



TT400 TURBOCOR COMPRESSOR

RETROFITTING A WATER-COOLED CHILLER WITH TURBOCOR'S NEWEST OIL-LESS COMPRESSOR

**COUNTY OF SAN DIEGO JUVENILE DETENTION
FACILITY**

January 20, 2006



8520 Tech Way, Suite 110
San Diego, CA 92123
Tel: 858-244-1177
Fax: 858-244-1178
Web: www.sdenergy.org

Background

The Juvenile Hall Complex is made up of the Juvenile Court, Juvenile Hall, and the Juvenile Probation Center. The area of the three facilities encompasses 52,405 sq. ft, 136,000 sq. ft, and 65,807 sq. ft respectively.

The County of San Diego is always looking for ways to reduce electrical usage and demand, and particular interest involved the HVAC system (last upgraded in 1998). The existing HVAC system included:

- 1) One 300-ton electric centrifugal chiller with a VFD (lead chiller)
- 2) One 450-ton electric centrifugal chiller with a VFD
- 3) Primary/secondary/tertiary chilled water distribution
- 4) Two dual duct VAV air-handlers serving the Juvenile Probation Center
- 5) Three single duct VAV air-handlers serving the Juvenile Court
- 6) Twenty-nine rooftop constant volume air-handlers serving the Juvenile Hall (100% outside air)
- 7) Johnson Controls energy management system (EMS)



Figure 1 – Existing centrifugal chillers: 450-ton in front and 300-ton in rear.

Pre-Retrofit Chillers

The central plant is made up of two eight year old centrifugals (300-ton and 450-ton units both equipped with variable frequency drives). The performance of the 450-ton chiller was monitored during the first two weeks of October 2005 and is shown below (Figure 2). The entering condenser water temperature was reset based on outdoor wetbulb temperature and was observed between 65°F – 72°F while the leaving chilled water was maintained at 46°F. The chiller consistently operated between 0.71 kW/ton and 2.0 kW/ton and averaged 0.935 kW/ton for the two week period.

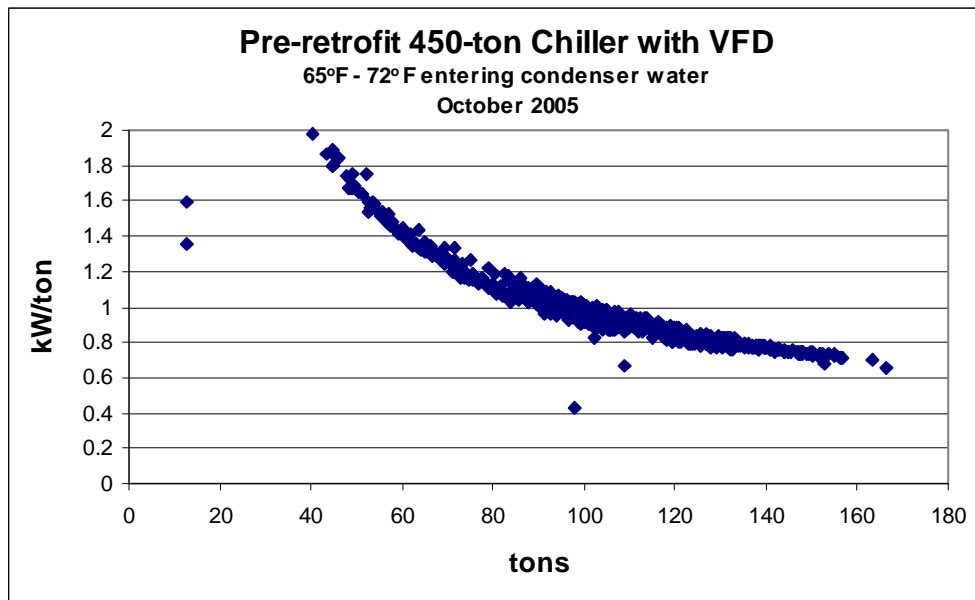


Figure 2 - A plot of the actual operating efficiency of the 450-ton pre-retrofit chiller with VFD.

Recommendation

The existing chillers had considerable operating problems (high energy usage, constant high lift alarms, surging, and difficulty staging and automatically bringing another chiller online). Also, because of the primary-secondary-tertiary system, significant mixing occurred in the decouplers and miscellaneous three-way valves making it impossible to fully load any one of the chillers (significant low delta T syndrome). Noticing the inefficient operation of the two centrifugal chillers as well as documenting the operating problems listed above, SDREO convinced the County of San Diego to retrofit both machines with Turbocor compressors. Three TT300 Turbocor compressors (90-tons each) were first installed on the 300-ton chiller in September 2005. The savings with these TT300 compressors have been well documented and several retrofits have been successfully operating in San Diego for more than 1.5 years. For the 450-ton machine, Turbocor's newest compressor, the TT400 (150 tons each) was selected. During the last two weeks of October 2005, the 450-ton chiller was retrofitted with three TT400 compressors. Total savings for the entire Turbocor retrofit project¹ was estimated at \$60,000 to \$70,000 per year.

Turbocor Technology

The Turbocor oil-less centrifugal compressor uses environmentally friendly R-134a refrigerant, magnetic bearings (no oil), and a direct drive system (no gears). It is currently manufactured in capacities of 60-150 tons. It weighs 80% less than traditional compressors (only 265 pounds each) and the direct drive system and magnetic bearings reduce noise and vibration. The compressor's rotor shaft and impellers levitate during compression and float on a magnetic cushion while an integrated variable frequency drive (VFD) provides an excellent part load efficiency. According to Danfoss Turbocor, the TT400 compressor has a 10% efficiency gain over the TT300 units. A plot of the part load efficiency (provided by Turbocor) of the new TT400 compressors versus the leading screw compressor is shown in Figure 3 below:

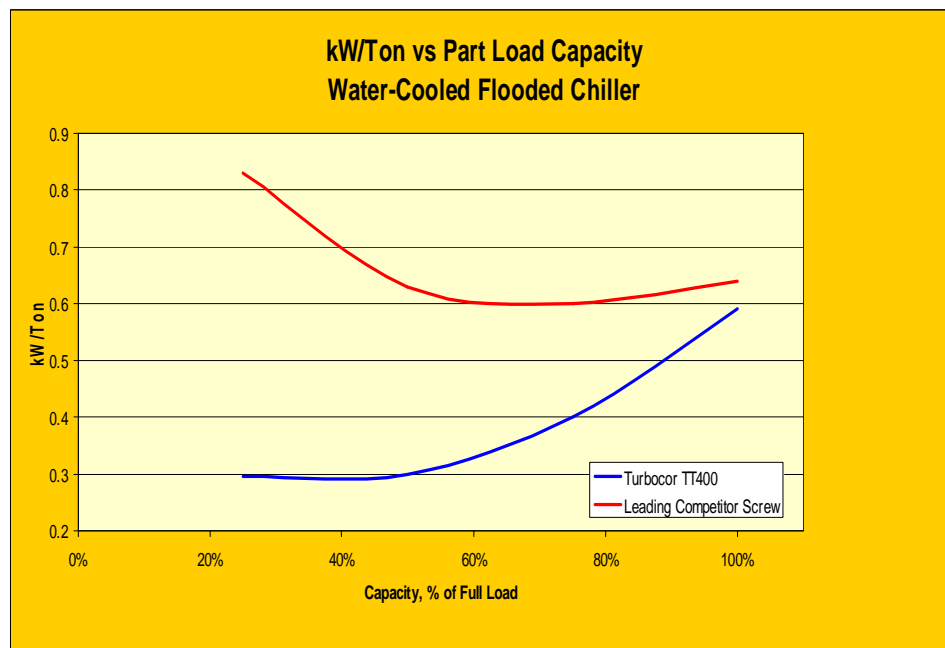
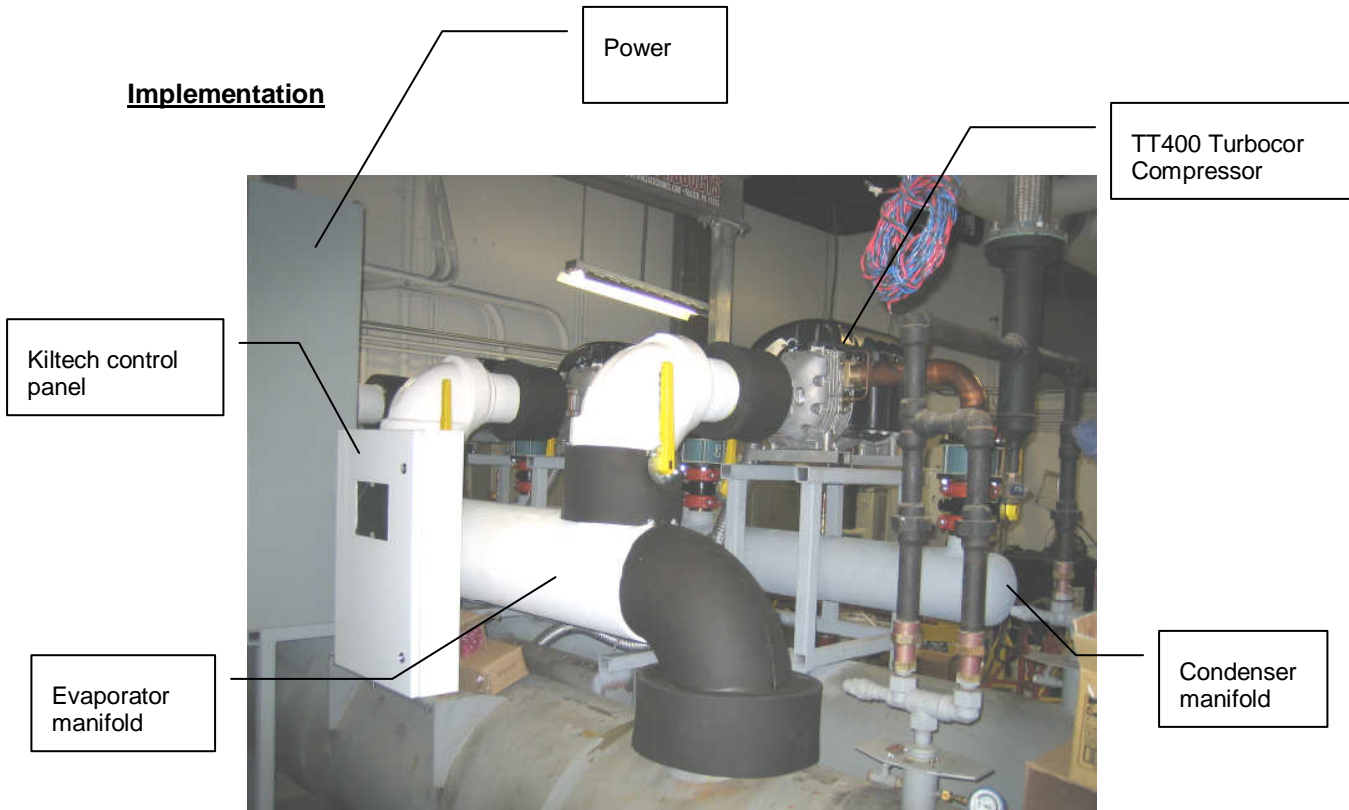


Figure 3 – Manufacturer's data: Comparative compressor part load curve efficiencies

¹ As part of this project the all variable speed Hartman LOOP control strategy was implemented. The decoupler was removed and variable frequency drives were installed on all condenser pumps, chilled water pumps and cooling tower fans. The savings from this retrofit was estimated at an additional \$42,000/yr. Total project savings (Turbocor and Hartman LOOP all variable speed retrofit) can be estimated at \$109,000 per year.

Implementation



Actual Performance

Performance data was collected during the months of October 2005 through January 2006 and is represented in Figures 4 through 7. Condenser temperature was maintained at 72°F while chilled water temperature was held at 45°F. The average efficiency (kW/ton) of the 450-ton chiller with three TT400 Turbocor compressors (150-ton each) during this monitored period was 0.324 kW/ton.

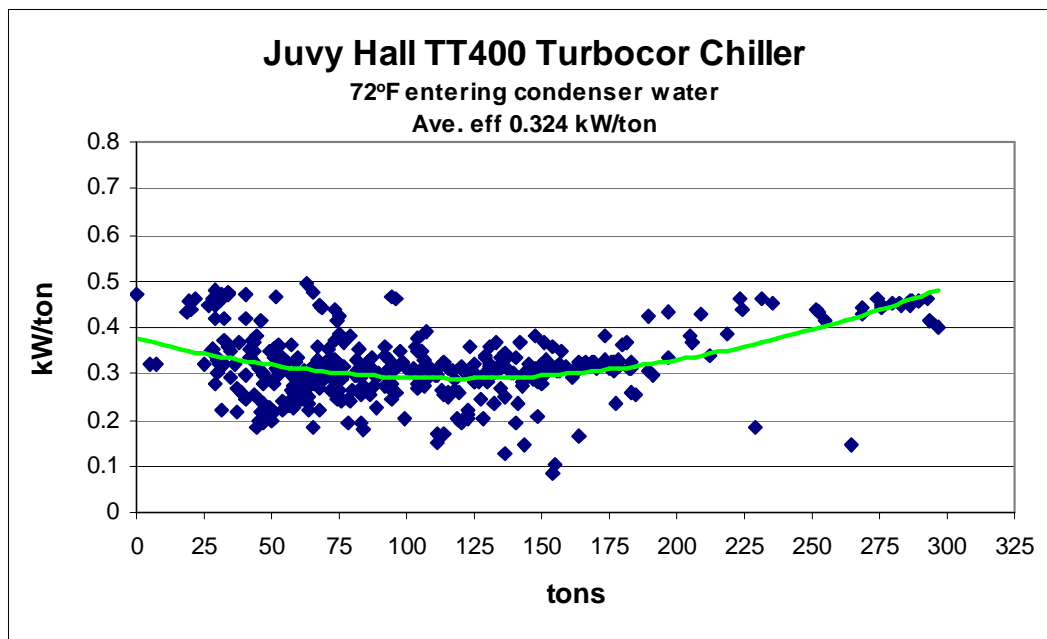


Figure 4 – Actual operating efficiency curve of the TT400 chiller.

The low night loads (typically 20-40 tons during fall, winter, and spring months) at the Juvenile Hall Complex can be stably handled efficiently and effectively using the TT400 compressors. Figure 5 below graphs the chiller power input verses tonnage output of the 450-ton TT400 chiller collected on Saturday, October 29, 2005. Notice the chiller can provide 30 tons of cooling and only pull 6.8 kW. The average chiller output for the day was 78.6 tons, for an average efficiency of 0.297 kW/ton.

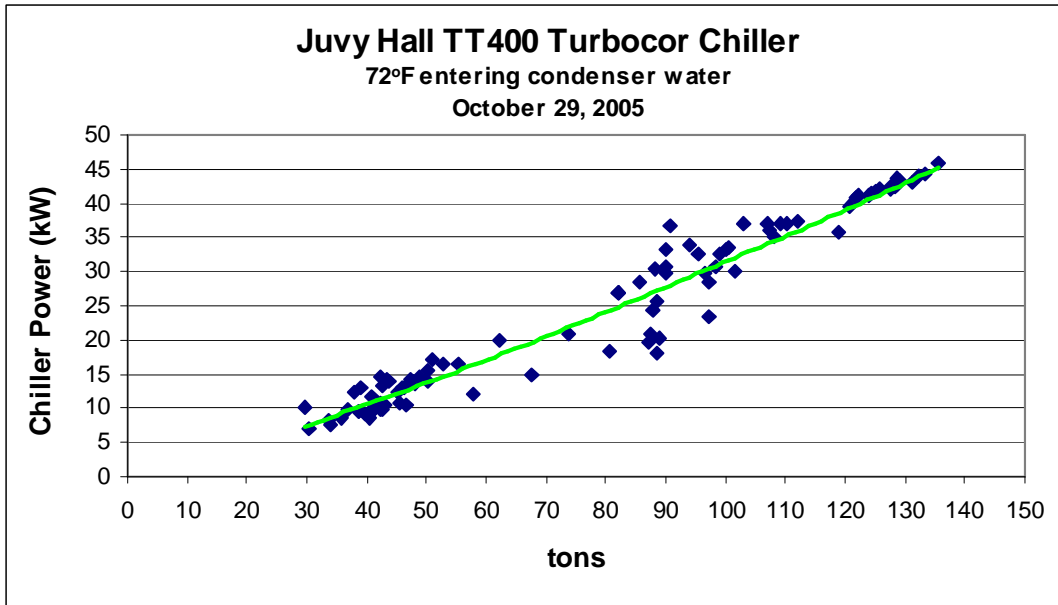


Figure 5 – Chiller input power (kW) vs. tonnage output (tons) of the Juvenile Hall Complex TT400 Turbocor Chiller on Saturday October 29, 2005.

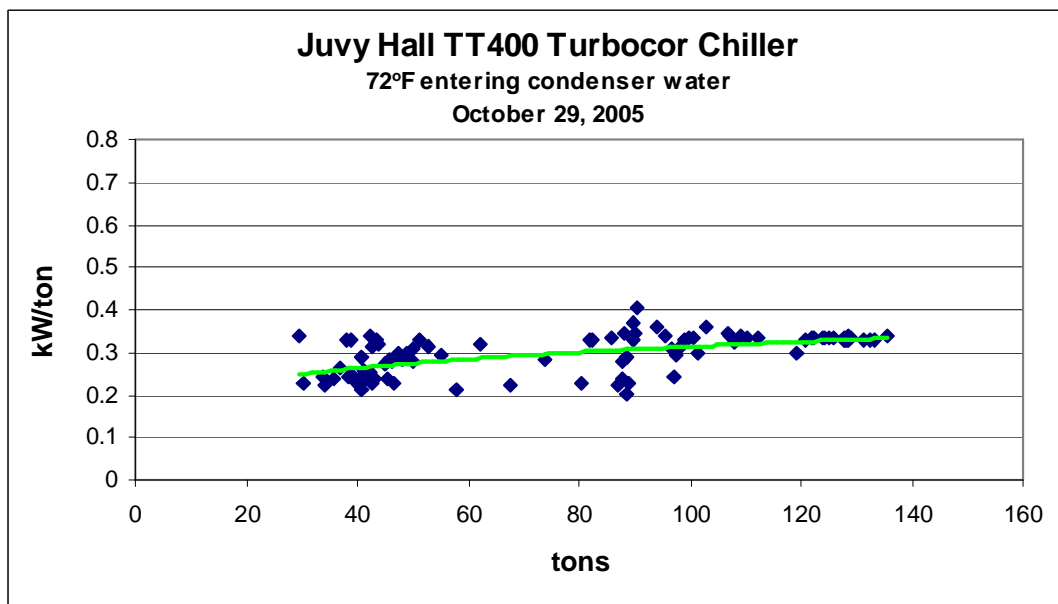


Figure 6 – Actual operating efficiency of the TT400 vs. tonnage output, with an average retrofitted efficiency of 0.297 kW/ton for Saturday, Oct. 29, 2005.

Savings and Payback Analysis

Using the actual data collected from October 2005 to January 2006, Figure 7 was created by extrapolating out the performance results of the existing single compressor chiller versus the retrofitted TT400 Turbocor machine.

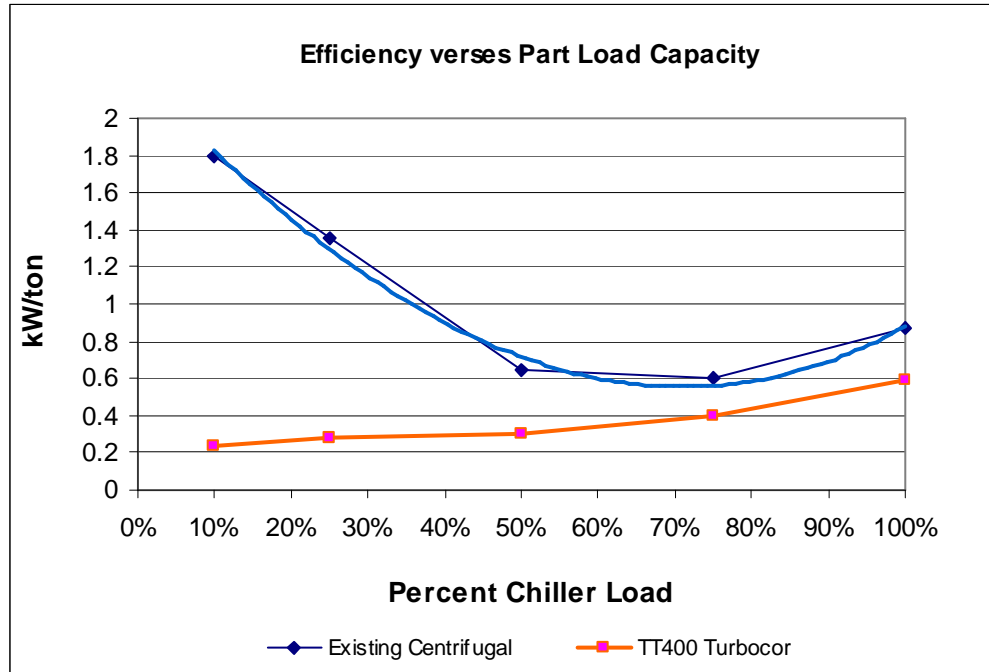


Figure 7 – Extrapolated efficiency versus part load curves for the existing 450-ton centrifugal chiller versus the retrofitted 450-ton TT400 Turbocor chiller.

To estimate annual savings from these efficiency improvements, Figure 7 was used. Based on an engineering analysis of the facility and an hour by hour simulation, the final breakdown is as follows:

ECO	Tonnage (tons)	Est. Annual Electrical Savings (kWh)	Peak Demand Reduction (kW)	Est. Annual Cost Savings (\$/yr)	Implementation Cost (\$)	Incentives (\$)	Final cost after incentive (\$)	Simple Payback (Years)
TT300 and TT400 Turbocor Retrofit								
1	750	535,211	61	\$67,000	\$360,000	\$74,930	\$285,070	4.3
All Variable Speed Plant Retrofit								
2	750	327,600	37	\$42,000	\$186,000	\$51,000	\$135,000	3.2
Totals		862,811	98	\$109,000	\$546,000	\$125,930	\$420,070	3.9

Conclusion

Benefits and points of interest include:

- Low load performance was greatly improved (70%-90% less energy).
- Surging and high lift alarms were eliminated.
- Sequencing of chillers was automated. Operator hassles and maintenance was reduced
- Oil-less compressor technology (reducing our dependency on foreign oil while increasing the efficiency of the machines).
- Variable condenser and evaporator flow was easily implemented with the oil-less chillers
- Noise was greatly reduced.
- Significant portion of the central plant upgrade was covered by incentives.
- Data presented is only from fall and winter months but measurement and verification will continue for the next year. The TT400 efficiency curve in Figure 7 will continuously be updated as condenser temperatures change and loads increase.

For more information about this retrofit please contact Ben Erpelding, P.E. (SDREO's Engineering Manager) at 858-244-1177 or Tom Shaw at Alpha Mechanical Services at 858-518-7113.



Figure 8 – Both chillers retrofitted with Turbocor oil-less compressors.