Measurement & Verification Report for Alltemp Refrigerant: Preliminary Findings

Plastics Components Inc.
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1 Executive Summary

Alltemp™ is a proprietary refrigerant developed and marketed by Sky Green Energy to replace R-22 in air conditioning and refrigeration applications. It is intended to reduce compressor energy use while providing a comparable or increased cooling effect.

To demonstrate the performance of this refrigerant in typical applications, Sky Green converted an existing process water chiller at a plastics injection molding facility in Germantown, WI. Portable data loggers were installed in early December 2015 and collected information through the end of July 2016. Both refrigeration circuits were converted from R-22 to Alltemp on May 8, 2016.

Although the data loggers were in place for 180 days, there were long periods where the chiller did not operate. The baseline period used for evaluation only spanned 68 days; the Alltemp evaluation period was only 56 days.

Baseline data revealed that the chiller was able to maintain chilled water temperature supply temperature up to a delta T of 60 °F after which the second compressor was required, increasing chiller energy use. With Alltemp-m, the second compressor was usually not needed until the delta T exceeded 80 °F. This gave Alltemp-m a significant energy reduction advantage in the 60 °F – 80 °F range where the chiller spends a significant amount of time. Compressor energy use was reduced by 34%, resulting in energy savings of 12,800 kWh and $1,550 annually at local utility rates[1].

[1] Wisconsin Electric Power Company Rate CG-2 On-Peak of $0.121/kWh ignoring demand charges.

2 Project Background

Plastics Components Inc. is a plastic injection-molding facility located in Germantown, WI. A process water chiller is used to cool the water that maintains injecting molder dies at a reasonable temperature. The chilled water supply temperature setpoint is between 50 °F and 70 °F; the return water temperature depends on the number of operating molders and the type of plastic being processed, but can be as high as 160 °F. For chilled water systems, this is an unusually high return water temperature.

Comment [MS1]: What is the real setpoint, and does it change?

The chiller being evaluated has the following characteristics:

Make & Model	Advantage C-APT25-RC-40HFX
Capacity	25 tons
Compressor type & quantity	2 x scroll
Refrigerant type & quantity	R-22
Volts / Amps / Phase, Comp 1	460 / 3 / 25 Amps
Volts / Amps / Phase, Comp 2	460 / 3 / 25 Amps
Metering device	TXV
Special Features	This is an air-cooled process water chiller with a CHWST of ~60 °F. The system has two condensers: 1) outdoor, and 2) indoor for winter heat recovery.

Portable data loggers from Onset Computer were used to measure compressor current, indoor and outdoor air temperature, and chilled water supply & return water temperature. The baseline monitoring period started on December 10, 2015 and continued until early May. On May 8, both refrigeration circuits were evacuated and Alltemp-m added. Data logging continued through July 26, 2016. Outside air temperature was monitored during December and January but the logger seems to have been lost and local readings of outside air temperature were not available after January 18, 2016.

Compressor current was measured in one-minute intervals on all three phases, which was then averaged into 15-minute blocks. The power input to each compressor was calculated based on assumed values of 460 V and a 0.8 power factor.

The total compressor power was initially compared to the chilled water temperature difference (delta T) while using either the indoor or outdoor condensers (R-22 only). Although the chilled water delta T reading were very low, there was no discernable power difference between the indoor and outdoor compressor.

This chiller has two compressors. Low cooling loads are satisfied by one compressor and higher loads with two operating compressors. Observations of compressor kW, chilled water delta T, and outdoor air temperature (where available) were used to evaluate system performance.

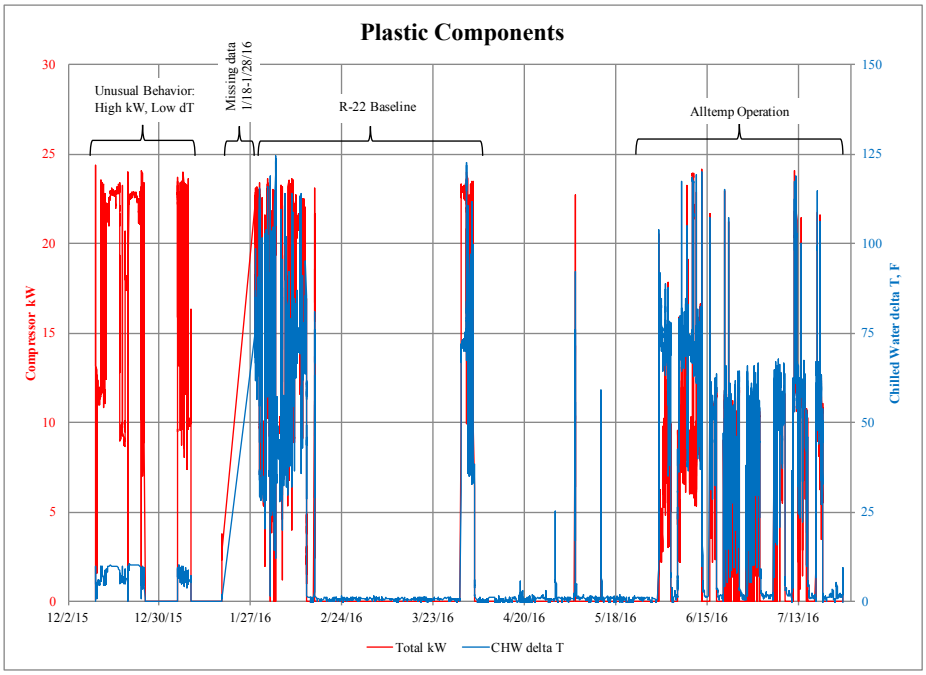
3 Results

3.1 Raw Data

Figure 1 illustrates the time-series data collected from December 10, 2015 through July 26, 2016. There is a gap of 10 days between 1/18/16 and 1/28/16 for unexplained reasons. In this graph, the red line indicates the total compressor power while the blue line is the chilled water delta T.

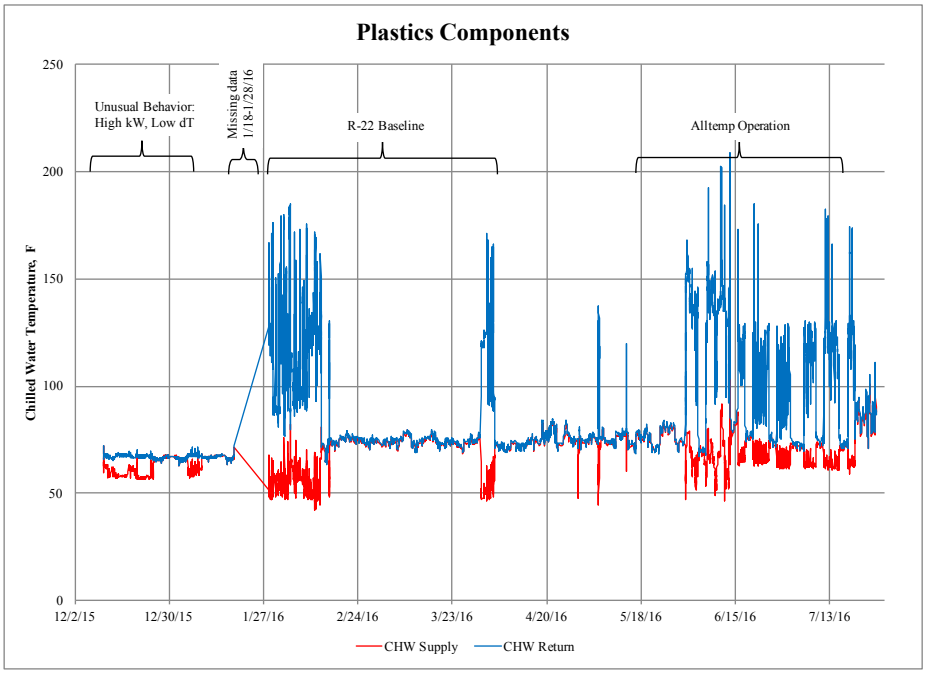
During the month of December and into early January, total compressor power (red) appears very high while delta T (blue) appears low. Starting 1/28/16, compressor power and delta T seem to be more closely correlated. There are a large number of periods when the chiller is not used; it is not known if the lack of operation was due to a plant shutdown or whether it was simply not needed. Based on this, the R-22 baseline period from 1/28/16 through 4/5/16 was chosen. Both circuits were converted to Alltemp-m on May 8. The Alltemp-m case was selected to be 5/31/16 through 7/26/16.

Figure 1: Compressor Power and Delta T



To ensure that the chiller maintains adequate cooling, the chilled water and supply temperatures were examined for the period as seen on a time series graph in Figure 2. During R-22 operation (the baseline period), the chilled water supply ranged between 45 °F and 65 °F with return water temperatures as high as 180 °F. During Alltemp-m operation (the post conversion period), chilled water supply temperatures ranged from 45 °F to as high as 85 °F up until June 15. After June 15, the chilled water supply temperatures ranged between 60 °F to 70 °F. It is not known if the narrower range of supply temperatures was related to a change in the CHWS setpoint, lower loads (lower return water temperature) or some other cause. The observations prior to June 15 indicate that Alltemp can provide chilled water as cold as R-22, about 45 °F. As that is the case, it is possible the CHWS setpoint was increased to the low 60s °F on or about June 15.

Figure 2: Chilled Water Delta T, Time Series



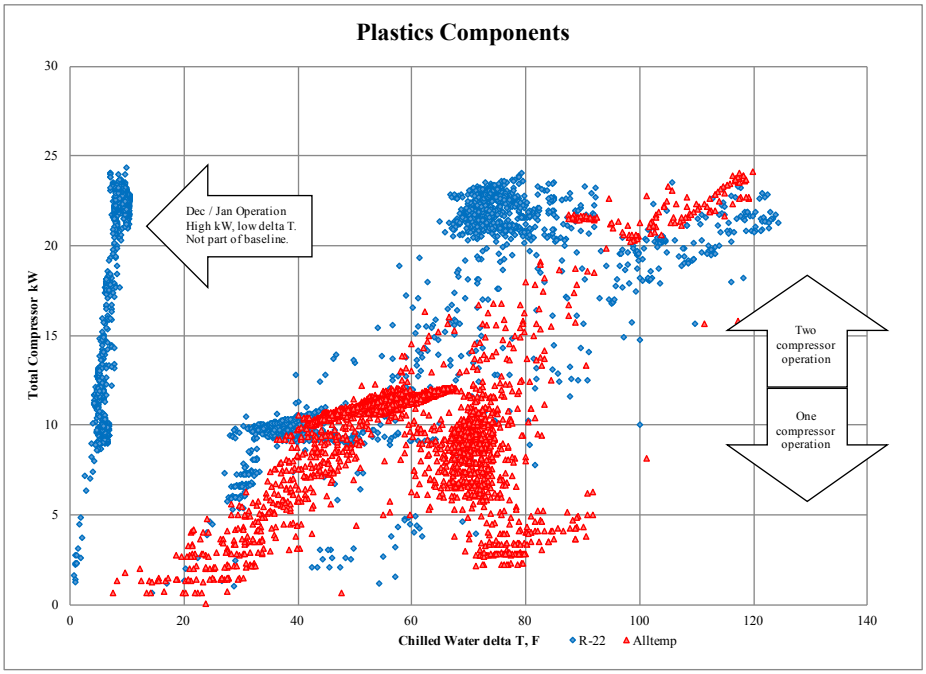
3.2 Compressor Power as a Function of Load

To compare chiller performance between the R-22 and Alltemp-m cases, the total compressor power was plotted as a function of the chilled water delta T, the indicator of load. Each observation represents a 15-minute average of both compressor power and chilled water

temperatures. Data was filtered to remove periods when the system was not operating (at least one chiller had to operate for 1 minute to be included.)

Figure 3 shows some interesting relationships. The R-22 data on the left side showing high compressor power and low delta T is confined to the period from December 10, 2015 through January 8, 2016. It is not known if this is related to the Christmas & New Year's Holidays, but it is a possibility to be explored. Because this data does not appear to be representative of typical behavior, it was excluded from the baseline analysis.

Figure 3: Compressor Power as f(CHW ΔT), R-22 vs. Alltemp



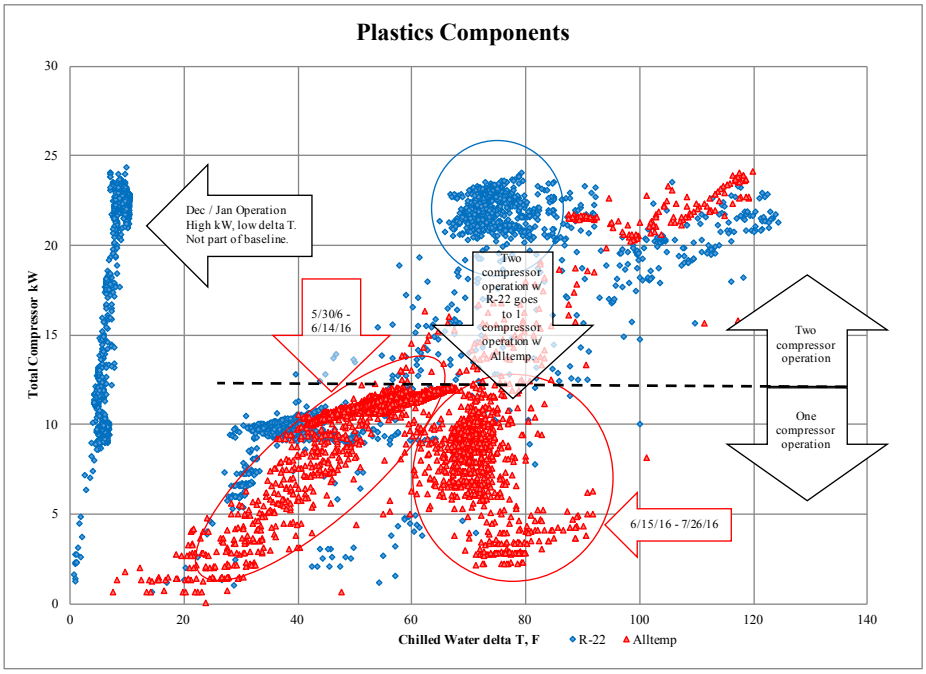
R-22 operation shows that a single compressor can meet the cooling load when delta T is 60 °F or less, after which the second compressor is required to operate to meet the load. With Alltemp-m, a single compressor can meet the load up to a delta T of 80 °F, after which the second compressor is required to assist.

Normally compressor power is compared to outdoor temperature as that determines the condensing temperature and head pressure. In this industrial application, the primary driver of compressor power appears to be the chilled water cooling load as quantified by Delta T. The

return water temperature is almost always higher than the ambient temperature, so the heat energy being removed is a “downhill” thermodynamic process.

Further review suggests that an operational change was made in mid-June. In the time-series graph Figure 2, chilled water supply temperature shows significant temperature variation up until June 15th, after which it seems to be more consistent, even with very high return water temperatures. Based on this, Alltemp-m observations were separated into two periods before and after June 15. Figure 4 shows different operational clusters, the first occurring between 5/30/16 and 6/15/16 where compressor kW increases somewhat linearly with delta T. The second cluster is represents the period after June 15, 2016 where delta T ranged between 60 °F and 80 °F with only a single compressor operating. There is not enough information available about system operation to postulate as to what might account for these differences.

Figure 4: Compressor Power as f(CHW ΔT), R-22 vs. Alltemp



4 Energy Savings

To quantify the effect of Alltemp-m on the compressor power input, the chilled water temperature data was divided into 10 °F bins where each bin represents a ±5 °F span around the bin temperature. Each observation represents the average compressor power and temperature over a 15-minute period. In Table 1, the average compressor power (sum of the average power of both compressors) for R-22 and Alltemp-m operation shows reductions (positive values of Delta kW) over most temperature ranges. Almost all bins are statistically significant as evidenced by a *t* value with an absolute value greater than 2. (Only the 20 °F and 60 °F bins were not different in a statistically significant sense.)

Table 1: Compressor Energy Savings

	R-22			Alltemp			Relevance			Results			
Delta T Bin	Avg kW	Std Dev	n	Ave kW	Std Dev	n	Delta kW	Delta kW, %	t	Hours	kWh R-22	kWh Alltemp	kWh Saved
0				0.46		1							
10	0.68		1	1.23	0.50	9	-0.54	-79%					
20	3.08	1.30	6	2.16	1.11	48	0.91	30%	1.6	13.5	42	29	12
30	8.65	1.64	244	3.43	1.41	105	5.22	60%	30.2	87.25	755	300	455
40	9.82	0.89	402	8.78	1.99	304	1.04	11%	8.5	176.5	1,733	1,550	183
50	8.96	2.30	112	10.64	0.96	667	-1.68	-19%	-7.6	194.75	1,744	2,071	-327
60	11.24	4.12	85	11.21	1.15	684	0.04	0%	0.1	192.25	2,161	2,155	7
70	21.46	2.56	547	9.03	2.27	821	12.43	58%	91.9	342	7,340	3,088	4,252
80	21.38	2.39	286	7.85	4.79	181	13.53	63%	35.3	116.75	2,496	917	1,579
90	19.49	3.32	60	15.51	7.59	58	3.98	20%	3.7	29.5	575	458	117
100	19.17	1.78	80	20.67	2.31	34	-1.50	-8%	-3.4	28.5	546	589	-43
110	20.33	1.44	42	21.96	1.25	36	-1.63	-8%	-5.3	19.5	397	428	-32
120	21.43	1.00	49	23.18	1.56	27	-1.76	-8%	-5.3	19	407	440	-33
										1219.5	18,197	12,026	6,171
													34%

Significant power reductions were achieved in the 70 °F and 80 °F bins. To estimate the energy savings achieved, the total operating hours in each bin were multiplied by the average kW for R-22 and Alltemp-m respectively. Under the aggregate load profile, the R-22 baseline energy use was just over 18,000 kWh. With Alltemp energy use was about 12,000 kWh – a savings of 6,200 kWh or 34% of the baseline energy use. The total evaluation period started 1/28/16 and ended 7/26/16, a duration of 180 days. If the second half of the year operates like the first, the annual savings are projected to be 12,800 kWh. At $0.121/kWh[2], cost savings are $1,550 annually.

[2] Wisconsin Electric Power Company Rate CG-2 On-Peak ignoring demand charges.