Industry Transformation in Refrigerated Warehouses

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ABSTRACT

Refrigerated warehouses are significant users of electric energy. For the past six years incentive programs have been effective in helping owners incorporate high efficiency features into their systems. These features included oversized condensers, oversized piping, computer controls, increased insulation, and other measures known to increase efficiency. In aggregate, these measures required higher first cost investment. Although this program was successful as a resource acquisition effort, in 1999 PG&E moved to a program that has greater potential for achieving sustainable change. Industry Transformation focuses on specific, clearly defined industries, in this case refrigerated warehouses. Additionally, Industry Transformation may provide a legitimate pathway to sustainability in the form of voluntary competitive strategies.

Industry benchmarking was completed through monitoring four warehouses, two with energy efficiency features and two that were considered less efficient industry standard warehouses. The objective was to demonstrate the potential for Industry Transformation as a competitive advantage, and to verify performance and value to builders and owners of high efficiency systems in this industry. Although a baseline in kW/ton was measured, the study showed the warehouses with the energy efficient features were, unfortunately, operated in a way that negated most of their energy saving potential. This paper discusses this analysis, highlighting potential savings with correct operating procedures, the need to retrain operating personnel and re-measure the operating efficiencies of all four warehouses this year.

Introduction

On the 2nd of December 1999 and industry roundtable was held in the Pacific Gas and Electric clubhouse in Fresno. This roundtable was attended by approximately 40 people from various segments of the San Joaquin Valley refrigerated warehouse industry and interested representatives from Pacific Gas Electric Co.. This function was the culmination of a nine month project examining refrigerated warehouse performance. Four warehouses were monitored by placing temperature, pressure and electrical usage sensors on compressors, condensers, pumps, fans and other components using energy (Doug Scott). Figure 1 is a listing of the characteristics of these four warehouses. The two high efficiency warehouses had features such as oversized condensers, oversized piping, improved computer controls and increased insulation.. Pacific Gas and Electric has sponsored warehouse efficiency programs for the past seven years, these programs were primarily rebate or incentive programs based on known engineering principles. Recent guidance from the

California Public Utilities Commission moved PG&E programs toward industry transformation and away from direct incentives. The 1999 program was an attempt to establish a baseline for measurement of efficient systems and to move toward programs that fostered market transformation, such as performance contracting.

Monitoring Project Summary

Four refrigerated warehouses in the Fresno/Kingsburg area were selected using the following criteria:

- All locations store similar fruit
- Ammonia systems
- Two system were rebated under PG&E program, two were not
- All have seasonal operations
- Four month study – July through October

The following instrumentation was installed on compressors, condensers, fans and pumps:

- pressures, temperatures
- energy usage
- compressor operation, including slide valve position
- five minute interval data collected

The data was analyzed and presented as follows:

- kW per Ton for compressors and entire system
- kW measured
- Tons calculated, common slide valve curves

Graphics

Figure 1, Refrigerated Warehouse Operating Characteristics, shows the size, peak load, load factor, average zone temperature, average suction temperature, average wet bulb and average condensing temperature for the four sites. Locations 1 and 2 are warehouses built to PG&E standards with oversized condensers, improved controls and insulation. Figure 2, Compressor Efficiency, kW/ton vs. Slide Valve Position, shows the dramatic effect compressor slide valve position has on efficiency. Compressor operation at less than 80% of capacity dramatically reduces efficiency. Figure 3, Low Side Comparison, is a comparison of the temperature difference (TD) between the average suction temperature and the average zone temperature of each warehouse. A low TD is desirable. Figure 4, High Side Comparison, is a comparison of the temperature difference (TD) between the average wet bulb temperature and the average condensing temperature. A low TD is desirable. Warehouses 1 and 2, with oversized condensers, were designed for a lower TD, they did not achieve this in practice due to poor operating procedures. (fixed, not floating head pressure).

Location	1	2	3	4
Refrigeration HP	825	675	1035	510
Capacity, Tons	900	713	875	414
Peak Load, Tons	495	540	525	327
Load Factor	55%	76%	60%	79%
Average Zone Temp	31.4	33.6	32.7	32.9
Average SST	17.3	23.0	20.6	23.7
Average WBT	59.6	61.2	62.4	67.8
Average SCT	80.0	81.7	80.9	88.2

Figure 1. Refrigerated Warehouse Operating Characteristics. Locations 1 and 2 were built to PG&E Criteria, Locations 3 and 4 were built to Industry Standards

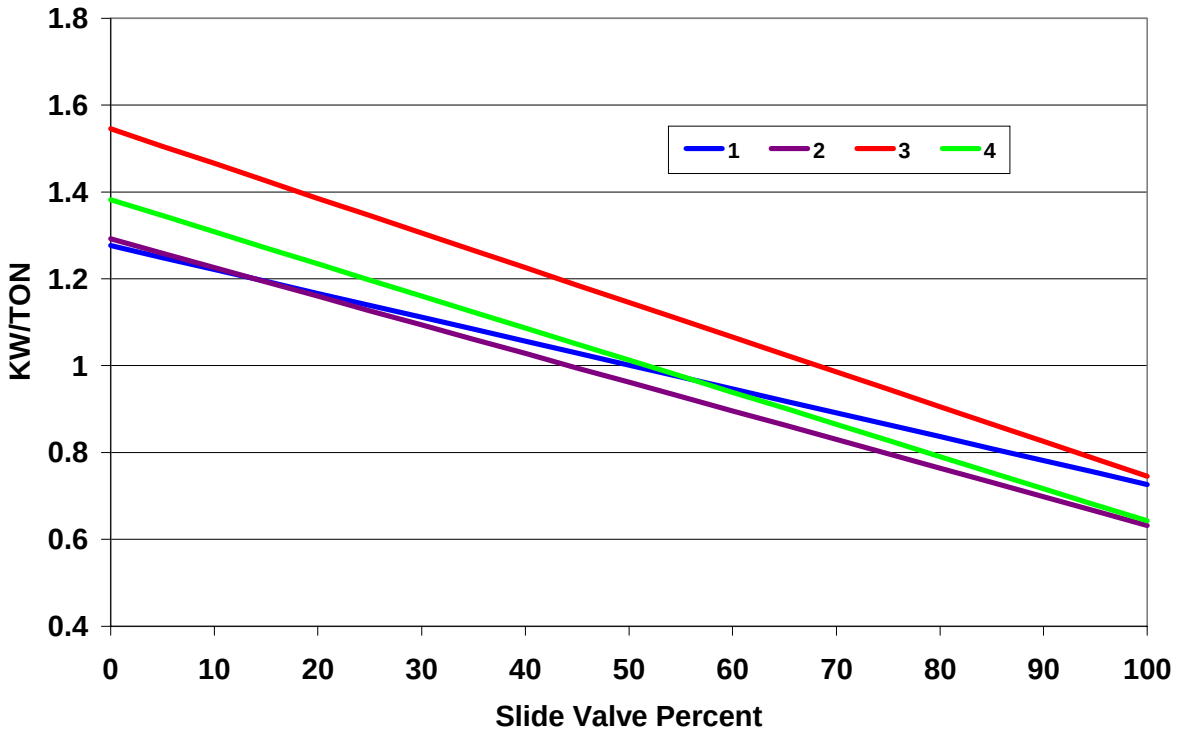

Figure 2. Compressor Efficiency, KW/Ton vs. Slide Valve Position, Demonstrating Inefficiency of Part Load Compressor Operation.

Graphics continued

Location	1	2	3	4
Average zone temp	31.4	33.6	32.7	32.9
Average suction temp	17.3	23.0	20.6	23.7
Average TD	14.1	10.6	12.1	9.2

Figure 3. Low Side Comparison, Showing Excessive TD.

Location	1	2	3	4
Average wet bulb temp	59.6	61.2	62.4	67.8
Average condensing temp	80.0	81.7	80.8	88.2
Average TD	20.4	20.5	18.4	20.4

Figure 4. High Side Comparison, Not Floating Head Pressure, Average TD 20 F Degrees vs. Design Maximum 10 F for Locations 1 & 2.

Results

The data shows very little difference between the efficiency of facilities that incorporated larger condensers, oversized piping, improved computer controls and other features that should have improved efficiency (Figure 1, locations1 and 2), and those that did not have these features (Figure 1, locations 3 and 4). Part load operation of compressors had a major effect on overall efficiency. Figure 2 above clearly shows the dramatic effect of slide valve position on compressor efficiency when operating at part load conditions. Average compressor efficiency declined from 0.7 kW/Ton at 100% load to 1.1 kW/Ton at 40% load. All four warehouses operated at suction pressures lower than optimum as shown in figure 3. Also, on the high side, none of the warehouses floated the head pressure, as shown in figure 4. In the case of warehouses 1 and 2, which were built with expensive oversized condensers, no significant gain was realized.

Conclusions

The data clearly shows that the systems in location 1 and 2 were not being operated to take advantage of their potentially higher efficiency. These warehouses did not float head pressure to take advantage of their larger condensers, they also operated at lower suction pressures than optimum and consistently operated larger compressors at part load, where slide valve position reduced efficiency. The combined loss of efficiency as the result of these operating errors is estimated at 25% to 30% (ASHRAE).

Future Opportunities

The PG&E refrigerated warehouse industry roundtable held December 1999 presented the conclusions of the study to industry leaders. They expressed great interest in the findings and a desire for further studies of this nature. To follow up, PG&E's Year 2000 program will monitor facilities 1 and 2 for another season. Prior to this evaluation these facilities will be re-commissioned and personnel retrained to insure system operation is fully understood. The benefits of floating head pressure, higher suction pressures and optimum staging of compressors to minimize part load operation will be emphasized. Savings of 20% to 30% are possible with these changes. The results of this evaluation and comparison with 1999 will be presented at another industry roundtable in November 2000. The objective of PG&E's Year 2000 program will be to demonstrate the significant savings available through energy efficient design and proper operation. The next step will be to encourage shared savings and performance contracting to capture these saving through the market place.

References

Doug Scott, 1999. *PG&E Industrial Refrigeration Efficiency Study. La Verne, CA. VaCom Technologies*

[ASHRAE] American Society of Heating, Refrigerating a Air Conditioning Engineers. 1998. *ASHRAE Handbook Refrigeration Systems and Applications, Chapter3, ASHRAE Handbook, Fundamentals, Chapter1*