design; the same compressor can be used in Phoenix, AZ or Fargo, ND.

Best Practices for Chillers

Local Electricity Rate Structure

Look at both consumption and demand charges. If demand charges are high, thermal storage or some other method of load shifting might be a cost-effective part of a new chiller plant design.

Chiller Manufacturer Presence

When choosing a chiller, consider whether or not the manufacturer operates in your locale. Some manufacturers might be able to provide better service because of having a stronger local presence.

Q & A

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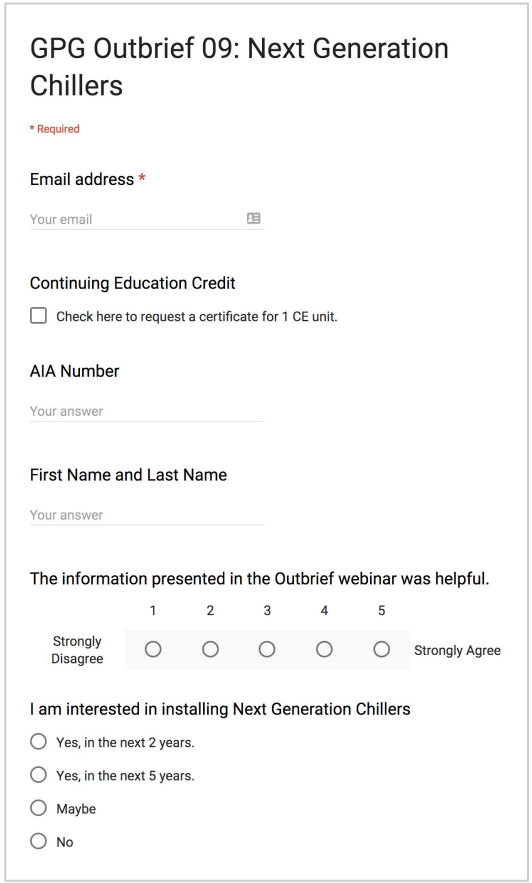

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Check here to request a certificate for 1 CE unit.

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First Name and Last Name

Your answer

The information presented in the Outbrief webinar was helpful.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I am interested in installing Next Generation Chillers

- ○ Yes, in the next 2 years.
- ○ Yes, in the next 5 years.
- ○ Maybe
- ○ No

Thank you

For more information: gsa.gov/GPG

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Kevin Powell, Program Manager kevin.powell@gsa.gov 510.423.3384