Energy Savings in Packaged HVAC Equipment

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ABSTRACT

Packaged HVAC equipment serves a significant percentage of the space conditioning needs of small and medium-sized commercial building space. Most of this equipment is maintained by service agreements with mechanical contractors. This service market is highly competitive and relatively low margin. Standard practice for maintenance of this equipment pays little to no attention to the operational energy efficiency of the units. Cost effective energy savings are available by enhancing the service offerings by contractors to optimize and maintain the operational efficiency of packaged HVAC equipment. Program offerings by utilities are seeking to acquire this resource.

PACKAGED HVAC EQUIPMENT

This article will describe the opportunity for energy savings and programmatic approaches to achieve those savings of a particular type of packaged unitary HVAC equipment. The target equipment for this effort is constant volume packaged HVAC equipment with air economizers in the three-ton to 20-ton size range. (This is not to imply that there are no operational energy savings in other types of packaged equipment.) Survey data suggest that there are over 300,000 such units installed in the four-state Pacific Northwest region, with more than 16,000 new units sold as replacements or new installations

each year. This suggests that there are millions of such units nationally. While these units are most frequently employed for strip mall, retail, small office, and "big box" stores, they are also a feature on many medium-sized commercial and institutional buildings. There are numerous manufacturers of this equipment, but the market is dominated by equipment from Trane, Carrier, and Lennox. Units may be air conditioning only, a heat pump, or utilize natural gas for a heat cycle in addition to a refrigerant cooling cycle.

SERVICE MARKET

Since the majority of this equipment is installed on buildings that employ minimal, if any, in-house maintenance staff, these units are typically maintained through a third-party service agreement with a mechanical contractor. The mechanical service contractor market is wide ranging in most metropolitan communities by size of firm and scope of offerings. (Smaller communities may have more limited options in choice of contractor.) Regardless, the service market is best described as extremely competitive and low margin. Customers often choose service contractors based on price and have very little knowledge of the HVAC equipment itself. The type of service agreement varies by customer. Many service agreements are "basic" in nature, specifying periodic maintenance inspections to insure continued functioning of the mechanical features of the unit. Any necessary repairs or replacement of parts are handled outside the scope of the service agreement. It is reasonable to characterize this approach as "run to failure." In fact, the service contractor's only opportunity for substantial profit in this arrangement is in replacement of broken parts or replacement of an entire unit.

More savvy customers take a longer-term approach and negotiate a more substantive service arrangement. These contracts may call for regular seasonal inspections and adjustments and even include repairs and/or replacement of broken parts. Service contractors utilize well-developed maintenance protocols, prescriptive by season, to insure technician rigor in inspection and documentation of problems and their resolution.

IT'S ABOUT THE "O"

In the world of O&M, there is great emphasis on maintenance, but much less so on operations. This is certainly true of the service market for packaged HVAC equipment. Regardless of the nature of the service agreement (basic to full service), there are ubiquitous opportunities for energy savings in the operation of this equipment. Even well-maintained, packaged HVAC equipment can be mined for cost-effective energy savings by improving the operational efficiency of the unit. Specifically, there are at least four areas where tuning or adjustments can be made that provide reduced energy use, especially in the cooling cycle of the unit.

Improved Economizer Function

The Pacific Northwest's climate is one of the best in the United States for air-side economizing. When there is a call for cooling, it is much more economical to use outside air for cooling than operate a compressor. In most parts of the region, energy codes have required air-side economizers for several years.

The economizer system relies on a combination of outdoor and supply/return temperature sensors, air dampers, modulating motor, and controls which determine the amount of outside air introduced into the conditioned space. When the space is occupied, some outside air is brought into the space for health/safety reasons. When there is a call for cooling, the system should try to provide cooling through use of the maximum amount of outside air possible (as long as outside air conditions are judged favorable by the sensor). If one or more of the links in this chain are broken or out of adjustment, the system will use more energy than needed to ventilate and cool the space.

Common problems that are identified with the economizer are inaccurate or failed sensors, an unreliable or failed economizer controller (which includes minimum air setting and economizer cut-in potentiometers), stuck or leaky air dampers, and minimum/maximum outside air rates well outside the expected amounts. Ventilation air rates follow ASHRAE guidelines and are typically 10-20 percent of the rated system flow. To maximize the "free cooling" provided by outside air, it is desirable for the outside air percentage to be as close to 100 percent of system flow as possible.

Economizer manufacturers provide detailed check-out procedures for finding and fixing problems with their systems. However, unless the technician is specifically charged with troubleshooting the economizer (and is paid enough to go through the entire procedure), it is unlikely a full check-out will be done. Programs such as premium service provide a substantial up-front incentive to pay for this time.

Another barrier to optimizing economizer operation is measurement of minimum and maximum outside air amounts. The classic way to do this is to use a combination of air temperature measurements to estimate outside air fractions and make adjustments. This approach is very difficult to do accurately and is less reliable when the outside air temperature is close to inside air temperature (common in the Pacific Northwest).

Recent improvements in air measurement technology, such as the TrueFlow plate, have made it possible for technicians to measure outside air fractions quickly, make adjustments, and then re-measure and fine-tune controller and damper settings.

A final issue that has bearing on economizer operation and occupant comfort is the type of thermostat in the conditioned space. Many packaged units are controlled by residential thermostats designed for only one stage of cooling. A two (or three) cooling stage commercial thermostat has an interstage differential which will increase economizer operating hours. The thermostat should also call for mechanical cooling within a reasonable time if economizing cannot do the job; this is a potential weak point of a single cooling stage thermostat.

With the introduction of several new multi-stage commercial thermostats into the market, the price barrier to using this type of thermostat has been removed.

Thermostat Settings and Schedules

Thermostat sensing reliability is probably better than ever; however, if settings and schedules are not optimized, conditioning energy can often be needlessly wasted. Depending on how a system was first set up, and upon who has access to the thermostat, schedules and settings can be very far from the most efficient.

One more aspect of some commercial thermostats needs mention, since it can be used to reduce heating energy. Many newer commercial thermostats contain an extra set of dry contacts which produce an output signal only when the system is in occupied mode. This set of contacts

can be attached to a relay and can take power away from the economizer control when ventilation air is not needed. Without this option, given that most commercial spaces run the air handler continuously, extra energy is used to heat outside air even when the space is unoccupied. Enabling this feature yields modest heating energy savings.

System (Evaporator) Airflow

A critical part of rooftop system performance is the amount of air moved across the evaporator and into the conditioned space. Equipment manufacturers generally specify 400 ft^3/min (CFM) per ton of nominal cooling capacity to optimize system capacity and efficiency.

Numerous studies (of both commercial and residential equipment) have found average airflows much closer to 325 CFM/ton (or even lower). This typically results in measurable capacity and efficiency reduction.

In many cases, duct work and high external static pressure limit the amount of air that can be moved through the system. In other cases, adjustment of control settings, blower lubrication/cleaning, or adjustment of sheaves/pulleys causes significant changes in flow. Use of the TrueFlow plates allows direct measurement of system airflow and allows the technician to see results of adjustments quickly.

Refrigerant Charge

When there is a need for mechanical cooling, the compressor and related air circulation fans operate to remove and reject heat from the conditioned space through the refrigeration cycle. The proper amount of refrigerant is needed to maintain system efficiency and capacity.

If the technician has a reliable measurement of system airflow (from use of the calibrated flow plates), a check of the temperature difference across the evaporator coil (after at least 15 minutes of compressor operation) will indicate the likelihood of a refrigerant problem. If a problem is indicated, a more in-depth review of system performance is warranted.

The evaporator and condenser coils should be kept clean so that heat transfer is optimized. This maintenance item is often neglected or not performed thoroughly (coils are brushed or sprayed with water rather than cleaned with detergent and rinsed). Research has shown that a dirty condenser coil increases high-side pressure and compressor running amps; a dirty evaporator tends to reduce system capacity ("tons") but has little effect on overall efficiency.

PROGRAM APPROACHES

An equally challenging endeavor to understanding and implementing technical fixes to packaged HVAC equipment is the development of utility supported cost-effective program approaches. A number of programs are in development, in pilot stage, or in active implementation that seek to acquire cost effective resources from this opportunity.
In southern California and eastern Washington, utilities are supporting the Air Care Plus® program which works with a set of qualified service contractors to provide an enhanced operations and maintenance service package. In Eugene, OR, the local utility, Eugene Water & Electric Board, is piloting a western premium economizer (WPE) program. WPE is an economizer specification for new equipment designed to optimize the free cooling available from packaged HVAC equipment. Units that meet this specification are eligible for a utility incentive.

Programs in this genre are also being explored by NY SERDA, NSTAR, and National Grid on the east coast of the U.S., and have been the subject of research by the California PIER effort.

PREMIUM SERVICE HVAC

In the Puget Sound region of western Washington, Puget Sound Energy is offering a "Premium Service HVAC" program for that utility's electric customers. This effort began as a pilot effort in 2004-2005 and was folded into its larger general commercial program structure beginning in 2006. The premium service HVAC program is administered under contract to PSE by the Northwest Energy Efficiency Council (NEEC), a regional non-profit trade association of the energy efficiency industry.

Ten local mechanical service contractors are currently offering the premium service HVAC program in the Puget Sound market. These contractors have volunteered to embrace this program approach as a service option for their existing and prospective customers. Each contractor has successfully completed training provided by a NEEC technical consultant, Seattle-based Ecotope, Inc., as well as having sales and marketing training on the premium service program.

The premium service HVAC program is available to PSE electricity customers who have constant volume packaged HVAC equipment

with an air economizer. The typical size range of equipment in the program is three to 20 tons. Units may be all electric, heat pumps, or gas packs.

Customers may participate by agreeing to a minimum three-year service agreement with any of the participating contractors. Contractors implement a rigorous inspection and diagnostic protocol that was developed specifically for the premium service program. Service technicians make immediate judgments during this field visit on repairs, replacements, or adjustments that are necessary to improve the operational efficiency on the unit. The program uses a classic "find and fix" approach.

Based on the work done on each individual unit participating in the program, PSE provides a rebate, paid to the contractor, ranging from $300 up to $750 per unit. Contractors have the freedom to establish additional service fees, over their standard baseline service agreement, for the premium service. In almost all cases, contractors do not charge any additional fee to the customer (beyond their existing service contract terms) for the premium service.

The program is therefore designed for a win-win-win proposition. The customer gets an enhanced service package that reduces energy costs, the utility achieves a cost effective conservation resource, and the contractor is compensated for the additional time required to diagnose and adjust the unit's operation.

During the three-year service agreement, contractors are required to perform inspections during regular seasonal maintenance visits that insure that the unit continues to operate at its improved efficiency point.

EARLY RESULTS

Since the inception of the pilot program offering in 2004, over 1,200 units have enrolled in the premium service program through participating contractors. In almost every case, regardless of age or type of unit, contractors have found opportunity to improve the energy performance on the unit. Field experience has validated that energy savings opportunities are available through improved air economizer function (including outside airflow adjustment, sensor and controller adjustment, and damper repair), thermostat type, settings and schedules, and system

(evaporator) air flow adjustments. Experience to date has found that refrigerant charge does not appear to be a significant problem in the commercial equipment participating in this program.

As the program matures, additional measurement and evaluation of energy savings from the range of as-found conditions and premium service unit adjustments will be necessary. To date, anecdotal evidence of energy savings seems to corroborate engineering estimates of savings ranging (in the Puget Sound climate) of 0.5 to 1.5 kWh/sq ft and 0.1 therm/sq ft (where natural gas savings are possible).

From the contractor perspective, the premium service program offers a way to differentiate their service in a highly competitive market. However, participation does require some changes in their business model as well as placing additional responsibilities on their trained technicians. The program requires extensive documentation of as-found and as-left conditions for each unit in the program. This is both a time and logistical burden for technicians. Weather also plays a role in the implementation of this program, given the significant additional time required for implementation of the service protocol and the rather rainy climate of the Puget Sound region for many months of the year.

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