General Services Administration
Public Buildings Service

GPG-031 | UPDATED NOVEMBER 2017

VARIABLE-SPEED DIRECT-DRIVE SCREW CHILLER

Both the Variable-Speed Screw Chiller and the Magnetic Bearing Chiller Should be Considered for New or End-of-Life Chiller Replacements

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. GSA's Proving Ground (GPG) program, in collaboration with researchers from Oak Ridge National Laboratory (ORNL), evaluated a recent development in chiller technology, the variable-speed direct-drive screw (VSS) chiller, against a baseline state-of-the-art chiller technology, the variable-speed magnetic bearing chiller (MBC). A previous GPG study of the MBC found energy savings of 42%, when compared to a conventional rotary-screw chiller.[1] The test bed design at the Sidney R. Yates Building in Washington, D.C. connected the VSS and MBC chiller 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 (M&V) from the Yates Building showed similar performance for both chillers, supporting the conclusion that both VSS and MBC should be considered for new or end-of-life chiller replacements. Individual site characteristics will determine the most cost-effective chiller technology for a particular application.

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance.

INTRODUCTION

"We created a broad range of operating conditions to simulate different climates. The VSS chiller was able to accommodate entering condenser-water temperatures from 55°F in spring to over 95°F in peak summer."

— Kenneth Thompson
Building Manager
Sidney R. Yates Building
Washington, D.C.
National Capital Region
U.S. General Services Administration

PERFORMANCE SPECIFICATIONS
275-ton Chiller Efficiency

IPLV² FEMP & SPECS (kW/ton)

Positive Displacement (FEMP)	**0.54**
Centrifugal (FEMP)	**0.55**
Variable Speed MBC	**0.33**
Variable Speed Screw	**0.33**

What Is This Technology?

VSS CHILLER MEETS CHANGING LOAD REQUIREMENTS WITH SPEED CONTROL ALONE

Most buildings are subject to changing weather and different use profiles, so most chillers have to accommodate shifting loads. Variable-speed chillers accomplish this flexibility in different ways and with varying degrees of efficiency, depending, in part, on the type of compressor they use. Centrifugal compressors, for instance, like those applied by the MBC, use mechanical "unloaders" to release pressure and maintain stable and efficient operation as load and lift requirements change. The positive displacement screw compressor used in this VSS chiller does not require unloaders; it meets lift and load requirements by regulating motor speed alone. The elimination of unloaders contributes to operating efficiency and enables the compressor to function under a broad range of operating conditions. It also eliminates "surge," which can happen when the design and speed of centrifugal compressors do not match load and lift requirements.

What We Did

ASSESSMENT OF VSS ALONGSIDE STATE-OF-THE-ART MBC CHILLER

GSA's GPG program worked with researchers from ORNL to design a study that would compare the VSS chiller with the current state-of-the-art MBC. The Sidney R. Yates Building in Washington, D.C. was selected for measurement and verification (M&V) because the chiller plant could support evaluation of the VSS technology against the MBC chiller technology that GPG had previously validated as representing best in class performance. The Yates Building is a 208,000 ft^2 brick office building completed in 1880 and renovated, most recently, in 2013. The recent renovation, which focused mainly on occupied spaces, included a new building automation system (BAS). Renovation also included "right sizing" the chiller plant. Two magnetic bearing chillers were initially specified; the ORNL project plan substituted a VSS for one of the units. Both were connected to the same chilled water and condenser water loops, creating operating conditions as close to identical as possible within a real-world environment. During the M&V, the chillers operated in an alternating fashion. Entering condenser water temperature was adjusted to simulate cooling tower conditions characteristic of different climate zones around the country.

Using the Yates Building's new BAS, as well as instrumentation installed expressly for the assessment, researchers gathered performance data during part of the summer of 2015, when the new chiller plant first came on line, and then for the entire summer of 2016. They also conducted several interviews with the site operations team to gather overall impressions of the two units.

FINDINGS

VSS PERFORMANCE COMPARED TO MBC Researchers concluded that the VSS consumed 11% less energy on average than the MBC: 0.623 kW/ton compared to 0.699 kW/ton for the MBC. Due to field measurement uncertainty, this result has a statistical margin of error ranging from the VSS using 24% less energy to 4% more energy than the MBC. It is important to note that these evaluation results also may have been impacted by two additional factors:

- The load profiles for the two chillers were as similar as possible under real-world conditions, but during data analysis it was discovered that the MBC had 8% more operating time at a higher load with higher condenser water temperatures, which could have had a small, but negative, effect on measured energy performance.
- The test design assumed chiller compressors of identical 275-ton capacity. After the conclusion of the study, researchers learned that, at odds with all submittals, the MBC vendor provided a chiller of 400-ton nominal capacity as "most efficient for the load"; it is unknown whether this substitution had any significant positive or negative impact on aggregate performance.

When researchers employed an alternative evaluation method, analyzing kilowatt-hours consumed versus outdoor air temperature, they found that the VSS saved 3.4% on average, compared to the MBC.

VERSATILITY UNDER DIFFERENT OPERATING CONDITIONS The VSS compressor was able to operate under conditions not normally found in the DC climate zone, handling swings in entering condenser water temperature from 55°F in spring to over 95°F in peak summer.

QUIET PERFORMANCE In laboratory settings, the VSS and MBC chillers have similar sound ratings: 77 to 83 decibels (a sound level similar to a vacuum cleaner or garbage disposal).

CONSIDER BOTH VSS AND MBC FOR END-OF-LIFE REPLACEMENT Both chillers performed well and have rated energy consumption that is more than 35% better than Federal Energy Management Program (FEMP) standards for water-cooled chillers. Individual site characteristics will determine the most cost-effective chiller technology for a particular application.

Average Energy Consumption at the Yates Building

VSS savings could range from +24% to -4% due to field measurement uncertainty

Combined Chillers/ Total Building % of full load	% of Full Year's Profile	VSS kW/ton (weighted)	MBC kW/ton (weighted)
20-30%	3.8%	0.020	0.021
30-40%	8.3%	0.044	0.049
40-50%	11.3%	0.062	0.070
50-60%	13.1%	0.075	0.086
60-70%	25.1%	0.154	0.176
70-80%	24.3%	0.163	0.183
80-90%	13.0%	0.097	0.106
90-100%	1.1%	0.009	0.010
		0.623	**0.699**

CONCLUSIONS

These Findings are based on the report, "Variable-Speed Screw Chiller, Sidney Yates Building, Washington, DC," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact
GSA's GPG program
gpg@gsa.gov

What We Concluded

VSS AND MBC RECOMMENDED AS END-OF-LIFE REPLACEMENT ACROSS ALL CLIMATE ZONES

As installed at the Yates Building test bed, the VSS chiller cost less to operate and demonstrated the ability to provide chilled water over a wide range of entering condenser water temperatures. Both the VSS chiller and the MBC represent a significant performance improvement relative to "like for like" replacement of positive displacement and centrifugal chillers meeting minimum FEMP performance criteria and should be considered for all new or end-of-life chiller replacements. The best-practices listed below can help select a chiller that will be most effective for a particular application.

BEST PRACTICES FOR CHILLER SELECTION

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.

Cooling Load Profile Look at your 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, such as data centers often do, focus on a chiller's efficiency at maximum capacity.

Condenser Water Supply Temperature Centrifugal compressors are custom designed to meet site-specific condenser water temperatures. For effective performance of magnetic bearing centrifugal chillers, water temperature must be considered during design. The variable-speed screw compressor is a universal design.

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.

Footnotes

[1]GPG-009: Variable-speed Oil-free Centrifugal Chiller with Magnetic Bearings Assessment; George Howard, Jr. Federal Building and U.S. Courthouse, Pine Bluff, Arkansas. S.A. Parker, J. Blanchard (PNNL), December 2013.

[2]IPLV, integrated part-load value, is a seasonal average efficiency measure using kW/ton.

VSS technology for test-bed measurement and verification provided by Carrier Corporation. MBC technology supplied by Daikin Applied.