Emerging Technologies

Demand Response Potential of Residential Appliances – Refrigerator A

DR 10.16.01

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EXECUTIVE SUMMARY

This project is part of a larger Southern California Edison (SCE) effort to evaluate Demand Response (DR) capabilities of various residential appliances in a laboratory environment. Several manufacturers have recently developed DR-capable appliances, but little is known about how DR capabilities will be implemented and what useful benefit from DR can be extracted by the utility. The testing performed under this project will give SCE a better understanding of how specific appliances react to certain DR signals before these appliances are installed at customer sites.

The overarching DR Appliance project is aimed at three types of residential appliances: refrigerators, dish washers, and clothes washers. This report is focused on refrigerator A, manufactured by a company referred to as manufacturer A.

The SCE project team developed and implemented a test plan to understand the power profile of refrigerator A under various baseline conditions that replicate typical consumer use, as well as the refrigerator's response to different DR signals received at different periods of operation and under different ambient conditions. The tests also sought to determine the effect of thermal mass on normal operation and demand response.
As a general statement, analyzing the DR response of refrigerator A was hampered by a lack of information on the details on the control scheme of the refrigerator under normal operation.

Overall, refrigerator A performed as anticipated for longer duration high and critical DR-priced events. Under normal residential kitchen operating conditions, the refrigerator generated demand reduction of approximately 90 watts (W) for longer-duration DR event signals. This amount of demand reduced depended on a number of factors, including the operational status of various components, ambient conditions, and the type of signal received.
The time duration of the response also depended on several variables. However, it appeared that the response would not last longer than 60 minutes.

The presence or absence of thermal mass in the refrigerator seemed to have minimal effect on the DR reduction potential.

Modifications could allow faster response, especially for short duration high price events. Further investigation should be conducted to better address long duration DR events.

ABBREVIATIONS AND ACRONYMS

AHAM	Association of Home Appliance Manufacturers
ASH	Anti-Sweat Heater
CFR	Code of Federal Regulations
DL	Delay Load
DOE	US Department of Energy
DR	Demand Response
EMS	Energy Management System
GE	General Electric
HAN	Home area network
LCD	Liquid crystal display
LED	Light emitting diode
NI	National Instruments
NIST	National Institute of Standards and Technology
RASS	Residential Appliance Saturation Survey
RTD	Resistance temperature device
SCE	Southern California Edison
SR	Spinning Reserve
THD	Total Harmonic Distortion
TTC	Technology Test Centers
UUT	Unit under test
W	Watt
Wh	Watt-hour
Wi-Fi	Wireless Connection

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INTRODUCTION

The major electrical grid failures over the past few decades, coupled with the emergence of widespread renewable generation and increased awareness of energy efficiency, are driving a growing push for an electric smart grid. Employing vast networks of communicating equipment on both the utility and customer sides of the meter, the smart grid is expected to improve visibility and control over how and when energy is consumed. Utilities have taken the lead for the smart grid components of the transmission and distribution system, as well as for smart meters, which enable communication between the utility and the customer.

In the residential sector, smart appliances are the key to realizing the full potential benefits of the smart grid. Such appliances achieve the highest levels of energy efficiency during normal operation and are also capable of responding to demand response (DR) events—periods when utilities need to drop electric load to manage pricing peaks or grid reliability events. Appliance manufacturers have embraced DR functionality and are just beginning to release their first DR-capable products.

Conceptually, DR allows the utility to send a signal to a customer's smart meter to alert it to high price conditions or in response to a critical adverse grid condition requiring a quick reduction in connected load to prevent widespread grid failure. The DR signal is then re-broadcast from the smart meter to the home area network (HAN) or to smart appliances, which react by reducing load as much as possible. Smart appliances have built-in algorithms that allow them to determine whether they can respond to the signal while maintaining an acceptable level of service to the consumer.

This report describes one part of a larger Southern California Edison (SCE) effort to evaluate the DR capabilities of various residential appliances in a laboratory environment. As noted above, several manufacturers have recently developed DR-capable appliances, but little is known about how DR capabilities will be implemented. This testing will give SCE a better understanding of how specific appliances will react to certain DR signals before these appliances are installed at customer sites. Future efforts may use this information to project grid impacts of large-scale adoption of this technology.

The overarching DR Appliance project is aimed at three types of residential appliances: refrigerators, dish washers, and clothes washers. This report is focused on refrigerator A, manufactured by a company referred to as manufacturer A.

BACKGROUND

Refrigerators are present in virtually every home in California[1] for the preservation of perishable food products. Unlike other appliances (such as dishwashers), which follow a cycle-based operation profile, refrigerators must perform their primary temperature-maintenance function 24 hours a day, 365 days a year in order to consistently maintain a safe food storage temperature. This unique operating schedule creates interesting paradigms when combining energy-efficient operation with the ability to respond to DR signals.

REFRIGERATOR DEMAND AND ENERGY USAGE

The 2009 California Residential Appliance Saturation Survey (RASS)[2] determined that annual refrigerator energy consumption ranged between 660–827 kilowatt-hours (kWh) for the first refrigerator in a residential unit. This population likely includes many older, less efficient units. For new homes (which most likely include new appliances), the average was 707 kWh versus 778 kWh for old homes. New refrigerators that qualify for ENERGY STAR® typically consume 500 kWh annually.

Power consuming components in a refrigerator typically include compressor, evaporator fan(s), condenser fan, anti-sweat heater (ASH), lights, ice maker, ice dispenser, defrost heater. The operation patterns and typical power demand of individual components or systems of components are detailed in Table 1.

Because all of these systems and components operate in response to different stimuli, predicting the operation of refrigerators can become extremely complex, even under controlled conditions.

Most manufacturers choose to add DR capability onto their already-efficient products, as the energy-aware consumer is the most likely to demand, and ultimately take advantage of, DR capability. These efficient units also have higher levels of sensing and control technology incorporated into their design, making it simpler to incorporate DR as an extra feature.

[1] California Energy Commission. 2010. "Residential Appliance Saturation Survey (RASS)" http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-V2.PDF

2 Ibid.

TABLE 1. OPERATION PATTERN AND TYPICAL PATTERN OF REFRIGERATOR COMPONENTS

SYSTEM	PURPOSE	OPERATION PATTERN	COMPONENTS	TYPICAL POWER (WATT)
Refrigeration	Maintains refrigerator and freezer cabinet temperature	Continuous according to thermostat	• Compressor • Condenser fan • Evaporator fan(s)	100 5 5
Anti-Sweat Heat	Prevents moisture (dew) from forming on door/frame	Continuous with compressor cycling	Anti-sweat heater	10
Lights	Illuminates cold cabinet for user	With door opening	Lights and drivers/ballasts	10
Ice Making	Supplies batches of ice cubes to the ice bin	Based on ice bin fill sensor	• Compressor • Fan • Heaters	100 5 20
Ice Dispensing	Dispenses ice in cube or crushed form	With user activation	• Auger • Crusher	20 100
Defrost	Removes ice and frost from evaporator coil	Periodic based on proprietary algorithms	Defrost heater	350

DEFINITION OF A SMART APPLIANCE

In 2010, joint petitioners to the U.S. Department of Energy (DOE) (including the Association of Home Appliance Manufacturers (AHAM) and efficiency advocates, such as the American Council for an Energy-Efficient Economy) proposed a guideline[3] for defining smart appliances that included implementation of DR strategies.

The Joint Petition defines a smart appliance as:

> *"a product that uses electricity for its main power source which has the capability to receive, interpret and act on a signal received from a utility, third party energy service provider or home energy management device, and automatically adjust its operation depending on both the signal's contents and settings from the consumer. The product will be sold with this capability, which can be built-in or added through an external device that easily connects to the appliance. The costs of such devices shall be included in the product purchase price.*
>
> *These signals must include (but are not limited to) appliance delay load, time-based pricing and notifications for load-shedding to meet spinning reserve requirements. Any appliance operation settings or modes shall be easy for an average, non-technical consumer to activate or implement. Additionally, a smart appliance or added device may or may not have the capability to provide alerts and information to consumers via either visual or audible means. The appliance may not be shipped with pre-set time duration limits*

[3] AHAM, et al. 2011. "Joint Petition To ENERGY STAR To Adopt Joint Stakeholder Agreement As It Relates To Smart Appliances" www.energystar.gov/products/specs/system/files/Petition_to_ENERGY_STAR_from_Joint_Stakeholders.pdf

that are less than those listed below, but may allow consumer-set time duration limits on smart operating modes, and will also allow consumers to override any specific mode (e.g. override a delay to allow immediate operation, limit delays to no more than a certain number of hours, or maintain a set room temperature).” [4]

DR EVENT DEFINITIONS

The Joint Petition breaks DR into two categories that are differentiated by the length of the event associated with the DR signal:[5]

- Spinning reserve: DR events that last up to 10 minutes
- Delay load: DR events that last from 10 minutes to 4 hours

Note that no category (and thus no required response) exists for events longer than 4 hours in duration, although it is likely that such events would occur.

A particular appliance’s ability to reduce load depends on the type of signal received and the operational status of the appliance at the time the signal is received.

As an overarching requirement, DR-capable appliances must still be able to provide consumers the anticipated value of their operation with no detriment to performance. For example, a DR-capable clothes washer should be able to clean the clothes and not damage them when responding to a DR event. Similarly, a refrigerator must maintain safe temperatures when responding to a DR event. In most cases, short interruptions of appliance operation would not affect performance. Longer-term interruptions could have detrimental impacts depending on a number of operational conditions and the type of appliance involved.

REFRIGERATOR DR REQUIREMENTS

The Joint Petition further defines minimum requirements for each type of appliance. Table 2 shows these minimum requirements for refrigerator and freezers.[6]

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[4] Ibid.

[5] Ibid.

[6] Ibid.

TABLE 2. REFRIGERATOR REQUIREMENTS BY DR EVENT TYPE

DR EVENT TYPE	DURATION	MINIMUM REQUIREMENTS
Spinning Reserve	Up to 10 minutes	upon receipt of a signal … the product must restrict its average energy consumption during this time period to a maximum of 50 percent of the average load over a 24 hour period (unless there is a consumer initiated function, such as door opening or ice or water dispensing).
Delay Load	10 minutes to 4 hours	upon receipt of a signal … the product must shift defrost cycles beyond the delay period and do one of the following -- (1) shift ice maker cycles beyond the delay period, or (2) reduce average wattage during the delay period by at least 9.6 watts (W) relative to average load over a 24 hour period, and may shift this wattage beyond the delay period
---	Over 4 hours	No response required

Manufacturers are free to incorporate additional functionality into their units. Each manufacturer that that the project team has consulted has implemented these minimum requirements in slightly different fashion. Some manufacturers, including manufacturer A, have adapted these requirements into response algorithms based on slightly different trigger signals.

Specifically, manufacturer A bases its DR actions on the price level of the signal received, and not on the duration of the DR event. The utility's current price is among the multiple pieces of information contained in the DR signal. Price is assigned one of four levels: Low, Normal, High, and Critical.

COMMUNICATIONS OVERVIEW AND TESTING

Communication with smart appliances can be achieved through multiple hardware configurations. It is important to note that the signals do not tell the device to turn off; rather, they alert it to the existence of an event and allow the internal algorithms in the device to determine whether or not a response is feasible.

- Option 1: Smart Meter ⟺ HAN ⟺ Smart Appliance: The meter receives a signal from the utility and communicates it to the HAN via ZigBee® or a similar protocol. The HAN translates the signal to communicate with multiple appliances and devices via a variety of communication protocols. This configuration is depicted in Figure 1.

  In a variant of this method, the end device is connected via a wireless connection (Wi-Fi) to a manufacturer's proprietary cloud-based server. The HAN communicates the DR event to the cloud-based server, which either relays the message directly to the appliance or translates it into an actionable command for the appliance.

- Option 2: Smart Meter ⟺ Smart Appliance: The meter receives a signal and communicates directly with the appliance using one of many protocols, such as ZigBee. This architecture eliminates the energy management system (EMS) shown in Figure 1. Most smart meters can pair with only a limited number of devices in this manner.

- Option 3: Utility ⟺ Smart Appliance: The utility communicates directly with the appliance using communication outside of the smart meter infrastructure (examples include an air conditioning cycling program using pager technology or direct appliance communication via the cloud). This method does not require either a smart meter or onsite EMS.

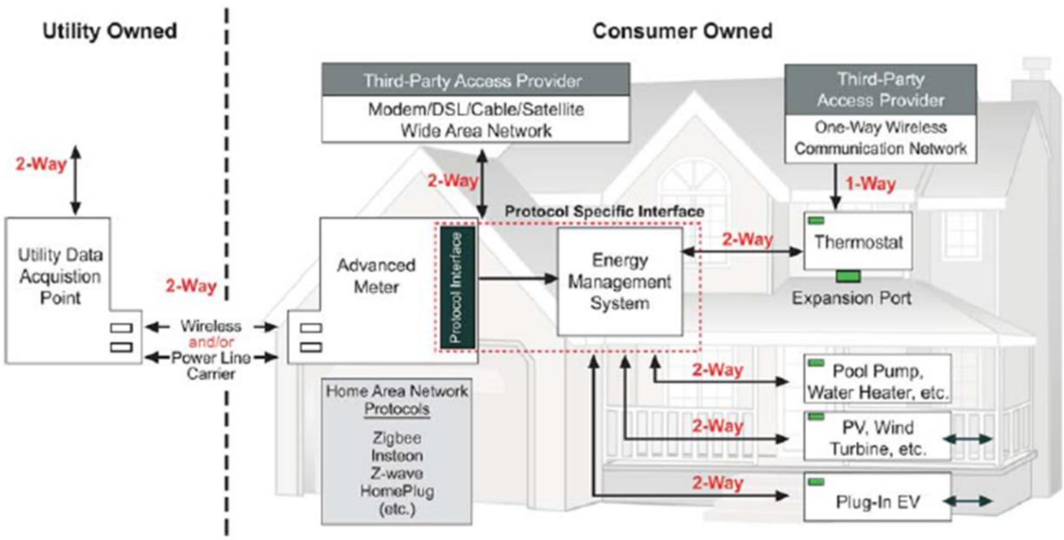

FIGURE 1. TYPICAL IN-HOME COMMUNICATION ARCHITECTURE

While all of these methods can theoretically provide connectivity to the end unit, various interested parties tend to support one over the others. Recent developments within the ENERGY STAR program have left it to the market to determine which method will achieve the greatest market penetration.

Prior to this project, SCE's Advanced Technologies group tested the communications capabilities of refrigerator A. These tests focused on its ability to receive and interpret DR event signals, including event cancellations, multiple events sent at once, or errant event data. They did not delve into the refrigerator's actual response to the event.

ASSESSMENT OBJECTIVES

The goal of this project is to observe the refrigerator's response to DR signals and quantify the demand reduction that can be expected during different segments of the operation cycle.

The main objectives for this project are:

- Acquire power profile data for the refrigerator running under various baseline conditions (see Table 3 for operating modes)
- Observe and quantify the response when a High price DR signal is received during different periods of operation
- Observe and quantify the response when a Critical price DR signal is received during different periods of operation
- Observe and quantify the response when a Critical price DR signal is received for multiple ambient temperature and humidity conditions
- Observe and quantify impacts of the presence of thermal mass on normal operation and demand response

PRODUCT EVALUATION

Manufacturer A supplied a prototype DR-capable French door refrigerator/freezer for testing. This unit, which is not currently commercially available, has integrated ZigBee communication capability and smart control system.

At a high level, the DR algorithms programmed into the refrigerator aimed at performing the following tasks:

- For High price events, the freezer setpoint temperature rises, causing the refrigeration components to turn off for a time. In addition, defrosts are delayed, anti-sweat heaters are disabled, and special cooling functions are disallowed.
- For Critical price events, all of the High actions are taken and the compressors and fans are required to turn and remain off for 10 minutes.
- The user can override any DR event by pushing a button on the user interface to avoid participating in an event for any reason.

The scope of testing laid out below is intended to both verify the functionality of the spinning reserve and delay load algorithms and quantify the DR potential during various phases of operation. Testing was conducted in a laboratory environment in SCE's Technology Test Centers (TTC). Testing in the laboratory enables repeated testing of the appliance using identical loads in controlled environment conditions, thereby minimizing the influence of uncontrolled variables.

TECHNICAL APPROACH

Manufacturer A provided SCE with detailed documentation of the control algorithms implemented in refrigerator A to meet the smart appliance requirements for refrigerators. Subsequently, the SCE project team developed a test plan to monitor the refrigerator's performance under various baseline operating conditions, as well as in response to DR events. The DR test scenarios were geared toward validating the expected responses rather than comprehensively demonstrating *all* potential DR event situations.

TEST PLAN

The test plan was loosely modeled after the DOE Uniform Test Method for Measuring the Energy Consumption of Electric Refrigerators and Electric Refrigerator-Freezers.[7] However, because the goal of this effort was to determine DR potential rather than quantify energy performance, compliance was limited to instrumentation and general appliance installation and testing practices.

During this project, the U.S. Environmental Protection Agency released the ENERGY STAR Test Method to Validate Demand Response.[8] Due to the developing nature of the ENERGY STAR document, the testing described here did not explicitly follow the ENERGY STAR Test Method, though it followed the same principles.

TEST UNIT INSTALLATION

The unit under test (UUT) was installed in TTC's controlled environment room 1 according to manufacturer specifications. Cold water for ice making was supplied through a tank that maintained constant pressure and room temperature supply. The refrigerator and freezer compartments were filled approximately 50% by volume with liquid-filled sponges (Figure 2). This inclusion of thermal mass in the cold compartments is a deviation from the federal test method, which requires an empty cabinet. For DR events, the presence of thermal mass is assumed to be extremely important as it slows temperature rise during compressor OFF times, allowing the unit to "coast" without refrigeration for longer periods of time. Four tests were conducted without thermal mass to determine whether the assumption about thermal mass and refrigerator operation holds true.

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[7] U.S. Department of Energy. Uniform Test Method for Measuring the Energy Consumption of Electric Refrigerators and Electric Refrigerator-Freezers. 10 CFR 430 Subpart B Appendix A1. http://www.gpo.gov/fdsys/pkg/CFR-2011-title10-vol3/xml/CFR-2011-title10-vol3-part430-subpartB-appA1.xml.

[8] ENERGY STAR® Program Requirements Product Specification for Residential Refrigerators, Refrigerator-Freezers, and Freezers Test Method to Validate Demand Response. May-2013. https://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Refrigerators%20and%20Freezers%20Demand%20Response%20Test%20Method.pdf

FIGURE 2. THERMAL MASS IN REFRIGERATOR CABINET

TEST UNIT REFRIGERATION SYSTEM

The unit had a unique refrigeration system with separate evaporators for the fresh food and freezer compartments. Refrigerant flow through the evaporators was controlled by a 3-way valve, as shown in Figure 3.

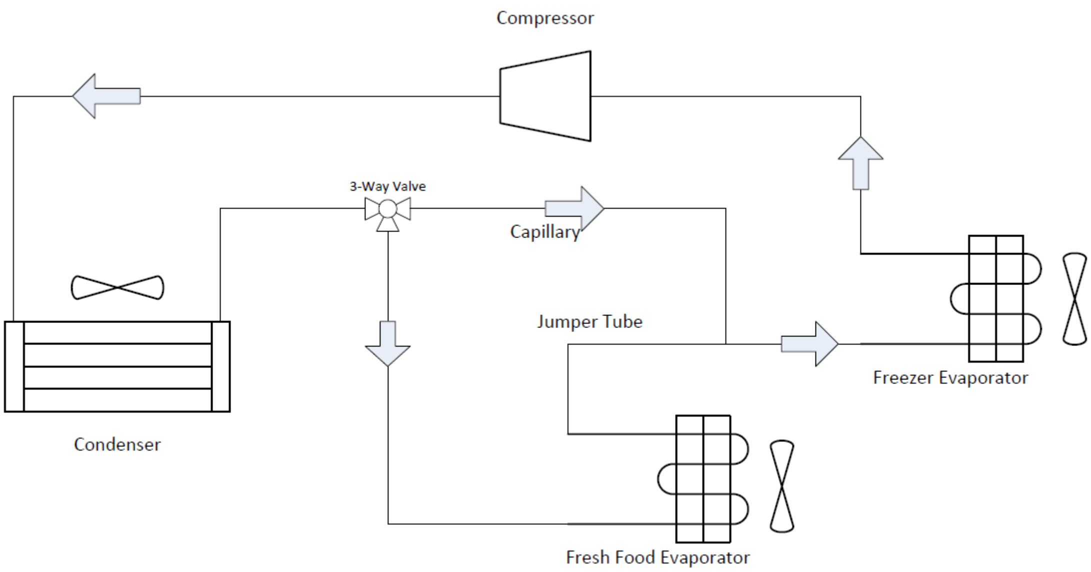


FIGURE 3. REFRIGERATION SYSTEM DIAGRAM

Baseline Tests

A set of baseline tests were developed to capture data on normal refrigerator operation with different combinations of components operating and under different ambient conditions (Table 3). Test A is believed to represent the most commonly used settings in normal operation in typical residential kitchen conditions. Thus, it is the most probable condition during a real DR event. The 90°F (Tests G and H) and 105°F (Test I and J) conditions were intended to examine the response of a secondary refrigerator located in the garage. All tests were conducted for four hours (commencing at the start of a compressor ON cycle for comparison purposes) and repeated three times each.

Table 3. Baseline Test Scenarios

Test	Room Temp (± 1°F)	Relative Hum (± 2%)	Ice Maker	ASH	Door Opening	Comments
A	75	50	On	On	None	
B	75	50	Off	On	None	
C	75	50	On	Off	None	Dispense 12-ounce cup of ice at test start. Repeat every hour.
D	75	50	Off	Off	6/hour for 1 hour	Based on ASHRAE 72
E	75	50	On	On	None	Change freezer setpoint to minimum setting
F	75	50	Off	Off	None	
G	90	30	On	On	None	Same humidity ratio as in other test condition (75°F/50%RH)
H	90	30	Off	Off	None	
I	105	19.5	On	On	None	Same humidity ratio as in other test condition (75°F/50%RH)
J	105	19.5	Off	Off	None	
A-TM	75	50	On	On	None	Remove all thermal mass
G-TM	90	30	On	On	None	Remove all thermal mass

The test plan called for water temperature to be maintained within ±5°F of ambient temperature with water pressure at 35±2.5 psig. The thermostat was set at 37°F in the refrigerator and 0°F in the freezer, except where indicated otherwise in the test scenarios. The ice maker was turned off by taping back the ice level sensor, tricking it into sensing the ice bin as full. The ASH was turned on and off by physically plugging in or unplugging its power cable. In all tests that required the ice maker to be ON, the ice maker was emptied prior to test initiation to ensure a continuous call for ice making during the entire test duration.

DR TESTS

A second set of tests was designed to capture the refrigerator's reaction to High and Critical events initiated during various phases of operation in differing ambient conditions, see Table 4. Test names correlate each DR test with the comparable baseline (e.g., Tests A1 and A2 are repeats of baseline Test A, with the addition of a DR event).

DR events were generated using a laboratory version of SCE's Smart Meter (setup detailed in next section). The High signal contained a Demand Response Load Control level 3 price signal with 8- or 60-minute duration, as indicated in the table. The Critical signal contained a DRLC level 4 price signal with a 60-minute duration. The test period was four hours, always beginning with the start of a compressor ON cycle to ease comparison between different test runs. Test A5 was eliminated due to the unpredictability of defrost and Test I3 was eliminated due to the unpredictability of the compressor running with 100% duty cycle. These tests are displayed in Table 4.

TABLE 4. DR TEST SCENARIOS

TEST	ROOM TEMP (± 1°F)	RELATIVE HUM (± 2%)	ICE MAKER	ASH	DOOR OPENING	COMMENTS
High-8 Event (Duration = 8 min)						
A1	75	50	On	On	None	High-8 initiated 2 minutes after compressor turns on
A2	75	50	On	On	None	High-8 during compressor off, 2 minutes before it should come back on
D1	75	50	Off	Off	6/hour for 1 hour	High-8 initiated 2 minutes after first door opening
G1	90	30	On	On	None	High-8 initiated 2 minutes after compressor turns on
I1	105	19.5	On	On	None	High-8 initiated 2 minutes after compressor turns on
High-60 Event (Duration = 60 min)						
A3	75	50	On	On	None	High-60 initiated 2 minutes after compressor turns on
A4	75	50	On	On	None	High-60 during compressor off, 2 minutes before it should come back on
~~**A5**~~	~~75~~	~~50~~	~~On~~	~~On~~	~~None~~	~~High-60 when defrost should occur (depends on ability to predict defrosts)~~
Critical-60 Event (Duration = 60 min)						
A6	75	50	On	On	None	Critical-60 initiated 2 minutes after compressor turns on
A7	75	50	On	On	None	Critical-60 initiated during compressor off, 2 minutes before it should come back on
A-TM1	75	50	On	On	None	Thermal mass removed and Critical-60 initiated 2 minutes after compressor turns on
E1	75	50	On	On	None	With freezer setpoint at minimum, Critical-60 during compressor off, 2 minutes before it should come back on
G2	90	30	On	On	None	Critical-60 initiated 2 minutes after compressor turns on
G3	90	30	On	On	None	Critical-60 during compressor off, 2 minutes before it should come back on
G-TM1	90	30	On	On	None	Thermal mass removed and Critical-60 initiated 2 minutes after compressor turns on
I2	105	19.5	On	On	None	Critical-60 initiated 2 minutes after compressor turns on
~~**I3**~~	~~105~~	~~19.5~~	~~On~~	~~On~~	~~None~~	~~Critical-60 during compressor off, 2 minutes before it should come back on~~

INSTRUMENTATION

The backbone of the data acquisition system for the test room consisted of LabVIEW software and National Instruments (NI) hardware. The system currently configured has capacity for 288 sensor inputs: 128 thermocouple channels, 64 resistance temperature device (RTD) channels, 64 current channels, and 32 voltage channels.

For this project, instrumentation was designed to follow the requirements of the DOE test method, with additional sensors added to enable more focused analysis of the DR-related performance of the UUT. Data was collected every 10 seconds on 57 channels.

Table 5 lists all of the sensor types, monitoring points, and pertinent accuracy information. All sensors were calibrated to NIST-traceable standards prior to installation. Accuracies listed are from sensor manufacturer data and do not necessarily include accuracy of the data acquisition system or calibration.

TABLE 5. SENSOR TYPE INSTRUMENTATION

SENSOR TYPE	MAKE/MODEL	ACCURACY (NIST TRACEABLE)	CALIBRATION DATE (LOCATION)	CORRESPONDING KEY MONITORING POINTS
Temperature (type-T special limits grade thermocouples)	Masy Systems, Ultra-Premium Probe	± 0.54 °F	3/2012 (In-house)	• Ambient temperature
Temperature (RTD)	Hy-Cal Engineering Model RTS-37-A-100 Platinum 100Ω	± 0.10% of reading	3/2012 (In-house)	• Water inlet temperature
Ambient Relative Humidity	Vaisala Model PTU303	± 0.4 °F ± 1% RH	8/2011 (Manufacturer)	• Ambient relative humidity
Water Pressure	Setra, Inc. Model C207 (0-100 psi)	± 0.13% of full scale	3/2012 (In-house)	• Water pressure
Power	HIOKI, Inc. Model 3169-21	± 0.2% of reading	3/2012 (In-house)	• Total refrigerator power • Refrigerator voltage • Refrigerator current • Refrigerator total harmonic distortion (THD)
Power	HIOKI, Inc. Model 3169-21	± 0.2% of reading	3/2012 (In-house)	• Compressor power • Compressor voltage • Compressor current • Compressor THD
Power	HIOKI, Inc. Model 3169-21	± 0.2% of reading	3/2012 (In-house)	• Deli pan heater power • Refrigerator defrost heater power • Freezer defrost heater power • Ice port heater power
Power	HIOKI, Inc. Model 3169-21	± 0.2% of reading	3/2012 (In-house)	• Freezer light switch power • Ice maker power 1 • Ice maker power 2 • Water valve and dispenser power
Current	OSI Hall Effect Current Transducer Model CTU-025R	± 0.5% of full scale	3/2012 (In-house)	• Refrigerator fan current • Freezer fan current • Ice box fan current • Condenser fan current • Ice auger current • Lighting current • Compressor current • ASH current
Scale	Sartorius Model CISL1N-U	± 0.1 gram (± 0.0035 ounces)	3/2012 (In-house)	• Water weight

Air temperature was measured in 5 locations inside the refrigerator (top, middle, and bottom shelf in the refrigerator and top and bottom shelf in the freezer). Product temperatures were measured at one location each in the refrigerator and freezer. Poles on either side of the refrigerator hold ambient temperature sensors at 1-foot increments. The computer in the foreground of Figure 4 interfaced with the laboratory smart meter test device to send DR signals. The DR signal was received by a wireless antenna built into the refrigerator. Power monitoring equipment is visible to the left of the meter.

FIGURE 4. DR EQUIPMENT SETUP

Details on measurements follow:

- Total power to the refrigerator was measured in conjunction with separate power measurements for some of the major components (especially those that respond to DR events), including the compressor, defrost heaters, ice maker, and auger motor.
- Attempts were made to measure the ASH, which varies based on the temperature and humidity in the space. Because proper monitoring equipment was not available, spot measurements were taken at each ambient test condition.
- Additional current measurements were taken on certain components, such as evaporator fans, ice box fan, condenser fan, ice auger, and LED lights, whose power demand was not crucial for the purpose of monitoring their ON/OFF cycling.
- The water supply connections and measurement equipment are shown in Figure 5. To measure water supply, the pressure vessel was filled with water and pressurized to maintain a continual supply to the refrigerator, and flow was deduced from the change in weight recorded by the scale. Water temperature was measured at the point where it entered into the refrigerator.

FIGURE 5. WATER SUPPLY AND INSTRUMENTATION

DATA ANALYSIS

The 10-second raw data collected in each test scenario was analyzed without transformation into longer averages. Data analysis and graphical representations are based on the 10-second data. Calculations necessary to proceed from raw data to final results are presented in the following sections. In some instances, inconsistent data collection intervals were observed; the cause is being investigated. This inconsistency resulted in slightly fewer data points for some test periods than the 1,440 (every 10 seconds for 4 hours) points that would be expected. The energy calculation uses the actual interval between measurements, so is not affected by this phenomenon.

Below are details on the power and energy equations.

POWER

EQUATION 1. POWER

$$P_{Misc} = P_{Total} - P_{Comp} - P_{WV+D} - P_{Ice\ Port\ Htr} - P_{Ice\ Maker} - P_{Auger\ Motor} - P_{Ref\ Def} - P_{Fzr\ Def}$$

Where:

P_{Misc} = miscellaneous power, W
P_{Comp} = compressor power, W
$P_{\text{WV+D}}$ = water valve + dispenser power, W
$P_{\text{Ice Port Htr}}$ = ice port heater power, W
$P_{\text{Ice Maker}}$ = ice maker power, W
$P_{\text{Auger Motor}}$ = auger motor power, W
$P_{\text{Ref Def}}$ = refrigerator defrost heater power, W
$P_{\text{Fzr Def}}$ = freezer defrost heater power, W

P_{Total} = total power, W

EQUATION 2. ENERGY

$$E = \left(\frac{1\,hr}{3600\,sec}\right)\sum_{n=0}^{1,440} P_n(t)(\Delta t_n)$$

Where:

E = energy consumed, watt-hours (Wh)
n = read number
$P_n(t)$ = instantaneous power demand, W
t = time, sec
Δt_n = time duration between readings, sec

RESULTS

The sections below provide details on the results of the effort to evaluate the DR responses of refrigerator A.

OVERVIEW OF REFRIGERATOR OPERATION

Before taking a deep dive into the results, it may be helpful to understand how the refrigerator works under normal operating conditions and how data is presented, as shown in Figure 6.

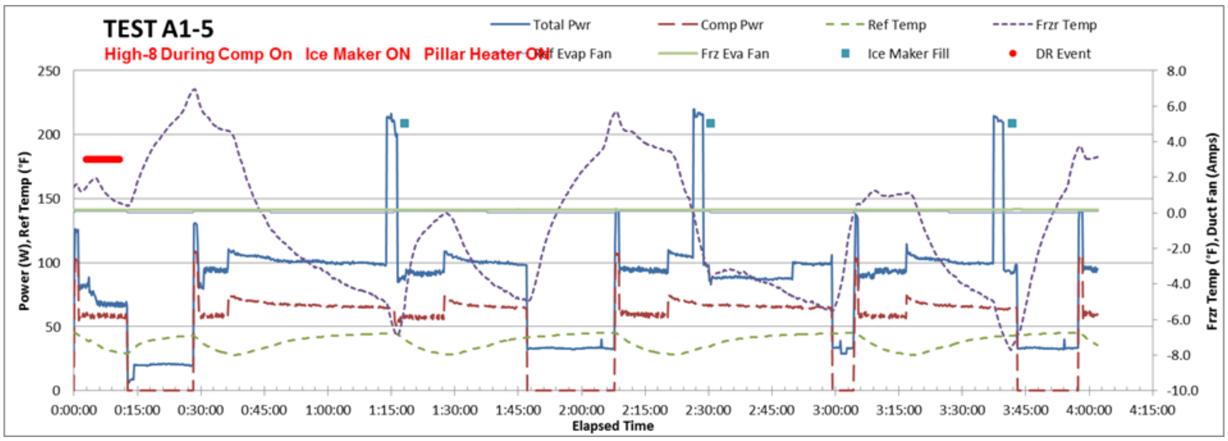


FIGURE 6. BASIC REFRIGERATOR OPERATING PROFILE

The following details explain refrigerator operation and Figure 6:

- The test name and pertinent test conditions are shown in the upper left of the figure.
- The compressor (red dashed line) cycles ON at high speed for 1 minute, then adjusts speed based on temperatures. The three-way valve can feed both the fresh food coil and freezer coil in series (seen at ~30–35 minute marks in Figure 6), only the freezer coil (~35–75 minutes), or neither coil (when the compressor is OFF). The compressor cycles OFF based on the freezer temperature (purple dashed line).
- The refrigerator evaporator fan (light blue line) cycles ON with the compressor and runs until approximately halfway through the compressor cycle time. The refrigerator temperature (green dashed line) pulls down with compressor ON cycles and gradually rises over the run time.
- The freezer evaporator fan (solid green line) is ON continuously.
- The pillar heater (also called the anti-sweat heater), not plotted due to measurement difficulty), remains ON, modulating power corresponding to the ambient temperature and humidity.
- The ice maker produces a batch of ice cubes approximately every hour and fifteen minutes. The spike on the total power (solid dark blue line) correlates to the ice ejection heater, which allows it to dump the cubes out of the tray.

The ice maker fill indicators (blue squares) represent water flowing into the empty tray to start the next batch of ice.

- The DR event indicator (red dots) shows the start and duration of a DR event. For this particular test, an 8-minute High event was initiated at approximately 2 minutes into the test. The compressor continued to run for a short time, then appeared to increase the freezer setpoint temperature (though after the event had ended), allowing the compressor to turn off earlier than it normally would have.

The following should be considered when reviewing evaluation results:

- Temperatures shown on the graphs are from one representative air temperature sensor, not the average of all temp sensors in a cabinet. The temperatures shown are intended to give an impression of temperature variation through the test period.
- The refrigerator's control thermostat is independent of these sensors, but should follow the general temperature profiles observed.
- The 10-second data interval may have missed some short-duration peaks in power demand (e.g., motor in-rush peaks).
- Each test was repeated a minimum of three times (A-1, A-2, A-3, etc.). The charts shown here are the best representations of operation under each set of test conditions.

BASELINE TESTS

KITCHEN CONDITIONS

The 75°F/50%RH ambient conditions closely represent what would be found in a typical residential kitchen. Test A (Figure 7) is the refrigerator operating in a manner consistent with normal consumer actions in those conditions, with the ice maker and pillar heater turned ON.

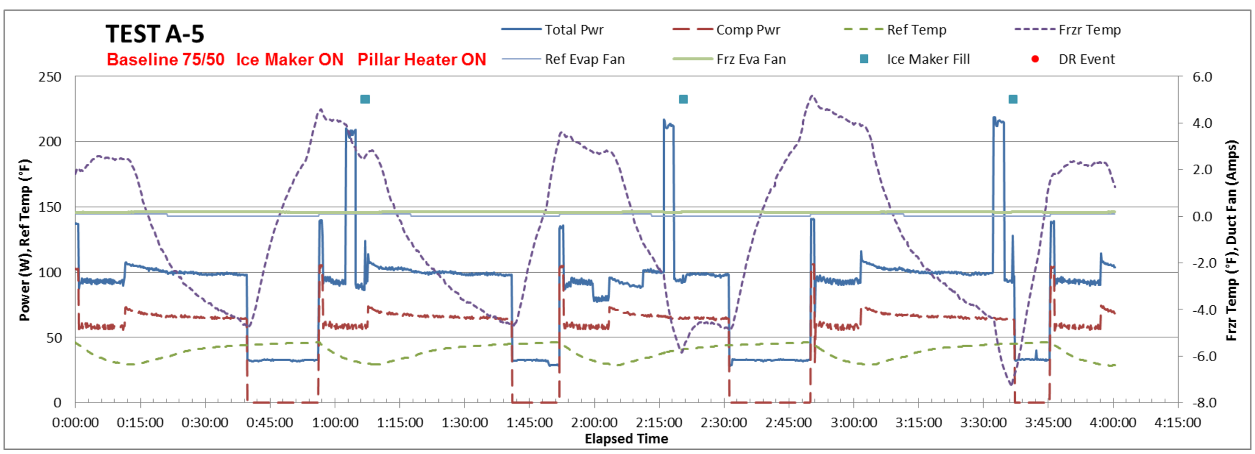


FIGURE 7. TEST A POWER AND TEMPERATURE PROFILE

Test B (Figure 8) depicts the cyclical operation of the refrigerator with the ice maker turned OFF. Under these conditions, total power about 20 W less, and the compressor duty cycle is reduced, and the freezer temperature shifted up about 1 degree compared to Test A.

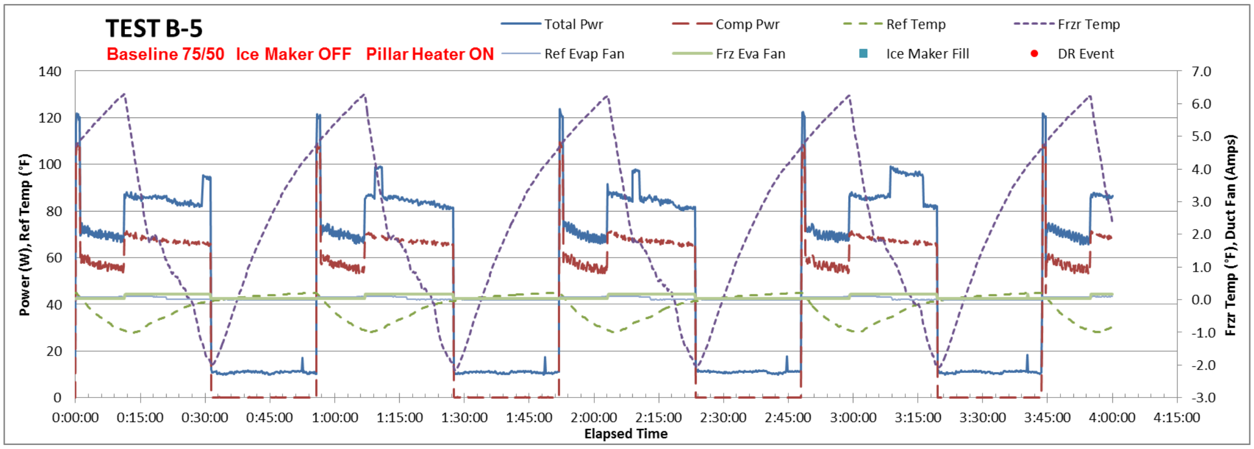


FIGURE 8. TEST B POWER AND TEMPERATURE PROFILE

Test C (Figure 9) depicts operation with the ice maker ON and pillar heater OFF. Note the longer duration compressor cycle, even longer than when the pillar heater was turned ON in Test A.

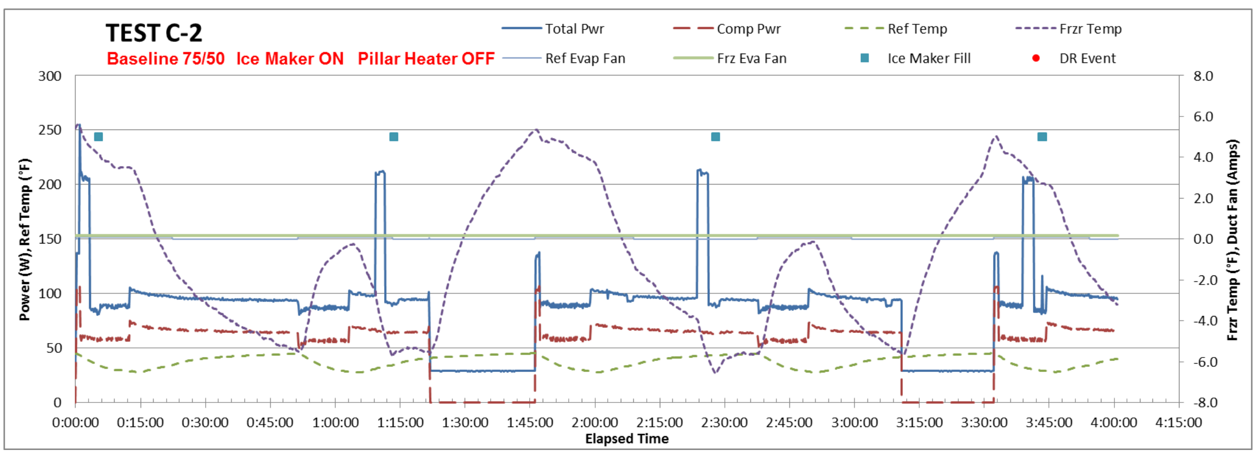


FIGURE 9. TEST C POWER AND TEMPERATURE PROFILE

In Test D (Figure 10) the refrigerator door was opened every 10 minutes for the first hour. Small fluctuations in refrigerator and freezer temperature were observed when the doors opened. The spikes on the total power line were caused by the LED cabinet lighting coming ON each time the door opened. The refrigeration appeared to return to normal operation soon after the door openings stopped.

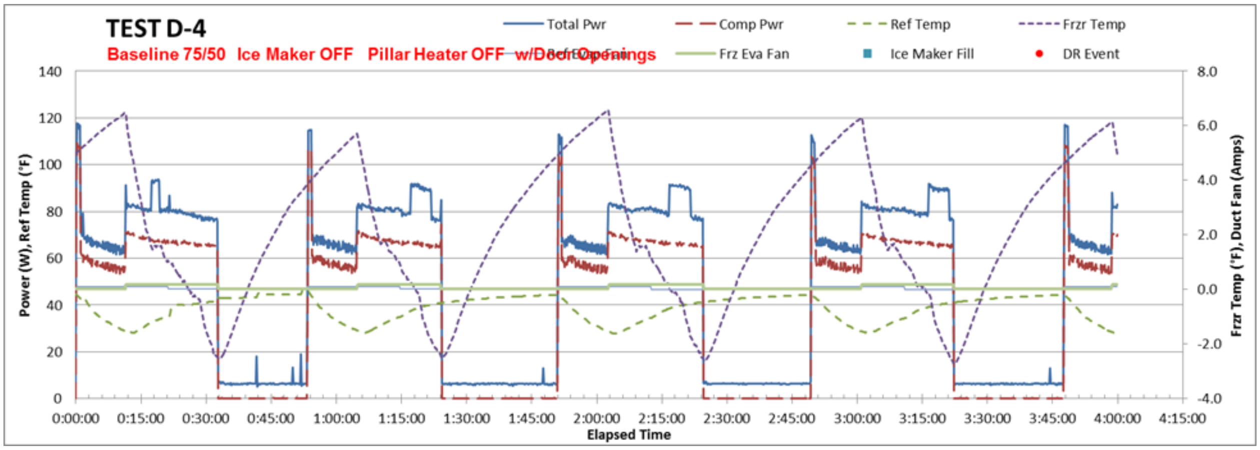


FIGURE 10. TEST D POWER AND TEMPERATURE PROFILE

The freezer temperature was changed to its lowest user selectable setting, -6°F, in Test E to see what effect the minimum temperature would have on compressor power and cycling (Figure 11). Power remained consistent with observations from Test A, but the compressor cycled OFF for only a few minutes one time during the 4-hour test period.

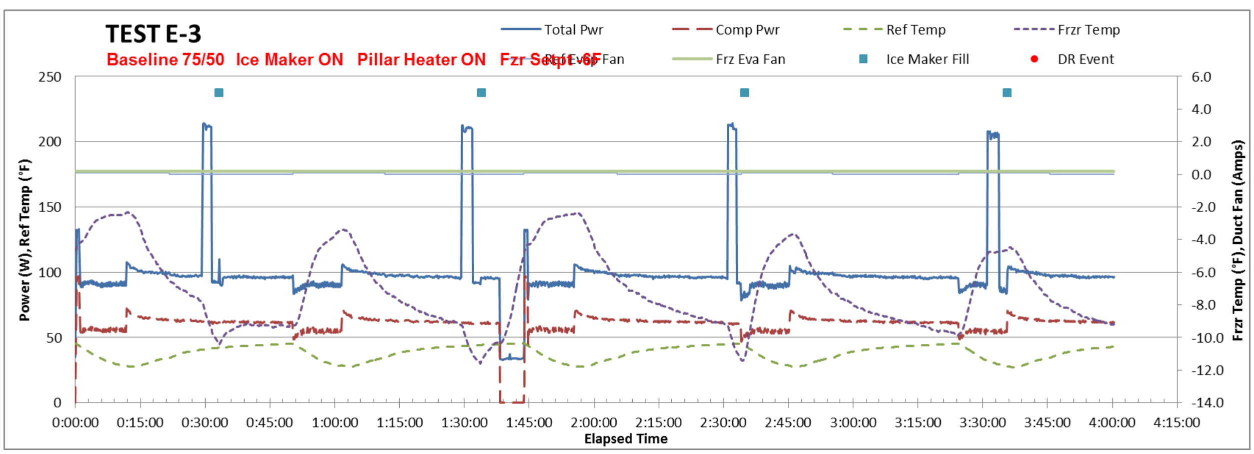


FIGURE 11. TEST E POWER AND TEMPERATURE PROFILE

With the ice maker and pillar heater were turned OFF in Test F (Figure 12), the compressor cycles were shorter than in tests with these components ON, and the temperature profile was consistent with that observed in Test D.

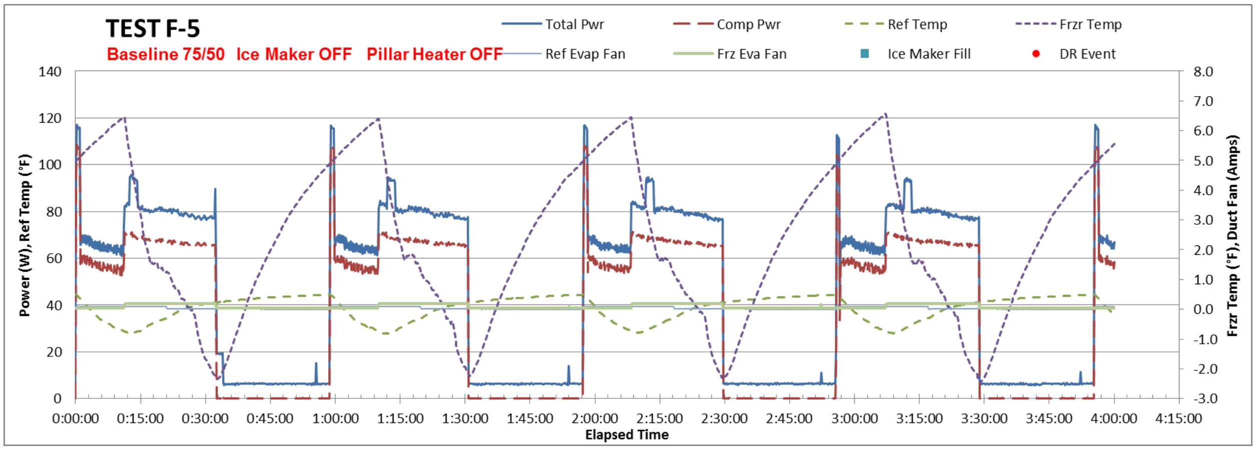


FIGURE 12. TEST F POWER AND TEMPERATURE PROFILE

GARAGE CONDITIONS

Tests at the 90°F/30%RH condition were intended to investigate how refrigerator A might operate when sitting in a garage on a warm day. The base assumption was that the difficulty of maintaining appropriate cabinet temperatures under these conditions might impair the refrigerator's ability to respond to DR events.

Except for the changed ambient conditions, the test procedure for Test G was identical to that for Test A (Figure 7). Figure 13 shows the long compressor cycles (the compressor ran during the entire 4-hour test period) and increased compressor power (~20 W on average) resulting from the warmer surroundings.

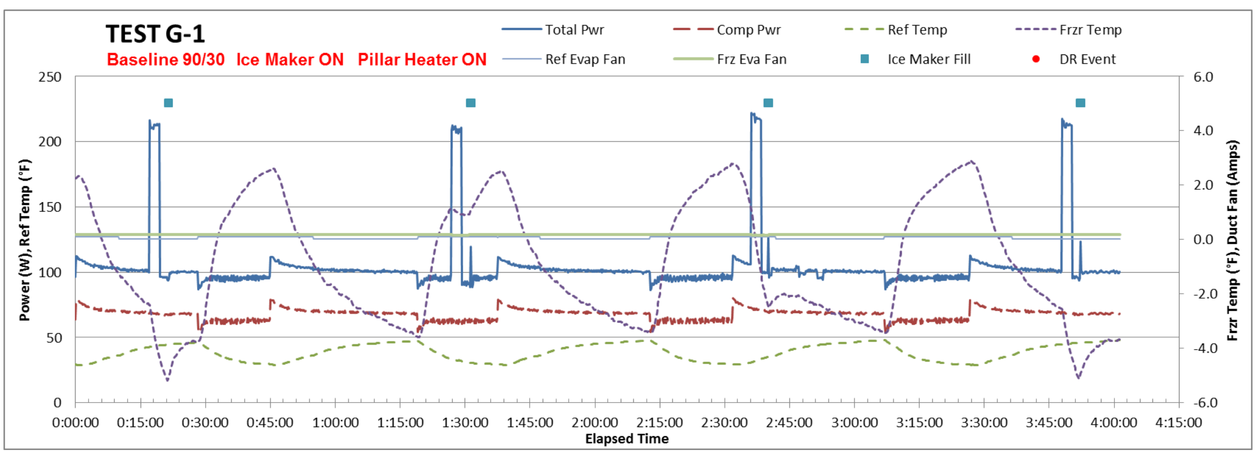


FIGURE 13. TEST G POWER AND TEMPERATURE PROFILE

Test H is similar to Test G except the ice maker and pillar heater were turned OFF (Figure 14). Compressor cycles were shorter than in Test G, and the freezer temperature operating range increased notably (approximately 2°F).

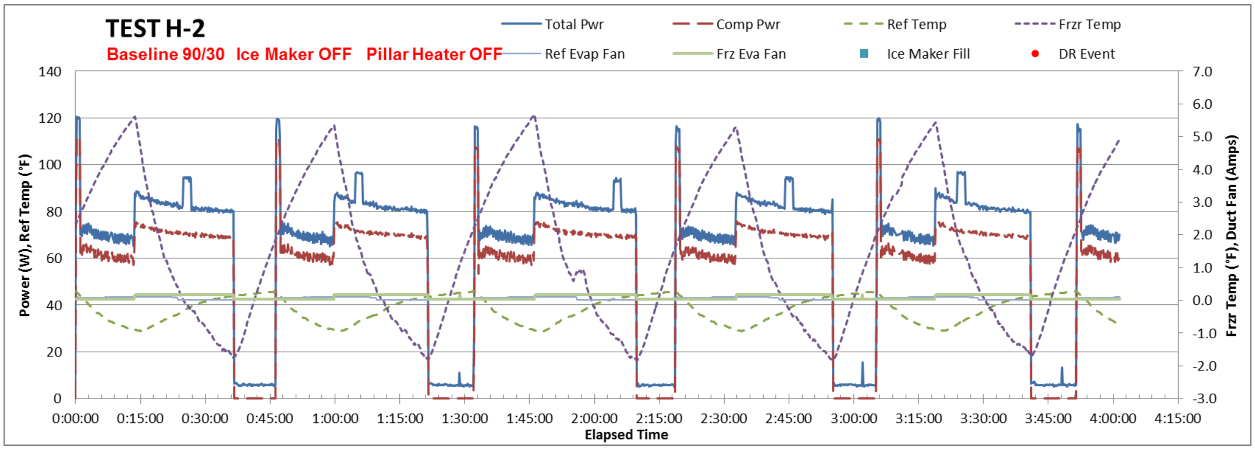


FIGURE 14. TEST H POWER AND TEMPERATURE PROFILE

EXTREME GARAGE CONDITIONS

Garage conditions on a very hot day were replicated by the 105°F/19.5%RH ambient condition. Due to the increased heat gain from the surroundings, freezer temperature in Test I (Figure 15) rose at a much faster rate during compressor OFF cycles than it did under other conditions. The compressor operated continuously and at higher power in order to maintain internal temperatures.

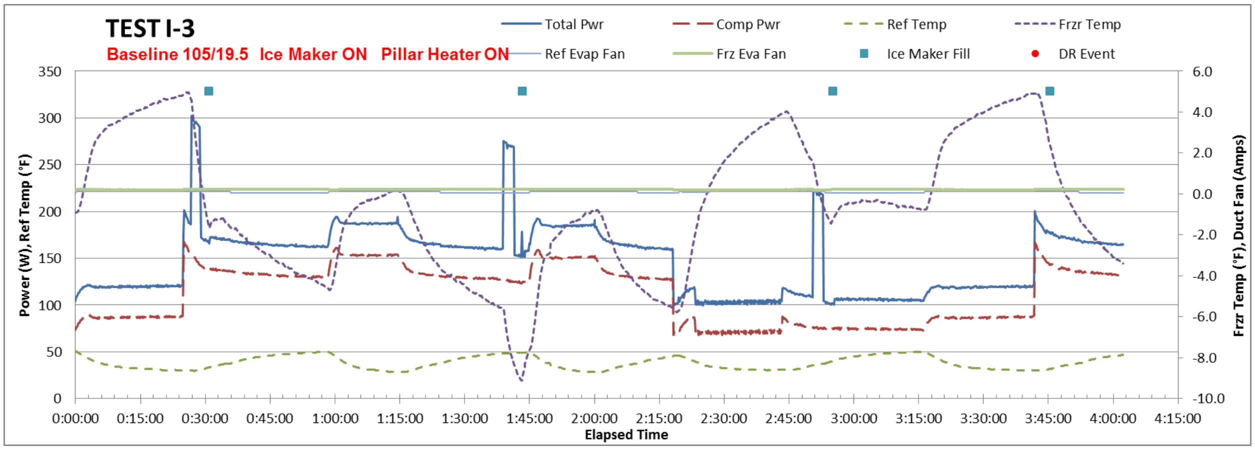


FIGURE 15. TEST I POWER AND TEMPERATURE PROFILE

Turning the ice maker and pillar heater OFF in Test J caused the compressor to cycle more frequently between high and low power levels (Figure 16).

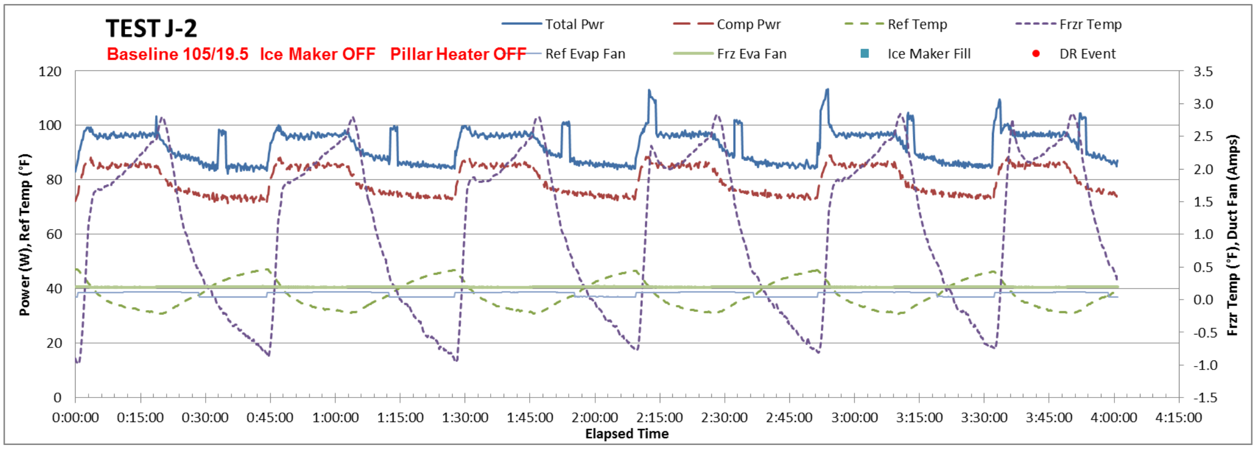


FIGURE 16. TEST J POWER AND TEMPERATURE PROFILE

Figure 17 shows the important comparative results between all of the baseline test conditions using averages of the three data sets collected for each test.

Test	TEST A	TEST B	TEST C	TEST D	TEST E	TEST F	TEST G	TEST H	TEST I	TEST J
Room Conditions	75/50						90/30		105/19.5	
Ice Maker (X=ON)	X		X		X		X		X	
Pillar Heater (X=ON)	X	X			X		X		X	
Other Conditions				Door Openings	Frzr Setpt -6°F					
Compressor Run Time	3:06:10	2:22:24	3:12:54	2:21:57	3:52:32	2:15:06	4:02:36	3:12:03	4:01:56	4:02:59
Average Power										
Compressor Average Power (W)	50	38	52	38	59	37	68	54	109	79
Total Average Power (W)	87	53	85	48	98	46	104	64	145	91
Avg Total Power During DR Event (W)	--	--	--	--	--	--	--	--	--	--
Avg Total Power Excluding DR Event (W)	87	53	85	48	98	46	104	64	145	91
Energy										
Compressor Energy (Wh)	203	154	209	154	238	147	276	218	442	320
Total Energy (Wh)	349	212	342	194	393	184	420	258	585	369
Room										
Average Room Temp	75.4	75.4	75.4	75.3	75.5	75.3	90.1	90.0	105.2	105.3
Average Room RH	52.6	52.4	52.7	52.5	53.6	52.4	30.0	30.3	19.5	19.5
Water Properties										
Total Water Flow (gal)	-0.1	0.0	0.0	0.0	0.1	0.0	-0.1	0.0	-0.1	0.0
Ref / Frzr Cabinet										
Avg Ref Temperature (°F)	39.9	39.7	38.9	39.6	39.1	39.7	40.6	40.2	40.8	40.7
Avg Frzr Temperature (°F)	0.1	1.6	0.2	1.4	-6.2	1.5	-0.4	0.9	-0.3	0.9

FIGURE 17. SUMMARY OF ALL BASELINE TEST RESULTS

HIGH-8 DR EVENT TESTS

The series of High-60 tests examines the refrigerator's response to DR events with High criticality (DRLC level 3) and 8-minute duration. In general, the refrigerator provided very small power reductions during High-8 events. It was anticipated that more significant reductions would be seen as a result of the ASH turning OFF and the compressor cycling OFF when the freezer temperature reset (see Product Evaluation section above). However, in the one case where the compressor did turn OFF, it did not occur during the event window. Additional graphs and summary results are contained in the Appendix.

KITCHEN CONDITIONS

In Test A1 (Figure 18) the High-8 event signal represented by the solid red line was sent while the compressor was ON. The compressor remained ON at constant power when the signal was received, though there was a slight drop in total power of the unit. The compressor did not turn off until after the 8-minute event had ended, when the thermostat reset, allowing the freezer temperature to climb higher than normal. This delay in temperature reset may be related to a minimum run-time feature to prevent short-cycling of the compressor. The refrigerator returned to normal operation after the event cleared and the compressor cycled back ON, though the first cycle was a bit longer than normal to enable the temperature pull-down. This result is a bit concerning as for short events, the load would need to be reduced *during* the event in order to provide maximum benefit.

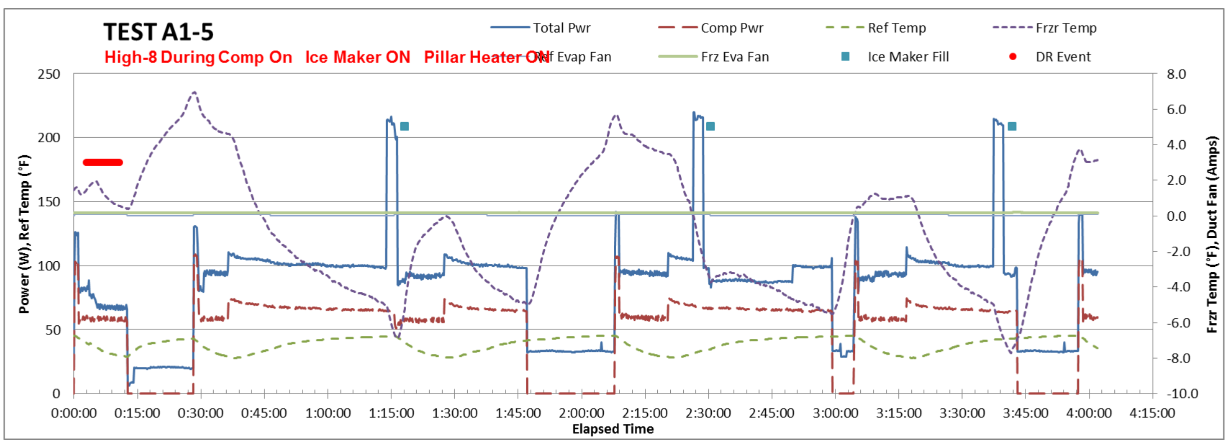


FIGURE 18. TEST A1 POWER AND TEMPERATURE PROFILE

In Test A2 (Figure 19) the High-8 event was initiated during the compressor OFF cycle, just before the compressor would normally have cycled back ON. The compressor cycled back ON as the freezer temperature reached its setpoint, but other components remained OFF for the duration of the event as shown by the reduced total power during the event.

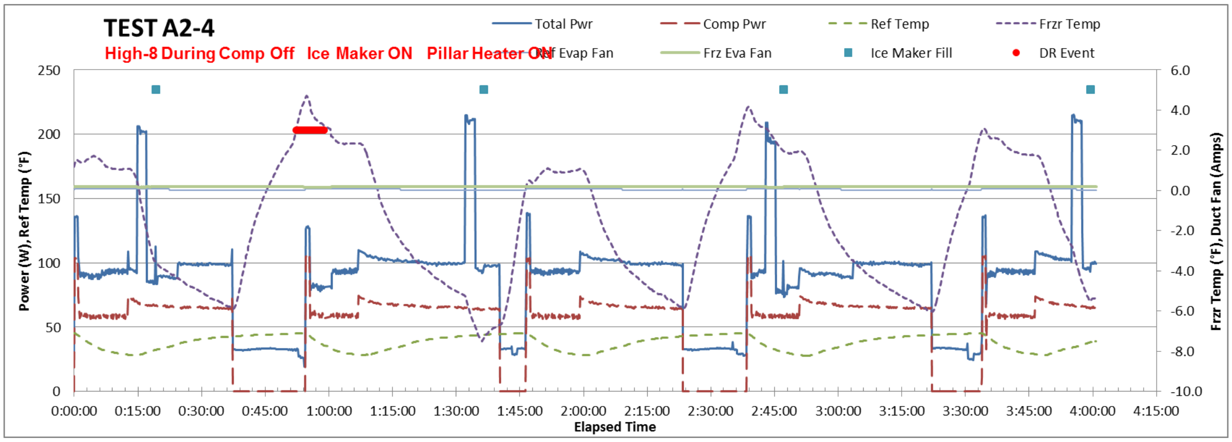


FIGURE 19. TEST A2 POWER AND TEMPERATURE PROFILE

For Test D1 (Figure 20) a slight decrease in total power was observed during the event, but no noticeable change in compressor operation occurred.

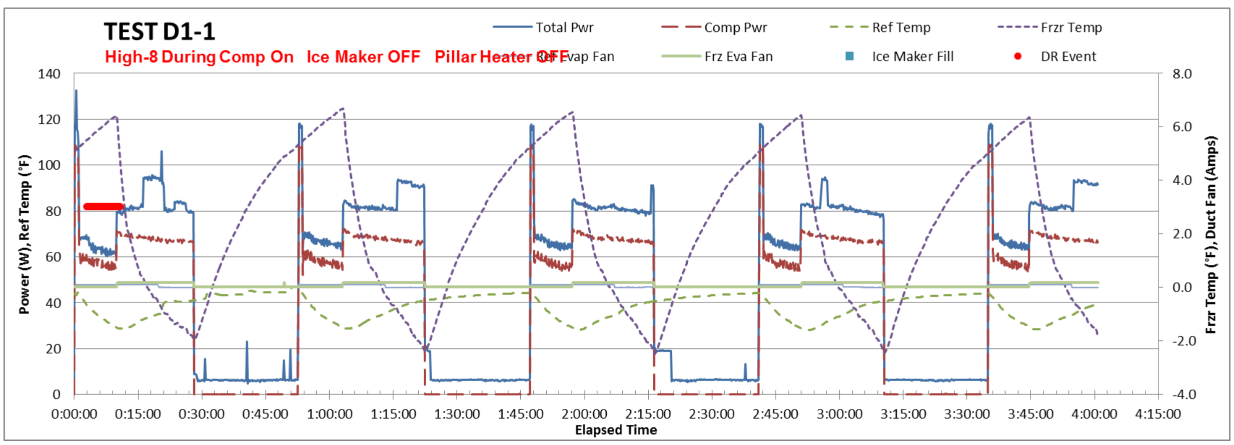


FIGURE 20. TEST D1 POWER AND TEMPERATURE PROFILE

In summary, for High-8 events at kitchen conditions, a small reduction in power consumed by auxiliary components occurred, but compressor operation showed almost no change. In the one case where the compressor changed its operating pattern, it did not actually turn OFF until after the event had expired.

GARAGE CONDITIONS

Results for Test G1 varied across the three test runs. In two of them, the compressor never shut OFF, though a slight drop in total power was observed during the event (see Figure 21). For Test G1-4 (Figure 22), however, the compressor actually shut OFF for the entire length of the event and allowed the freezer temperature to increase.

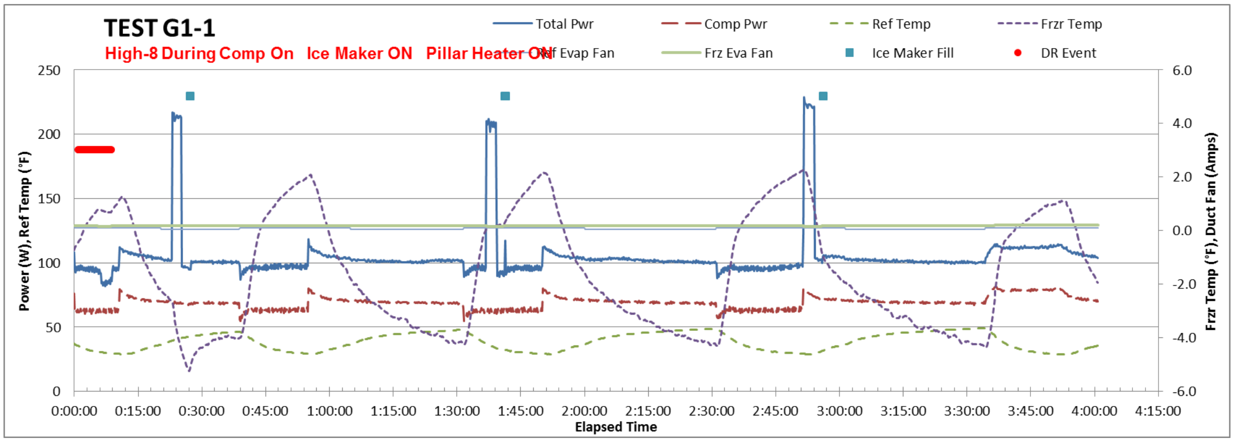


FIGURE 21. TEST G1-1 POWER AND TEMPERATURE PROFILE

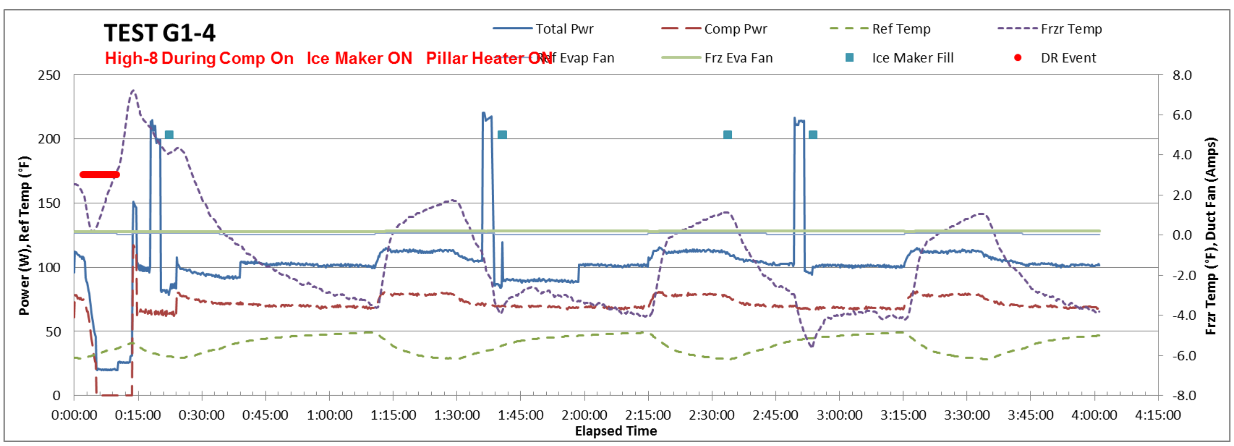


FIGURE 22. TEST G1-4 POWER AND TEMPERATURE PROFILE

EXTREME GARAGE CONDITIONS

The response at the extreme condition was not consistent between test runs:

In Test I1-1 (Figure 23) the compressor shifted to a lower power level and the freezer temperature setpoint remained in its normal range. After the event ended, the freezer setpoint seemed to drop by 4–6°; the reason for this drop is unclear.

- In Test I1-2 (Figure 24), a similar phenomenon was observed, but the shift to lower setpoint happened much sooner than in Test I1-1.
- In Test I2-3 (Figure 25), the compressor shut OFF in response to the event signal, remained OFF for approximately 10 minutes, and then appeared to shift to a lower freezer setpoint.

In the baseline extreme garage tests, significant operational variability was evident between data sets and even within data sets. Thus, the inconsistencies in the DR responses may be a function of how the control system deals with unusual conditions, rather than a problematic response to the event itself.

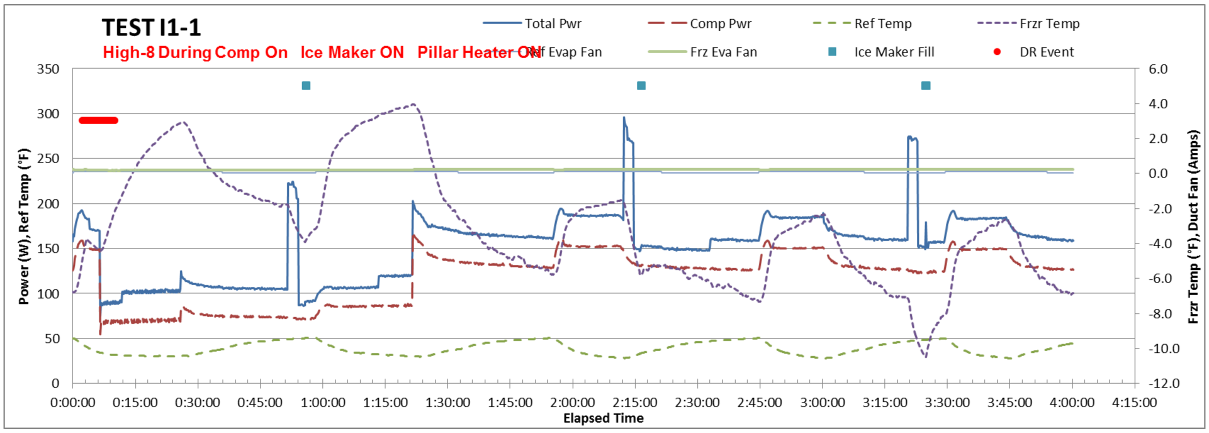


FIGURE 23. TEST I1-1 POWER AND TEMPERATURE PROFILE

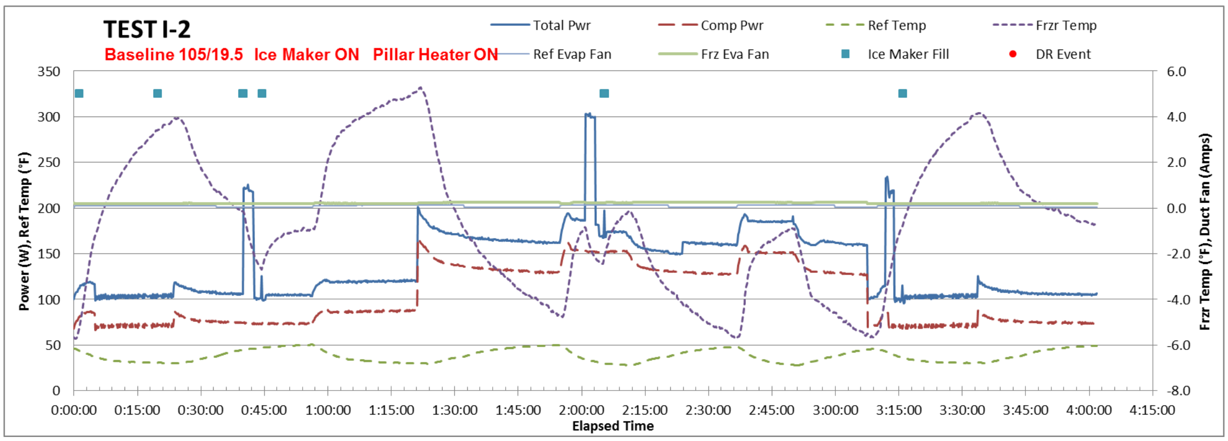


FIGURE 24. TEST I1-2 POWER AND TEMPERATURE PROFILE

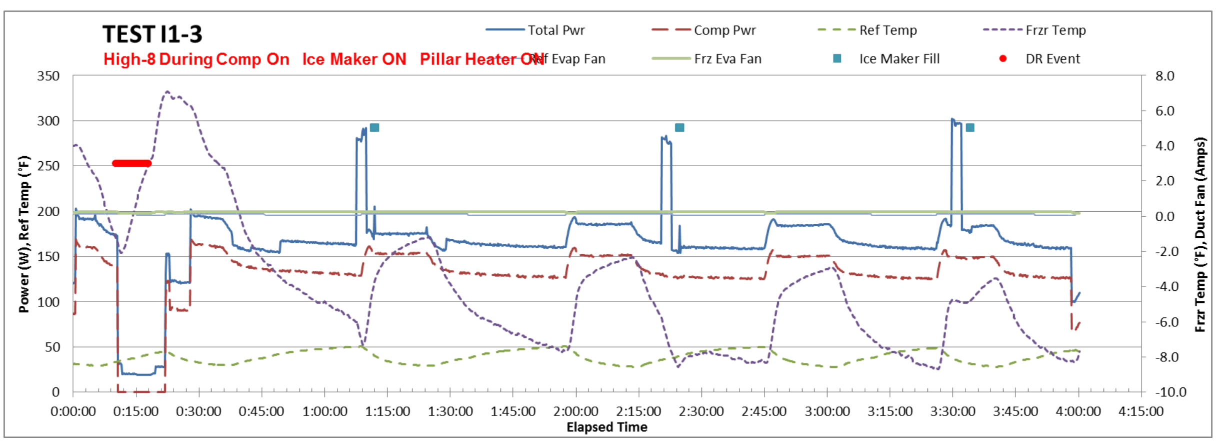


FIGURE 25. TEST I1-3 POWER AND TEMPERATURE PROFILE

HIGH-60 DR EVENT TESTS

The series of High-60 tests examines the refrigerator's response to DR events with high criticality (DRLC level 3) and a 60-minute duration. A signal for a 60-minute duration event was sent at various stages of the refrigerator's normal operating cycle to observe the refrigerator's response. The anticipated response was the same as for anticipated response to the High-8 tests, with a longer sustained power reduction.

KITCHEN CONDITIONS

In Test A3 (Figure 26), the High-60 event was initiated 2 minutes after the compressor cycled ON. A slight drop in total power occurred, but the compressor continued to run for about 10 minutes, possibly because of a short-cycling prevention scheme in the compressor controls. After the compressor turned OFF, the maximum freezer temperature climbed to almost 10°F, about 5°F higher than in the baseline Test A. The fresh food compartment temperature did not change. During the event, the compressor cycled ON one time to maintain the freezer temperature. After the event ended, the compressor ran for over 1.5 hours to bring the temperature back into the normal operating range.

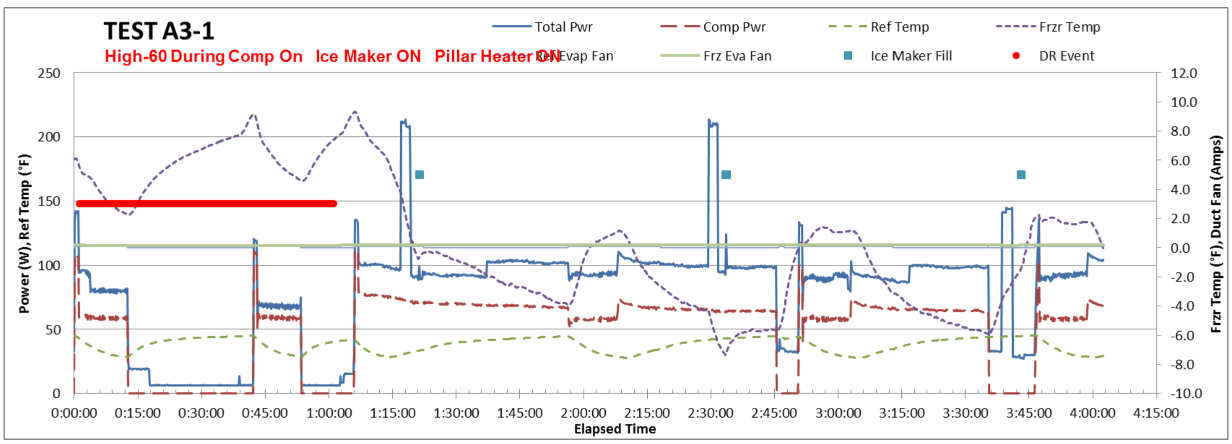


FIGURE 26. TEST A3 POWER AND TEMPERATURE PROFILE

In Test A4 (Figure 27), the High-60 event started while the compressor was OFF. Interestingly, the compressor turned ON very soon after the event started and ran for a short period of time (similar to the ~10 minutes observed in Test A3) , then turned OFF and allowed the temperuature to climb. The compressor may have turned ON due to latencies in the communication system from the time the signal is sent by the Smart Meter, to the time it is received by the refrigerator, to the time that the refrigerator processes the signal and acts upon it.

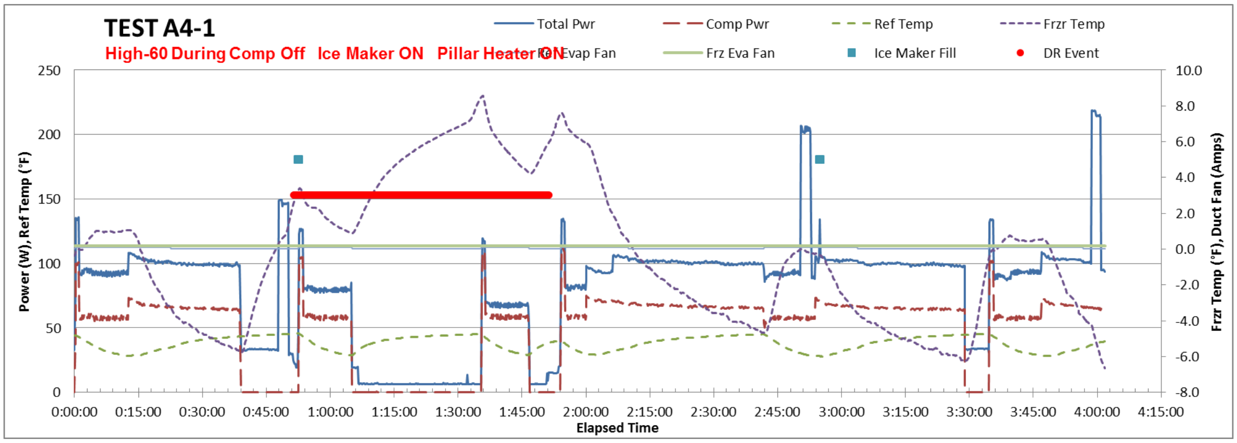


FIGURE 27. TEST A4 POWER AND TEMPERATURE PROFILE

GARAGE CONDITIONS

No High-60 tests were conducted at garage conditions.

EXTREME GARAGE CONDITIONS

No High-60 tests were conducted at extreme garage conditions.

CRITICAL-60 DR EVENT TESTS

The series of Critical-60 tests examines the refrigerator's response to DR events with extreme criticality (DRLC level 4) and 60-minute duration. A signal for a 60-minute duration event was sent at various stages of the refrigerator's normal operating cycle to observe the refrigerator's response.

As stated in the Product Evaluation section above, the refrigerator was expected to make the same changes as for High events, with the addition of a mandatory 10-minute OFF period for the compressor and fans. In general, the refrigerator responded as anticipated. The following sections provide details on individual test runs.

KITCHEN CONDITIONS

In Test A6 (Figure 28) a Critical-60 event was initiated shortly after the compressor cycled ON. The compressor instantly shut OFF for 10 minutes and the total power draw of the refrigerator was reduced to ~20 W. At the end of 10 minutes, the compressor cycled ON and cooled the compartment, and then cycled OFF and allowed the temperature to climb to the new setpoint, around 10°F. This resulted in a significant power reduction for a significant part of the DR event. Once the event ended, the refrigerator returned to normal operation. The first compressor ON cycle after the event lasted about 1 hour and 15 minutes to bring the refrigerator back into normal operating range.

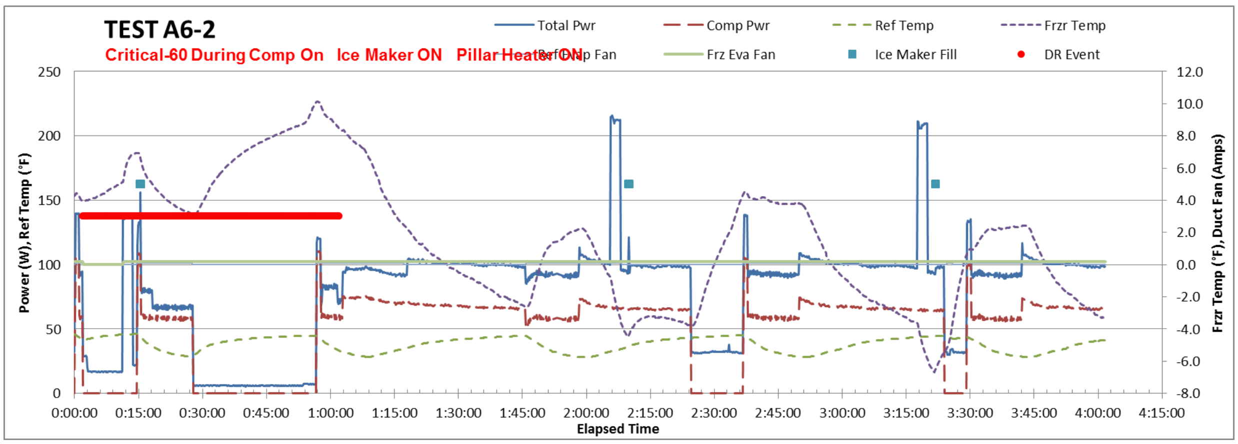


FIGURE 28. TEST A6 POWER AND TEMPERATURE PROFILE

Similar operational patterns were observed in Test A7 (Figure 29) when the Critical-60 event started during the compressor OFF cycle.

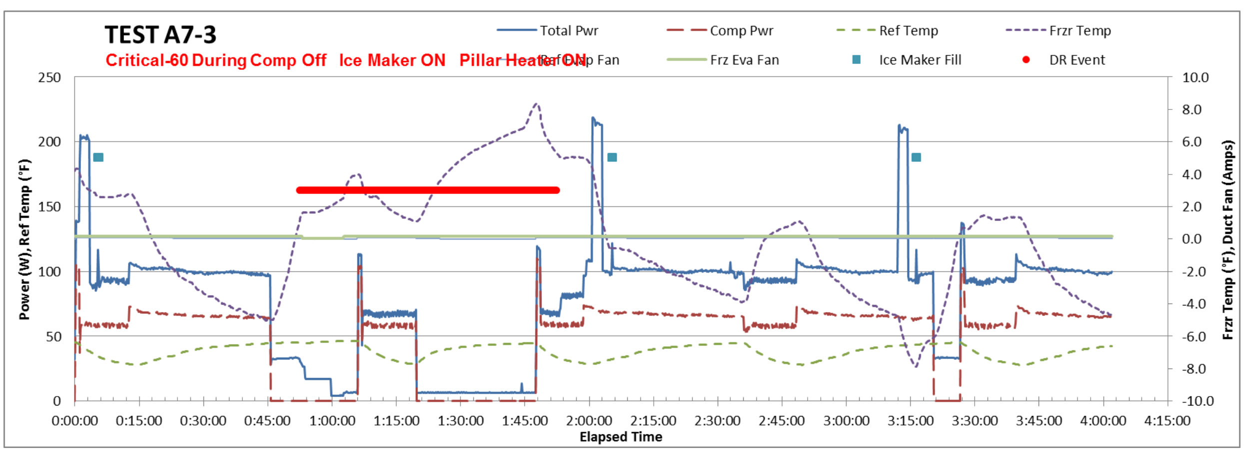


FIGURE 29. TEST A7 POWER AND TEMPERATURE PROFILE

Similar patterns were observed in Test E1 (Figure 30). However, the freezer temperature range was lower due to the lower setpoint for that test condition.

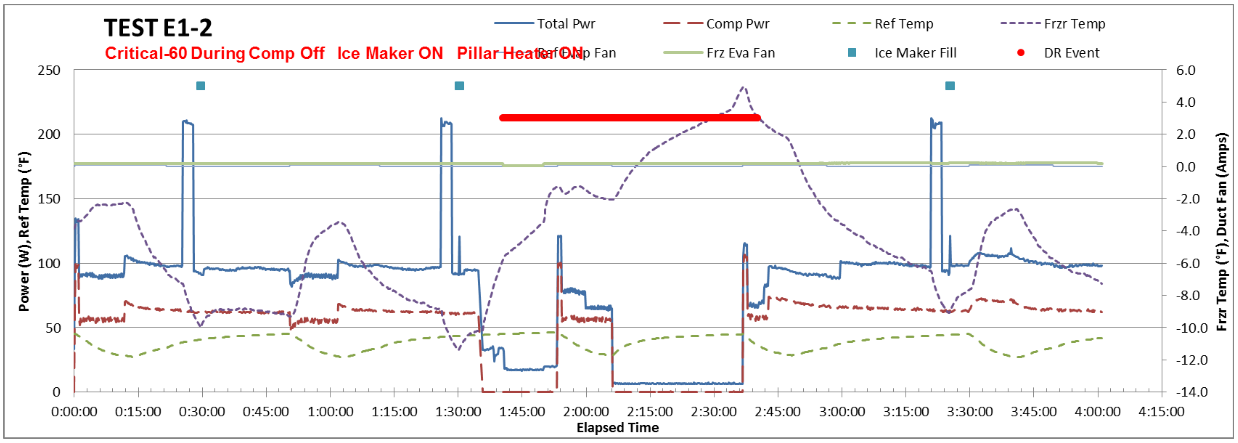


FIGURE 30. TEST E1 POWER AND TEMPERATURE PROFILE

GARAGE CONDITIONS

Even with increased ambient temperature, the response observed in Test G2 at garage conditions (Figure 31) showed a pattern similar to that of the other High-60 event tests.

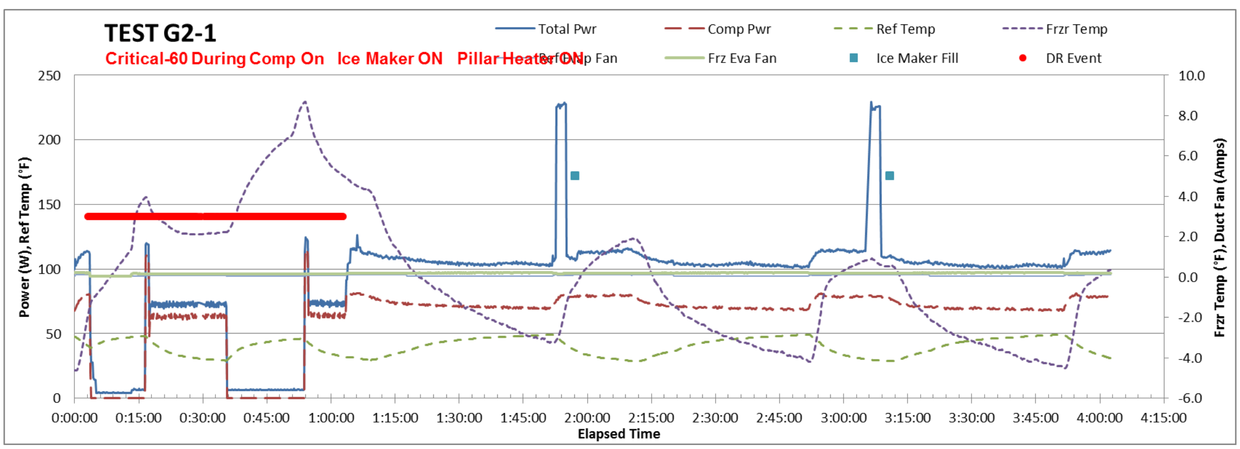


FIGURE 31. TEST G2 POWER AND TEMPERATURE PROFILE

EXTREME GARAGE CONDITIONS

As the temperature climbed even higher, the compressor shut OFF immediately in Test I2 (Figure 32), then came back on as the temperature quickly climbed to setpoint. Once the compressor came ON, it did not turn back OFF, as it had a difficult time bringing the temperature back down to normal range.

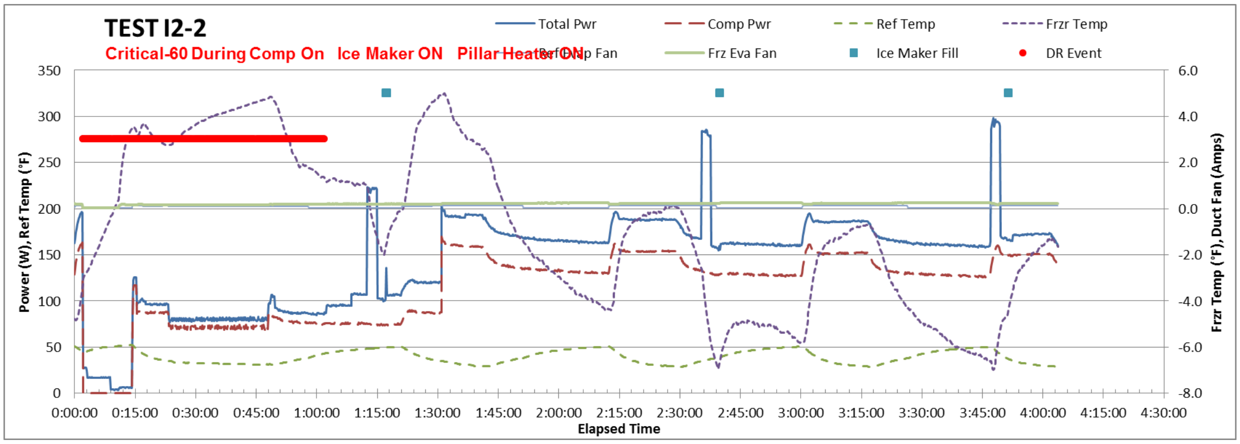


FIGURE 32. TEST I2 POWER AND TEMPERATURE PROFILE

TESTS WITH NO THERMAL MASS

The standard test methods currently used to rate energy performance of residential refrigerators (AHAM HRF-1, DOE Appendix A1, etc.) specify a virtually empty refrigerated cabinet. For the historic purpose of determining energy consumption, this specification is an acceptable proxy, as the presence or absence of thermal mass would not significantly affect energy use in an undisturbed (no door openings or other user interactions) refrigerator once the temperature was stabilized.

For DR testing, however, the system of a refrigerator with thermal mass (food and drinks) may behave differently than the system of an empty refrigerator. Specifically, the thermal mass would likely allow the system to “coast” for a longer period of time during a DR event. There was concern that the specification would not accurately reflect the in-field response to a DR event, and therefore impact power consumption results, which are very important to DR program developers and implementers. To address this concern (as noted earlier), the DR tests included a thermal mass to create more realistic field responses.

A final set of tests were intended to quantify the impact of thermal mass. In this series, several test scenarios were repeated after removal of the thermal mass from both the refrigerator and freezer compartments.

No Thermal Mass Baseline Comparisons

For a comparison with Test A (Figure 33), Test A-TM (Figure 34) replicated Test A but with the thermal mass removed. Interestingly, in Test !-TM, the compressor only cycled OFF twice when no thermal mass was present versus four times when it was present. Further, the temperature range seemed somewhat less consistent with an empty cabinet.

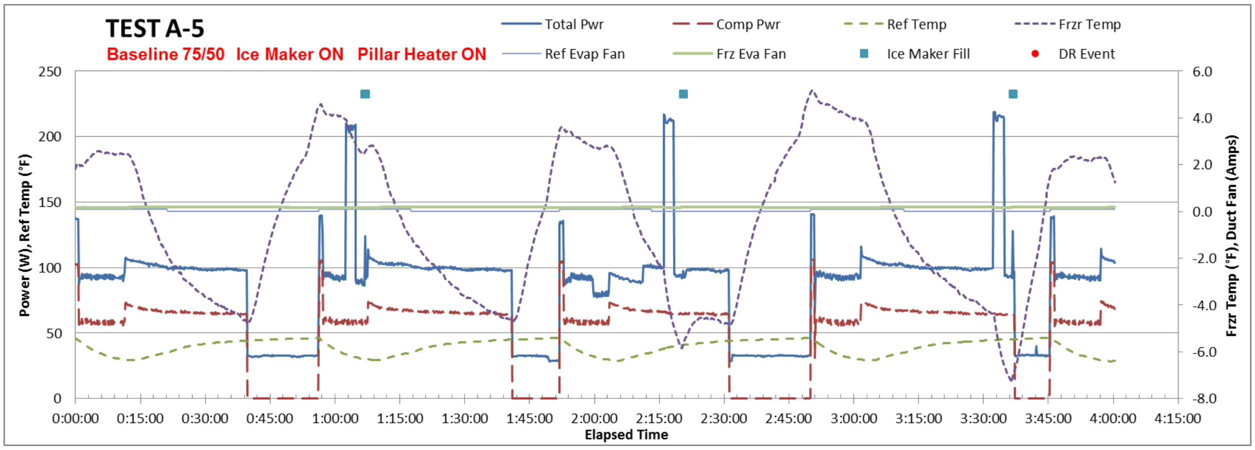


Figure 33. Test A Power and Temperature Profile (With Thermal Mass)

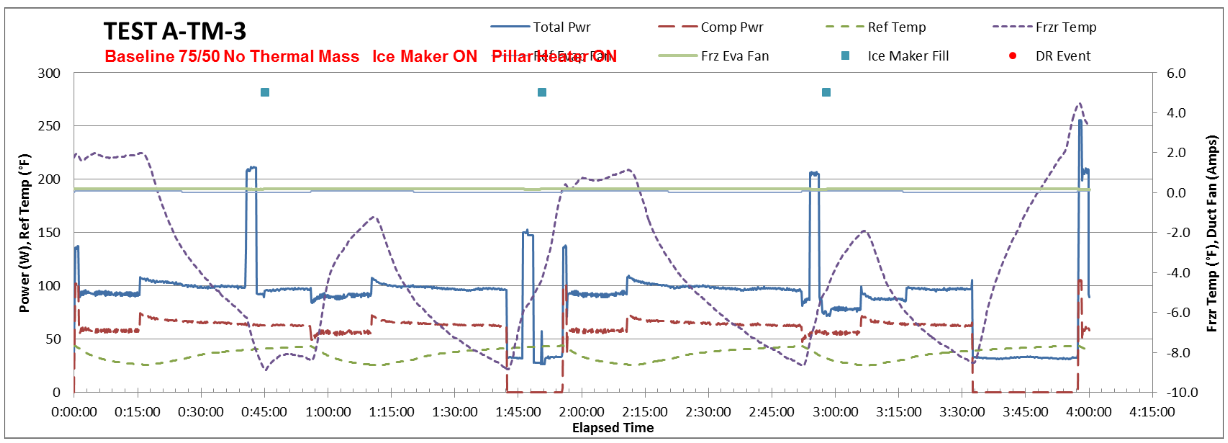


Figure 34. Test A-TM Power and Temperature Profile (Without Thermal Mass)

At garage conditions, thermal mass seemed to have little effect on results (shown in Figure 35 and Figure 36). A few differences in compressor operation patterns were observed between Test G, with thermal mass, and Test G-TM, without thermal mass. Most apparent is the extended temperature pull-down time when no thermal mass was present.

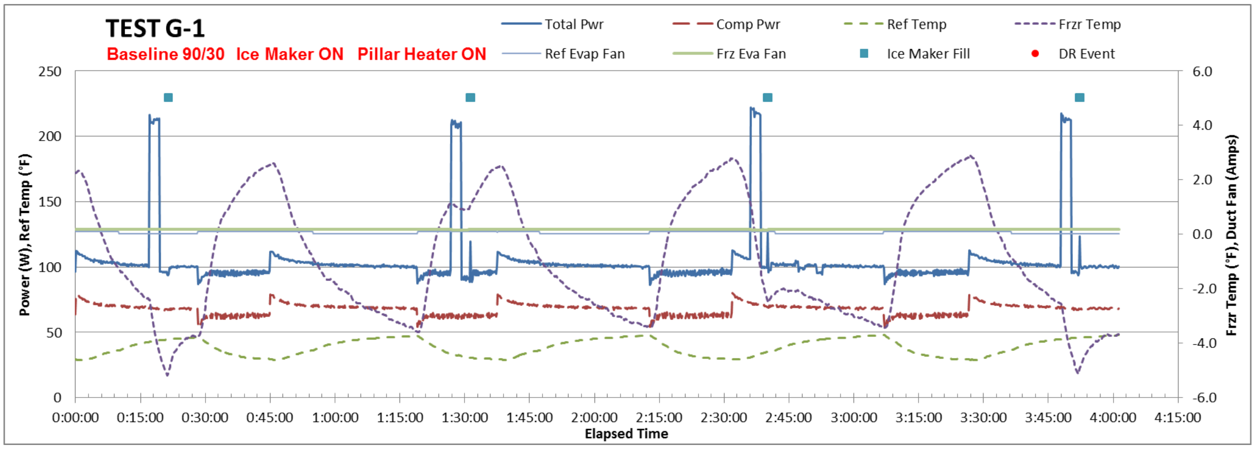


FIGURE 35. TEST G POWER AND TEMPERATURE PROFILE (WITH THERMAL MASS)

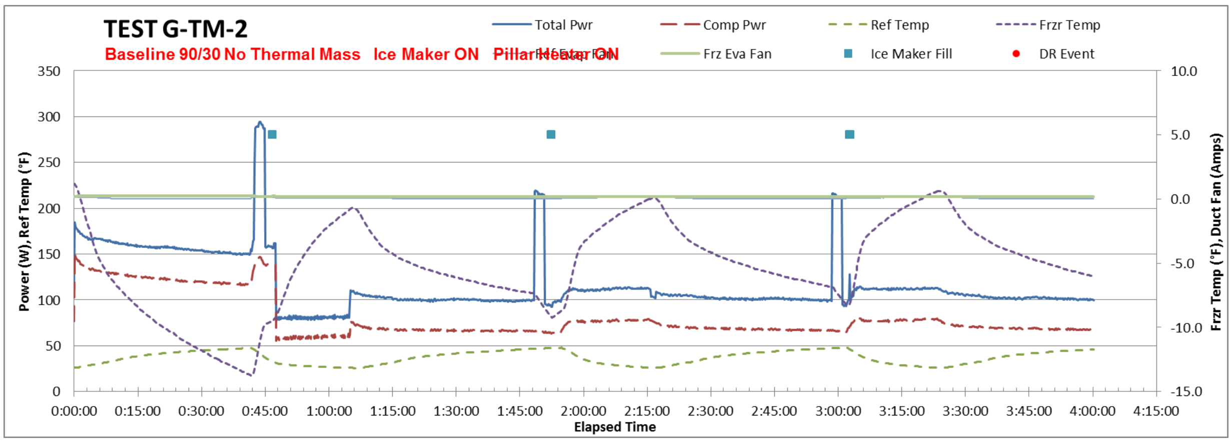


FIGURE 36. TEST G-TM POWER AND TEMPERATURE PROFILE (WITHOUT THERMAL MASS)

NO THERMAL MASS WITH DR EVENTS

Introducing a Critical 60 DR event allowed comparisons of the effect of thermal mass via Test A6 (thermal mass included), as shown in Figure 37, and Test A-TM1 (thermal mass excluded), as shown in Figure 38. In these tests, the refrigerator without thermal mass was able to sustain compressor-less operation for longer than the refrigerator with thermal mass.

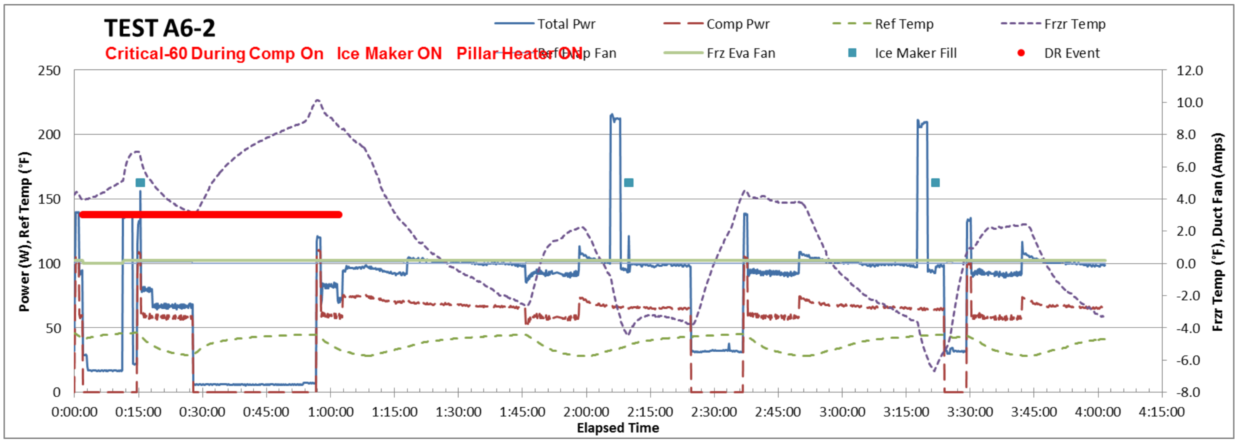


FIGURE 37. TEST A6 POWER AND TEMPERATURE PROFILE (WITH THERMAL MASS)

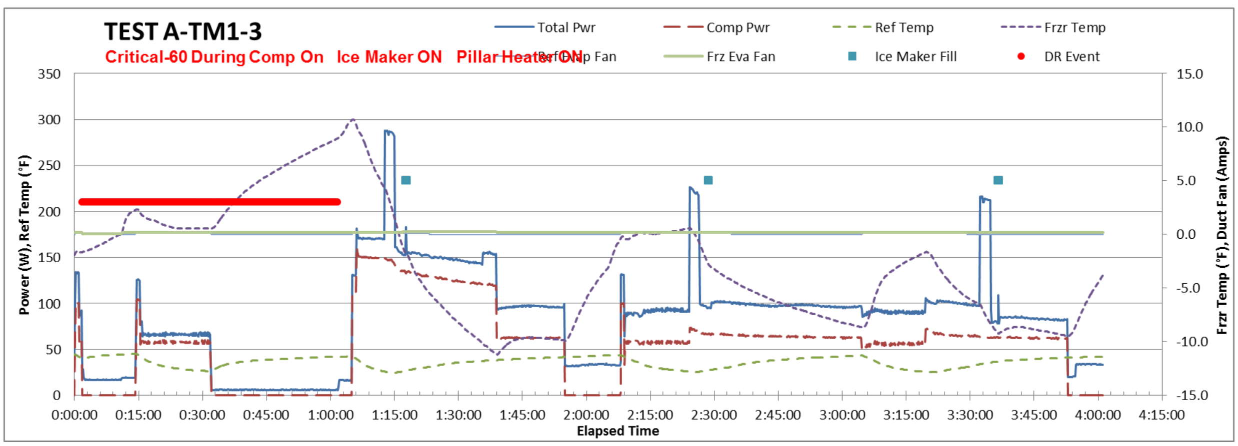


FIGURE 38. TEST A-TM1 POWER AND TEMPERATURE PROFILE (WITHOUT THERMAL MASS)

Introducing a Critical 60 DR event conditions allowed comparisons of the thermal mass impacts under garage via Test G2 (thermal mass included), shown in Figure 39, and Test G-TM1 (thermal mass excluded), as shown in Figure 40. In these tests, the compressor remained OFF longer and compressor operation and temperature control appeared to be much smoother when thermal mass was present than when the refrigerator was empty.

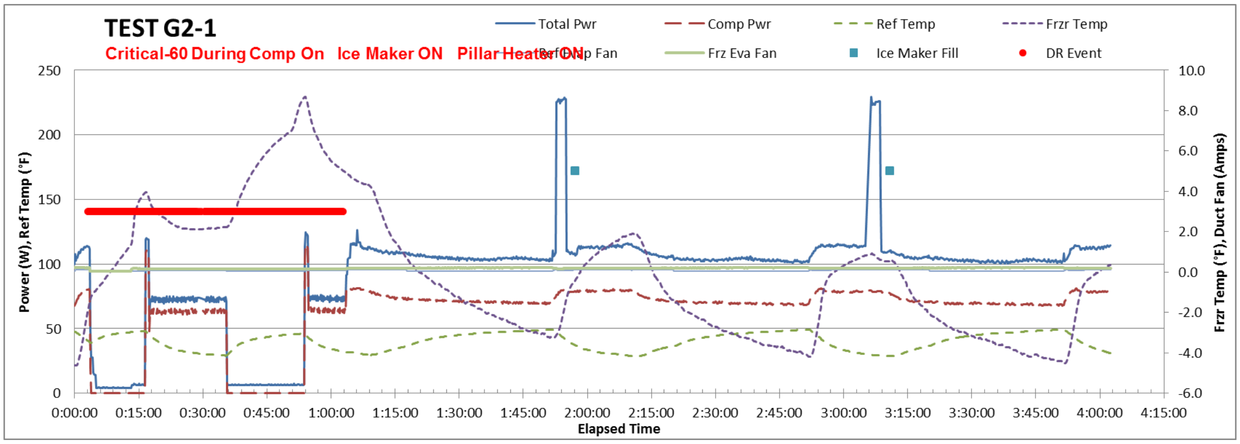


FIGURE 39. TEST G2 POWER AND TEMPERATURE PROFILE (WITH THERMAL MASS)

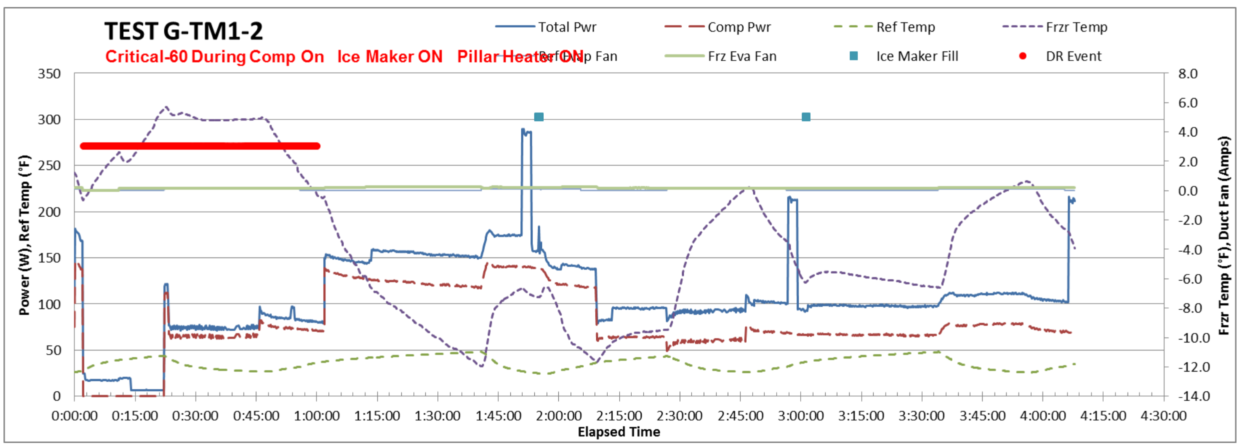


FIGURE 40. TEST G-TM1 POWER AND TEMPERATURE PROFILE (WITHOUT THERMAL MASS)

Conclusions

Overall, the refrigerator was able to achieve power reductions in response to DR events in most instances. For High level events, small reductions were observed immediately and larger compressor reductions resulting from increased setpoints occurred after some delay. Because of the delays, the reductions did not necessarily fall within the event duration for very short (8-minute) events tested here.

For Critical events, mandatory compressor and fan OFF cycles, combined with increased temperature setpoint, provided predictable long-lasting power reductions. However, based on observations from the tests, it is unlikely that savings would persist more than an hour, as temperatures would begin to creep up and compressors would start to cool the space back down. Longer DR event durations that might have tested savings persistence were not included in this test scope.

The effect of the presence of thermal mass on DR potential seems to be minimal. Quantification of this and other potential benefits may be possible with the recently developed ENERGY STAR test methods, which provide some mechanism to quantify expected demand reductions rather than simply verify that a DR capability exists.

At a higher level, there appears to be a disconnect between utility needs during DR events, the AHAM definitions of spinning reserve and delay load, and the prescribed refrigerator response to each type of signal.

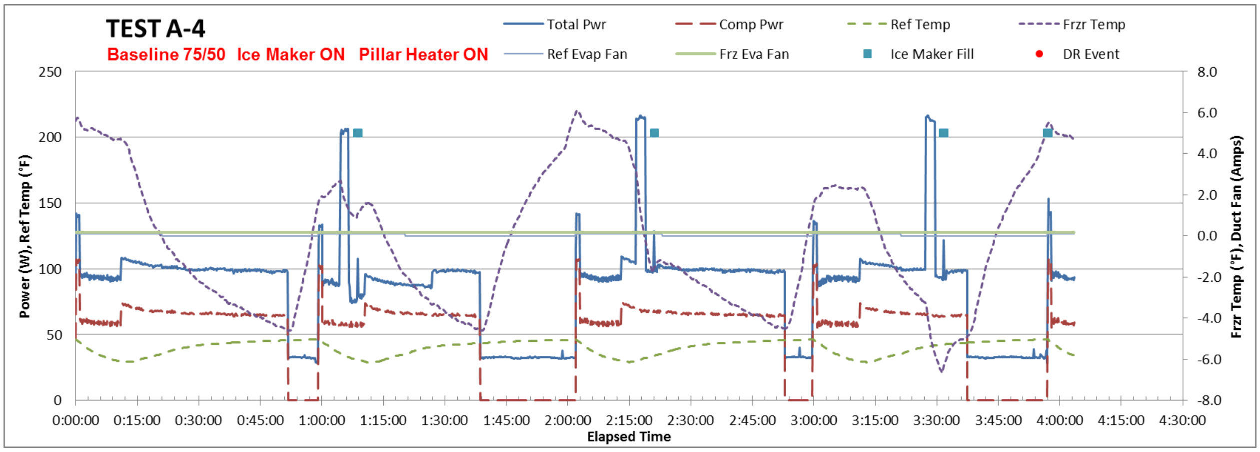
DR events can take several different forms; some may last an entire afternoon due to increased stress on the grid from a heat wave while others may be in response to an isolated catastrophic event on the grid. In the case of an immediate response, the duration of the event may be unknown. It is highly unlikely that a utility would call an event with duration shorter than 10 minutes. Thus, the only way to take advantage of the spinning reserve capability would be as part of an aggregating program where multiple communicating refrigerators are successively cycled through spinning reserve events.

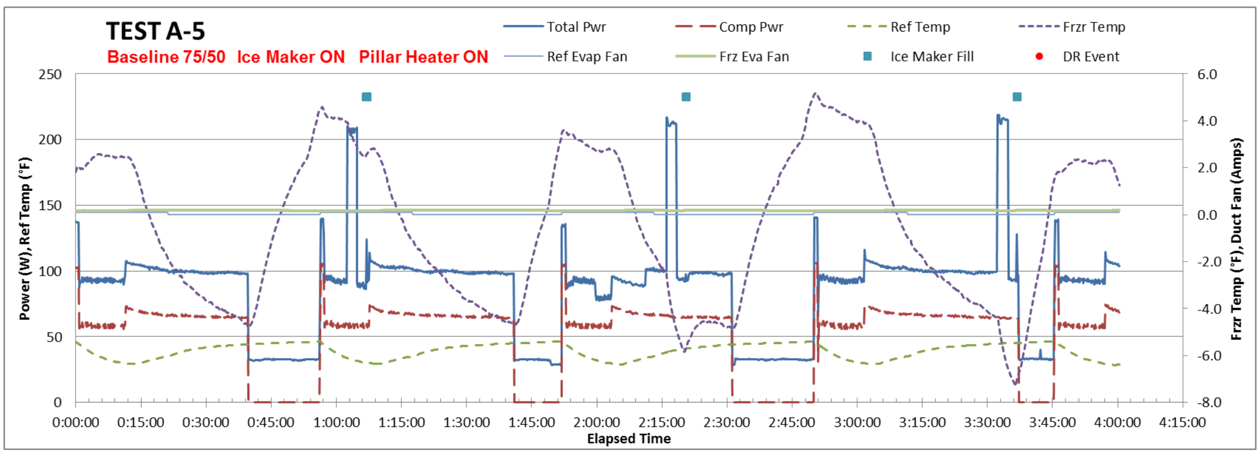
For the longer duration events, individual units would be able to respond with smaller power reductions for longer periods of time. But, for very long events (such as an event lasting the 12:00–6:00 summertime peak on SCE’s system), a single event with a 4-hour maximum duration limit could not take care of the entire time period. Thus, the participating units would again need to be broken into aggregated response groups to attain benefit through the entire period.

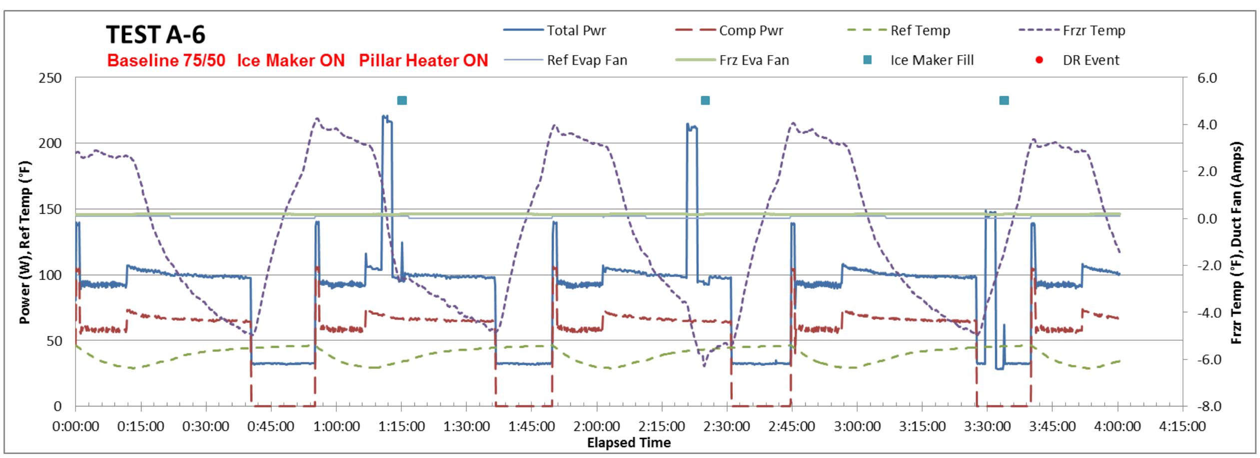
Future interaction with AHAM and standards-setting agencies will attempt to address these issues. Furthermore, understanding of the response of other smart appliances and computer simulation of grid-wide DR events that account for account usage diversity and duty cycles are necessary to fully understand the achievable impact of adoption.

APPENDIX

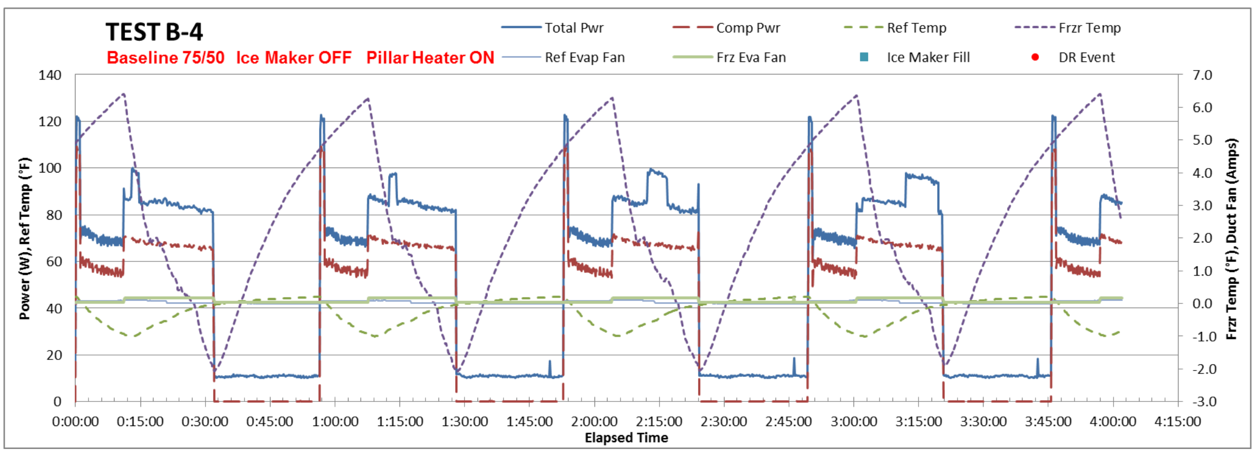
A.1 – BASELINE TEST AT KITCHEN CONDITIONS

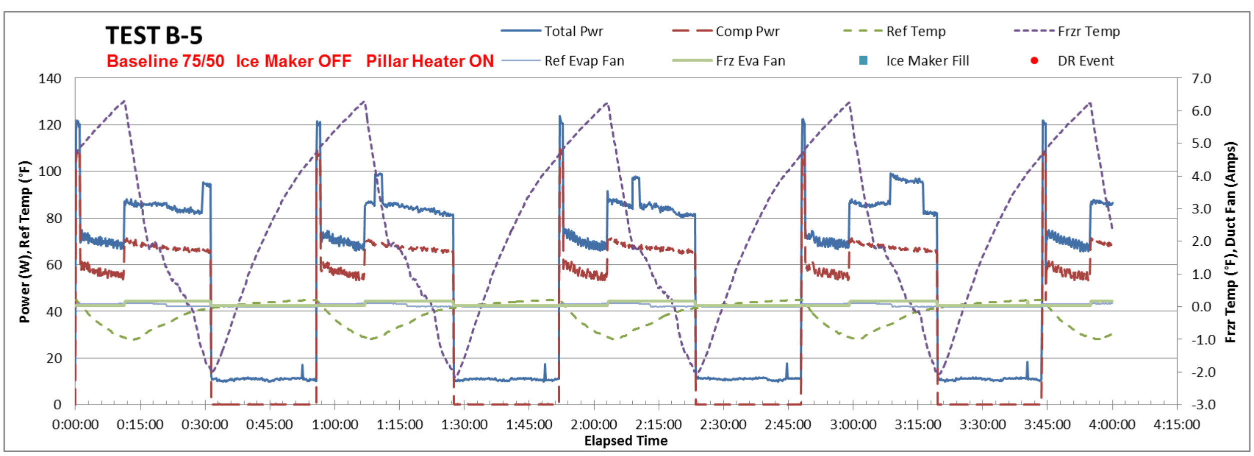


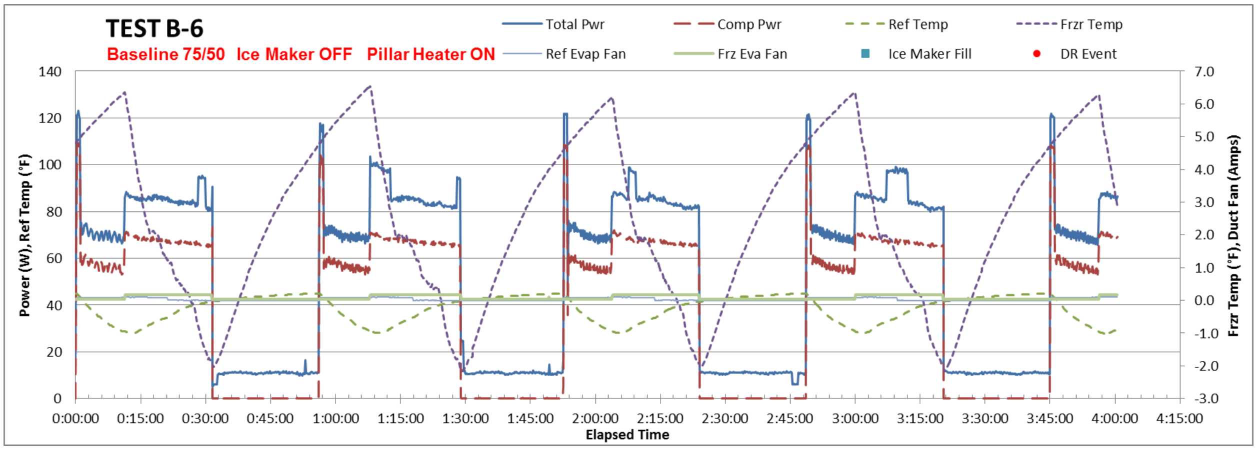




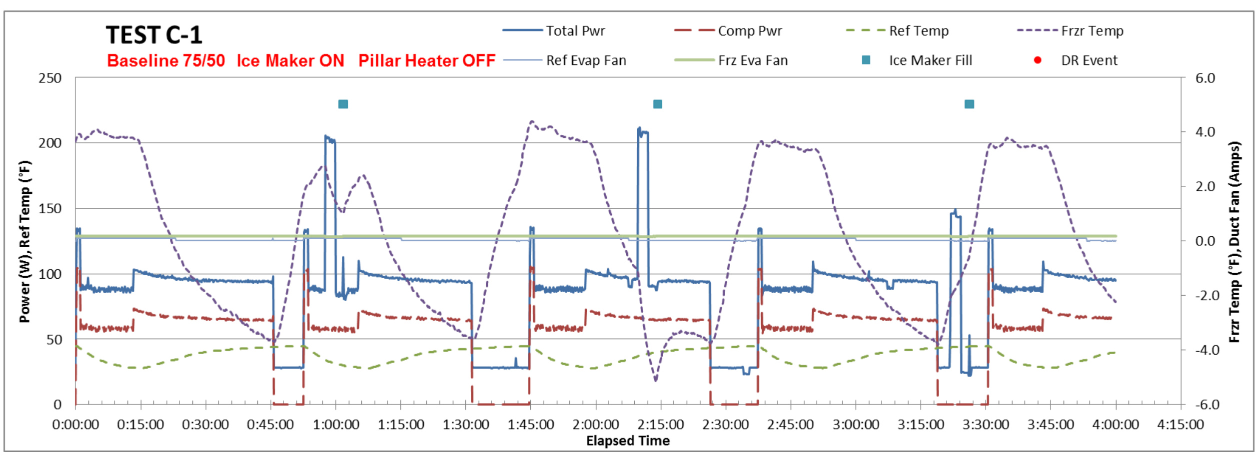
Data Category	TEST A-4	TEST A-5	TEST A-6	TEST A Avg	TEST A-4 Deviation From Average	TEST A-5 Deviation From Average	TEST A-6 Deviation From Average
	Baseline 75/50 Ice Maker ON Pillar Heater ON	Baseline 75/50 Ice Maker ON Pillar Heater ON	Baseline 75/50 Ice Maker ON Pillar Heater ON				
Test							
Date	3/21/13	3/21/13	3/22/13				
Start Time	11:59:16	16:53:06	0:23:06				
Duration	4:03:30	4:00:20	4:00:29				
Compressor Run Time	3:06:31	3:05:40	3:06:20	3:06:10	0.2%	-0.3%	0.1%
Average Power							
Compressor Average Power (W)	50	50	51	50	-0.6%	0.3%	0.3%
Total Average Power (W)	86	87	87	87	-1.1%	0.3%	0.8%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	86	87	87	87	-1.1%	0.3%	0.8%
Energy							
Compressor Energy (Wh)	203	202	203	203	0.4%	-0.5%	0.0%
Total Energy (Wh)	348	348	350	349	-0.1%	-0.3%	0.4%
Room							
Average Room Temp	75.5	75.4	75.2	75.4	0.2%	0.0%	-0.2%
Average Room RH	53.2	53.0	51.7	52.6	1.1%	0.7%	-1.8%
Water Properties							
Total Water Flow (gal)	-0.1	-0.1	-0.1	-0.1	1.3%	1.3%	-2.5%
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	40.0	39.8	39.8	39.9	0.3%	-0.2%	-0.1%
Avg Frzr Temperature (°F)	0.2	0.0	0.2	0.1	38.8%	-70.3%	31.6%

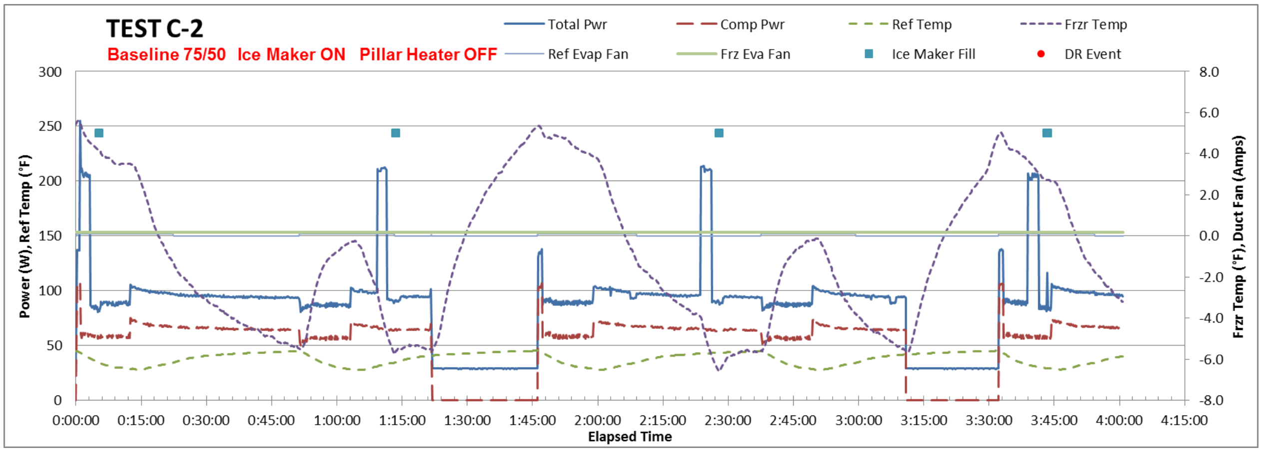


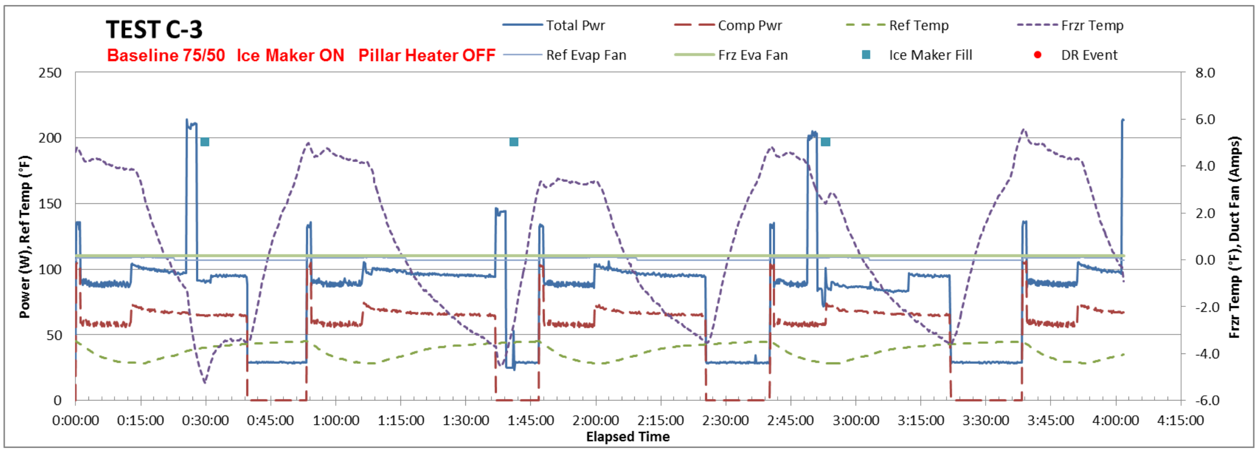




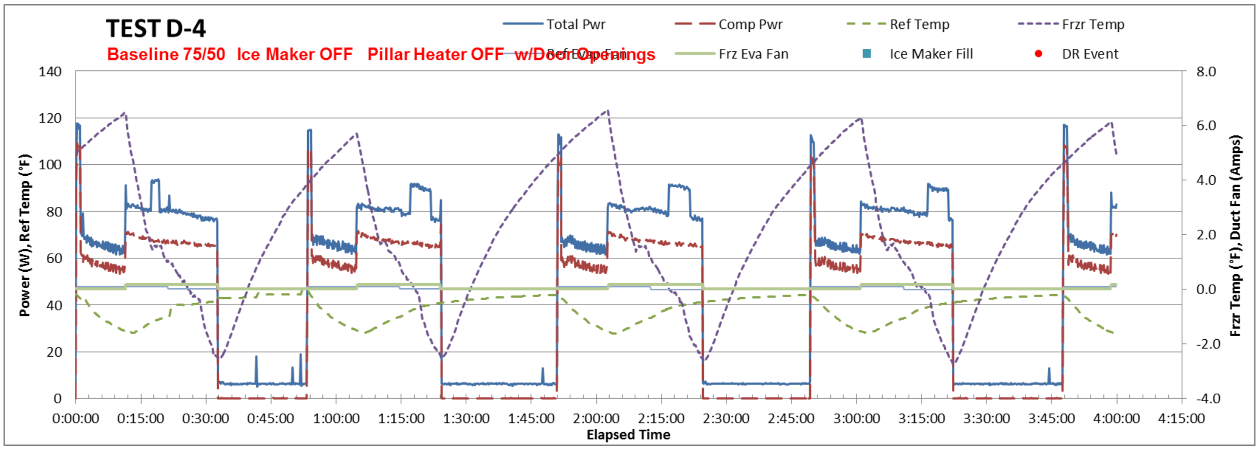
Data Category	TEST B-4 Baseline 75/50 Ice Maker OFF Pillar Heater ON	TEST B-5 Baseline 75/50 Ice Maker OFF Pillar Heater ON	TEST B-6 Baseline 75/50 Ice Maker OFF Pillar Heater ON	TEST B Avg	TEST B-4 Deviation From Average	TEST B-5 Deviation From Average	TEST B-6 Deviation From Average
Test							
Date	3/24/13	3/24/13	3/24/13				
Start Time	10:10:31	14:52:20	19:32:00				
Duration	4:01:59	4:00:00	4:00:30				
Compressor Run Time	2:22:11	2:22:19	2:22:41	2:22:24	-0.1%	-0.1%	0.2%
Average Power							
Compressor Average Power (W)	38	38	39	38	-0.7%	0.2%	0.5%
Total Average Power (W)	52	53	53	53	-0.5%	0.1%	0.4%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	52	53	53	53	-0.5%	0.1%	0.4%
Energy							
Compressor Energy (Wh)	154	154	154	154	0.0%	-0.1%	0.1%
Total Energy (Wh)	212	211	212	212	0.2%	-0.2%	0.1%
Room							
Average Room Temp	75.3	75.5	75.3	75.4	-0.1%	0.1%	-0.1%
Average Room RH	51.8	52.7	52.8	52.4	-1.1%	0.5%	0.6%
Water Properties							
Total Water Flow (gal)	0.0	0.0	0.0	0.0	200.0%	50.0%	-250.0%
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	39.7	39.7	39.7	39.7	0.0%	-0.1%	0.1%
Avg Frzr Temperature (°F)	1.6	1.5	1.6	1.6	0.5%	-2.1%	1.7%

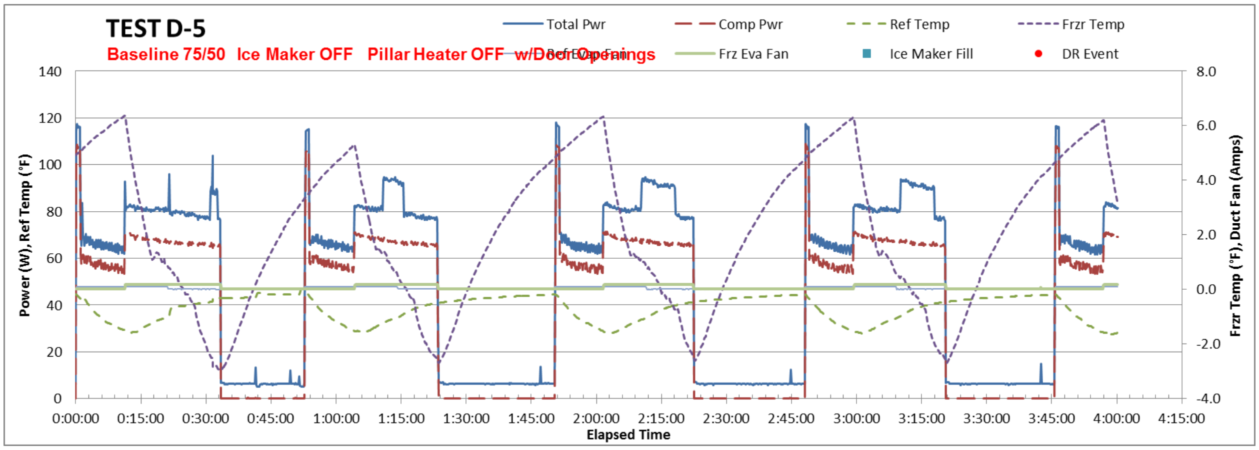


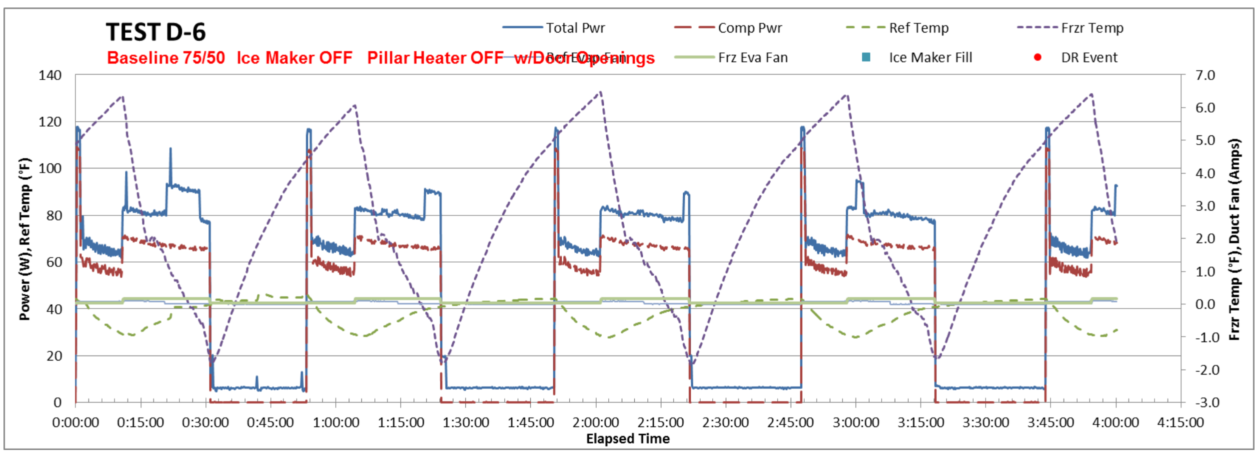




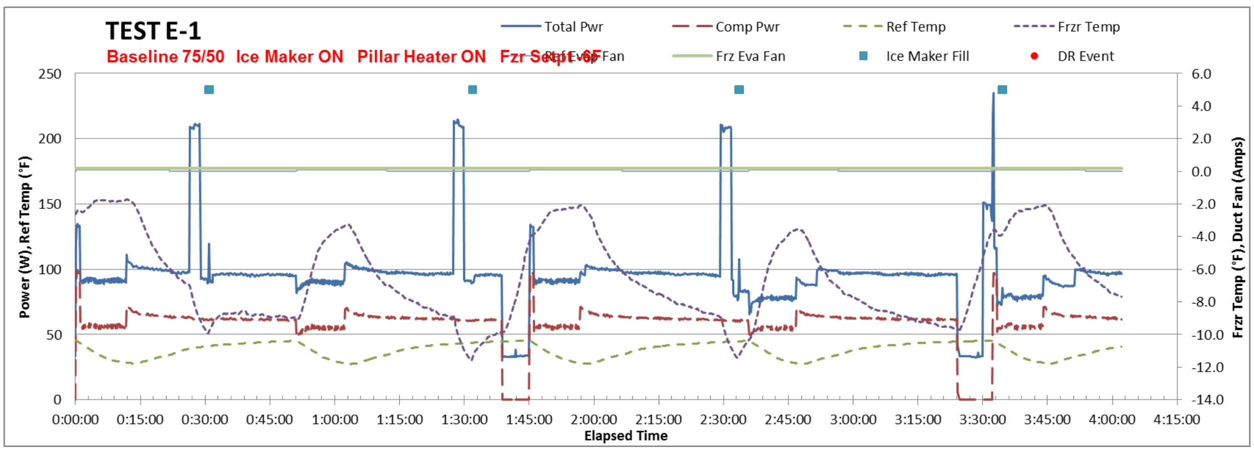
Data Category	TEST C-1	TEST C-2	TEST C-3	TEST C Avg	TEST C-1 Deviation From Average	TEST C-2 Deviation From Average	TEST C-3 Deviation From Average
	Baseline 75/50 Ice Maker ON Pillar Heater OFF	Baseline 75/50 Ice Maker ON Pillar Heater OFF	Baseline 75/50 Ice Maker ON Pillar Heater OFF				
Test							
Date	3/29/13	4/1/13	4/2/13				
Start Time	7:02:32	12:44:47	11:38:12				
Duration	3:59:59	4:00:47	4:01:50				
Compressor Run Time	3:16:49	3:15:03	3:06:50	3:12:54	2.0%	1.1%	-3.1%
Average Power							
Compressor Average Power (W)	53	52	50	52	2.4%	0.6%	-3.0%
Total Average Power (W)	86	87	83	85	0.9%	1.9%	-2.8%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	86	87	83	85	0.9%	1.9%	-2.8%
Energy							
Compressor Energy (Wh)	213	209	203	209	2.2%	0.4%	-2.6%
Total Energy (Wh)	344	348	334	342	0.6%	1.8%	-2.4%
Room							
Average Room Temp	75.3	75.4	75.4	75.4	-0.1%	0.0%	0.1%
Average Room RH	52.5	52.4	53.3	52.7	-0.5%	-0.6%	1.1%
Water Properties							
Total Water Flow (gal)	-0.1	0.1	0.1	0.0	-326.0%	200.0%	126.0%
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	38.9	39.0	38.9	38.9	-0.1%	0.2%	0.0%
Avg Frzr Temperature (°F)	0.1	-0.1	0.7	0.2	-37.4%	-153.1%	190.5%

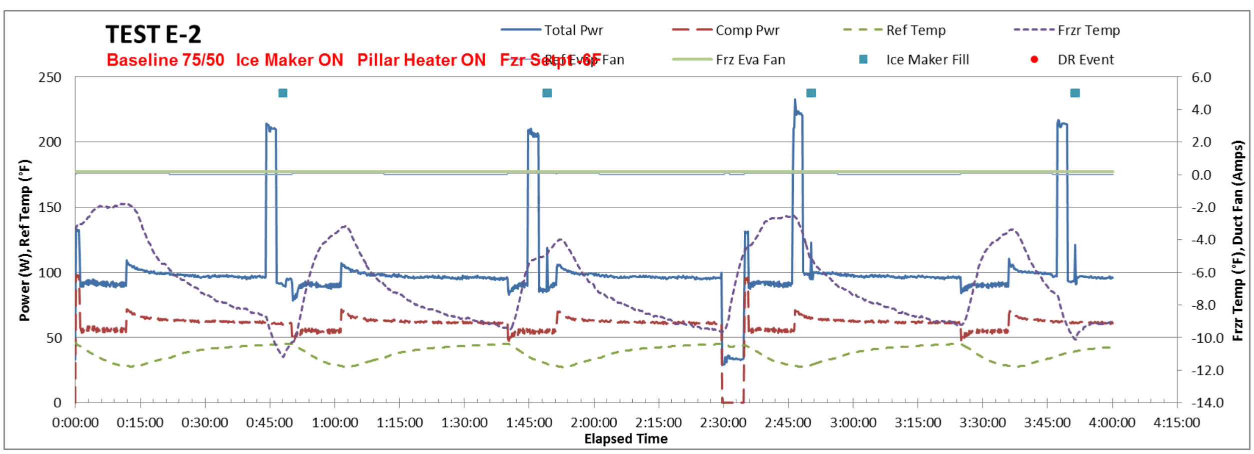

TEST D-4
Baseline 75/50 Ice Maker OFF Pillar Heater OFF w/Door Openings
Total Pwr
Comp Pwr
Ref Temp
Frzr Temp
Ref Eva Fan
Frz Eva Fan
Ice Maker Fill
DR Event
Power (W), Ref Temp (°F)
Frzr Temp (°F), Duct Fan (Amps)
Elapsed Time

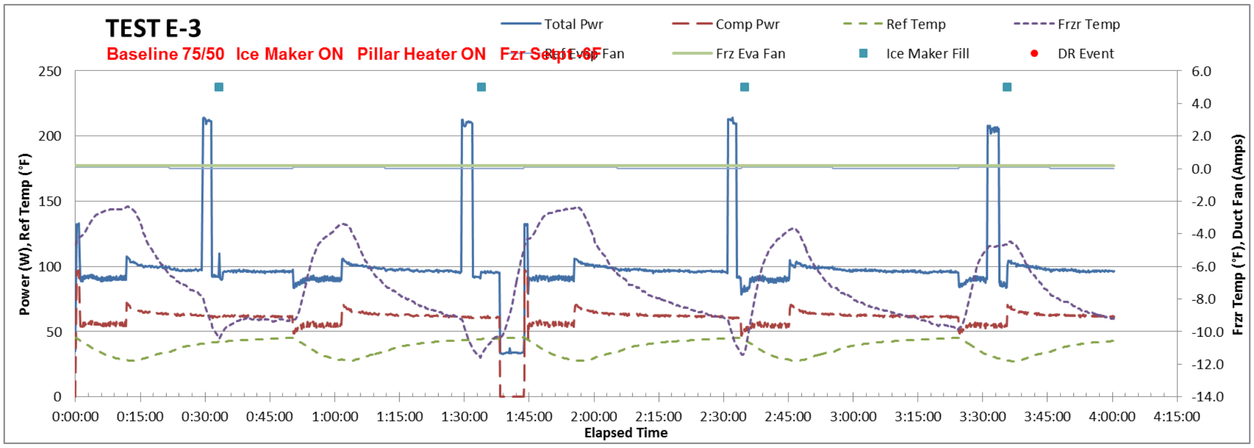

TEST D-5
Baseline 75/50 Ice Maker OFF Pillar Heater OFF w/Door Openings
Total Pwr
Comp Pwr
Ref Temp
Frzr Temp
Ref Eva Fan
Frz Eva Fan
Ice Maker Fill
DR Event
Power (W), Ref Temp (°F)
Frzr Temp (°F), Duct Fan (Amps)
Elapsed Time


TEST D-6
Baseline 75/50 Ice Maker OFF Pillar Heater OFF w/Door Openings
Total Pwr
Comp Pwr
Ref Temp
Frzr Temp
Ref Eva Fan
Frz Eva Fan
Ice Maker Fill
DR Event
Power (W), Ref Temp (°F)
Frzr Temp (°F), Duct Fan (Amps)
Elapsed Time

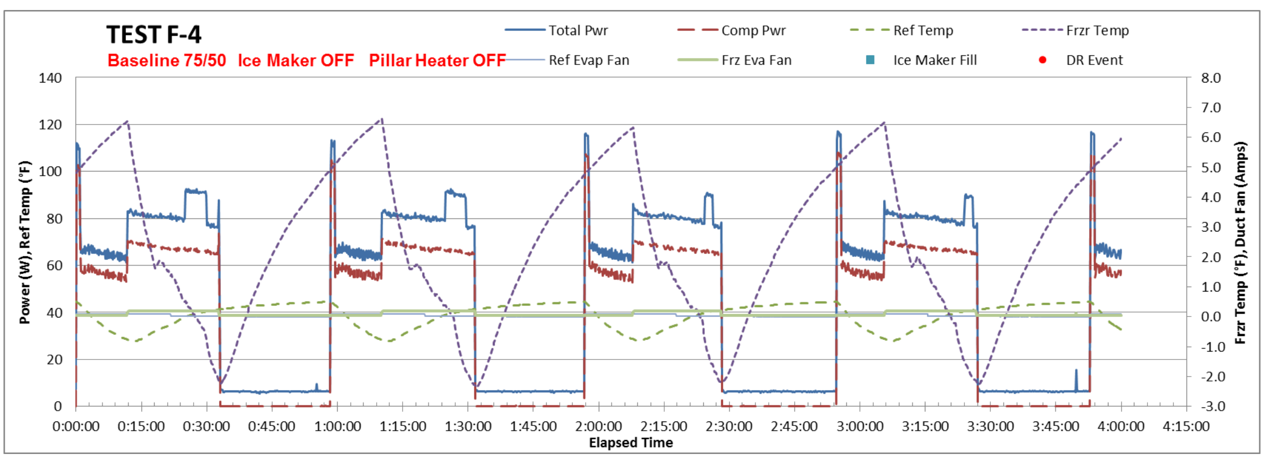
Data Category	TEST D-4	TEST D-5	TEST D-6	TEST D Avg	TEST D-4 Deviation From Average	TEST D-5 Deviation From Average	TEST D-6 Deviation From Average
	Baseline 75/50 Ice Maker OFF Pillar Heater OFF w/Door Openings	Baseline 75/50 Ice Maker OFF Pillar Heater OFF w/Door Openings	Baseline 75/50 Ice Maker OFF Pillar Heater OFF w/Door Openings				
Test							
Date	3/26/13	3/26/13	3/28/13				
Start Time	7:50:46	14:34:56	7:51:23				
Duration	3:59:50	4:00:10	4:00:10				
Compressor Run Time	2:22:30	2:23:10	2:20:11	2:21:57	0.4%	0.9%	-1.2%
Average Power							
Compressor Average Power (W)	38	39	38	38	0.0%	0.7%	-0.7%
Total Average Power (W)	48	49	48	48	-0.3%	1.1%	-0.7%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	48	49	48	48	-0.3%	1.1%	-0.7%
Energy							
Compressor Energy (Wh)	154	155	153	154	0.0%	0.7%	-0.7%
Total Energy (Wh)	193	196	192	194	-0.3%	1.1%	-0.7%
Room							
Average Room Temp	75.3	75.5	75.3	75.3	-0.1%	0.2%	-0.1%
Average Room RH	52.0	53.4	52.2	52.5	-0.9%	1.6%	-0.7%
Water Properties							
Total Water Flow (gal)	0.0	0.0	0.0	0.0	-100.0%	-100.0%	200.0%
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	39.7	39.6	39.5	39.6	0.2%	0.0%	-0.2%
Avg Frzr Temperature (°F)	1.4	1.3	1.6	1.4	-4.6%	-9.4%	14.0%

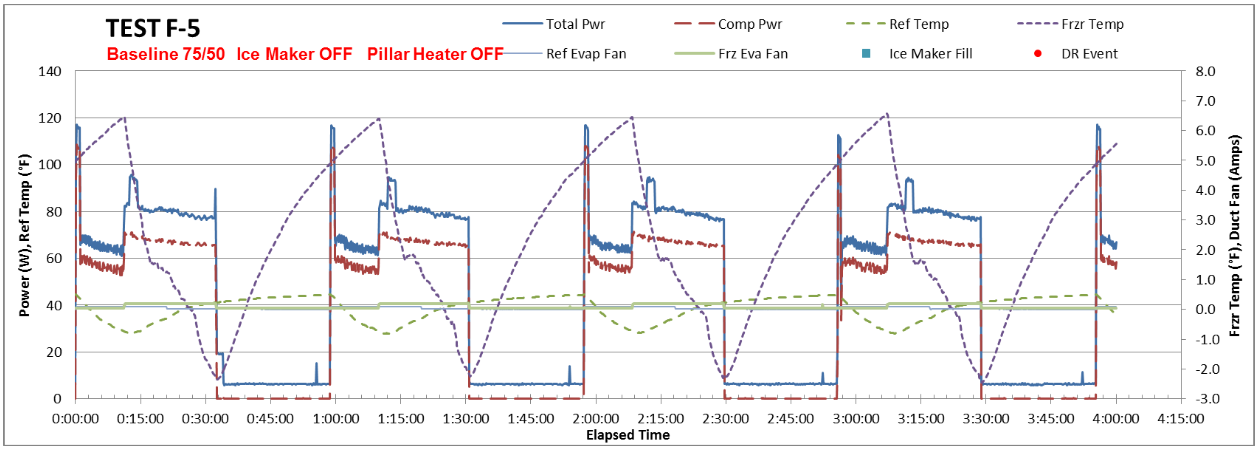


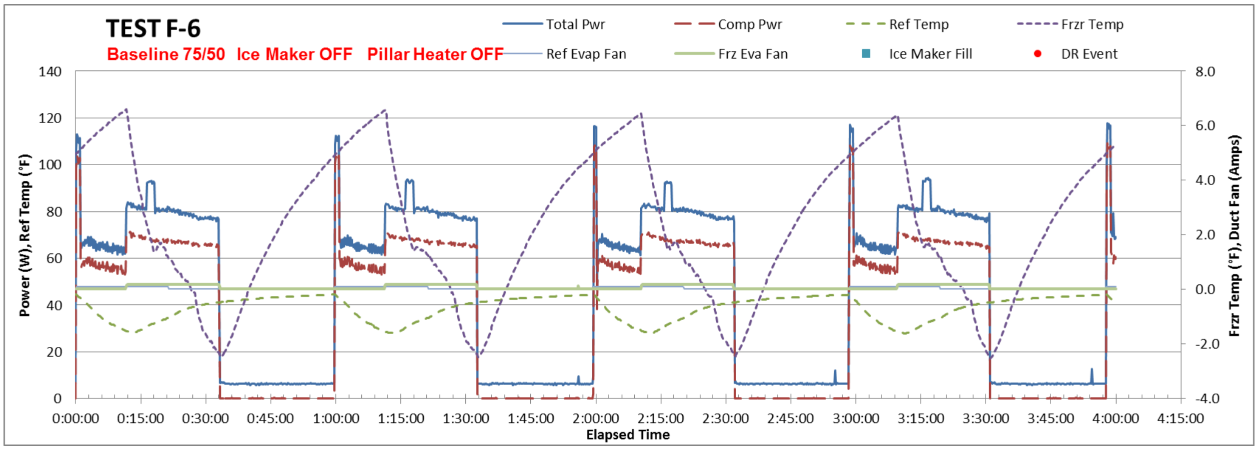




Data Category	TEST E-1 Baseline 75/50 Ice Maker ON Pillar Heater ON Fzr Setpt -6F	TEST E-2 Baseline 75/50 Ice Maker ON Pillar Heater ON Fzr Setpt -6F	TEST E-3 Baseline 75/50 Ice Maker ON Pillar Heater ON Fzr Setpt -6F	TEST E Avg	TEST E-1 Deviation From Average	TEST E-2 Deviation From Average	TEST E-3 Deviation From Average
Test							
Date	4/4/13	4/4/13	4/4/13				
Start Time	10:03:28	17:55:48	22:14:27				
Duration	4:02:10	4:00:09	4:00:20				
Compressor Run Time	3:47:49	3:54:58	3:54:50	3:52:32	-2.0%	1.0%	1.0%
Average Power							
Compressor Average Power (W)	58	60	60	59	-2.1%	1.1%	1.0%
Total Average Power (W)	95	99	99	98	-2.7%	1.5%	1.2%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	95	99	99	98	-2.7%	1.5%	1.2%
Energy							
Compressor Energy (Wh)	234	240	240	238	-1.7%	0.8%	0.8%
Total Energy (Wh)	384	398	397	393	-2.2%	1.3%	1.0%
Room							
Average Room Temp	75.5	75.5	75.4	75.5	0.0%	0.1%	0.0%
Average Room RH	53.5	53.9	53.3	53.6	-0.2%	0.7%	-0.5%
Water Properties							
Total Water Flow (gal)	0.1	0.1	0.1	0.1	1.4%	-1.4%	0.0%
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	39.1	39.1	39.1	39.1	-0.1%	0.1%	0.0%
Avg Frzr Temperature (°F)	-6.1	-6.2	-6.3	-6.2	-1.4%	-0.7%	2.1%

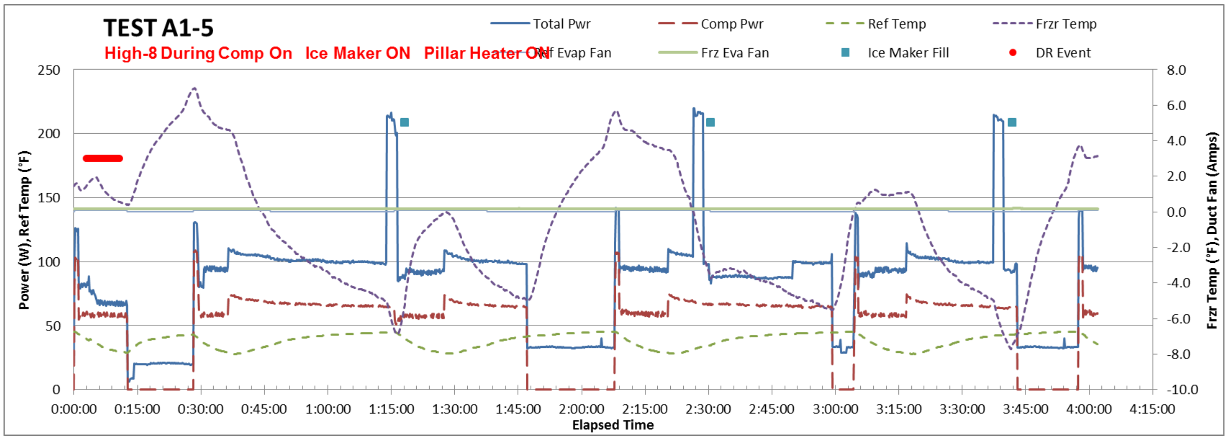


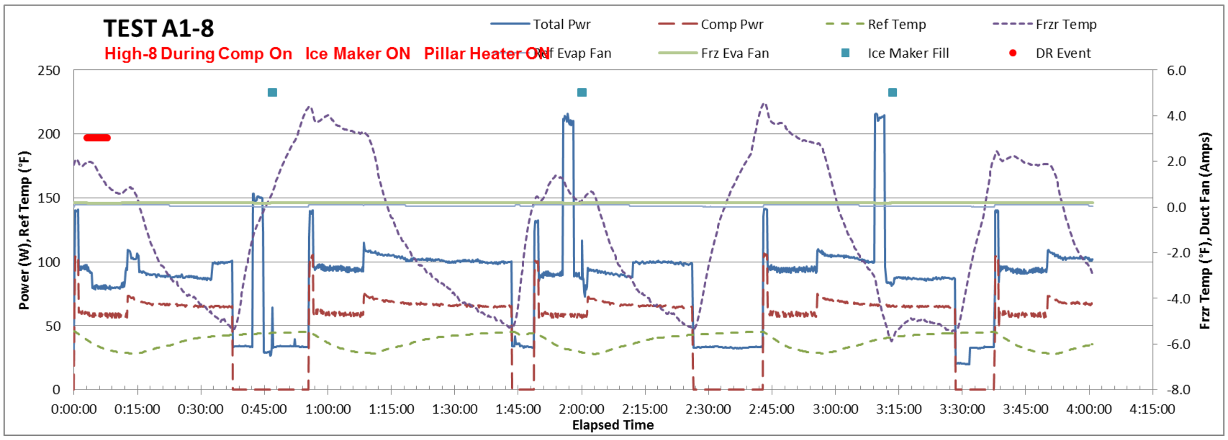


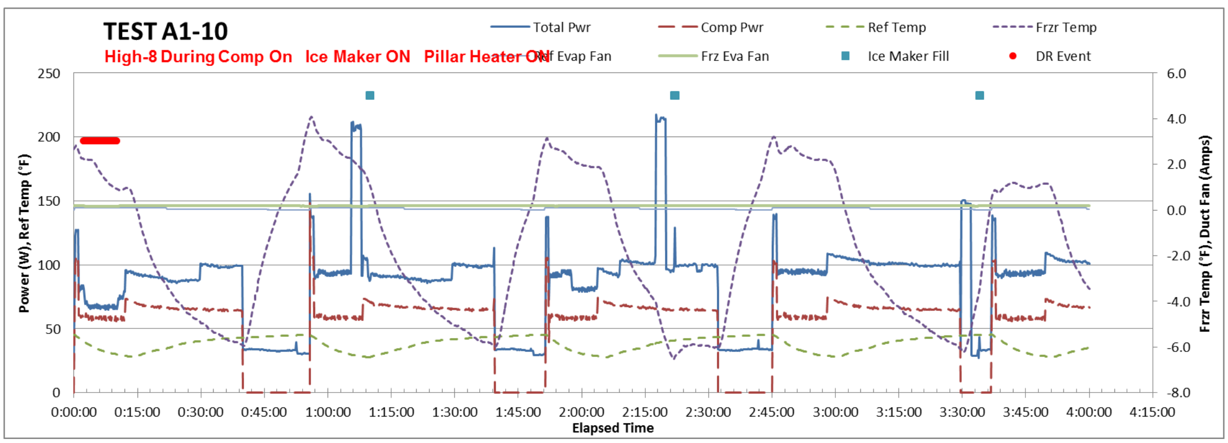


Data Category	TEST F-4	TEST F-5	TEST F-6	TEST F Avg	TEST F-4 Deviation From Average	TEST F-5 Deviation From Average	TEST F-6 Deviation From Average
	Baseline 75/50 Ice Maker OFF Pillar Heater OFF	Baseline 75/50 Ice Maker OFF Pillar Heater OFF	Baseline 75/50 Ice Maker OFF Pillar Heater OFF				
Test							
Date	3/25/13	3/25/13	3/26/13				
Start Time	18:07:38	22:58:47	3:53:07				
Duration	3:59:59	4:00:00	3:59:59				
Compressor Run Time	2:16:59	2:14:50	2:13:30	2:15:06	1.4%	-0.2%	-1.2%
Average Power							
Compressor Average Power (W)	37	37	36	37	1.3%	-0.2%	-1.1%
Total Average Power (W)	47	46	45	46	1.5%	-0.2%	-1.2%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	47	46	45	46	1.5%	-0.2%	-1.2%
Energy							
Compressor Energy (Wh)	148	146	145	147	1.3%	-0.3%	-1.0%
Total Energy (Wh)	187	184	182	184	1.5%	-0.3%	-1.2%
Room							
Average Room Temp	75.4	75.3	75.2	75.3	0.2%	0.0%	-0.1%
Average Room RH	53.5	52.4	51.4	52.4	2.0%	0.0%	-2.0%
Water Properties							
Total Water Flow (gal)	0.0	0.0	0.0	0.0	#DIV/0!	#DIV/0!	#DIV/0!
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	39.7	39.7	39.7	39.7	0.0%	-0.1%	0.0%
Avg Frzr Temperature (°F)	1.5	1.5	1.4	1.5	3.8%	-0.6%	-3.2%

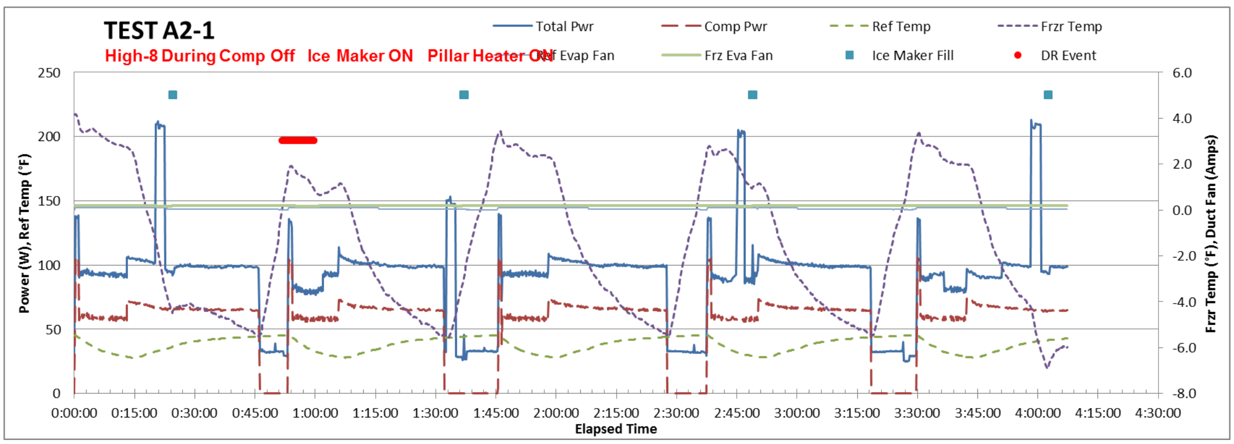
A.2 – HIGH-8 DR EVENTS AT KITCHEN CONDITIONS

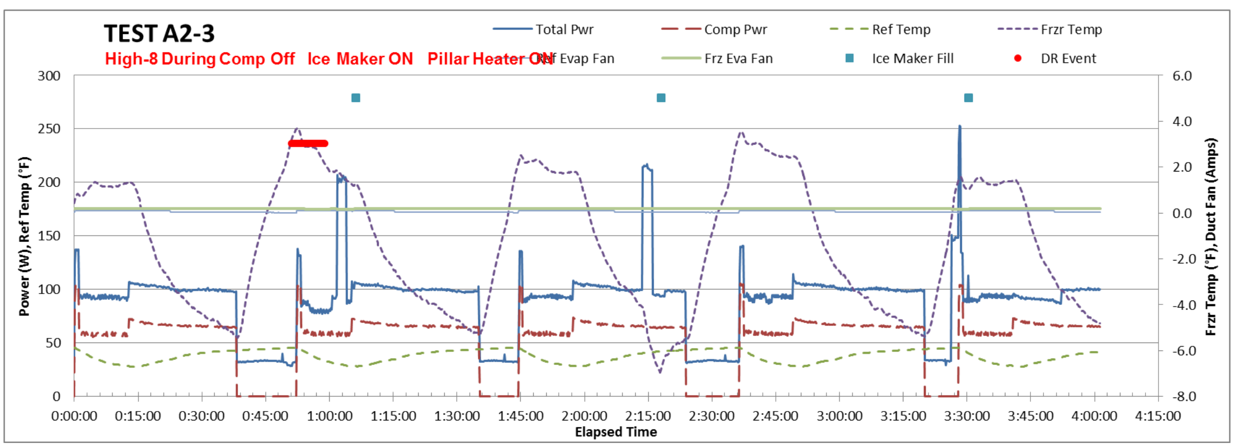


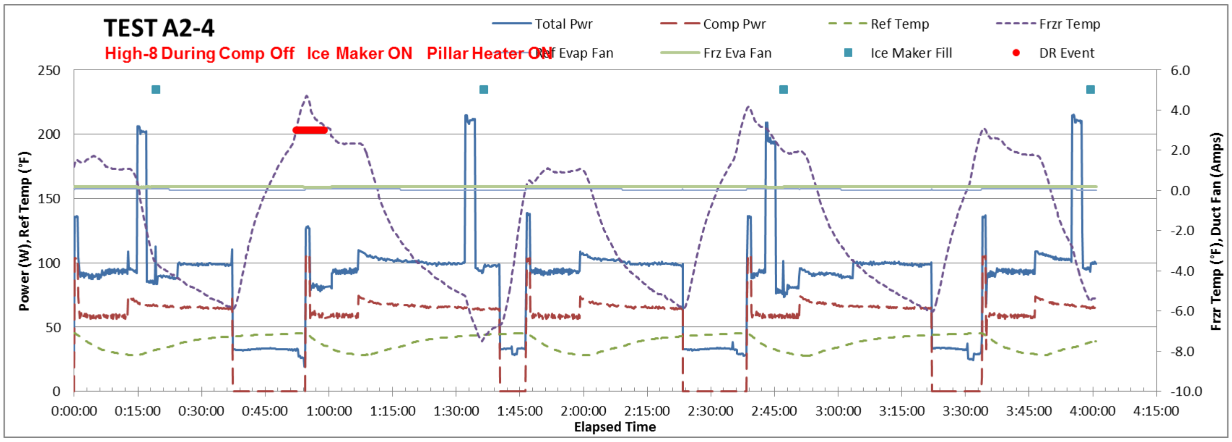




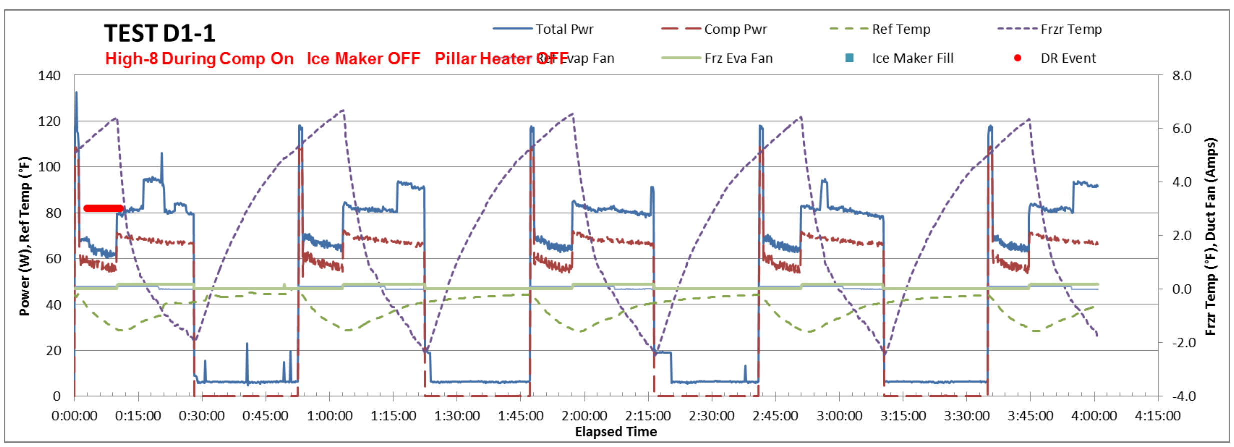
Data Category	TEST A1-5	TEST A1-8	TEST A1-10	TEST A1 Avg	TEST A1-5 Deviation From Average	TEST A1-8 Deviation From Average	TEST A1-10 Deviation From Average	TEST A Avg	TEST A1 Avg Deviation From TEST A Avg
	High-8 During Comp On Ice Maker ON Pillar Heater ON	High-8 During Comp On Ice Maker ON Pillar Heater ON	High-8 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	5/8/13	5/8/13	5/9/13						
Start Time	9:31:02	16:06:50	13:42:48						
Duration	4:01:59	4:00:50	4:00:00						
Compressor Run Time	3:05:57	3:11:37	3:12:00	3:09:51	-2.1%	0.9%	1.1%	3:06:10	2.0%
Average Power									
Compressor Average Power (W)	50	52	52	51	-2.7%	1.1%	1.6%	50	2.0%
Total Average Power (W)	84	87	86	86	-1.8%	1.2%	0.6%	87	-1.0%
Avg Total Power During DR Event (W)	71	83	68	74	-4.3%	12.5%	-8.2%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	85	87	87	86	-1.7%	0.8%	0.9%	87	-0.5%
Energy									
Compressor Energy (Wh)	202	209	209	206	-2.2%	1.1%	1.1%	203	1.9%
Total Energy (Wh)	340	349	345	345	-1.3%	1.1%	0.1%	349	-1.1%
Room									
Average Room Temp	75.3	75.3	75.4	75.3	-0.1%	0.0%	0.1%	75.4	-0.1%
Average Room RH	52.5	52.1	54.2	52.9	-0.8%	-1.5%	2.3%	52.6	0.5%
Water Properties									
Total Water Flow (gal)	0.1	0.1	0.1	0.1	0.0%	0.0%	0.0%	-0.1	-205.1%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.5	39.4	39.3	39.4	0.2%	-0.1%	-0.2%	39.9	-1.2%
Avg Frzr Temperature (°F)	-0.1	-0.2	-0.5	-0.2	-61.2%	-24.9%	86.2%	0.1	-280.1%

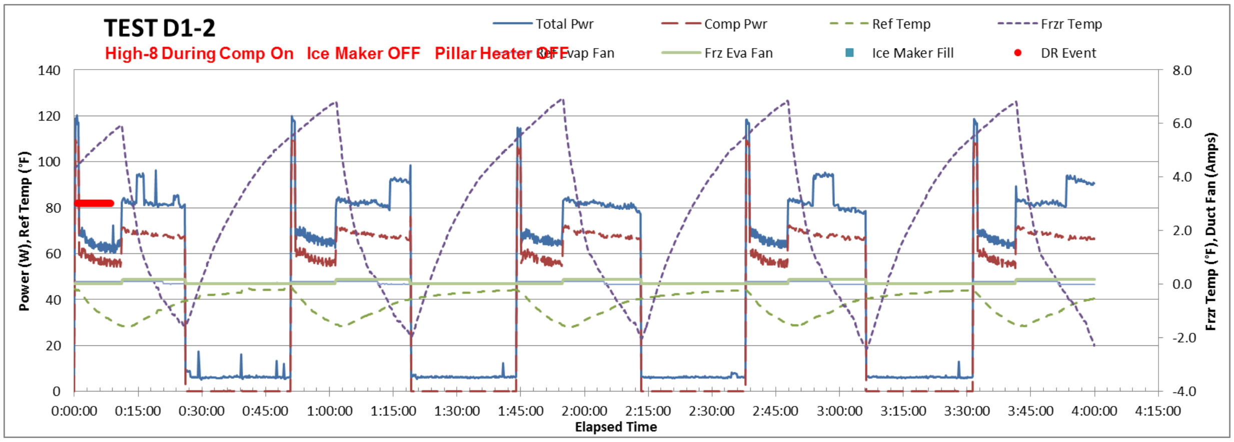


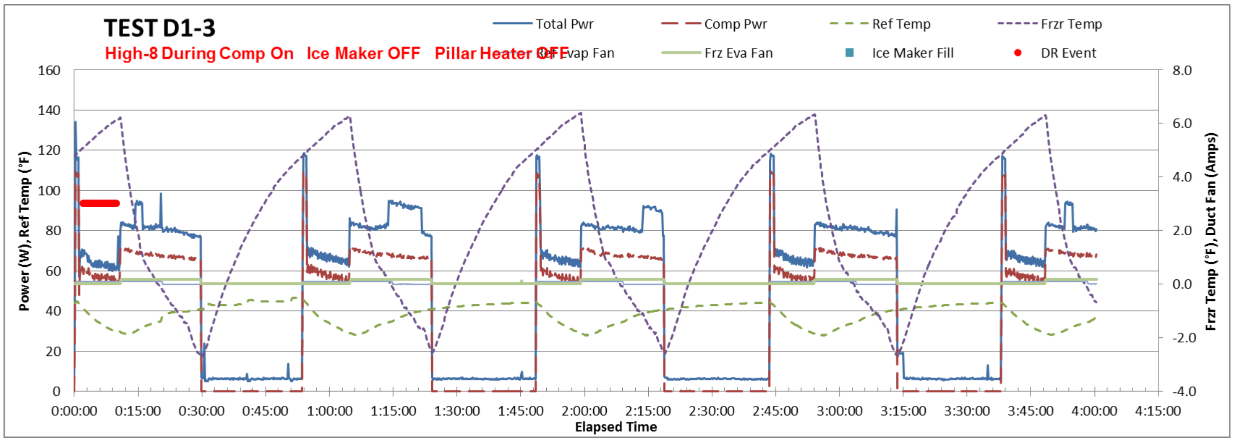




Data Category	TEST A2-1	TEST A2-3	TEST A2-4	TEST A2 Avg	TEST A2-1 Deviation From Average	TEST A2-3 Deviation From Average	TEST A2-4 Deviation From Average	TEST A Avg	TEST A2 Avg Deviation From TEST A Avg
	High-8 During Comp Off Ice Maker ON Pillar Heater ON	High-8 During Comp Off Ice Maker ON Pillar Heater ON	High-8 During Comp Off Ice Maker ON Pillar Heater ON						
Test									
Date	5/3/13	5/14/13	5/15/13						
Start Time	6:18:12	13:19:50	8:22:48						
Duration	4:07:20	4:01:18	4:00:49						
Compressor Run Time	3:25:19	3:17:25	3:10:48	3:17:51	3.8%	-0.2%	-3.6%	3:06:10	6.3%
Average Power									
Compressor Average Power (W)	54	53	52	53	1.8%	0.7%	-2.6%	50	5.0%
Total Average Power (W)	90	90	88	89	1.0%	0.6%	-1.6%	87	2.8%
Avg Total Power During DR Event (W)	77	81	71	76	1.1%	5.9%	-7.1%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	90	90	88	90	1.0%	0.5%	-1.5%	87	3.3%
Energy									
Compressor Energy (Wh)	222	214	207	215	3.6%	-0.1%	-3.5%	203	5.9%
Total Energy (Wh)	373	361	352	362	3.0%	-0.3%	-2.7%	349	3.7%
Room									
Average Room Temp	75.4	75.6	75.3	75.4	0.0%	0.2%	-0.2%	75.4	0.1%
Average Room RH	47.9	51.6	51.6	50.4	-4.9%	2.4%	2.5%	52.6	-4.2%
Water Properties									
Total Water Flow (gal)	0.1	0.1	0.1	0.1	9.5%	-17.5%	8.0%	-0.1	-227.4%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.3	39.3	39.3	39.3	0.0%	0.0%	0.0%	39.9	-1.5%
Avg Frzr Temperature (°F)	-0.5	-0.5	-0.4	-0.4	11.4%	5.4%	-16.9%	0.1	-417.0%

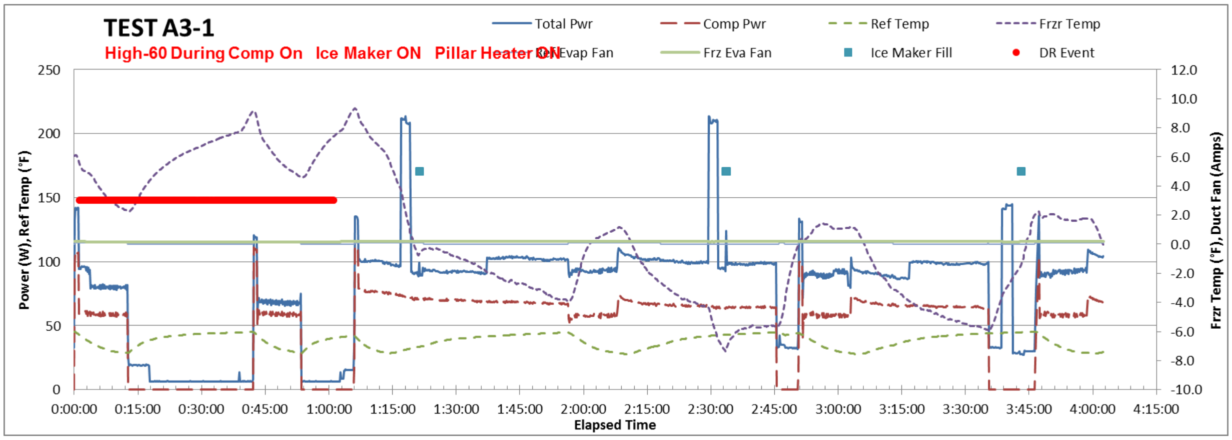


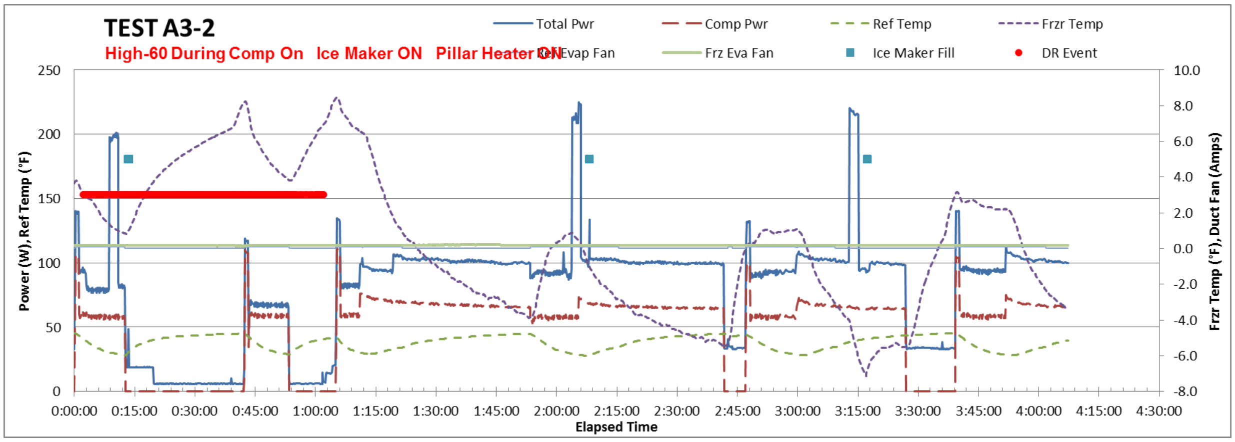


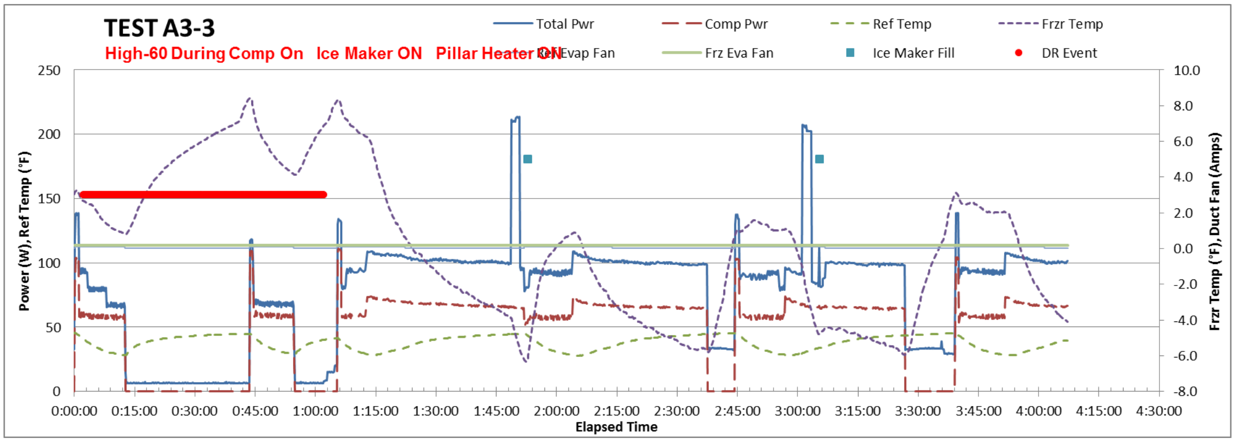


Data Category	TEST D1-1	TEST D1-2	TEST D1-3	TEST D1 Avg	TEST D1-1 Deviation From Average	TEST D1-2 Deviation From Average	TEST D1-3 Deviation From Average	TEST D Avg	TEST D1 Avg Deviation From TEST D Avg
	High-8 During Comp On Ice Maker OFF Pillar Heater OFF	High-8 During Comp On Ice Maker OFF Pillar Heater OFF	High-8 During Comp On Ice Maker OFF Pillar Heater OFF						
Test									
Date	6/19/13	6/19/13	6/20/13						
Start Time	7:24:00	15:41:10	10:35:19						
Duration	4:00:50	3:59:59	4:00:29						
Compressor Run Time	2:22:21	2:20:27	2:22:51	2:21:53	0.3%	-1.0%	0.7%	2:21:57	0.0%
Average Power									
Compressor Average Power (W)	39	39	39	39	0.0%	-0.7%	0.7%	38	1.1%
Total Average Power (W)	49	49	49	49	0.6%	-0.8%	0.2%	48	1.4%
Avg Total Power During DR Event (W)	65	67	64	65	0.1%	2.3%	-2.4%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	48.9	48.1	48.8	49	0.6%	-1.0%	0.4%	48	0.2%
Energy									
Compressor Energy (Wh)	157	154	157	156	0.5%	-0.9%	0.5%	154	1.4%
Total Energy (Wh)	199	195	197	197	1.1%	-1.1%	0.0%	194	1.7%
Room									
Average Room Temp	75.1	75.2	75.1	75	0.0%	0.1%	0.0%	75	-0.3%
Average Room RH	51.7	51.9	52.2	52	-0.5%	0.0%	0.5%	53	-1.1%
Water Properties									
Total Water Flow (gal)	0.0	0.0	0.0	0.0	#DIV/0!	#DIV/0!	#DIV/0!	0.0	-100.0%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.5	39.4	39.5	39.5	0.1%	-0.2%	0.1%	39.6	-0.4%
Avg Frzr Temperature (°F)	1.5	1.9	1.5	1.6	-5.2%	15.0%	-9.8%	1.4	12.8%

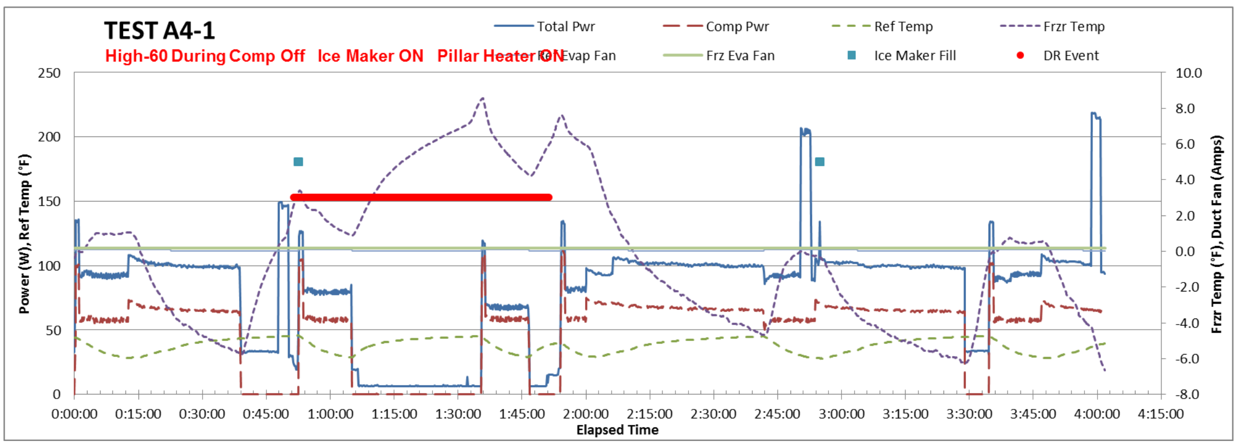
A.3 – HIGH-60 DR EVENTS AT KITCHEN CONDITIONS

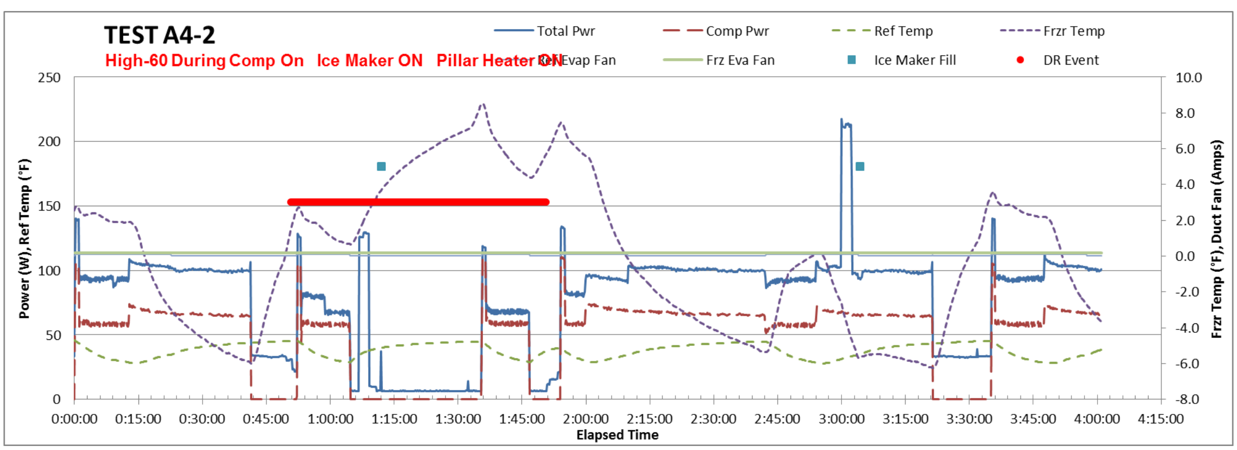


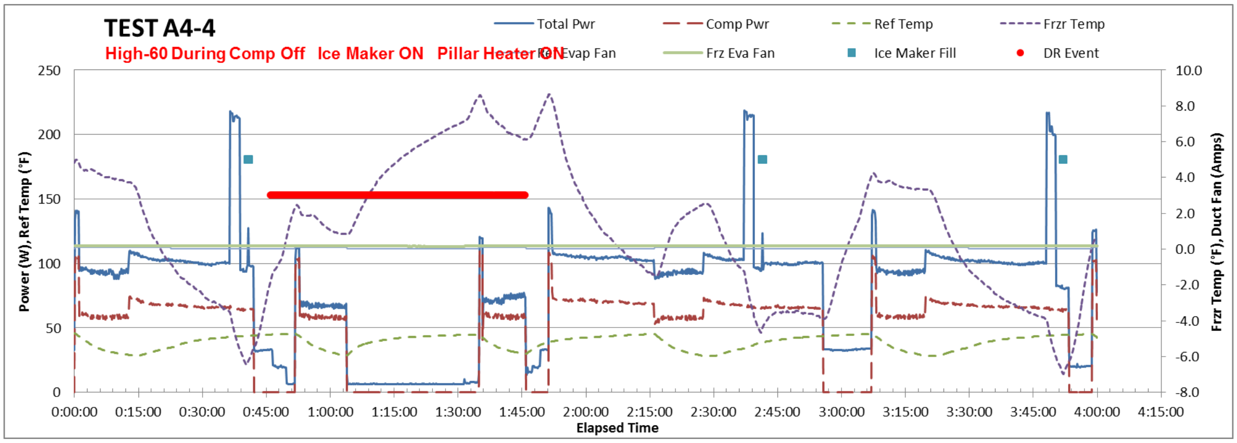




Data Category	TEST A3-1	TEST A3-2	TEST A3-3	TEST A3 Avg	TEST A3-1 Deviation From Average	TEST A3-2 Deviation From Average	TEST A3-3 Deviation From Average	TEST A Avg	TEST A3 Avg Deviation From TEST A1-10 Deviation From
	High-60 During Comp On Ice Maker ON Pillar Heater ON	High-60 During Comp On Ice Maker ON Pillar Heater ON	High-60 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	5/2/13	5/6/13	5/7/13						
Start Time	8:39:44	14:04:46	7:50:41						
Duration	4:02:29	4:07:19	4:07:10						
Compressor Run Time	3:04:11	3:08:20	3:06:21	3:06:17	-1.1%	1.1%	0.0%	3:06:10	0.1%
Average Power									
Compressor Average Power (W)	50	50	49	49	1.0%	0.9%	-1.8%	50	-1.8%
Total Average Power (W)	79	81	77	79	-0.5%	2.7%	-2.2%	87	-8.6%
Avg Total Power During DR Event (W)	34	39	31	35	-0.7%	12.2%	-11.5%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	94	95	93	94	-0.1%	0.9%	-0.8%	87	8.3%
Energy									
Compressor Energy (Wh)	202	204	202	203	-0.3%	0.6%	-0.3%	203	0.0%
Total Energy (Wh)	319	333	322	325	-1.7%	2.5%	-0.8%	349	-6.9%
Room									
Average Room Temp	75.4	75.3	75.3	75.3	0.1%	-0.1%	0.0%	75.4	-0.1%
Average Room RH	51.9	53.1	52.1	52.4	-0.9%	1.4%	-0.5%	52.6	-0.5%
Water Properties									
Total Water Flow (gal)	0.1	0.1	0.0	0.1	13.8%	11.7%	-25.5%	-0.1	-192.4%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.3	39.3	39.3	39.3	0.0%	0.1%	0.0%	39.9	-1.4%
Avg Frzr Temperature (°F)	1.0	0.7	0.9	0.9	14.9%	-17.2%	2.3%	0.1	539.8%

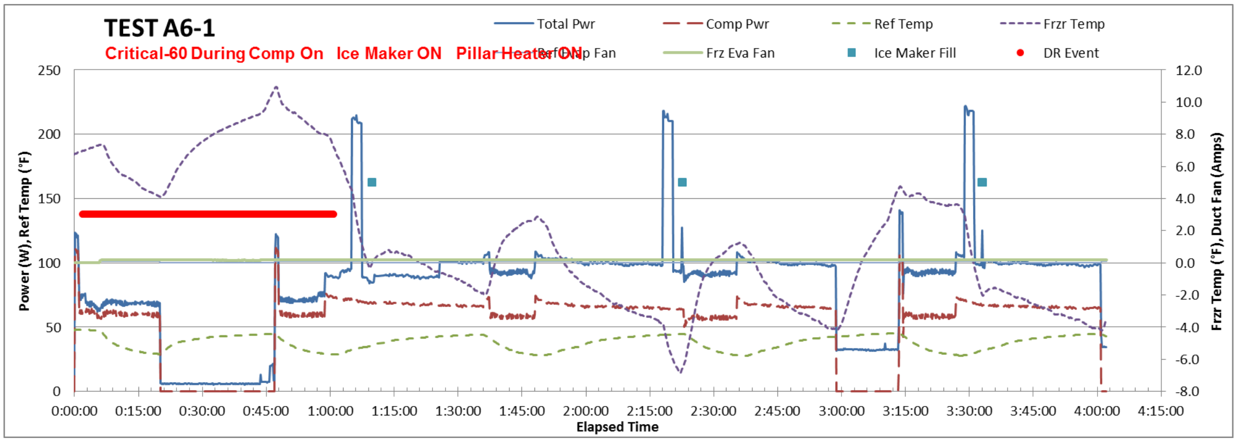


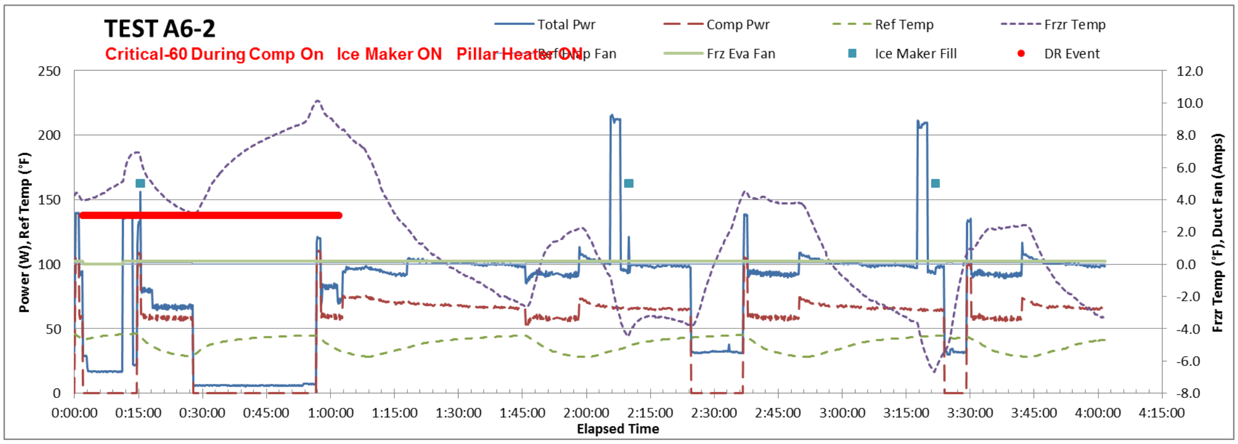


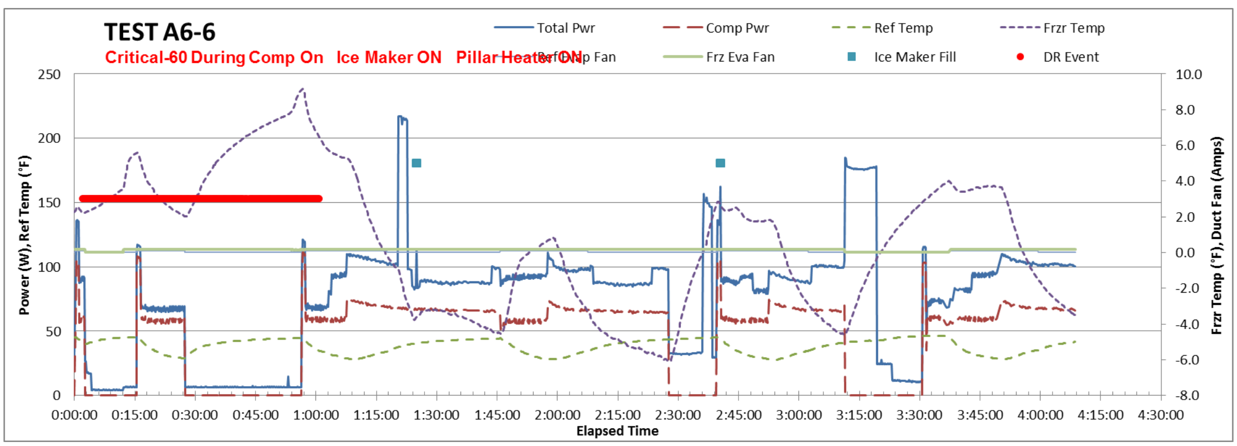


Data Category	TEST A4-1	TEST A4-2	TEST A4-4	TEST A4 Avg	TEST A4-1 Deviation From Average	TEST A4-2 Deviation From Average	TEST A4-4 Deviation From Average	TEST A Avg	TEST A4 Avg Deviation From TEST A Avg
	High-60 During Comp Off Ice Maker ON Pillar Heater ON	High-60 During Comp On Ice Maker ON Pillar Heater ON	High-60 During Comp Off Ice Maker ON Pillar Heater ON						
Test									
Date	4/30/13	5/1/13	6/21/13						
Start Time	6:26:58	6:55:16	6:53:07						
Duration	4:01:50	4:00:59	3:59:59						
Compressor Run Time	3:04:50	2:58:29	2:57:30	3:00:16	2.5%	-1.0%	-1.5%	3:06:10	-3.2%
Average Power									
Compressor Average Power (W)	49	48	49	49	1.3%	-1.4%	0.1%	50	-3.3%
Total Average Power (W)	80	77	79	79	1.7%	-1.9%	0.2%	87	-8.9%
Avg Total Power During DR Event (W)	36	39	33	36	-0.6%	7.9%	-7.3%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	95	90	94	93	2.0%	-3.2%	1.2%	87	7.7%
Energy									
Compressor Energy (Wh)	200	193	195	196	1.8%	-1.4%	-0.4%	203	-3.2%
Total Energy (Wh)	325	312	317	318	2.2%	-1.9%	-0.3%	349	-8.9%
Room									
Average Room Temp	75.4	75.3	75.2	75.3	0.1%	0.0%	-0.1%	75.4	-0.1%
Average Room RH	52.3	53.4	50.6	52.1	0.4%	2.4%	-2.8%	52.6	-1.0%
Water Properties									
Total Water Flow (gal)	0.0	0.0	-0.1	0.0	516.7%	483.3%	-1000.0%	-0.1	-111.5%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.3	39.2	39.7	39.4	-0.2%	-0.5%	0.7%	39.9	-1.1%
Avg Frzr Temperature (°F)	0.6	1.0	1.2	0.9	-33.1%	3.4%	29.8%	0.1	582.2%

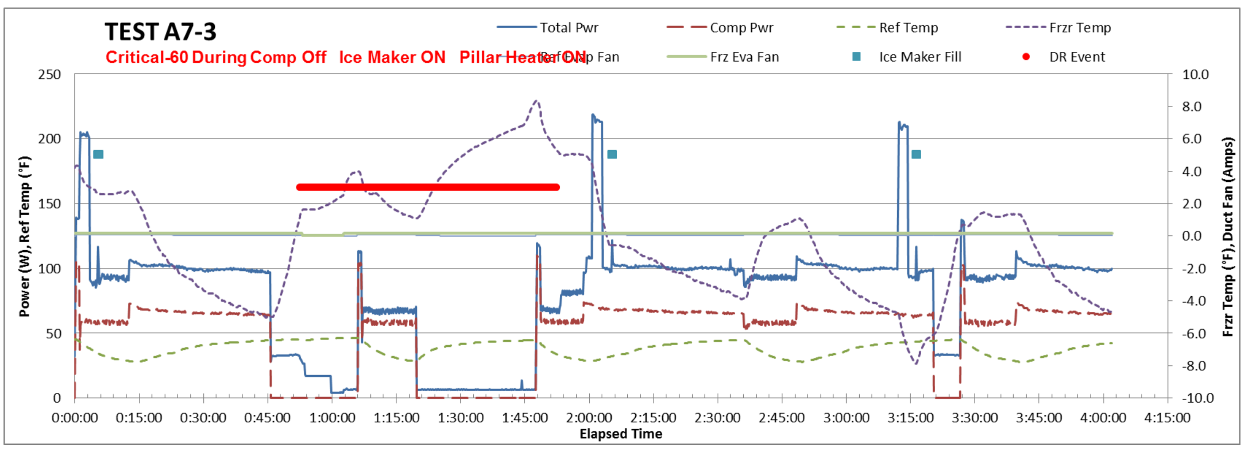
A.4 – CRITICAL-60 DR EVENTS AT KITCHEN CONDITIONS

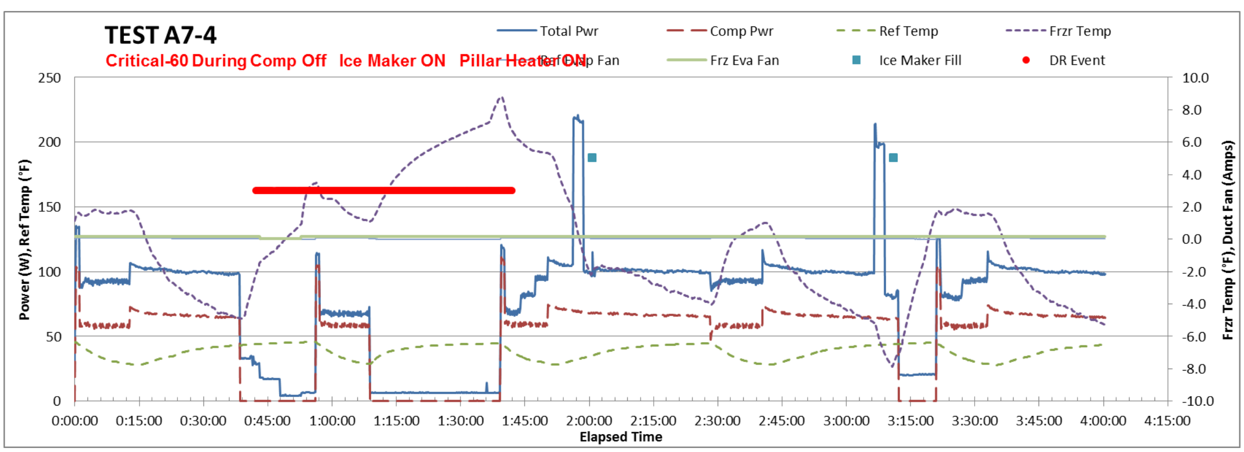


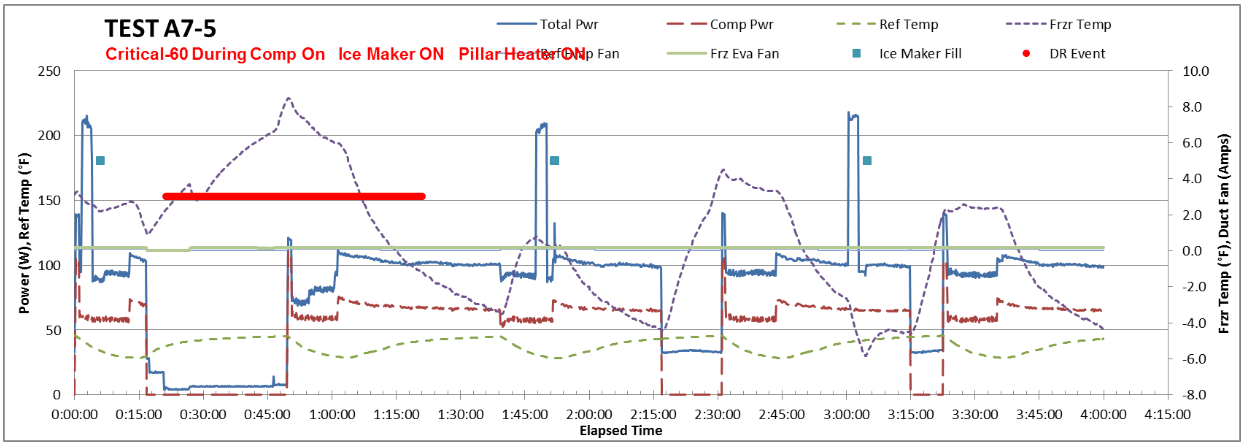




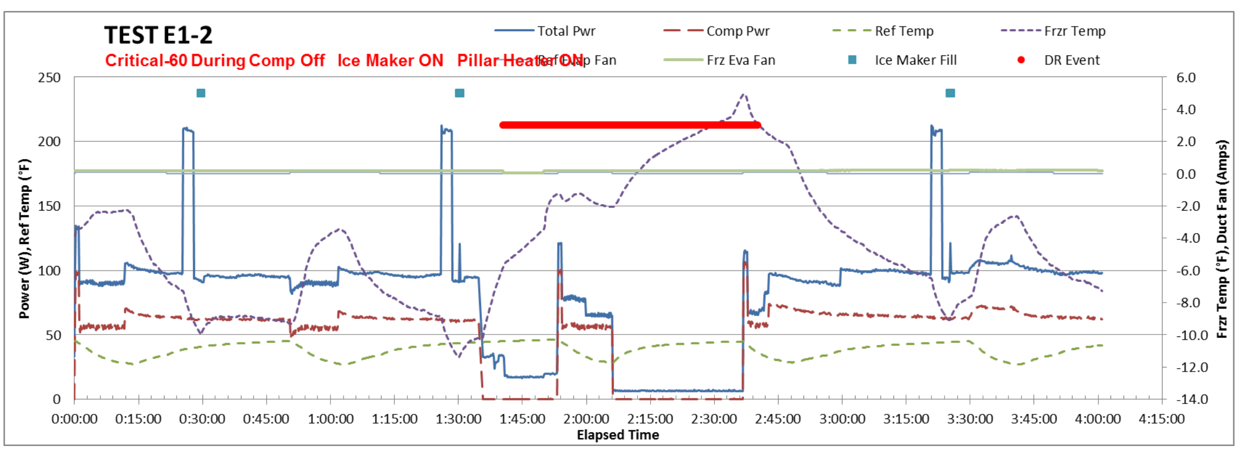
Data Category	TEST A6-1	TEST A6-2	TEST A6-6	TEST A6 Avg	TEST A6-1 Deviation From Average	TEST A6-2 Deviation From Average	TEST A6-6 Deviation From Average	TEST A Avg	TEST A6 Avg Deviation From TEST A Avg
	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	4/24/13	4/25/13	5/3/13						
Start Time	14:12:09	8:13:57	13:24:02						
Duration	4:02:09	4:01:40	4:08:39						
Compressor Run Time	3:19:20	3:02:30	2:55:29	3:05:46	7.3%	-1.8%	-5.5%	3:06:10	-0.2%
Average Power									
Compressor Average Power (W)	53	50	46	50	7.5%	0.2%	-7.8%	50	-1.6%
Total Average Power (W)	83	80	76	80	4.0%	0.6%	-4.5%	87	-8.1%
Avg Total Power During DR Event (W)	43	36	27	35	22.0%	2.0%	-24.0%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	96	95	92	94	1.8%	0.9%	-2.7%	87	8.6%
Energy									
Compressor Energy (Wh)	216	200	191	202	6.7%	-0.9%	-5.8%	203	-0.1%
Total Energy (Wh)	335	323	315	324	3.2%	-0.3%	-2.9%	349	-7.1%
Room									
Average Room Temp	75.4	75.5	75.6	75.5	-0.1%	-0.1%	0.2%	75.4	0.2%
Average Room RH	52.2	51.5	49.2	51.0	2.5%	1.0%	-3.5%	52.6	-3.1%
Water Properties									
Total Water Flow (gal)	0.1	0.1	0.0	0.1	10.7%	12.8%	-23.5%	-0.1	-194.9%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.5	39.4	39.5	39.5	0.1%	-0.1%	0.0%	39.9	-1.0%
Avg Frzr Temperature (°F)	1.4	1.6	1.2	1.4	0.1%	13.6%	-13.7%	0.1	938.1%

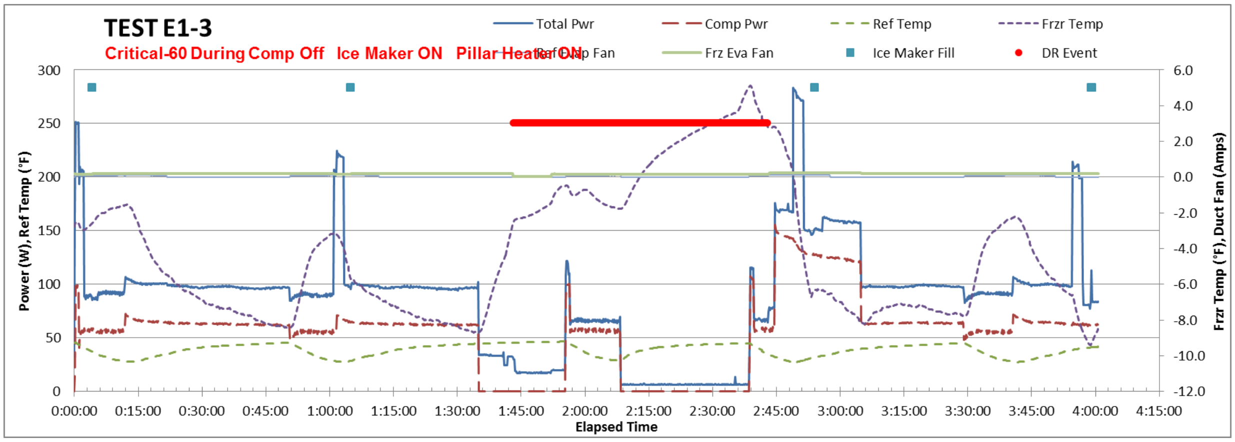


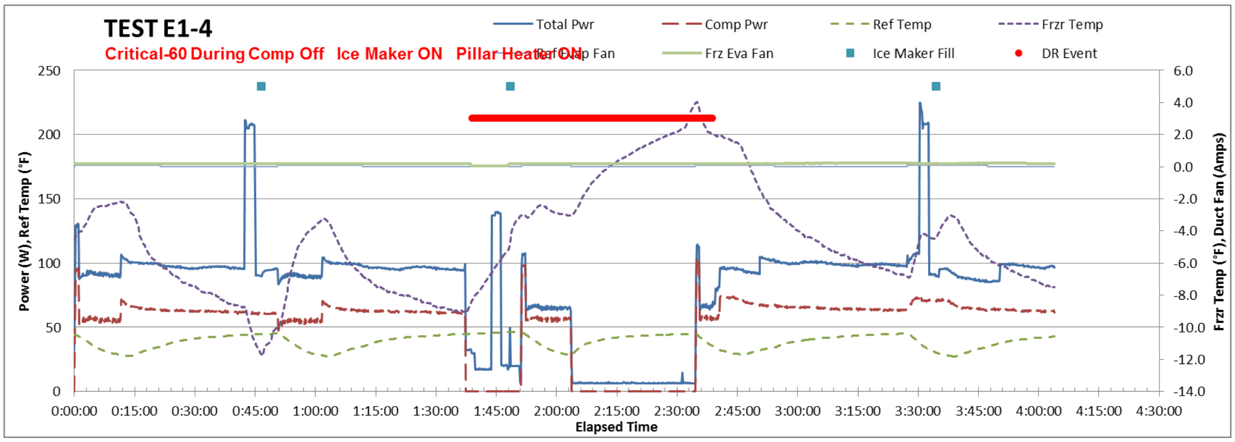




Data Category	TEST A7-3	TEST A7-4	TEST A7-5	TEST A7 Avg	TEST A7-3 Deviation From Average	TEST A7-4 Deviation From Average	TEST A7-5 Deviation From Average	TEST A Avg	TEST A7 Avg Deviation From TEST A Avg
	Critical-60 During Comp Off Ice Maker ON Pillar Heater ON	Critical-60 During Comp Off Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	5/13/13	5/14/13	6/21/13						
Start Time	13:01:25	6:27:39	14:19:46						
Duration	4:01:57	4:00:21	3:59:59						
Compressor Run Time	3:07:37	3:03:20	3:05:30	3:05:29	1.2%	-1.2%	0.0%	3:06:10	-0.4%
Average Power									
Compressor Average Power (W)	50	50	50	50	-0.1%	-0.7%	0.8%	50	-0.7%
Total Average Power (W)	80	78	84	81	-0.6%	-3.3%	3.9%	87	-6.8%
Avg Total Power During DR Event (W)	28	25	53	35	-20.8%	-29.9%	50.7%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	98	96	94	96	1.9%	-0.2%	-1.7%	87	10.5%
Energy									
Compressor Energy (Wh)	202	199	202	201	0.6%	-1.1%	0.5%	203	-0.8%
Total Energy (Wh)	325	312	336	324	0.2%	-3.7%	3.5%	349	-7.0%
Room									
Average Room Temp	75.6	75.3	75.3	75.4	0.3%	-0.1%	-0.2%	75.4	0.0%
Average Room RH	52.4	51.2	51.9	51.8	1.1%	-1.3%	0.2%	52.6	-1.5%
Water Properties									
Total Water Flow (gal)	0.1	0.0	-0.1	0.0	330.8%	176.9%	-507.7%	-0.1	-124.8%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.5	39.5	39.4	39.4	0.2%	0.0%	-0.2%	39.9	-1.1%
Avg Frzr Temperature (°F)	0.3	0.4	0.8	0.5	-42.8%	-27.5%	70.3%	0.1	260.5%

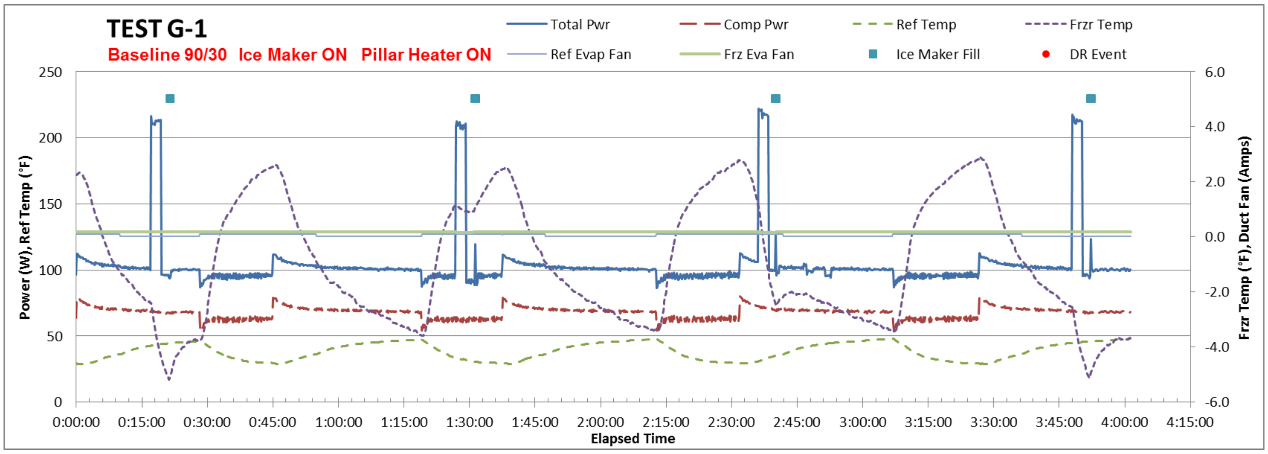


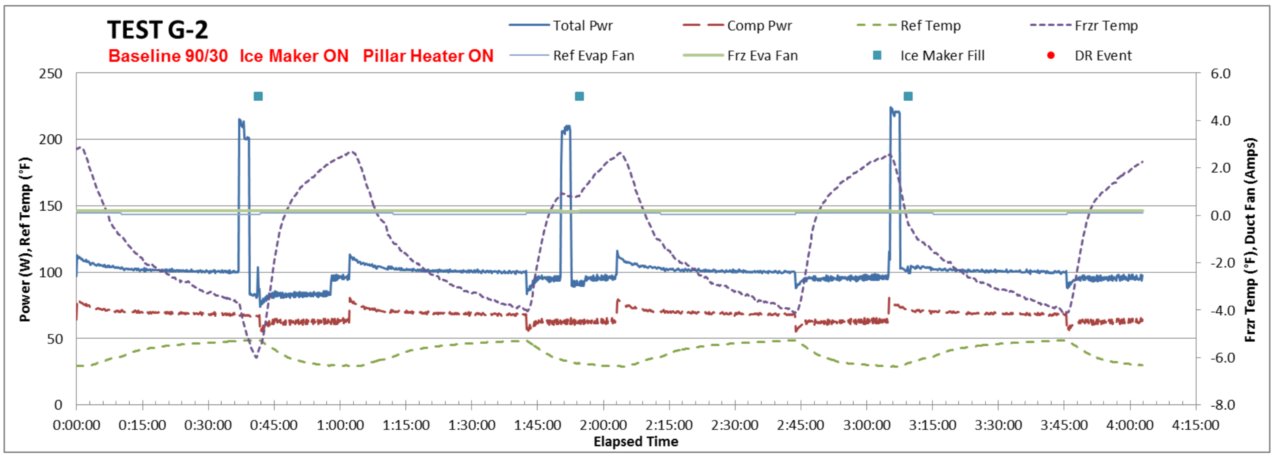


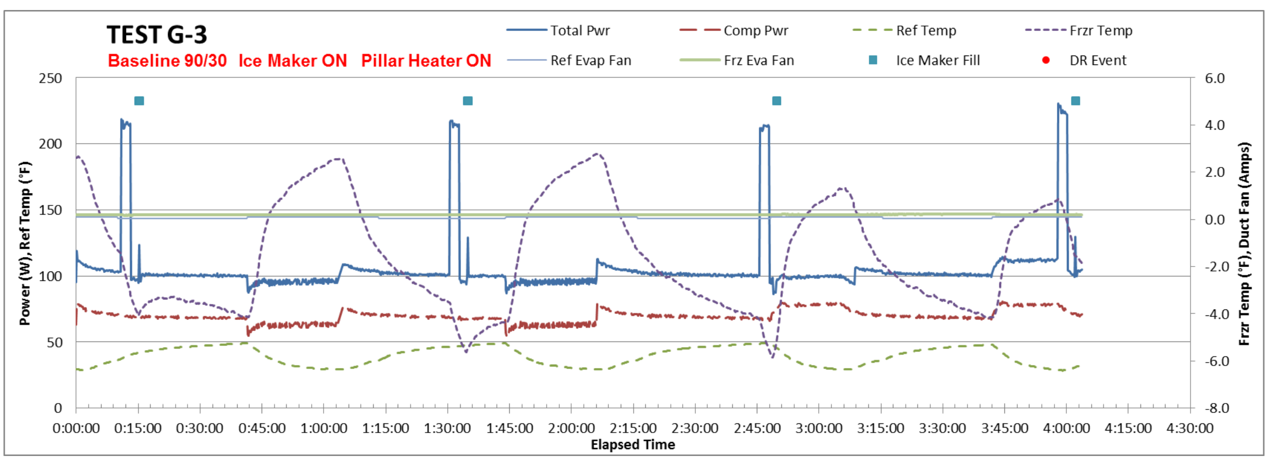


Data Category	TEST E1-2	TEST E1-3	TEST E1-4	TEST E1 Avg	TEST E1-2 Deviation From Average	TEST E1-3 Deviation From Average	TEST E1-4 Deviation From Average	TEST E Avg	TEST E1 Avg Deviation From TEST E Avg
	Critical-60 During Comp Off Ice Maker ON Pillar Heater ON	Critical-60 During Comp Off Ice Maker ON Pillar Heater ON	Critical-60 During Comp Off Ice Maker ON Pillar Heater ON						
Test									
Date	6/12/13	6/14/13	6/18/13						
Start Time	5:27:36	7:22:50	12:15:02						
Duration	4:00:58	4:00:40	4:03:50						
Compressor Run Time	3:11:49	3:10:00	3:19:00	3:13:36	-0.9%	-1.9%	2.8%	3:52:32	-16.7%
Average Power									
Compressor Average Power (W)	51	55	51	52	-3.0%	4.7%	-1.6%	#REF!	#REF!
Total Average Power (W)	82	87	82	83	-2.0%	4.0%	-2.0%	59	41.0%
Avg Total Power During DR Event (W)	28	27	32	29	-2.9%	-5.9%	8.9%	98	-70.4%
Avg Total Power Excluding DR Event (W)	100	106	98	101	-1.8%	4.7%	-2.9%	#DIV/0!	#DIV/0!
Energy									
Compressor Energy (Wh)	203	219	210	211	-3.8%	4.2%	-0.4%	0	#DIV/0!
Total Energy (Wh)	328	348	333	336	-2.6%	3.4%	-0.9%	#REF!	#REF!
Room									
Average Room Temp	75.2	75.2	75.3	75.2	0.0%	-0.1%	0.1%	392.9	-80.9%
Average Room RH	51.9	51.8	52.3	52.0	-0.2%	-0.3%	0.5%	0.0	#DIV/0!
Water Properties									
Total Water Flow (gal)	0.1	0.1	0.1	0.1	-8.8%	17.7%	-8.8%	53.6	-99.9%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	39.4	39.5	39.5	39.5	-0.2%	0.0%	0.2%	0.1	47487.2%
Avg Frzr Temperature (°F)	-4.2	-4.2	-4.7	-4.3	-4.3%	-2.9%	7.2%	0.0	#DIV/0!

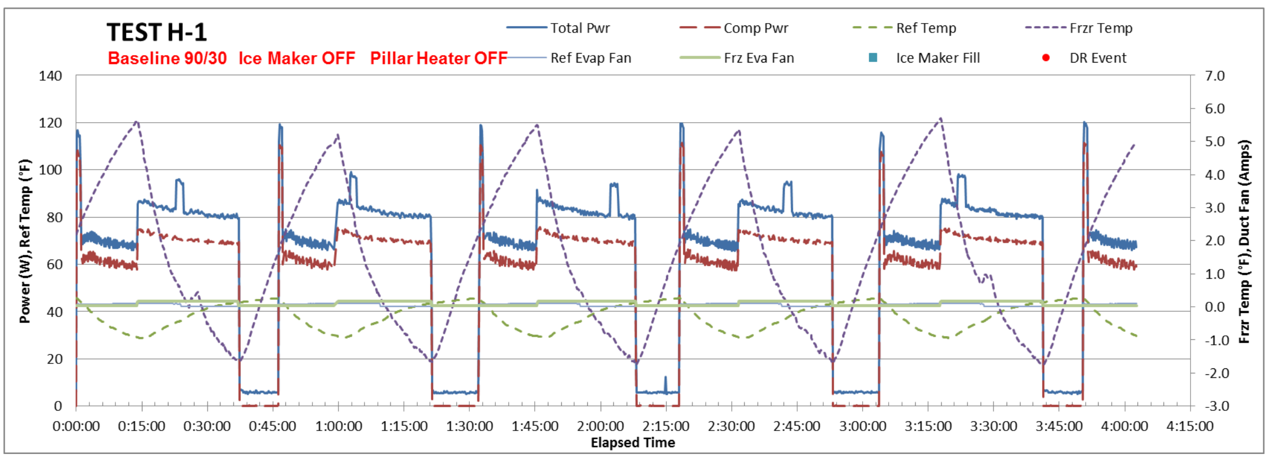
A.5 – BASELINE TESTS AT GARAGE CONDITIONS

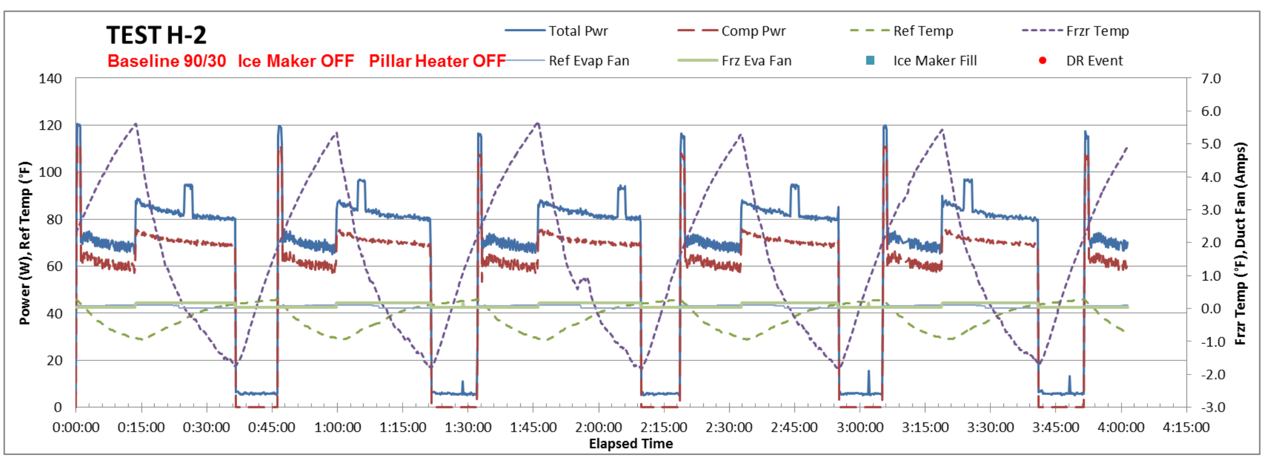


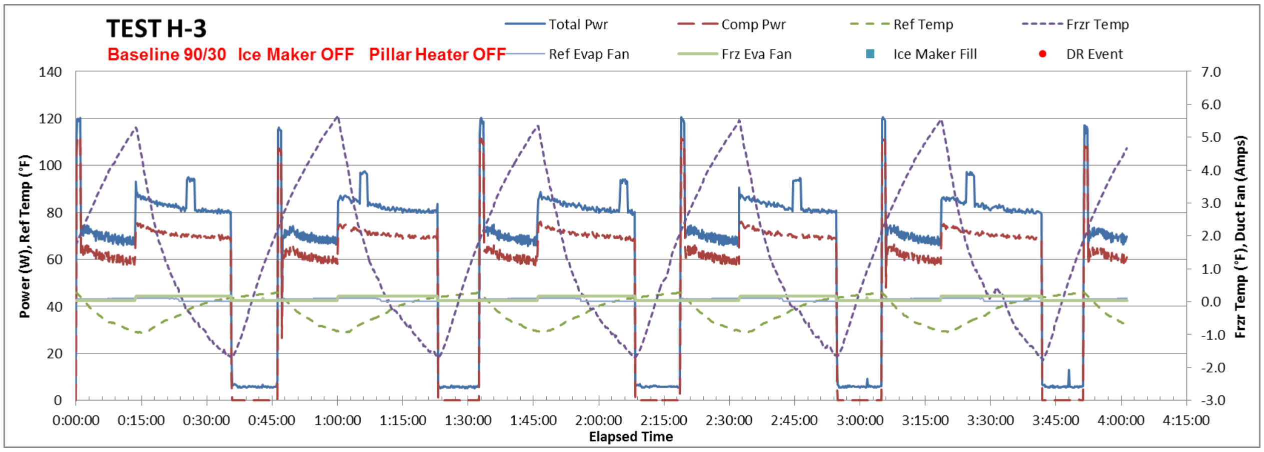




Data Category	TEST G-1	TEST G-2	TEST G-3	TEST G Avg	TEST G-1 Deviation From Average	TEST G-2 Deviation From Average	TEST G-3 Deviation From Average
	Baseline 90/30 Ice Maker ON Pillar Heater ON	Baseline 90/30 Ice Maker ON Pillar Heater ON	Baseline 90/30 Ice Maker ON Pillar Heater ON				
Test	0%	0%	0%				
Date	4/10/13	4/10/13	4/10/13				
Start Time	4:28:09	8:50:47	12:57:56				
Duration	4:01:18	4:02:49	4:03:41				
Compressor Run Time	4:01:18	4:02:49	4:03:41	4:02:36	-0.5%	0.1%	0.4%
Average Power	0%	0%	0%				
Compressor Average Power (W)	68	67	70	68	-0.8%	-1.2%	2.1%
Total Average Power (W)	104	102	106	104	0.4%	-2.1%	1.6%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	104	102	106	104	0.4%	-2.1%	1.6%
Energy	0%	0%	0%				
Compressor Energy (Wh)	272	273	283	276	-1.4%	-1.2%	2.5%
Total Energy (Wh)	420	412	429	420	-0.1%	-2.0%	2.1%
Room	0%	0%	0%				
Average Room Temp	90.1	90.1	90.2	90.1	0.0%	0.0%	0.1%
Average Room RH	30.1	30.0	30.0	30.0	0.3%	-0.1%	-0.2%
Water Properties	0%	0%	0%				
Total Water Flow (gal)	-0.1	-0.1	-0.1	-0.1	9.4%	-18.7%	9.4%
Ref / Frzr Cabinet	0.0	0.0	0.0				
Avg Ref Temperature (°F)	40.3	40.8	40.8	40.6	-0.9%	0.4%	0.5%
Avg Frzr Temperature (°F)	-0.3	-0.4	-0.6	-0.4	-28.5%	-6.1%	34.6%

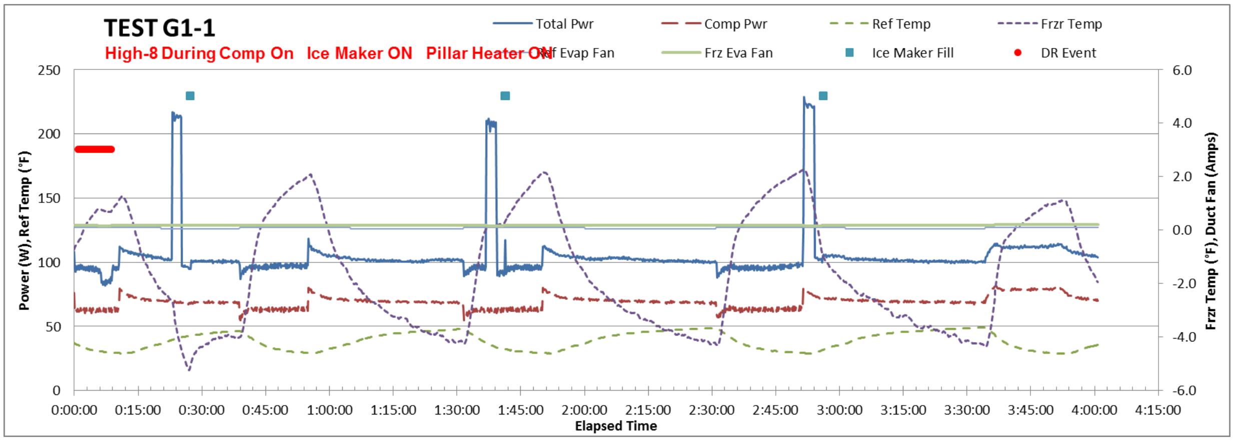


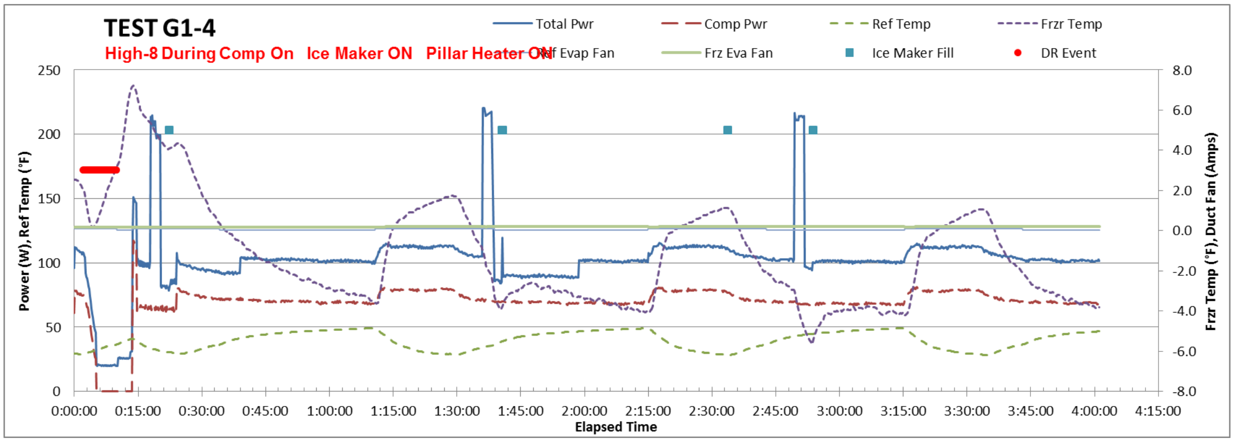


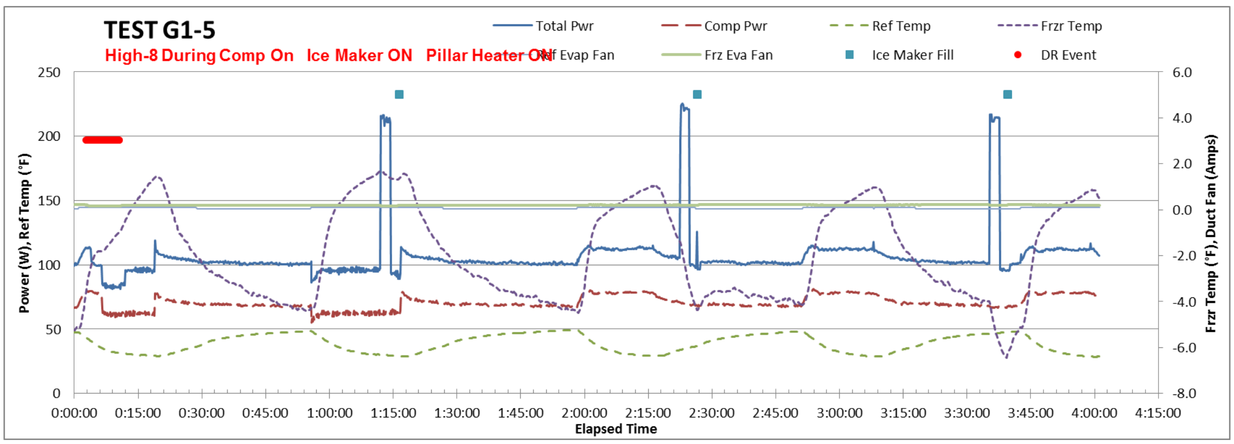


Data Category	TEST H-1	TEST H-2	TEST H-3	TEST H Avg	TEST H-1 Deviation From Average	TEST H-2 Deviation From Average	TEST H-3 Deviation From Average
	Baseline 90/30 Ice Maker OFF Pillar Heater OFF	Baseline 90/30 Ice Maker OFF Pillar Heater OFF	Baseline 90/30 Ice Maker OFF Pillar Heater OFF				
Test							
Date	4/13/13	4/13/13	4/13/13				
Start Time	10:42:11	15:18:30	19:56:30				
Duration	4:02:39	4:01:30	4:01:20				
Compressor Run Time	3:13:10	3:11:40	3:11:19	3:12:03	0.6%	-0.2%	-0.4%
Average Power							
Compressor Average Power (W)	54	54	54	54	-0.1%	-0.2%	0.3%
Total Average Power (W)	64	64	64	64	-0.1%	-0.1%	0.3%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	64	64	64	64	-0.1%	-0.1%	0.3%
Energy							
Compressor Energy (Wh)	220	218	217	218	0.6%	-0.2%	-0.5%
Total Energy (Wh)	260	258	257	258	0.6%	-0.2%	-0.4%
Room							
Average Room Temp	90.0	90.0	89.9	90.0	0.0%	0.0%	0.0%
Average Room RH	30.3	30.3	30.3	30.3	0.0%	0.1%	0.0%
Water Properties							
Total Water Flow (gal)	0.0	0.0	0.0	0.0	#DIV/0!	#DIV/0!	#DIV/0!
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	40.1	40.2	40.2	40.2	-0.1%	0.1%	0.0%
Avg Frzr Temperature (°F)	0.9	0.9	0.9	0.9	1.6%	-1.8%	0.2%

A.6 – HIGH-8 DR EVENTS AT GARAGE CONDITIONS

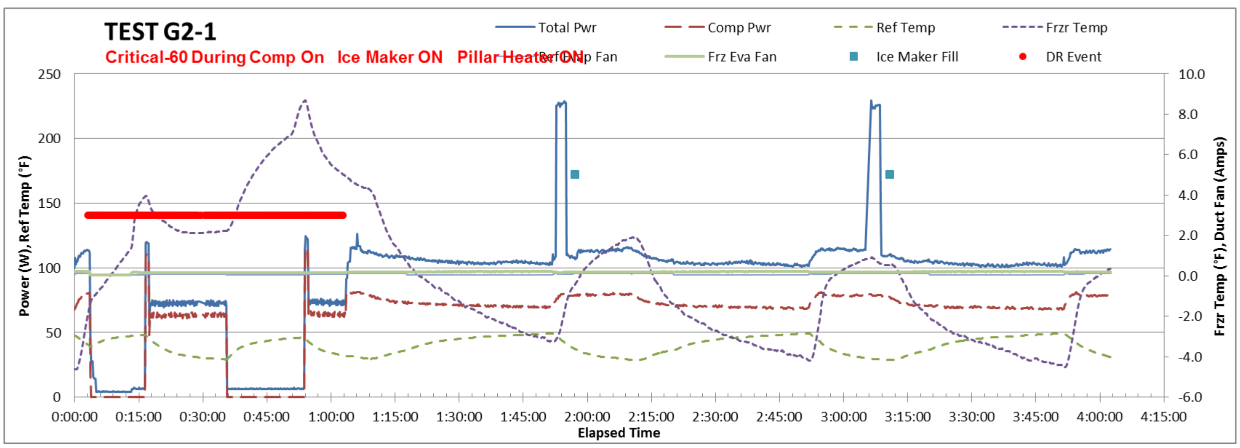


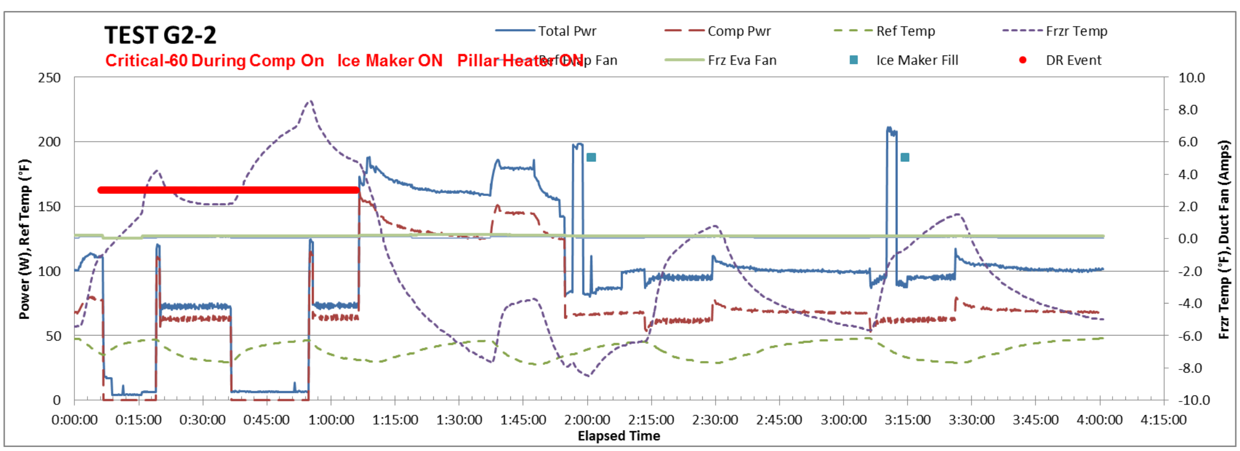


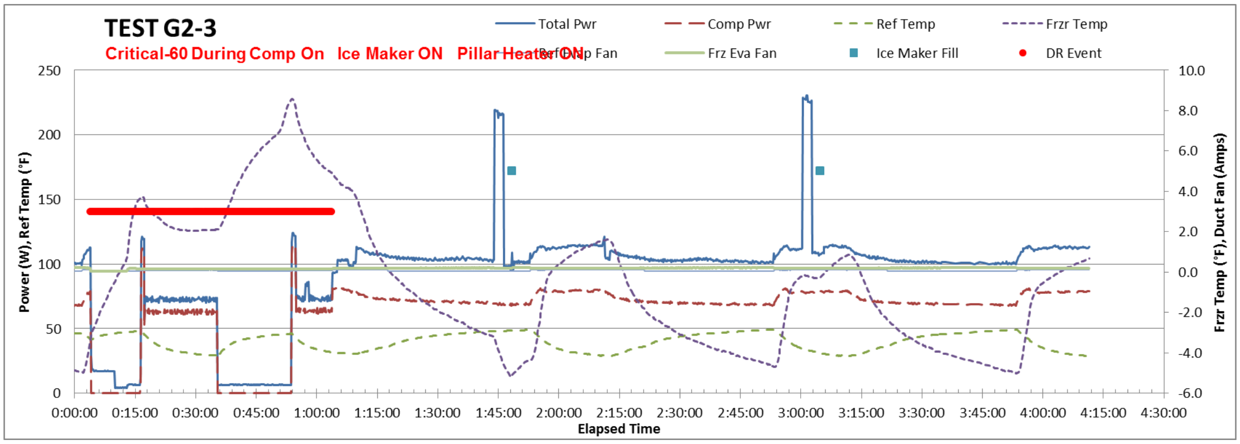


Data Category	TEST G1-1	TEST G1-4	TEST G1-5	TEST G1 Avg	TEST G1-1 Deviation From Average	TEST G1-4 Deviation From Average	TEST G1-5 Deviation From Average	TEST G Avg	TEST G1 Avg Deviation From TEST G Avg
	High-8 During Comp On Ice Maker ON Pillar Heater ON	High-8 During Comp On Ice Maker ON Pillar Heater ON	High-8 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	5/17/13	5/24/13	5/24/13						
Start Time	7:09:05	7:37:50	15:23:10						
Duration	4:00:50	4:01:10	4:01:10						
Compressor Run Time	4:00:50	3:52:40	4:01:10	3:58:13	1.1%	-2.3%	1.2%	4:02:36	-1.8%
Average Power									
Compressor Average Power (W)	69	69	71	70	-0.9%	-0.5%	1.4%	68	1.9%
Total Average Power (W)	105	103	107	105	0.1%	-2.1%	2.0%	104	0.7%
Avg Total Power During DR Event (W)	92	41	93	75	21.8%	-45.5%	23.7%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	105	105	107	106	-0.4%	-1.0%	1.5%	104	1.7%
Energy									
Compressor Energy (Wh)	277	279	284	280	-1.0%	-0.4%	1.4%	276	1.3%
Total Energy (Wh)	421	414	429	421	-0.2%	-1.7%	1.9%	420	0.2%
Room									
Average Room Temp	90.2	90.8	90.9	90.6	-0.5%	0.2%	0.3%	90.1	0.5%
Average Room RH	28.3	29.6	30.6	29.5	-4.1%	0.5%	3.6%	30.0	-1.7%
Water Properties									
Total Water Flow (gal)	0.1	0.1	0.1	0.1	2.4%	0.6%	-3.0%	-0.1	-185.4%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	40.4	41.0	40.8	40.7	-0.9%	0.7%	0.2%	40.6	0.2%
Avg Frzr Temperature (°F)	-0.5	-0.4	-1.1	-0.7	-21.4%	-39.3%	60.7%	-0.4	52.7%

A.5 – Critical-60 DR Events at Garage Conditions

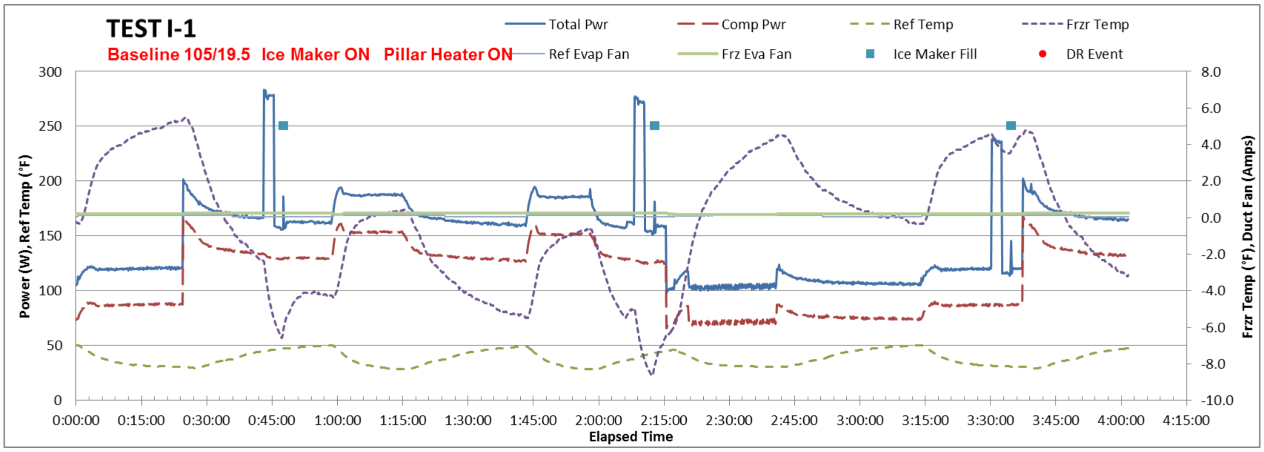


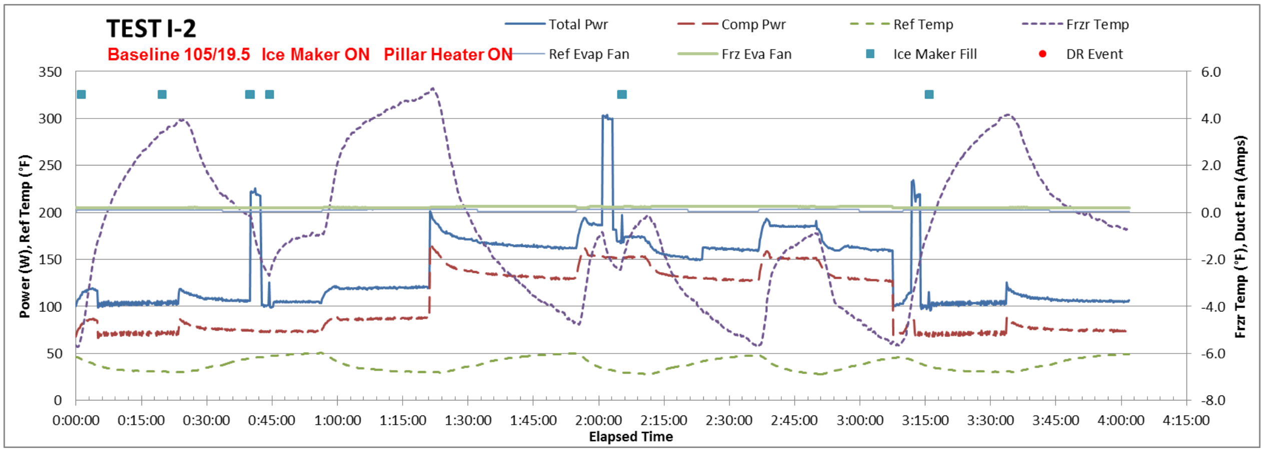


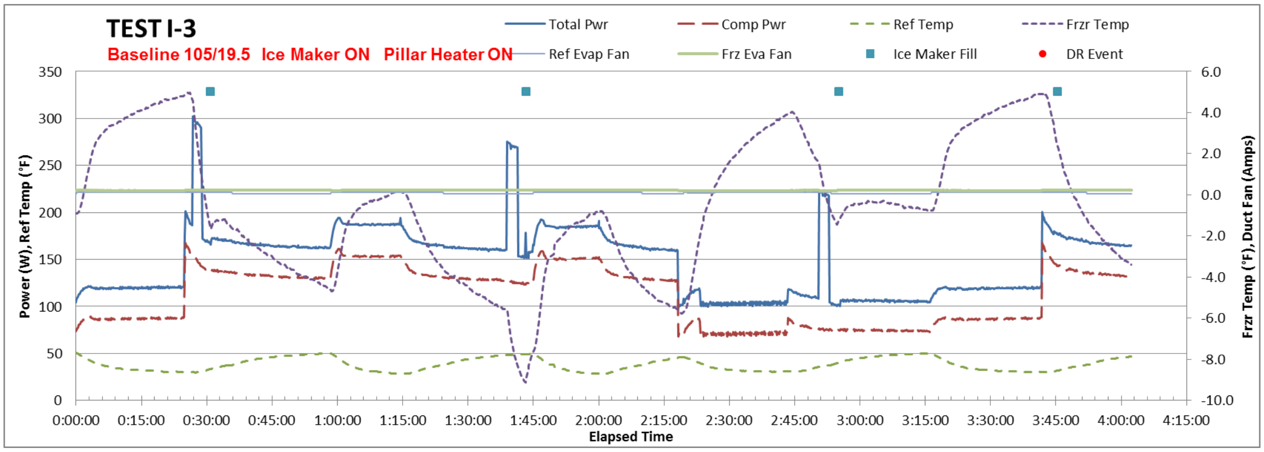


Data Category	TEST G2-1	TEST G2-2	TEST G2-3	TEST G2 Avg	TEST G2-1 Deviation From Average	TEST G2-2 Deviation From Average	TEST G2-3 Deviation From Average	TEST G Avg	TEST G2 Avg Deviation From TEST G Avg
	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	5/21/13	5/22/13	5/22/13						
Start Time	14:53:57	7:43:54	15:00:15						
Duration	4:02:28	4:00:50	4:11:28						
Compressor Run Time	3:31:28	3:30:10	3:40:50	3:34:09	-1.3%	-1.9%	3.1%	4:02:36	-11.7%
Average Power									
Compressor Average Power (W)	63	72	63	66	-4.6%	9.1%	-4.5%	68	-3.3%
Total Average Power (W)	92	100	92	95	-2.5%	5.3%	-2.8%	104	-8.8%
Avg Total Power During DR Event (W)	40	41	41	41	-2.4%	0.5%	1.9%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	110	119	109	113	-2.7%	5.9%	-3.2%	104	8.4%
Energy									
Compressor Energy (Wh)	255	290	266	270	-5.6%	7.3%	-1.7%	276	-2.2%
Total Energy (Wh)	376	402	388	389	-3.3%	3.4%	-0.1%	420	-7.6%
Room									
Average Room Temp	90.2	90.1	90.2	90.2	0.1%	-0.1%	0.0%	90.1	0.0%
Average Room RH	32.8	27.7	30.5	30.4	8.1%	-8.6%	0.6%	30.0	1.1%
Water Properties									
Total Water Flow (gal)	0.0	0.0	0.0	0.0	-0.9%	1.8%	-0.9%	-0.1	-158.3%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	41.4	40.7	41.1	41.1	0.8%	-0.9%	0.1%	40.6	1.1%
Avg Frzr Temperature (°F)	0.6	-0.7	0.5	0.2	276.6%	-499.1%	222.6%	-0.4	-137.9%

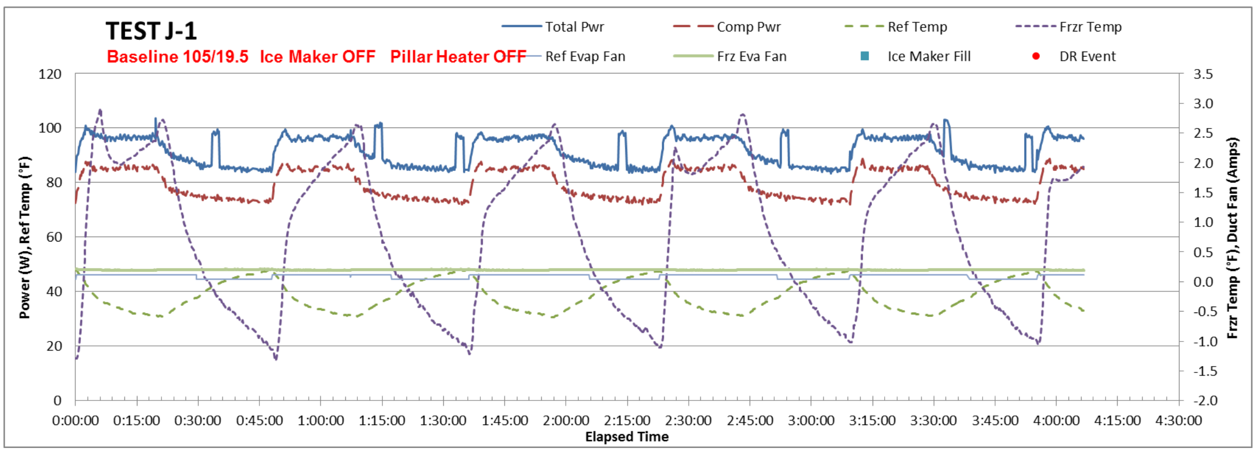
A.6 – Baseline Tests at Extreme Garage Conditions

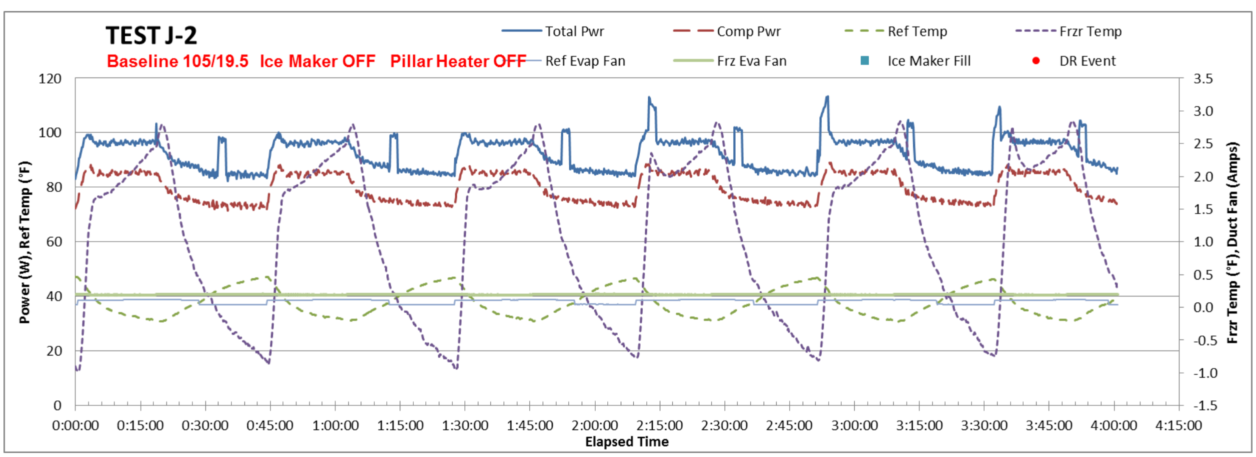


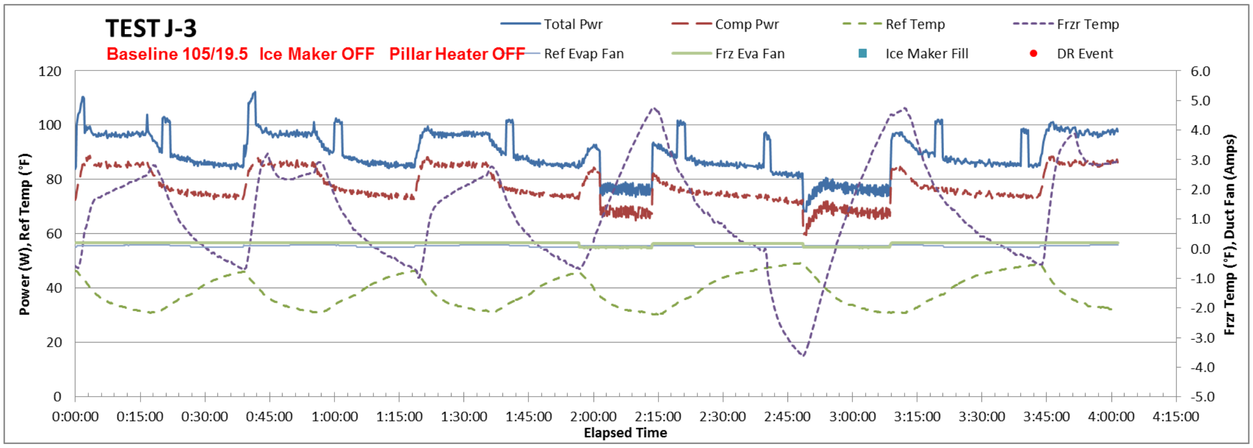




Data Category	TEST I-1	TEST I-2	TEST I-3	TEST I Avg	TEST I-1 Deviation From Average	TEST I-2 Deviation From Average	TEST I-3 Deviation From Average
	Baseline 105/19.5 Ice Maker ON Pillar Heater ON	Baseline 105/19.5 Ice Maker ON Pillar Heater ON	Baseline 105/19.5 Ice Maker ON Pillar Heater ON				
Test							
Date	4/17/13	4/17/13	4/18/13				
Start Time	17:35:43	23:04:54	3:11:12				
Duration	4:01:39	4:01:48	4:02:20				
Compressor Run Time	4:01:39	4:01:48	4:02:20	4:01:56	-0.1%	-0.1%	0.2%
Average Power							
Compressor Average Power (W)	113	104	112	109	3.0%	-5.4%	2.3%
Total Average Power (W)	149	138	148	145	2.7%	-4.7%	2.0%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	149	138	148	145	2.7%	-4.7%	2.0%
Energy							
Compressor Energy (Wh)	455	418	453	442	2.9%	-5.4%	2.5%
Total Energy (Wh)	600	558	598	585	2.5%	-4.7%	2.2%
Room							
Average Room Temp	105.2	105.2	105.2	105.2	0.0%	0.0%	0.0%
Average Room RH	19.5	19.6	19.5	19.5	0.0%	0.1%	-0.1%
Water Properties							
Total Water Flow (gal)	-0.1	-0.1	-0.1	-0.1	0.6%	0.6%	-1.2%
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	40.7	40.8	40.8	40.8	-0.1%	0.2%	0.0%
Avg Frzr Temperature (°F)	-0.2	-0.5	-0.4	-0.3	-48.5%	37.8%	10.7%

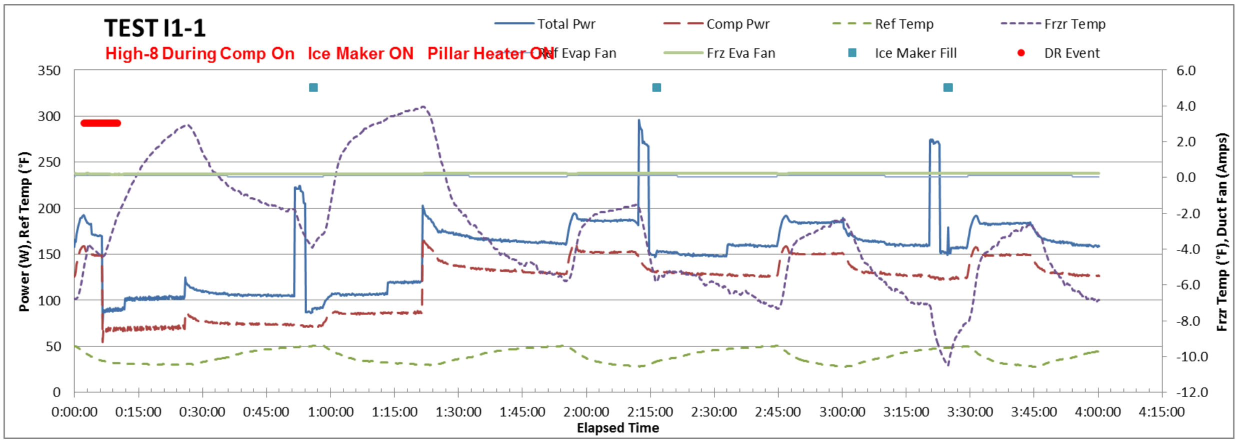


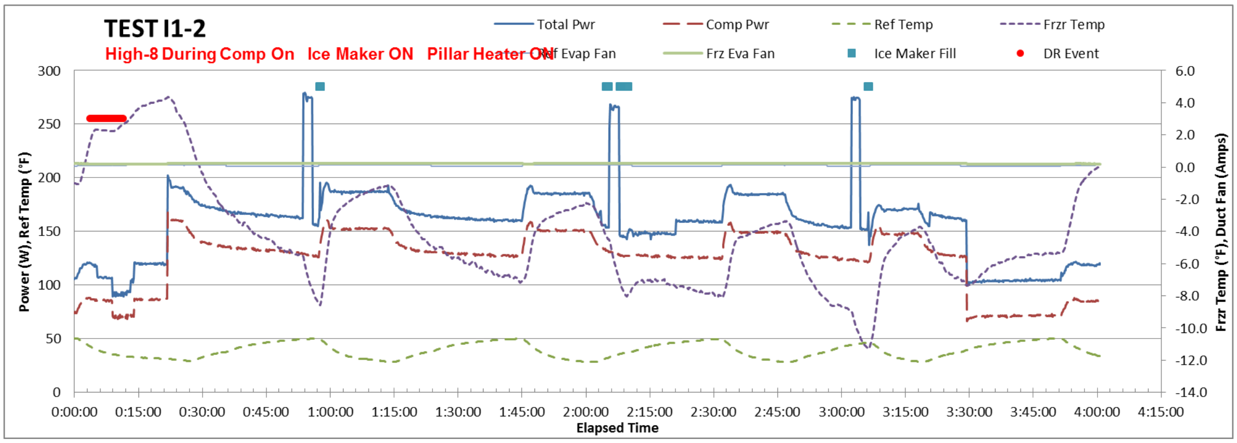


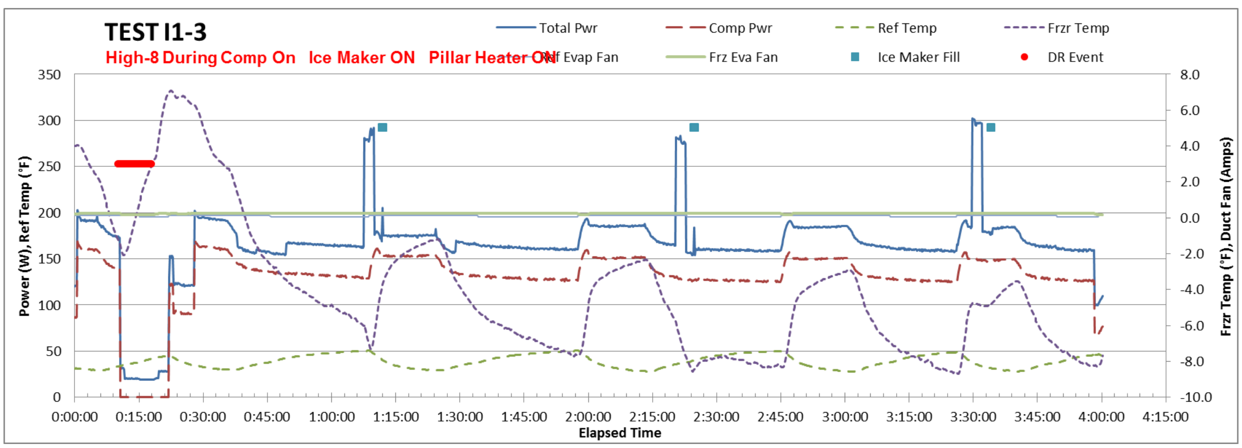


Data Category	TEST J-1	TEST J-2	TEST J-3	TEST J Avg	TEST J-1 Deviation From Average	TEST J-2 Deviation From Average	TEST J-3 Deviation From Average
	Baseline 105/19.5 Ice Maker OFF Pillar Heater OFF	Baseline 105/19.5 Ice Maker OFF Pillar Heater OFF	Baseline 105/19.5 Ice Maker OFF Pillar Heater OFF				
Test							
Date	4/16/13	4/16/13	4/16/13				
Start Time	9:28:26	14:07:24	18:18:54				
Duration	4:06:38	4:00:50	4:01:30				
Compressor Run Time	4:06:38	4:00:50	4:01:30	4:02:59	1.5%	-0.9%	-0.6%
Average Power							
Compressor Average Power (W)	80	80	77	79	0.8%	1.1%	-2.0%
Total Average Power (W)	92	92	89	91	0.7%	1.3%	-2.0%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	92	92	89	91	0.7%	1.3%	-2.0%
Energy							
Compressor Energy (Wh)	327	320	312	320	2.2%	0.3%	-2.5%
Total Energy (Wh)	377	371	360	369	2.2%	0.4%	-2.6%
Room							
Average Room Temp	105.3	105.3	105.3	105.3	0.0%	0.0%	0.0%
Average Room RH	19.5	19.5	19.5	19.5	0.1%	-0.2%	0.1%
Water Properties							
Total Water Flow (gal)	0.0	0.0	0.0	0.0	#DIV/0!	#DIV/0!	#DIV/0!
Ref / Frzr Cabinet							
Avg Ref Temperature (°F)	40.8	40.4	40.8	40.7	0.3%	-0.6%	0.3%
Avg Frzr Temperature (°F)	0.7	1.0	1.0	0.9	-21.1%	7.3%	13.8%

A.7 – High-8 DR Events at Extreme Garage Conditions

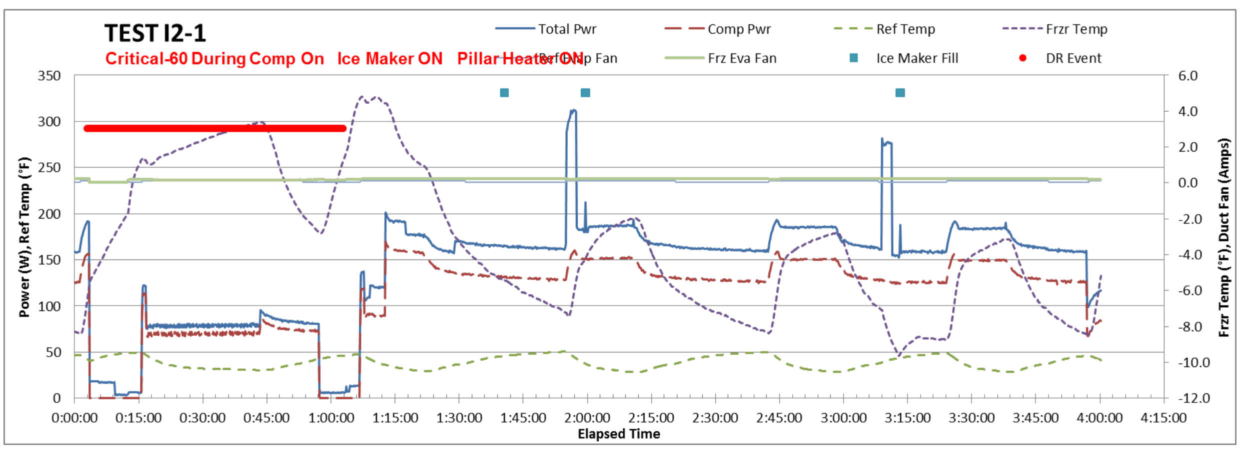


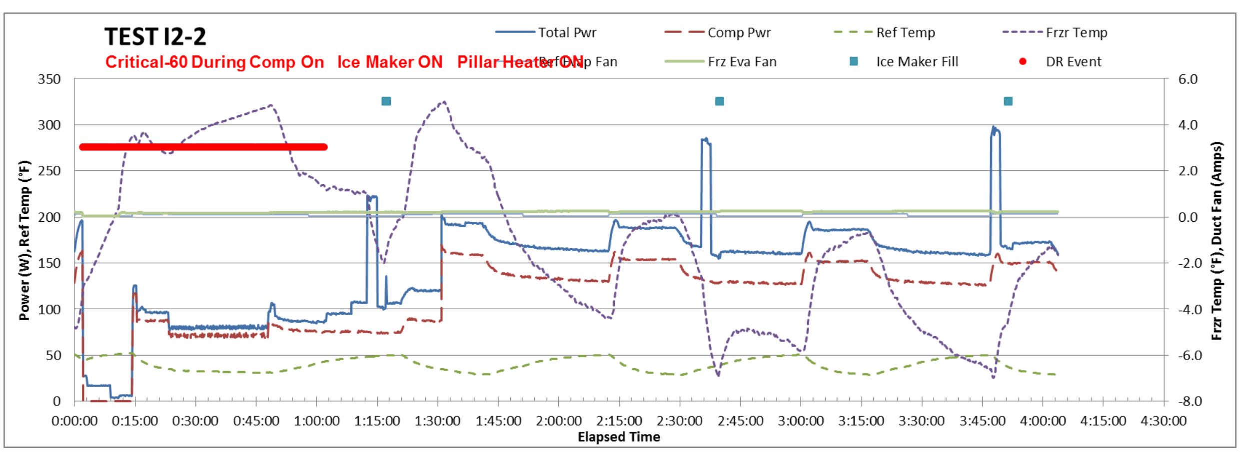


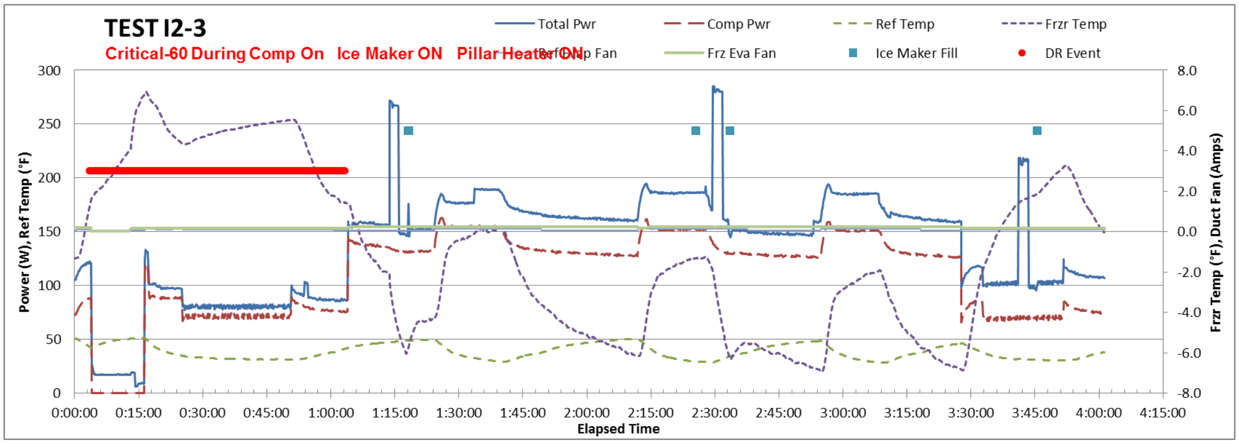


Data Category	TEST I1-1	TEST I1-2	TEST I1-3	TEST I1 Avg	TEST I1-1 Deviation From Average	TEST I1-2 Deviation From Average	TEST I1-3 Deviation From Average	TEST I Avg	TEST I1 Avg Deviation From TEST I Avg
	High-8 During Comp On Ice Maker ON Pillar Heater ON	High-8 During Comp On Ice Maker ON Pillar Heater ON	High-8 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	5/30/13	5/30/13	5/31/13						
Start Time	7:36:40	14:06:28	7:12:57						
Duration	4:00:10	4:00:40	4:00:10						
Compressor Run Time	4:00:10	4:00:40	3:48:50	3:56:33	1.5%	1.7%	-3.3%	4:01:56	-2.2%
Average Power									
Compressor Average Power (W)	118	124	130	124	-4.7%	0.0%	4.8%	109	13.6%
Total Average Power (W)	152	159	165	159	-4.0%	0.1%	3.9%	145	9.5%
Avg Total Power During DR Event (W)	134	104	31	90	49.7%	16.1%	-65.7%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	153	161	169	161	-5.0%	-0.2%	5.2%	145	11.1%
Energy									
Compressor Energy (Wh)	474	499	521	498	-4.8%	0.1%	4.7%	442	12.6%
Total Energy (Wh)	610	637	660	635	-4.0%	0.2%	3.8%	585	8.6%
Room									
Average Room Temp	105.1	105.2	105.2	105.2	0.0%	0.0%	0.0%	105.2	0.0%
Average Room RH	21.0	21.9	21.6	21.5	-2.5%	1.9%	0.6%	19.5	10.1%
Water Properties									
Total Water Flow (gal)	0.1	-4.0	0.1	-1.3	-105.2%	210.5%	-105.3%	-0.1	1876.8%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	41.3	41.4	41.2	41.3	0.0%	0.3%	-0.3%	40.8	1.3%
Avg Frzr Temperature (°F)	-2.3	-3.2	-2.6	-2.7	-15.8%	18.8%	-3.0%	-0.3	698.4%

A.8 – Critical-60 DR Events at Extreme Garage Conditions

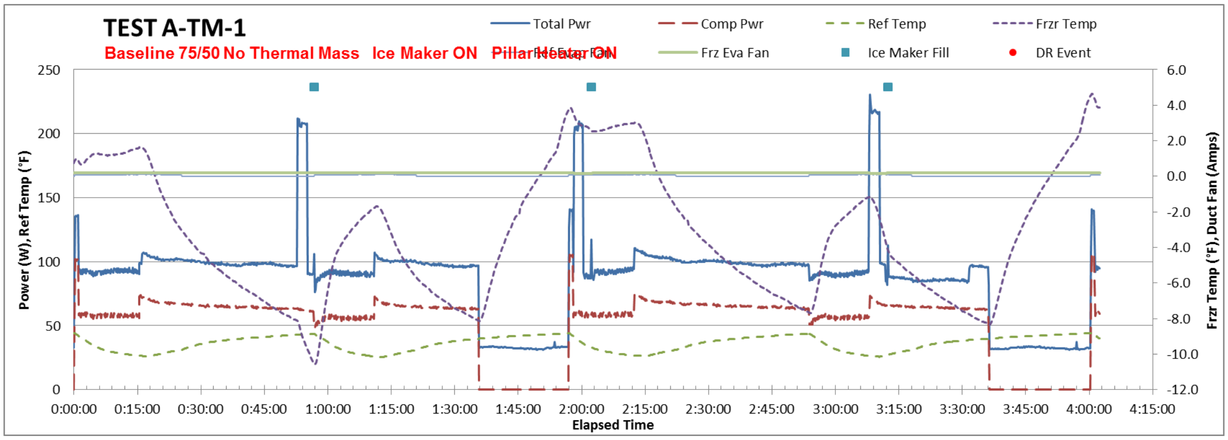


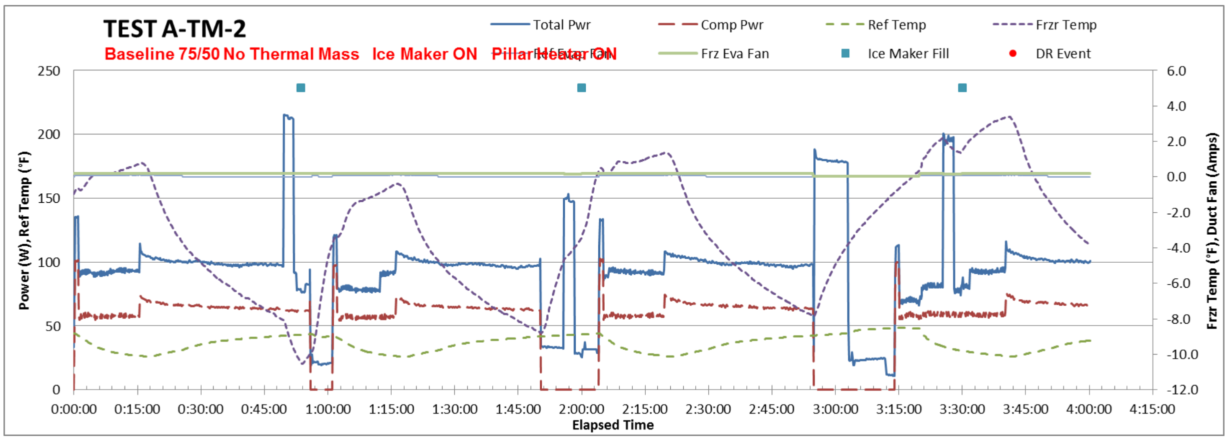


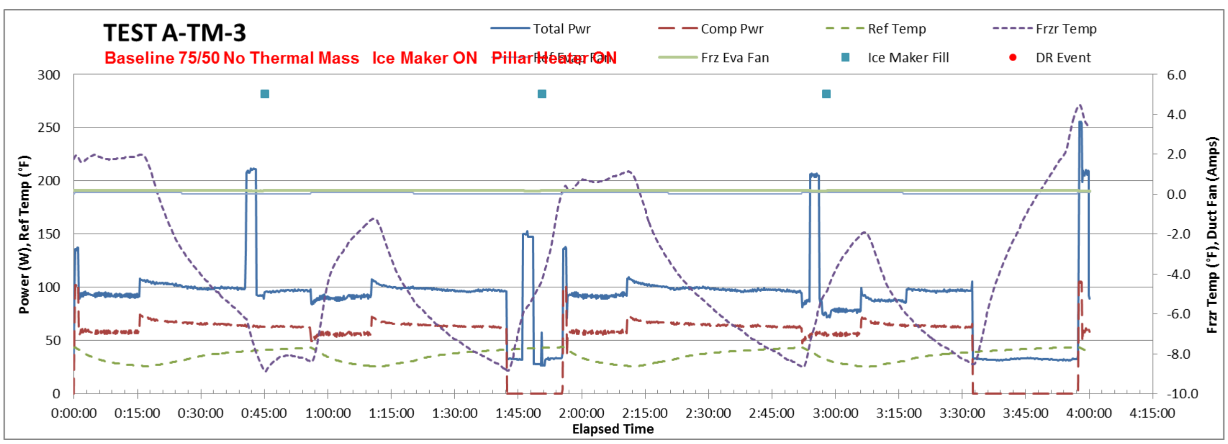


Data Category	TEST I2-1	TEST I2-2	TEST I2-3	TEST I2 Avg	TEST I2-1 Deviation From Average	TEST I2-2 Deviation From Average	TEST I2-3 Deviation From Average	TEST I Avg	TEST I2 Avg Deviation From TEST I Avg
	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	5/31/13	6/3/13	6/4/13						
Start Time	16:10:06	11:28:02	11:54:39						
Duration	4:00:10	4:03:41	4:01:19						
Compressor Run Time	3:38:30	3:51:21	3:48:49	3:46:13	-3.4%	2.3%	1.1%	4:01:56	-6.5%
Average Power									
Compressor Average Power (W)	112	114	109	112	0.4%	1.7%	-2.1%	109	2.0%
Total Average Power (W)	141	143	138	141	0.2%	1.9%	-2.1%	145	-3.0%
Avg Total Power During DR Event (W)	61	72	73	68	-11.1%	4.7%	6.3%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	168	167	159	164	1.9%	1.4%	-3.3%	145	13.5%
Energy									
Compressor Energy (Wh)	449	462	439	450	-0.2%	2.6%	-2.4%	442	1.8%
Total Energy (Wh)	564	582	553	566	-0.4%	2.8%	-2.4%	585	-3.2%
Room									
Average Room Temp	105.2	105.1	105.1	105.1	0.0%	0.0%	0.0%	105.2	-0.1%
Average Room RH	21.5	20.2	20.9	20.9	3.1%	-3.3%	0.1%	19.5	6.7%
Water Properties									
Total Water Flow (gal)	0.0	0.1	0.1	0.1	-22.1%	13.0%	9.1%	-0.1	-193.9%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	41.4	42.1	41.5	41.6	-0.7%	1.0%	-0.3%	40.8	2.1%
Avg Frzr Temperature (°F)	-2.3	-0.6	-0.6	-1.2	98.5%	-50.7%	-47.8%	-0.3	246.3%

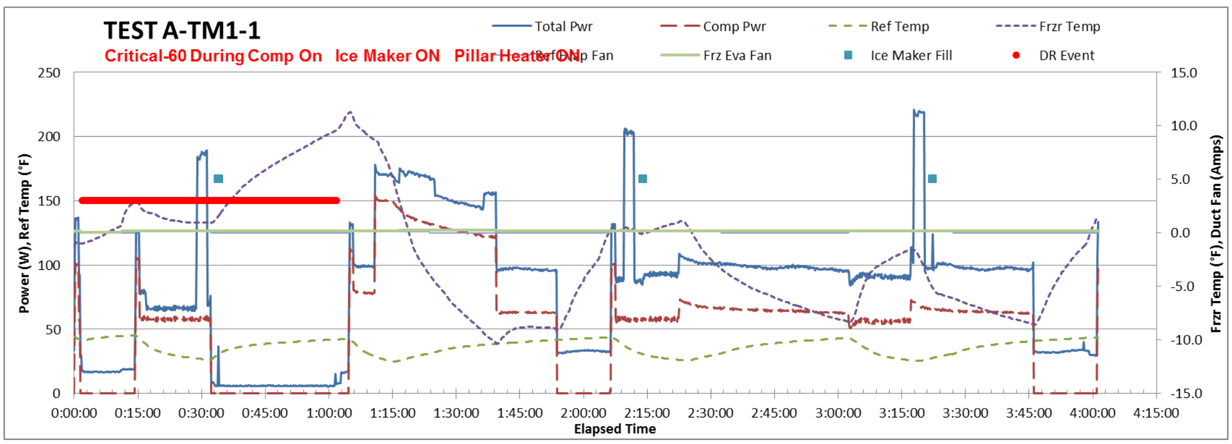
A.9 –Tests with No Thermal Mass

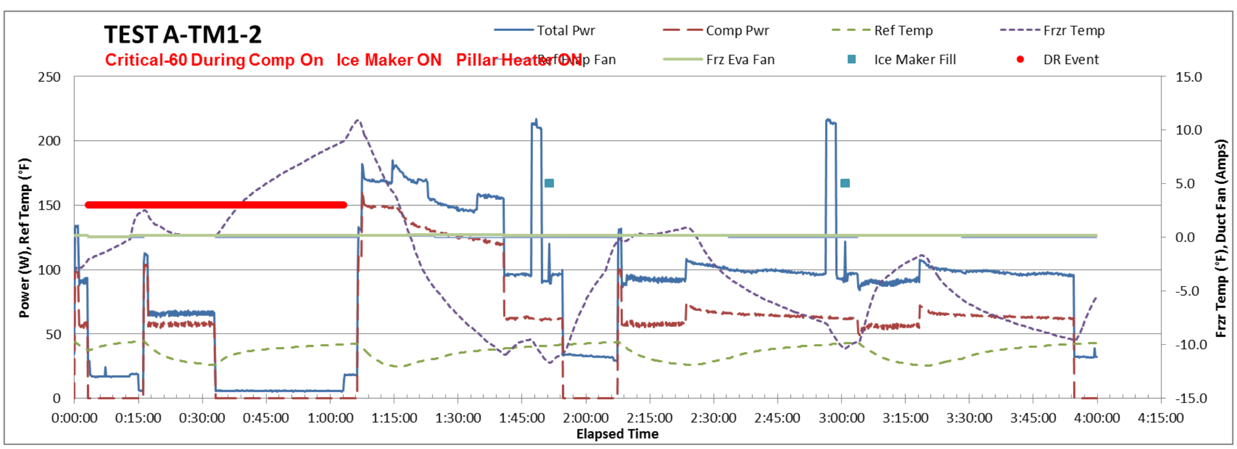


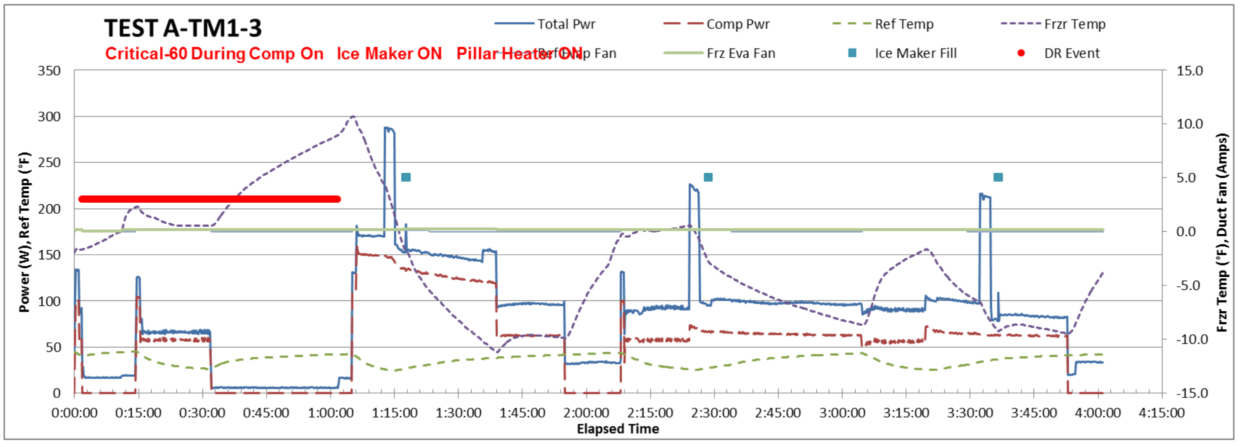




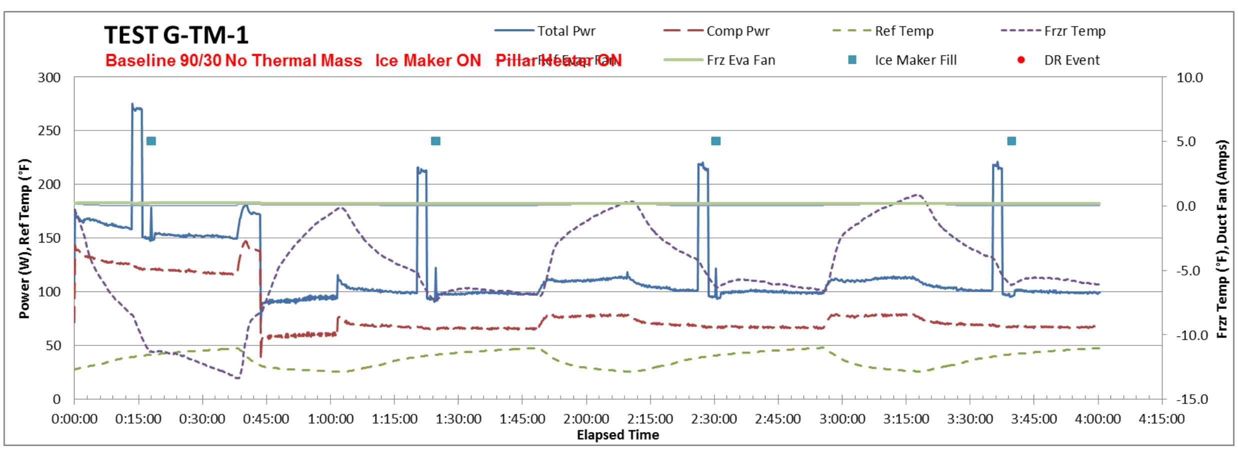
Data Category	TEST A-TM-1 Baseline 75/50 No Thermal Mass Ice Maker ON Pillar Heater ON	TEST A-TM-2 Baseline 75/50 No Thermal Mass Ice Maker ON Pillar Heater ON	TEST A-TM-3 Baseline 75/50 No Thermal Mass Ice Maker ON Pillar Heater ON	TEST A-TM Avg	TEST A-TM-1 Deviation From Average	TEST A-TM-2 Deviation From Average	TEST A-TM-3 Deviation From Average	TEST A Avg	TEST A-TM Avg Deviation From TEST A Avg
Test									
Date	6/27/13	6/27/13	6/28/13						
Start Time	10:41:45	18:39:04	0:52:04						
Duration	4:02:30	4:00:10	4:00:09						
Compressor Run Time	3:17:10	3:21:50	3:22:09	3:20:23	-1.6%	0.7%	0.9%	3:06:10	7.6%
Average Power									
Compressor Average Power (W)	52	53	53	53	-1.8%	1.3%	0.5%	50	4.8%
Total Average Power (W)	88	93	90	90	-2.8%	2.9%	-0.1%	87	4.3%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	88	93	90	90	-2.8%	2.9%	-0.1%	87	4.3%
Energy									
Compressor Energy (Wh)	209	214	212	212	-1.5%	1.2%	0.3%	203	4.6%
Total Energy (Wh)	354	372	362	363	-2.4%	2.7%	-0.3%	349	4.0%
Room									
Average Room Temp	75.3	75.3	75.3	75.3	0.0%	0.0%	0.0%	75.4	-0.1%
Average Room RH	52.8	52.1	52.1	52.3	0.9%	-0.4%	-0.5%	52.6	-0.6%
Water Properties									
Total Water Flow (gal)	0.1	0.1	0.1	0.1	0.0%	0.0%	0.0%	-0.1	-205.1%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	36.3	36.6	36.0	36.3	-0.1%	0.9%	-0.8%	39.9	-8.9%
Avg Frzr Temperature (°F)	-1.9	-1.8	-2.5	-2.1	-8.6%	-12.7%	21.3%	0.1	-1637.5%

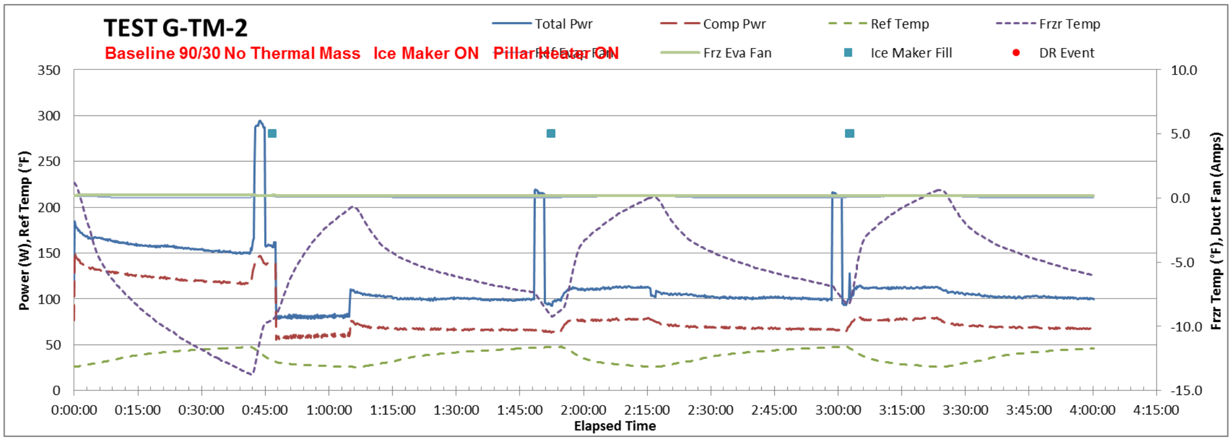


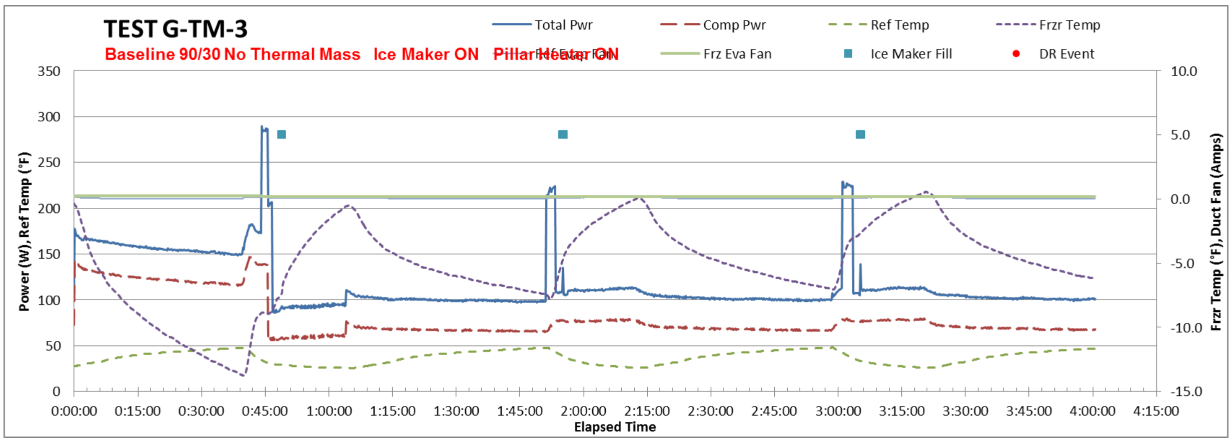




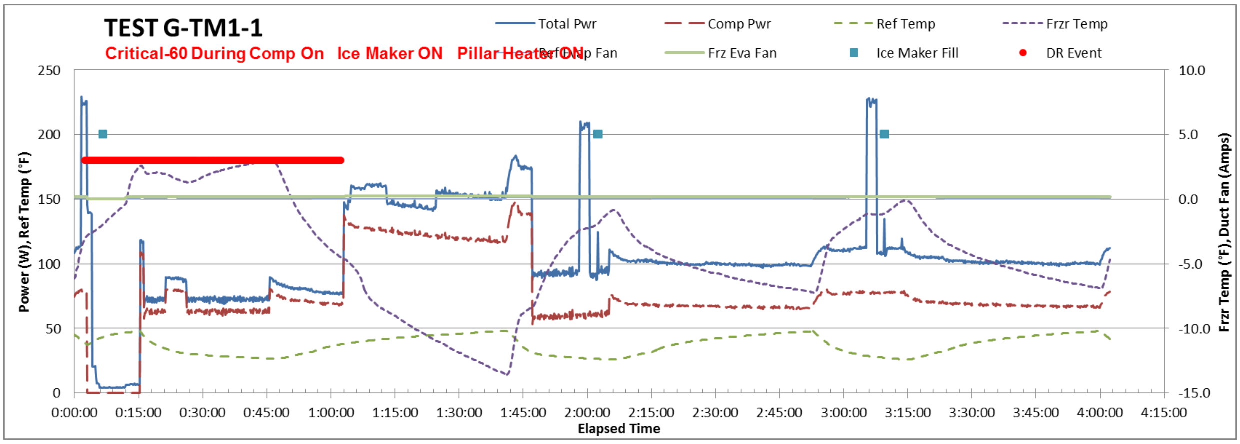
Data Category	TEST A-TM1-1	TEST A-TM1-2	TEST A-TM1-3	TEST A-TM1 Avg	TEST A-TM1-1 Deviation From Average	TEST A-TM1-2 Deviation From Average	TEST A-TM1-3 Deviation From Average	TEST A Avg	TEST A-TM1 Avg Deviation From TEST A Avg
	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	7/2/13	7/3/13	7/5/13						
Start Time	13:37:06	15:10:45	14:14:10						
Duration	4:01:20	3:59:50	4:01:10						
Compressor Run Time	2:48:23	2:55:00	2:54:08	2:52:30	-2.4%	1.4%	0.9%	3:06:10	-7.3%
Average Power									
Compressor Average Power (W)	53	56	55	54	-3.1%	2.3%	0.9%	50	8.1%
Total Average Power (W)	83	84	83	83	-1.0%	1.2%	-0.1%	87	-3.7%
Avg Total Power During DR Event (W)	33	26	27	29	14.9%	-10.2%	-4.8%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	99	104	102	102	-2.6%	2.3%	0.3%	87	17.3%
Energy									
Compressor Energy (Wh)	212	223	220	218	-2.9%	1.9%	1.0%	203	7.8%
Total Energy (Wh)	332	338	335	335	-0.8%	0.8%	0.0%	349	-4.0%
Room									
Average Room Temp	75.3	75.3	75.3	75.3	0.0%	0.0%	0.0%	75.4	-0.1%
Average Room RH	52.9	52.5	52.6	52.7	0.4%	-0.3%	-0.1%	52.6	0.1%
Water Properties									
Total Water Flow (gal)	-0.1	0.0	-0.1	-0.1	11.0%	-26.0%	15.1%	-0.1	-7.0%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	36.6	36.4	36.5	36.5	0.2%	-0.3%	0.0%	39.9	-8.5%
Avg Frzr Temperature (°F)	-0.8	-1.8	-1.7	-1.4	-46.1%	26.9%	19.2%	0.1	-1137.5%

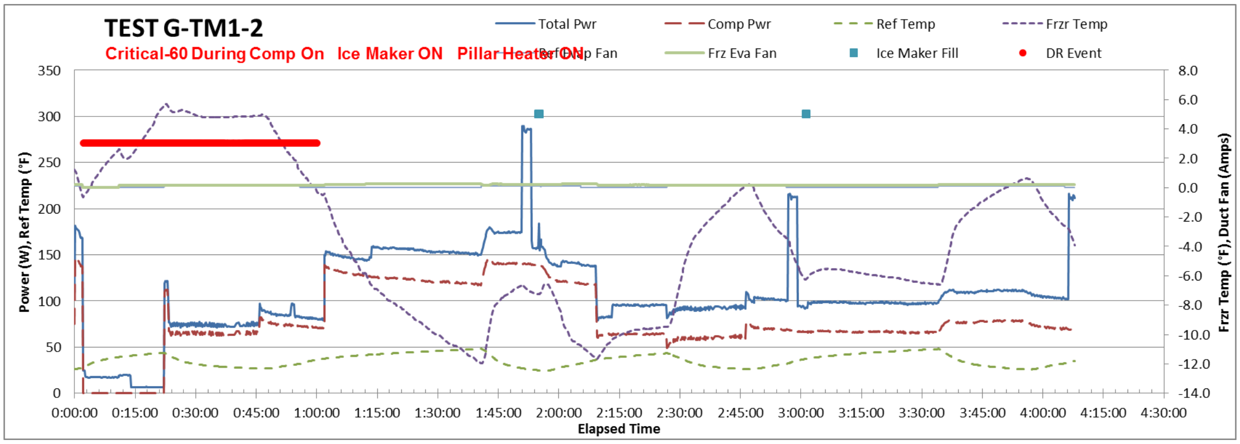


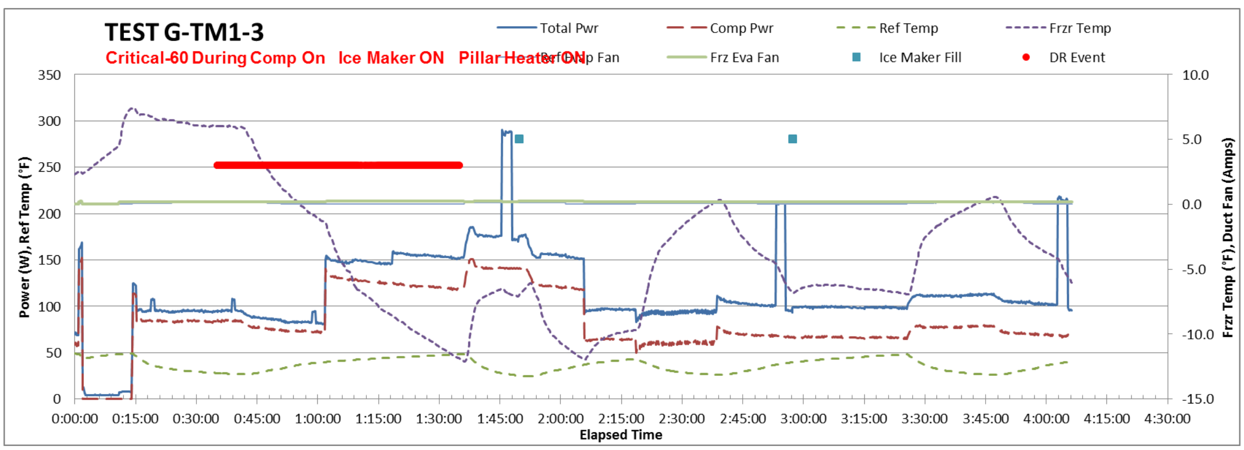




Data Category	TEST G-TM-1	TEST G-TM-2	TEST G-TM-3	TEST G-TM Avg	TEST G-TM-1 Deviation From Average	TEST G-TM-2 Deviation From Average	TEST G-TM-3 Deviation From Average	TEST G Avg	TEST G-TM Avg Deviation From TEST G Avg
	Baseline 90/30 No Thermal Mass Ice Maker ON Pillar Heater ON	Baseline 90/30 No Thermal Mass Ice Maker ON Pillar Heater ON	Baseline 90/30 No Thermal Mass Ice Maker ON Pillar Heater ON						
Test									
Date	7/12/13	7/15/13	7/15/13						
Start Time	19:41:30	18:04:45	22:38:55						
Duration	4:00:20	4:00:10	4:00:30						
Compressor Run Time	4:00:20	4:00:10	4:00:30	4:00:20	0.0%	-0.1%	0.1%	4:02:36	-0.9%
Average Power									
Compressor Average Power (W)	80	81	80	80	-0.8%	0.7%	0.1%	68	17.4%
Total Average Power (W)	117	117	117	117	0.1%	-0.2%	0.1%	104	12.4%
Avg Total Power During DR Event (W)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	117	117	117	117	0.1%	-0.2%	0.1%	104	12.4%
Energy									
Compressor Energy (Wh)	318	323	321	321	-0.8%	0.6%	0.1%	276	16.2%
Total Energy (Wh)	469	467	469	468	0.1%	-0.3%	0.1%	420	11.4%
Room									
Average Room Temp	90.2	90.4	90.4	90.4	-0.1%	0.1%	0.1%	90.1	0.2%
Average Room RH	32.6	32.1	30.8	31.8	2.4%	0.8%	-3.2%	30.0	6.0%
Water Properties									
Total Water Flow (gal)	-0.1	-0.1	-0.1	-0.1	23.9%	-12.0%	-12.0%	-0.1	-4.2%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	37.6	37.5	37.5	37.5	0.2%	-0.1%	0.0%	40.6	-7.7%
Avg Frzr Temperature (°F)	-3.2	-3.4	-3.3	-3.3	-2.4%	2.4%	-0.1%	-0.4	638.4%


TEST G-TM1-1
Critical-60 During Comp On Ice Maker ON Pillar Heater ON
Total Pwr
Comp Pwr
Ref Temp
Frzr Temp
Ref Dmp Fan
Frz Eva Fan
Ice Maker Fill
DR Event
Power (W), Ref Temp (°F)
Frzr Temp (°F), Duct Fan (Amps)
Elapsed Time


TEST G-TM1-2
Critical-60 During Comp On Ice Maker ON Pillar Heater ON
Total Pwr
Comp Pwr
Ref Temp
Frzr Temp
Ref Dmp Fan
Frz Eva Fan
Ice Maker Fill
DR Event
Power (W), Ref Temp (°F)
Frzr Temp (°F), Duct Fan (Amps)
Elapsed Time


TEST G-TM1-3
Critical-60 During Comp On Ice Maker ON Pillar Heater ON
Total Pwr
Comp Pwr
Ref Temp
Frzr Temp
Ref Dmp Fan
Frz Eva Fan
Ice Maker Fill
DR Event
Power (W), Ref Temp (°F)
Frzr Temp (°F), Duct Fan (Amps)
Elapsed Time

Data Category	TEST G-TM1-1	TEST G-TM1-2	TEST G-TM1-3	TEST G-TM1 Avg	TEST G-TM1-1 Deviation From Average	TEST G-TM1-2 Deviation From Average	TEST G-TM1-3 Deviation From Average	TEST G-TM Avg	TEST G-TM1 Avg Deviation From TEST G-TM Avg
	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON	Critical-60 During Comp On Ice Maker ON Pillar Heater ON						
Test									
Date	7/16/13	7/17/13	7/18/13						
Start Time	7:20:32	10:22:41	9:49:59						
Duration	4:02:20	4:07:50	4:06:20						
Compressor Run Time	3:49:59	3:47:30	3:54:00	3:50:30	-0.2%	-1.3%	1.5%	4:00:20	-4.1%
Average Power									
Compressor Average Power (W)	76	80	83	79	-4.6%	0.4%	4.3%	80	-1.1%
Total Average Power (W)	106	108	113	109	-2.9%	-0.7%	3.5%	117	-7.1%
Avg Total Power During DR Event (W)	67	56	122	82	-17.9%	-31.6%	49.6%	#DIV/0!	#DIV/0!
Avg Total Power Excluding DR Event (W)	118	123	110	117	1.1%	5.3%	-6.4%	117	0.2%
Energy									
Compressor Energy (Wh)	305	328	341	325	-6.0%	1.0%	5.0%	321	1.1%
Total Energy (Wh)	426	444	463	444	-4.1%	-0.1%	4.2%	468	-5.1%
Room									
Average Room Temp	90.4	91.2	90.8	90.8	-0.5%	0.4%	0.0%	90.4	0.5%
Average Room RH	31.2	24.4	29.5	28.4	9.9%	-13.9%	4.0%	31.8	-10.8%
Water Properties									
Total Water Flow (gal)	-0.1	0.0	0.0	-0.1	28.6%	-16.7%	-11.9%	-0.1	-31.5%
Ref / Frzr Cabinet									
Avg Ref Temperature (°F)	37.9	36.9	37.5	37.5	1.3%	-1.5%	0.2%	37.5	-0.2%
Avg Frzr Temperature (°F)	-2.7	-2.3	-2.2	-2.4	12.6%	-3.5%	-9.1%	-3.3	-27.4%