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SECOND NATURE®

A Comparative Study Of Variable Speed Secondary Coolant Systems

INTRODUCTION

Second Nature (SN) Medium-Temperature secondary systems have been widely used throughout the commercial refrigeration industry for more than a decade. Over 1000 installations across North America use propylene glycol as a secondary coolant. Second Nature systems allow customers to greatly reduce their initial refrigerant charge and dramatically lower environmentally harmful refrigerant leak rates.

Since the arrival of these systems, questions about their energy efficiency have been raised. Some prospective customers wonder whether the addition of an extra integral step of heat transfer between the primary and secondary sides of the system causes the primary side to run at a lower suction pressure while at the same time requiring more power to pump the secondary fluid through the store. Customers' experience, however, has shown that other factors offset these concerns including the use of more effective coils in display cases and walk-ins and the fact that the low suction superheat entering the compressors on the primary side increases compressor efficiency. More recently, the introduction of variable-speed pump drives and controls has been instrumental in significantly reducing pump energy during periods of decreased demand.

Prior to the advent of variable-speed pump controls, the most common approach to controlling pumps relied on constant speed operation to circulate fluid through the chillers from the mechanical center to the store and back. This seemingly simple circulation loop was somewhat complicated in that as the loads varied under normal operating conditions, cycling off in low load conditions and during circuit defrosts for instance, the system essentially worked as a variable volume system. When such cycling takes place constant speed pumps can only adjust to the change by either moving up or down their curve, or cycling entirely off if a drastic load change occurs. By being constrained to the full speed pump curve, therefore, any potential adjustment of the pump to flow or pressure is negligible compared to the actual change in load within the system. This often produces an undesired affect of creating too much flow in the system, causing more energy to be consumed than would otherwise be needed.

As with almost any new technology (including SN systems themselves) variable speed drive systems have met with some skepticism in regards to their complexity and reliability, not to mention the increased first cost of the equipment. These concerns may seem justifiable until one realizes the benefits of the approach. Like most any new technology, variable speed drives went through many stages of development until the reliability of today's systems became established. Any challenge there might be in adding drives to existing systems (or in the design phase to new systems) is now negligible. When drives are applied to handle loads across the entire system, as opposed to just individual pumps, the advantages of integrating them into a system becomes rather clear.

CASE STUDIES

In order to understand how this technology works to improve the energy consumption of an entire system, a study in 2010 was conducted that gathered information from real field installations. The study carried out over a twelve-month period, compared data from three different systems installed in nearly identical stores within a geographically and climatically contiguous area. The installations included a traditional direct-expansion (DX) system, and a Second Nature Medium Temperature system with constant speed pumping (SNMT-CS), as well as another Second Nature system with variable speed pumping (SNMT-VS). The results showed that when compared to the traditional DX system, both SNMT systems performed measurably better and that the variable speed-equipped system obtained the greatest energy efficiency in the stores studied.

Although the stores were as nearly similar as any set of three different stores could be – they varied by no more than 2% in square footage and with system capacities ranging from 1004 MBtuh to only 1091 MBtuh between them – the results of the study could be considered less than conclusive given that the stores were not exactly identical. One of the stores for instance, operated one more hour per day than the other two and the number of coils, compressors, condenser fans and type of piping (engineered plastic versus copper) differed between the SNMT stores and the DX store. But none-the-less the data was clear.

Analysis of the data was performed to calculate the average monthly energy efficacy ratio (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.

The findings showed significant results 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 showed an annual energy savings of 5.2% compared to the DX baseline store, and the SNMT-VS store showed an annual energy savings of 10.2% compared to the DX store. But the fact that certain variables differed between stores prevented the results from being considered definitive.

As it happened, another study that could ever better address any remaining concerns and categorically establish the effectiveness of variable speed pump control had already been started. In this second study, a single store that was originally equipped with constant speed pumps, had variable speed equipment and monitoring devices added.

The store selected for the study, a large marketplace-style supermarket located in northeast Virginia was equipped with triplex constant speed pump stations consisting of three 10hp pumps. The pumps were initially controlled using differential pressure across the pump station headers. The differential pressure setpoints for the system allowed the pumps to cycle on and off as needed depending on the refrigeration load of each system. The secondary and primary sides of each system were connected by two large parallel chillers, both of which had a design capacity of 592000 Btu per hour, for a total design refrigeration load of 1184000 Btu per hour. The parallel racks on the primary side of the systems, consisting of four screw compressors using 404A refrigerant, handled the load from the chillers.

After the store's first year of operation, variable speed drives and a control panel were added to the existing constant speed control for one of the systems to use in the study. The new panel was installed in such a way that the pumps could be switched from one type of control to the other. The variable speed controls consisted of a Programmable Logic Controller (PLC), switchgear and individual variable speed pump drives. As recommended by Hill PHOENIX, variable speed control was accomplished through the use of end-of-loop differential pressure transducers placed at each end of the two loops connected to the system. By monitoring each of the system's loops, the PLC continuously adjusted pump speed and cycling in order to achieve optimal coolant flow and energy use.

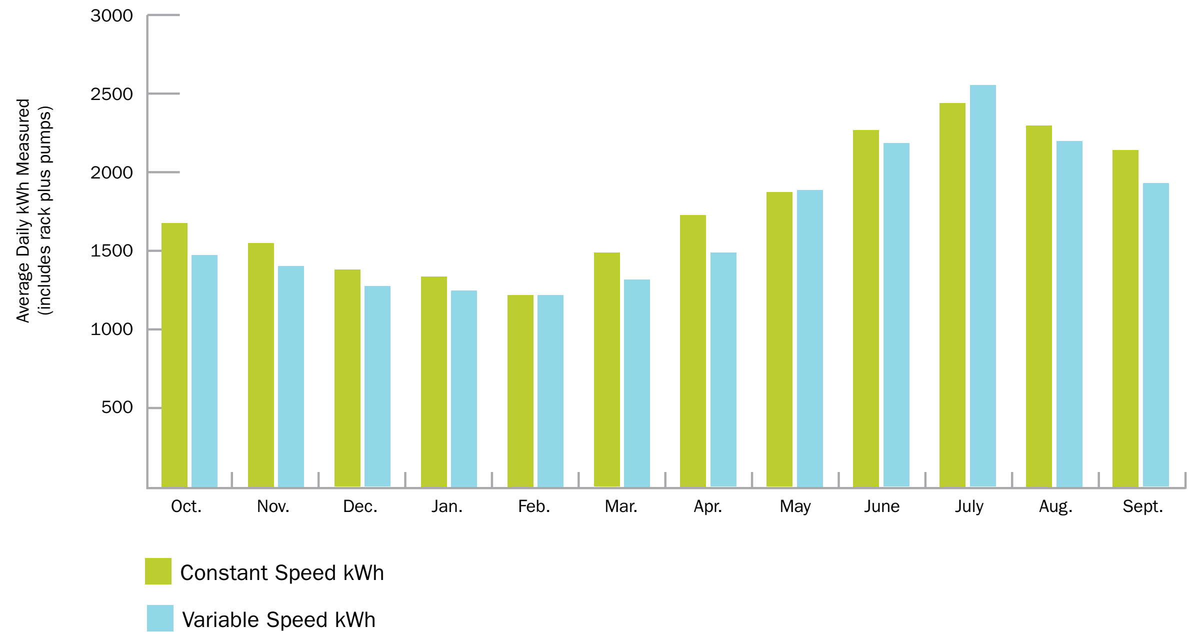
The main power feeds to the pumps were equipped with Square D PowerLogic Ion 6200 power monitoring meters. Along with the pumps the same model power meters were installed on the refrigeration rack. The meters continuously recorded power consumption for both portions of the system so as to provide as comprehensive an energy comparison as possible in a real-world environment.

STUDY METHODOLOGY

The study was conducted over the course of a twelve-month period by continuously monitoring the system's power consumption while alternately switching each week between constant speed and variable speed pump control. On the Monday of each week during the study the system was switched from one control method to the other in order to provide a good data sample from each week throughout the year. Along with the power data, the daily average outdoor air temperature was recorded for the store's location as a reference point.

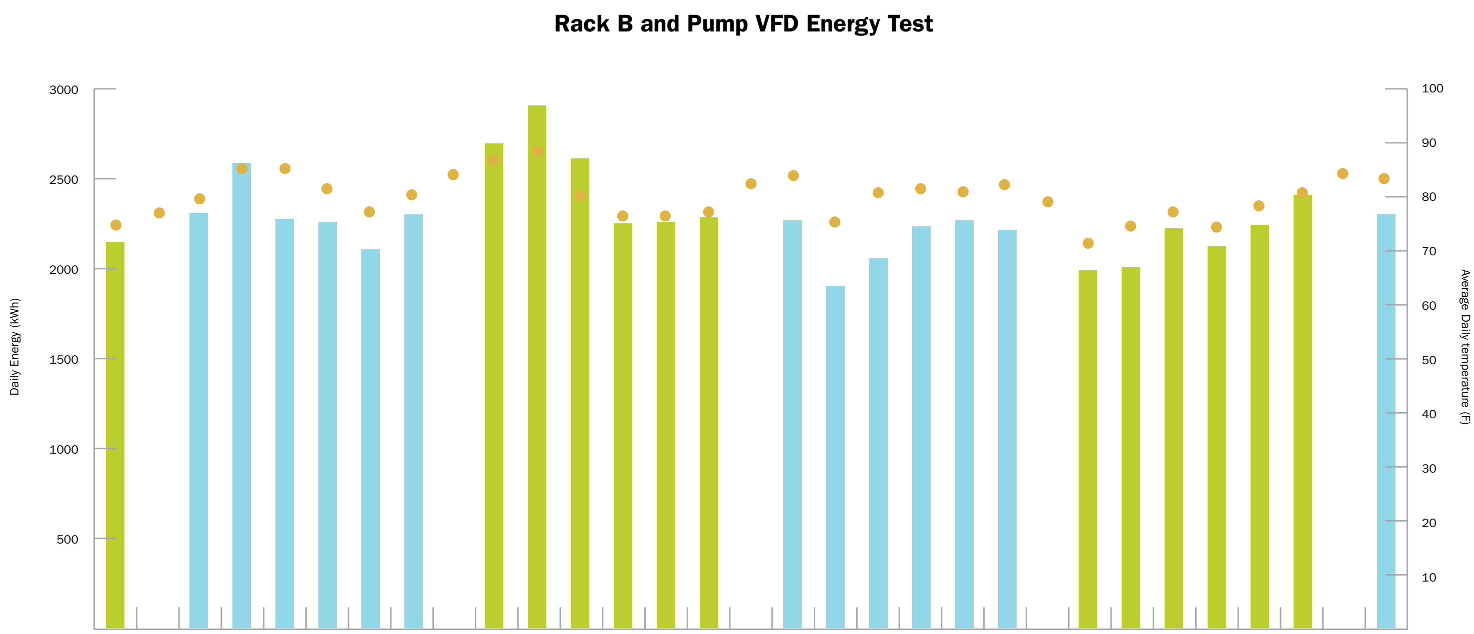
RESULTS

12-Month Energy Combined Rack and Pump Energy Data



Results of the study show that over the course of the study period a clear decrease in energy consumption was observed when the system ran in variable speed mode. Taking a single month's data for pump energy, August 2010, for instance, shows how significant the difference between the two approaches was. As the ambient temperature fell, energy consumption by the pumps in constant speed operation actually rose whereas in variable speed operation it remained fairly consistent. For the month, constant speed power consumption reached a high of nearly 3000 kWh but variable speed power consumption never exceeded 2600 kWh. The total month's energy consumption for the constant speed system was 2329.38 kWh and 2244.68 kWh for the variable speed drives. At $0.07 per kWh, the 84.70 kWh savings amounts to a reduction of $183.80 for the month.

One Month's Combined Rack and Pump Energy Data



Date	8-1	8-2	8-3	8-4	8-5	8-6	8-7	8-8	8-9	8-10	8-11	8-12	8-13	8-14	8-15	8-16	8-17	8-18	8-19	8-20	8-21	8-22	8-23	8-24	8-25	8-26	8-27	8-28	8-29	8-30	8-31
Daily Energy (kWh)	2155	0	2321	2593	2289	2265	2114	2306	0	2708	2915	2623	2261	2273	2299	0	2275	1909	2058	2239	2273	2226	0	1994	2010	2237	2128	2258	2420	0	2313
Average Daily Temp (F)	75.0	77.0	80.0	85.5	85.5	81.5	77.5	80.5	84.0	87.0	88.5	80.5	76.5	76.5	77.0	82.5	84.0	75.5	81.0	81.5	81.0	82.5	79.0	71.5	74.5	77.5	74.5	78.5	81.0	84.5	83.5

Off Drives daily average (kWh) = 2329.38
On Drives daily average (kWh) = 2244.68
Average Daily Temperature (F)

Difference (kWh) = 84.70
Estimated August Savings (at $0.07/kWh) = $183.80

Over the course of the entire year, the data showed an average daily difference of 110.4 kWh or an estimated annual savings of $2,820.

It should be noted that while the savings observed for this study were based on a $0.07/kWh rate, other areas of the country have different power rates and will therefore see different rates of return. One other note to consider is that the store in this study has multiple racks and pump stations, only one set of which was utilized for investigation. The predicted complete annual savings for the entire store, based on the verified results of the study, is $5484 with an ROI period of 1.01 years.

CONCLUSION

The best explanation of the improved energy efficiency shown by the data in this study is likely the result of improved temperature control provided by the variable speed control. Better temperature control requires less compressor energy than is otherwise needed to handle the wider temperature swings associated with constant speed control. The 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 pronounced though no less noticeable. Over the course of the study it is clearly apparent that variable speed pump control was better able to match loads, especially in the cooler, lower humidity months.

In the other study noted above, it seemed reasonable to assume that if the three stores in that study had been truly identical except for the types of refrigeration systems they used, the differences in energy consumption might have been more clearly accounted for. In this study, those differences were eliminated. From the latter study, variable speed pump control can clearly be seen to provide greater energy efficiency over traditional constant speed pump control. In fact, as far as the chain's regional maintenance manager was concerned, the study "made a believer" out of him.

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