



# SECOND NATURE<sup>®</sup>

A COMPARATIVE STUDY  
OF SECONDARY GLYCOL  
AND DIRECT EXPANSION  
REFRIGERATION SYSTEMS





Second Nature Medium-Temperature secondary systems have been widely applied in commercial refrigeration since their introduction in the late 1990's. With more than 700 installations throughout North America using propylene glycol as secondary coolant, these systems have enabled customers to greatly reduce initial refrigerant charge and dramatically lower leakage rates of refrigerants that contribute to ozone depletion and climate change.

Since their introduction, questions have been raised regarding the energy efficiency of these systems - the addition of an extra step of heat transfer requires the primary refrigeration system to run at a lower suction pressure, and additional power is required to pump the secondary fluid throughout the distribution piping. However, other factors work to offset these requirements including the use of more effective coils in display cases and the fact that low suction superheat entering the compressors in the primary system increases compressor efficiency. More recently, variable-speed pumping of the secondary fluid has been introduced to significantly reduce pump energy during periods of lower load.

In an effort to understand how all these factors work together to influence energy consumption of the total system, a study was initiated in 2010 to gather information on real field installations. The study, conducted over a 12-month period, gathered information on three different systems installed in nearly identical stores and climates. The installations included a traditional direct-expansion (DX) system, a Second Nature MT system with constant speed pumping, and a Second Nature MT system with variable speed pumping. The results found that when compared to the traditional DX system, the Second Nature MT systems provided measurably better energy efficiency in the stores studied.

*The differences in recorded energy use for each system were significant.*

# Types of Refrigeration Systems



*Traditional DX system*



*SNMT system equipped with variable-speed (VS) inverter-controlled pumps*

Beginning in September of 2010, the medium-temperature refrigeration systems of three Lowes Food stores in a climatically similar area of North Carolina were monitored for energy use. The three stores chosen for the study were selected based on their being very similar in size along with other factors.

The types of refrigeration systems used in the stores were a traditional DX system, a conventional SNMT system with constant-speed (CS) pumps, and a SNMT system equipped with variable-speed (VS) inverter-controlled pumps. The primary refrigerant in all three systems (DX and SNMT) was R-404A. The sizes of the stores were nearly identical with the DX store at 49,008 sq. ft., the conventional SNMT-CS store at 49,171 sq. ft., and the SNMT-VS store at 50,029 sq. ft., a difference of approximately 2%. The capacities for the systems were also very similar, with the DX store at 1091 MBtuh, the SNMT-CS store at 1007 MBtuh, and the SNMT-VS store at 1004 MBtuh - variations in the load of the three stores would be taken into account in the analysis of the data.

As with any study of this type, there are other factors that vary between the stores that can impact results but are difficult to account for in the analysis. The hours of operation for the DX store were one hour more per day than the two SNMT stores, 126 hrs./wk. vs. 119 hrs./wk. With regard to system design, all three stores employed parallel racks with reciprocating compressors; the DX store used two racks — one with 5 compressors and the other with 4, and the



# Used in the Study

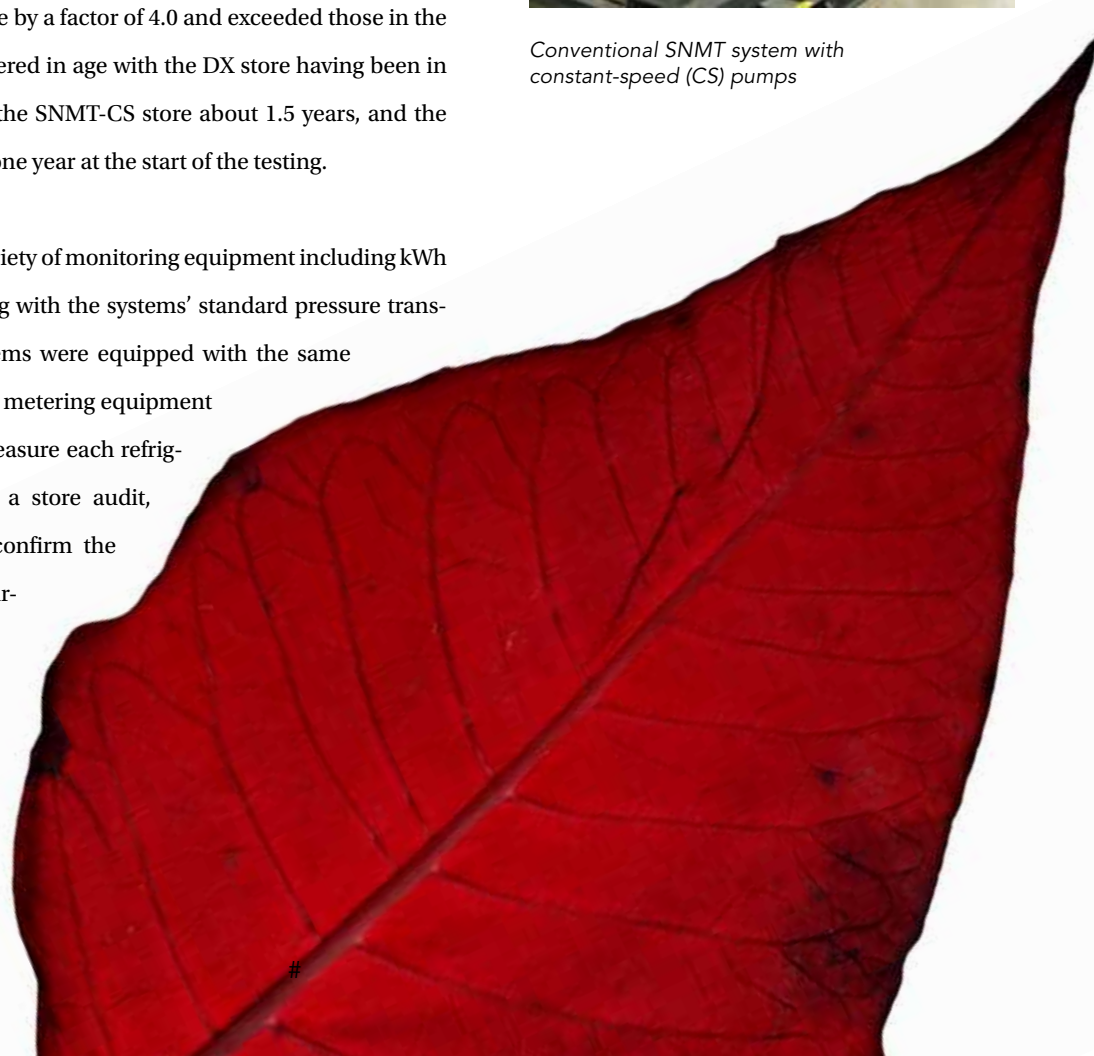
SNMT stores each had one rack with 7 compressors. All the stores used two air-cooled condensers, the only difference being that the condensers on the DX store were 10-fan models while the condensers on the SNMT stores were 8-fan units.

The SNMT systems both made use of two 7.5 hp pumps to circulate the glycol and used two brazed-plate heat exchangers as the glycol chillers. The store piping for the SNMT systems used engineered ABS plastic in a loop configuration whereas the DX system used AC&R copper in a traditional circuited piping system. Some other differences between the stores were the number of cases in each one. The DX store contained 73 cases and 9 walk-ins whereas the SNMT-CS store had 52 cases and 9 walk-ins and the SNMT-VS store had 59 cases and 8 walk-ins. The sales volume for the three stores also varied – the DX store was located in a more populated area while the two secondary stores were in more rural areas. The amount of perishable sales between the stores was provided by the customer and can be used as an indicator of sales volume: the DX store's perishable sales exceeded those in the SNMT-CS store by a factor of 4.0 and exceeded those in the SNMT-VS store by 2.5. The stores also differed in age with the DX store having been in operation for approximately three years, the SNMT-CS store about 1.5 years, and the SNMT-VS store open only approximately one year at the start of the testing.

Data for the study was obtained using a variety of monitoring equipment including kWh transducers and EMS data recorders along with the systems' standard pressure transducers and temperature probes. All systems were equipped with the same power data logging equipment and power metering equipment (Veris Enercept and CCS Wattnode) to measure each refrigeration component individually. During a store audit, validation power meters were used to confirm the accuracy of these devices. Voltage and current measurements were taken to verify readings for each rack, condenser, and pump, and discharge air temperature and velocity measurements were taken to verify case performance.



*Conventional SNMT system with constant-speed (CS) pumps*



# Discussion of the Data

## Comparitive Store Data

Actual Monthly kWh

	DX	SNMT-CS	SNMT-VS
Sept. 2010	68179	59084	57456
Oct. 2010	59710	52492	48051
Nov. 2010	52387	46887	39171
Dec. 2010	49193	46330	35075
Jan 2011	49687	43563	36253
Feb 2011	46320	42519	35409
Mar 2011	52573	49790	41912
Apr 2011	58403	52067	49460
May 2011	65831	57878	58003
Jun 2011	70307	59114	64683
Jul 2011	78488	64916	69820
Aug 2011	74119	63729	67393
Total YTD	725201	638373	602690
Cost YTD*	\$72,520	\$63,837	\$60,269

\*Cost based on a flat rate of \$0.10/kWh electricity cost. Savings based on baseline comparison; baseline store DX.

Data was recorded for the three systems from September 2010 through August 2011. Monthly average ambient temperatures for the three locations were very consistent as seen on the graph, and annual average temperature did not vary by more than 0.5 degrees. Analysis was performed to calculate the average monthly EER of each of the three systems, and after correcting the monthly energy to account for differences in the store's refrigeration loads, the relative energy cost savings of each system was calculated.

Note that due to a problem with the monitoring equipment, some power data for one of the DX system racks for one day in August was not recorded (indicated in yellow).

# Comparative Store Data

Normalized Monthly kWh

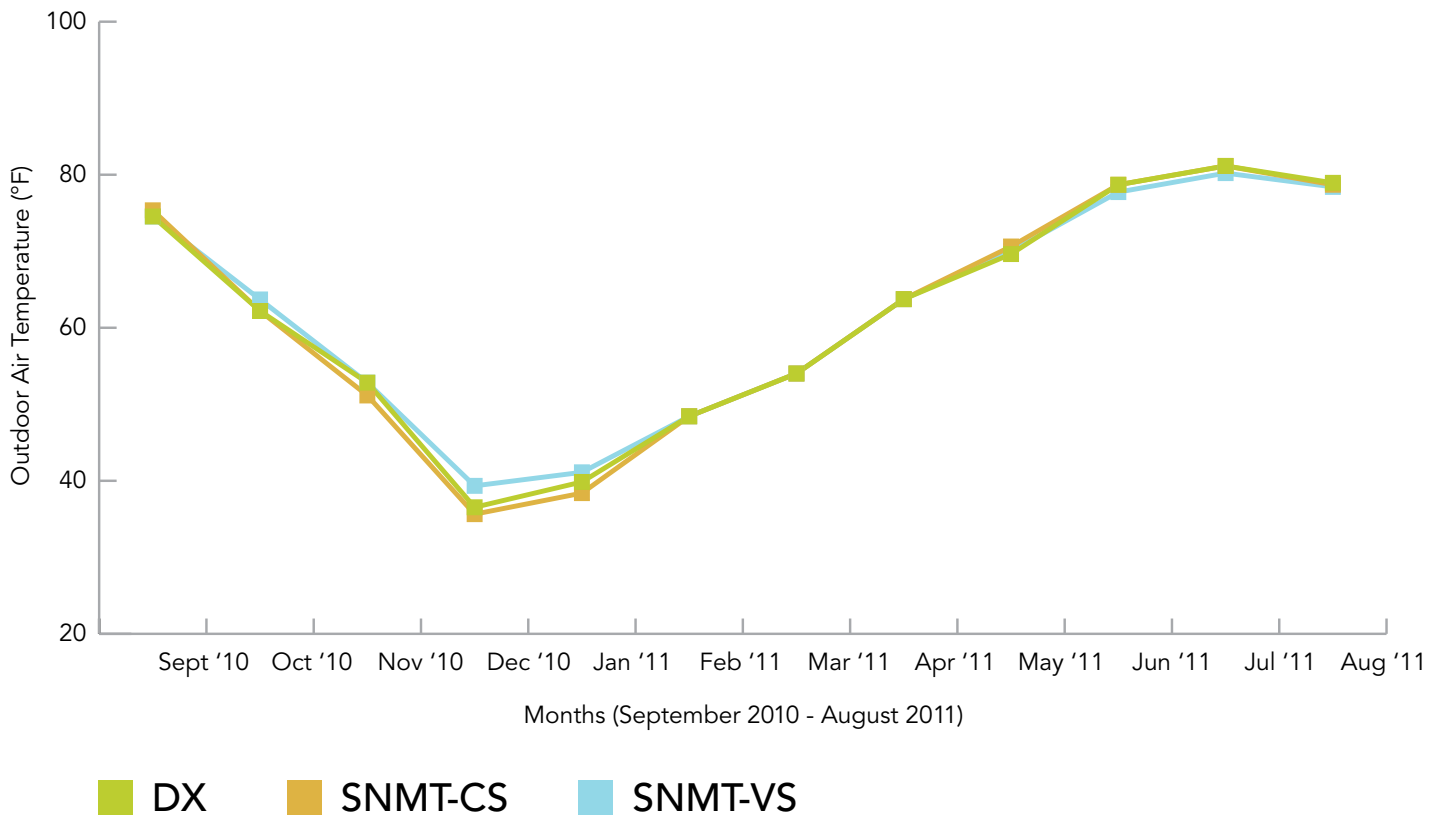
	SNMT-CS	SNMT-VS
Sept. 2010	63597	62060
Oct. 2010	56501	51902
Nov. 2010	50468	42310
Dec. 2010	49868	37886
Jan 2011	46890	39158
Feb 2011	45767	38247
Mar 2011	53593	45271
Apr 2011	56044	53423
May 2011	62299	62651
Jun 2011	63629	69867
Jul 2011	69874	75415
Aug 2011	68597	72793
Total YTD	687132	650990
Cost YTD*	\$68,713	\$65,099
<b>Savings YTD*</b>	<b>\$3,806</b>	<b>\$7,421</b>

*Data normalized to account for differences in store loads to present equal comparison to DX store*

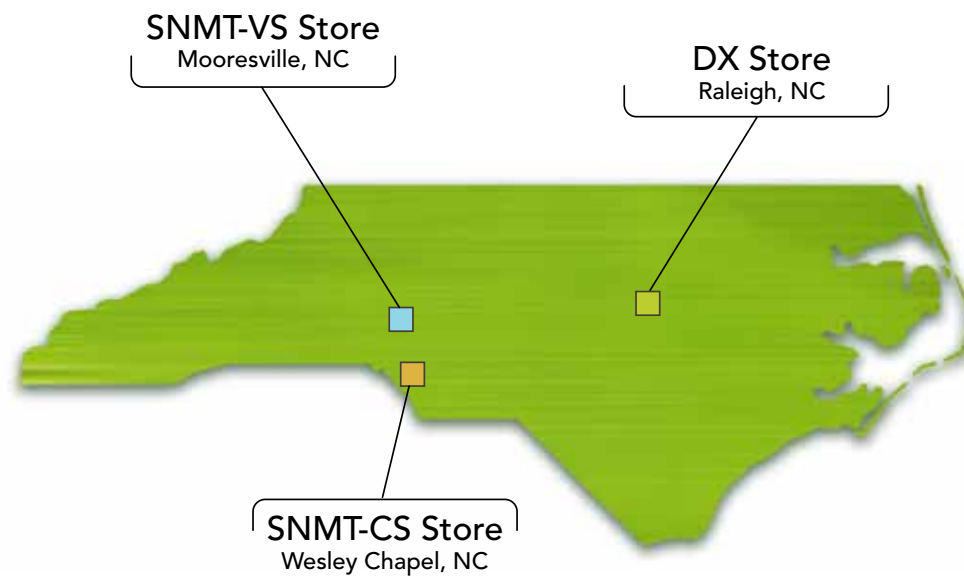
Significant results were found between the energy consumption of the three systems, with both of the Second Nature secondary stores outperforming the DX baseline store. After normalization, the SNMT-CS store (secondary with constant speed pumps) showed an annual energy savings of 5.2% compared to the DX baseline store, and the SNMT-VS store (secondary with variable-speed pumps) showed an annual energy savings of 10.2% compared to the DX store.

# Discussion of the Data


Outside Air Temperatures for Duration of Study



Store Locations in North Carolina





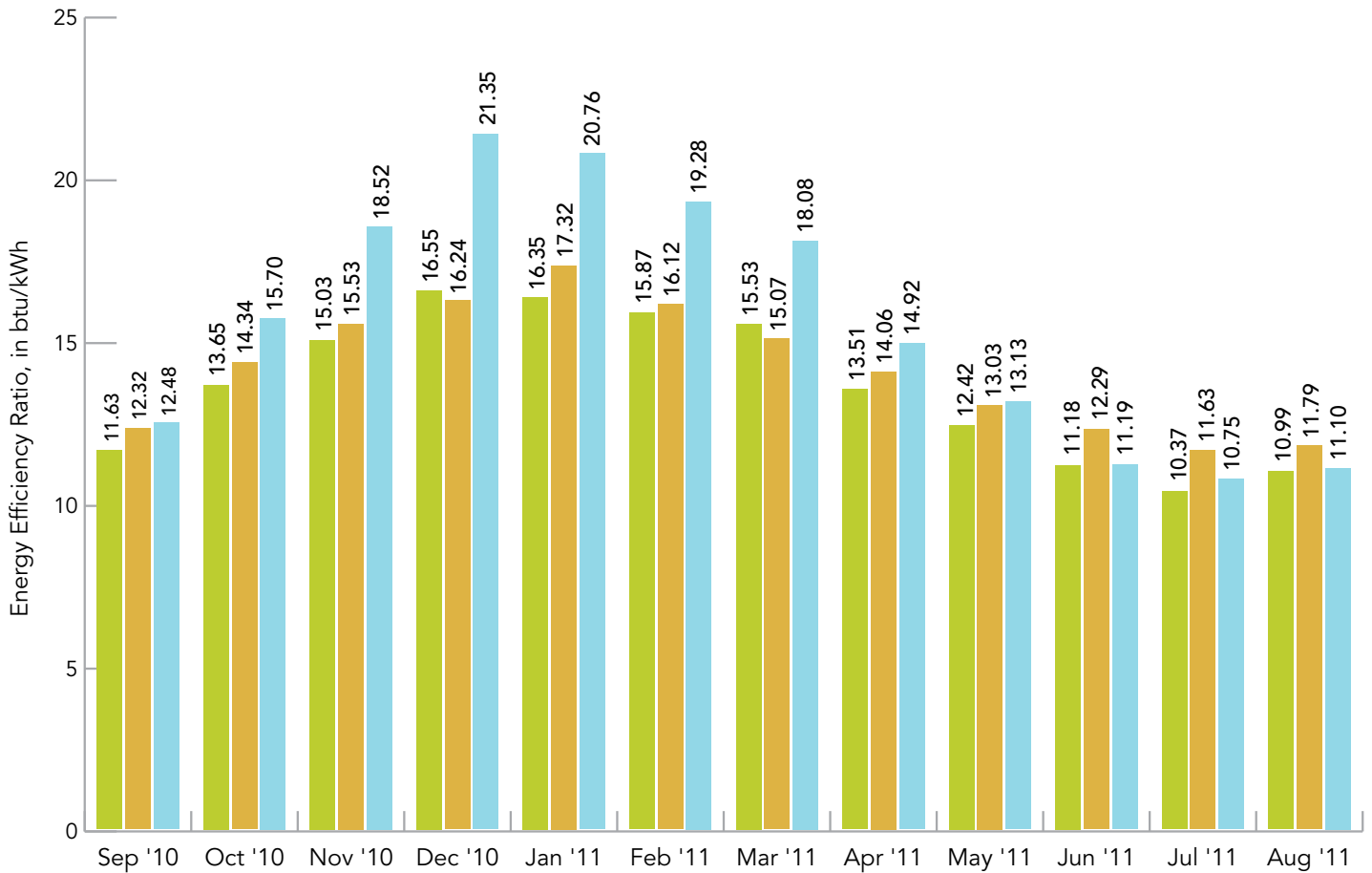


These findings would seem to run contrary to the perception within the industry that secondary refrigeration, by virtue of the additional pumps and step of heat transfer it requires, uses more energy to operate. Even with this perception, customers typically felt that even if they were not getting any energy savings, there were still other benefits of Second Nature refrigeration systems that made it attractive. Customers for instance, found that being able to reduce the number of TXVs in the system from more than 50 for a typical DX system down to just one or two for each brazed plate heat exchanger in a SN system was a tremendous advantage. Even more importantly, an average HFC charge reduction of 50% (over comparable medium-temperature DX systems) along with lower installation costs due to the need for less piping material, and the fact that line evacuation is not required during store piping installation, has long made SNMT systems an effective choice on these merits alone. The decision for many still unconvinced customers about whether to go with Second Nature or not, nevertheless, comes down to energy. The best energy performance that most observers were willing to concede was that secondary systems under the right circumstances could perform at energy-parity with traditional systems. The findings of this study, however, show conclusively that for the stores in this study Second Nature significantly outperforms the traditional DX system.



# Results of the Study


Average EER for twelve-month period



■ DX (Direct Expansion Baseline)

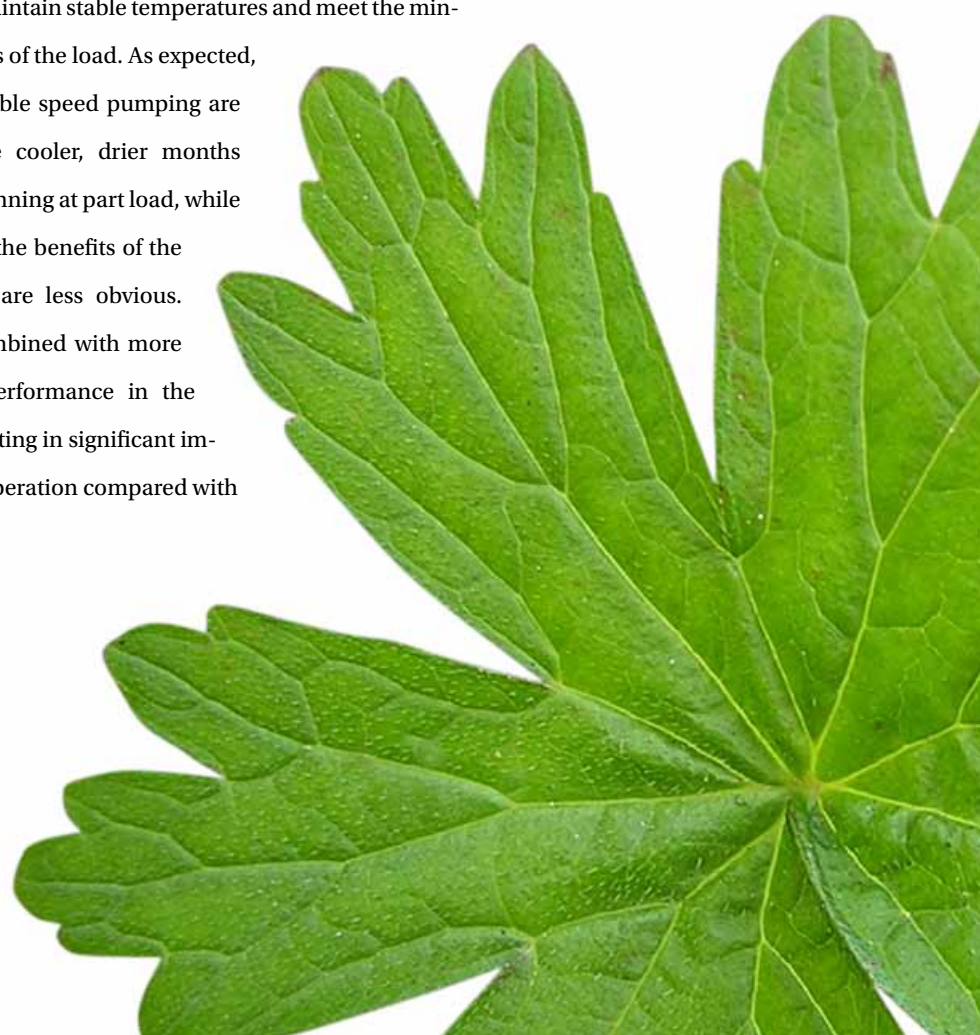
■ SNMT-CS (Second Nature with Constant Speed Pumps)

■ SNMT-VS (Second Nature with Variable Speed Pumps)

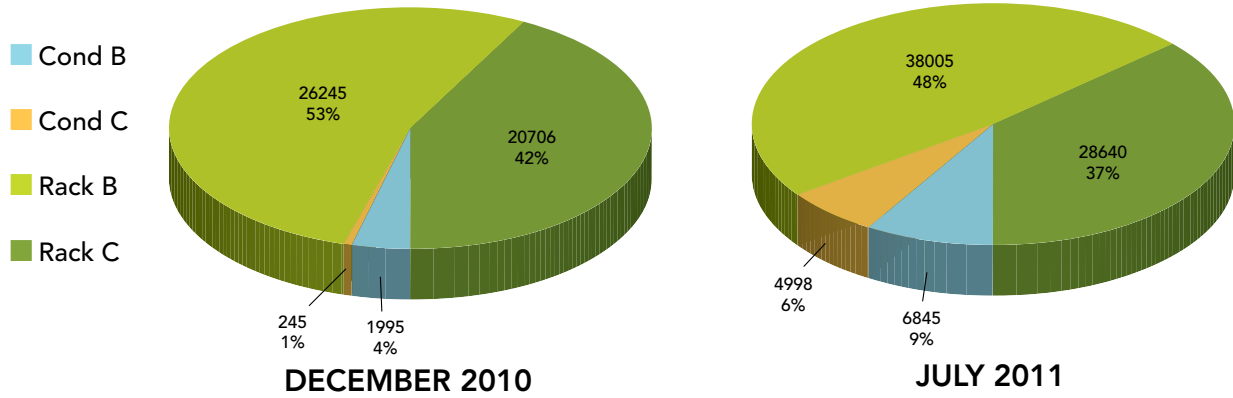


Given the perception that Second Nature systems required more energy to operate, the question remains: how is it possible that the Second Nature systems actually performed better?

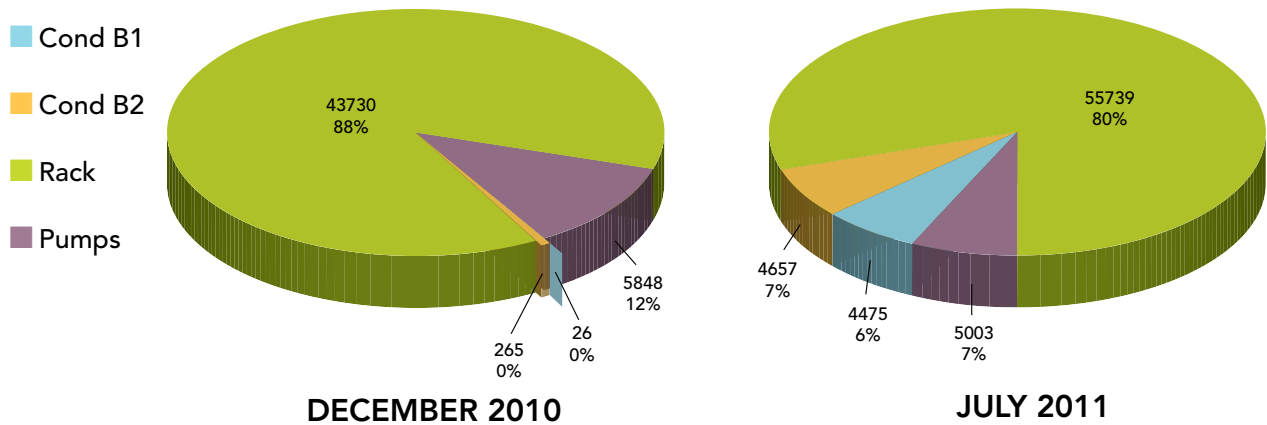
The best explanation of the superior energy efficiency shown by the data in this study is likely the result of improved temperature control provided by the Second Nature systems. Better temperature control requires less compressor energy than is otherwise needed to handle the wider temperature swings associated with DX refrigeration systems. On this basis, the better than five percent advantage of the SNMT-CS system over the DX system makes sense. Likewise, the even better performance of the variable-speed system is understandable given that the pumps in that system run only as much as necessary to maintain stable temperatures and meet the minimum flow requirements of the load. As expected, the benefits of the variable speed pumping are found primarily in the cooler, drier months when the systems are running at part load, while in the warmer months, the benefits of the variable speed pumps are less obvious. All these effects are combined with more efficient compressor performance in the secondary systems resulting in significant improvements in system operation compared with traditional DX systems.



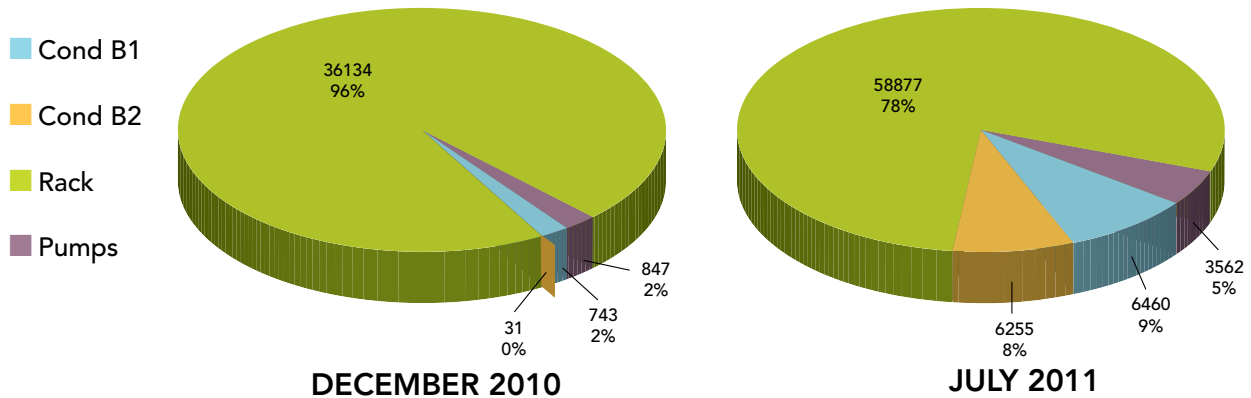
## DX kWh Breakdown



## SNMT-CS kWh Breakdown




## SNMT-VS kWh Breakdown



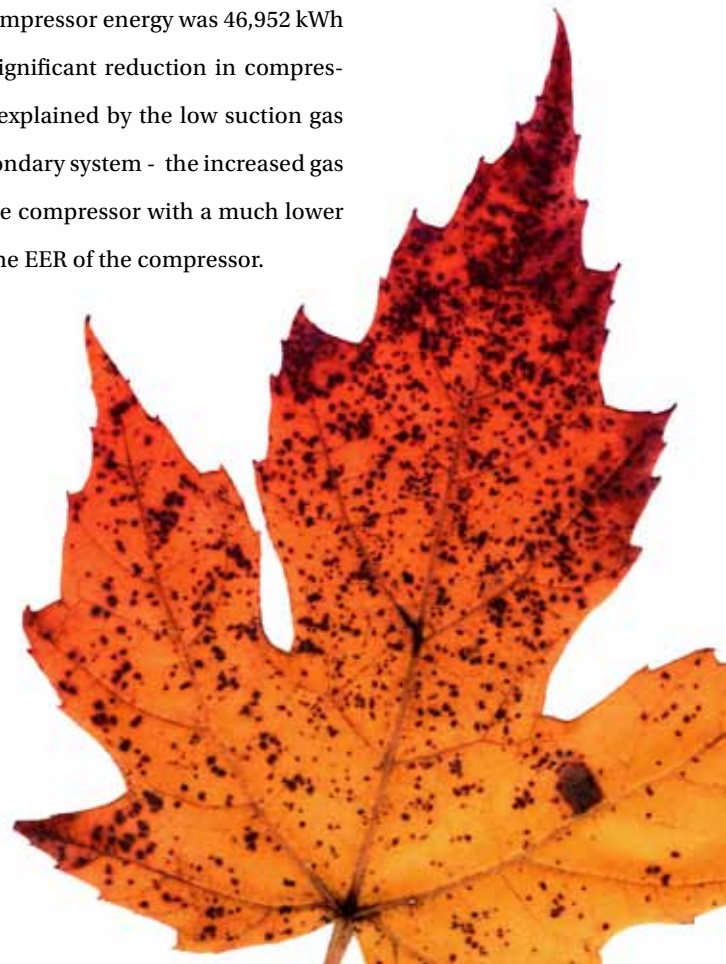
NOTE: December and July data represent coldest and warmest ambient temperature months, respectively.





A breakdown of the data between winter and summer operating conditions for the stores shows energy consumption of each of the major components of the systems. Data for the SNMT-VS store for instance, shows that in December of 2010, a majority of the energy used by the system (96%) went to the primary rack. In July of the following year, the proportion of energy going to the rack dropped to 78% with the pumps and condensers accounting for the remainder (note that the differences in the condenser energy use between the two systems relates to how heat reclaim is applied in each one). At both times of year, the differences in pump energy between the two Second Nature systems can be seen: 12% vs. 2% in December and 7% vs. 5% in July.

The most notable difference in this data is when the DX baseline store is compared to the SNMT-VS store. After normalizing for differences in Btu/Hr refrigeration load, in July the DX store compressor energy was 66,645 kWh while the SNMT-VS store was 58,887 kWh, and in December the DX store compressor energy was 46,952 kWh while the SNMT-VS store was 36,134 kWh. The significant reduction in compressor energy for the secondary store is most likely explained by the low suction gas temperatures entering the compressors in the secondary system - the increased gas density causes a higher mass flow rate through the compressor with a much lower increase in power consumption, thus increasing the EER of the compressor.





In the final analysis, it is reasonable to assume that if three stores were truly identical in every way except for the types of refrigeration systems they used, the differences in energy consumption between the three would be narrower. Variations in shopping traffic, indoor ambient conditions, and subtle differences in set-up of controls can all play a part in altering the energy consumption of these complex systems.

The key understanding from this study is twofold. First is that the perceived energy penalty of these systems can be mitigated by performance characteristics unique to secondary – more stable case temperatures, enhanced coil performance with fully-flooded operation and increased compressor efficiency from low suction gas temperatures. Second is that secondary fluid pump energy can be greatly improved through the use of variable speed pumping and has the most significant impact at part-load conditions.

These effects combined with a significant decrease in refrigerant charge and dramatically lower annual leak rates result in substantial reductions in direct refrigerant emissions. Second Nature systems can therefore be an important tool to help customers reduce equivalent carbon emissions and assist in meeting overall sustainability goals.







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