

# Maximizing Demand Response

Understanding Air Conditioning Load Relative to Outside Temperature

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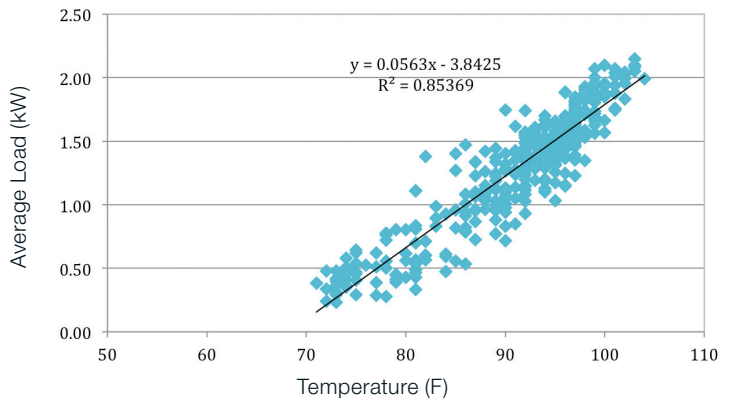
## INTRODUCTION

Utility energy engineers need to fully comprehend all factors affecting the amount of load they can get from the installation of their demand response assets. Generally speaking, estimates are projected based on optimal conditions. However, variables such as outside temperatures exceeding base ranges can affect outcomes, thus impacting efficiency and reducing kW load.

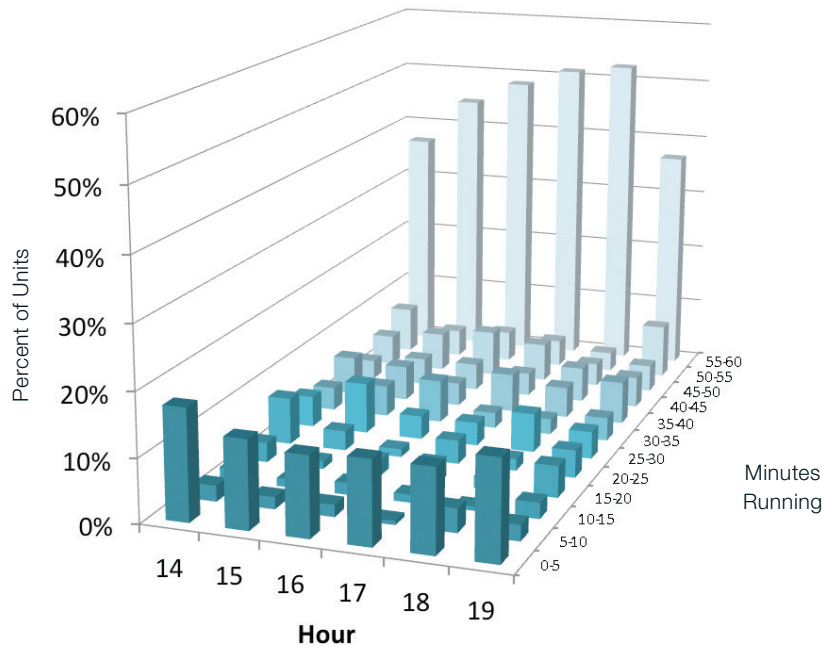
This white paper offers insight into air conditioner operations at temperatures above the Manual J–Cooling 1% Dry Bulb temperature. Air Conditioner contractors are directed by the Manual to select an air conditioner size that would run close to 100% of the time above this temperature.<sup>1</sup> The data represented below suggest that considerably less than 40% of the air conditioners run at 94°F, which is the Manual J–Cooling 1% Dry Bulb temperature for the region where this data was collected.

## LOAD INCREASE DUE TO TEMPERATURE

The first chart plots the average load increase as a function of temperature beyond the 97°F point. This data was obtained for each program hour during this past summer from all of the residential M&V sites for the non-event days and from the comparison group sites for the event days. The primary explanation for the continued increase is the fact that all of the air conditioning compressors and air handler fans were not running continuously.

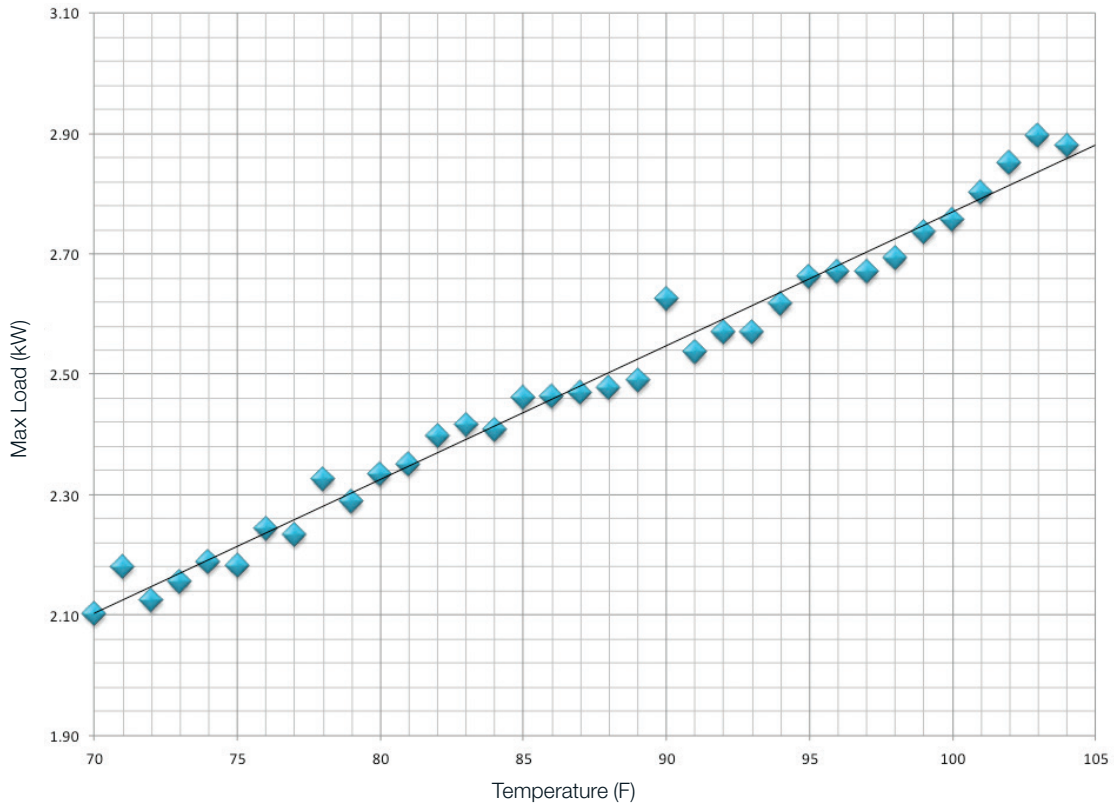


Furthermore, all of the compressors were not running at the requisite high temperatures. This is demonstrated by data reflected in the following chart, obtained from one summer program day, June 28, 2013, a non-event day with high afternoon temperatures. For each air conditioner, the run time was estimated by taking the energy measurement for that hour and dividing by the peak kW estimate for that air conditioner extrapolated over the course of the summer. Accompanying the graph is a table with the values used to create the graph.



Hour	Runtime (Minutes)												Temp (F)
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	
14	18%	3%	2%	3%	8%	5%	4%	6%	3%	5%	8%	37%	99
15	14%	2%	1%	1%	3%	8%	5%	6%	4%	6%	4%	45%	101
16	13%	2%	2%	3%	1%	4%	7%	4%	4%	8%	5%	48%	103
17	13%	1%	1%	3%	4%	4%	3%	6%	4%	6%	4%	51%	103
18	13%	4%	1%	2%	2%	6%	3%	5%	6%	4%	3%	53%	104
19	16%	3%	3%	5%	4%	4%	4%	7%	5%	4%	9%	37%	101

This table shows the runtime variation of the compressors through the program day. The NOAA temperature for each hour has been provided for comparison.



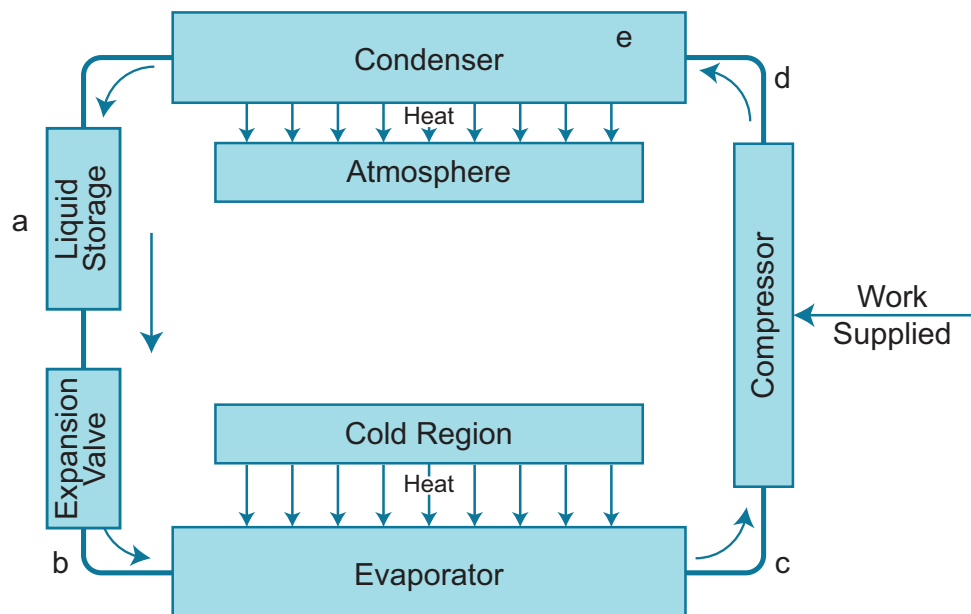
**LOAD INCREASE DUE TO COMPRESSOR OPERATION**

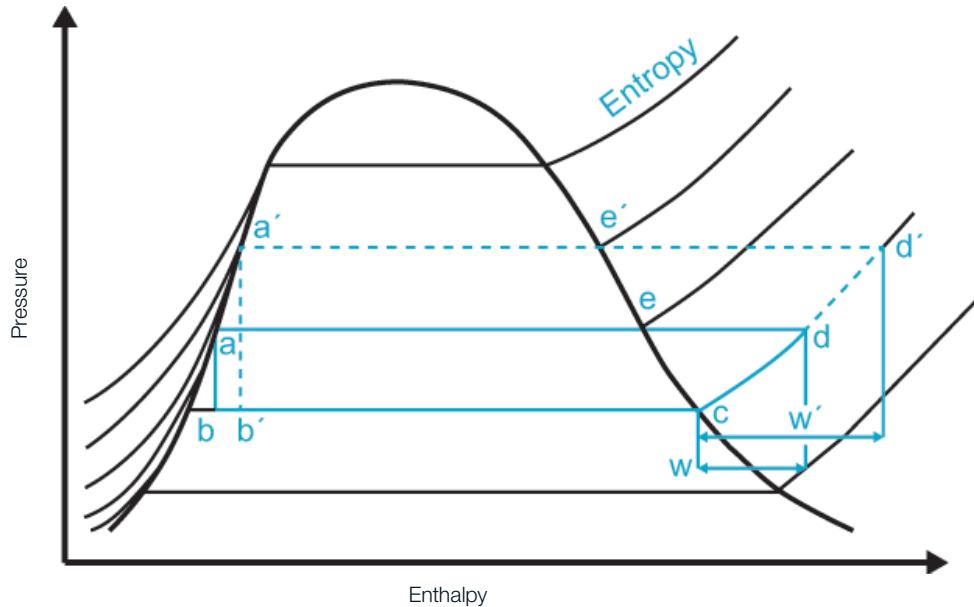
As you will note from the graph above, the outside temperature, though less significant than the other factors, has an interesting impact on the AC compressor use as well. We see that the peak kW varies as a function of temperature. We created this chart by associating the measured kWh for each five minute interval with the NOAA reported temperature for that hour and plotting twelve times the highest value, which we assume approximates the power when the compressor is running for the entire five minutes.

**AIR CONDITIONER OPERATION**

To facilitate the following discussion, here is a simplified schematic of a split system residential air conditioner.<sup>2</sup>

The annotations in blue on the following Mollier diagram<sup>3</sup> represent my interpretation of this phenomena. As I do not have exact measurements to match the figure, consider the values to be for illustration purposes only.





Based on these three observations from the M&V data illustrations, one can conclude that the load continues to increase beyond the Manual J–Cooling 1% Dry Bulb temperature.

### PHYSICS DRIVING COMPRESSOR TEMPERATURE UTILITY ENERGY ENGINEERS NEED TO FULLY DEPENDENCE

On the Mollier diagram above, consider an initial operating point where temperature for the evaporating coolant is at 30°F and the condensing coolant is at 120°F. The transition from point **a** to **b** represents the passage of the gas through the expansion valve, which is essentially isenthalpic, and pressure drops from about 300 psi to 70 psi. The liquid evaporates and takes us to point **c**. From **c** to **d**, the compressor raises the pressure back to 300 psi by expending work **W** isentropically. Condensation takes place from **d** through **e** to **c**, back to expansion valve.

If the outside temperature is higher, condensation takes place at a higher temperature and therefore in equilibrium at a higher pressure. This is represented on this chart with the “primed” points and the dotted lines. For discussion purposes, suppose condensation of the coolant is taking place at 160°F, which has an equilibrium pressure of about 400 psi. Also, suppose evaporation takes place at the same temperature 30°F. Here the line **b'** to **c** is shorter, indicating that, per pound of coolant flowing through the system, less heat is extracted from the inside air at the evaporator. This suggests that the system is less efficient at high temperatures. In addition, for the new operating point **c** to **d'**, more work **W'** is expended to compress the gas from 30 psi to 400 psi. This explains why the current (amps) must increase, which also increases the power draw of the compressor, and why we see an increase in kW as a function of outside temperature.

### CONCLUSION

- 1) Air conditioner loads do not appear to flatten at extreme temperatures as might be expected.
- 2) Many residential air conditioning systems do not reach 100% runtime even at temperatures significantly over the Manual J–1% Cooling Dry Bulb Temperature.
- 3) Air conditioner compressor loads increase as outside temperatures increase due to the intrinsic operational physics, in addition to cooling driven load. As a result, there is some additional demand response potential even after the natural duty cycle of the air conditioner reaches 100%.

### Bibliography

- 1 Burdick, Arlan, Strategy Guide: Accurate Heating and Cooling Calculations, IBACOS, Inc., June 2011, p. 12.
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- 3 Perry, Robert H. and Chilton, Cecil H., Chemical Engineers' Handbook, 5 ed., McGraw-Hill Book Company, New York, 1973, p. 3-195.

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