LEEF™ Technology

The Breakthrough Refrigeration Technology in Environmental Test Chambers That Produces High Energy Efficiency & A Lower Carbon Footprint

Weiss Technik North America, Inc.

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Table of Contents

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Summary

The design of refrigeration systems used by environmental simulation test chamber manufacturers has remained essentially unchanged for many years. However, as testing requirements have evolved, manufacturers have gradually increased compressor horsepower to provide greater cooling capacities. This method has provided reliable results, but refrigeration systems with larger compressor horsepower increase operating expenses by consuming more power. This needs to change because most of the United States' electricity is produced by using non-renewable resources, and any reduction in a company's electricity usage reduces its carbon footprint, in addition to providing cost savings. While a more efficient refrigeration system is needed, the design method of increasing compressor horsepower has become common practice in industry, with no one challenging this concept – until now.

A Patent Pending refrigeration system has been developed which offers the same cooling capacities as current market designs but can provide up to 40% energy savings on cooling requirements while simultaneously providing faster pull down rates and improved set point accuracy. This system was the result of collaboration between engineers in the United States and Germany after completing a rigorous analysis of their respective refrigeration systems. This innovation has been named "LEEF™", an acronym for "Leading Energy Efficiency Footprint™", which acknowledges the importance of environmental sustainability and corporate responsibility.

Introduction

Environmental simulation test chambers (test chambers) are used to test a variety of products across multiple market sectors, including server racks and cell phones, aircraft and spacecraft components, military equipment, textiles, and even entire automobiles. Over time, as test requirements and product specifications have evolved, users have adapted and updated their procedures and facilities to keep up with these changes, but the refrigeration systems responsible for their results have remained unchanged.

The purpose of this white paper is to explain why the current design surrounding test chamber refrigeration systems needs to change, as well as present a solution to the need for a lower operating cost refrigeration system.

Problem Statement

A widespread procedure for test chamber users is to load the product, decrease the temperature from ambient to cold, soak at the cold temperature, increase the temperature from cold to hot, soak at the hot temperature, and repeat the cycle. The product can be inspected at various points in the cycle or tested after all cycles have completed. The inspections can be focused on finding defects or meeting specific requirements, such as national or international regulatory standards, to ensure the product will not fail during its life cycle.

A common, overall temperature range for test chambers equipped with cascade refrigeration systems is -73° Celsius (C) to +180°C, and the test profile that users adhere to dictates how quickly the test chamber must change the test space conditions. The test profile could be an industry standard, written by in-house engineers, or commercially adopted from the military, to name a few possibilities.

Regardless of origin, test profiles have changed and will continue to change to keep pace with technology, market demands, and the latest safety requirements. A test profile that previously dictated a change rate of 1°C per minute may now demand a change rate of 2°C per minute, which requires an increase in cooling capacity within the same test space.

Test chamber manufacturers have achieved increased cooling capacities by increasing the size of the refrigeration system, and by default, compressor horsepower. While this method has been proven to provide reliable and sufficient results, it has a drawback – larger refrigeration systems require more power.

Figure 1 shows a near perfect linear relationship between cooling capacities and power needed to operate the system[1]. The trendline approximation shows that approximately twice as much power is required to operate a classic refrigeration system with twice as much cooling capacity. (The data and assumptions can be found in Appendix I.)

As users purchase test chambers with increased cooling capacities to meet new testing specifications and requirements, they are spending more capital on a new test chamber with a larger refrigeration system. Many users run their test chambers continuously to maximize throughput, so they are also significantly increasing their operating expenses by operating a test chamber with a larger refrigeration system. Figure 2 shows the average electricity prices in the United States since 2001[2]. These steadily increasing prices only add to the already increased operating expenses incurred by test chamber users, especially between July and September with the consistent spikes. The design of the classic refrigeration system for test chambers needs to change because current practices only produce more power-hungry equipment for users.

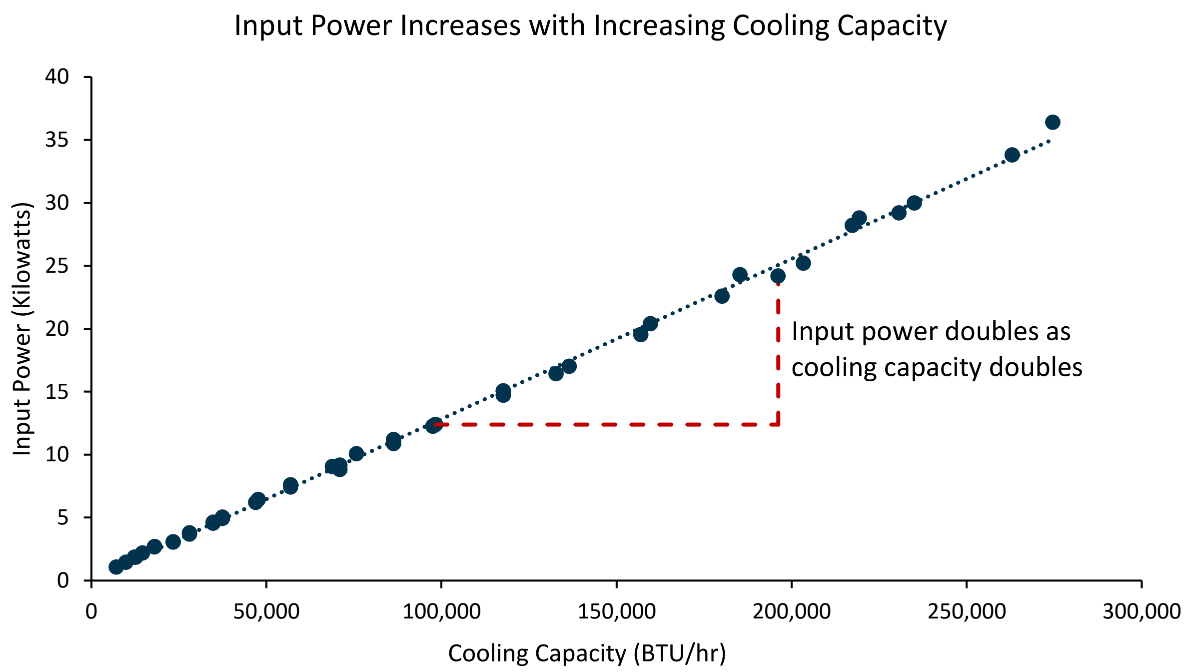

Figure 1: Relationship Between Input Power and Cooling Capacities[1]

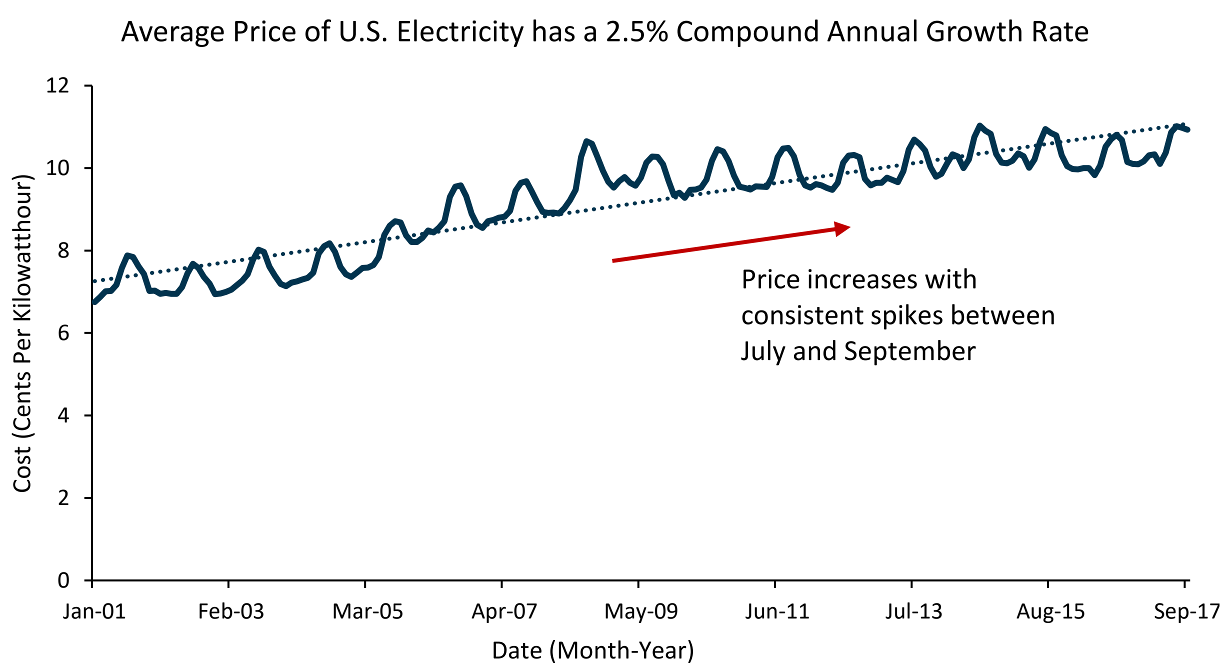

Figure 2: Average U.S. Electricity Price Since 2001[2]

The market needs a test chamber that has a more energy efficient refrigeration system. An energy efficient test chamber would reduce operating costs and, more importantly, would reduce carbon emissions in the electricity generation process.

Figure 3 shows the sources of the United States' electricity generation for 2016[3]. This shows how important it is to make improvements in energy efficiency. Any reduction in a company's electricity usage helps reduce the overall dependency on non-renewable resources.

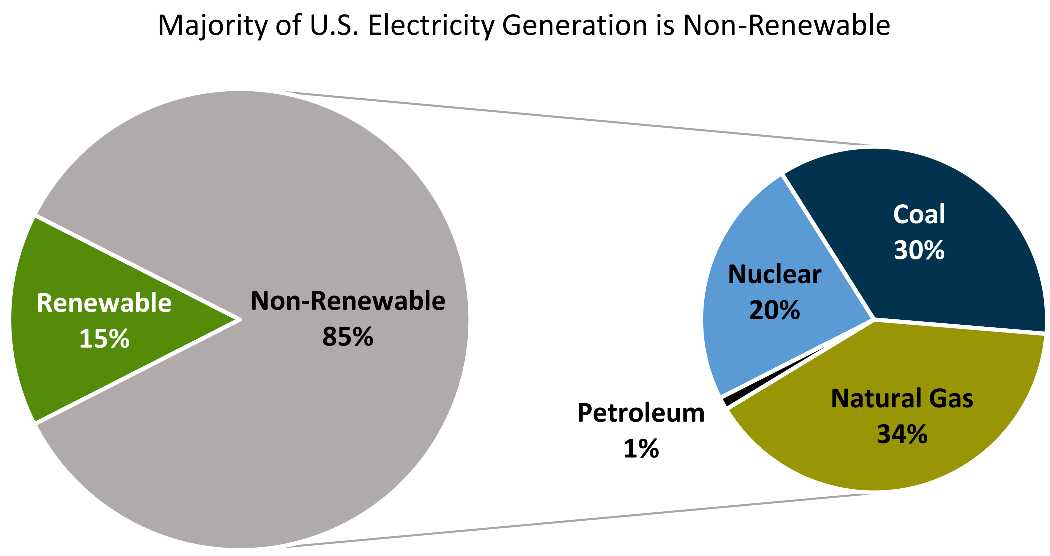

Figure 3: Sources of U.S. Electricity Generation, 2016[3]

Weiss Technik North America, Inc. tasked itself with delivering a solution. After 3 years of extensive research and development, collaborating with the German engineers of Weiss Umwelttechnik, GmbH, and rigorously analyzing the 2 companies' respective existing refrigeration systems, a new type of refrigeration system was developed. This system has been named "LEEF™", an acronym for "Leading Energy Efficiency Footprint™", which acknowledges the importance of environmental sustainability and corporate responsibility.

Solution

Figure 4 presents the LEEF™ Technology (LEEF™) logo. Seeing this logo on a test chamber ensures users are doing their part to reduce the dependency of non-renewable resources by conducting tests with a refrigeration system that is up to 40% more efficient during cooling and provides faster change rates. In addition to helping users decrease their carbon footprint, LEEF™ was also designed to obtain a smaller physical footprint, allowing users to better utilize their workspace.

Figure 4: LEEF™ Technology Logo

The benchmark was an existing Weiss Technik North America, Inc. test chamber, which used a classic refrigeration system. It had a comparable test space volume and cooling capacity, and the comparisons were run using empty chambers and the same temperature set points.

The following figures are a few of the results from the final stages of in-house testing. The solid red lines are the temperature set points, solid green lines are real-time LEEF™ data, solid blue lines are real-time classic refrigeration data, and dashed green and blue lines signify either averages or 1 standard deviation (σ) for the respective refrigeration systems.

An example of the improved energy efficiency is shown in Figure 5. It displays the results from a power profile test comparing LEEF™ to a classic refrigeration system. This test was chosen to demonstrate power consumption differences at soak temperatures of +85°C, -40°C, and ambient, and to show differences during hot and cold change rates. In this example, LEEF™ was 34% more energy efficient on average. While there was no significant difference during the +85°C soak, there were noticeable savings during the ambient soak, and the greatest energy savings occurred during the -40°C soak. Users can see up to 40% energy savings by soaking at colder temperatures for longer periods of time.

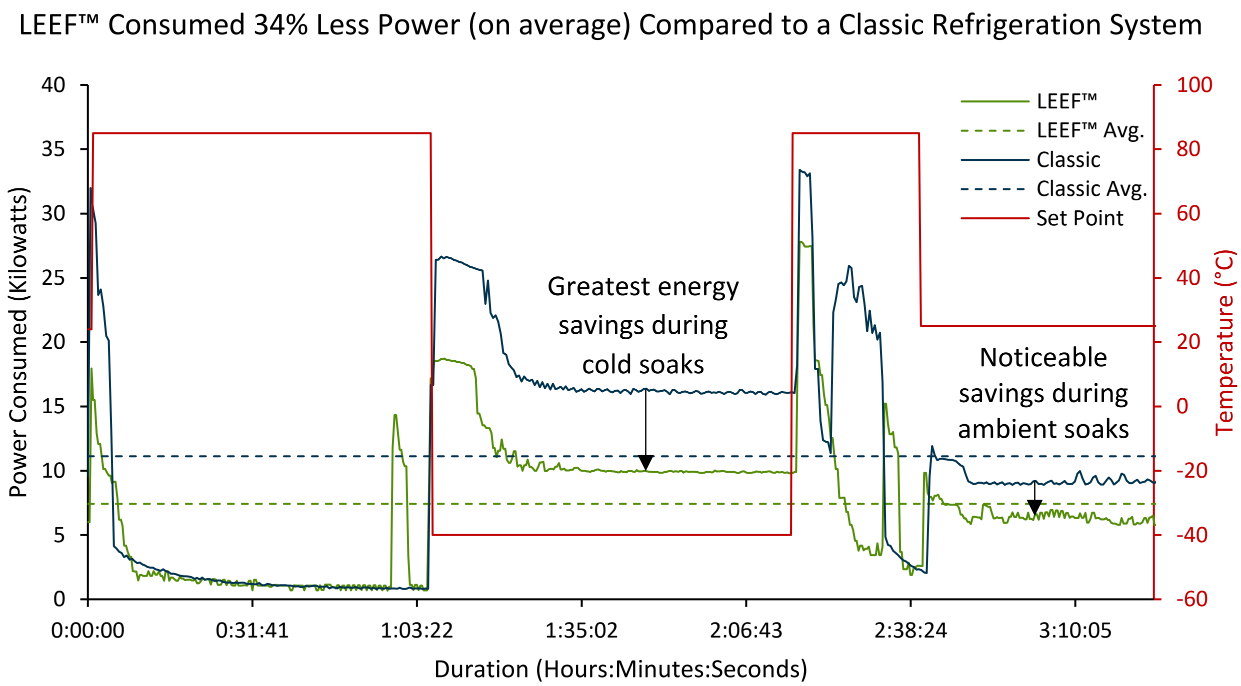

Figure 5: Power Profile Test Comparing LEEF™ and Classic Refrigeration Systems

In addition to increased energy efficiencies, LEEF™ delivers improved performance. An example is shown in Figure 6. It shows the same +85°C to -40°C pull down near the 1:03:22 mark of Figure 5, except measured temperature is displayed instead of power consumption. The test was measured per IEC 60068-3-5 (illustrated by dashed red lines), and LEEF™ reached the lower -27.5°C IEC 60068-3-5 limit 63 seconds faster than the classic refrigeration system. Most test profiles demand multiple thermal cycles, and by reaching the set points faster, LEEF™ can reduce overall testing time. The shortened testing time also contributes to lower operating expenses and reduced electricity usage.

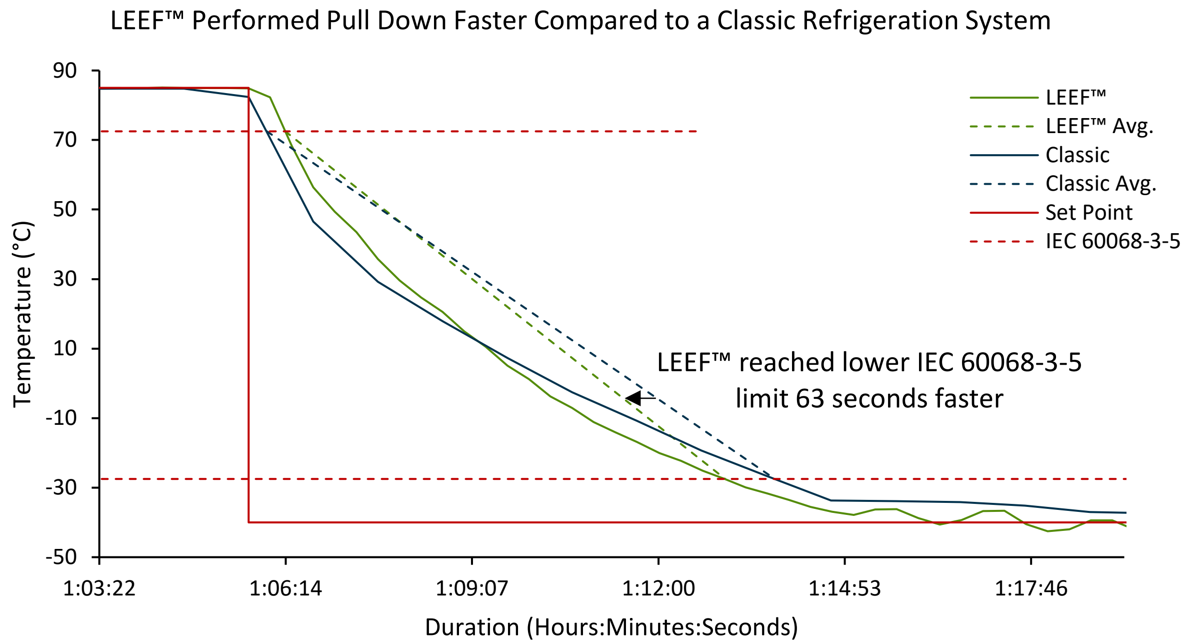

Figure 6: +85°C to -40°C Pull Down Comparing LEEF™ and Classic Refrigeration Systems

Table 1 further analyzes the pull down from +85°C to -40°C in Figure 6. Despite having a slightly larger test space volume than the benchmark chamber with a classic refrigeration system, LEEF™ had a 15.7% faster pull down rate and consumed 35.7% less power (on average) in the process.

Users will also see improved set point accuracy with LEEF™. While it was tested against the classic refrigeration system over a wide range of conditions, Figure 7 shows the improved accuracy at 2 common soak temperatures (+85°C and -40°C), after temperatures had stabilized for both systems. In each case, the control with LEEF™, was more accurate than the classic refrigeration system. It was also concluded that at the +85°C soak temperature, the standard deviation of LEEF™ is less than the classic refrigeration system at a 95% confidence level.

Table 1: +85°C to -40°C Comparison Between LEEF™ and Classic Refrigeration Systems

	LEEF™	**Classic**
Empty Test Space Volume (Cubic feet)	40.8	36.7
IEC 60068-3-5 Change Rate (°C per minute)	14.7 **(15.7% faster)**	12.7
Average Power Consumed (Kilowatts)	16.2 **(35.7% lower)**	25.2

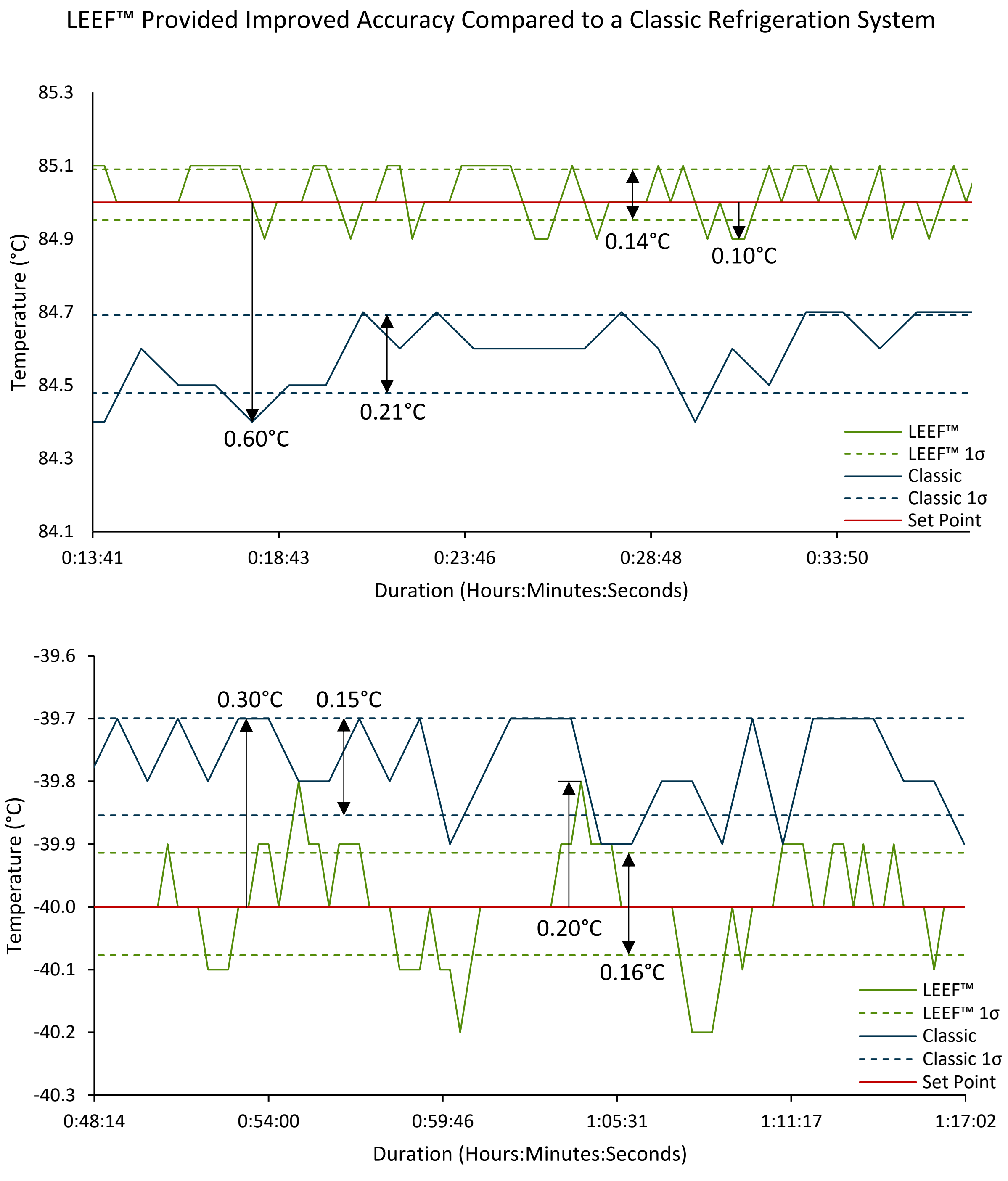

Figure 7: Temperature Fluctuation Comparison Between LEEF™ and Classic Refrigeration Systems

Conclusion

After years of refrigeration systems growing larger and more expensive, Weiss Technik North America, Inc. has developed a solution to stop this negative trend. LEEF™ Technology provides improved performance and set point accuracy at a lower operating cost compared to a classic refrigeration system. Test chambers with this technology will allow users to perform their needed tests and contribute to the movement of environmental sustainability by operating a refrigeration system that offers the same cooling capacities as current market designs but can provide up to 40% energy savings on cooling requirements.

Future Projects & Additional Information

The improved performance and energy efficiency of LEEF™ has been proven, and Weiss Technik North America, Inc. is currently working on expanding the capabilities of LEEF™ Technology so it can be incorporated into existing product lines that currently use classic cascade refrigeration systems. This will result in higher quality products, reduced operating costs for test chamber users, and it will contribute to the movement of environmental sustainability. More announcements will be made as projects are completed and released.

For any questions, please visit the Weiss Technik North America, Inc. website at: www.weiss-na.com or call 616-554-5020.

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Appendix I: Raw Data for Figure 1 - Relationship Between Input Power and Cooling Capacities

The following data was obtained using Bitzer's online software[1]. The following assumptions were made:

- Compressors: Semi-hermetic reciprocating
- Refrigerant: R404A
- Reference Temperature: Dew Point
- Single compressor
- Evaporating Saturated Suction Temperature: -10°C
- Condensing Saturated Discharge Temperature: 45°C
- Voltage: 460 V
- Frequency: 60 Hz
- Suction gas temperature: 20°C
- Liquid Subcooling Temperature: 0 K
- Operating Mode: Auto
- Capacity Control: Without
- 1 kW = 3,412.142 BTU/hr
- Only compressor model was changed
- Compressors with similar capacities and input power were excluded from this list but were included in Figure 1

Represented Model	Cooling Capacity (kW)	Cooling Capacity (BTU/hr)	Input Power (kW)
2KES-05Y	2.08	7,097	1.06
2JES-07Y	2.88	9,827	1.45
2HES-1Y	3.62	12,352	1.86
2GES-2Y	4.29	14,638	2.18
2FES-2Y	5.29	18,050	2.71
2EES-2Y	6.85	23,373	3.09
2DES-2Y	8.22	28,048	3.78
2CES-3Y	10.19	34,770	4.64
4FES-3Y	10.99	37,499	5.04
4EES-4Y	13.97	47,668	6.44
4DES-5Y	16.69	56,949	7.60
4CES-6Y	20.2	68,925	9.06
4BES-9Y	22.2	75,750	10.08
4TES-9Y	25.3	86,327	11.19
4PES-12Y	28.8	98,270	12.39
4NES-14Y	34.5	117,719	15.06
4JE-15Y	40	136,486	17.03
4JE-22Y	38.9	132,732	16.43
4HE-18Y	46.8	159,688	20.40
4GE-23Y	54.3	185,279	24.30
4GE-30Y	52.8	180,161	22.60
4FE-28Y	64.3	219,401	28.80
4FE-35Y	63.7	217,353	28.20
6JE-25Y	59.6	203,364	25.20
6HE-28Y	68.9	235,097	30.00
6GE-34Y	80.5	274,677	36.40
6GE-40Y	77.1	263,076	33.80