2016

An investigative analysis of an advanced trim and respond control strategy for variable air volume HVAC systems

Nicholas Haberl
Iowa State University

An investigative analysis of an advanced trim and respond control strategy for variable air volume HVAC systems

by

Nicholas Haberl

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Mechanical Engineering

Program of Study Committee:
Song-Charng Kong, Co-major Professor
Gregory Maxwell, Co-major Professor
Soumik Sarkar

Iowa State University

Ames, Iowa

2016

DEDICATION

To my parents,

Scott and Kirsten Haberl,

without whom my success would not be possible.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

NOMENCLATURE

" WC	Inches water column
AFRC	Armed Forces Readiness Center
Ahr	Amp hour
AHU	Air handling unit
BACnet	Building Automation and Control network
CBECS	Commercial Buildings Energy Consumption Survey
CPL	Custom programming language
cfm	Cubic feet per minute
CT	Current transformer
DAS	Data acquisition system
DDC	Direct digital control
DX	Direct expansion
EER	Energy efficiency ratio
ERV	Energy recovery ventilation
ESTCP	Environmental Security Technology Certification Program
FSP	Fixed static pressure
HRV	Heat recovery ventilator
HVAC	Heating ventilation and air conditioning
IAARNG	Iowa Army National Guard
IEC	Iowa Energy Center
JFHQ	Joint Forces Headquarters

kW	Kilowatt
kWh	Kilowatt-hour
LEED	Leadership in Energy & Environmental Design
MAU	Make-up air unit
MBH	Mega British thermal unit per hour
MDP	Most open damper position
MEPS	Military Entrance Processing Station
RC	Readiness Center
RP	Respond rate
RTU	Rooftop unit
SPmax	Static pressure maximum
SPmin	Static pressure minimum
SPset	Static pressure setpoint
TAB	Terminal air box
TM	Trim rate
TTR	Tiered trim and respond
TR	Trim and respond
VAC	Volts of alternating current
VAV	Variable air volume
VFD	Variable frequency drive

ACKNOWLEDGMENTS

I would like to thank my major professors, Dr. Song-Charng Kong and Dr. Gregory Maxwell, and my committee member, Dr. Soumik Sarkar, for their guidance and support throughout the course of this research.

I would also like to thank Iowa Energy Center staff, Dr. Xiaohui Zhou and Troy Barker, Iowa Army National Guard staff, Kimberly Dickey, Jeff Hedens, Dave Umland, David Shea, Scott Repp and Eric Challen, and Taylor Engineering Inc. staff, Hwkong Cheng and Jeff Stein for their guidance, discussions and cooperation without whom, this thesis would not have been possible.

ABSTRACT

Energy efficiency, particularly HVAC energy use in buildings, offers a large potential of reducing overall energy consumption. By optimizing fan controls in variable air volume (VAV) HVAC systems, up to 30 to 50% of fan energy can be saved using trim and respond (TR) strategies compared to constant pressure strategies. The tiered trim and respond (TTR) strategy has shown promise in realizing significant fan energy savings in real buildings without issues of static pressure oscillation.

This study proposed the demonstration of the TTR strategy at five Iowa Army National Guard facilities comparing against fixed static pressure (FSP) and traditional TR strategies over a ten-month period. The DDC and HVAC systems at each site were equipped with the necessary hardware and software needed to properly test and record all data needed. Functional mode and power verification testing were conducted to confirm the correct implementation of the TTR method and fan power readings from the DDC system and installed data logging systems.

After a ten-month period, the fan energy savings results for the TTR and FSP comparison were as follows: Boone RC AHU-1 20.86% and AHU-2 10.69%, Des Moines MEPS AHU-1 27.30%, JFHQ AHU-1 4.73%, AHU-4 12.83%, AHU-9 59.92% and AHU-12 15.83%, Muscatine AFRC RTU-1 18.91%, RTU-3 29.46%, RTU-4 36.54% and Waterloo RC RTU-1 33.80%. The fan energy savings results of the TTR and TR comparisons are as follows: JFHQ AHU-2 -25.90% and AHU-3 -47.27%. The temperature control comparisons results on the TTR and TR comparison air handling units (AHUs) are as follows: JFHQ AHU-2 4.35% and AHU-3 7.76%.

While the original proposal of 30 to 50% of fan energy savings is possible, a value closer to 20 to 30% fan energy savings is more realistic. Numerous instances of mechanical failure, setpoint alterations, scheduling errors and other issues that while hindered the capabilities of the TTR strategy, reflected the true nature of a real building. The study showed that the TTR strategy is most successful with less number of VAV zones and proper control of AHU supply air temperature. One recommendation is to recommission heating or cooling airflow setpoints so the VAV zone damper is not left wide open when under the control of the TTR strategy.

Static pressure control was as expected on 3 of the 5 sites studied. The TTR strategy was able to respond to building loads while minimizing or eliminating issues with static pressure oscillation. However, the TTR strategy displayed numerous instances of frequent static pressure oscillation, especially at sites that had difficulty in controlling zone temperatures from inactive boiler or chiller service. The results from the TTR and TR comparison showed that temperature control with a radiant in-floor heating system was difficult for both static pressure reset strategies studied.

In future studies, boiler and chiller data including: operation, temperature, setpoints, etc. should be trended. A comparison of the TTR strategy with fixed supply air temperature and an outside air based supply air temperature reset strategy would be insightful. Parameters such as the TM and RP rates, Step Timer and damper position thresholds could be refined to maintain a quick response to changing building loads. Lastly, as industries and professional standards progress with improved building standards, the focus of future studies should shift from comparing against fixed static pressure strategies to existing static pressure reset strategies in not only fan energy savings, but whole building energy savings as well.

CHAPTER 1

INTRODUCTION

1.1 Background

With rising awareness of the United States' growing demand for energy and the resulting carbon emissions, strong steps have been taken to improve areas in energy efficiency, grid distribution and power generation. One area in particular, energy efficiency, has shown to be one of the most cost effective ways of reducing our carbon footprint by directly reducing energy consumption. However, much more work is needed within the broad field of energy efficiency.

In 2012, the commercial sector comprised of 18% of the total energy consumed by the US (EIA, 2016). This includes primary and electrical energy, providing a great potential for reducing overall energy consumption. Within the commercial sector, energy consumption tied to HVAC systems resulted in 44% of the total use in commercial buildings in 2012. Ventilation alone accounted for 16% of electricity use and 10% of total energy use in commercial buildings (EIA, 2016).

Energy efficiency tied to HVAC systems provides a large potential to reduce overall energy use and must be effective in not only buildings of varying function and size, but in age as well. From the 2012 Commercial Building Energy Consumption Survey (CBECS), over half of the US commercial building stock was constructed before 1980 (EIA, 2016).

In a typical commercial building's HVAC system with a variable air volume (VAV) system, each room or zone's airflow is controlled by a VAV terminal air unit or box. As a VAV zones temperature deviates from its temperature setpoints, the VAV box "requests" for either cooling or heating airflow. Providing this airflow is a supply fan within the HVAC system's air handling unit (AHU) that is controlled by a variable frequency drive (VFD). The VFD controls the speed of the supply fan and therefore the static pressure rise needed to alleviate building load demand. The direct digital control (DDC) system controls the VFD via speed command signal. In many commercial facilities the command signal to the VFD is controlled to maintain a constant static pressure, or a fixed static pressure (FSP). This setpoint is usually meant to satisfy the most critical building loads during cold, winter or warm, summer days.

However, this setpoint is not needed during most days, creating excessive static pressure rise in the supply fan and wasting energy. One way to improve energy efficiency, particularly within HVAC systems, is to optimize the fan control in VAV air handling and rooftop units. This can be achieved by minimizing the static pressure rise in supply fans needed to meet building load demands.

1.2 Literature Review

According to both the ASHRAE Standard 90.1 2004 and California Building Title 24 Section 140.4-(c), commercial buildings with VAV systems that have direct digital controls (DDC) at the zone level must implement strategies to reset static pressure to meet the demand of the most open damper; "i.e. the [static pressure] setpoint is reset lower until one *zone* damper is nearly wide open." (ASHRAE 2004, CEC 2013).

Academic and professional studies have shown that resetting the static pressure in VAV systems can significantly reduce fan energy use from 30 to 50% compared to existing constant pressure strategies (Taylor, 2007). Control strategies resetting static pressure from zonal based demand also outperformed other reset control strategies based on system wide and outside air temperature based demand in energy savings (Kimla, 2009). Not only does resetting the static pressure reduce fan energy use, but other benefits are observed as well. Liu (2010) demonstrated that noticeable savings in thermal energy and reduction in duct leakage occur in air handlers using static pressure reset strategies. As such, reducing static pressure in HVAC systems based on zonal demand has taken a foothold in many professional industries.

One zonal demand based reset strategy, the tiered trim and respond (TTR) strategy, has shown promise in saving fan energy while minimizing static pressure oscillation that typically plague traditional trim and respond (TR) static pressure reset strategies. The TTR strategy showed significant energy savings over other tested PID and TR strategies, while minimizing static pressure oscillation in a laboratory setting (Nelson & Housholder, 2011). When demonstrated in a real building on the campus of Iowa State University, the TTR strategy showed fan energy savings of 37% and improved thermal comfort over an existing FSP strategy. Additionally, the TTR strategy did not display any issues concerning "hunting" or excessive damper oscillation.

The research from Nelson and Housholder (2011) introduced the TTR strategy in a building that was recently constructed and proposed that 30 to 50% fan energy savings could be realized with the TTR strategy over existing fixed static pressure control methods. However, as stated earlier, many commercial facilities installed today are at least 35 years of age or older. The facility originally tested was of relatively newer construction, contained 51 VAV boxes, and a DDC system capable of collecting data every five seconds. The functions of the facility mainly pertained to offices, conference rooms and computer labs. To improve upon this new strategy, a study is needed to compare the fan energy savings performance involving a wide breadth of commercial building functions, age, DDC system manufacturers, VAV system complexities and AHU sizes.

1.3 Research Objectives

This study proposes the demonstration of the TTR strategy at multiple facilities under the Iowa Army National Guard over a ten month period. In doing so, these facilities will be sampled to reflect a wide variety of typical functions, DDC systems, age, floor space and HVAC equipment installed in commercial buildings across the nation. The objective of this study is to determine the viability of the TTR strategy, and achieve a more thorough understanding of its performance. Key quantitative metrics include fan energy savings and temperature control performance based on comparisons from existing FSP and TR strategies. It is predicted that fan energy savings of at least 30% are achievable over conventional FSP strategies implemented in many commercial facilities. Qualitative results will be observed in determining the overall performance of the static pressure control from the TTR strategy as well. Lastly, a summary of discovered issues throughout the study will be logged to better understand the system wide effects of the TTR strategy.

CHAPTER 2

EXPERIMENTAL SETUP

2.1 Experimental Procedure

In this study, fan energy consumption and zone temperature control of the TTR strategy was compared to existing FSP and TR strategies that are common throughout many commercial and Iowa Army National Guard facilities. By alternating between two static pressure control strategies every two weeks while recording fan energy use, zone temperature, VAV box damper positions and other relevant HVAC data, a comparative study mitigating the effects of abnormal weather, occupant usage, and other factors can be achieved. To obtain an accurate depiction of the potential fan energy savings of the TTR strategy, a selection criterion was used in determining which Iowa Army National Guard facilities were adequate for the study.

Once a number of facilities were chosen, a site investigation was conducted to determine the viability and any additional equipment and software that would be needed at each site. HVAC and DDC system equipment and software were inspected to affirm the capabilities needed to complete the study. The facilities' technical documents regarding construction drawings, mechanical specifications, and HVAC equipment layouts were also reviewed. After the appropriate investigations were completed and technical documents reviewed, it was decided to either install any necessary equipment or software to properly conduct the study or select another Iowa Army National Guard facility.

After the installation of any necessary equipment and software, local HVAC contractors and technicians were hired to implement their own custom TTR program to fit the specific DDC system installed at each site. While each custom TTR program is unique in language and DDC system, the TTR strategy itself was the same across all sites. To ensure this, a standardized functional mode test was conducted at each site, confirming the correct implementation of the TTR strategy. At the same time, fan power readings from the DDC system, VFD display, and installed data logging equipment were verified with a reference power meter to ensure the accuracy of their readings.

Once the functional mode tests and power reading verifications were completed, an initial demonstration period began. During this period, functional modes alternated daily. Data collection and analysis was more frequent with the intent to discover and resolve any issues relating to hardware or HVAC equipment as soon as possible. If it was discovered the TTR program was not operating as originally intended, changes were made to alleviate issues. After enough time had passed without issues related to the functional modes, the official demonstration period began.

The official demonstration period would begin with the TTR and FSP or TR strategies alternating every two weeks. As data was continuously trended and logged by the DDC systems at each site, local facility engineers would download data weekly. Data analysis was used to compile results and confirm the correct operation of the functional modes and associated HVAC equipment. Again, any issues discovered during data analysis were dealt with accordingly.

2.2 Technology Description

The TTR strategy is an advanced static pressure reset strategy developed by Nelson and Housholder in 2011. The strategy had a profound effect on fan energy savings in a facility not dissimilar to a wide number of existing commercial buildings. The strategy works by resetting the static pressure setpoint to a minimal value based on the most open damper position of all the VAV boxes attached to a particular AHU or RTU. By using damper position information, either feedback or command signal, of all attached VAV boxes the TTR strategy is able to maintain appropriate thermal comfort at the zone level using controls information available in most conventional HVAC DDC systems. The strategy was built upon many other previously developed trim and respond strategies; however few strategies have achieved similar energy savings with minimal static pressure oscillation using this type of controls information at the zone level (Nelson & Housholder, 2011).

The TTR strategy is comprised of three functional blocks: the *Most Open Damper Position Selection*, *Static Pressure Setpoint Calculation* and *Limit Check Section*. First, in the *Most Open Damper Position Selection*, the most open damper position value is selected from all VAV boxes attached to a particular AHU or RTU. This value is labeled as the most open damper position (MDP).

Next, in the *Static Pressure Setpoint Calculation*, the MDP is compared to a set of specified ranges of [Low1, Low2, Low3] and [High1, High2, High3]. The deadband [Low1, High1] is a range where the static pressure setpoint (SPset) will remain unchanged if the MDP is between these two values. If the MDP deviates above the specified deadband [High1, High2, High3], the SPset is raised by a summation of the respond rates [RP1, RP1+RP2, RP1+RP2+RP3], respectively. Similarly, if the MDP deviates below the deadband [Low1, Low2, Low3] the SPset is reduced by a summation of trim rates [TM1, TM1+TM2, TM1+TM2+TM3], respectively. Table 2.1 provides a summary of conditions and responses of the TTR strategy.

Table 2.1 Illustration of the TTR strategy.

Condition	Response
If MDP > High3	SPSet = SPSet + RP1 + RP2 + RP3
If MDP > High2	SPSet = SPSet + RP1 + RP2
If MDP > High1	SPSet = SPSet + RP1
If High1> MDP > Low1	No change
If MDP < Low1	SPSet = SPSet - TM1
If MDP < Low2	SPSet = SPSet - TM1 - TM2
If MDP < Low3	SPSet = SPSet - TM1 - TM2 - TM3
	High3>High2>High1>Low1>Low2>Low3 (values of 95%, 92%, 90%, 85%, 83%, 80%, respectively)
MDP	Maximum Damper Position (Feedback or Command Signal)
SPSet	Static Pressure Setpoint
TM1,2,3, RP1,2,3	Trim and response rates. All positive numbers.

In Table 2.1, suggested values for the deadband [Low1, High1] are provided. These values have been altered from the suggested values of 90% and 98% from the ASHRAE Application Handbook for the traditional TR strategy to 85% and 90% (Nelson & Housholder, 2011). Figure 2.1 displays the expected airflow percentage compared to the damper position of a typical VAV box.

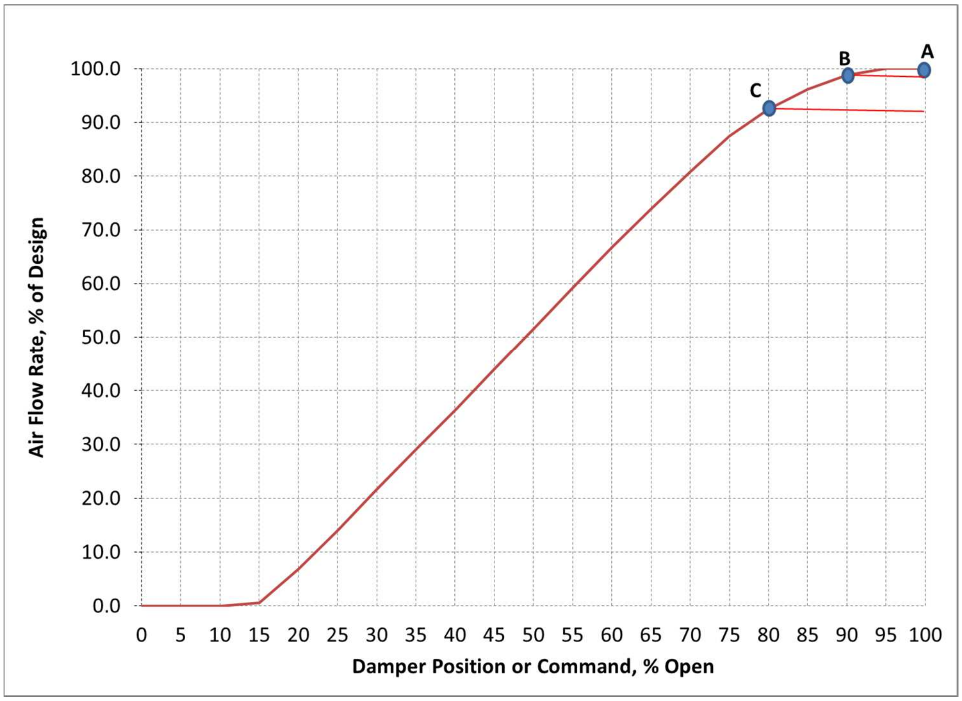

Figure 2.1 Damper position vs airflow rate for a typical VAV box.

The TTR strategy attempts to minimize issues concerning instability by shifting the deadband [Low1, High1] down the damper position axis while maintaining the relatively flat slope of the damper position vs airflow curve.

The appropriate TM and RP rates are calculated using a formula developed by Nelson and Housholder (2011), provided in Equation 2.1. The remaining TM and RP rates are provided in Equation 2.2 and 2.3.

$$\text{TM1, RP1} = \frac{(\text{SPmax-SPmin}) \times \text{Step Timer}}{900} \tag{2.1}$$

$$\text{TM2} = 2 \times \text{TM1 and RP2} = 2 \times \text{RP1} \tag{2.2}$$

$$\text{TM3} = 3 \times \text{TM1 and RP3} = 3 \times \text{RP1} \tag{2.3}$$

Equation 2.1 provides the suggested TM1 and RP1 rate using the maximum and minimum allowable static pressure setpoints (SPmax and SPmin, respectively) and the Step Timer of the TTR strategy. The denominator value comes from the rule of thumb that the supply fan should be able to traverse the entire static pressure range within 15 minutes at the lowest TM or RP rate (Nelson & Housholder, 2011).

Lastly, in the *Limit Check Section*, the strategy calculates a new SPset using the conditions and response provided in Table 2.1. The SPset is then compared to the SPmax and SPmin specified in the DDC system. If the new SPset is below the SPmin, the resulting setpoint is reverted to the SPmin. For example, if the new SPset value equals 0.36" WC and the SPmin value is 0.40" WC, the new SPset value will revert to the SPmin value of 0.40" WC. Likewise, if the SPset is above the maximum allowed static pressure setpoint, SPset is reverted to the SPmax.

All of the functional blocks described occur at a predefined interval, known as the Step Timer. This interval, typically every 1 to 5 minutes, is dependent on the capabilities of the DDC system, as many calculations have to be completed at the defined rate, and the HVAC equipment, as the supply fan and VFD must react quickly enough to achieve the new SPset value before the next Step Timer interval.

2.3 Facility Descriptions

Several demonstration sites were assessed to determine their viability to study the performance of the TTR strategy. The sites used for this study were selected based on the following criteria:

- Geographic location
- Facility function, floor space, and representativeness
- Mechanical HVAC equipment

- Commercial DDC system manufacturer

Given Iowa's climate, many commercial facilities nationwide endure similar weather. Data collected on the performance of the TTR strategy during cold winter and warm summer days are vital to the success of this study. Because the TTR strategy controls the static pressure from the zone level, the HVAC and DDC system at the facility must have the necessary control points and hardware available. This includes a forced-air mechanical system with the ability to control the static pressure setpoint command via supply fan speed by VFD and damper position feedback or command signal across all applicable VAV zones. The selected facilities must also be representative of typical commercial installations by its physical characteristics and daily functions. Lastly, a variety of commercial DDC system platforms provide a wider range of data as vendor offerings vary across the nation.

Once the demonstration sites were selected from the listed criteria, a site investigation was conducted. The objective of the investigation was to closely inspect HVAC equipment and hardware, DDC system software and their capabilities. Key items include:

- Building use and typical occupant functions
- Installed AHU/RTU specifications, setpoints, size, rating, etc.
- Supply and return fan VFD specifications, physical location
- AHU/RTU electrical panel layouts and physical locations
- DDC system capabilities, available data points, trends, history logs, memory, etc.
- Emergency power strategies, installed backup systems
- Cellular reception for potential data logging systems

The following paragraphs provide a summary of what was found at each site:

Site #1: Boone Readiness Center

Originally constructed in 1963, the Boone Readiness Center (RC) is a 77,321 sq. ft., single floor facility that serves various functions and zones: maintenance areas, kitchens, storage areas, drill halls, latrines, class rooms and administrative offices. Major remodel projects occurred in 1986 and 2005, involving VAV zone alterations, new ductwork, HVAC equipment and DDC system. This building serves as a representative sample of hundreds of National Guard buildings nationwide that are of similar construction and function. The building lies in a north – south orientation, with the north and south portions of the building containing classrooms and offices, and the center portion containing a large drill hall.

The building is served by three AHUs, two of which are VAV systems, AHU-1 and AHU-2. AHU-1 serves the northern zones of the facility, while AHU-2 serves the southern zones. The drill hall located in the center of the building is served by AHU-3, a constant air volume system, and was constructed with radiant in-floor heating. A total of 67 single-duct reheat VAV boxes are served from AHU-1 and AHU-2, 29 and 38 boxes respectively. For the purposes of this study, only AHU-1 and AHU-2 are studied as both are VAV systems.

AHU-1 is a factory built, mixed air unit with a 15 MHP supply fan and 10 MHP return fan. The unit is rated for 12,000 cfm at a max external static pressure of 2.20" WC with heating and cooling coils serving 29 pressure independent VAV boxes, each with heating coils for reheat service. The zones attached to this unit consist of classrooms, several offices, latrines, a fitness room and a kitchen.

AHU-2 is a factory built, mixed air unit with a 15 MHP supply fan and 10 MHP return fan. This unit is rated for 12,000 cfm at a max external static pressure of 1.70" WC with heating and cooling coils serving 38 pressure independent VAV boxes all with heating coils for reheat service. The zones attached to this unit are several offices, classrooms, storage rooms, vault spaces, mechanical zones, a boiler room and conference rooms.

In addition to these AHUs, the Boone RC facility has numerous exhaust fans, hoods, outside dampers, and a single make-up air unit (MAU). These primarily serve areas to alleviate indoor air quality concerns of latrines, kitchen areas, and mechanical rooms. For the purposes of this study, this equipment was not trended within the DDC system, or provided input to the TTR programs installed at this facility. Table 2.2 provides a summary of the specifications of the two AHUs studied.

Table 2.2 Boone Readiness Center AHU details.

Site	Unit		Supply Fan				Return Fan			
	ID Tag	VAVs	Fans	CFM	MHP	Ext. SP	Fans	CFM	MHP	Ext. SP
Boone RC	AHU-1	28	1	12,000	15	2.20"	1	12,000	10	1.75"
	AHU-2	38	1	12,000	15	1.70"	1	12,000	10	1.75"

Along with the AHUs, the facility also contains a shared boiler, chiller and an economizer. Both the boiler and chiller were not trended for this study. However, data from the supply air temperature were used to confirm normal operation of the boiler and chillers.

The DDC system for this facility was installed in 2005 and incorporated a fixed supply air temperature setpoint and FSP strategy for both AHUs. Occupancy schedules were often altered due to the nature of the building's functions. During the site investigation, it was determined that a 3rd party export utility and additional computer hardware were needed to trend the data points needed for this research. Many VAV boxes and their associated equipment were found to be in need of repair or replacement such as space temperature sensors, damper actuators and fire safety dampers.

Site # 2: Des Moines Military Entrance Processing Station

The Des Moines Military Entrance Processing Station (MEPS), constructed in 2008, is a 28,200 sq. ft., single floor facility. The building lies in a north – south orientation, with main entrances facing the east. The Des Moines MEPS is served by one AHU, AHU-1, located in the mechanical room, serving 34 pressure independent VAV boxes. The type of zones served our administrative offices, medical testing labs, classrooms, storage rooms and a kitchen.

AHU-1 is a factory built, mixed air unit with a 20 MHP supply fan and a 10 MHP return fan. The unit is rated to supply 22,000 cfm of air at a max external static pressure of 2.00" WC. Serving 34 pressure independent VAV boxes, each with reheat coils, the unit also contains cooling and heating coils with a humidifier and heat recovery ventilator unit (HRV). The HRV has a 5 MHP fan with a max supply of 3,000 cfm and a sensible effectiveness of 71%. 2 boilers serve AHU-1 and VAV heating coils, while a single 72 ton chiller serves the cooling coils of AHU-1. Both the boiler and chiller are controlled from a separate DDC system and were not trended for this study. However, data from the supply air temperature were used to confirm normal operation of the boiler and chillers. Table 2.3 provides the specifications for the AHU at the Des Moines MEPS.

Table 2.3 Des Moines Military Entrance Processing Station AHU details.

Site	Unit		Supply Fan				Return Fan			
	ID Tag	VAVs	Fans	CFM	MHP	Ext. SP	Fans	CFM	MHP	Ext. SP
Des Moines MEPS	AHU-1	34	1	22,000	20	2.00"	1	22,000	10	0.90"

Along with AHU-1, the facility contains 3 exhaust fans serving mechanical rooms. For the purposes of this study, this equipment was not trended within the DDC system, nor provided input to the TTR programs installed at this facility.

The DDC system at this site incorporated a fixed supply air temperature strategy and form of static pressure reset strategy. Occupant zone temperature control had since been removed. Additional software was needed to properly export the data for this study.

Site #3: Joint Forces Headquarters

The Joint Forces Headquarters (JFHQ) is the largest of the 5 facilities at 237,126 sq. ft. The multi-use, four-floor facility constructed in 1994 contains IAARNG Executive Leadership Offices, high-level offices, service bays, classrooms, training areas, drill halls and Iowa Homeland Security & Emergency Management. This emergency response and readiness support facility is similar to those in every other U.S. state. This particular facility utilizes radiant in-floor heating for a majority of the zones and a mix of VAV boxes that are cooling only, or have electric reheat.

JFHQ contains a total of 12 AHUs, 6 of which meet the criteria for this study. The ID tags for these units are as follows: AHU-1, AHU-2, AHU-3, AHU-4, AHU-9 and AHU-12. AHUs 1, 2, 3, 4 and 9 are factory built units with supply fans of 20 MHP or less. Each of these units is located on the upper most floors in separate penthouses. The following paragraphs provide a summary of these units.

AHUs 1, 2, 3, and 4 are each factory built, mixed air units with a 20 MHP supply fan. These units each contain a heating and cooling coil and are rated to supply 16,000 cfm of air at a max external static pressure of 3.00" WC. Each unit is in their own penthouse above the 2nd floor of the facility. AHU-1 serves 40 pressure independent VAV boxes with cooling only service and 2 pressure independent VAV boxes with electric reheat. AHU-2 serves 49 pressure independent VAV boxes with cooling service only and a single pressure independent VAV box with electric reheat. AHU-3 serves 37 pressure independent VAV boxes with cooling service only and a single pressure independent VAV box with electric reheat. AHU-4 serves 37 pressure independent VAV boxes with cooling service only and 4 pressure independent VAV boxes with electric reheat.

AHU-9 is a factory built, mixed air unit with a 7.5 MHP supply fan. The unit contains heating and cooling coils and can supply 5,800 cfm of air at a max external static pressure of 2.25” WC. AHU-9 serves 5 pressure independent VAV boxes with cooling service only.

AHU-12 is a custom built-up, mixed air unit with four 30 MHP supply and four 7.5 MHP return fans located in the basement of the facility. The supply fans are paired to 2 VFDs that operate in parallel, i.e. supply fans ES-1 and ES-2 are controlled by one VFD and supply fans ES-3 and ES-4 are controlled by another. This configuration also follows for the four return fans. The unit contains heating and cooling coils and is rated to deliver a total of 87,000 cfm of air at a max external static pressure of 6.00” WC. The unit also serves 29 pressure independent VAV boxes with cooling service only and 18 pressure independent VAV boxes with electric reheat coils. Table 2.4 provides the specifications of the penthouse AHUs and AHU-12.

Table 2.4 Joint Forces Headquarters AHU details.

Site	Unit		Supply Fan				Return Fan			
	ID Tag	VAVs	Fans	CFM	MHP	Ext. SP	Fans	CFM	MHP	Ext. SP
JFHQ	AHU-1	42	1	16,000	20	3.00"	-	-	-	-
	AHU-2	50	1	16,000	20	3.00"	-	-	-	-
	AHU-3	38	1	16,000	20	3.00"	-	-	-	-
	AHU-4	41	1	16,000	20	3.00"	-	-	-	-
	AHU-9	5	1	5,800	7.5	2.25"	-	-	-	-
	AHU-12	47	4	21,750	30	6.00"	4	19,500	7.5	0.50"

All AHU and VAV box heating coils and the radiant in-floor heating are served from a single gas fired boiler, rated to deliver 2343 MBH. The penthouse AHUs cooling coils are served by 2 125 ton chillers with evaporative cooling. AHU-12 cooling coils are served by a 300 ton chiller with an attached cooling tower. While this equipment was not directly trended, data from the AHUs supply air temperature were used to confirm normal operation of the boiler and chillers.

In 2014, the JFHQ received major upgrades to the DDC system, installing a web-based multi-protocol Building Automation and Energy Management Platform. The AHUs supply air temperature are typically controlled using reset strategies based on outside air temperature, while the AHUs static pressure are controlled with request-based TR strategies.

Site #4: Muscatine Armed Forces Reserve Center

The Muscatine Armed Forces Reserve Center (AFRC) is a 37,392 sq. ft., single floor LEED Silver certified facility. Constructed in 2011, the facility contains kitchens, classrooms, fitness training areas, vehicle service bays, and administrative offices. Hundreds of similar facilities are located across the country, serving several agencies. The facility contains a total of 5 RTUs; 3 of which meet the criteria of this study. The first RTU, RTU-1 serves the kitchen area while RTU-3 and RTU-4 serve the east and west portions of the facility.

RTU-1 is a packaged rooftop, mixed air unit with a 3 MHP supply fan. The unit contains direct expansion (DX) cooling with an EER of 11.1 and a refrigeration capacity of 15 nominal tons and hot water heating coils. The unit is rated to supply 2,235 cfm of air at a max external static pressure of 2.10” WC. RTU-1 serves 3 hot water reheat only pressure independent VAV boxes in the kitchen area of the facility. The kitchen area is also served by several exhaust fans and MAUs that are not trended for this study.

RTU-3 is a packaged rooftop unit with a 10 MHP supply fan and 2 MHP exhaust fan. The mixed air unit contains a DX cooling coil with an EER of 10.7and a refrigeration capacity of 30 nominal tons, hot water heating coil and an ERV wheel. The unit is rated to supply 10,250 cfm of air at a max external static pressure on 2.20” WC. RTU-3 serves 17 hot water reheat only, pressure independent VAV boxes.

RTU-4 is a packaged rooftop unit with a 10 MHP supply fan and 2 MHP exhaust fan. The mixed air unit contains a DX cooling coil with an EER of 10.7 and a capacity of 30 nominal tons, hot water heating coil and an ERV wheel. The unit is rated to supply 9,610 cfm of air at a max external static pressure on 2.20” WC. RTU-4 serves 16 hot water reheat only, pressure independent VAV boxes. Table 2.5 provides the specifications of the 3 RTUs studied.

Table 2.5 Muscatine Armed Forces Reserve Center RTU details.

Site	Unit		Supply Fan				Return Fan			
	ID Tag	VAVs	Fans	CFM	MHP	Ext. SP	Fans	CFM	MHP	Ext. SP
Muscatine AFRC	RTU-1	3	1	2,235	2	2.10"	-	-	-	-
	RTU-3	17	1	10,250	15	2.20"	1	2,335	2	1.20"
	RTU-4	16	1	9,610	10	2.20"	1	1,830	2	1.20"

2 boilers rated to deliver 940 MBH each serve the building heating water supply, including the hot water coils for RTU-1, RTU-3 and RTU-4. A fan coil unit also serves the mail room, however it was not trended for this study.

The Muscatine AFRC facility utilizes a building automation system with a BACnet interface. Typically this facility uses a form of static pressure reset strategy along with a supply air temperature reset strategy. It was discovered that due limitations of the network controllers and cost constraints of the study, data collection of the VAV box trends were limited to 30 minute intervals.

Site #5: Waterloo Readiness Center

The Waterloo Readiness Center (RC) is part of a two floor, 34,185 sq. ft. Army Aviation Support Facility originally constructed in 1974. The facility consists of classrooms and administration offices (Readiness Center) and an aviation hangar with maintenance bays and mechanical shops (Army Aviation Support Facility). For this study, only the Readiness Center portion of the facility was studied. The Readiness Center was part of major addition in 1999 that added offices, a kitchen, classrooms, a library, administration spaces, and various training spaces to the existing aviation hanger, maintenance bays, and armory. The Readiness Center is a single floor attachment with a north-south orientation. The facility also serves as a representative sample of other aviation support sites for the National Guard that are installed nationwide.

The Waterloo Readiness Center is served by a single RTU, RTU-1, serving a total of 14 pressure independent VAV boxes. RTU-1 is a rooftop packaged unit with a 3 MHP supply fan and two 2 MHP return fans. The mixed air unit contains DX cooling and gas fired heating coils and can deliver 5,220 cfm of air at a max external static pressure of 1.60” WC. RTU-1 serves 14 VAV boxes, 12 of which have electric reheat. In addition, the facility has hoods and motor operated dampers serving various rooms such as kitchens, lockers, supply storage and mechanical areas that are not trended for this study. Table 2.6 provides specifications of the packaged rooftop unit.

Table 2.6 Waterloo Readiness Center RTU details.

Site	Unit		Supply Fan				Return Fan			
	ID Tag	VAVs	Fans	CFM	MHP	Ext. SP	Fans	CFM	MHP	Ext. SP
Waterloo RC	RTU-1	14	1	5,220	3	1.60"	2	2,610	1	0.70"

The Waterloo RC facility utilizes a building automation system with a BACnet interface. The existing system already uses a form of static pressure reset and a reset strategy for supply air temperature. It was discovered that because the rooftop is a packaged unit, some trends were internal to the RTU and not able to be trended. This mainly pertained to the supply air temperature setpoint that is internal to the packaged unit.

All of the sites investigated were found to have viable HVAC and DDC systems for this study. Each site is a representative sample of National Guard and commercial facilities nationwide that experience similar weather, functions, and static pressure control strategies. Tables 2.7 and 2.8 summarize the facility, HVAC and DDC system information and specifications collected from the site investigations.

Table 2.7 Site investigation results, facility details.

Facility Details	Boone RC	Des Moines MEPS	JFHQ	Muscatine AFRC	Waterloo RC
Date Constructed	1963	2008	1994	2011	1974
Climate Zone	5A	5A	5A	5A	6A
Size	77,321 ft^2	28,200 ft^2	237,126 ft^2	37,392 ft^2	34,185 ft^2
# of Floors	1	1	4	1	2
# of Units	2 AHUs	1 AHU	6 AHUs	3 RTUs	1 RTU
# of VAV boxes	64	34	223	36	14
DDC System	#1	#2	#3	#4	#5
Control Strategy					
Pressure	Fixed	Reset	Reset	Reset	Fixed
Temperature	Fixed	Reset	Reset	Reset	Fixed

Table 2.8 Site investigation results, HVAC equipment details.

Site	Unit		Supply Fan				Return Fan			
	ID Tag	VAVs	Fans	CFM	MHP	Ext. SP	Fans	CFM	MHP	Ext. SP
Boone RC	AHU-1	28	1	12,000	15	2.20"	1	12,000	10	1.75"
	AHU-2	36	1	12,000	15	1.70"	1	12,000	10	1.75"
Des Moines MEPS	AHU-1	34	1	22,000	20	2.00"	1	22,000	10	0.90"
JFHQ	AHU-1	42	1	16,000	20	3.00"	-	-	-	-
	AHU-2	50	1	16,000	20	3.00"	-	-	-	-
	AHU-3	38	1	16,000	20	3.00"	-	-	-	-
	AHU-4	41	1	16,000	20	3.00"	-	-	-	-
	AHU-9	5	1	5,800	7.5	2.25"	-	-	-	-
	AHU-12	47	4	21,750	30	6.00"	4	19,500	7.5	0.50"
Muscatine AFRC	RTU-1	3	1	2,235	2	2.10"	-	-	-	-
	RTU-3	17	1	10,250	15	2.20"	1	2,335	2	1.20"
	RTU-4	16	1	9,610	10	2.20"	1	1,830	2	1.20"
Waterloo RC	RTU-1	14	1	5,220	3	1.60"	2	2,610	1	0.70"

During the site investigations, many of the facilities required additional equipment and software to properly conduct the study. Many of the VFDs were too old to record power use, or existing DDC software was unable to trend data reliably. Calibrations, repairs and replacements were needed on numerous sensors, fire safety dampers, damper actuators, etc. Another prevalent issue was the need to reset airflow setpoints for some VAV zones as the existing static pressure setpoints were vastly reduced from design static pressure setpoints from when the facilities were first commissioned. This was done mostly due to noise complaints or units tripping from high static pressure alarm faults.

2.4 Custom TTR Programming

To implement the TTR strategy at all 5 sites, local HVAC contractors were hired to implement the strategy on their respective DDC system. In doing so, the custom programming languages (CPLs) created across all sites are unique, but contain the same components of the TTR strategy as stated earlier: the most open damper position selection, static pressure setpoint calculation and limit check section. Overall, each CPL for the TTR strategy will contain these three functions. The TTR strategy begins with the most open damper position selection. A series of logic statements are used to determine the maximum damper position, from either feedback or command signal, within the VAV system. Figures 2.2 and 2.3 illustrate how this section was implemented in some DDC systems.

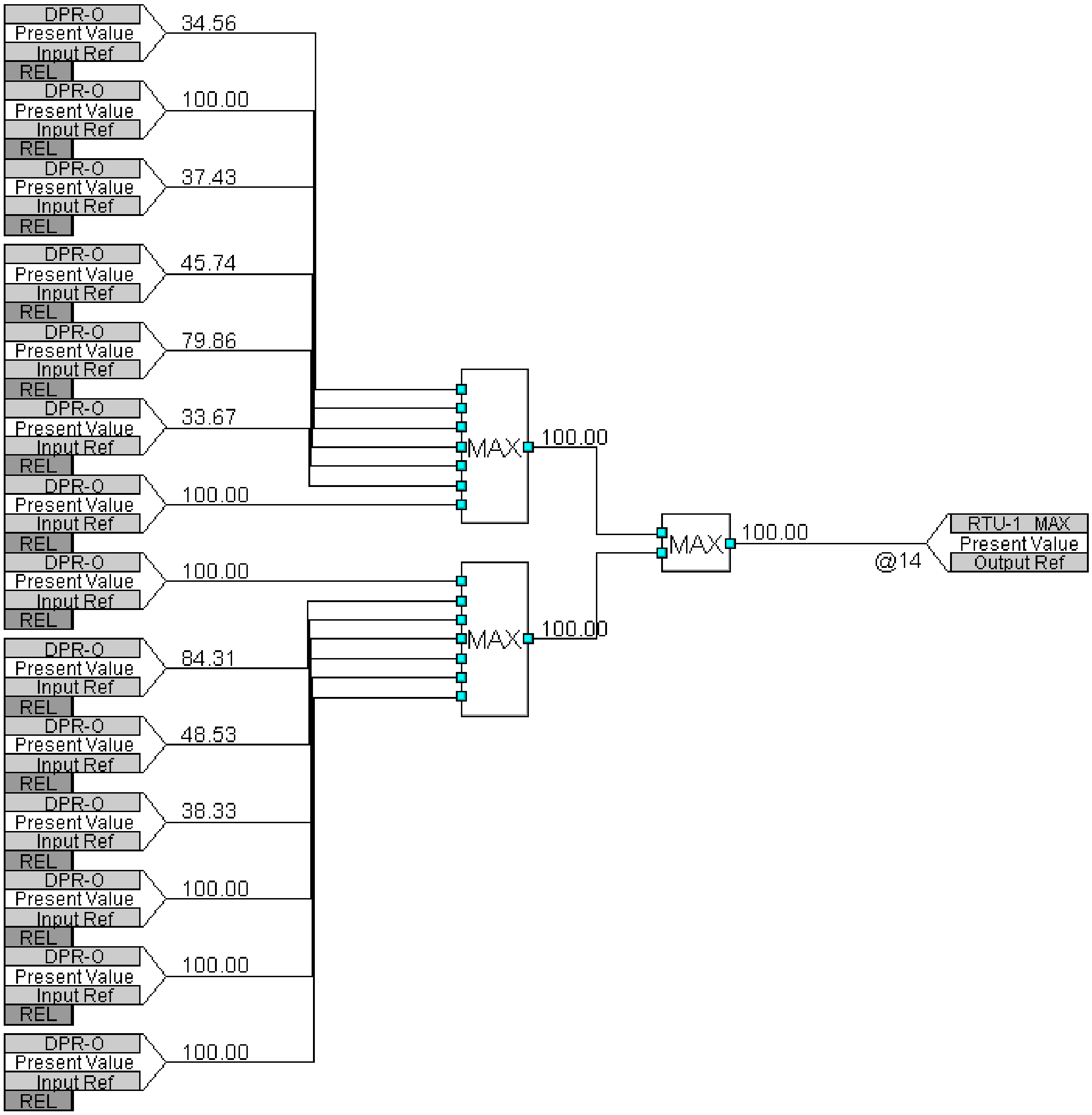

Figure 2.2 Most open damper position selection from DDC system #5.

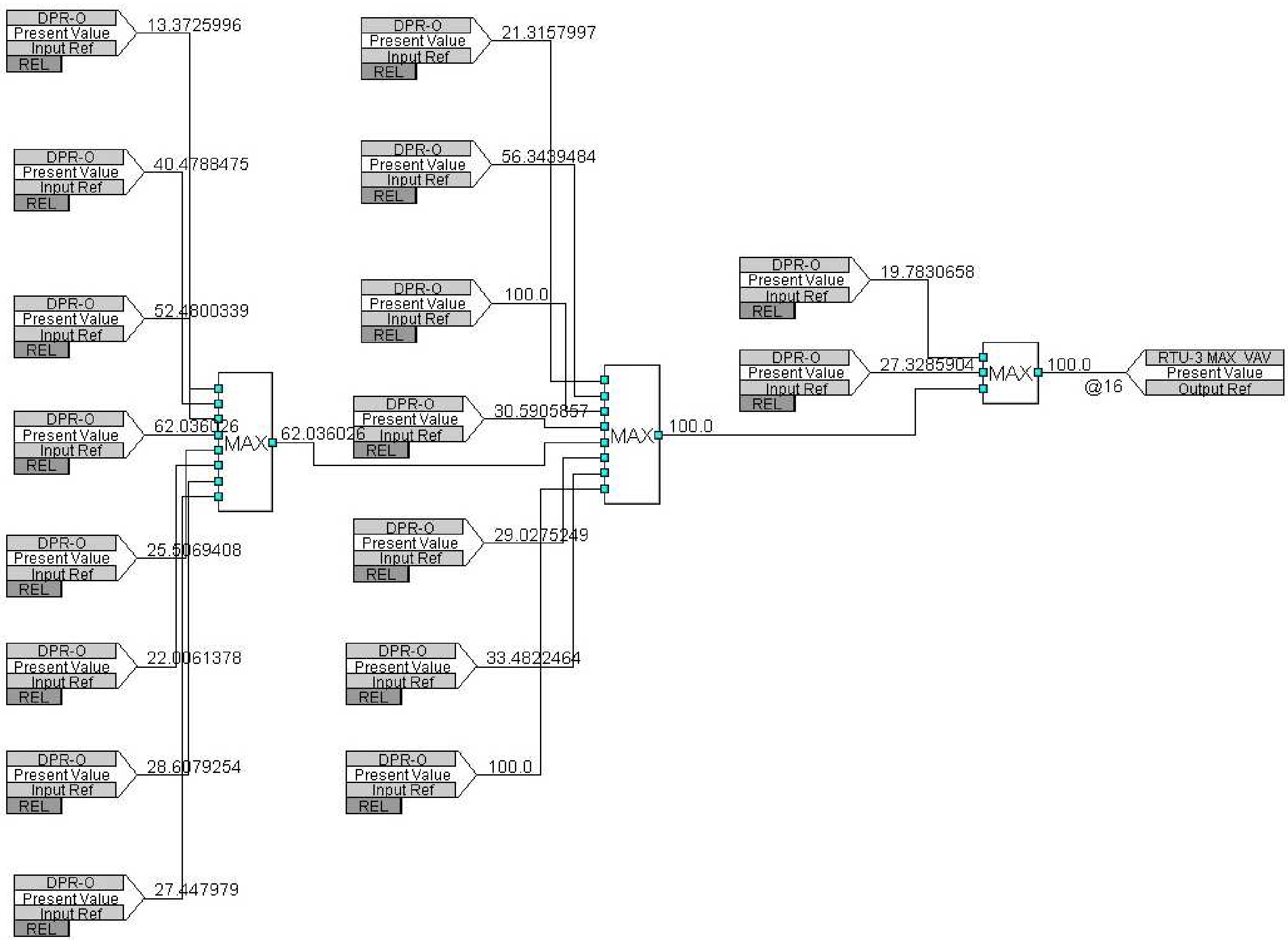

Figure 2.3 Most open damper position selection from DDC system #4**.**

The CPLs shown, Figure 2.2 and 2.3, are unique in the steps taken, but achieve the same effect. The damper position values are selected from the DDC system, and then compared in a “Max” functional block that passes on the greatest value. After a series of steps using the “Max” functional block, the MDP is selected from all VAV box dampers.

Once the MDP is selected, the CPL then determines the new static pressure setpoint using the TTR strategy. Again, this is achieved by a second set of logic statements, leading to the summation of TM or RP values based on the max damper position. Figures 2.4 and 2.5 show an example of functional blocks used for calculating the new static pressure setpoint.

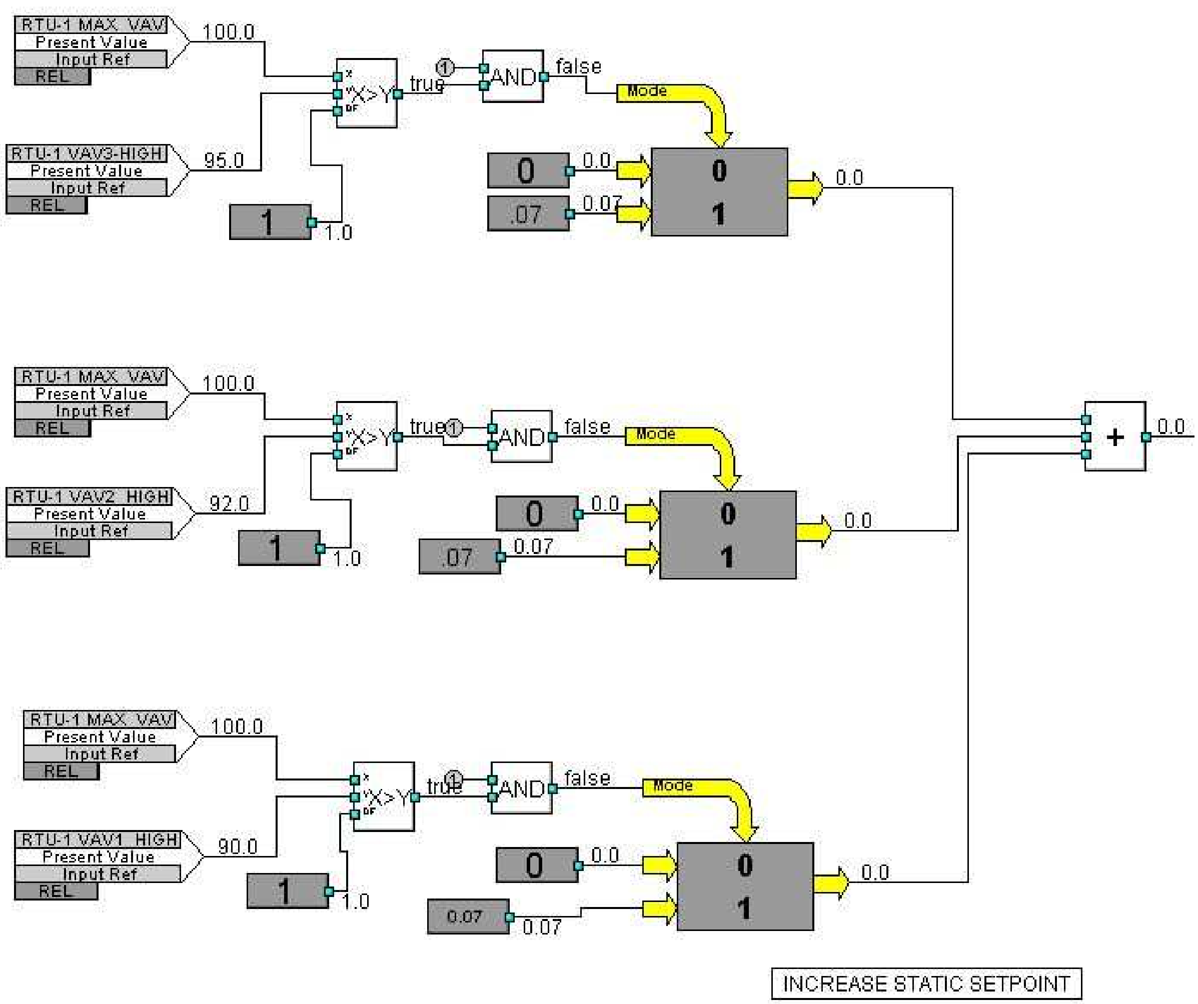

Figure 2.4 Static pressure setpoint calculation, TM tiers, from DDC system #4.

In Figure 2.4 an example of the static pressure calculation is provided. Here the MDP is compared to the set of ranges [High1, High2, High3]. If the MDP is greater than the listed ranges, a true signal is carried on to the TM summation. A true or false logic function is used to determine which TM tiers are summed. For example, if the MDP equals 96, all three tiers will be summed as 96 is greater than High1, High2 and High3 (90, 92 and 95, respectively). Figure 2.5 provides an example of the static pressure calculation when the MDP value is greater than Low1, Low2 and Low3, where the RP values would not be summed. Note the TTR strategy was disabled at the time of capturing Figures 2.4 and 2.5.

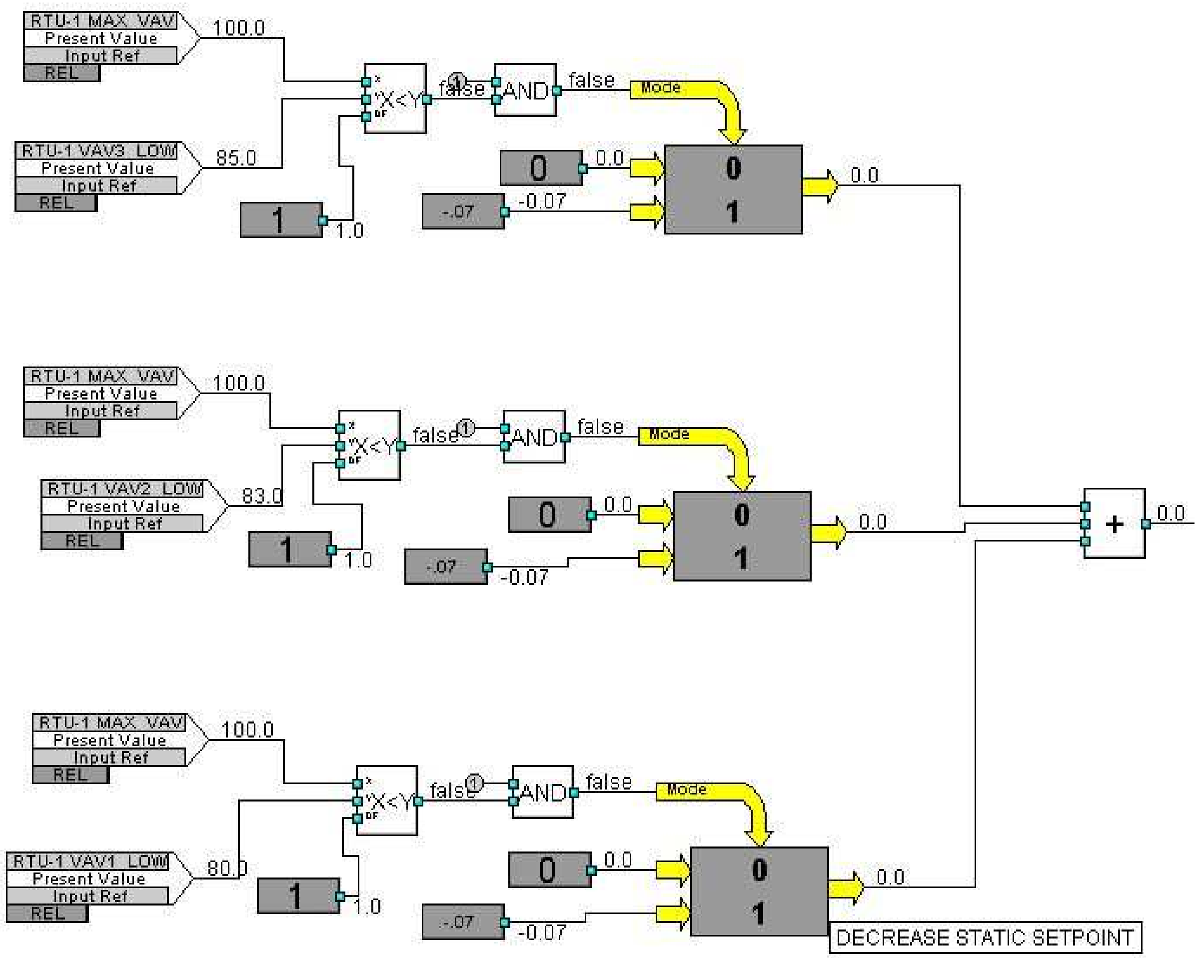

Figure 2.5 Static pressure setpoint calculation, RP tiers, from DDC system #4.

Just as in Figure 2.4, the steps taken in Figure 2.5 are similar, only summing the RP values to decrease the static pressure setpoint rather than increase the setpoint if the MDP value is less than Low1, Low2, or Low3.

Lastly, the newly calculated static pressure setpoint is compared to the facility operator defined limits of the static pressure range. These are the maximum and minimum setpoints the static pressure setpoint is allowed to traverse. If the calculated value is above the established maximum static pressure setpoint, or below the minimum static pressure setpoint, the value is reverted to the established maximum static pressure setpoint or minimum static pressure setpoint, respectively. The Figure 2.6 shows the logic statements used for the limit check section.

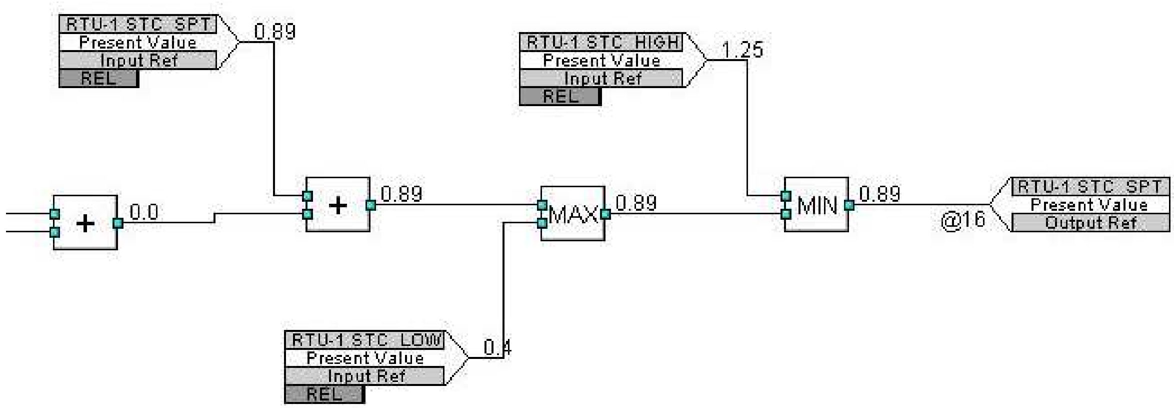

Figure 2.6 Limit check section, from DDC system #4.

In Figure 2.6, the summed TM or RP values are added to the previous static pressure setpoint. Next, the new static pressure setpoint is compared to the predefined minimum static pressure setpoint. The greater of the two values is carried on to a comparison with the predefined maximum static pressure setpoint. The lesser of the two values is the new static pressure setpoint.

2.5 Data Collection

Due to the scope of this research, a wide array of data points were collected. A number of hardware and software installations were required at each site to fulfill the data collection needs of the study, including a breadth of HVAC data, collection intervals at 1 or 2 minutes, and history logs lasting several weeks. Table 2.9 below provides the AHU/RTU trends and Table 2.10 provides the VAV trends. Trends were recorded and analyzed in 1 or 2 minute intervals unless stated otherwise.

Table 2.9 AHU/RTU trends available at each site.

AHU/RTU Trend	Boone RC	Des Moines MEPS	JFHQ	Muscatine AFRC	Waterloo RC
Date/Time	Yes	Yes	Yes	Yes	Yes
Outside Air Temperature	Yes	No	No	Yes	Yes
Outside Air Humidity	Yes	No	No	Yes	Yes
Functional Mode	Yes	Yes	Yes	Yes	Yes
Occupancy Status	Yes	Yes	Yes	Yes	Yes
Static Pressure Setpoint	Yes	Yes	Yes	Yes	Yes
Static Pressure	Yes	Yes	Yes	Yes	Yes
Supply Air Temperature Setpoint	Yes	Yes	Yes	No	No
Supply Air Temperature	Yes	Yes	Yes	Yes	Yes
Supply Fan Speed	Yes	Yes	Yes	Yes	Yes
Return Fan Speed	Yes	Yes	Yes	Yes	Yes
Supply Fan Power	Yes	Yes	Yes	Yes	Yes
Return Fan Power	Yes	Yes	Yes	Yes	Yes
Supply Fan Energy	Yes	Yes	Yes	Yes	Yes
Return Fan Energy	Yes	Yes	Yes	Yes	Yes
Most Open Damper	Yes	No	Yes	No	No

Table 2.10 VAV box trends available at each site.

VAV Trend	Boone RC	Des Moines MEPS	JFHQ	Muscatine AFRC	Waterloo RC
Airflow	NA	NA	Yes	NA	NA
Damper Position	Command	Feedback	Feedback	Command*	Command
Space Temperature Setpoint	Yes	No**	No	Yes*	No
Space Temperature	Yes	Yes	Yes	Yes*	Yes
Heating Setpoint	No	Yes**	Yes	No	Yes
Cooling Setpoint	No	Yes**	Yes	No	Yes
Supply Air Temperature	NA	Yes	NA	NA	NA

*Trended at 30 minute intervals.
**Trends reversed from hardware replacement during study.

From Table 2.9, the weather related trends at the Des Moines MEPS and JFHQ were unavailable but were deemed close enough (~30 miles) to the Boone RC facility. The most open damper trends for Des Moines MEPS, Muscatine AFRC and Waterloo RC were calculated during the data analysis.

As the main objective of this study is to demonstrate the fan energy savings using the TTR strategy, the trends involving functional mode, static pressure, static pressure setpoint, most open damper position and fan motor power were key measurements. VAV trends pertaining to space temperature and space temperature setpoints were also important to demonstrate temperature control performances between TTR and TR strategies. The remaining trends are intended to reveal underlying issues pertaining to HVAC/DDC systems and any flaws within the TTR strategy.

To achieve the collection of the data points listed above, local HVAC contractors were hired to also setup their respective DDC system with the capability to trend and export these data. Many sites had this capability already, while others required the installation of additional hardware and/or 3rd party export utilities.

Many of the alterations were software based as the existing DDC systems were configured only to trend live data without recording any history. Some supply and return fan VFDs required communication cards to be installed by local HVAC contractors to record power use, while others did not have this option available. For these VFDs, data logging systems were procured and installed to record the fan motor power from the input side of the respective VFD.

VFD Communication Card Installation

Several VFDs within the JFHQ site had the option for a communication card installation to fulfill the power data logging requirements. This option was chosen over the installation of data logging systems due to cost constraints. The installation was later verified with a reference power meter, comparing the power readings from the VFD display, DDC system and power meter. This pertained to all JFHQ AHUs except AHU-2.

Data Logger Installation

For the VFDs that did not have optional communication cards to record power and energy data within the DDC system, 3rd party data logging systems were designed, procured and installed. A typical system installation contained Accu-CT split-core current transformers (CTs), WattNode Pulse Output watt transducers, Onset pulse adapters, and a HOBO™ data logger from Onset with cellular network connectivity. Due to the capabilities of the CT's and watt transducers, the data logging system could only record power use on the input side of the VFDs. The purchased equipment came with certification from the manufacturer guaranteeing their rated accuracy. The accuracy of the current transformers were rated ± 0.75% from 1% to 120% of rated primary current (listed in Table 2.11). The listed accuracy of the watt transducers from WattNode were rated to at most ±3% of reading given the conditions expected during the study. The pulse adapter from Onset provides a resolution of 1 pulse, resulting in a variable resolution that is dependent on the size of the connected CTs. For this study, the resolution with the 20A rated CTs attached is .06924808 kW and with the 50A rated CTs attached is 0.17312520 kW. Table 2.11 and 2.12 specify the sites and AHUs/RTUs that required data logging hardware and Figure 2.7 illustrates a wiring diagram of a typical data acquisition system (DAS) installation found at these sites.

Table 2.11 Installed data logging equipment.

Site	Des Moines MEPS*		JFHQ	Waterloo RC
Unit	AHU-1		AHU-2	RTU-1
Data Loggers	1		1	1
Manufacturer	Onset		Onset	Onset
Model	HOBO RX3000		HOBO U30-GSM	HOBO U30-GSM
Pulse Adapter	2		1	2
Manufacturer	Onset		Onset	Onset
Model	S-UCC-M006		S-UCC-M006	S-UCC-M006
VFD	Supply Fan	Return Fan	Supply Fan	Supply Fan
Watt Transducers	1	1	1	1
Manufacturer	WattNode	WattNode	WattNode	WattNode
Model	T-WNB-3D-480	T-WNB-3D-480	T-WNB-3D-480	T-WNB-3D-480
Rating	480Y-3P	480Y-3P	480Y-3P	480Y-3P
CTs	3	3	3	3
Manufacturer	Accu-CT	Accu-CT	Accu-CT	Accu-CT
Model	T-ACT-0750-050	T-ACT-0750-020	T-ACT-0750-050	T-ACT-0750-020
Size	50 Amps	20 Amps	50 Amps	20 Amps

*Equipment was installed later on during the study.

Table 2.12 Installed data logging equipment (continued).

Site	Muscatine AFRC				
Unit	RTU-1	RTU-3		RTU-4	
Data Loggers	1	1		1	
Manufacturer	Onset	Onset		Onset	
Model	HOBO U30-GSM	HOBO U30-GSM		HOBO U30-GSM	
Pulse Adapter	1	2		2	
Manufacturer	Onset	Onset		Onset	
Model	S-UCC-M006	S-UCC-M006		S-UCC-M006	
VFD	Supply Fan	Supply Fan	Return Fan	Supply Fan	Return Fan
Watt Transducers	1	1	1	1	1
Manufacturer	WattNode	WattNode	WattNode	WattNode	WattNode
Model	T-WNB-3D-480	T-WNB-3D-480	T-WNB-3D-480	T-WNB-3D-480	T-WNB-3D-480
Rating	480Y-3P	480Y-3P	480Y-3P	480Y-3P	480Y-3P
CTs	3	3	3	3	3
Manufacturer	Accu-CT	Accu-CT	Accu-CT	Accu-CT	Accu-CT
Model	T-ACT-0750-020	T-ACT-0750-020	T-ACT-0750-020	T-ACT-0750-020	T-ACT-0750-020
Size	20 Amps	20 Amps	20 Amps	20 Amps	20 Amps

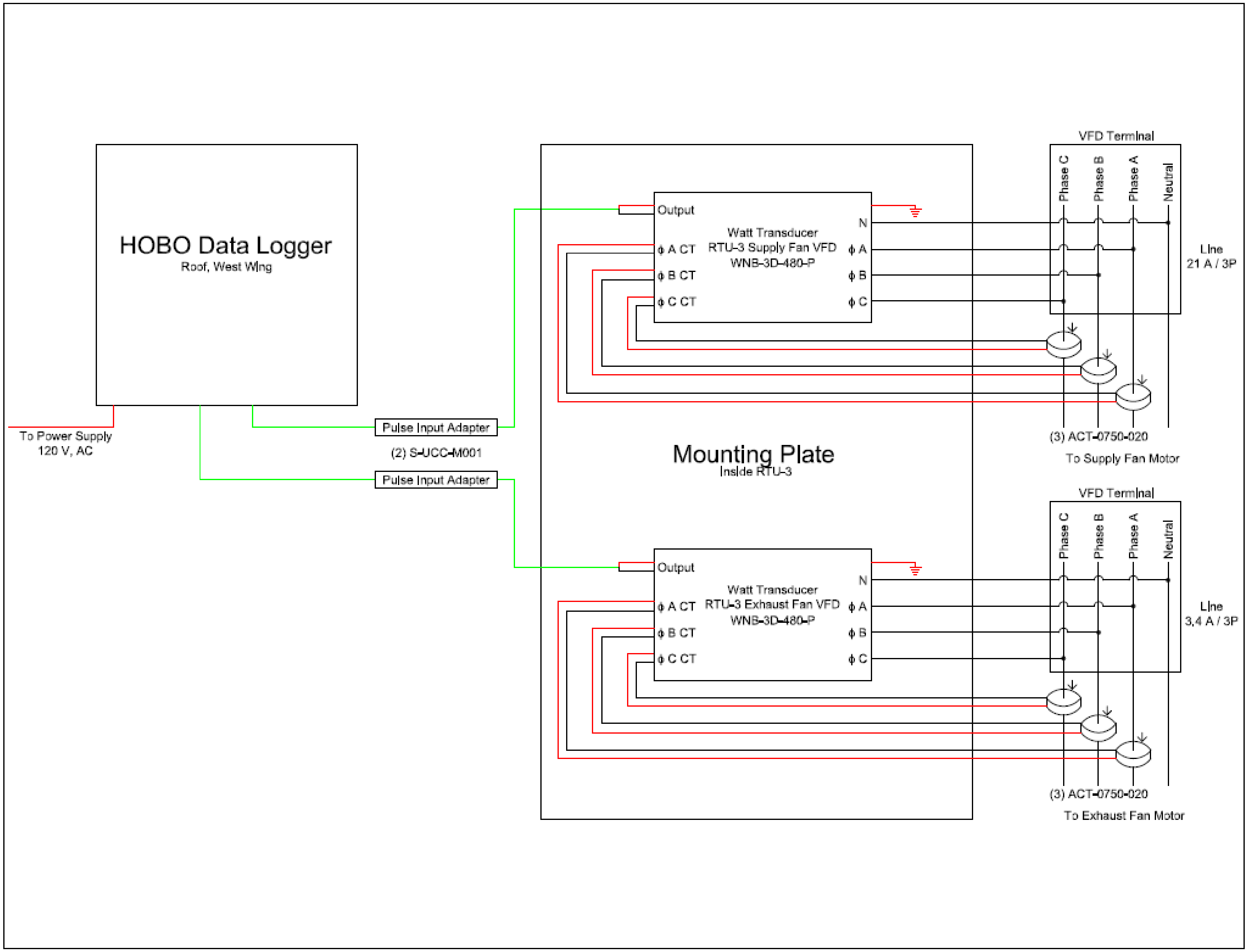

Figure 2.7 DAS installation details, typical.

With the watt transducer tied into the voltage line of the VFD input and the attached CTs measuring the current in each phase, the input power, in kW, was outputted in the form of "pulses" by the pulse adapter. The pulse adapter would then count the amount pulses in a user defined interval, 1 minute for this study, and relay the pulse counts to the data logger at that defined interval. Figure 2.8 shows the CTs clamped around the input power of the RTU-1 supply fan VFD at Muscatine AFRC.

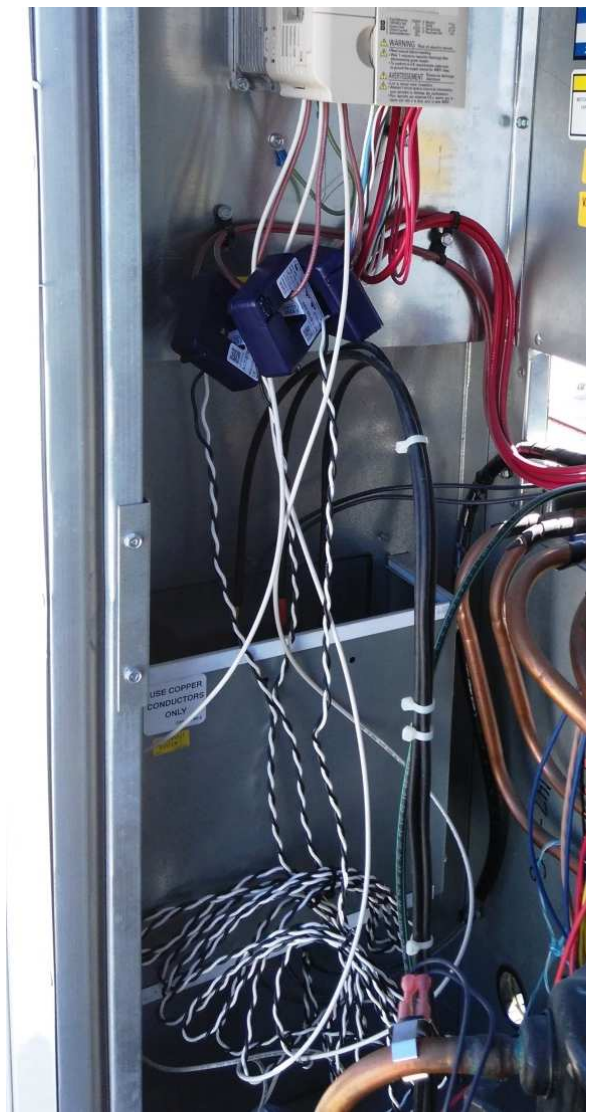

Figure 2.8 Installed CTs on RTU-1 at Muscatine Armed Forces Reserve Center.

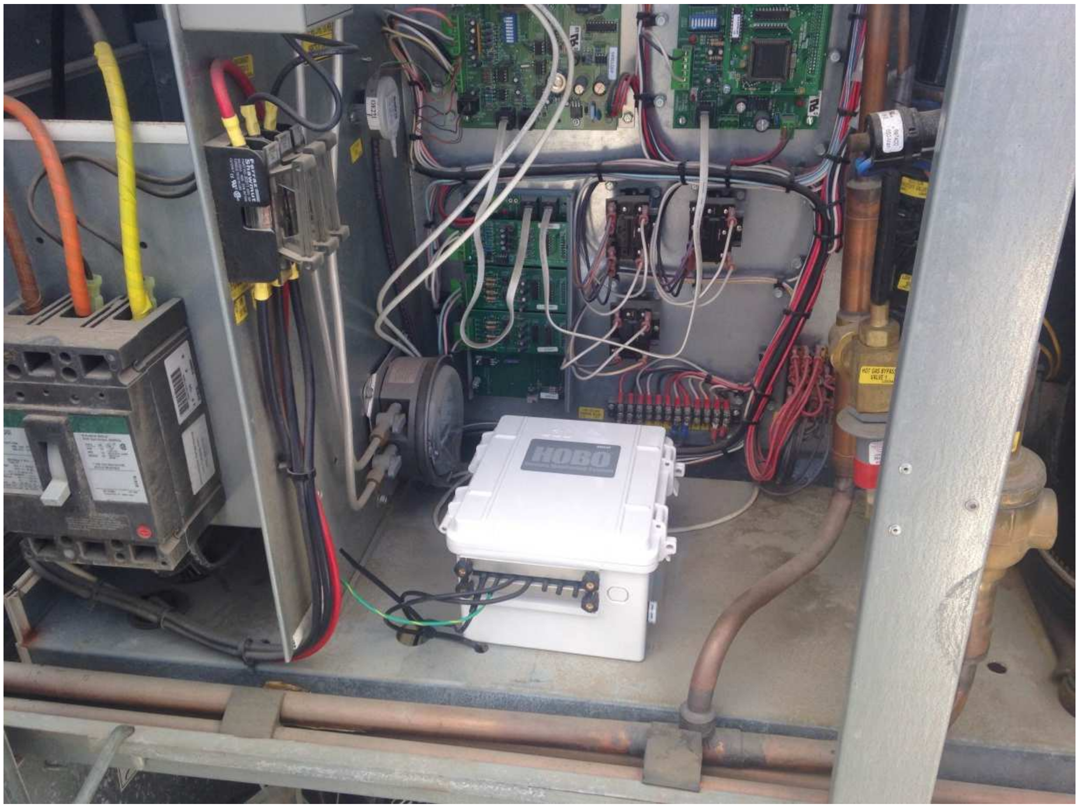

Figure 2.9 HOBO data logger installed in RTU-1 at Waterloo Readiness Center.

The data logger (Figure 2.8) would then upload the pulse count data at a predefined interval, every 15 minutes, to a private server account over cellular network. The server would then convert the pulse counts from each watt transducer to units of kW, and display live readings and data logger status on the server's webpage. Here the kW data were exported in a .csv or text file by direct download or email. To ensure continuous operation in cases such as power loss, surge, etc., the data logger was plugged into a standard 110VAC outlet, and in-line fuses were installed on the voltage side of the watt transducers. The data logger also contained a 4 Ah lead-acid battery that would last approximately 2 weeks with the data collection and upload rates used during this study.

Along with the additional hardware and software installed at each site, strategies to mitigate interruptions regarding power loss were implemented. For most sites, this included an uninterruptable power supply (UPS) to be installed to the DDC system and computer interface. This would allow the DDC system/hardware adequate time to safely shutdown in the event of power loss. Most sites had existing onsite emergency generators that would provide power within minutes, requiring the installed UPS to provide power during the lapse between a power outage and the startup of emergency generators.

Data Collection Procedure

Throughout the demonstration period of the research, data were collected every two weeks. This would provide a full set of completed TTR, FSP or TR data to process and analyze. Data were downloaded from the DDC system computer and sent through email or USB drive. During the CPL installation by local HVAC contractors, data download functions were implemented to the DDC system software. This allowed the data trends to be placed into standardized formats and downloaded as .csv or .xlsx files to be easily exported and processed.

2.6 Data Analysis

As data were collected throughout the study, data analysis was used to verify the correct operation of the functional modes and associated HVAC equipment. To accomplish this, several computer scripts were written in MATLAB, and standardized templates were constructed in Microsoft Excel. Because the collected data were in a .csv or .xlsx file format, data were processed using MATLAB and exported into a preformatted Microsoft Excel spreadsheet.

After the raw data collected from each site were processed and exported to a preformatted Excel file, the data were analyzed with several charts that displayed the various data trends. Most importantly for the AHUs and RTUs, most open damper position and static pressure setpoint was inspected to ensure the ongoing correct operation of the TTR strategy. The static pressure trend was used to ensure the AHU or RTU was able to maintain the static pressure setpoint and to confirm or adjust the TM and RP rates and formula of the TTR strategy during preliminary testing. Supply air temperature setpoint and supply air temperature were also observed to ensure operations of the boilers and chillers or if the AHU or RTU had the capability to properly serve the demands of their VAV zones.

VAV zone trends were closely inspected to determine normal operation, or deduce any probable causes of incorrect operations that would adversely affect the TTR strategy such as a stuck open damper. These trends made up the bulk of the processed data file as the AHUs and RTUs contained numerous VAV boxes with several trends per box.

Once all trends were inspected, a report based on the performance and issues was created. Depending on the severity of the performance or issues, the findings would be relayed to facility engineers or appropriate HVAC contractors. The reports were also used to update National Guard staff on the progress of the study.

CHAPTER 3

PRELIMINARY TESTING & OBSERVATIONS

3.1 Testing and Verification

Before the official demonstration could begin, various testing and verification processes were needed in order to validate the correct implementation of all software and hardware installed for this study. To do so, functional tests were needed for the installed TTR logic and the power readings of the VFD display, DDC system, and installed communication cards needed to be verified. Also, refinement of TM and RP calculations was needed due to observations of static pressure oscillation during initial testing.

Functional Mode Testing

With a variety of custom TTR programs installed by local contractors at the selected Iowa Army National Guard sites, a standardized functional test for the TTR control logic was implemented. The objective of the functional test was to verify the correct operation of the custom TTR programs in each of the DDC systems used. The test was provided by Taylor Engineering, Inc. and was performed on a dynamic, macro-enabled excel sheet, with the recommended TTR formula and settings installed in background functions. To complete the functional test, the DDC system and spreadsheet would run side by side in a live comparison. Using the test inputs provided from the spreadsheet, the response from the DDC system and the expected response from the spreadsheet were compared. Any discrepancies found were noted and resolved as soon as possible.

The functional test began with the entering of site and AHU specific data: Date, Time, maximum and minimum static pressure setpoint limits, initial static pressure setpoint, TTR cycle time, and VAV boxes to test the most open damper position and static pressure setpoint calculation of the TTR programs. With these entries, the functional test spreadsheet would generate the recommended TM and RP rates, and asked the operator to verify if the results matched what was observed from the DDC system.

The functional test then progressed through several scenarios. This required manually overriding the test VAV box damper positions from the DDC system. With this information, the custom TTR program in the DDC system would output the newly calculated static pressure setpoint and send the appropriate command signal to the supply fan VFD. This was compared to the expected static pressure setpoint from the test spreadsheet and used to verify the supply fan response to the changing static pressure setpoints. The static pressure setpoint was first compared to the initial static pressure setpoint value from Step 1. In the proceeding steps, the test VAV box damper positions were altered to achieve an expected response from the DDC system. For example, with all VAV box damper positions at 85%, the static pressure setpoint should remain unchanged the next following TTR step time cycle. If one of the VAV box damper positions was then adjusted to 92%, the static pressure setpoint should increase by an amount equal to TM1.

Along with the setpoint comparison, the functional test included a comparison for the limit check section of the custom TTR programs. By adjusting the test VAV box damper positions to 99%, this would increase the static pressure setpoint calculation by an amount equal to TM1+TM2+TM3. However, the resulting static pressure setpoint could not be greater than the predefined maximum static pressure setpoint.

For the remaining steps, the test VAV box damper positions were then decreased in order to simulate a reduction in building demand. This was to verify the correct summation of the RP1, RP2 and RP3 values and the limit check of the minimum static pressure setpoint. Once the testing was completed, the test forms were submitted for review.

Power Measurement Verification

To ensure proper readings of the VFDs studied during this study, a standardized testing procedure was created to verify the accuracy of the VFD display and DDC system trends and the accuracy of the VFD display and data logging systems. Using a Fluke 41B Power Harmonics Analyzer with a Fluke 80i-500s AC current probe, the VFDs at Des Moines MEPS, Boone RC and JFHQ were tested and verified.

The Fluke 41B had a listed accuracy for watt measurements of ± 1% + 4 digits and a resolution of 0.01 kW in the 1 kW range used for testing. The reference power meter was certified by the manufacturer to be properly calibrated during the time of the testing. The current probe had a listed accuracy for AC current from 1 to 20A of 10% + 0.3A for 10 to 45 Hz and 5% + 0.3A for 45 to 60 Hz. For AC current from 20 to 100A, the accuracy was 10% for 10 to 45 Hz and 5% for 45 to 60 Hz. The AC current probe was certified by the manufacturer to be properly calibrated during the time of the testing.

To collect test readings from the VFDs using the reference power meter, the VFD panel control was selected to "hand" operation to freely adjust the speed command signal. Starting at the minimum allowed speed, typically 20 Hz or 30% and then rising by 10 Hz or 15% each interval to the maximum allowed speed, typically 60 Hz or 100%. The power readings were recorded after the VFD speed had stabilized, typically after one or two minutes. Table 3.1 provides sample results from JFHQ AHU-2 supply fan VFD.

Table 3.1 Power verification results from JFHQ AHU-2 supply fan.

AHU-2 SF		Input		Output	Error	
Speed %	Frequency Hz	Power Meter kW	Data Logger kW	VFD Display kW	Data Logger %	Reading %
30.00%	18	0.465	0.519	0.41	11.61%	21.00%
45.00%	27	1.33	1.38	1.3	3.76%	5.80%
60.00%	36	2.6	2.77	2.65	6.54%	4.33%
75.00%	45	3.85	3.98	3.8	3.38%	4.52%
90.00%	54.2	5.95	5.54	5.9	6.89%	6.50%
100.00%	60	-	-	-	-	-

In Table 3.1, the “VFD Efficiency” column is a comparison of the “Power Meter” input power readings and the “VFD Display” output power. The “Error” column is a comparison of the trended power data and the actual power data. For the JFHQ AHU-2 supply fan, this was a comparison of the data logger input power readings and the “VFD Display” output power.

While the tests included the full allowable range of speed of the VFDs, larger errors at low frequencies were acceptable as the supply and return fans do not normally operate in this range. All tested VFDs had limits of 18 Hz to 20 Hz as the minimum setting, while the maximum was either 60 Hz or indirectly limited by an external high static pressure alarm within the DDC system or AHU that tripped the unit if faulted. VFDs also inherently have losses resulting in error due to internal workings; a portion of the error was also attributed to the resolution of the VFD displays, typically ±.05 kW.

3.2 Initial Demonstration

After the TTR programs and power reading equipment were installed and verified, an initial demonstration was conducted to ensure the parameters used such as TM, RP and Step Timer values were adequate. During this time, functional modes alternated daily between TTR and FSP or TTR and TR. Table 3.2 provides the initial parameters and the functional mode comparisons and Table 3.3 provides temperature control strategies and setpoints used.

Table 3.2 Initial functional mode comparison and TTR parameters.

Site	Unit	Functional Mode		TTR Parameters			Step Timer
				TM1/RP1	TM2/RP2	TM3/RP3	
Boone RC	AHU-1	TTR	FSP	0.036"	0.072"	0.108"	90
	AHU-2	TTR	FSP	0.030"	0.060"	0.090"	90
Des Moines MEPS	AHU-1	TTR	FSP	0.038"	0.076"	0.114"	60
JFHQ	AHU-1	TTR	FSP	0.060"	0.120"	0.180"	120
	AHU-2	TTR	TR	0.050"	0.100"	0.150"	120
	AHU-3	TTR	TR	0.060"	0.120"	0.180"	120
	AHU-4	TTR	FSP	0.050"	0.100"	0.150"	120
	AHU-9	TTR	FSP	0.040"	0.080"	0.120"	120
	AHU-12	TTR	FSP	0.020"	0.040"	0.060"	120
Muscatine AFRC	RTU-1	TTR	FSP	0.030"	0.060"	0.090"	120
	RTU-3	TTR	FSP	0.080"	0.160"	0.240"	120
	RTU-4	TTR	FSP	0.070"	0.140"	0.210"	120
Waterloo RC	RTU-1	TTR	FSP	0.090"	0.180"	0.270"	90

Table 3.3 Initial temperature control strategy and static pressure setpoint limits.

Site	Unit	Temperature Control		TTR		FSP/TR	
				SPmin	SPmax	SPmin	SPmax
Boone RC	AHU-1	Fixed	55°F	0.40"	2.20"	-	2.20"
	AHU-2	Fixed	55°F	0.40"	1.70"	-	1.70"
Des Moines MEPS	AHU-1	Reset	OA	0.25"	1.40"	-	1.40"
JFHQ	AHU-1	Reset	OA	0.50"	2.40"	-	2.40"
	AHU-2	Reset	OA	0.50"	2.00"	0.50"	2.00"
	AHU-3	Reset	OA	0.50"	2.40"	0.50"	2.40"
	AHU-4	Reset	OA	0.50"	2.00"	-	2.00"
	AHU-9	Reset	OA	0.20"	1.40"	-	1.40"
	AHU-12	Reset	OA	0.80"	2.70"	-	2.70"
Muscatine AFRC	RTU-1	Fixed	55°F	0.40"	1.25"	-	1.25"
	RTU-3	Fixed	55°F	0.40"	2.30"	-	2.30"
	RTU-4	Fixed	55°F	0.40"	2.50"	-	2.30"
Waterloo RC	RTU-1	Fixed	55°F	0.70"	1.60"	-	1.60"

From Table 3.3, the SPmax values used during the initial demonstration vary greatly from what was discovered in the site investigation. The values first seen were from initial commissioning documents, while the values in Table 3.3 are used typically at the recommendation of the facility managers and engineers. Many of the SPmax values have been reduced due to occupant complaints of noise, and frequent unit trips due to high static pressure alarm faults. The existing reduction of the SPmax values may inhibit any available energy savings provided by the TTR strategy.

With these parameters used for several weeks, data from initial demonstration were downloaded and analyzed. To ensure data were from normal or valid test days, a set of criteria was used to determine if a particular day's data should be deemed valid and used for analysis:

- Normal occupancy hours – i.e. if the site normally has a 10 hour occupancy schedule, days where occupancy was switched to 24 hour occupancy in error would be ignored in analysis. However, due to the nature of some of the facilities functions, a 24 hour occupancy schedule was used but was then returned to normal at a later time.

- Operational supply and return fan – i.e. days where a supply and/or return fan tripped for extended periods of time were ignored during analysis.
- Setpoints were not altered to negatively affect the study – i.e. days with altered static pressure setpoints reducing TTR static pressure setpoint below FSP setpoint were ignored during analysis.
- Data are full and complete – i.e. days with incomplete or missing trends of key measurements for extended periods of time were ignored during analysis.
- Functional mode switch occurred automatically at midnight – i.e. days that the functional mode had to be switched manually were ignored.

Initial Observations

Early on during the initial demonstration, instances of excessive static pressure oscillation were present in nearly all TTR days across each site. This was largely attributed to the initial TM and RP parameters used but some instances were caused by dampers in need of repair or replacement. As such, dampers and other related equipment were repaired or replaced and parameters were adjusted to better accommodate each AHU/RTUs capabilities. Figures 3.4, 3.5, 3.6, 3.7 and 3.8 provide early examples of excessive static pressure oscillation and quick ramp-ups from the TTR strategy during a 24 hour period.

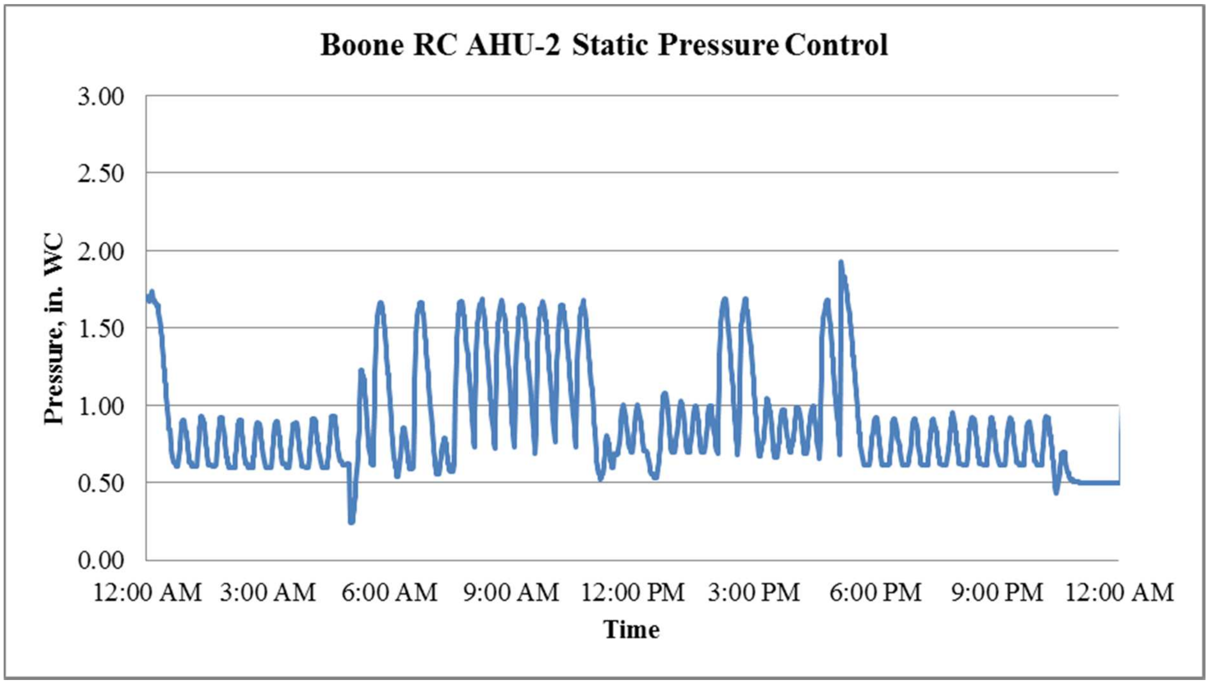

Figure 3.4 Static pressure oscillation from initial TTR parameters, 5/25/2015.

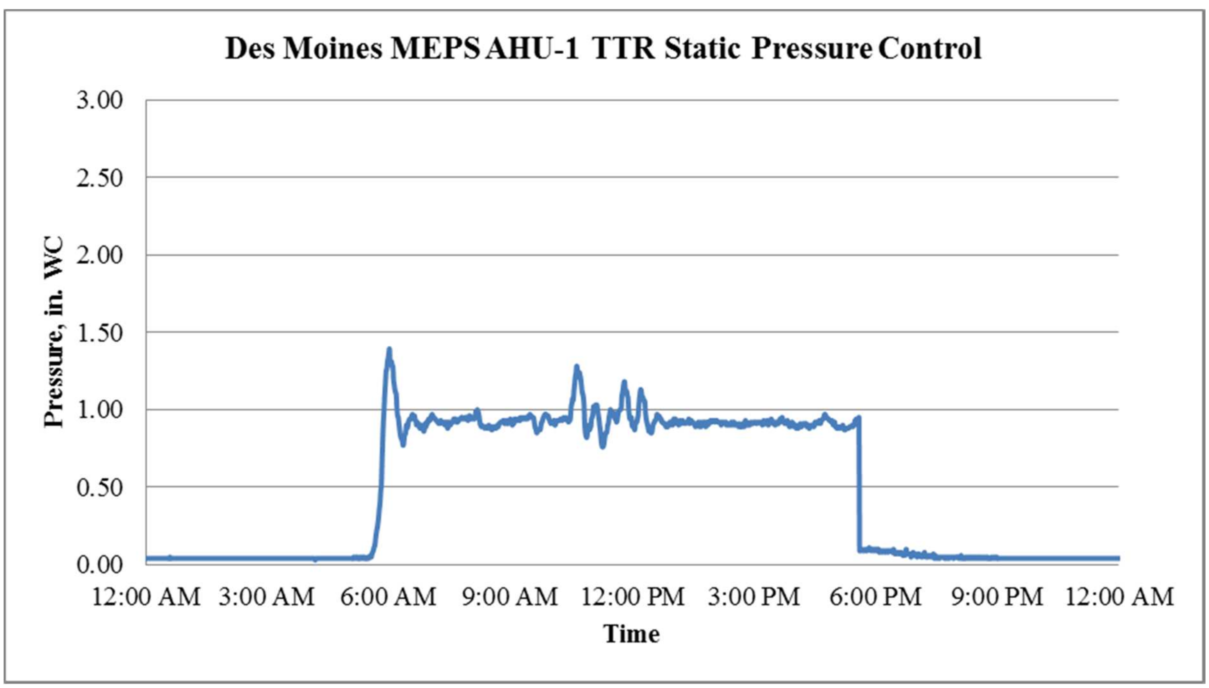

Figure 3.5 Static pressure ramp up from initial TTR parameters, 6/2/2015.

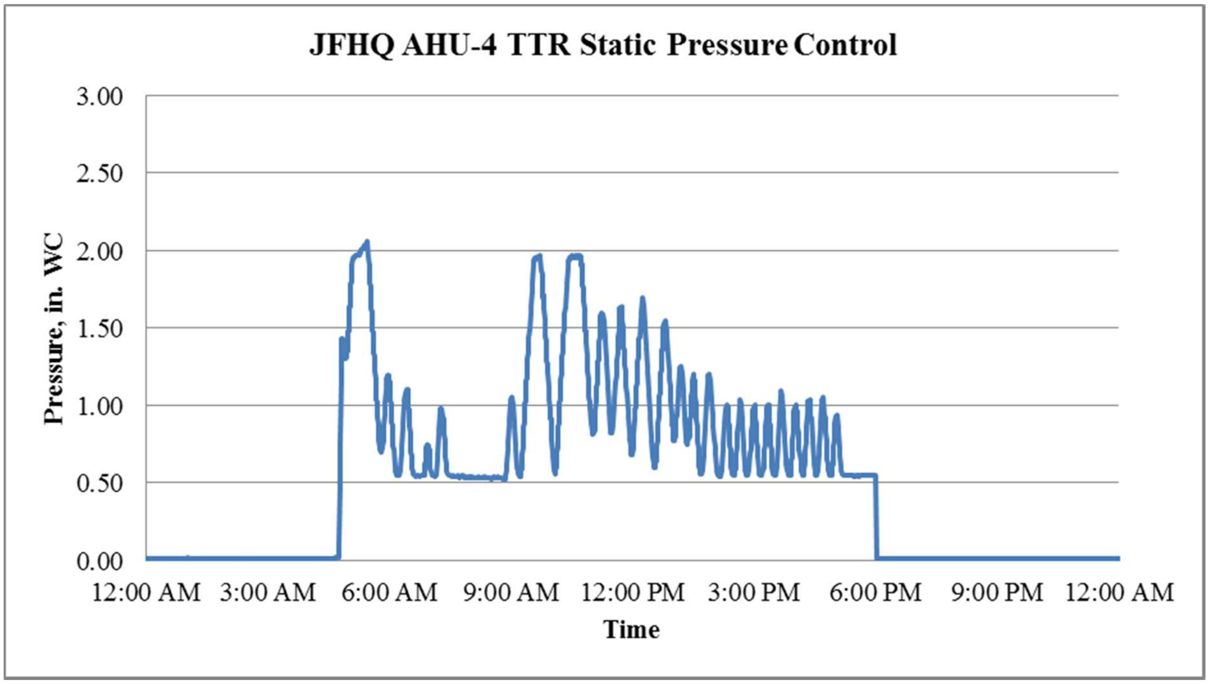

Figure 3.6 Static pressure oscillation from initial TTR parameters, 7/8/2015.

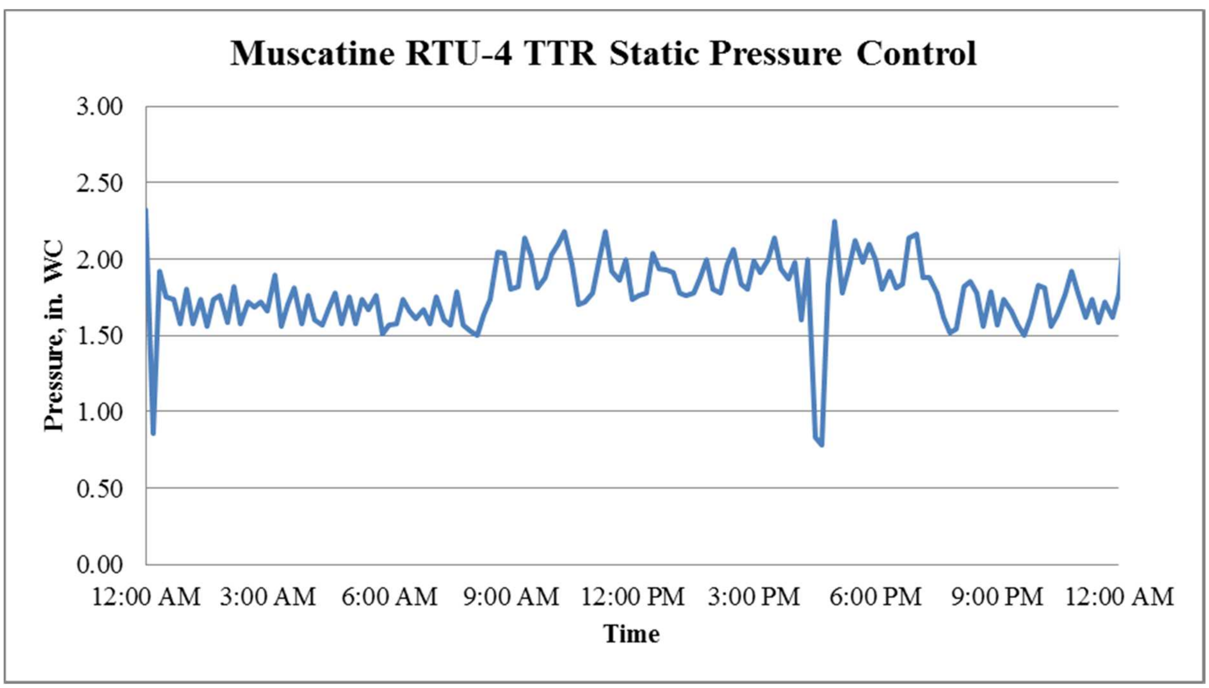

Figure 3.7 Static pressure oscillation from initial TTR parameters, 6/5/2015.

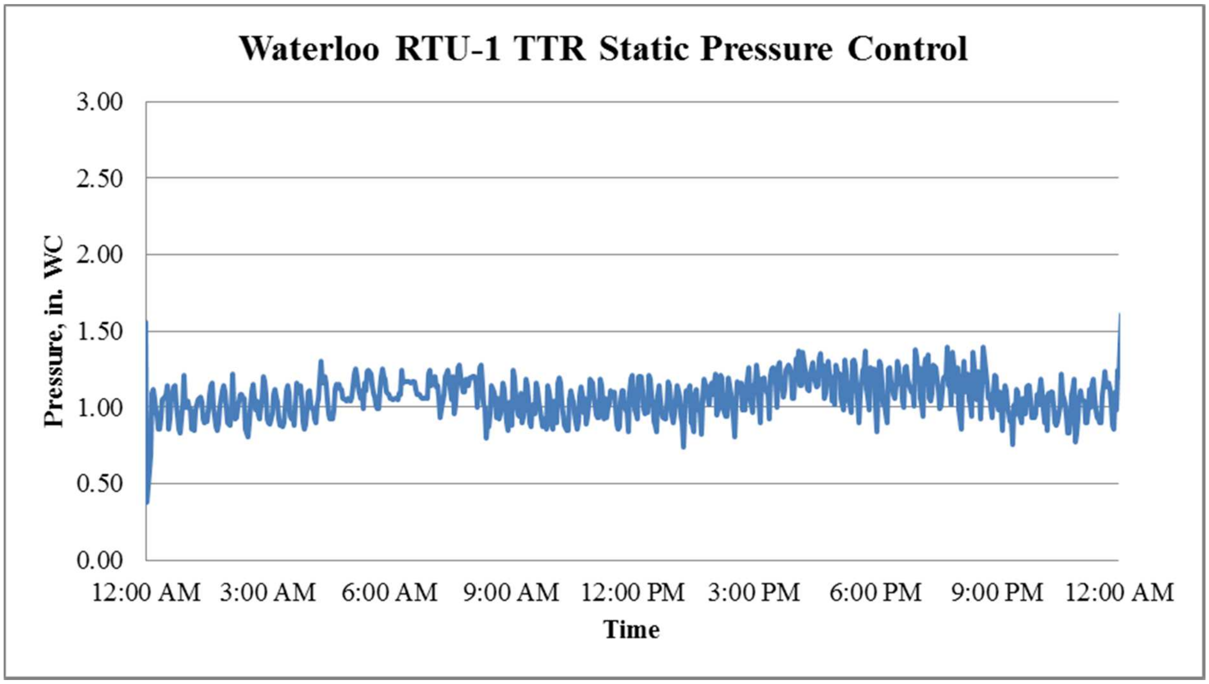

Figure 3.8 Static pressure oscillation from initial TTR parameters, 6/5/2015.

As seen in the previous figures, static pressure oscillated heavily with the initial TTR strategy. Figures 3.5 and 3.6 showed instances with large ramp ups in static pressure, and in some cases this would cause units to trip due to high static alarms. Figures 3.4, 3.7 and 3.8 provide examples of excessive static pressure oscillation that was apparent early on. To minimize these issues, adjustments were made to the TM and RP values, the summation of the TM and RP tiers and lengthening of the step timer. Table 3.4 displays the new response given for the MDP value used for the official demonstration. Tables 3.5 and 3.6 provide the TM and RP values and step timer used during the official demonstration.

Table 3.4 Refined TTR strategy used during the official demonstration.

Condition	Response
If MDP > High3	SPSet = SPSet + RP3
If MDP > High2	SPSet = SPSet + RP2
If MDP > High1	SPSet = SPSet + RP1
If High1> MDP > Low1	No change
If MDP < Low1	SPSet = SPSet - TM1
If MDP < Low2	SPSet = SPSet - TM2
If MDP < Low3	SPSet = SPSet - TM3
	High3>High2>High1>Low1>Low2>Low3 (suggested values 95%, 92%, 90%, 85%, 83%, 80%, respectively)
MDP	Maximum Damper Position (Feedback or Command Signal)
SPSet	Static Pressure Setpoint
TM1,2,3, RP1,2,3	Trim and response rates. All positive numbers.

Table 3.5 Functional mode comparison and TTR parameters used during official demonstration.

Site	Unit	Functional Mode		TTR Parameters			Step Timer
				TM1/RP1	TM2/RP2	TM3/RP3	
Boone RC	AHU-1	TTR	FSP	0.036"	0.072"	0.108"	180
	AHU-2	TTR	FSP	0.030"	0.060"	0.090"	180
Des Moines MEPS	AHU-1	TTR	FSP	0.0380"	0.076"	0.114"	300
JFHQ	AHU-1	TTR	FSP	0.040"	0.080"	0.120"	300
	AHU-2	TTR	TR	0.025"	0.050"	0.075"	300
	AHU-3	TTR	TR	0.040"	0.080"	0.120"	300
	AHU-4	TTR	FSP	0.025"	0.050"	0.075"	300
	AHU-9	TTR	FSP	0.025"	0.050"	0.075"	300
	AHU-12	TTR	FSP	0.020"	0.040"	0.060"	300
Muscatine AFRC	RTU-1	TTR	FSP	-0.005" 0.010"	-0.010" 0.020"	-0.015" 0.030"	300
	RTU-3	TTR	FSP	0.030"	0.060"	0.090"	300
	RTU-4	TTR	FSP	0.028"	0.056"	0.084"	300
Waterloo RC	RTU-1	TTR	FSP	0.030"	0.060"	0.090"	300

Table 3.6 Temperature control strategy and static pressure setpoints used during official demonstration.

Site	Unit	Temperature Control		TTR		FSP/TR	
				SPmin	SPmax	SPmin	SPmax
Boone RC	AHU-1	Fixed	55°F	0.40"	2.20"	-	2.20"
	AHU-2	Fixed	55°F	0.40"	1.70"	-	1.70"
Des Moines MEPS	AHU-1	Reset	OA	0.25"	1.40"	-	1.40"
JFHQ	AHU-1	Reset	OA	0.50"	2.40"	-	1.50"
	AHU-2	Reset	OA	0.10"	1.50"	0.10"	1.50"
	AHU-3	Reset	OA	0.50"	2.40"	0.50"	2.40"
	AHU-4	Reset	OA	0.50"	1.80"	-	1.50"
	AHU-9	Reset	OA	0.20"	1.40"	-	1.40"
	AHU-12	Reset	OA	0.80"	1.50"	-	1.50"
Muscatine AFRC	RTU-1	Fixed	55°F	0.40"	1.25"	-	1.25"
	RTU-3	Fixed	55°F	0.40"	2.30"	-	2.30"
	RTU-4	Fixed	55°F	0.40"	2.50"	-	2.30"
Waterloo RC	RTU-1	Fixed	55°F	0.50"	1.60"	-	1.60"

As shown in Tables 3.5 and 3.6, TM and RP rates for all AHUs and RTUs were reduced significantly. Along with these reductions, the SPmax and SPmin were adjusted to alleviate issues perceived early on due to excessive noise or faults from high static pressure alarms. The step timer within the TTR strategy was lengthened due to numerous observations of slow responses of the static pressure setpoint command vs static pressure.

For this study, 2 AHUs will compare the TTR and TR functional modes, while the remaining AHUs and RTUs will compare the TTR and FSP functional modes. For the a TTR and TR comparisons, temperature reset based on outside air temperature was used; for the TTR and FSP comparisons, both temperature reset based on outside air temperature and fixed temperature was used. Table 3.6 specifies which sites used a fixed supply air temperature and an outside air based reset supply air temperature.

CHAPTER 4

RESULTS

4.1 Fan Performance

After a demonstration period from July 2015 to May 2016, at least six months of valid testing data were collected from each site. While each site accumulated different amounts of valid test days, at least thirteen weeks of valid FSP or TR data and eight weeks of valid TTR data were recorded from each site. Table 4.1 provides the fan energy savings over this time period for each unit and site.

Table 4.1 Average fan energy savings per unit per day.

Site	Unit	FSP/TR* kWh	TTR kWh	% Fan Energy Savings	% Total Fan Energy Savings
Boone RC	AHU-1	79.07	62.58	20.86%	16.72%
	AHU-2	89.27	79.73	10.66%	
Des Moines MEPS	AHU-1	55.19	40.12	27.30%	27.30%
JFHQ	AHU-1	66.97	63.80	4.71%	17.85%
	AHU-2*	34.02	42.84	-25.90%	
	AHU-3*	29.89	44.02	-47.27%	
	AHU-4	32.89	28.67	12.83%	
	AHU-9	10.49	4.20	59.92%	
	AHU-12	606.11	510.19	15.83%	
Muscatine AFRC	RTU-1	2.94	2.39	18.88%	32.47%
	RTU-3	74.47	52.53	29.46%	
	RTU-4	59.91	38.02	36.54%	
Waterloo RC	RTU-1	39.90	26.41	33.80%	33.80%

From Table 4.1, the potential fan energy savings of 30 to 50% were realized by only 3 of the units studied. However, a majority of the units comparing the TTR and FSP strategy showed fan energy savings greater than 20%. This is not surprising given the nature and real world setting of the facilities studied. Intuitively, the units with the least number of VAV zones generally showed the greatest fan energy savings from the TTR strategy over FSP strategies. This would make sense as the VAV system with the least amount of zones should be easier to maintain control. Table 4.2 is a rearranged table providing the results according to number of attached VAV zones in ascending order.

Table 4.2 Average fan energy savings of TTR over FSP per unit per day by VAV zones.

Site	Unit	VAVs	FSP kWh	TTR kWh	% Fan Energy Savings
Muscatine AFRC	RTU-1	3	10.49	4.20	18.91%
JFHQ	AHU-9	5	29.89	44.02	59.92%
Waterloo RC	RTU-1	14	74.47	52.51	33.80%
Muscatine AFRC	RTU-4	16	2.94	2.39	36.54%
	RTU-3	17	74.47	52.51	29.46%
Boone RC	AHU-1	28	79.07	62.58	20.86%
Des Moines MEPS	AHU-1	34	55.19	40.42	27.30%
Boone RC	AHU-2	36	89.27	79.73	10.69%
JFHQ	AHU-4	41	34.02	42.84	12.83%
	AHU-1	42	66.97	63.80	4.73%
	AHU-12	47	606.11	510.19	15.83%

In this study, units with 34 VAV boxes or less performed exceedingly well, with half meeting the proposed 30 to 50% range. However, Table 4.2 also provides insight to the vulnerability of the TTR strategy when large numbers of VAV zones are attached to an AHU or RTU. As the number of attached VAV zones increases, the fan energy savings percentage decreases.

The largest facility studied, JFHQ, saw many of the units studied fall well short of the 30% mark. This was due to a combination of a large amount of VAV zones, radiant in-floor heating system and a temperature reset strategy based on outside air temperature. A majority of the VAV zones at this site could only provide cooling only service, with radiant tubing providing the only heating service. In addition, several instances of inactive chillers and boiler were noted. This is discussed in detail later on.

The oldest facility studied, Boone RC, also failed to realize the goal of 30% fan energy savings. This facility suffered from intermittent operation of boiler and chiller, downed network equipment and several alterations pertaining to setpoints and occupancy schedules. Again, this will be discussed later on.

When comparing the fan energy savings of the TTR strategy vs traditional TR strategies, the results were less hopeful. Table 4.1 also provides the fan energy savings at JFHQ when compared to TR strategies. Both TR methods outperformed the TTR strategy in terms of fan energy. However, AHU-2 and AHU-3 had 50 and 38 VAV boxes, respectively. The results shown in Table 4.1 are not surprising as both the TR strategies used required a minimum amount of "air requests" before action is taken to adjust the static pressure setpoint. This allowed the strategies to work even with several rogues zones caused the MDP value to remain at 100%. Though, this method may inherently leave some VAV zones constantly above or below their respective space temperature setpoints. The temperature control comparison between the TTR and TR strategies is discussed later on.

Tiered Trim and Respond vs. Fixed Static Pressure

Boone Readiness Center

At the Boone RC, the TTR strategy was compared to a FSP strategy on both AHUs. The results shown in Table 4.3 illustrate the vulnerability of the TTR method when trying to control a large number of VAV zones.

Table 4.3 Average Boone RC fan energy savings per unit per day, FSP vs TTR.

Site	Unit	FSP kWh	TTR kWh	% Fan Energy Savings	% Total Fan Energy Savings
Boone RC	AHU-1	79.07	62.58	20.86%	16.72%
	AHU-2	89.27	79.73	10.69%	

While the TTR strategy on AHU-1 performed moderately well against the FSP strategy, it did not display the same success on AHU-2. AHU-2 regularly suffered from rogue zones that drove the MDP value to 100% and bugs in the TTR program that caused the SPset value to "reset" or jump to the SPmax value. The rogue zones were caused by incorrectly sized VAV boxes and reheating controls driving dampers to 100% open with boiler operation disabled. Both AHUs had difficulties maintaining temperature setpoints in various zones. For example, many zones with exterior walls showed difficulties maintaining space temperature within setpoints during cold winter days. See Appendix C for issues during specific test dates.

In combination with these observances, swathes of data were lost due to export utility malfunctions. This lead to a majority of valid test days occurring on cold, winter days. Of the 10 months studied, only 8 weeks of TTR and 15 weeks of FSP results were captured. The TTR results range from July to early January, while the FSP results range from July to April. This was due to the loss of the DDC network controller midway through the project causing over 4 months delay in the study. There were also several alterations to occupancy schedules during TTR enabled weeks. See Appendix A for specific valid test dates.

Another observed issue was excessive static pressure oscillation during TTR days, even with significant reductions in TM and RP rates. Figures 4.1 and 4.2 provide an example of these observations.

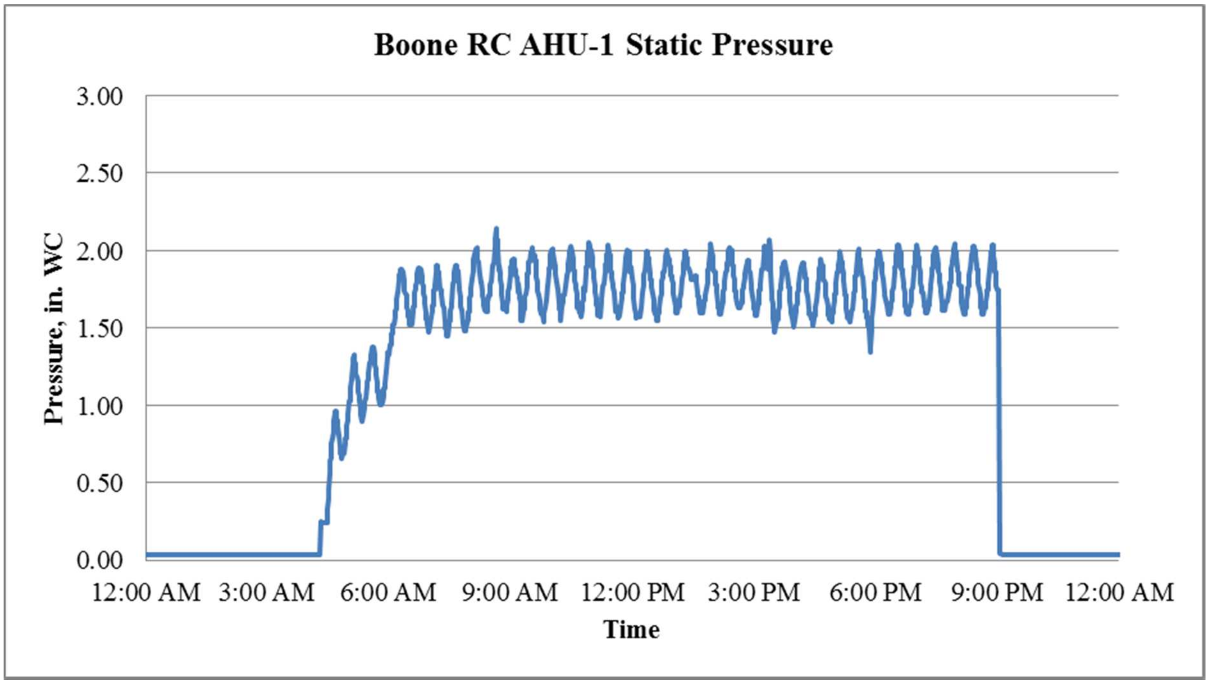

Figure 4.1 TTR strategy static pressure control, 10/21/2015.

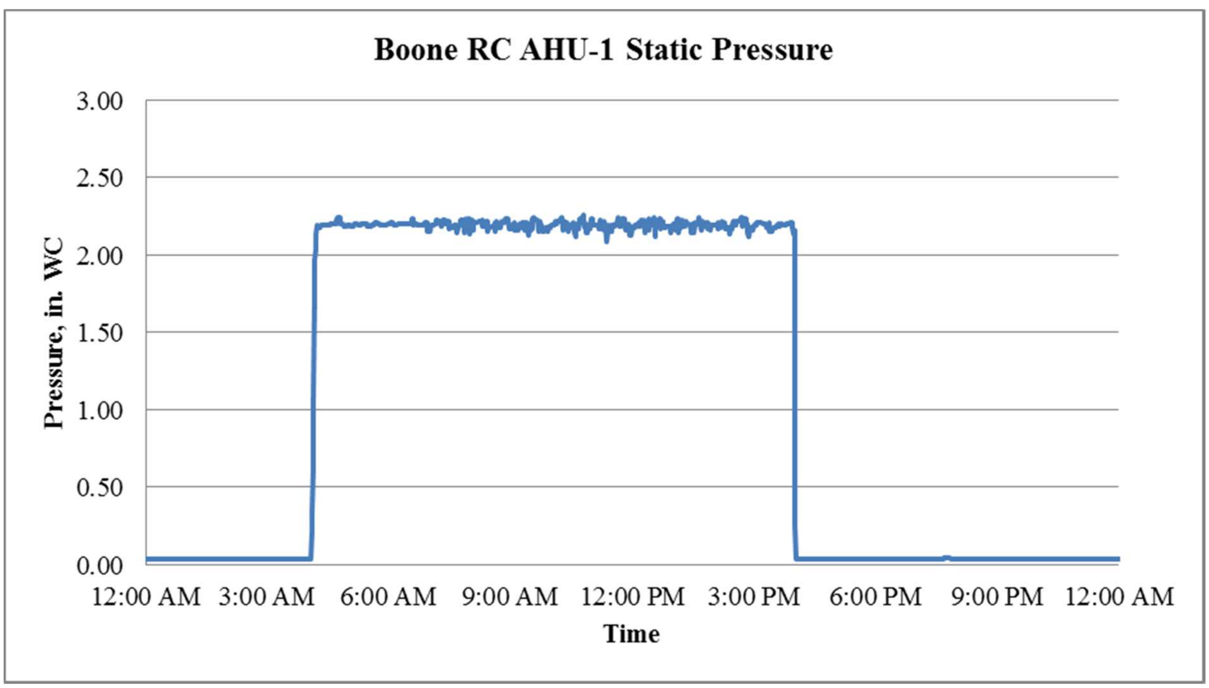

Figure 4.2 FSP strategy static pressure control, 12/1/2015.

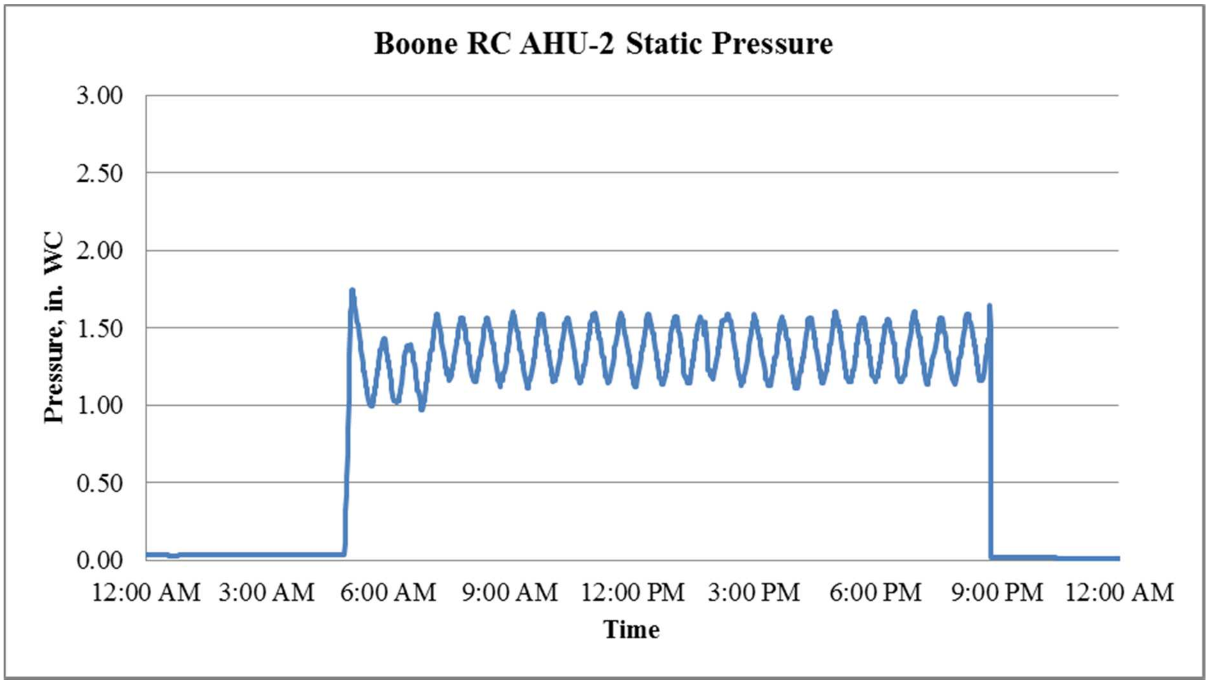

Figure 4.3 TTR strategy static pressure control, 7/22/2015.

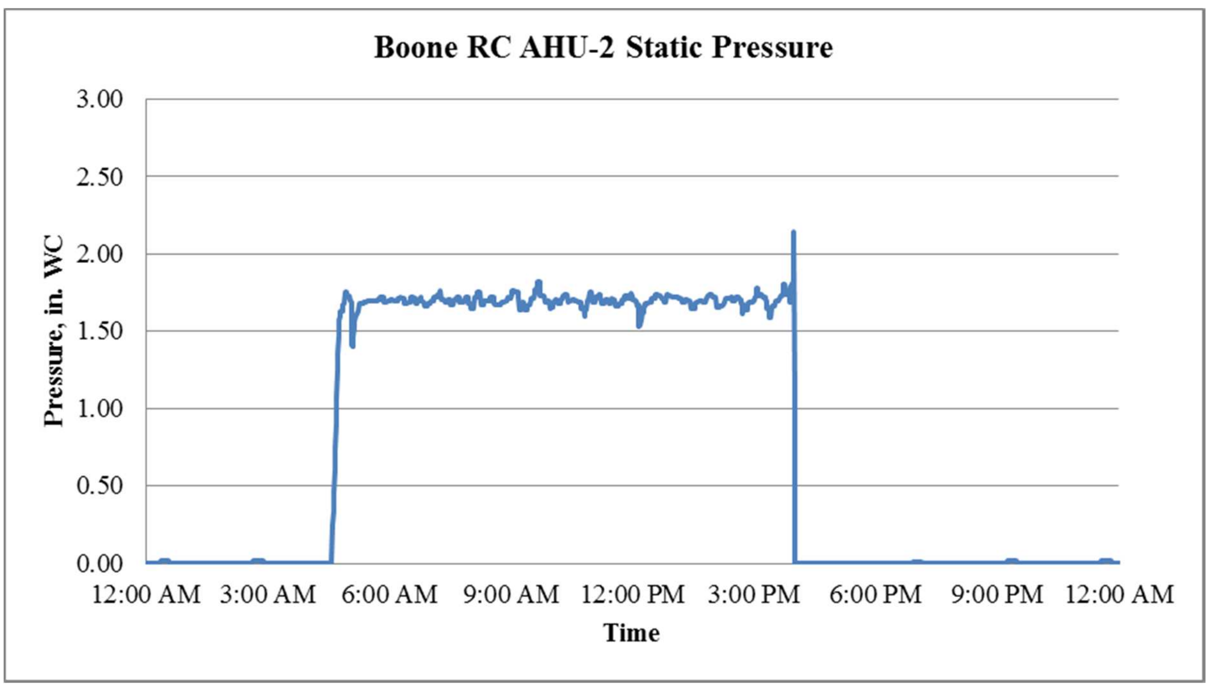

Figure 4.4 FSP strategy static pressure control, 12/3/2015.

The TTR strategy at the Boone RC facility performed poorly in minimizing static pressure oscillation. This oscillation could be attributed to the state of the equipment, as the Boone RC is the oldest facility and with the earliest renovations pertaining to the HVAC equipment studied. The available damper position information, command signal only, may also play a part in the excessive oscillation observed in both AHUs. Figures 4.2 and 4.4 provide an example of the static pressure control for AHU-1 and AHU-2 under the FSP strategy.

Overall, the Boone RC displayed the difficulties of the TTR strategy. One takeaway from this facility was the importance of temperature control while enabling a static pressure reset control strategy. Correct and full operation of a facility’s boiler and chiller are necessary for any zonal-based static pressure reset strategy.

Des Moines Military Entrance Processing Station

At the Des Moines MEPS, the TTR strategy was compared with a FSP strategy. The results in Table 4.4 provides the results of the study from Des Moines MEPS, and sheds light on the potential of the TTR strategy at a relatively newer facility with a factory built AHU.

Table 4.4 Average Des Moines MEPS fan energy savings per unit per day.

Site	Unit	FSP kWh	TTR kWh	% Fan Energy Savings	% Total Fan Energy Savings
Des Moines MEPS	AHU-1	55.19	40.12	27.30%	27.30%

The results of the TTR strategy showed significant fan energy savings at a site containing a wide range of zone types. Again at this site, most issues with wide open VAV dampers were traced back to inoperable chiller or boiler. One rogue zone observed during the study would have the damper position at 100%, requesting reheat service while boiler operation was disabled. However, issues such as this were far fewer than those observed at the Boone RC and other sites.

The Des Moines MEPS also suffered from a downed network controller mid-way through the study. From October to late December, no data were recorded during the study. Of the 10 months studied, 10 weeks of valid TTR data and 15 weeks of valid FSP data were recorded. See Appendix C for specific valid test dates.

The DDC system at the Des Moines MEPS contained the feedback signal for the damper position of the VAV zones. This should imply an improved control of the static pressure during TTR days over command signal for damper position. Figures 4.5 and 4.6 provide an example of typical static pressure control from the TTR strategy and Figure 4.7 provides an example of FSP strategy static pressure control.

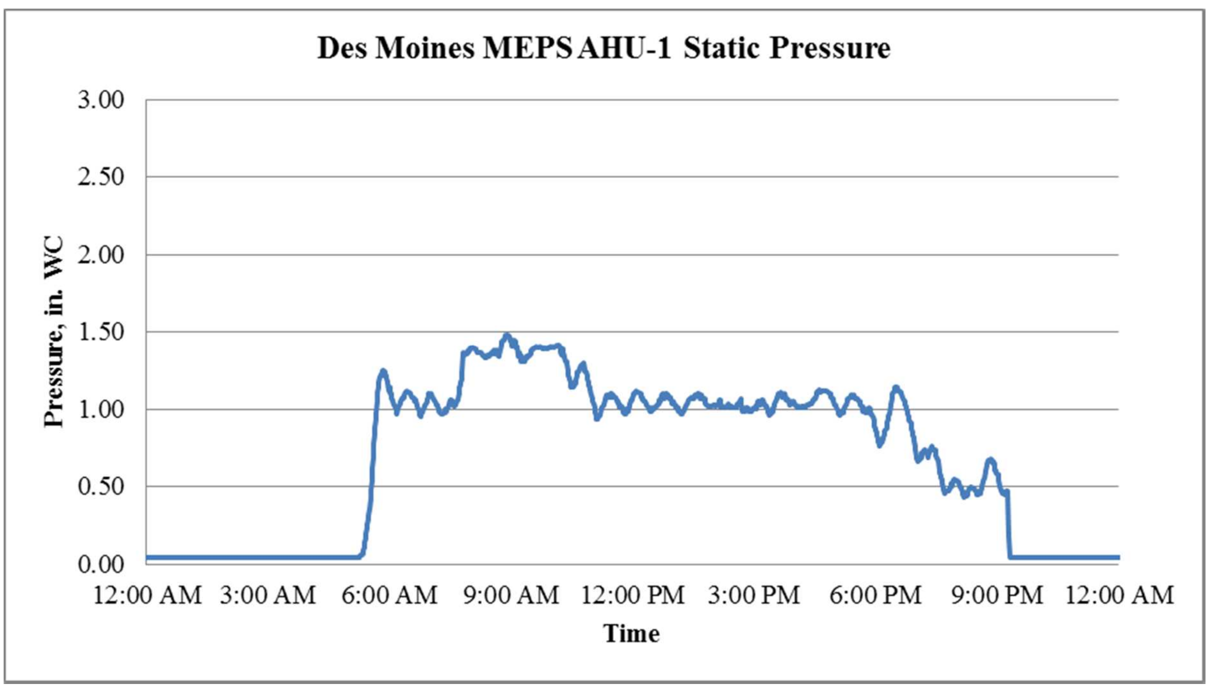

Figure 4.5 TTR strategy static pressure control, 5/17/2016.

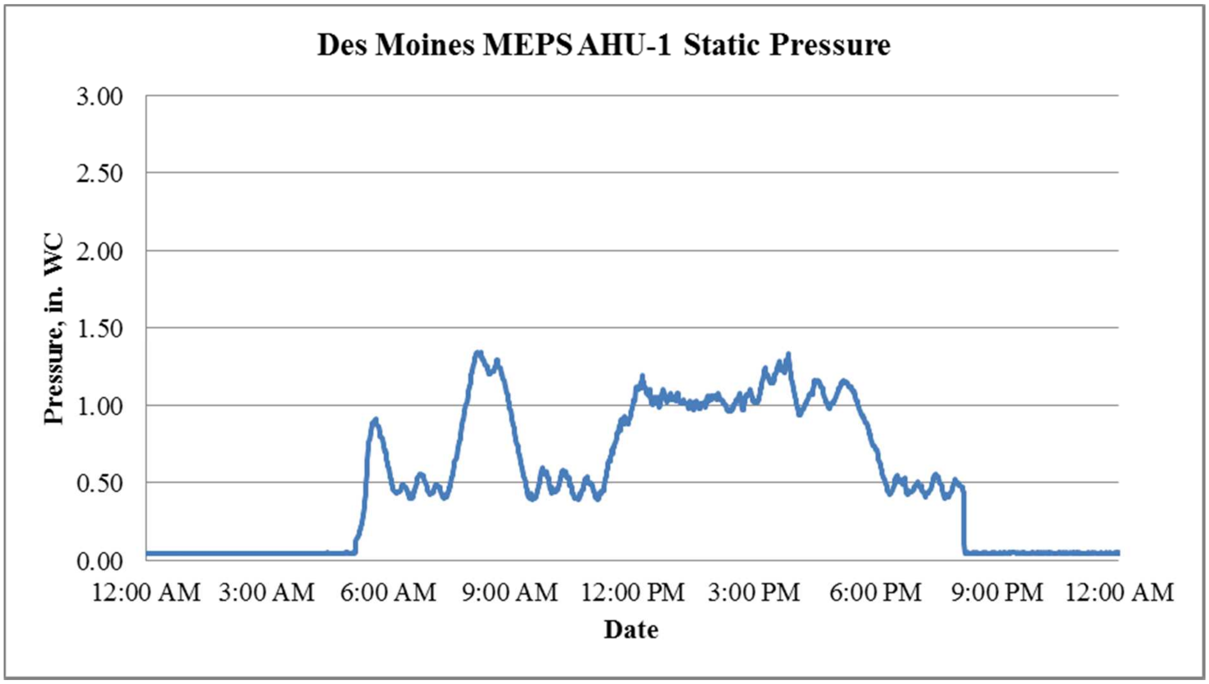

Figure 4.6 TTR strategy static pressure control, 3/25/2016.

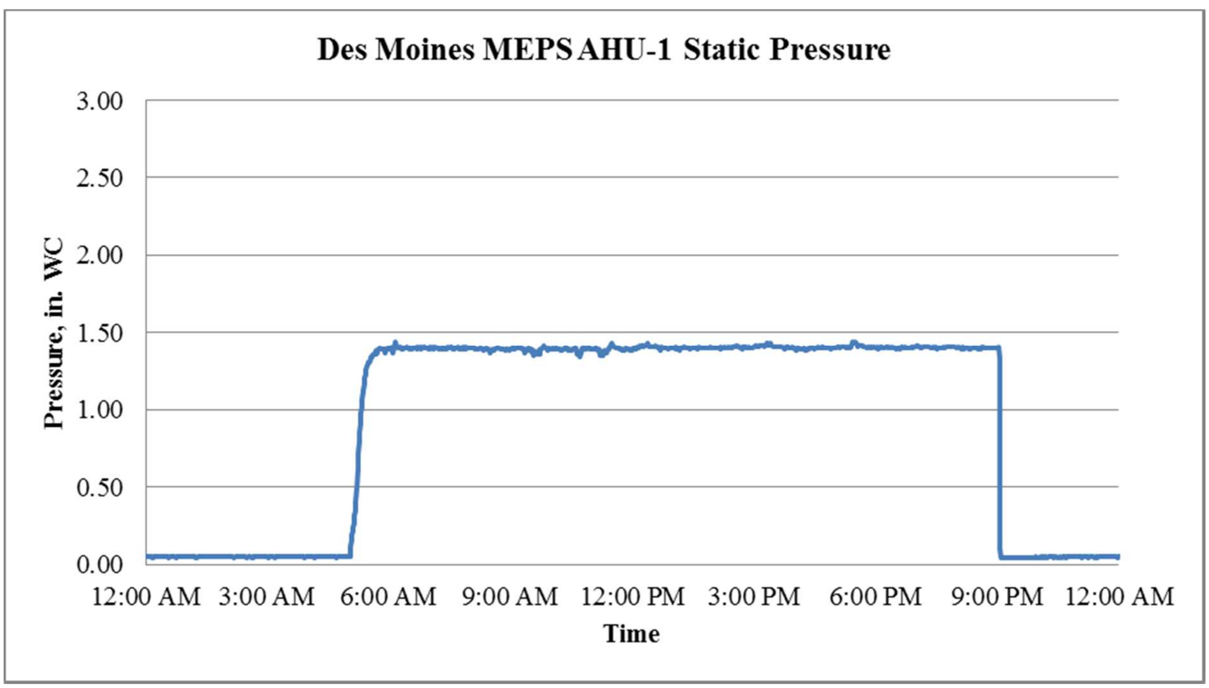

Figure 4.7 FSP strategy static pressure control, 1/19/2016.

From Figure 4.5 and 4.6, the static pressure control is much tighter than observed control in other command signal based damper position sites. Additionally, static pressure oscillation was minimal or nonexistent at the Des Moines MEPS site. The TTR strategy also demonstrated its ability to react to changing building load demands, increasing static pressure when needed and decreasing when not needed.

At the Des Moines MEPS facility, the TTR strategy demonstrated its potential in reducing fan energy use while minimizing static pressure oscillation. While the strategy did not reach the fan energy savings mark of 30%, it demonstrated that stable control is achievable with adequate operation of the boiler and chiller. Throughout the study, zone temperatures were rarely outside their temperature setpoints.

Joint Forces Headquarters

The JFHQ contained 4 AHUs comparing the TTR and FSP strategy and 2 AHUs comparing the TTR and traditional TR strategies. For the TTR and TR strategy comparisons, a temperature control comparison was done as fan energy savings was expected to be similar and less insightful. Table 4.5 provides the results of the TTR and FSP and TTR and TR strategy comparisons.

Table 4.5 Average JFHQ fan energy savings per unit per day.

Site	Unit	FSP kWh	TTR kWh	% Fan Energy Savings	% Total Fan Energy Savings
JFHQ	AHU-1	66.97	63.80	4.73%	17.85%
	AHU-4	33.69	28.67	12.83%	
	AHU-9	10.75	4.20	59.92%	
	AHU-12	606.11	510.19	15.83%	

The fan energy savings results from JFHQ shed light on the shortcomings of the TTR strategy. The inadequate performance may stem from a combination of large number of VAV zones per AHU, with the exception of AHU-9, radiant in-floor tubing as the single source of heating for nearly all VAV zones, a temperature reset strategy based on outside air temperature and significant reduction in static pressure limits from when the site was commissioned. Intermittent operation of boiler and chiller in addition with cooling-only service from the VAV boxes made zone temperature control difficult for nearly all zones, and therefore minimized the effectiveness of the TTR strategy.

The most significant reason limiting the fan energy savings was the reductions in static pressure limits set by facility managers. At the JFHQ, the existing static pressure limits were vastly reduced from the static pressure setpoints found in the original commissioning documents. This was stated by facility managers to reduce levels of noise, frequency of unit trip due to high static alarm faults and provide adequate airflow to already known rogue zones. This was evident by the MDP value being near or at 100% open during FSP and TTR days. It was common practice to manually raise or lower static pressure setpoints to accommodate cold heating-demand and warm cooling-demand days as well. If the static pressure setpoint for a FSP strategy has already been reduced to meet the needs of most of the facilities' zones, the fan energy savings from the TTR strategy are minimal.

At the JFHQ, radiant in-floor heating was used throughout the facility, and in many zones was the only source of heating. Regardless of static pressure control strategy used, numerous observations of simultaneous heating and cooling were noted. This added to the instability of the TTR strategies used in most of the AHUs studied and the TR strategies. Supply air temperature was also a factor, as supply air temperature setpoints from the AHUs at times were not sufficient to satisfy occupant controlled temperature setpoints in some zones.

The data collection from JFHQ also suffered setbacks from downed network controllers, equipment outages and network security clearance issues due to the facilities functions. However, 15 weeks of both valid TTR and FSP strategy data were recorded. AHU-12 suffered an outage on 2 of its 4 supply fans from November 2015 to mid-January 2016. Data recorded during these days were invalidated only for AHU-12 and Total Fan energy results. See Appendix A for specific valid test dates.

The DDC system at the JFHQ contained the feedback signal for the damper position of the VAV zones. Again, this should imply an improved control of the static pressure during TTR days. Figures 4.6 and 4.7 provide TTR and FSP static pressure control on AHU-1. Figures 4.8 and 4.9 provide TTR and FSP strategy static pressure control on AHU-4. Figures 4.10 and 4.11 provide TTR and FSP strategy static pressure control on AHU-9. Figures 4.12 and 4.13 provide TTR and FSP strategy static pressure control on AHU-12.

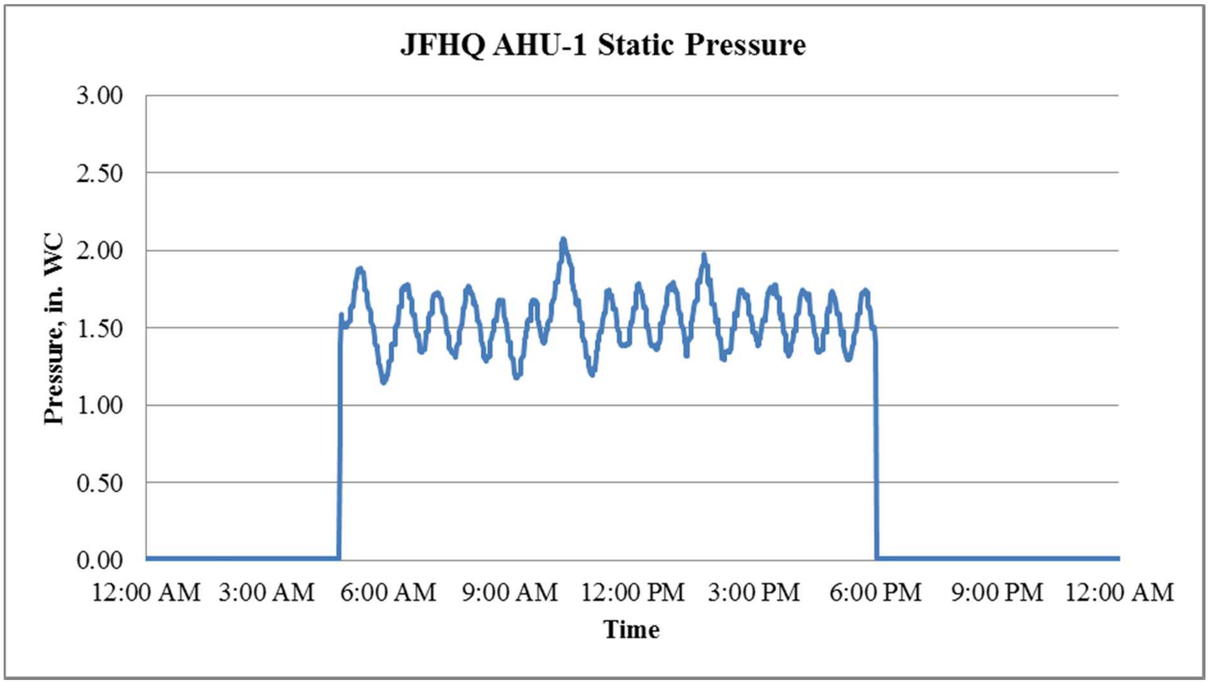

Figure 4.8 TTR strategy static pressure control, 10/22/2015.

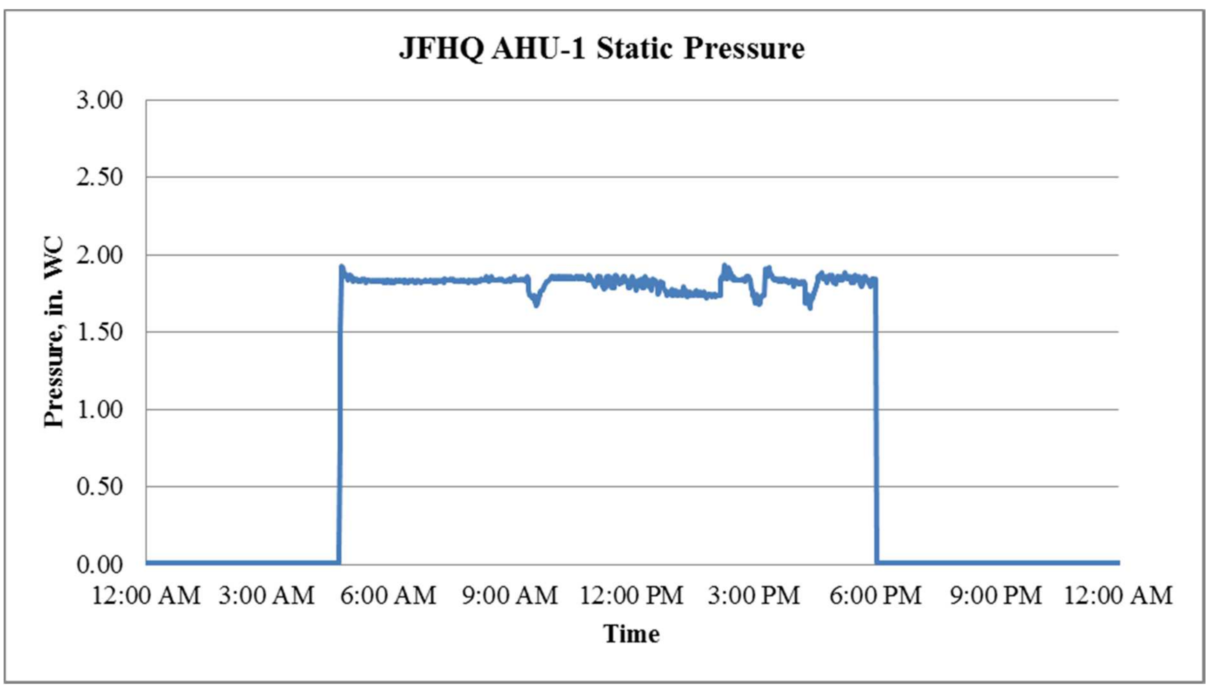

Figure 4.9 FSP strategy static pressure control, 11/10/2015.

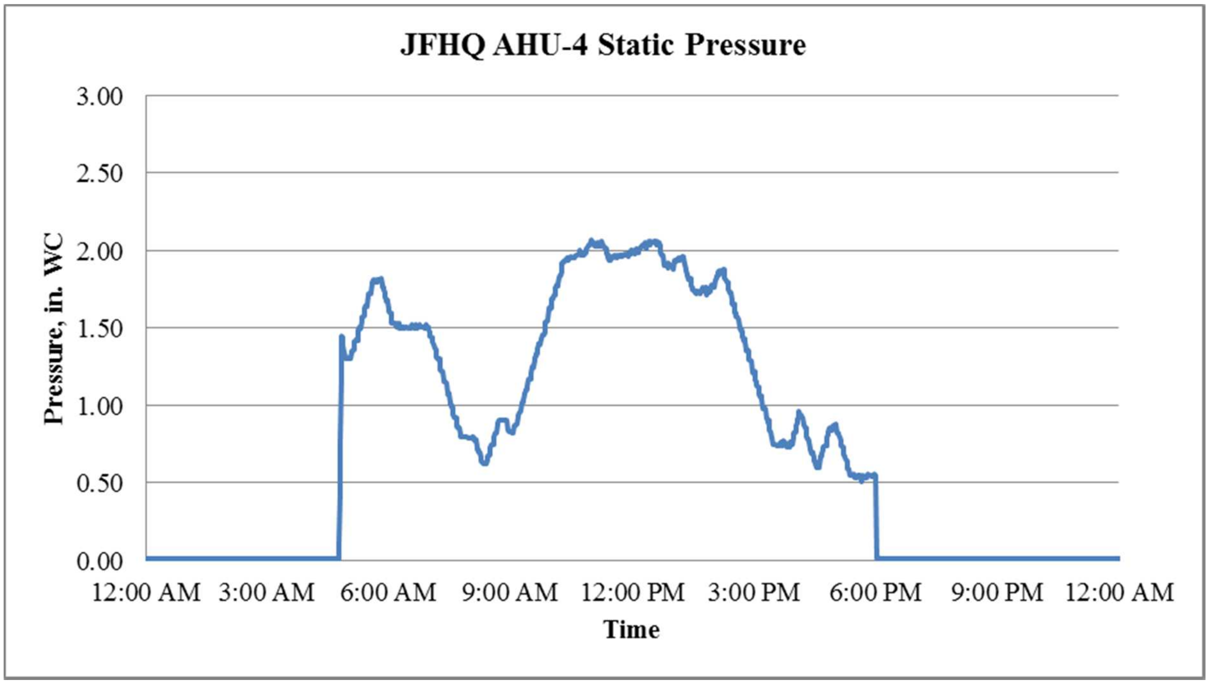

Figure 4.10 TTR strategy static pressure control, 3/17/2016.

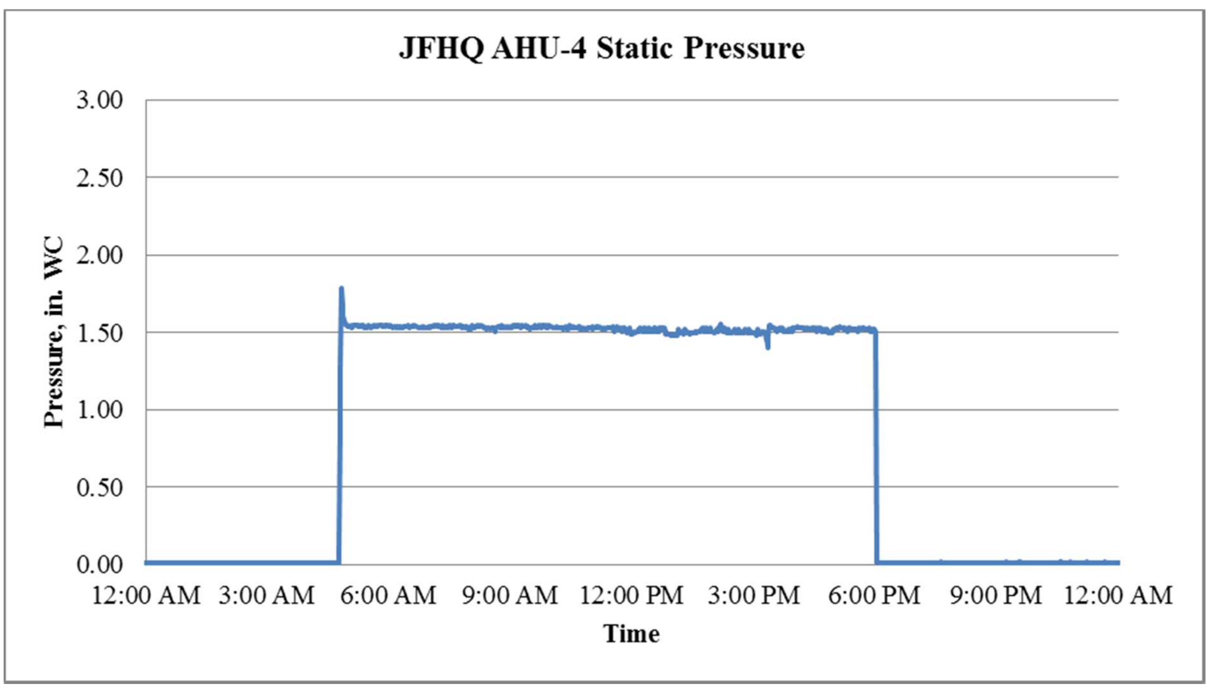

Figure 4.11 FSP strategy static pressure control, 11/11/2015.

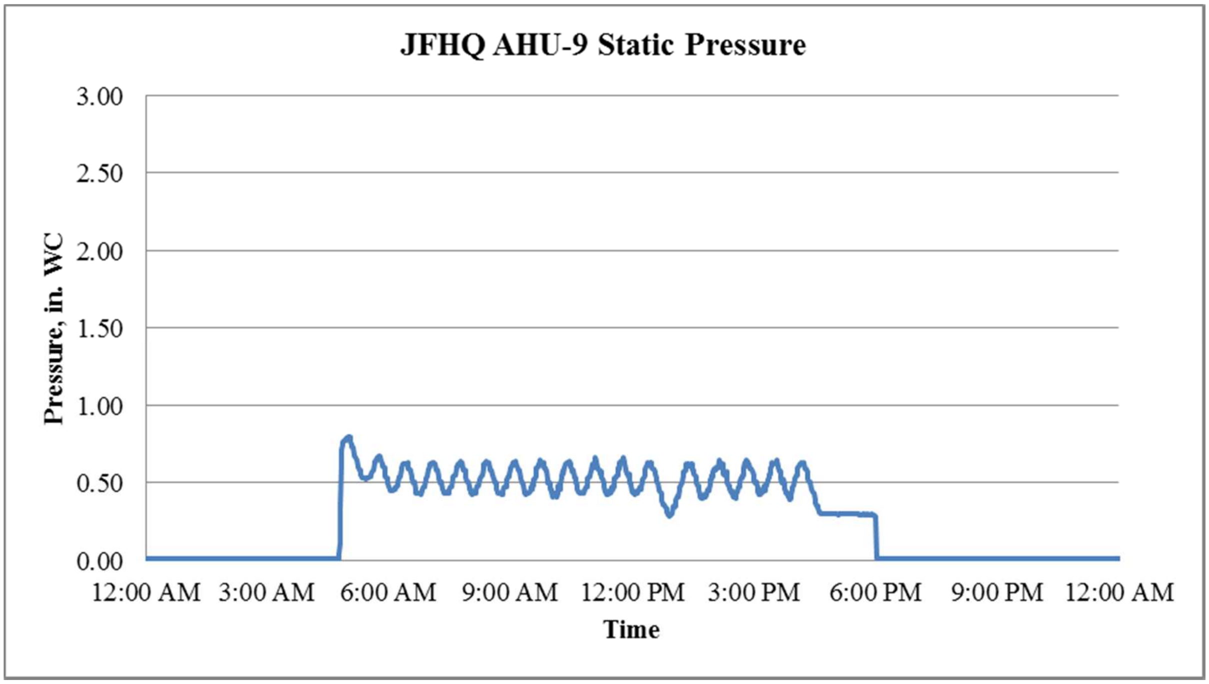

Figure 4.12 TTR strategy static pressure control, 5/12/2016.

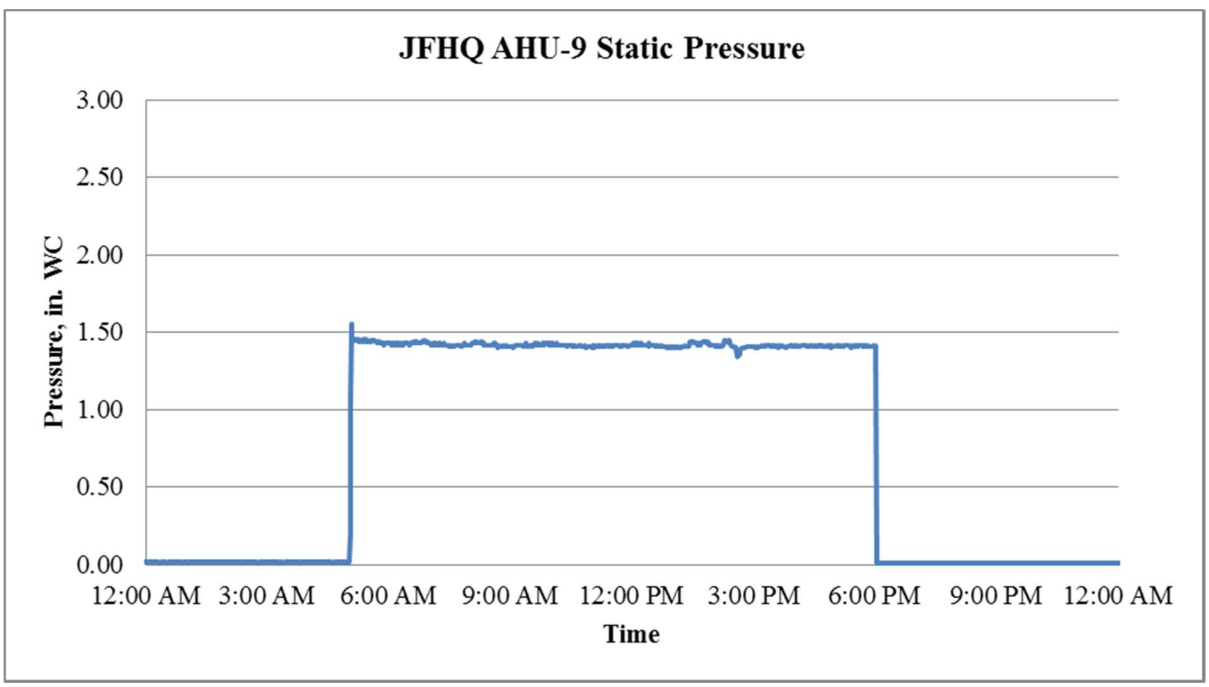

Figure 4.13 FSP strategy static pressure control, 9/11/2016.

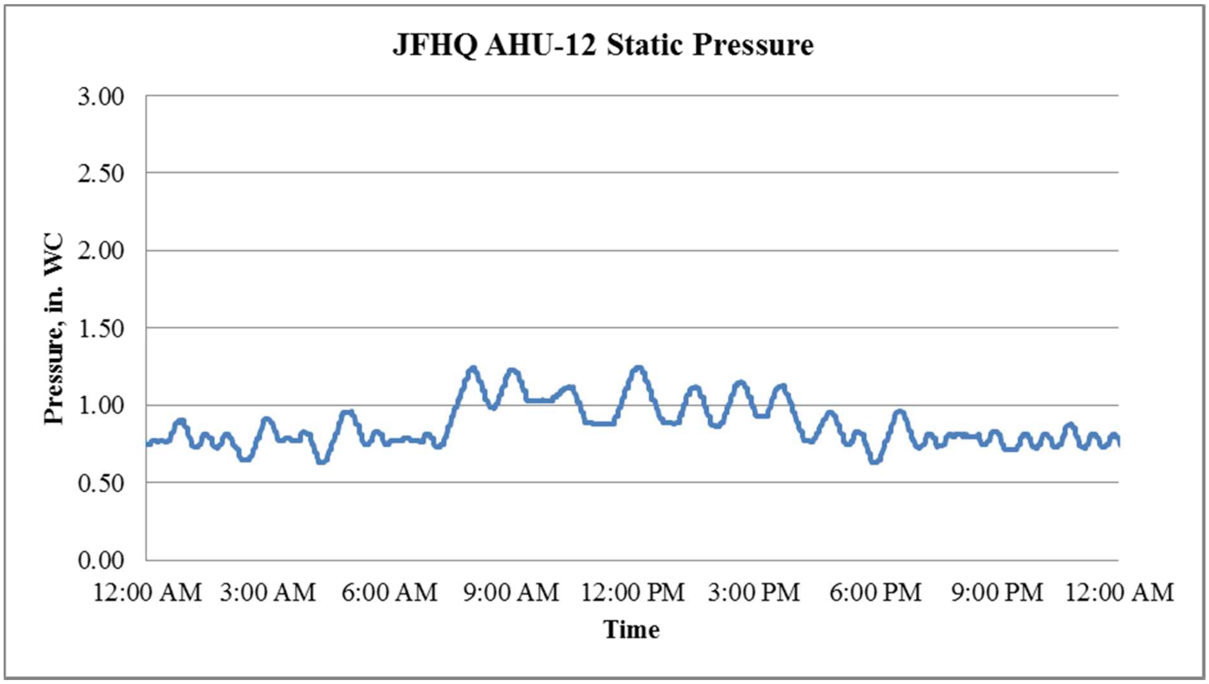

Figure 4.14 TTR strategy static pressure control, 9/24/2015.

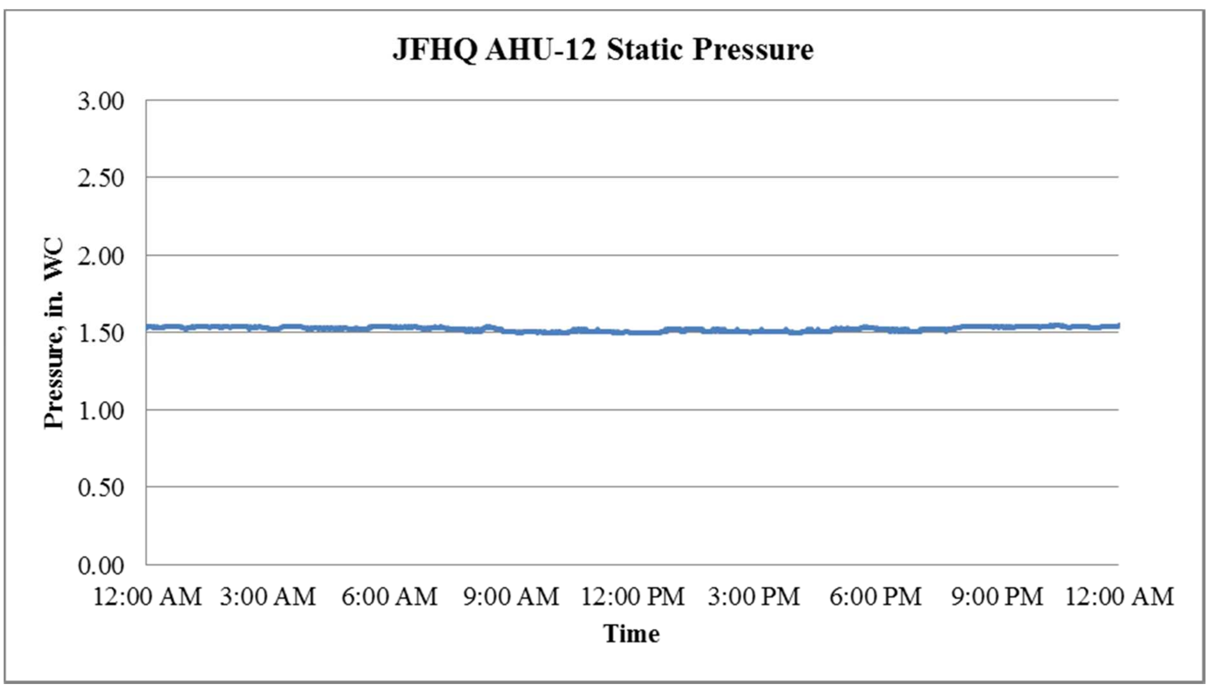

Figure 4.15 FSP strategy static pressure control, 9/15/2015.

From Figure 4.8, the TTR strategy displayed heavy static pressure oscillation on AHU-1. Instances of the TTR strategy reacting to building loads was difficult to find, as the strategy held the static pressure at or near the SPmax for most of the study. This is also apparent from the poor fan energy savings result over the FSP strategy. Figure 4.9 provides an example of the relatively stable static pressure control under the FSP strategy.

From Figure 4.10, the TTR strategy performed better as seen in AHU-1, reacting to building load demand. However, static pressure oscillation was still present but not as severe. Figure 4.11 provides an example of the relatively stable static pressure control under the FSP strategy.

Figure 4.12 provides an example of the static pressure control from the TTR strategy an AHU-9. Due to the size and number of zones served by this AHU, the fan energy savings (~60%) over the FSP strategy are not as insightful as the other results. Static pressure oscillation was observed from this AHU, though the static pressure under the TTR strategy was at or near the SPmin. Figure 4.13 provides the static pressure control under the FSP strategy which was stable.

Figure 4.14 provides the static pressure control from the TTR strategy on AHU-12, the largest of the AHUs at the JFHQ. The figure displays the TTR strategy reacting to building load demand, however oscillation in static pressure is apparent. Figure 4.15 provides the static pressure control under the FSP strategy, which was stable.

Overall, the TTR strategy performed less than expected at the JFHQ. With the exception of AHU-9, the fan energy savings for the TTR and FSP strategy comparison was marginal at best. Numerous observations of static pressure oscillation and frequent high static alarms caused units to trip throughout the study hindered the reset strategy.

Along with the Boone RC facility, the issues and results at the JFHQ is a demonstration of the importance of proper boiler and chiller operation. Additionally, the use of radiant in-floor heating and cooling-only VAV boxes and reduction in static pressure limits made control zone temperature difficult. Numerous zones throughout the study were constantly outside their temperature setpoints.

Muscatine Armed Forces Reserve Center

The Muscatine AFRC site compared the TTR strategy and the FSP strategy on 3 RTUs. Table 4.6 provides the results of the study at a relatively newer, LEED Silver rated facility.

Table 4.6 Average Muscatine AFRC fan energy savings per unit per day.

Site	Unit	FSP kWh	TTR kWh	% Fan Energy Savings	% Total Fan Energy Savings
Muscatine AFRC	RTU-1	2.94	2.39	18.91%	32.37%
	RTU-3	74.47	52.51	29.46%	
	RTU-4	59.91	38.02	36.54%	

The TTR strategy performed well on RTU-3 and RTU-4. RTU-1 saw only modest savings, though the small supply fan size and type of zones served by the unit may inhibit any available energy savings. The 3 zones served by RTU-1 were kitchen areas and typically occupied a few hours every day.

The Muscatine AFRC site suffered very few setbacks in data collection. In total, 16 weeks of valid FSP and 15 weeks of valid TTR strategy data were recorded. The date range for the data recorded during this study was from July 2015 to May 2016. However, from December to February, RTU-4 was not operational due to high static pressure alarm faults.

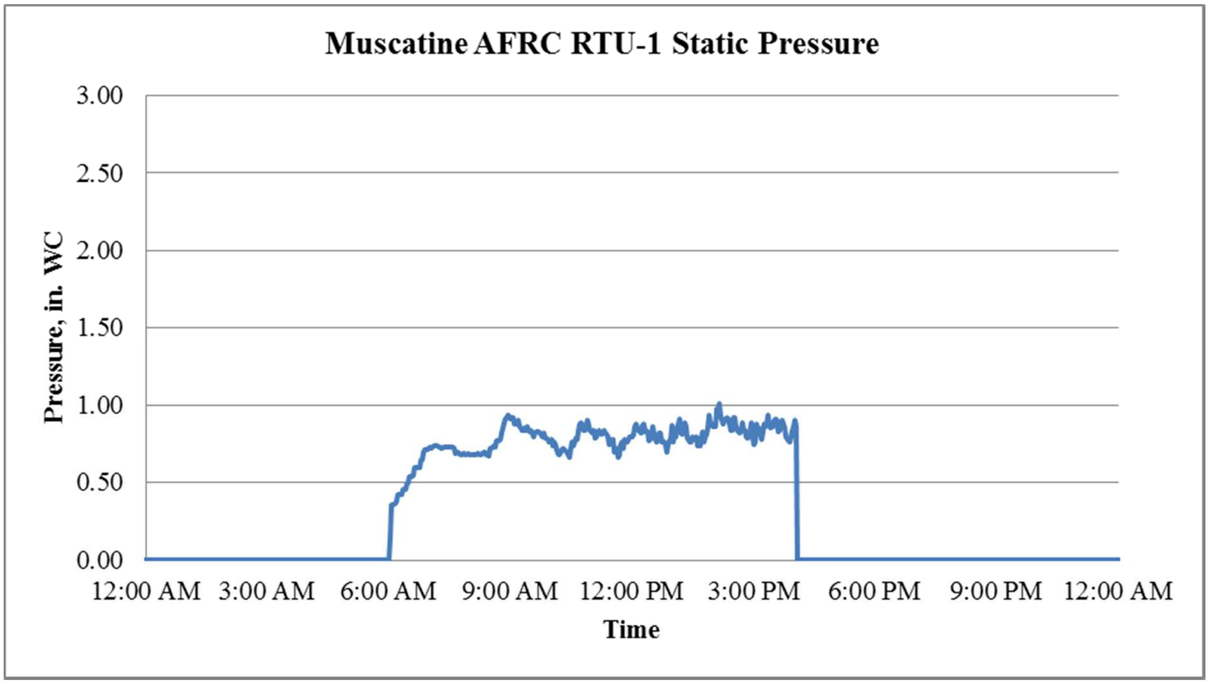

Figure 4.16 TTR strategy static pressure control, 4/18/2016.

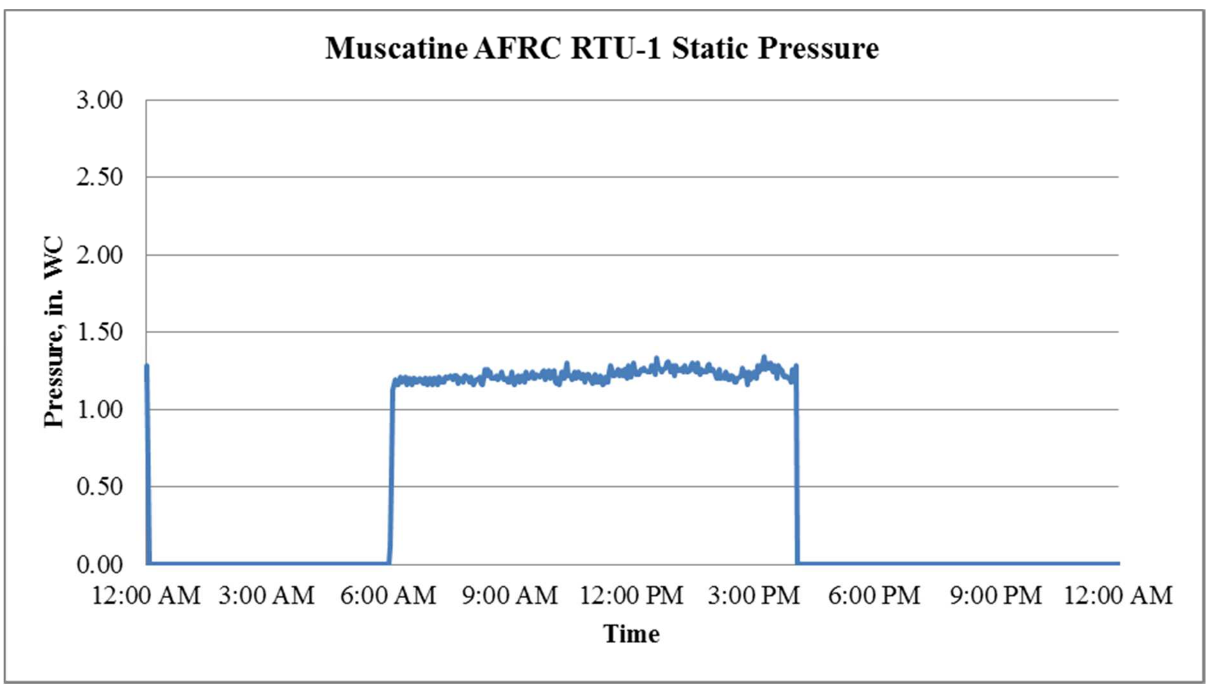

Figure 4.17 FSP strategy static pressure control, 4/4/2016.

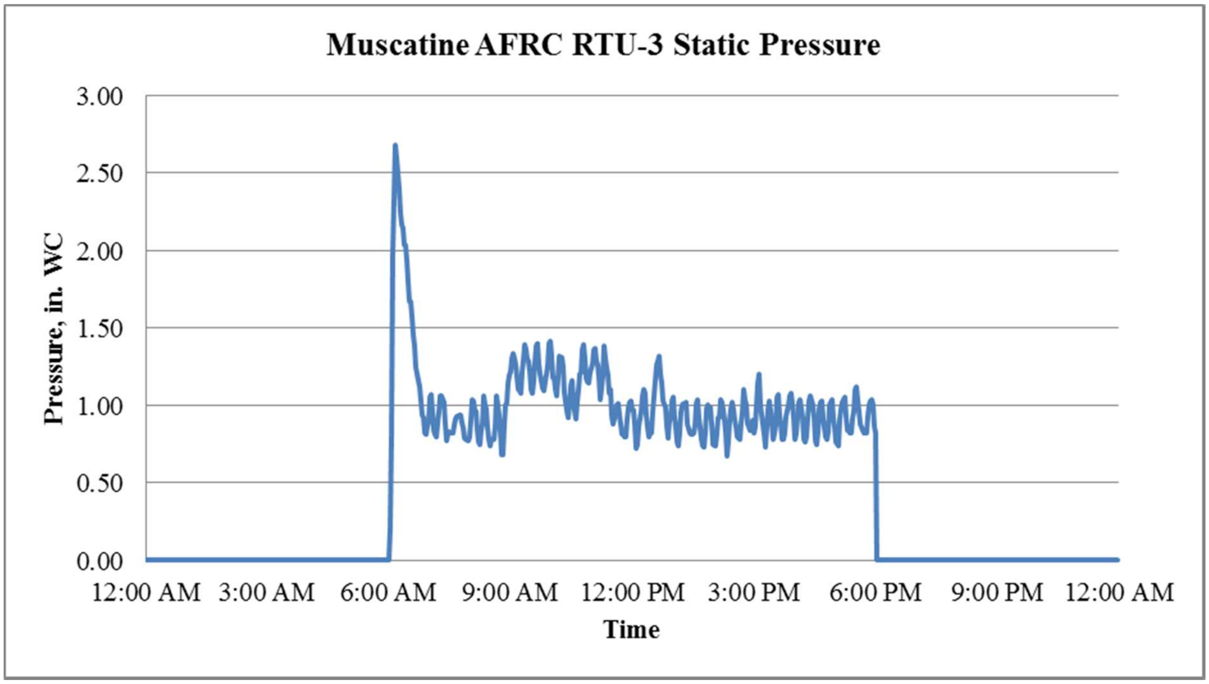

Figure 4.18 TTR strategy static pressure control, 4/22/2016.

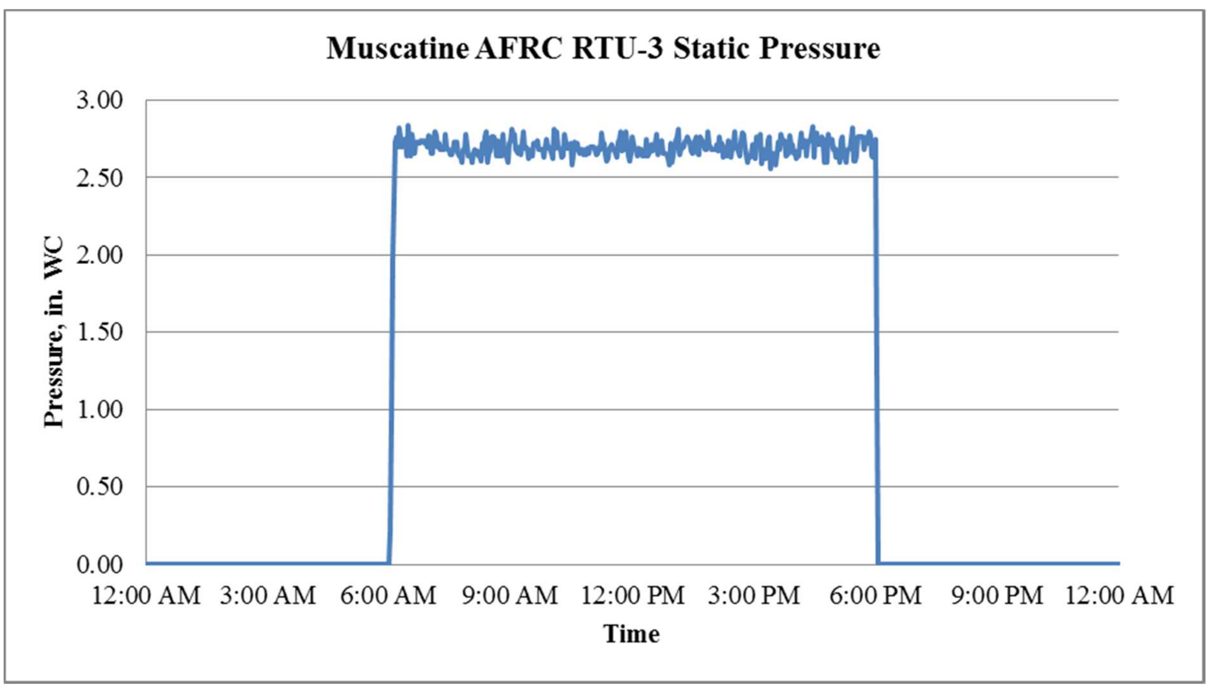

Figure 4.19 FSP strategy static pressure control, 4/5/2016.

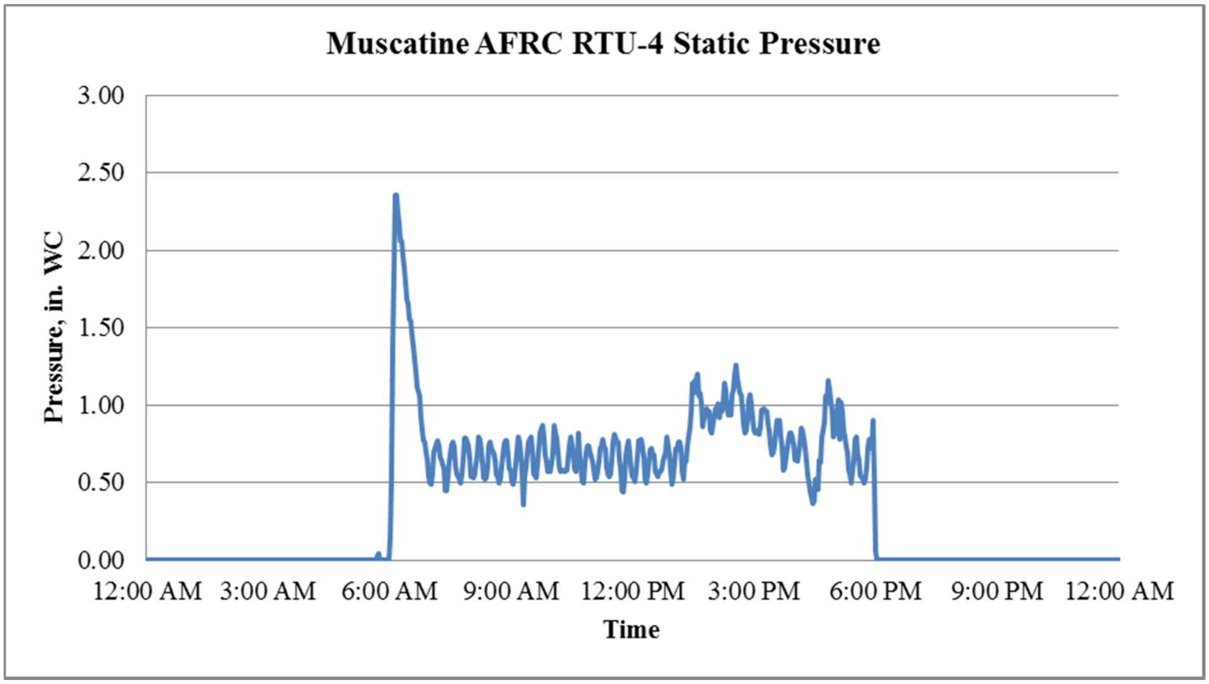

Figure 4.20 TTR strategy static pressure control, 4/20/2016.

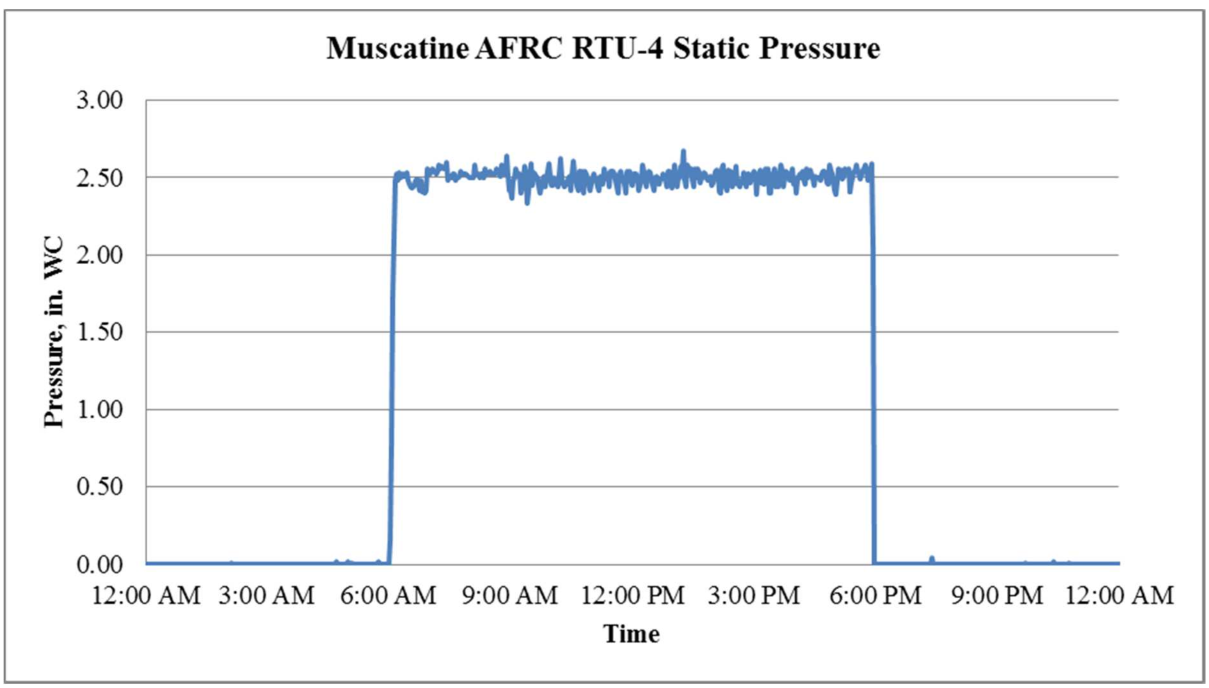

Figure 4.21 FSP strategy static pressure control, 4/6/2016.

From the example in Figure 4.16, the TTR strategy is able maintain relatively stable control of the static pressure. The RP parameters for RTU-1 were augmented slightly in anticipation of frequent oscillation due to the number and function of VAV zones served. The RP values were halved from the TM values, meaning the RTU could respond quickly to increasing building loads but reduce the SPset at a slower rate. Figure 4.17 provides an example of the stable control from the FSP strategy.

Figure 4.18 provides an example of the static pressure control from the TTR strategy on RTU-3. While the strategy is able to react to changing building loads, small yet frequent oscillation of static pressure is present. Figure 4.19 provides an example of the static pressure control under FSP strategy on RTU-3.

Like RTU-3, RTU-4 presented similar static pressure control form the TTR strategy. Figure 4.20 provides an example of the TTR strategy reacting to building loads, yet static pressure oscillating frequently. Figure 4.21 provides an example of the static pressure control under the FSP strategy.

Another point of discussion from the Muscatine AFRC site arises from the control signal of RTU-3 and RTU-4’s exhaust fans. The speed control signal for these exhaust fans are constant. However, for the factory and custom built-up AHUs, the return fan speed control signal is either parallel or resets based on supply fan speed. This may inhibit the fan energy savings potential of the TTR strategy over a FSP strategy.

Waterloo Readiness Center

The TTR strategy at the Waterloo RC fared well against the FSP strategy in terms of fan energy savings. Of the 5 sites studied the Waterloo RC was the least complex, having only 14 VAV zones. Table 4.7 provides the results of the TTR strategy at the Waterloo RC.

Table 4.7 Average Waterloo RC fan energy savings per unit per day.

Site	Unit	FSP kWh	TTR kWh	% Fan Energy Savings	% Total Fan Energy Savings
Waterloo RC	RTU-1	74.47	52.51	33.80%	33.80%

Though it was one of the oldest facilities, the Waterloo RC performed exceedingly well in terms of fan energy savings. This can most likely be attributed to the small number of the VAV zones within the facility.

Early on, issues pertaining to scheduling automatic switchover between the TTR strategy and FSP strategy were discovered. This lead to data collected during the first four weeks of the demonstration to be invalidated. However, the Waterloo RC provided the greatest amount of valid data. The date range for the data recorded during this study was from July 2015 to May 2016. In total, 22 weeks of valid FSP and 20 weeks of valid TTR strategy data were recorded.

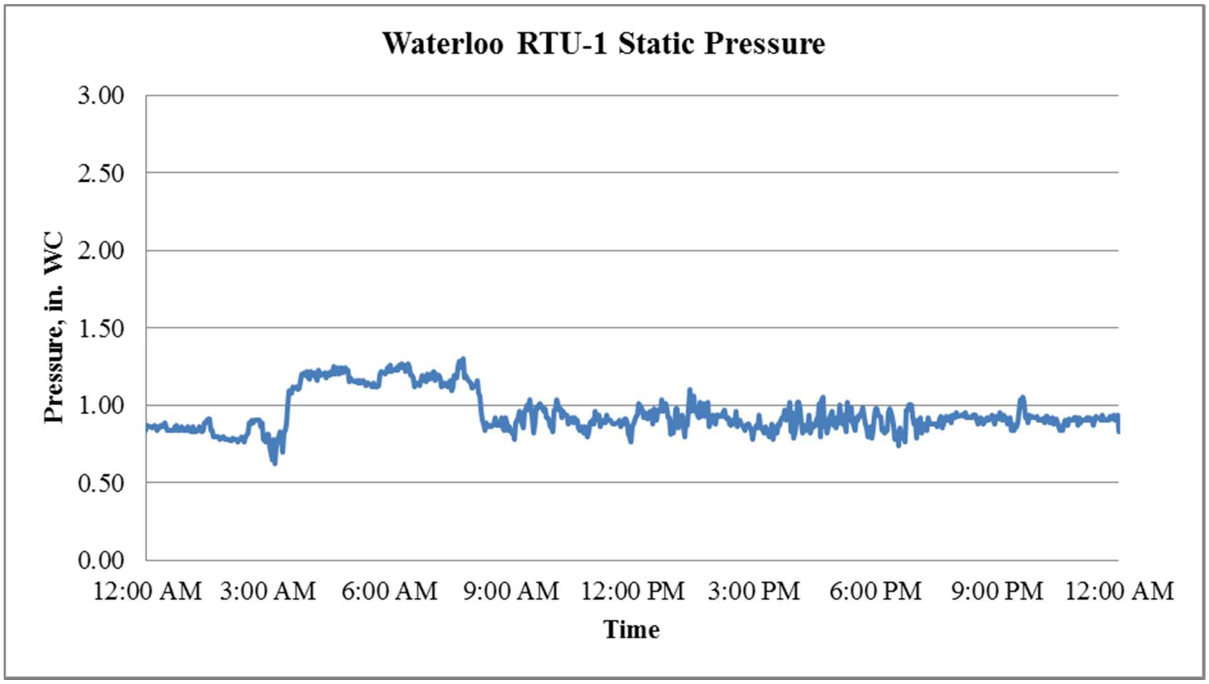

Figure 4.22 TTR strategy static pressure control, 11/18/2015.

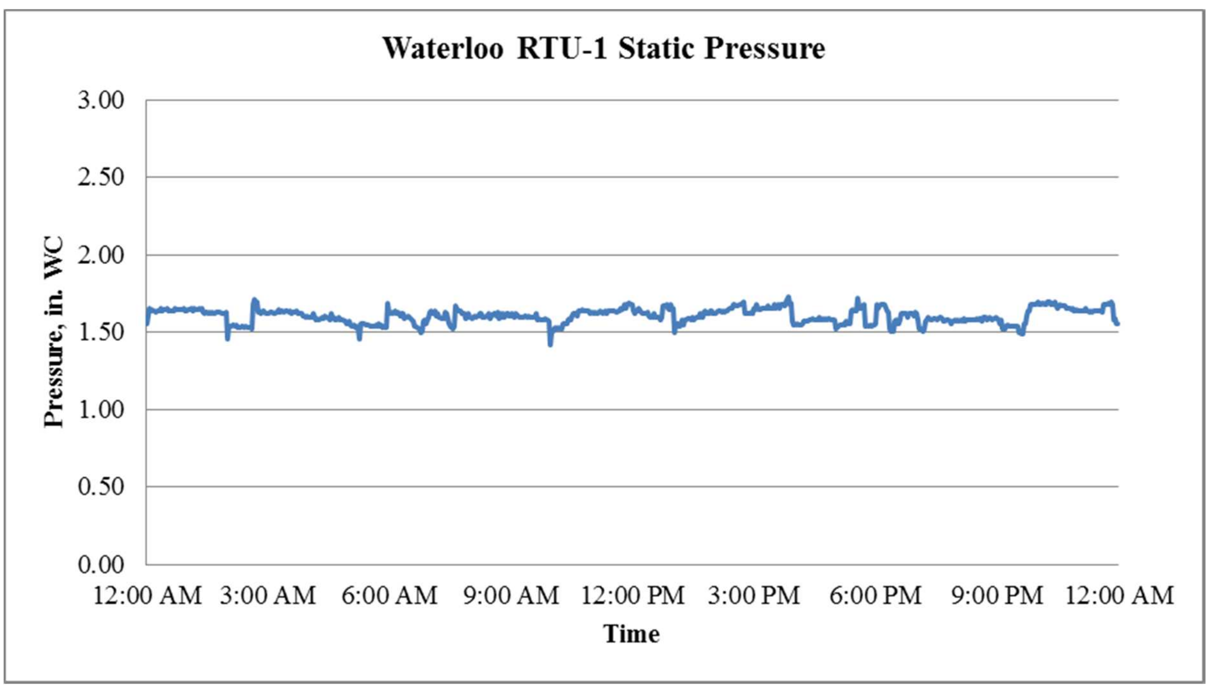

Figure 4.23 FSP strategy static pressure control, 11/28/2015.

The static pressure control of the TTR strategy performed well on RTU-1. From Figure 4.22 the TTR strategy reacted to building loads while the presence of static pressure oscillation was minimal or non-existent. Given that the static pressure control was not always stable in the FSP strategy as seen in Figure 4.23, the TTR strategy exceeded expectations.

Like the Muscatine AFRC, RTU-1 at the Waterloo RC suffered from intermittent operation of the exhaust fan. The control signal for RTU-1's exhaust fan was dependent of the supply fan speed, like the RTUs of Muscatine AFRC. The intermittent operation was due to overcurrent faults within the exhaust fans VFDs. The overcurrent faults would trip the exhaust fan if the VFD drew too much current. This would often happen during days when the FSP strategy was active, as the FSP typically requires a higher static pressure setpoint. During TTR strategy days, the static pressure setpoint was typically lower than the FSP strategy, resulting in operation of both supply and exhaust fans. This was at first believed to have skewed the results of the fan energy savings comparison, as the FSP strategy days would only contain energy data from the supply fan while TTR strategy days would contain energy data from the supply and exhaust fans. However, after a separate analysis ignoring days when the exhaust fan was operational, the increase in fan energy savings of the TTR strategy was negligible (< 3% increase in fan energy savings). Table 4.8 provides the results from Waterloo RC without days when the exhaust fan was operational for both FSP and TTR strategy days.

Table 4.8 Average Waterloo RC fan energy savings without exhaust fan operation.

Site	Unit	FSP kWh	TTR kWh	% Fan Energy Savings	% Total Fan Energy Savings
Waterloo RC	RTU-1	39.11	24.80	36.57%	36.57%

Tiered Trim and Respond vs Trim and Respond

At the JFHQ, a form of static pressure reset was already in use before this study. To compare the TTR strategy with existing TR strategies, AHU-2 and AHU-3 were selected for this comparison. Table 4.9 provides the final results of TTR and TR comparison.

Table 4.9 Average JFHQ fan energy savings per day per unit.

Site	Unit	TR kWh	TTR kWh	% Fan Energy Savings
JFHQ	AHU-2	34.02	42.85	-25.90%
	AHU-3	29.89	44.02	-47.27%

The TTR strategy was out performed by both TR strategies in fan energy savings. The existing TR strategies were able to ignore a certain number of zones before increasing or decreasing the SPset value. For this particular facility, the TR strategies benefitted greatly from ignoring some zones as temperature control was difficult with the combination of radiant in-floor heating and cooling-only VAV boxes.

When comparing the static pressure control, the TTR strategy was able to perform better than the TR strategy used on AHU-2 but not the TR strategy on AHU-3. Figures 4.24, 4.25, 4.26 and 4.27 provide examples of the static pressure control on AHU-2 from both the TTR and TR strategies. Figures 4.28, 4.29, 4.30 and 4.31 provide examples of the static pressure control on AHU-2 from both the TTR and TR strategies.

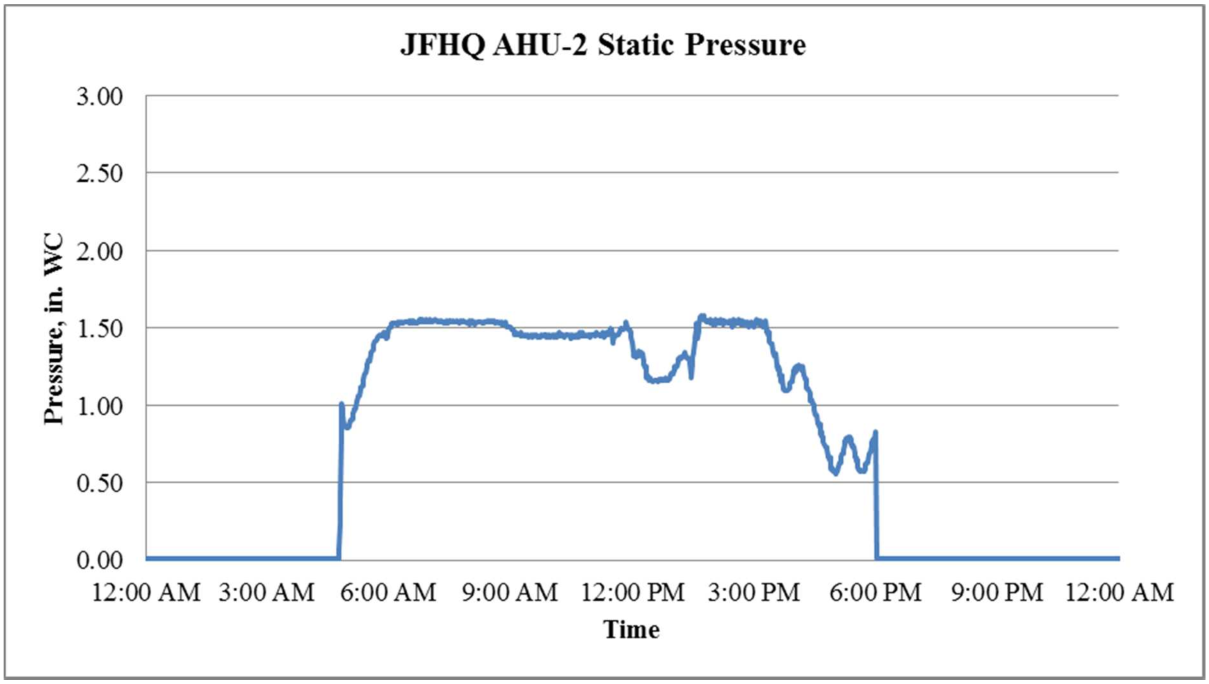

Figure 4.24 TTR strategy static pressure control, 5/4/2016.

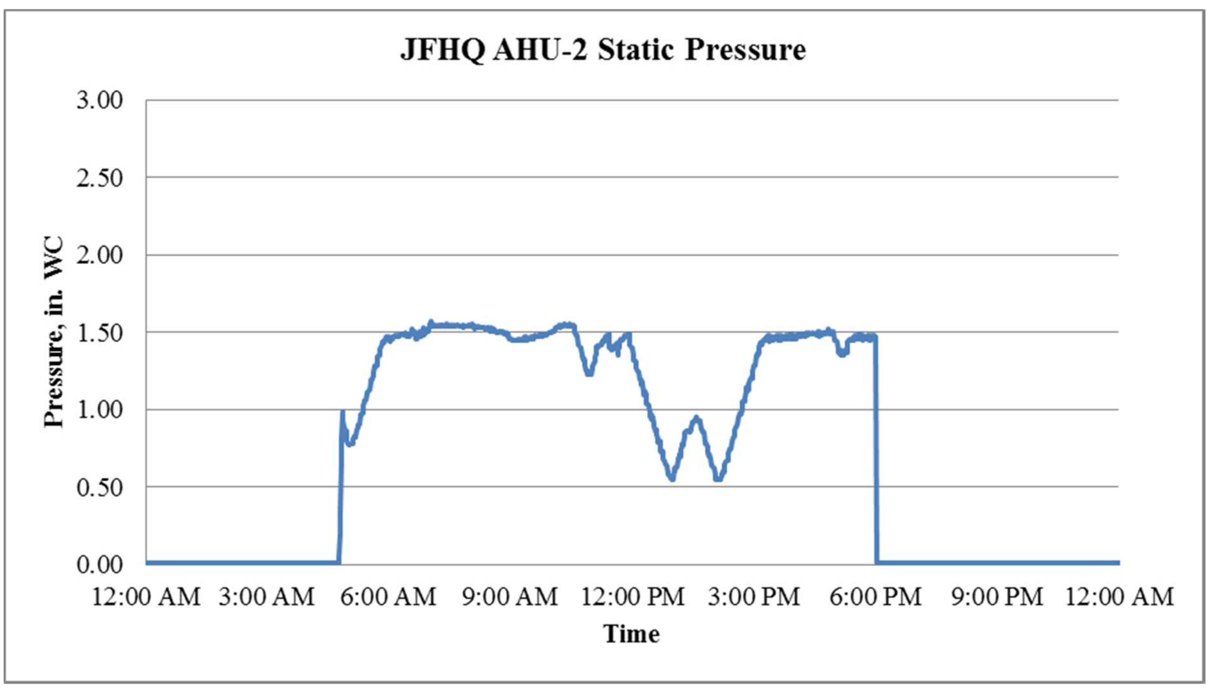

Figure 4.25 TTR strategy static pressure control, 5/5/2016.

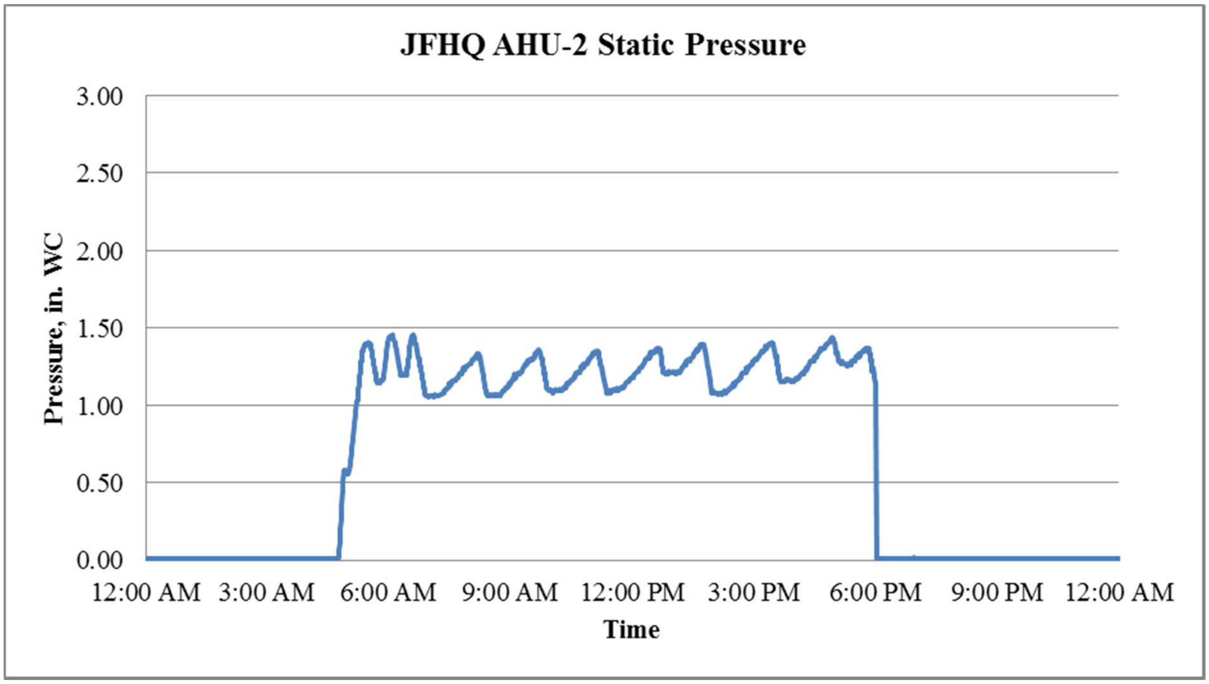

Figure 4.26 TR strategy static pressure control, 4/27/2016.

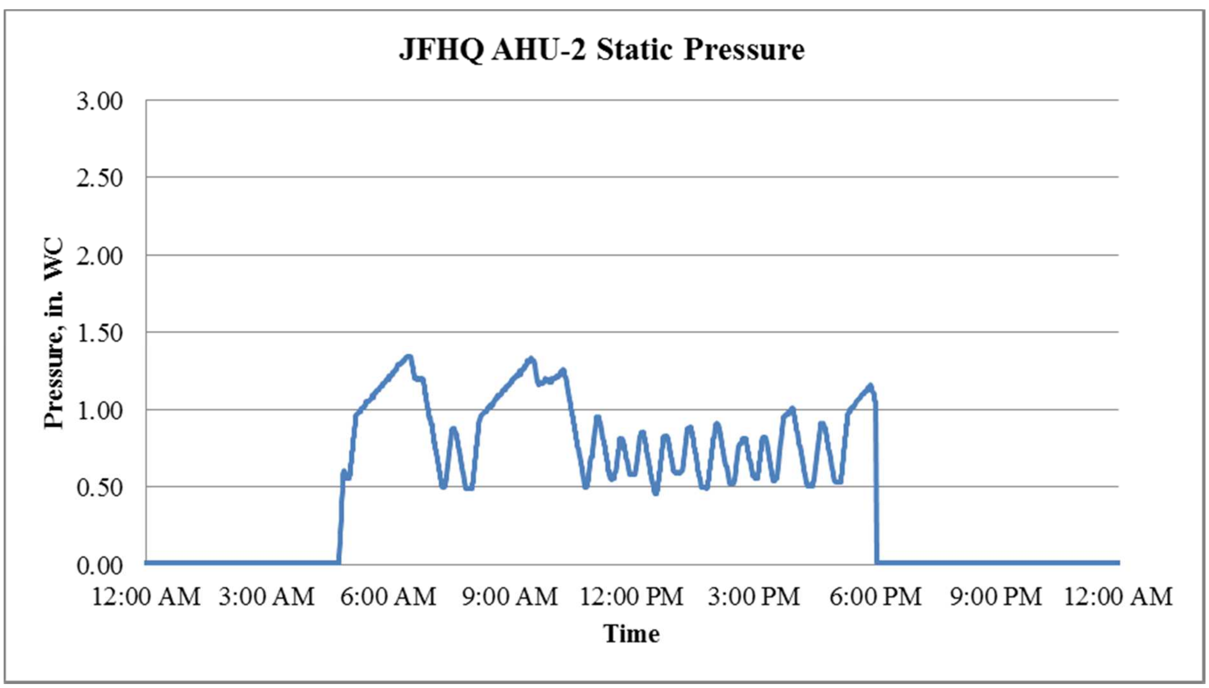

Figure 4.27 TR strategy static pressure control, 4/28/2016.

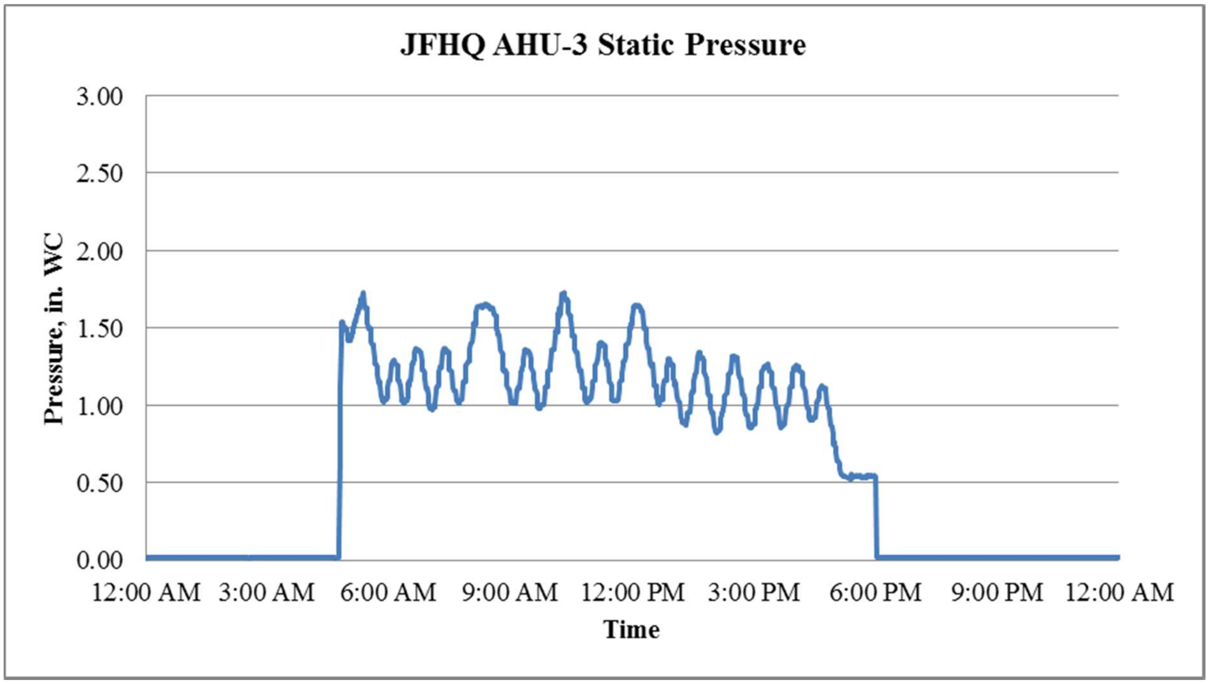

Figure 4.28 TTR strategy static pressure control, 10/22/2015.

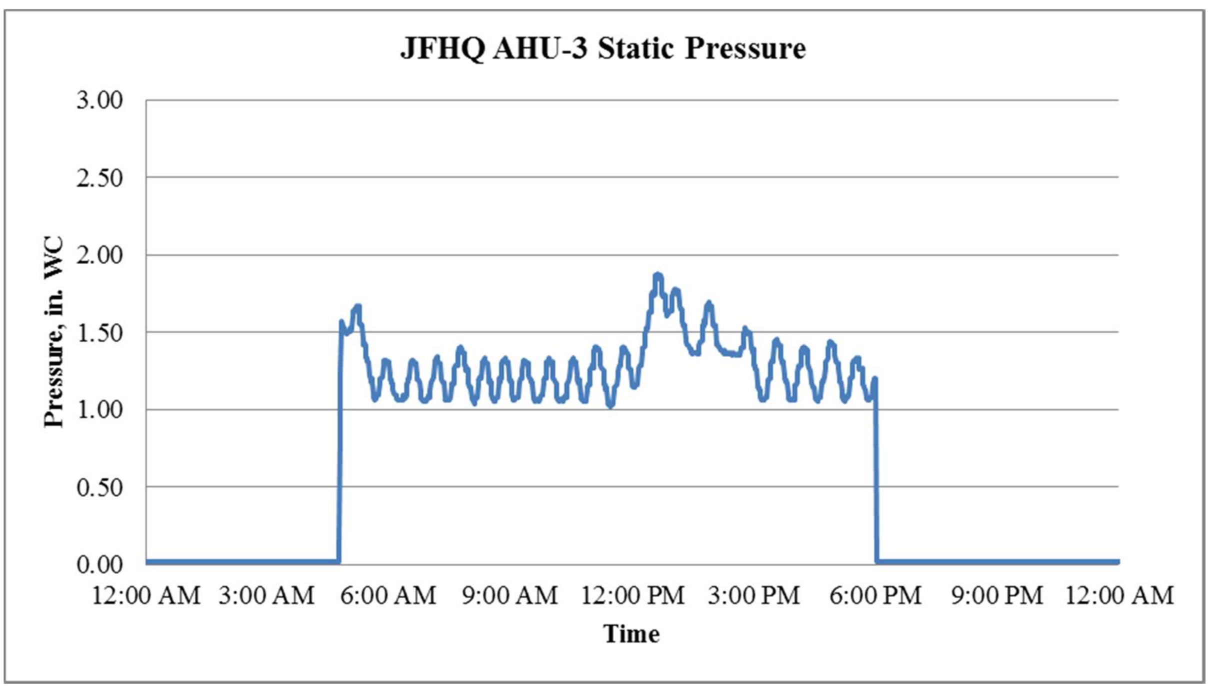

Figure 4.29 TTR strategy static pressure control, 12/23/2015.

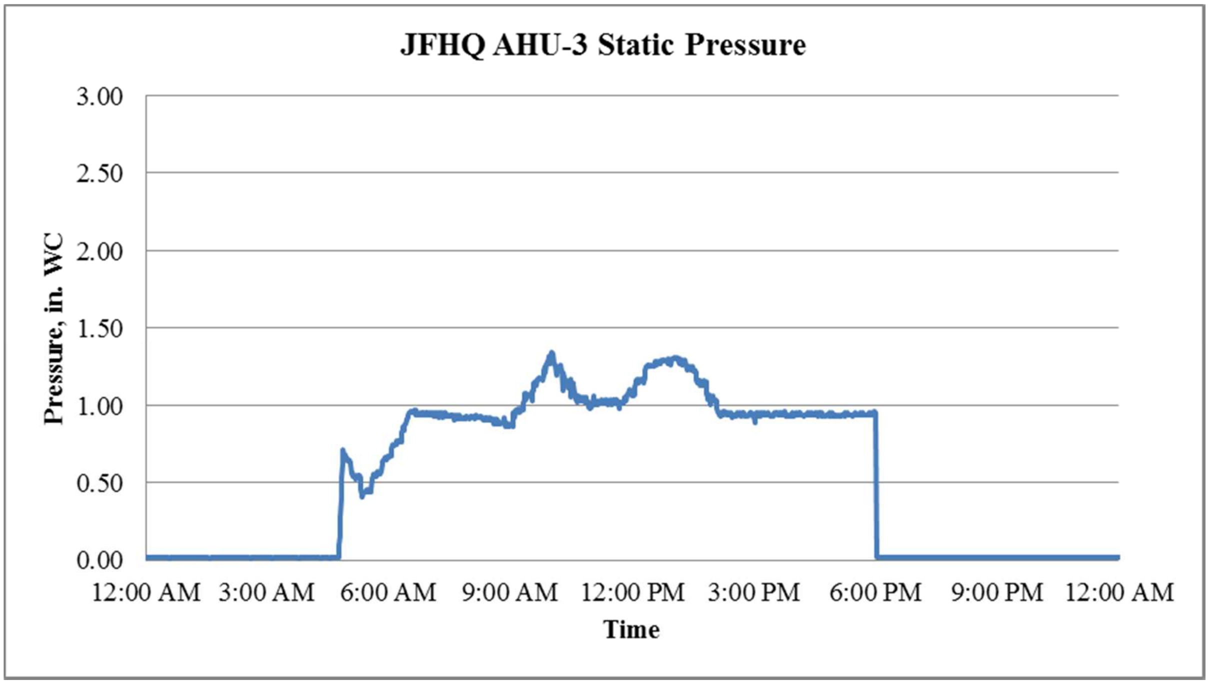

Figure 4.30 TR strategy static pressure control, 12/10/2015.

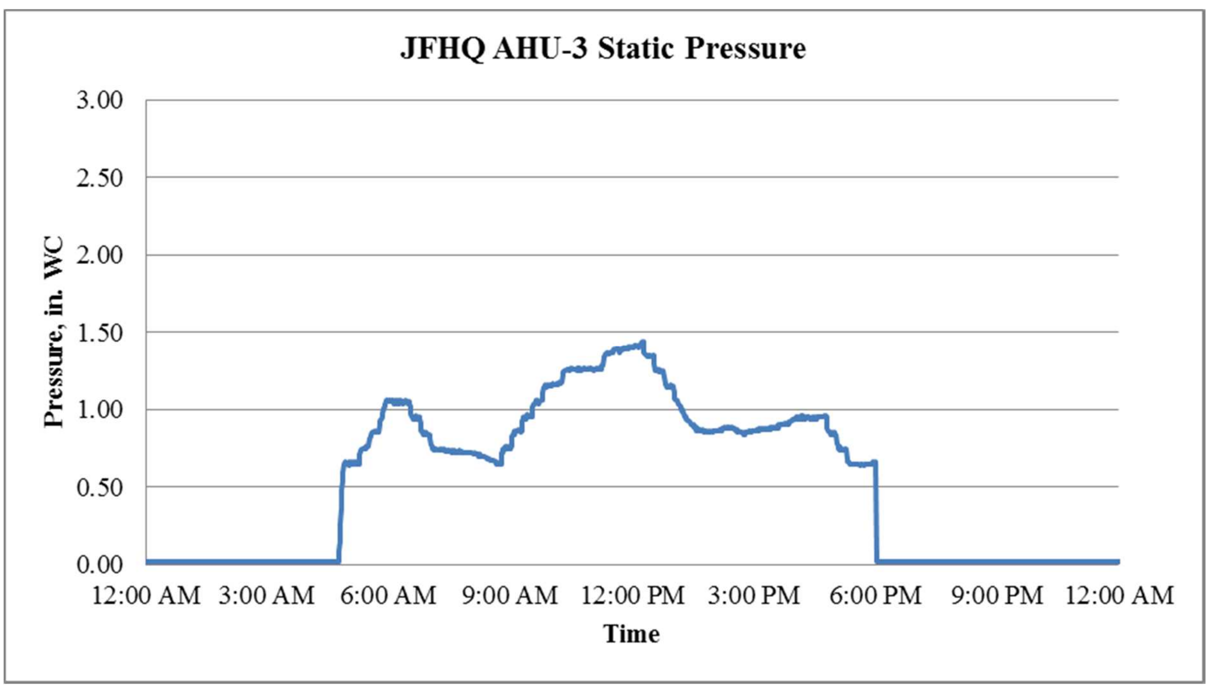

Figure 4.31 TR strategy static pressure control, 12/9/2015.

On AHU-2, static pressure control from both strategies was difficult to maintain. Both strategies showed frequent static pressure oscillation. While the oscillation seemed to be less frequent from the TTR strategy, the static pressure was higher on average than the TR. This correlates with the greater average fan energy use from the TTR strategy. During the study, it was difficult to observe meaningful static pressure control from the TTR strategy due to near constant wide open dampers from various zones in the facility. Very few days were recorded with the TTR strategy using less fan energy than the TR strategy.

The TTR strategy on AHU-3 was outperformed by the TR strategy in both fan energy savings and static pressure control. Like AHU-2, very few days were recorded with the TTR strategy using less fan energy per day on average. Both strategies were able to react to building load, though the TR strategy did so with minimal to no oscillation.

4.2 Temperature Control Performance

While the two TR strategies performed well in reducing fan energy use, concerns arise when controlling zone temperature. As the tested TR strategies ignore some VAV zones, this approach would inherently be prone to leaving the ignored zones' temperatures outside their heating and cooling setpoints. To compare the temperature control of the TTR and TR strategies, space temperature of AHU-2 and AHU-3's VAV zones were tracked and compared against their heating and cooling setpoints. Table 4.10 provides the results given as average percentage of time each units VAV boxes' temperature was outside its setpoints.

Table 4.10 Average zone temperature control per week per unit.

Site	Unit	TR %	TTR %	TR vs TTR %
JFHQ	AHU-2	29.77%	28.47%	4.35%
	AHU-3	22.55%	20.80%	7.76%

In Table 4.10, the results given are the average percentage of time that units VAV zones' temperature was outside their cooling or heating setpoints by more than 1.0°F during occupied hours. The TTR strategy performed marginally better over the TR strategy, as temperature control was hindered by intermittent boiler/chiller operation and radiant in-floor heating/VAV box cooling only service. While Table 4.10 does not provide definitive evidence the TTR program is superior in temperature control, it does provide evidence that zone temperature control at the JFHQ was difficult for both static pressure reset strategies. The TR and TTR strategies both demonstrated a significant lack of zone temperature control in AHU-2 and AHU-3's VAV zones. Another cause might be related to the reduced static pressure limits from when the facility was first commissioned. Both AHU-2 and AHU-3 were commissioned with a static pressure limit of 3.00" WC, however this limit had since be reduced to 1.50" WC and 2.40" WC during the study, respectively. With the reduced static pressure limits, many VAV box sizes were no longer adequate to deliver the airflow needed to alleviate zone demand.

4.3 Lessons Learned

The sites studied for this demonstration provided an array of results that sharpen the realities of the TTR strategy. While the strategy is capable of 30 to 50% fan energy savings over existing FSP strategies, difficulties arise when implementing in real buildings. In real buildings, equipment does not always operate as intended and day to day operations and setpoints deviate from original design and commissioning. Reduction in static pressure limits increase the damper position needed to provide adequate airflow. Maintenance is not always consistent, and operations of related equipment such as boilers and chillers are sometimes disabled to preserve lifetime or due to operational costs. Zones are sometimes refitted to functions not accounted for in their original design. All these in combination can make temperature control difficult and in turn, make static pressure control difficult for any zone based static pressure reset algorithm.

From the initial demonstration, Equation 2.1 was used to determine the TM and RP rates for each AHU and RTU. However, unlike the static pressure control observed from Nelson and Housholder, observations of frequent and heavy oscillation were prevalent at nearly every site. These rates were initially calculated from Equation 2.1, which worked exceedingly well for a Step Timer of 5 seconds. Though during this study Step Timers ranged from 3 to 5 minutes, significantly greater than studied earlier. The original equation with the longer Step Timer resulted in TM and RP rates much too large to achieve stable static pressure control. To accommodate this, larger denominators of 3600 and 9000 were used.

During the official demonstration static pressure setpoints were altered frequently, by facility managers and engineers for various reasons. However most of the CPL's written for the TTR strategy did not update the TM and RP values accordingly. Future implementations of the TTR strategy should incorporate an automatic update to the TM and RP rates and functional mode testing should contain a step to check for this.

CHAPTER 5

CONCLUSION

5.1 Summary

Improvements in energy efficiency is one of the most cost effective methods to reduce energy consumption and in turn reduce carbon emissions. In commercial facilities today, a significant portion of energy consumption comes from HVAC systems. More specifically, ventilation accounts for 16% of commercial building's electricity use. To reduce building energy consumption, several advancements have been made to optimize fan control in VAV systems. By minimizing the static pressure rise needed from supply fans, significant energy savings can be achieved.

The TTR strategy can reduce fan energy consumption using simple controls at the zone level. By using available zone damper position information in combination with a forced-air mechanical system controlled by a variable speed drive, the strategy has shown profound results in saving energy in real buildings (Nelson & Housholder, 2011). This study furthered this research and demonstrated the TTR strategy at 5 Iowa Army National Guard sites across the state of Iowa. The sites chosen for this study varied in size, function, geographic location and equipment.

After a demonstration period of 10 months from July 2015 to May 2016, at least six months of valid data were recorded at each site. By comparing the TTR strategy against FSP and traditional TR strategies on a two week basis, results of fan energy savings for each site and temperature control for the TR comparisons was collected. The results of the TTR and FSP strategy comparison are as follows: Boone RC AHU-1 20.86% and AHU-2 10.69%, Des

Moines MEPS AHU-1 27.30%, JFHQ: AHU-1 4.73%, AHU-4 12.83%, AHU-9 59.92% and AHU-12 15.83%, Muscatine AFRC: RTU-1 18.91%, RTU-3 29.46%, RTU-4 36.54% and Waterloo RC: RTU-1 33.80%. The fan energy savings results of the TTR and TR comparisons are as follows: JFHQ: AHU-2 -25.90% and AHU-3 -47.27%. The temperature control comparisons results on the TTR and TR comparison AHUs are as follows: JFHQ AHU-2 4.35% and AHU-3 7.76%.

Throughout the study, relevant HVAC data were recorded and trended to ensure proper operation of the TTR strategy and other associated mechanical equipment. This allowed numerous instances of mechanical failure, setpoint alterations, scheduling errors and other issues to be observed that while hindered the capabilities of the TTR strategy, reflected the true nature of a real building. This study concludes that while the original proposal of 30 to 50% of fan energy savings is possible, a more realistic value is closer to 20 to 30% fan energy savings when compared to constant pressure strategies.

The study showed that the TTR strategy is most successful with fewer number of VAV zones and proper control of supply air temperature. Many times during the demonstration boiler and chillers were not operational, leaving the TTR strategy unable to alleviate building demand. At some sites, controls sequences for VAV zones required maximum airflow when in cooling or heating modes. This regressed the TTR strategy to the FSP strategies, with the static pressure setpoint at its maximum as zones demand maximum airflow. One recommendation would be to recommission maximum heating or cooling airflow setpoints so the VAV box damper is not left wide open when under the control of the TTR strategy.

From the 5 sites studied, static pressure control was as expected on 3 of them. The TTR strategy was able to respond to changing building loads while minimizing or eliminating issues with static pressure oscillation. However, at 2 of the sites, Boone RC and JFHQ, the TTR strategy displayed numerous instances of frequent static pressure oscillation. These same sites also had difficulty controlling zone temperature from inactive boiler and chiller service. The JFHQ site had a radiant in-floor heating system that led to simultaneous heating and cooling demand. The results from the TTR and TR temperature control comparison showed that temperature control at the JFHQ was difficult for both zonal-based static pressure reset strategies.

5.2 Future Work

The TTR strategy performed best at sites with stable control of supply air temperature and a smaller number of VAV zones. To improve upon the strategy, several concerns need to be addressed. In future studies or demonstration, boiler and chiller operation, temperature, setpoints, etc. should be trended. For this study, each site's boilers and chillers were not trended, and in some cases were under a completely separate DDC system. A comparison of the TTR strategy with fixed supply air temperature and an outside air based supply air temperature reset strategy would also be insightful. The largest facility in this demonstration was found to have little control over its zone temperature, and therefore hindered the abilities of the TTR strategy. Parameters such as the TM and RP rates, Step Timer and damper position deadband and threshold could be refined to avoid issues with high static pressure alarms while maintaining a quick response to changing building loads. Lastly, as professional industries move forward with improved building standards, the focus of future studies should shift from comparing the TTR strategy against fixed static pressure strategies to existing static pressure reset strategies in not only fan energy savings, but whole building energy savings as well.

REFERENCES

ASHRAE. 2013. ANSI/ASHRAE/IESNA, Standard 90.1- 2013: Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta: ASHRAE.

ASHRAE. 2015. ASHRAE Handbook – HVAC Applications. Atlanta: ASHRAE.

California Energy Commission, 2012. 2013 Building Energy Efficiency Standards. http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/final_rulemaking_documents/44_Final_Express_Terms/2013_Standards_FINAL.pdf

Kimla, W. 2009. Optimized Fan Control in Variable Air Volume HVAC System Using Static Pressure Resets: Strategy Selection and Savings Analysis. Master Thesis. Texas A&M University.

Liu, M., J. Feng, Z. Wang, L. Wu, K. Zheng, and X. Pang. 2010. Impacts of static pressure reset on VAV system air leakage, fan power and thermal energy.

Nelson, R., and B. Householder. 2011. Final Report for Iowa Energy Center Grant 90-86: A Study on Static Pressure Reset and Instability in Variable Air Volume HVAC systems. http://www.iowaenergycenter.org/wp-content/uploads/2013/01/Static-Pressure-Reset-Final-Report_Secured-file.pdf

Taylor, S. 2007. Increasing efficiency with VAV system static pressure setpoint reset. *ASHRAE Journal*: 24-32

U.S. Energy Information Administration. 2016. Commercial Buildings Energy Consumption Survey (CBECS) 2012: Building Stock Results.

U.S. Energy Information Administration. 2016. Commercial Buildings Energy Consumption Survey (CBECS) 2012: Energy Usage Summary.

APPENDIX A

FAN ENERGY RESULTS

Daily fan energy use data highlighted in 'Yellow' were ignored in final results. Cells with "-" contained no data available for analysis that day.

Boone Readiness Center – Fixed Static Pressure

Fixed Static Pressure								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh
7/6/2015	Monday	26.985	33.356	60.341	96.734	46.907	143.641	203.982
7/7/2015	Tuesday	36.432	42.304	78.736	85.225	38.833	124.058	202.794
7/8/2015	Wednesday	38.921	47.095	86.016	99.241	48.091	147.332	233.347
7/9/2015	Thursday	28.503	34.636	63.139	87.039	41.133	128.171	191.310
7/10/2015	Friday	48.835	55.274	104.109	64.529	29.469	93.998	198.107
7/11/2015	Saturday	59.060	64.789	123.849	48.197	20.992	69.188	193.037
7/12/2015	Sunday	35.253	35.053	70.306	34.989	15.640	50.629	120.935
7/13/2015	Monday	38.202	38.504	76.706	45.005	20.422	65.428	142.133
7/14/2015	Tuesday	37.810	38.359	76.169	44.030	19.908	63.938	140.107
7/15/2015	Wednesday	43.607	47.252	90.858	54.700	24.440	79.140	169.998
7/16/2015	Thursday	29.914	35.691	65.606	42.962	19.068	62.030	127.636
7/17/2015	Friday	26.922	30.487	57.410	43.742	19.612	63.353	120.763
7/18/2015	Saturday	26.772	28.420	55.193	28.738	11.667	40.405	95.598
8/2/2015	Sunday	17.210	21.817	39.027	26.142	11.255	37.397	76.423
8/3/2015	Monday	30.692	36.682	67.374	42.012	19.273	61.285	128.659
8/4/2015	Tuesday	27.724	32.980	60.704	39.192	17.458	56.650	117.354
8/5/2015	Wednesday	36.067	43.977	80.043	48.833	21.385	70.218	150.262
8/6/2015	Thursday	23.236	29.608	52.844	40.791	18.067	58.858	111.701
8/7/2015	Friday	38.828	47.316	86.145	46.255	20.082	66.337	152.481
8/8/2015	Saturday	56.948	68.591	125.539	49.495	20.887	70.382	195.921
8/9/2015	Sunday	47.478	55.126	102.604	45.893	20.352	66.245	168.849
8/10/2015	Monday	30.922	36.677	67.598	45.452	21.030	66.482	134.080
8/11/2015	Tuesday	27.238	32.858	60.097	46.998	21.687	68.685	128.782
8/12/2015	Wednesday	35.155	42.241	77.396	63.127	29.210	92.337	169.732
8/13/2015	Thursday	27.888	33.430	61.318	49.070	23.405	72.475	133.793
8/14/2015	Friday	28.113	32.965	61.079	49.340	23.162	72.502	133.580
8/15/2015	Saturday	21.808	25.354	47.163	36.465	16.922	53.387	100.549
8/30/2015	Sunday	-	-	-	-	-	-	-
8/31/2015	Monday	-	-	-	-	-	-	-
9/1/2015	Tuesday	-	-	-	-	-	-	-
9/2/2015	Wednesday	19.015	22.829	41.844	51.487	26.117	77.603	119.447
9/3/2015	Thursday	25.757	31.044	56.800	55.472	27.728	83.200	140.000
9/4/2015	Friday	28.498	32.863	61.362	51.938	25.308	77.247	138.608
9/5/2015	Saturday	22.917	26.046	48.963	38.787	18.660	57.447	106.409

Boone Readiness Center – Fixed Static Pressure (Continued)

Fixed Static Pressure								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh
9/6/2015	Sunday	23.142	25.691	48.833	36.248	16.853	53.102	101.935
9/7/2015	Monday	30.638	35.312	65.950	49.352	23.837	73.188	139.138
9/8/2015	Tuesday	32.690	37.513	70.203	48.985	23.520	72.505	142.708
9/9/2015	Wednesday	32.917	40.483	73.399	72.965	35.818	108.783	182.183
9/10/2015	Thursday	29.468	34.702	64.170	63.905	33.337	97.242	161.412
9/11/2015	Friday	63.663	72.571	136.235	70.427	34.108	104.535	240.770
9/12/2015	Saturday	85.772	92.843	178.614	75.113	39.823	114.937	293.551
9/27/2015	Sunday	30.142	52.602	82.744	177.360	103.023	280.383	363.127
9/28/2015	Monday	46.842	62.687	109.529	180.507	105.510	286.017	395.545
9/29/2015	Tuesday	52.573	72.469	125.042	168.243	97.932	266.175	391.217
9/30/2015	Wednesday	68.795	83.066	151.861	159.592	95.997	255.588	407.449
10/1/2015	Thursday	64.608	82.690	147.298	128.552	68.140	196.692	343.990
10/2/2015	Friday	54.103	62.009	116.112	91.153	49.467	140.620	256.732
10/3/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
*AHU's operating during normally unoccupied hours, fixed 10/2								
10/4/2015	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10/5/2015	Monday	49.583	51.855	101.439	82.298	46.517	128.815	230.254
10/6/2015	Tuesday	40.652	46.410	87.062	65.790	35.108	100.898	187.960
10/7/2015	Wednesday	43.077	52.017	95.093	97.018	52.417	149.435	244.528
10/8/2015	Thursday	30.883	37.143	68.027	59.055	30.732	89.787	157.813
10/9/2015	Friday	35.747	43.393	79.140	53.650	27.418	81.068	160.208
10/10/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10/25/2015	Sunday	27.198	47.011	74.209	90.488	46.687	137.175	211.384
10/26/2015	Monday	45.237	50.180	95.416	64.343	34.857	99.200	194.616
10/27/2015	Tuesday	39.265	46.209	85.474	55.470	29.102	84.572	170.045
10/28/2015	Wednesday	57.010	66.085	123.095	80.372	41.937	122.308	245.404
10/29/2015	Thursday	45.793	50.120	95.913	63.513	34.240	97.753	193.666
10/30/2015	Friday	45.113	49.534	94.647	67.877	36.878	104.755	199.402
10/31/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11/1/2015	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11/2/2015	Monday	33.205	38.225	71.430	60.570	32.200	92.770	164.200
11/3/2015	Tuesday	33.127	40.577	73.704	43.775	21.162	64.937	138.640
11/4/2015	Wednesday	51.813	61.999	113.812	74.177	37.220	111.397	225.209
11/5/2015	Thursday	34.497	41.092	75.589	58.168	30.250	88.418	164.007
11/6/2015	Friday	52.277	67.784	120.061	90.920	45.352	136.272	256.332
11/7/2015	Saturday	40.237	69.085	109.321	129.752	67.473	197.225	306.546
11/22/2015	Sunday	-	-	-	-	-	-	0.000
11/23/2015	Monday	-	-	-	-	-	-	0.000
11/24/2015	Tuesday	-	-	-	-	-	-	0.000
11/25/2015	Wednesday	49.425	52.435	101.860	67.345	36.143	100.538	202.398
11/26/2015	Thursday	50.448	52.681	103.129	76.190	43.097	119.287	222.416
11/27/2015	Friday	52.827	53.696	106.523	73.217	40.585	113.802	220.325
11/28/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Boone Readiness Center – Fixed Static Pressure (Continued)

Fixed Static Pressure								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh
11/29/2015	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11/30/2015	Monday	48.385	49.717	98.102	71.237	38.983	110.220	208.322
12/1/2015	Tuesday	49.948	51.721	101.670	74.130	41.417	115.547	217.216
12/2/2015	Wednesday	71.272	73.495	144.766	96.555	52.032	148.587	293.353
12/3/2015	Thursday	50.517	52.119	102.635	69.278	37.485	106.763	209.399
12/4/2015	Friday	65.722	76.766	142.488	107.905	56.853	164.758	307.246
12/5/2015	Saturday	48.590	76.355	124.945	133.597	71.077	204.673	329.618
12/20/2015	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12/21/2015	Monday	48.573	51.101	99.675	72.815	40.012	112.827	212.501
12/22/2015	Tuesday	48.757	51.082	99.839	71.625	39.798	111.423	211.262
12/23/2015	Wednesday	71.598	73.313	144.911	95.922	52.788	148.710	293.621
12/24/2015	Thursday	48.608	51.099	99.707	73.168	40.515	113.683	213.391
12/25/2015	Friday	54.372	54.383	108.754	81.657	46.247	127.903	236.658
12/26/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12/27/2015	Sunday	58.052	57.526	115.578	0.000	0.000	0.000	115.578
12/28/2015	Monday	58.017	56.928	114.944	92.723	58.697	151.420	266.364
12/29/2015	Tuesday	51.542	52.526	104.068	81.670	48.977	130.647	234.714
12/30/2015	Wednesday	67.878	70.993	138.871	104.355	57.222	161.577	300.448
12/31/2015	Thursday	49.572	50.945	100.517	73.297	39.898	113.195	213.712
1/1/2016	Friday	50.233	51.501	101.734	73.275	39.810	113.085	214.819
1/2/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/17/2015	Sunday	106.652	100.371	207.022	144.185	105.242	249.427	456.449
1/18/2015	Monday	76.485	71.503	147.988	4.658	3.420	8.078	156.067
1/19/2015	Tuesday	32.540	34.549	67.089	75.913	52.740	128.653	195.742
1/20/2015	Wednesday	41.757	45.833	87.590	95.862	60.805	156.667	244.256
1/21/2015	Thursday	19.723	20.015	39.739	37.837	24.953	62.790	102.529
1/22/2015	Friday	-	-	-	-	-	-	-
1/23/2015	Saturday	-	-	-	-	-	-	-
1/24/2016	Sunday	-	-	-	-	-	-	-
1/25/2016	Monday	-	-	-	-	-	-	-
1/26/2016	Tuesday	-	-	-	-	-	-	-
1/27/2016	Wednesday	-	-	-	-	-	-	-
1/28/2016	Thursday	-	-	-	-	-	-	-
1/29/2016	Friday	-	-	-	-	-	-	-
1/30/2016	Saturday	-	-	-	-	-	-	-
2/14/2016	Sunday	-	-	-	-	-	-	-
2/15/2016	Monday	-	-	-	-	-	-	-
2/16/2016	Tuesday	-	-	-	-	-	-	-
2/17/2016	Wednesday	-	-	-	-	-	-	-
2/18/2016	Thursday	-	-	-	-	-	-	-
2/19/2016	Friday	-	-	-	-	-	-	-
2/20/2016	Saturday	-	-	-	-	-	-	-

Boone Readiness Center – Fixed Static Pressure (Continued)

Fixed Static Pressure								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh
2/21/2016	Sunday	-	-	-	-	-	-	-
2/22/2016	Monday	-	-	-	-	-	-	-
2/23/2016	Tuesday	-	-	-	-	-	-	-
2/24/2016	Wednesday	-	-	-	-	-	-	-
2/25/2016	Thursday	-	-	-	-	-	-	-
2/26/2016	Friday	-	-	-	-	-	-	-
2/27/2016	Saturday	-	-	-	-	-	-	-
3/13/2016	Sunday	-	-	-	-	-	-	-
3/14/2016	Monday	-	-	-	-	-	-	-
3/15/2016	Tuesday	-	-	-	-	-	-	-
3/16/2016	Wednesday	-	-	-	-	-	-	-
3/17/2016	Thursday	-	-	-	-	-	-	-
3/18/2016	Friday	-	-	-	-	-	-	-
3/19/2016	Saturday	-	-	-	-	-	-	-
3/20/2016	Sunday	-	-	-	-	-	-	-
3/21/2016	Monday	-	-	-	-	-	-	-
3/22/2016	Tuesday	-	-	-	-	-	-	-
3/23/2016	Wednesday	-	-	-	-	-	-	-
3/24/2016	Thursday	-	-	-	-	-	-	-
3/25/2016	Friday	-	-	-	-	-	-	-
3/26/2016	Saturday	-	-	-	-	-	-	-
4/10/2016	Sunday	-	-	-	-	-	-	-
4/11/2016	Monday	-	-	-	-	-	-	-
4/12/2016	Tuesday	-	-	-	-	-	-	-
4/13/2016	Wednesday	-	-	-	-	-	-	-
4/14/2016	Thursday	-	-	-	-	-	-	-
4/15/2016	Friday	-	-	-	-	-	-	-
4/16/2016	Saturday	-	-	-	-	-	-	-
4/17/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4/18/2016	Monday	22.390	28.518	50.908	44.403	34.305	78.708	129.617
4/19/2016	Tuesday	28.390	37.147	65.537	48.385	37.463	85.848	151.386
4/20/2016	Wednesday	51.067	60.519	111.586	76.432	59.445	135.877	247.463
4/21/2016	Thursday	40.972	45.756	86.727	68.518	56.408	124.927	211.654
4/22/2016	Friday	36.022	42.589	78.610	61.620	49.692	111.312	189.922
4/23/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Boone Readiness Center – Tiered Trim and Respond

Tiered Trim and Respond								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh
7/19/2015	Sunday	21.550	25.0326	46.583	18.377	5.216	23.593	70.176
7/20/2015	Monday	18.067	23.4806	41.547	31.902	11.420	43.322	84.869
7/21/2015	Tuesday	15.104	20.5627	35.667	34.892	13.416	48.308	83.974
7/22/2015	Wednesday	14.138	20.4386	34.577	48.560	19.040	67.600	102.177
7/23/2015	Thursday	7.230	10.7238	17.953	37.345	15.116	52.461	70.414
7/24/2015	Friday	21.690	30.4917	52.181	41.196	17.547	58.744	110.925
7/25/2015	Saturday	30.123	41.6670	71.790	37.283	16.873	54.157	125.947
7/26/2015	Sunday	27.005	36.210	63.215	34.946	15.511	50.456	113.671
7/27/2015	Monday	22.042	27.653	49.695	37.047	14.680	51.727	101.421
7/28/2015	Tuesday	21.148	28.244	49.392	38.905	16.080	54.985	104.377
7/29/2015	Wednesday	28.228	35.994	64.223	48.769	19.968	68.737	132.960
7/30/2015	Thursday	27.342	31.636	58.978	37.910	16.280	54.190	113.168
7/31/2015	Friday	38.010	39.689	77.699	19.397	5.591	24.989	102.687
8/1/2015	Saturday	26.918	28.528	55.446	36.613	18.328	54.942	110.388
8/16/2015	Sunday	-	-	-	-	-	-	-
8/17/2015	Monday	-	-	-	-	-	-	-
8/18/2015	Tuesday	-	-	-	-	-	-	-
8/19/2015	Wednesday	-	-	-	-	-	-	-
8/20/2015	Thursday	-	-	-	-	-	-	-
8/21/2015	Friday	-	-	-	-	-	-	-
8/22/2015	Saturday	-	-	-	-	-	-	-
8/23/2015	Sunday	-	-	-	-	-	-	-
8/24/2015	Monday	-	-	-	-	-	-	-
8/25/2015	Tuesday	-	-	-	-	-	-	-
8/26/2015	Wednesday	-	-	-	-	-	-	-
8/27/2015	Thursday	-	-	-	-	-	-	-
8/28/2015	Friday	-	-	-	-	-	-	-
8/29/2015	Saturday	-	-	-	-	-	-	-
9/13/2015	Sunday	53.328	59.958	113.286	0.000	0.000	0.000	113.286
9/14/2015	Monday	28.742	34.174	62.916	25.952	13.298	39.250	102.166
9/15/2015	Tuesday	26.487	32.203	58.690	69.370	36.433	105.803	164.493
9/16/2015	Wednesday	31.535	39.114	70.649	90.745	48.192	138.937	209.586
9/17/2015	Thursday	27.243	31.064	58.307	111.002	60.828	171.830	230.137
9/18/2015	Friday	34.672	45.857	80.528	176.300	101.628	277.928	358.457
9/19/2015	Saturday	7.895	13.086	20.981	177.980	103.512	281.492	302.472
*AHU's operating during normally unoccupied hours								
9/20/2015	Sunday	9.203	15.446	24.650	189.775	111.742	301.517	326.166
9/21/2015	Monday	41.833	46.984	88.818	180.363	104.990	285.353	374.171
9/22/2015	Tuesday	33.513	42.276	75.789	180.433	105.525	285.958	361.747
9/23/2015	Wednesday	50.490	61.873	112.363	197.083	127.980	325.063	437.426
9/24/2015	Thursday	31.713	39.468	71.181	179.740	110.080	289.820	361.001
9/25/2015	Friday	31.352	40.044	71.395	175.432	100.483	275.915	347.310
9/26/2015	Saturday	8.160	12.479	20.639	173.922	99.903	273.825	294.464

Boone Readiness Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
10/11/2015	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10/12/2015	Monday	21.298	28.884	50.182	51.549	25.712	77.261	127.443
10/13/2015	Tuesday	25.382	32.850	58.232	56.004	29.645	85.649	143.881
10/14/2015	Wednesday	34.367	44.523	78.890	77.526	39.353	116.879	195.769
10/15/2015	Thursday	26.942	34.164	61.106	68.258	4.985	73.243	134.349
10/16/2015	Friday	30.735	38.566	69.301	57.423	30.238	87.662	156.962
10/17/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10/18/2015	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10/19/2015	Monday	29.523	35.214	64.737	71.707	38.955	110.662	175.399
10/20/2015	Tuesday	25.350	32.369	57.719	62.595	33.280	95.875	153.594
10/21/2015	Wednesday	35.900	47.042	82.942	83.520	43.108	126.628	209.570
10/22/2015	Thursday	30.045	37.918	67.963	54.862	28.058	82.920	150.883
10/23/2015	Friday	35.733	48.191	83.925	106.147	56.398	162.545	246.470
10/24/2015	Saturday	12.157	26.200	38.357	111.358	55.647	167.005	205.362
11/8/2015	Sunday	13.357	27.362	40.719	120.565	62.148	182.713	223.433
11/9/2015	Monday	43.935	49.463	93.398	104.435	57.105	161.540	254.938
11/10/2015	Tuesday	40.307	44.825	85.132	0.000	0.000	0.000	85.132
11/11/2015	Wednesday	51.713	59.146	110.859	0.000	0.000	0.000	110.859
11/12/2015	Thursday	37.767	42.715	80.482	29.660	14.277	43.937	124.418
11/13/2015	Friday	40.918	45.098	86.016	56.437	28.955	85.392	171.408
11/14/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11/15/2015	Sunday	-	-	-	-	-	-	-
11/16/2015	Monday	-	-	-	-	-	-	-
11/17/2015	Tuesday	-	-	-	-	-	-	-
11/18/2015	Wednesday	-	-	-	-	-	-	-
11/19/2015	Thursday	-	-	-	-	-	-	-
11/20/2015	Friday	-	-	-	-	-	-	-
11/21/2015	Saturday	-	-	-	-	-	-	-
	*Lost data from export utility software							
12/6/2015	Sunday	27.742	26.706	54.447	101.190	47.230	148.420	202.867
12/7/2015	Monday	47.702	41.725	89.426	67.158	36.220	103.378	192.805
12/8/2015	Tuesday	41.280	45.585	86.865	63.727	33.140	96.867	183.732
12/9/2015	Wednesday	54.738	60.617	115.356	83.938	43.523	127.462	242.817
12/10/2015	Thursday	34.070	52.761	86.831	73.237	47.722	120.958	207.789
12/11/2015	Friday	36.355	41.878	78.233	66.202	49.335	115.537	193.770
12/12/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12/13/2015	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12/14/2015	Monday	38.473	42.601	81.074	65.212	35.417	100.628	181.702
12/15/2015	Tuesday	41.520	44.971	86.491	60.213	31.517	91.730	178.221
12/16/2015	Wednesday	62.402	66.115	128.516	93.400	49.858	143.258	271.775
12/17/2015	Thursday	40.257	44.003	84.259	0.000	0.000	0.000	84.259
12/18/2015	Friday	37.912	42.096	80.008	52.465	29.273	81.738	161.746
12/19/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Boone Readiness Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
1/3/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/4/2016	Monday	61.638	63.746	125.385	62.213	35.653	97.867	223.251
1/5/2016	Tuesday	35.867	39.703	75.569	72.177	39.100	111.277	186.846
1/6/2016	Wednesday	55.140	60.194	115.334	97.905	52.527	150.432	265.766
1/7/2016	Thursday	46.442	54.220	100.662	111.750	60.552	172.302	272.963
1/8/2016	Friday	64.705	71.718	136.423	152.880	85.970	238.850	375.273
1/9/2016	Saturday	29.638	43.106	72.744	173.125	98.972	272.097	344.841
	*AHU's operating during normally unoccupied hours							
1/10/2016	Sunday	25.879	34.020	59.899	139.420	86.687	226.107	286.006
1/11/2016	Monday	41.406	43.334	84.740	60.542	36.342	96.883	181.623
1/12/2016	Tuesday	43.425	44.224	87.649	42.693	25.476	68.169	155.818
1/13/2016	Wednesday	69.205	71.433	140.638	120.962	78.130	199.092	339.730
1/14/2016	Thursday	61.228	67.017	128.246	148.103	92.247	240.350	368.596
1/15/2016	Friday	76.507	78.507	155.014	153.267	95.748	249.015	404.029
1/16/2016	Saturday	88.485	86.672	175.157	183.982	122.145	306.127	481.283
	*AHU's operating during normally unoccupied hours							
1/31/2016	Sunday	-	-	-	-	-	-	-
2/1/2016	Monday	-	-	-	-	-	-	-
2/2/2016	Tuesday	-	-	-	-	-	-	-
2/3/2016	Wednesday	-	-	-	-	-	-	-
2/4/2016	Thursday	-	-	-	-	-	-	-
2/5/2016	Friday	-	-	-	-	-	-	-
2/6/2016	Saturday	-	-	-	-	-	-	-
2/7/2016	Sunday	-	-	-	-	-	-	-
2/8/2016	Monday	-	-	-	-	-	-	-
2/9/2016	Tuesday	-	-	-	-	-	-	-
2/10/2016	Wednesday	-	-	-	-	-	-	-
2/11/2016	Thursday	-	-	-	-	-	-	-
2/12/2016	Friday	-	-	-	-	-	-	-
2/13/2016	Saturday	-	-	-	-	-	-	-
2/28/2016	Sunday	-	-	-	-	-	-	-
2/29/2016	Monday	-	-	-	-	-	-	-
3/1/2016	Tuesday	-	-	-	-	-	-	-
3/2/2016	Wednesday	-	-	-	-	-	-	-
3/3/2016	Thursday	-	-	-	-	-	-	-
3/4/2016	Friday	-	-	-	-	-	-	-
3/5/2016	Saturday	-	-	-	-	-	-	-
3/6/2016	Sunday	-	-	-	-	-	-	-
3/7/2016	Monday	-	-	-	-	-	-	-
3/8/2016	Tuesday	-	-	-	-	-	-	-
3/9/2016	Wednesday	-	-	-	-	-	-	-
3/10/2016	Thursday	-	-	-	-	-	-	-
3/11/2016	Friday	-	-	-	-	-	-	-
3/12/2016	Saturday	-	-	-	-	-	-	-

Boone Readiness Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond								
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1	AHU-2 Supply Fan	AHU-2 Return Fan	AHU-2	Total Fan Energy
3/27/2016	Sunday	-	-	-	-	-	-	-
3/28/2016	Monday	-	-	-	-	-	-	-
3/29/2016	Tuesday	-	-	-	-	-	-	-
3/30/2016	Wednesday	-	-	-	-	-	-	-
3/31/2016	Thursday	-	-	-	-	-	-	-
4/1/2016	Friday	-	-	-	-	-	-	-
4/2/2016	Saturday	-	-	-	-	-	-	-
4/3/2016	Sunday	-	-	-	-	-	-	-
4/4/2016	Monday	-	-	-	-	-	-	-
4/5/2016	Tuesday	-	-	-	-	-	-	-
4/6/2016	Wednesday	-	-	-	-	-	-	-
4/7/2016	Thursday	-	-	-	-	-	-	-
4/8/2016	Friday	-	-	-	-	-	-	-
4/9/2016	Saturday	-	-	-	-	-	-	-

Des Moines Military Entrance Processing Station – Fixed Static Pressure

Fixed Static Pressure				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
7/7/2015	Tuesday	30.993	15.387	46.380
7/8/2015	Wednesday	27.223	13.677	40.900
7/9/2015	Thursday	30.332	14.982	45.313
7/10/2015	Friday	33.410	16.235	49.645
7/11/2015	Saturday	7.037	5.787	12.823
7/12/2015	Sunday	25.097	13.708	38.805
7/13/2015	Monday	123.098	55.977	179.075
7/14/2015	Tuesday	141.388	65.197	206.585
7/15/2015	Wednesday	44.818	21.617	66.435
7/30/2015	Thursday	30.672	16.098	46.770
7/31/2015	Friday	43.803	25.218	69.022
8/1/2015	Saturday	9.585	5.775	15.360
8/2/2015	Sunday	9.637	8.258	17.895
8/3/2015	Monday	68.567	33.743	102.310
8/4/2015	Tuesday	59.507	29.485	88.992
8/5/2015	Wednesday	48.958	25.418	74.377
8/6/2015	Thursday	44.670	23.382	68.052
8/7/2015	Friday	41.013	21.448	62.462
8/8/2015	Saturday	0.000	0.000	0.000
8/9/2015	Sunday	9.647	8.377	18.023
8/10/2015	Monday	60.682	30.390	91.072
8/11/2015	Tuesday	48.547	25.320	73.867
8/12/2015	Wednesday	50.888	26.127	77.015
8/13/2015	Thursday	100.227	51.457	151.683
8/14/2015	Friday	87.278	45.517	132.795
8/15/2015	Saturday	9.540	8.307	17.847
8/16/2015	Sunday	19.217	16.665	35.882
8/17/2015	Monday	130.657	64.387	195.043

Des Moines Military Entrance Processing Station – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
8/18/2015	Tuesday	46.052	23.995	70.047
8/19/2015	Wednesday	33.113	17.578	50.692
8/20/2015	Thursday	35.163	18.645	53.808
8/21/2015	Friday	43.205	22.302	65.507
8/22/2015	Saturday	9.532	8.370	17.902
8/23/2015	Sunday	9.643	8.548	18.192
8/24/2015	Monday	41.673	21.657	63.330
8/25/2015	Tuesday	39.377	21.108	60.485
8/26/2015	Wednesday	38.707	20.363	59.070
8/27/2015	Thursday	36.243	18.967	55.210
8/28/2015	Friday	35.248	18.555	53.803
8/29/2015	Saturday	9.560	8.428	17.988
8/30/2015	Sunday	9.492	8.440	17.932
8/31/2015	Monday	43.243	22.837	66.080
9/1/2015	Tuesday	75.908	35.948	111.857
9/2/2015	Wednesday	96.162	43.902	140.063
9/3/2015	Thursday	54.715	27.688	82.403
9/4/2015	Friday	45.510	23.535	69.045
9/5/2015	Saturday	13.368	9.492	22.860
9/20/2015	Sunday	11.727	4.412	16.138
9/21/2015	Monday	40.510	11.388	51.898
9/22/2015	Tuesday	44.057	12.972	57.028
9/23/2015	Wednesday	41.003	11.715	52.718
9/24/2015	Thursday	40.927	11.698	52.625
9/25/2015	Friday	37.905	10.348	48.253
9/26/2015	Saturday	11.822	4.675	16.497
9/27/2015	Sunday	45.780	13.373	59.153
9/28/2015	Monday	53.393	15.357	68.750
9/29/2015	Tuesday	56.103	15.347	71.450
9/30/2015	Wednesday	0.182	0.182	0.363
10/1/2015	Thursday	-	-	0.000
10/2/2015	Friday	11.377	4.257	15.633
10/3/2015	Saturday	0.000	0.000	0.000

Des Moines Military Entrance Processing Station – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
10/18/2015	Sunday	-	-	-
10/19/2015	Monday	-	-	-
10/20/2015	Tuesday	-	-	-
10/21/2015	Wednesday	-	-	-
10/22/2015	Thursday	-	-	-
10/23/2015	Friday	31.967	8.927	40.893
10/24/2015	Saturday	17.065	5.965	23.030
10/25/2015	Sunday	-	-	-
10/26/2015	Monday	-	-	-
10/27/2015	Tuesday	-	-	-
10/28/2015	Wednesday	-	-	-
10/29/2015	Thursday	-	-	-
10/30/2015	Friday	-	-	-
10/31/2015	Saturday	-	-	-
11/15/2015	Sunday	-	-	-
11/16/2015	Monday	-	-	-
11/17/2015	Tuesday	-	-	-
11/18/2015	Wednesday	-	-	-
11/19/2015	Thursday	-	-	-
11/20/2015	Friday	-	-	-
11/21/2015	Saturday	-	-	-
11/22/2015	Sunday	-	-	-
11/23/2015	Monday	-	-	-
11/24/2015	Tuesday	-	-	-
11/25/2015	Wednesday	-	-	-
11/26/2015	Thursday	-	-	-
11/27/2015	Friday	-	-	-
11/28/2015	Saturday	-	-	-

Des Moines Military Entrance Processing Station – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
12/13/2015	Sunday	-	-	-
12/14/2015	Monday	-	-	-
12/15/2015	Tuesday	-	-	-
12/16/2015	Wednesday	-	-	-
12/17/2015	Thursday	-	-	-
12/18/2015	Friday	-	-	-
12/19/2015	Saturday	-	-	-
12/20/2015	Sunday	-	-	-
12/21/2015	Monday	-	-	-
12/22/2015	Tuesday	-	-	-
12/23/2015	Wednesday	49.622	13.355	62.977
12/24/2015	Thursday	38.178	10.493	48.671
12/25/2015	Friday	32.320	9.002	41.322
12/26/2015	Saturday	0.000	0.000	0.000
1/10/2016	Sunday	0.020	0.013	0.033
1/11/2016	Monday	0.000	0.000	0.000
1/12/2016	Tuesday	0.000	0.000	0.000
1/13/2016	Wednesday	0.000	0.000	0.000
1/14/2016	Thursday	46.773	16.377	63.150
1/15/2016	Friday	46.163	12.869	59.032
1/16/2016	Saturday	0.000	0.000	0.000
1/17/2016	Sunday	0.000	0.000	0.000
1/18/2016	Monday	34.620	9.498	44.118
1/19/2016	Tuesday	42.345	11.537	53.882
1/20/2016	Wednesday	43.628	12.067	55.695
1/21/2016	Thursday	50.660	14.943	65.603
1/22/2016	Friday	43.523	12.817	56.340
1/23/2016	Saturday	0.000	0.000	0.000

Des Moines Military Entrance Processing Station – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
2/7/2016	Sunday	0.000	0.000	0.000
2/8/2016	Monday	44.053	11.975	56.028
2/9/2016	Tuesday	43.575	12.013	55.588
2/10/2016	Wednesday	40.907	10.822	51.728
2/11/2016	Thursday	41.270	11.152	52.422
2/12/2016	Friday	41.662	10.993	52.655
2/13/2016	Saturday	0.000	0.000	0.000

2/14/2016	Sunday	0.000	0.000	0.000
2/15/2016	Monday	36.642	9.800	46.442
2/16/2016	Tuesday	42.698	11.548	54.247
2/17/2016	Wednesday	44.523	11.855	56.378
2/18/2016	Thursday	46.810	12.723	59.533
2/19/2016	Friday	65.708	18.275	83.983
2/20/2016	Saturday	0.000	0.000	0.000

3/6/2016	Sunday	0.000	0.000	0.000
3/7/2016	Monday	91.687	27.188	118.875
3/8/2016	Tuesday	145.298	45.898	191.197
3/9/2016	Wednesday	117.487	33.300	150.787
3/10/2016	Thursday	105.867	31.382	137.248
3/11/2016	Friday	50.342	13.827	64.168
3/12/2016	Saturday	0.000	0.000	0.000

3/13/2016	Sunday	0.000	0.000	0.000
3/14/2016	Monday	41.828	10.693	52.522
3/15/2016	Tuesday	41.653	10.535	52.188
3/16/2016	Wednesday	40.952	11.143	52.095
3/17/2016	Thursday	46.705	12.382	59.087
3/18/2016	Friday	42.515	11.430	53.945
3/19/2016	Saturday	0.000	0.000	0.000

Des Moines Military Entrance Processing Station – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
4/3/2016	Sunday	0.000	0.000	0.000
4/4/2016	Monday	101.390	29.880	131.270
4/5/2016	Tuesday	50.782	13.753	64.535
4/6/2016	Wednesday	74.090	21.018	95.108
4/7/2016	Thursday	83.845	23.660	107.505
4/8/2016	Friday	67.365	18.863	86.228
4/9/2016	Saturday	0.000	0.000	0.000
4/10/2016	Sunday	0.000	0.000	0.000
4/11/2016	Monday	82.180	23.203	105.383
4/12/2016	Tuesday	47.537	12.448	59.985
4/13/2016	Wednesday	46.618	11.985	58.603
4/14/2016	Thursday	48.928	13.148	62.077
4/15/2016	Friday	44.430	11.513	55.943
4/16/2016	Saturday	0.000	0.000	0.000
5/1/2016	Sunday	0.000	0.000	0.000
5/2/2016	Monday	49.328	13.362	62.690
5/3/2016	Tuesday	47.818	12.888	60.707
5/4/2016	Wednesday	50.253	14.080	64.333
5/5/2016	Thursday	50.170	13.453	63.623
5/6/2016	Friday	44.832	11.542	56.373
5/7/2016	Saturday	0.000	0.000	0.000
5/8/2016	Sunday	0.000	0.000	0.000
5/9/2016	Monday	46.588	12.238	58.827
5/10/2016	Tuesday	49.148	13.392	62.540
5/11/2016	Wednesday	48.182	12.742	60.923
5/12/2016	Thursday	45.372	11.843	57.215
5/13/2016	Friday	43.808	11.450	55.258
5/14/2016	Saturday	0.000	0.000	0.000

Des Moines Military Entrance Processing Station – Tiered Trim and Respond

Tiered Trim and Respond				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
7/15/2015	Wednesday	44.040	22.508	66.548
7/16/2015	Thursday	44.977	23.953	68.930
7/17/2015	Friday	49.158	25.077	74.235
7/18/2015	Saturday	2.483	2.375	4.858
7/19/2015	Sunday	2.432	2.383	4.815
7/20/2015	Monday	58.252	28.227	86.478
7/21/2015	Tuesday	42.082	20.755	62.837
7/22/2015	Wednesday	41.310	20.852	62.162
7/23/2015	Thursday	38.510	19.092	57.602
7/24/2015	Friday	48.202	24.880	73.082
7/25/2015	Saturday	2.470	2.397	4.867
7/26/2015	Sunday	2.480	2.385	4.865
7/27/2015	Monday	104.715	47.462	152.177
7/28/2015	Tuesday	66.895	32.645	99.540
7/29/2015	Wednesday	42.258	21.080	63.338
7/30/2015	Thursday	16.407	8.098	24.505
9/6/2015	Sunday	5.065	3.160	8.225
9/7/2015	Monday	35.765	17.295	53.060
9/8/2015	Tuesday	41.593	20.973	62.567
9/9/2015	Wednesday	36.465	18.125	54.590
9/10/2015	Thursday	42.965	21.612	64.577
9/11/2015	Friday	25.758	13.128	38.887
9/12/2015	Saturday	8.053	3.378	11.432
9/13/2015	Sunday	8.412	3.557	11.968
9/14/2015	Monday	28.032	7.065	35.097
9/15/2015	Tuesday	30.017	7.968	37.985
9/16/2015	Wednesday	31.802	8.248	40.050
9/17/2015	Thursday	36.970	9.658	46.628
9/18/2015	Friday	27.012	7.018	34.030
9/19/2015	Saturday	3.613	2.480	6.093

Des Moines Military Entrance Processing Station – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
10/4/2015	Sunday	3.615	2.467	6.082
10/5/2015	Monday	-	-	-
10/6/2015	Tuesday	26.622	6.965	33.587
10/7/2015	Wednesday	-	-	-
10/8/2015	Thursday	-	-	-
10/9/2015	Friday	-	-	-
10/10/2015	Saturday	-	-	-
10/11/2015	Sunday	-	-	-
10/12/2015	Monday	-	-	-
10/13/2015	Tuesday	-	-	-
10/14/2015	Wednesday	-	-	-
10/15/2015	Thursday	-	-	-
10/16/2015	Friday	-	-	-
10/17/2015	Saturday	-	-	-
11/1/2015	Sunday	-	-	-
11/2/2015	Monday	-	-	-
11/3/2015	Tuesday	-	-	-
11/4/2015	Wednesday	-	-	-
11/5/2015	Thursday	-	-	-
11/6/2015	Friday	-	-	-
11/7/2015	Saturday	-	-	-
11/8/2015	Sunday	-	-	-
11/9/2015	Monday	-	-	-
11/10/2015	Tuesday	-	-	-
11/11/2015	Wednesday	-	-	-
11/12/2015	Thursday	-	-	-
11/13/2015	Friday	-	-	-
11/14/2015	Saturday	-	-	-

Des Moines Military Entrance Processing Station – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
11/29/2015	Sunday	-	-	-
11/30/2015	Monday	-	-	-
12/1/2015	Tuesday	-	-	-
12/2/2015	Wednesday	-	-	-
12/3/2015	Thursday	-	-	-
12/4/2015	Friday	-	-	-
12/5/2015	Saturday	-	-	-
12/6/2015	Sunday	-	-	-
12/7/2015	Monday	-	-	-
12/8/2015	Tuesday	-	-	-
12/9/2015	Wednesday	-	-	-
12/10/2015	Thursday	-	-	-
12/11/2015	Friday	-	-	-
12/12/2015	Saturday	-	-	-
12/27/2015	Sunday	0.000	0.000	0.000
12/28/2015	Monday	17.565	5.575	23.140
12/29/2015	Tuesday	26.345	6.480	32.825
12/30/2015	Wednesday	22.298	5.345	27.643
12/31/2015	Thursday	14.458	3.248	17.707
1/1/2016	Friday	13.240	3.067	16.307
1/2/2016	Saturday	0.000	0.000	0.000
1/3/2016	Sunday	0.000	0.000	0.000
1/4/2016	Monday	16.772	3.747	20.518
1/5/2016	Tuesday	20.037	4.715	24.752
1/6/2016	Wednesday	27.423	6.830	34.253
1/7/2016	Thursday	39.285	10.803	50.088
1/8/2016	Friday	37.338	9.638	46.977
1/9/2016	Saturday	0.000	0.000	0.000

Des Moines Military Entrance Processing Station – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
1/24/2016	Sunday	0.000	0.000	0.000
1/25/2016	Monday	41.863	10.827	52.690
1/26/2016	Tuesday	40.637	9.977	50.613
1/27/2016	Wednesday	41.490	10.582	52.072
1/28/2016	Thursday	50.790	13.392	64.182
1/29/2016	Friday	38.252	9.398	47.650
1/30/2016	Saturday	0.000	0.000	0.000
*TTR Max Stpt at 1.2"				
1/31/2016	Sunday	0.000	0.000	0.000
2/1/2016	Monday	49.922	13.348	63.270
2/2/2016	Tuesday	19.303	4.637	23.940
2/3/2016	Wednesday	25.333	6.188	31.522
2/4/2016	Thursday	30.543	7.390	37.933
2/5/2016	Friday	37.240	9.297	46.537
2/6/2016	Saturday	0.000	0.000	0.000
*TTR Max Stpt at 1.2"				
2/21/2016	Sunday	2.847	0.615	3.462
2/22/2016	Monday	40.295	9.770	50.065
2/23/2016	Tuesday	35.480	8.665	44.145
2/24/2016	Wednesday	35.710	8.993	44.703
2/25/2016	Thursday	34.543	9.002	43.545
2/26/2016	Friday	39.373	9.480	48.853
2/27/2016	Saturday	0.000	0.000	0.000
*TTR Max Stpt at 1.2"				
2/28/2016	Sunday	0.000	0.000	0.000
2/29/2016	Monday	45.707	12.752	58.458
3/1/2016	Tuesday	32.603	8.513	41.117
3/2/2016	Wednesday	26.450	6.353	32.803
3/3/2016	Thursday	32.767	7.828	40.595
3/4/2016	Friday	26.923	6.550	33.473
3/5/2016	Saturday	0.000	0.000	0.000

Des Moines Military Entrance Processing Station – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
3/20/2016	Sunday	0.000	0.000	0.000
3/21/2016	Monday	36.912	10.273	47.185
3/22/2016	Tuesday	28.567	6.750	35.317
3/23/2016	Wednesday	50.923	13.620	64.543
3/24/2016	Thursday	33.040	9.953	42.993
3/25/2016	Friday	26.448	7.415	33.863
3/26/2016	Saturday	0.000	0.000	0.000
3/27/2016	Sunday	0.000	0.000	0.000
3/28/2016	Monday	41.697	11.042	52.738
3/29/2016	Tuesday	30.742	7.317	38.058
3/30/2016	Wednesday	27.960	7.515	35.475
3/31/2016	Thursday	62.565	17.435	80.000
4/1/2016	Friday	48.307	13.025	61.332
4/2/2016	Saturday	0.000	0.000	0.000
4/17/2016	Sunday	0.000	0.000	0.000
4/18/2016	Monday	51.268	13.890	65.158
4/19/2016	Tuesday	56.993	15.827	72.820
4/20/2016	Wednesday	47.238	12.843	60.082
4/21/2016	Thursday	48.115	12.892	61.007
4/22/2016	Friday	45.173	12.303	57.477
4/23/2016	Saturday	0.000	0.000	0.000
4/24/2016	Sunday	0.000	0.000	0.000
4/25/2016	Monday	49.055	12.588	61.643
4/26/2016	Tuesday	64.112	18.193	82.305
4/27/2016	Wednesday	92.387	25.918	118.305
4/28/2016	Thursday	67.418	18.597	86.015
4/29/2016	Friday	85.978	24.227	110.205
4/30/2016	Saturday	0.000	0.000	0.000

Des Moines Military Entrance Processing Station – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		AHU-1 Supply Fan	AHU-1 Return Fan	AHU-1
mm/dd/yy	day	kWh	kWh	kWh
5/15/2016	Sunday	0.000	0.000	0.000
5/16/2016	Monday	36.045	8.987	45.032
5/17/2016	Tuesday	41.652	9.972	51.623
5/18/2016	Wednesday	39.812	9.600	49.412
5/19/2016	Thursday	42.623	10.515	53.138
5/20/2016	Friday	31.582	7.427	39.008
5/21/2016	Saturday	0.000	0.000	0.000

Joint Forces Headquarters – Fixed Static Pressure & Trim and Respond

Fixed Static Pressure			TR		Fixed Static Pressure					
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
8/9/2015	Sunday	62.557	-	26.172	13.155	1.187	557.274	40.745	598.019	674.918
8/10/2015	Monday	126.207	-	83.090	54.642	18.848	567.687	41.062	608.749	808.445
8/11/2015	Tuesday	118.515	-	62.548	51.998	13.918	573.631	41.717	615.348	799.780
8/12/2015	Wednesday	105.050	-	68.432	45.728	12.580	572.898	41.692	614.590	777.948
8/13/2015	Thursday	104.663	59.705	68.160	44.662	12.802	573.493	41.453	614.947	777.073
8/14/2015	Friday	104.117	55.363	58.850	45.837	13.437	574.341	41.433	615.774	779.164
8/15/2015	Saturday	65.382	3.566	8.650	8.918	0.000	573.597	41.298	614.895	689.195
8/16/2015	Sunday	56.102	4.712	19.323	10.038	2.628	572.906	41.077	613.982	682.751
8/17/2015	Monday	109.042	73.440	63.932	51.018	17.208	570.679	41.060	611.739	789.007
8/18/2015	Tuesday	87.490	52.644	39.053	40.542	13.248	574.824	42.438	617.262	758.542
8/19/2015	Wednesday	64.092	43.024	34.475	39.762	11.270	575.345	43.363	618.708	733.831
8/20/2015	Thursday	71.763	48.619	48.515	40.637	10.760	590.531	46.573	637.104	760.264
8/21/2015	Friday	74.372	53.017	45.360	41.642	10.793	566.988	41.055	608.043	734.850
8/22/2015	Saturday	42.833	0.000	0.000	0.000	0.000	562.243	40.772	603.015	645.848
9/6/2015	Sunday	100.803	35.205	33.873	69.207	27.580	527.876	35.963	563.839	761.429
9/7/2015	Monday	100.775	32.014	33.483	69.450	27.145	528.320	35.975	564.295	761.665
9/8/2015	Tuesday	101.730	36.307	34.563	69.377	26.432	531.410	35.993	567.403	764.941
9/9/2015	Wednesday	106.262	48.250	40.092	70.663	23.542	535.391	36.000	571.391	771.857
9/10/2015	Thursday	112.215	48.149	45.383	69.930	24.168	541.087	36.007	577.093	783.407
9/11/2015	Friday	105.655	39.724	41.897	69.055	21.942	557.709	40.837	598.546	795.198
9/12/2015	Saturday	57.780	24.803	22.498	36.238	11.378	569.650	43.742	613.392	718.788
9/13/2015	Sunday	58.735	31.301	23.638	37.258	11.645	566.030	42.822	608.851	716.490
9/14/2015	Monday	108.637	45.748	45.382	69.042	21.603	548.570	38.925	587.495	786.776
9/15/2015	Tuesday	105.470	40.661	36.107	68.683	21.677	549.363	38.855	588.218	784.048
9/16/2015	Wednesday	110.247	55.469	40.127	70.115	23.060	549.248	38.747	587.995	791.417
9/17/2015	Thursday	101.042	41.513	32.735	69.480	24.037	548.285	38.073	586.359	780.917
9/18/2015	Friday	99.783	32.346	32.347	69.380	22.447	550.982	39.270	590.252	781.862
9/19/2015	Saturday	95.780	22.460	30.623	70.288	19.187	570.984	42.990	613.974	799.229
10/4/2015	Sunday	92.245	24.852	24.388	56.482	18.807	575.286	44.065	619.351	786.884
10/5/2015	Monday	93.040	41.524	25.635	55.452	19.178	564.688	40.852	605.540	773.210
10/6/2015	Tuesday	93.157	35.243	25.503	54.597	19.615	559.141	40.715	599.856	767.225
10/7/2015	Wednesday	97.643	36.097	29.822	53.145	19.798	554.579	40.770	595.349	765.935
10/8/2015	Thursday	104.515	43.050	37.840	52.718	21.743	553.973	40.688	594.661	773.638
10/9/2015	Friday	87.810	36.221	24.172	52.650	20.838	564.227	41.508	605.735	767.034
10/10/2015	Saturday	83.330	37.107	22.980	52.787	19.142	549.780	39.458	589.238	744.497
10/11/2015	Sunday	83.650	28.257	24.832	52.957	18.883	533.250	35.998	569.248	724.738
10/12/2015	Monday	85.622	22.157	22.997	52.807	19.538	533.407	36.085	569.492	727.459
10/13/2015	Tuesday	92.898	38.696	33.972	52.723	19.452	556.435	39.718	596.154	761.227
10/14/2015	Wednesday	95.317	44.389	32.800	52.832	19.063	574.876	43.885	618.761	785.973
10/15/2015	Thursday	74.997	34.140	25.547	39.548	14.287	576.140	43.917	620.057	748.889
10/16/2015	Friday	57.390	32.481	28.243	29.958	10.583	583.664	45.270	628.934	726.866
10/17/2015	Saturday	57.658	24.846	14.242	35.637	12.777	567.581	42.610	610.191	716.263
11/1/2015	Sunday	0.000	0.000	0.000	0.000	0.000	585.993	43.935	629.928	629.928
11/2/2015	Monday	0.000	41.143	16.305	29.423	10.378	562.558	42.350	604.908	644.709
11/3/2015	Tuesday	40.172	46.164	19.053	29.855	11.552	455.087	39.787	494.874	576.452
11/4/2015	Wednesday	80.205	43.694	18.740	29.742	11.940	311.413	40.498	351.911	473.798
11/5/2015	Thursday	71.727	35.603	18.918	29.688	11.900	315.360	41.035	356.395	469.710
11/6/2015	Friday	69.208	36.319	24.578	30.218	10.965	325.128	44.448	369.576	479.968
11/7/2015	Saturday	58.983	28.710	17.328	28.312	9.610	334.961	45.838	380.799	477.704

Joint Forces Headquarters – Fixed Static Pressure & Trim and Respond (continued)

Fixed Static Pressure			TR		Fixed Static Pressure					
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
11/8/2015	Sunday	57.192	21.860	20.548	28.400	9.393	327.561	44.673	372.234	467.219
11/9/2015	Monday	63.223	30.470	13.097	30.203	10.410	329.224	45.285	374.509	478.345
11/10/2015	Tuesday	68.213	32.868	13.277	30.013	10.625	326.383	44.285	370.668	479.520
11/11/2015	Wednesday	65.340	26.575	11.257	29.962	10.585	328.962	44.383	373.345	479.232
11/12/2015	Thursday	67.068	38.353	15.833	30.422	10.592	330.075	44.450	374.525	482.607
11/13/2015	Friday	63.337	25.744	10.990	30.635	10.612	332.719	45.978	378.697	483.281
11/14/2015	Saturday	0.000	0.000	0.000	0.000	0.000	324.085	43.538	367.623	367.623
							*AHU-12 ES 34 shut down on 11/3			
11/29/2015	Sunday	0.000	0.000	0.000	0.000	0.000	311.873	38.445	350.318	350.318
11/30/2015	Monday	68.185	36.610	25.130	32.302	10.413	316.464	40.730	357.194	468.094
12/1/2015	Tuesday	74.200	45.463	28.288	34.400	10.603	317.054	40.543	357.598	476.801
12/2/2015	Wednesday	74.660	44.551	27.193	34.025	10.625	305.968	36.350	342.318	461.628
12/3/2015	Thursday	82.977	48.184	34.012	35.770	10.622	305.418	36.302	341.720	471.088
12/4/2015	Friday	71.580	42.747	35.413	34.400	10.608	304.341	36.010	340.352	456.940
12/5/2015	Saturday	0.000	0.000	0.000	0.000	0.000	305.000	36.005	341.005	341.005
							*AHU-12 ES 34 shut down on 11/3			
12/6/2015	Sunday	0.000	0.000	0.000	0.000	0.000	305.557	36.005	341.562	341.562
12/7/2015	Monday	83.177	45.287	29.625	32.395	10.415	306.349	36.600	342.949	468.936
12/8/2015	Tuesday	74.952	42.341	32.320	33.320	10.625	311.847	38.863	350.710	469.607
12/9/2015	Wednesday	83.270	43.578	40.352	35.522	10.615	326.997	44.007	371.003	500.410
12/10/2015	Thursday	73.013	35.251	37.220	33.790	10.810	338.239	47.432	385.671	503.284
12/11/2015	Friday	69.575	33.976	35.485	32.990	11.123	331.340	45.468	376.808	490.496
12/12/2015	Saturday	0.000	0.000	0.000	0.000	0.000	325.734	43.622	369.356	369.356
12/27/2015	Sunday	0.000	0.000	0.000	0.000	0.000	313.112	40.640	353.752	353.752
12/28/2015	Monday	84.760	49.722	24.365	32.978	10.370	320.297	42.713	363.011	491.119
12/29/2015	Tuesday	94.562	42.436	33.232	33.485	10.613	321.180	41.677	362.857	501.517
12/30/2015	Wednesday	91.545	39.793	33.005	33.715	10.613	319.185	40.808	359.994	495.867
12/31/2015	Thursday	89.580	41.212	30.020	37.037	10.573	316.151	40.642	356.793	493.983
1/1/2016	Friday	84.495	48.625	22.850	34.045	10.602	304.800	36.180	340.980	470.122
1/2/2016	Saturday	0.000	0.000	0.000	0.000	0.000	306.274	36.868	343.142	343.142
1/3/2016	Sunday	0.000	0.000	0.000	0.000	0.000	311.245	39.322	350.567	350.567
1/4/2016	Monday	91.763	51.017	29.917	34.240	10.368	318.212	41.858	360.070	496.442
1/5/2016	Tuesday	100.368	41.218	32.497	38.257	10.608	311.202	39.673	350.875	500.109
1/6/2016	Wednesday	63.462	55.787	33.453	38.373	10.622	325.486	44.185	369.671	482.128
1/7/2016	Thursday	66.147	47.673	37.423	34.977	10.603	332.372	46.597	378.968	490.695
1/8/2016	Friday	93.383	47.523	40.825	34.515	10.620	333.081	47.200	380.281	518.799
1/9/2016	Saturday	27.455	4.074	5.577	19.368	6.897	320.406	41.718	362.124	415.844
1/24/2016	Sunday	0.000	0.000	0.000	0.000	0.000	554.421	40.800	595.221	595.221
1/25/2016	Monday	101.688	38.578	37.535	33.077	10.415	566.523	42.388	608.912	754.092
1/26/2016	Tuesday	99.777	35.468	34.767	35.903	10.615	566.470	41.530	608.000	754.295
1/27/2016	Wednesday	107.423	29.933	36.077	35.400	10.593	551.461	39.862	591.322	744.739
1/28/2016	Thursday	93.832	46.435	38.093	35.850	10.607	550.360	40.585	590.945	731.233
1/29/2016	Friday	94.173	51.375	31.460	38.037	10.623	546.282	39.975	586.257	729.090
1/30/2016	Saturday	0.000	0.000	0.000	0.000	0.000	547.454	40.432	587.886	587.886
1/31/2016	Sunday	0.000	0.000	0.000	0.000	0.000	548.334	40.717	589.051	589.051
2/1/2016	Monday	111.247	50.212	43.872	34.028	10.418	544.227	38.550	582.777	738.470
2/2/2016	Tuesday	55.357	52.696	32.543	33.585	10.563	554.000	40.007	594.007	693.512
2/3/2016	Wednesday	55.528	54.090	38.183	34.762	10.602	560.530	40.877	601.407	702.298
2/4/2016	Thursday	57.505	52.734	34.457	38.282	10.527	560.394	41.152	601.546	707.859
2/5/2016	Friday	57.335	53.057	0.000	37.892	10.542	557.152	39.958	597.110	702.879
2/6/2016	Saturday	0.000	0.000	0.000	0.000	0.000	559.328	40.832	600.160	600.160

Joint Forces Headquarters – Fixed Static Pressure (continued)

Fixed Static Pressure			TR		Fixed Static Pressure					
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
2/21/2016	Sunday	0.000	0.000	0.000	0.000	0.000	575.961	45.255	621.216	621.216
2/22/2016	Monday	84.373	47.667	74.745	37.072	10.418	578.394	44.905	623.299	755.162
2/23/2016	Tuesday	77.550	56.548	49.588	34.353	10.558	567.526	42.680	610.206	732.668
2/24/2016	Wednesday	84.697	46.273	65.465	37.188	10.607	555.621	41.110	596.731	729.223
2/25/2016	Thursday	86.082	53.167	62.635	37.413	10.605	549.130	39.175	588.305	722.405
2/26/2016	Friday	79.802	53.291	66.008	33.885	10.615	547.923	39.388	587.311	711.613
2/27/2016	Saturday	0.000	0.000	0.000	0.000	0.000	532.576	37.780	570.356	570.356
2/28/2016	Sunday	0.000	0.000	0.000	0.000	0.000	556.089	40.900	596.989	596.989
2/29/2016	Monday	77.010	54.353	49.742	32.805	10.407	561.842	41.977	603.818	724.040
3/1/2016	Tuesday	88.890	24.411	29.870	32.540	10.602	551.707	39.375	591.082	723.114
3/2/2016	Wednesday	71.212	55.377	54.075	32.775	10.567	568.552	42.957	611.508	726.062
3/3/2016	Thursday	57.218	60.859	28.547	35.150	10.635	572.173	43.547	615.720	718.723
3/4/2016	Friday	73.913	55.057	60.592	34.442	10.613	578.882	43.953	622.835	741.804
3/5/2016	Saturday	0.000	0.000	0.000	0.000	0.000	578.515	45.525	624.040	624.040
3/20/2016	Sunday	0.000	0.000	0.000	0.000	0.000	570.813	42.645	613.458	613.458
3/21/2016	Monday	75.635	46.222	47.675	38.397	10.392	584.936	45.225	630.161	754.584
3/22/2016	Tuesday	73.442	36.625	34.017	35.893	10.542	582.877	45.205	628.082	747.958
3/23/2016	Wednesday	95.662	58.539	44.375	36.830	10.623	594.486	47.775	642.261	785.376
3/24/2016	Thursday	56.085	64.267	37.498	36.937	10.613	583.045	44.732	627.777	731.411
3/25/2016	Friday	75.892	58.372	64.878	44.388	10.600	573.020	43.055	616.075	746.955
3/26/2016	Saturday	0.000	0.000	-	0.000	0.000	555.696	40.767	596.463	596.463
3/27/2016	Sunday	0.000	0.000	-	0.000	0.000	552.003	40.742	592.745	592.745
3/28/2016	Monday	72.548	42.592	-	42.110	10.402	555.656	40.278	595.935	720.995
3/29/2016	Tuesday	91.418	52.310	-	42.510	10.608	568.279	42.275	610.554	755.091
3/30/2016	Wednesday	80.795	44.046	-	37.745	10.515	587.001	45.805	632.806	761.861
3/31/2016	Thursday	99.100	52.852	-	40.562	10.632	612.417	51.040	663.457	813.750
4/1/2016	Friday	0.000	54.217	-	39.155	10.617	594.799	47.198	641.998	691.769
4/2/2016	Saturday	0.000	0.000	-	0.000	0.000	594.720	45.805	640.525	640.525
4/17/2016	Sunday	0.000	0.000	-	0.000	0.000	531.657	36.527	568.184	568.184
4/18/2016	Monday	80.770	64.882	-	36.770	10.418	523.628	34.825	558.453	686.411
4/19/2016	Tuesday	73.857	56.101	-	37.452	10.625	569.214	42.007	611.221	733.154
4/20/2016	Wednesday	73.240	52.379	-	34.030	10.613	582.449	44.548	626.998	744.881
4/21/2016	Thursday	67.488	39.905	-	34.293	10.613	577.199	43.610	620.809	733.204
4/22/2016	Friday	61.492	36.792	-	33.190	10.625	580.963	44.513	625.477	730.783
4/23/2016	Saturday	0.000	0.000	-	0.000	0.000	558.771	40.305	599.076	599.076
					*AHU-4 FSP reduced to 1.3"					
4/24/2016	Sunday	0.000	0.000	-	0.000	0.000	550.022	37.998	588.020	588.020
4/25/2016	Monday	75.710	61.788	-	35.633	10.550	563.216	40.480	603.696	725.589
4/26/2016	Tuesday	67.117	47.445	-	33.947	10.718	581.729	43.932	625.661	737.442
4/27/2016	Wednesday	70.913	51.360	-	33.733	10.627	599.929	48.547	648.476	763.749
4/28/2016	Thursday	69.917	33.771	-	34.172	10.615	597.528	47.813	645.342	760.045
4/29/2016	Friday	68.350	25.294	-	34.347	10.615	584.833	45.823	630.656	743.968
4/30/2016	Saturday	0.000	0.000	-	0.000	0.000	581.170	45.547	626.716	626.716
5/15/2016	Sunday	0.000	0.000	-	0.000	0.000	570.773	42.018	612.791	612.791
5/16/2016	Monday	93.610	64.527	-	49.140	15.203	581.280	44.627	625.907	783.860
5/17/2016	Tuesday	102.518	45.673	-	58.143	19.187	572.585	42.653	615.238	795.087
5/18/2016	Wednesday	100.160	60.620	75.443	62.208	19.213	565.688	41.525	607.213	788.794
5/19/2016	Thursday	106.353	56.407	92.782	62.785	19.200	563.792	40.680	604.472	792.810
5/20/2016	Friday	103.222	62.899	81.648	59.422	19.215	570.098	42.083	612.181	794.040
5/21/2016	Saturday	95.618	40.188	71.847	56.623	19.190	557.887	40.372	598.258	769.690

Joint Forces Headquarters – Fixed Static Pressure & Trim and Respond (continued)

Fixed Static Pressure			TR		Fixed Static Pressure					
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
5/22/2016	Sunday	92.902	29.567	65.887	56.277	19.200	330.593	24.615	355.208	523.586
5/23/2016	Monday	98.253	34.005	66.915	55.528	19.202	371.964	26.273	398.237	571.220
5/24/2016	Tuesday	101.060	29.783	67.322	55.352	19.188	544.485	36.503	580.989	756.589
5/25/2016	Wednesday	95.845	29.653	68.085	55.608	19.215	541.643	36.015	577.658	748.327
5/26/2016	Thursday	95.727	37.294	69.330	57.675	19.202	543.257	36.802	580.058	752.662
5/27/2016	Friday	96.463	66.131	68.433	58.073	19.202	537.878	36.000	573.878	747.617
5/28/2016	Saturday	84.618	39.683	29.287	55.373	19.275	528.758	35.753	528.758	688.024

*24 hour occupancy *AHU-3 TR mode resumed 5/26 *AHU-12 tripped 5/22

Joint Forces Headquarters – Tiered Trim and Respond

Tiered Trim and Respond										
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
7/26/2015	Sunday	33.818	7.260	31.628	12.578	2.637	369.172	15.858	385.031	434.064
7/27/2015	Monday	91.672	76.905	101.240	54.038	11.372	373.028	16.538	389.566	546.648
7/28/2015	Tuesday	74.532	59.645	69.302	32.185	7.208	377.658	16.043	393.701	507.626
7/29/2015	Wednesday	68.318	62.270	74.662	38.030	6.152	373.475	16.587	390.061	502.561
7/30/2015	Thursday	89.395	66.959	77.658	45.020	7.668	377.609	17.068	394.677	536.760
7/31/2015	Friday	70.013	60.712	78.208	43.048	6.340	377.575	16.853	394.428	513.830
8/1/2015	Saturday	30.675	6.094	10.668	9.652	0.000	370.071	16.855	386.926	427.253
8/2/2015	Sunday	35.358	9.966	33.977	15.782	1.170	370.401	16.833	387.234	439.544
8/3/2015	Monday	124.225	81.562	128.537	65.157	10.742	391.744	17.587	409.330	609.454
8/4/2015	Tuesday	61.767	60.262	60.398	36.095	6.723	429.881	22.280	452.161	556.746
8/5/2015	Wednesday	67.635	54.719	50.443	25.388	6.513	403.392	18.743	422.135	521.672
8/6/2015	Thursday	69.062	58.724	71.250	34.272	6.347	402.992	17.853	420.846	530.526
8/7/2015	Friday	69.213	59.318	70.527	35.760	6.252	414.028	18.082	432.110	543.335
8/8/2015	Saturday	21.622	0.329	1.557	0.000	0.000	396.290	17.058	413.349	434.970
8/9/2015	Sunday	-	5.653	-	-	-	-	-	-	0.000
8/10/2015	Monday	-	77.710	-	-	-	-	-	-	0.000
8/11/2015	Tuesday	-	69.585	-	-	-	-	-	-	0.000
8/12/2015	Wednesday	-	60.571	-	-	-	-	-	-	0.000
8/23/2015	Sunday	20.862	1.786	12.875	1.262	0.000	403.944	20.173	424.117	446.240
8/24/2015	Monday	117.273	73.945	113.453	54.610	6.293	455.990	23.147	479.137	657.313
8/25/2015	Tuesday	86.008	63.413	104.463	45.653	7.713	505.270	30.248	535.519	674.894
8/26/2015	Wednesday	73.040	60.539	88.478	36.867	9.623	461.788	28.730	490.518	610.048
8/27/2015	Thursday	61.037	57.250	59.190	24.805	9.108	426.854	23.772	450.626	545.576
8/28/2015	Friday	69.320	52.647	41.895	21.417	9.605	355.582	15.958	371.540	471.882
8/29/2015	Saturday	38.282	27.593	30.548	15.445	6.575	347.325	15.668	362.993	423.295
8/30/2015	Sunday	58.652	48.233	45.297	29.058	9.808	350.385	15.672	366.057	463.575
8/31/2015	Monday	90.038	83.374	62.428	45.257	11.428	350.741	15.035	365.776	512.499
9/1/2015	Tuesday	100.318	67.441	71.747	46.393	12.827	351.585	14.860	366.445	525.984
9/2/2015	Wednesday	111.153	69.086	70.087	42.682	14.012	360.717	15.285	376.002	543.849
9/3/2015	Thursday	91.773	67.421	57.658	38.575	15.147	367.704	15.865	383.569	529.064
9/4/2015	Friday	99.127	69.201	72.203	49.425	17.763	360.573	15.860	376.433	542.748
9/5/2015	Saturday	90.992	49.159	51.453	34.902	17.015	357.093	15.813	372.906	515.814
9/20/2015	Sunday	81.087	45.497	30.297	77.555	4.985	371.348	16.498	387.847	551.473
9/21/2015	Monday	87.230	52.682	35.233	58.550	6.133	365.479	16.085	381.564	533.478
9/22/2015	Tuesday	86.507	55.631	39.457	60.615	9.022	381.596	16.677	398.273	554.416
9/23/2015	Wednesday	80.790	56.107	32.448	57.087	10.382	379.599	17.210	396.809	545.067
9/24/2015	Thursday	80.480	59.148	46.070	53.957	9.735	386.319	17.260	403.579	547.751
9/25/2015	Friday	80.203	73.780	32.558	58.607	8.068	372.355	16.970	389.325	536.204
9/26/2015	Saturday	89.225	76.366	30.917	54.277	7.585	358.405	14.973	373.379	524.465
9/27/2015	Sunday	59.715	47.102	34.388	32.045	5.453	458.340	25.835	484.175	581.389
9/28/2015	Monday	133.492	115.665	93.355	107.948	16.383	508.338	33.007	541.344	799.168
9/29/2015	Tuesday	89.602	92.634	51.078	77.460	15.008	382.911	15.683	398.595	580.665
9/30/2015	Wednesday	93.273	86.003	47.682	65.372	10.985	416.008	18.693	434.702	604.332
10/1/2015	Thursday	98.448	78.867	53.625	58.677	6.917	413.471	17.192	430.663	594.704
10/2/2015	Friday	96.660	73.313	43.267	39.738	6.318	415.770	19.248	435.019	577.735
10/3/2015	Saturday	89.427	61.930	38.187	38.620	4.800	463.245	22.023	485.268	618.115

Joint Forces Headquarters - Tiered Trim and Respond (Continued)

Tiered Trim and Respond										
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
10/25/2015	Sunday	0.000	0.000	0.000	0.000	0.000	438.442	23.858	462.301	462.301
10/26/2015	Monday	45.778	39.054	45.757	20.897	5.842	456.987	26.303	483.290	555.807
10/27/2015	Tuesday	51.493	45.515	36.562	17.193	3.673	401.727	16.550	418.277	490.637
10/28/2015	Wednesday	68.278	47.038	37.458	17.448	4.357	455.210	23.550	478.760	568.844
10/29/2015	Thursday	50.680	45.633	28.732	20.975	2.767	484.102	24.532	508.633	583.055
10/30/2015	Friday	23.097	44.337	31.573	19.705	2.777	479.486	26.768	506.254	551.832
10/31/2015	Saturday	0.000	0.000	0.000	0.000	0.000	383.150	14.440	397.590	397.590
11/15/2015	Sunday	0.000	0.000	0.000	0.000	0.000	279.122	27.682	306.804	306.804
11/16/2015	Monday	30.005	42.952	29.295	18.352	2.723	295.215	32.922	328.137	379.217
11/17/2015	Tuesday	11.912	44.337	32.225	17.973	2.775	295.688	34.978	330.667	363.327
11/18/2015	Wednesday	38.820	41.250	47.795	18.908	2.782	269.123	26.458	295.581	356.091
11/19/2015	Thursday	51.113	40.641	49.455	20.060	2.958	276.021	26.722	302.742	376.874
11/20/2015	Friday	69.030	45.699	35.083	22.377	2.763	273.612	25.247	298.859	393.029
11/21/2015	Saturday	0.000	0.000	0.000	0.000	0.000	262.355	21.980	284.335	284.335
		*SPmax was reduced to 1.5" from 2.4"					*AHU-12 ES 34 shut down on 11/3			
11/22/2015	Sunday	0.000	0.000	0.000	0.000	0.000	268.532	23.732	292.264	292.264
11/23/2015	Monday	83.925	44.409	56.605	38.108	2.707	270.194	23.967	294.160	418.900
11/24/2015	Tuesday	71.028	47.921	49.382	31.547	2.772	271.689	24.545	296.234	401.581
11/25/2015	Wednesday	59.083	45.569	45.282	15.970	2.838	282.701	27.643	310.344	388.236
11/26/2015	Thursday	58.848	44.069	34.275	19.818	6.855	238.166	18.615	256.781	342.303
11/27/2015	Friday	64.402	44.360	31.693	21.695	2.970	250.489	19.030	269.519	358.586
11/28/2015	Saturday	0.000	0.000	0.000	0.000	0.000	255.310	20.275	275.585	275.585
		*SPmax was reduced to 1.5", effectively limiting TTR to FSP						*AHU-12 ES 34 shut down on 11/3		
12/13/2015	Sunday	0.000	0.000	0.000	0.000	0.000	215.415	14.500	229.915	229.915
12/14/2015	Monday	88.303	51.156	44.168	23.023	11.743	253.158	21.395	274.553	397.623
12/15/2015	Tuesday	86.475	49.808	45.462	26.750	7.318	270.986	26.623	297.609	418.152
12/16/2015	Wednesday	84.582	50.131	45.223	24.213	5.798	232.722	20.067	252.789	367.382
12/17/2015	Thursday	75.940	49.664	43.850	28.313	2.770	199.735	14.823	214.558	321.582
12/18/2015	Friday	86.868	49.554	57.093	39.895	2.782	229.039	19.418	248.457	378.002
12/19/2015	Saturday	0.000	0.000	0.000	0.000	0.000	255.128	23.188	278.316	278.316
		*SPmax was reduced to 1.5", effectively limiting TTR to FSP						*AHU-12 ES 34 shut down on 11/3		
12/20/2015	Sunday	0.000	0.000	0.000	0.000	0.000	227.702	17.083	244.785	244.785
12/21/2015	Monday	77.533	48.178	39.923	29.982	3.715	277.816	29.597	307.413	418.643
12/22/2015	Tuesday	76.958	49.892	42.012	28.912	2.758	292.093	33.078	325.171	433.800
12/23/2015	Wednesday	86.102	51.032	45.020	31.623	2.777	308.176	37.513	345.689	466.191
12/24/2015	Thursday	65.345	48.504	38.298	23.312	2.760	280.557	28.332	308.888	400.305
12/25/2015	Friday	80.795	49.776	32.978	22.835	2.772	263.862	25.510	289.372	395.774
12/26/2015	Saturday	0.000	0.000	0.000	0.000	0.000	278.981	27.280	306.261	306.261
		*SPmax was reduced to 1.5", effectively limiting TTR to FSP								
1/10/2016	Sunday	75.838	14.955	14.958	20.900	4.933	310.331	39.230	349.561	451.232
1/11/2016	Monday	120.103	54.846	54.225	27.585	3.600	308.086	37.998	346.084	497.373
1/12/2016	Tuesday	131.203	54.708	55.562	33.480	4.463	380.057	22.038	402.095	571.242
1/13/2016	Wednesday	107.022	40.638	65.197	30.953	3.160	486.268	25.885	512.153	653.288
1/14/2016	Thursday	95.628	40.347	65.757	36.890	2.773	505.769	29.233	535.002	670.294
1/15/2016	Friday	79.580	39.392	42.828	31.250	2.767	477.722	25.262	502.984	616.580
1/16/2016	Saturday	29.762	11.657	7.442	9.825	2.218	471.984	27.338	499.323	541.128
1/17/2016	Sunday	59.950	16.000	14.400	19.330	4.800	487.082	28.278	515.360	599.440
1/18/2016	Monday	102.783	47.852	37.868	37.068	4.893	497.219	30.223	527.442	672.187
1/19/2016	Tuesday	103.842	45.151	41.118	29.368	3.603	511.176	32.767	543.943	680.756
1/20/2016	Wednesday	87.258	41.916	44.652	29.633	2.767	535.633	36.925	572.558	692.217
1/21/2016	Thursday	95.045	40.609	50.377	35.067	2.760	558.845	40.738	599.583	732.455
1/22/2016	Friday	84.505	39.752	37.342	23.913	2.767	557.777	40.820	598.597	709.782
1/23/2016	Saturday	0.000	0.000	0.000	0.000	0.000	552.484	40.800	593.284	593.284

Joint Forces Headquarters - Tiered Trim and Respond (Continued)

Tiered Trim and Respond										
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
2/7/2016	Sunday	0.000	0.000	0.000	0.000	0.000	537.638	37.322	574.960	574.960
2/8/2016	Monday	51.543	51.548	0.000	37.148	2.722	533.581	36.073	569.654	661.068
2/9/2016	Tuesday	72.528	49.866	0.000	40.915	2.773	527.731	35.333	563.064	679.281
2/10/2016	Wednesday	69.782	51.089	0.000	42.692	2.767	526.211	34.527	560.738	675.978
2/11/2016	Thursday	97.027	56.286	0.000	51.728	3.120	515.657	33.783	549.440	701.315
2/12/2016	Friday	94.292	51.816	0.000	42.678	3.763	514.500	33.730	548.230	688.964
2/13/2016	Saturday	30.688	7.398	0.000	7.940	2.077	516.337	32.365	548.702	589.407
2/14/2016	Sunday	0.000	0.000	0.000	0.000	0.000	525.155	35.858	561.013	561.013
2/15/2016	Monday	69.747	45.134	0.000	21.695	2.727	524.826	34.963	559.789	653.958
2/16/2016	Tuesday	78.855	49.970	0.000	38.442	2.772	545.179	38.993	584.173	704.241
2/17/2016	Wednesday	82.198	49.502	0.000	32.232	2.760	571.811	43.348	615.159	732.349
2/18/2016	Thursday	76.368	48.250	0.000	28.390	2.787	547.816	39.125	586.941	694.486
2/19/2016	Friday	71.972	46.747	0.000	31.067	2.203	525.516	33.952	559.468	664.710
2/20/2016	Saturday	0.000	0.000	0.000	0.000	0.000	583.658	45.647	629.305	629.305
3/6/2016	Sunday	0.000	0.000	0.000	0.000	0.000	547.511	38.342	585.853	585.853
3/7/2016	Monday	69.525	54.171	70.982	48.830	2.723	559.719	40.545	600.264	721.342
3/8/2016	Tuesday	94.947	74.461	97.452	65.517	3.795	590.992	47.043	638.036	802.294
3/9/2016	Wednesday	77.885	58.868	113.108	43.505	3.742	617.686	51.663	669.349	794.481
3/10/2016	Thursday	91.143	59.887	92.690	37.345	3.002	604.869	49.343	654.212	785.702
3/11/2016	Friday	64.595	46.383	66.947	23.288	2.768	579.532	44.492	624.024	714.676
3/12/2016	Saturday	0.000	0.000	0.000	0.000	0.000	583.530	45.645	629.175	629.175
3/13/2016	Sunday	0.000	0.000	0.000	0.000	0.000	559.107	43.438	602.546	602.546
3/14/2016	Monday	65.978	53.392	59.967	26.350	2.730	569.515	42.702	612.217	707.275
3/15/2016	Tuesday	71.272	49.173	72.950	30.252	2.843	591.833	46.930	638.763	743.130
3/16/2016	Wednesday	65.817	54.999	74.323	39.582	2.925	554.927	39.893	594.820	703.143
3/17/2016	Thursday	74.798	58.594	86.335	38.108	2.755	584.392	45.270	629.662	745.324
3/18/2016	Friday	65.480	58.228	83.215	32.318	2.900	580.349	44.817	625.165	725.864
3/19/2016	Saturday	0.000	0.000	0.000	0.000	0.000	569.497	42.792	612.288	612.288
4/3/2016	Sunday	0.000	0.000	-	0.000	0.000	562.161	40.220	602.381	602.381
4/4/2016	Monday	117.122	76.588	-	60.917	2.727	594.063	47.230	641.293	822.058
4/5/2016	Tuesday	86.665	60.709	-	50.037	2.765	593.266	47.075	640.341	779.808
4/6/2016	Wednesday	75.240	62.374	-	41.690	2.645	564.743	42.443	607.186	726.761
4/7/2016	Thursday	80.645	57.717	-	43.852	2.765	554.003	40.805	594.808	722.070
4/8/2016	Friday	74.697	56.517	-	43.610	2.507	547.576	39.077	586.653	707.466
4/9/2016	Saturday	0.000	0.000	-	0.000	0.000	545.329	39.082	584.411	584.411
		*AHU-1 and AHU-4 Spmax was reduced to 1.5" on 4/6								
4/10/2016	Sunday	-	-	-	-	-	-	-	-	-
4/11/2016	Monday	-	-	-	-	-	-	-	-	-
4/12/2016	Tuesday	-	-	-	-	-	-	-	-	-
4/13/2016	Wednesday	-	-	-	-	-	-	-	-	-
4/14/2016	Thursday	-	-	-	-	-	-	-	-	-
4/15/2016	Friday	-	-	-	-	-	-	-	-	-
4/16/2016	Saturday	-	-	-	-	-	-	-	-	-
5/1/2016	Sunday	0.000	0.000	-	0.000	0.000	561.927	40.778	602.706	602.706
5/2/2016	Monday	57.883	42.641	-	35.855	2.735	561.920	40.718	602.638	699.112
5/3/2016	Tuesday	64.217	53.299	-	40.312	2.770	557.869	40.447	598.315	705.614
5/4/2016	Wednesday	62.565	49.274	-	38.857	2.768	563.227	41.120	604.347	708.537
5/5/2016	Thursday	61.540	46.920	-	35.903	2.780	557.178	40.012	597.190	697.413
5/6/2016	Friday	62.630	51.560	-	39.532	3.113	556.058	39.385	595.443	700.718
5/7/2016	Saturday	0.000	0.000	-	0.000	0.000	544.085	36.812	580.897	580.897

Joint Forces Headquarters - Tiered Trim and Respond (Continued)

Tiered Trim and Respond										
Date		AHU-1	AHU-2	AHU-3	AHU-4	AHU-9	AHU-12 Supply Fan	AHU-12 Return Fan	AHU-12	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
5/8/2016	Sunday	0.000	0.000	-	0.000	0.000	559.382	39.637	599.019	599.019
5/9/2016	Monday	72.218	63.283	-	42.595	4.905	570.113	41.953	612.066	731.785
5/10/2016	Tuesday	68.105	57.636	-	38.262	4.070	546.612	38.128	584.740	695.177
5/11/2016	Wednesday	63.885	55.400	-	36.665	5.150	567.507	42.315	609.822	715.522
5/12/2016	Thursday	64.215	55.553	-	37.177	4.297	560.118	40.975	601.093	706.782
5/13/2016	Friday	63.438	55.980	-	36.333	3.183	577.569	44.590	622.159	725.114
5/14/2016	Saturday	0.000	0.000	-	0.000	0.000	583.332	45.037	628.369	628.369

Muscatine Armed Forces Reserve Center – Fixed Static Pressure

Fixed Static Pressure										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
7/25/2015	Saturday	1.475	1.475	4.386	16.429	20.815	19.586	23.947	43.533	65.823
7/26/2015	Sunday	4.716	4.716	0.272	0.090	0.362	18.517	0.000	18.517	23.595
7/27/2015	Monday	4.814	4.814	28.797	19.226	48.022	48.662	0.000	48.662	101.498
7/28/2015	Tuesday	1.895	1.895	24.295	19.276	43.571	43.799	0.000	43.799	89.265
7/29/2015	Wednesday	2.206	2.206	30.459	19.276	49.735	42.592	0.000	42.592	94.533
7/30/2015	Thursday	3.527	3.527	38.826	22.889	61.715	50.166	0.000	50.166	115.408
7/31/2015	Friday	7.674	7.674	67.018	37.192	104.210	61.960	0.000	61.960	173.844
*RTU-1 Occupied during normally unoccupied hours 7/31 *RTU-3 was in TTR Mode *RTU-4 tripped 7/25 and 7/26										
8/1/2015	Saturday	7.697	7.697	75.116	37.386	112.502	62.551	0.000	62.551	182.749
8/2/2015	Sunday	8.092	8.092	75.673	36.875	112.548	62.176	0.000	62.176	182.815
8/3/2015	Monday	3.348	3.348	38.615	19.235	57.850	44.506	0.000	44.506	105.704
8/4/2015	Tuesday	2.368	2.368	37.255	20.949	58.204	46.721	0.000	46.721	107.293
8/5/2015	Wednesday	3.539	3.539	34.520	19.353	53.873	57.257	0.000	57.257	114.668
8/6/2015	Thursday	3.851	3.851	44.179	22.725	66.904	73.069	0.000	73.069	143.825
8/7/2015	Friday	2.468	2.468	36.598	19.198	55.795	69.163	0.000	69.163	127.426
8/22/2015	Saturday	3.780	3.780	0.000	0.000	0.000	21.043	0.000	21.043	24.823
8/23/2015	Sunday	1.417	1.417	0.000	0.000	0.000	21.114	0.000	21.114	22.531
8/24/2015	Monday	3.043	3.043	41.424	19.519	60.943	51.341	0.000	51.341	115.327
8/25/2015	Tuesday	1.783	1.783	38.273	19.653	57.926	51.900	0.000	51.900	111.609
8/26/2015	Wednesday	1.802	1.802	24.956	19.585	44.540	49.248	0.000	49.248	95.590
8/27/2015	Thursday	1.806	1.806	29.294	23.153	52.447	53.014	0.000	53.014	107.268
8/28/2015	Friday	3.154	3.154	22.261	19.805	42.066	43.836	0.000	43.836	89.056
8/29/2015	Saturday	7.612	7.612	46.632	37.725	84.357	58.884	0.000	58.884	150.852
8/30/2015	Sunday	8.395	8.395	44.054	37.831	81.886	59.263	0.000	59.263	149.544
8/31/2015	Monday	3.517	3.517	22.154	19.346	41.499	38.060	0.000	38.060	83.076
9/1/2015	Tuesday	2.096	2.096	25.319	19.162	44.482	36.430	0.000	36.430	83.008
9/2/2015	Wednesday	2.072	2.072	25.129	19.332	44.461	47.051	0.000	47.051	93.583
9/3/2015	Thursday	2.292	2.292	27.803	22.485	50.288	50.280	0.000	50.280	102.860
9/4/2015	Friday	3.903	3.903	22.082	19.284	41.366	46.607	0.000	46.607	91.877
9/19/2015	Saturday	7.320	7.320	82.232	37.734	119.967	61.391	36.060	97.451	224.737
9/20/2015	Sunday	0.000	0.000	0.000	0.000	0.000	25.815	36.691	62.506	62.506
9/21/2015	Monday	3.070	3.070	41.836	19.535	61.371	46.869	36.579	83.449	147.890
9/22/2015	Tuesday	2.698	2.698	41.578	19.564	61.141	47.861	36.594	84.455	148.295
9/23/2015	Wednesday	2.154	2.154	41.656	19.459	61.115	46.205	36.660	82.865	146.133
9/24/2015	Thursday	2.322	2.322	48.618	23.016	71.634	51.980	36.575	88.554	162.510
9/25/2015	Friday	1.754	1.754	40.234	19.582	59.816	47.672	36.749	84.420	145.991
9/26/2015	Saturday	0.966	0.966	0.000	0.000	0.000	25.774	36.625	62.399	63.365
9/27/2015	Sunday	0.890	0.890	0.000	0.000	0.000	26.032	36.509	62.540	63.430
9/28/2015	Monday	4.142	4.142	44.668	19.467	64.135	48.445	36.550	84.995	153.273
9/29/2015	Tuesday	2.009	2.009	44.214	19.613	63.827	52.752	36.815	89.567	155.403
9/30/2015	Wednesday	1.837	1.837	44.843	19.777	64.620	46.543	36.915	83.458	149.915
10/1/2015	Thursday	2.101	2.101	55.193	23.401	78.594	50.423	36.819	87.242	167.937
10/2/2015	Friday	2.282	2.282	44.894	20.076	64.970	46.032	36.636	82.667	149.919
10/17/2015	Saturday	0.000	0.000	55.392	26.432	81.824	19.882	32.543	52.425	134.249
10/18/2015	Sunday	0.276	0.276	4.996	5.593	10.589	20.010	33.678	53.688	64.553
10/19/2015	Monday	3.963	3.963	58.737	31.546	90.283	45.152	36.256	81.408	175.655
10/20/2015	Tuesday	2.283	2.283	46.154	20.002	66.156	45.202	36.157	81.358	149.797
10/21/2015	Wednesday	2.330	2.330	41.630	19.385	61.014	44.914	34.707	79.621	142.966
10/22/2015	Thursday	2.050	2.050	54.645	23.369	78.014	50.588	36.403	86.991	167.054
10/23/2015	Friday	7.064	7.064	83.579	37.852	121.431	65.090	36.120	101.210	229.705

Muscatine Armed Forces Reserve Center – Fixed Static Pressure (Continued)

Fixed Static Pressure										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
10/24/2015	Saturday	6.904	6.904	80.480	37.906	118.387	62.263	36.325	98.588	223.879
10/25/2015	Sunday	0.000	0.000	3.135	3.641	6.776	22.323	36.606	58.929	65.705
10/26/2015	Monday	3.794	3.794	55.015	29.268	84.283	45.109	36.489	81.598	169.675
10/27/2015	Tuesday	2.534	2.534	49.632	28.274	77.906	46.231	36.521	82.753	163.193
10/28/2015	Wednesday	2.124	2.124	51.559	28.376	79.934	46.170	34.720	80.890	162.948
10/29/2015	Thursday	2.998	2.998	65.407	37.216	102.623	49.285	36.221	85.506	191.128
10/30/2015	Friday	2.958	2.958	53.997	31.704	85.701	43.959	36.625	80.584	169.243
11/14/2015	Saturday	0.840	0.840	40.127	38.901	79.028	3.015	4.898	7.913	87.781
11/15/2015	Sunday	0.000	0.000	39.923	38.705	78.628	0.000	0.000	0.000	78.628
11/16/2015	Monday	3.602	3.602	64.331	38.488	102.820	37.342	21.288	58.630	165.052
11/17/2015	Tuesday	2.112	2.112	64.974	38.160	103.135	43.452	17.406	60.858	166.104
11/18/2015	Wednesday	2.128	2.128	61.351	37.694	99.046	38.058	18.227	56.285	157.459
11/19/2015	Thursday	2.611	2.611	73.142	38.284	111.426	42.995	24.990	67.985	182.022
11/20/2015	Friday	2.925	2.925	68.671	38.578	107.249	36.818	21.282	58.100	168.274
11/21/2015	Saturday	5.403	5.403	38.602	38.877	77.479	22.378	32.993	55.371	138.253
11/22/2015	Sunday	7.248	7.248	39.507	38.834	78.342	22.690	36.414	59.104	144.694
11/23/2015	Monday	5.779	5.779	78.234	38.433	116.667	50.417	28.819	79.236	201.682
11/24/2015	Tuesday	3.602	3.602	72.320	38.565	110.886	46.579	27.234	73.813	188.301
11/25/2015	Wednesday	2.860	2.860	72.405	38.298	110.702	43.863	25.905	69.767	183.330
11/26/2015	Thursday	0.000	0.000	35.562	38.468	74.031	0.000	0.000	0.000	74.031
11/27/2015	Friday	4.016	4.016	40.581	39.025	79.605	20.758	33.824	54.582	138.204
12/12/2015	Saturday	0.000	0.000	35.188	38.954	74.143	2.613	3.363	5.976	80.119
12/13/2015	Sunday	0.000	0.000	33.217	38.373	71.590	0.000	0.000	0.000	71.590
12/14/2015	Monday	3.184	3.184	72.332	38.106	110.438	36.586	19.685	56.271	169.893
12/15/2015	Tuesday	2.309	2.309	68.756	38.789	107.546	38.477	22.725	61.201	171.057
12/16/2015	Wednesday	2.395	2.395	70.409	38.441	108.850	40.680	27.106	67.786	179.031
12/17/2015	Thursday	2.727	2.727	78.306	39.022	117.328	49.799	30.488	80.286	200.342
12/18/2015	Friday	3.287	3.287	73.740	39.314	113.054	46.574	30.939	77.513	193.854
12/19/2015	Saturday	5.262	5.262	38.890	40.130	79.020	22.291	37.896	60.187	144.469
12/20/2015	Sunday	5.047	5.047	40.385	39.222	79.608	22.599	37.157	59.756	144.411
12/21/2015	Monday	4.598	4.598	82.912	38.595	121.507	51.359	25.311	76.670	202.776
12/22/2015	Tuesday	2.868	2.868	76.482	38.750	115.232	48.895	30.399	79.294	197.394
12/23/2015	Wednesday	2.447	2.447	76.863	37.911	114.774	45.977	26.746	72.723	189.944
12/24/2015	Thursday	2.427	2.427	75.576	38.875	114.451	0.000	0.000	0.000	116.878
12/25/2015	Friday	2.763	2.763	37.343	39.799	77.142	0.000	0.000	0.000	79.905
							*RTU-4 tripped due to hi-static alarm			
1/9/2016	Saturday	7.070	7.070	89.478	39.238	128.716	0.000	0.000	0.000	135.786
1/10/2016	Sunday	7.209	7.209	88.910	39.633	128.543	0.000	0.000	0.000	135.752
1/11/2016	Monday	3.449	3.449	56.773	23.001	79.774	0.000	0.000	0.000	83.222
1/12/2016	Tuesday	2.462	2.462	58.157	23.300	81.457	0.000	0.000	0.000	83.918
1/13/2016	Wednesday	2.651	2.651	62.612	23.019	85.631	0.000	0.000	0.000	88.282
1/14/2016	Thursday	2.549	2.549	70.558	26.012	96.570	0.000	0.000	0.000	99.119
1/15/2016	Friday	4.397	4.397	80.604	31.944	112.548	52.228	22.517	74.745	191.690
1/16/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/17/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/18/2016	Monday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/19/2016	Tuesday	3.503	3.503	66.727	23.623	90.350	7.284	1.661	8.945	102.798
1/20/2016	Wednesday	3.184	3.184	63.926	23.288	87.214	0.000	0.000	0.000	90.399
1/21/2016	Thursday	3.003	3.003	67.983	26.984	94.967	0.000	0.000	0.000	97.970
1/22/2016	Friday	3.242	3.242	58.937	23.190	82.127	0.000	0.000	0.000	85.369

Muscatine Armed Forces Reserve Center – Fixed Static Pressure (Continued)

Fixed Static Pressure										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
2/6/2016	Saturday	6.748	6.748	99.417	39.250	138.667	73.119	37.517	110.637	256.052
2/7/2016	Sunday	6.662	6.662	90.604	38.391	128.995	66.836	36.708	103.544	239.201
2/8/2016	Monday	3.269	3.269	47.802	19.658	67.460	35.340	18.814	54.153	124.882
2/9/2016	Tuesday	2.014	2.014	49.666	19.786	69.452	40.140	18.886	59.026	130.492
2/10/2016	Wednesday	1.798	1.798	51.238	19.871	71.109	42.900	18.779	61.679	134.586
2/11/2016	Thursday	1.922	1.922	58.794	23.704	82.498	48.710	23.018	71.728	156.147
2/12/2016	Friday	1.962	1.962	49.552	19.915	69.466	40.052	19.022	59.074	130.503
2/13/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2/14/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2/15/2016	Monday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2/16/2016	Tuesday	2.553	2.553	59.181	19.563	78.743	47.153	18.549	65.703	146.999
2/17/2016	Wednesday	1.991	1.991	56.019	19.743	75.762	44.168	18.688	62.855	140.608
2/18/2016	Thursday	2.194	2.194	65.596	23.195	88.791	50.647	22.562	73.209	164.194
2/19/2016	Friday	1.738	1.738	62.548	19.052	81.601	37.402	18.217	55.619	138.958
3/5/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/6/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/7/2016	Monday	3.395	3.395	55.341	19.136	74.476	38.718	18.294	57.012	134.884
3/8/2016	Tuesday	1.721	1.721	51.223	18.957	70.179	36.216	18.144	54.360	126.260
3/9/2016	Wednesday	1.439	1.439	46.583	19.259	65.842	32.580	13.980	46.560	113.842
3/10/2016	Thursday	1.541	1.541	55.986	22.995	78.981	42.943	22.428	65.371	145.893
3/11/2016	Friday	1.738	1.738	48.818	19.750	68.567	34.751	18.835	53.586	123.892
3/12/2016	Saturday	6.793	6.793	87.434	39.076	126.509	72.473	36.822	109.294	242.597
3/13/2016	Sunday	6.078	6.078	77.051	36.708	113.760	73.536	34.540	108.075	227.913
3/14/2016	Monday	2.700	2.700	44.042	19.183	63.225	36.685	18.261	54.946	120.870
3/15/2016	Tuesday	1.440	1.440	41.978	19.034	61.012	36.714	18.179	54.893	117.345
3/16/2016	Wednesday	1.544	1.544	51.098	21.057	72.155	39.799	19.913	59.713	133.412
3/17/2016	Thursday	6.205	6.205	86.612	38.533	125.145	67.029	36.718	103.746	235.096
3/18/2016	Friday	6.025	6.025	79.395	38.794	118.189	61.272	36.727	97.999	222.212
4/2/2016	Saturday	6.319	6.319	89.332	38.965	128.297	64.456	36.773	101.229	235.845
4/3/2016	Sunday	6.538	6.538	87.795	38.080	125.875	63.756	36.173	99.928	232.341
4/4/2016	Monday	2.394	2.394	41.204	19.426	60.630	30.416	18.474	48.890	111.914
4/5/2016	Tuesday	1.608	1.608	47.223	19.582	66.805	33.749	18.507	52.256	120.668
4/6/2016	Wednesday	1.472	1.472	47.763	19.025	66.787	32.049	18.017	50.066	118.325
4/7/2016	Thursday	1.611	1.611	56.581	22.711	79.293	39.679	22.363	62.042	142.945
4/8/2016	Friday	1.745	1.745	49.520	19.574	69.095	33.191	18.706	51.897	122.736
4/9/2016	Saturday	6.096	6.096	89.099	38.808	127.907	64.419	37.006	101.425	235.428
4/10/2016	Sunday	6.143	6.143	86.205	37.955	124.159	61.400	35.988	97.388	227.691
4/11/2016	Monday	2.598	2.598	42.965	19.311	62.276	30.671	18.468	49.140	114.014
4/12/2016	Tuesday	1.502	1.502	44.703	19.493	64.196	32.077	18.478	50.555	116.253
4/13/2016	Wednesday	1.529	1.529	46.836	19.388	66.224	32.309	18.250	50.559	118.313
4/14/2016	Thursday	1.439	1.439	51.920	23.068	74.988	36.998	22.264	59.263	135.689
4/15/2016	Friday	1.475	1.475	41.103	19.279	60.382	30.134	18.208	48.342	110.199
4/30/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.282	0.000	0.282	0.282
5/1/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.272	0.000	0.272	0.272
5/2/2016	Monday	2.252	2.252	52.706	19.201	71.907	32.993	18.388	51.381	125.540
5/3/2016	Tuesday	1.495	1.495	46.315	19.086	65.401	31.070	18.397	49.467	116.363
5/4/2016	Wednesday	1.482	1.482	47.389	19.032	66.420	29.809	18.240	48.049	115.951
5/5/2016	Thursday	1.355	1.355	53.630	23.048	76.678	37.351	22.350	59.701	137.734
5/6/2016	Friday	6.546	6.546	83.857	37.815	121.672	59.640	36.141	95.780	223.999

Muscatine Armed Forces Reserve Center – Fixed Static Pressure (Continued)

Fixed Static Pressure										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
5/7/2016	Saturday	7.175	7.175	81.195	37.845	119.040	61.042	36.116	97.159	223.374
5/8/2016	Sunday	6.014	6.014	83.653	37.968	121.620	60.398	36.165	96.563	224.198
5/9/2016	Monday	2.743	2.743	39.889	19.086	58.975	31.170	18.151	49.321	111.039
5/10/2016	Tuesday	1.559	1.559	38.543	18.972	57.515	31.651	16.091	47.742	106.816
5/11/2016	Wednesday	1.510	1.510	41.047	19.033	60.080	31.955	18.196	50.151	111.740
5/12/2016	Thursday	1.570	1.570	55.685	22.581	78.265	39.185	22.284	61.469	141.304
5/13/2016	Friday	1.602	1.602	43.775	19.327	63.102	30.055	18.600	48.655	113.359

Muscatine Armed Forces Reserve Center – Tiered Trim and Respond

Tiered Trim and Respond										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
7/11/2015	Saturday	6.340	6.340	30.947	37.684	68.631	34.435	37.008	71.443	146.414
7/12/2015	Sunday	6.431	6.431	30.334	37.019	67.353	33.820	36.601	70.421	144.205
7/13/2015	Monday	2.559	2.559	17.621	18.900	36.521	30.390	36.151	66.540	105.621
7/14/2015	Tuesday	1.265	1.265	10.372	19.076	29.448	28.852	36.263	65.115	95.828
7/15/2015	Wednesday	3.924	3.924	16.543	19.425	35.969	25.463	36.877	62.339	102.232
7/16/2015	Thursday	2.361	2.361	18.208	22.895	41.102	27.663	34.587	62.251	105.714
7/17/2015	Friday	1.650	1.650	16.453	19.634	36.087	25.825	34.012	59.837	97.575
							*Incorrect TTR operation			
7/18/2015	Saturday	3.360	3.360	8.135	37.264	45.399	15.319	36.376	51.695	100.454
7/19/2015	Sunday	3.398	3.398	8.910	37.122	46.032	15.762	36.547	52.309	101.738
7/20/2015	Monday	2.710	2.710	18.553	19.200	37.753	30.755	36.373	67.128	107.591
7/21/2015	Tuesday	1.800	1.800	18.905	19.350	38.255	31.098	36.553	67.651	107.706
7/22/2015	Wednesday	2.254	2.254	20.081	19.526	39.606	29.702	36.623	66.325	108.185
7/23/2015	Thursday	1.986	1.986	21.660	22.831	44.491	28.730	36.592	65.322	111.799
7/24/2015	Friday	1.972	1.972	16.014	19.229	35.243	26.752	36.474	63.226	100.441
							*Incorrect TTR operation			
8/8/2015	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8/9/2015	Sunday	0.000	0.000	2.082	2.956	5.038	1.005	0.000	1.005	6.043
8/10/2015	Monday	2.821	2.821	20.320	21.415	41.735	21.939	0.000	21.939	66.494
8/11/2015	Tuesday	2.448	2.448	19.559	19.372	38.931	13.998	0.000	13.998	55.378
8/12/2015	Wednesday	3.190	3.190	20.103	19.415	39.518	13.636	0.000	13.636	56.344
8/13/2015	Thursday	1.980	1.980	23.023	22.843	45.865	15.694	0.000	15.694	63.540
8/14/2015	Friday	1.675	1.675	19.570	19.353	38.922	13.731	0.000	13.731	54.327
8/15/2015	Saturday	0.000	0.000	0.000	0.000	0.000	3.361	0.000	3.361	3.361
8/16/2015	Sunday	0.000	0.000	0.000	0.000	0.000	3.455	0.000	3.455	3.455
8/17/2015	Monday	2.852	2.852	20.175	19.340	39.515	21.766	0.000	21.766	64.133
8/18/2015	Tuesday	1.648	1.648	17.828	19.303	37.131	13.972	0.000	13.972	52.751
8/19/2015	Wednesday	3.346	3.346	22.566	19.069	41.634	14.606	0.000	14.606	59.586
8/20/2015	Thursday	1.862	1.862	22.474	22.932	45.406	19.999	0.000	19.999	67.266
8/21/2015	Friday	2.446	2.446	17.015	19.368	36.383	17.108	0.000	17.108	55.936
9/5/2015	Saturday	6.866	6.866	37.839	37.089	74.929	26.471	0.000	26.471	108.266
9/6/2015	Sunday	0.000	0.000	0.000	0.000	0.000	3.963	0.000	3.963	3.963
9/7/2015	Monday	4.343	4.343	19.399	19.279	38.677	21.126	0.000	21.126	64.147
9/8/2015	Tuesday	3.329	3.329	18.434	19.221	37.655	18.965	0.000	18.965	59.948
9/9/2015	Wednesday	2.643	2.643	17.972	19.403	37.375	14.351	0.000	14.351	54.369
9/10/2015	Thursday	2.862	2.862	21.994	22.704	44.698	15.902	25.195	41.096	88.657
9/11/2015	Friday	1.588	1.588	22.569	19.890	42.459	15.450	36.876	52.326	96.374
9/12/2015	Saturday	5.338	5.338	39.867	38.295	78.163	21.728	36.891	58.618	142.119
9/13/2015	Sunday	5.573	5.573	38.020	38.006	76.025	21.905	36.651	58.556	140.155
9/14/2015	Monday	2.671	2.671	21.148	19.411	40.560	16.077	36.458	52.535	95.765
9/15/2015	Tuesday	1.859	1.859	20.105	19.359	39.464	14.954	36.489	51.443	92.767
9/16/2015	Wednesday	2.338	2.338	18.834	19.368	38.202	14.774	36.490	51.264	91.804
9/17/2015	Thursday	3.721	3.721	20.471	22.728	43.199	16.494	35.419	51.913	98.833
9/18/2015	Friday	2.753	2.753	17.544	19.408	36.952	14.513	32.499	47.013	86.717

Muscatine Armed Forces Reserve Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
10/3/2015	Saturday	5.273	5.273	46.227	38.406	84.633	21.090	36.460	57.550	147.456
10/4/2015	Sunday	5.312	5.312	40.542	38.126	78.668	19.466	36.593	56.059	140.039
10/5/2015	Monday	2.344	2.344	22.259	19.725	41.984	14.435	36.701	51.136	95.464
10/6/2015	Tuesday	1.631	1.631	22.613	19.616	42.229	15.759	36.674	52.432	96.292
10/7/2015	Wednesday	2.035	2.035	22.032	19.491	41.523	14.115	36.599	50.714	94.272
10/8/2015	Thursday	1.627	1.627	24.460	22.962	47.421	15.415	36.274	51.689	100.737
10/9/2015	Friday	1.563	1.563	26.479	19.681	46.161	14.990	36.280	51.270	98.994
10/10/2015	Saturday	0.000	0.000	0.000	0.000	0.000	4.363	36.206	40.569	40.569
10/11/2015	Sunday	0.000	0.000	0.000	0.000	0.000	4.028	35.936	39.964	39.964
10/12/2015	Monday	0.969	0.969	0.000	0.000	0.000	4.146	35.825	39.971	40.941
10/13/2015	Tuesday	1.493	1.493	28.567	26.415	54.982	15.453	36.011	51.464	107.939
10/14/2015	Wednesday	1.664	1.664	28.432	31.450	59.882	15.478	36.306	51.784	113.330
10/15/2015	Thursday	0.000	0.000	43.817	38.007	81.824	5.381	36.439	41.820	123.644
10/16/2015	Friday	1.527	1.527	22.329	20.074	42.403	13.389	36.309	49.698	93.628
10/31/2015	Saturday	0.000	0.000	18.247	38.014	56.261	4.645	35.692	40.337	96.598
11/1/2015	Sunday	1.107	1.107	11.801	14.832	26.633	3.145	36.208	39.353	67.092
11/2/2015	Monday	3.223	3.223	32.558	22.029	54.587	17.437	36.071	53.508	111.319
11/3/2015	Tuesday	1.893	1.893	24.538	19.573	44.111	14.168	36.450	50.618	96.622
11/4/2015	Wednesday	1.611	1.611	25.084	19.561	44.645	13.920	36.331	50.251	96.508
11/5/2015	Thursday	1.765	1.765	24.890	23.247	48.137	14.892	35.747	50.639	100.540
11/6/2015	Friday	1.608	1.608	22.200	20.036	42.236	12.972	30.872	43.844	87.688
11/7/2015	Saturday	5.131	5.131	44.462	38.861	83.323	21.305	36.645	57.950	146.404
11/8/2015	Sunday	5.347	5.347	36.749	38.908	75.657	21.925	36.412	58.337	139.341
11/9/2015	Monday	2.501	2.501	27.109	38.825	65.935	13.215	21.508	34.723	103.159
11/10/2015	Tuesday	2.014	2.014	30.590	38.567	69.157	15.640	21.466	37.105	108.276
11/11/2015	Wednesday	0.000	0.000	10.578	38.007	48.584	0.000	0.000	0.000	48.584
11/12/2015	Thursday	2.084	2.084	38.264	38.258	76.523	16.951	25.149	42.099	120.706
11/13/2015	Friday	1.858	1.858	32.296	38.943	71.239	14.719	21.530	36.249	109.346
11/28/2015	Saturday	4.593	4.593	33.942	39.211	73.153	6.126	36.947	43.073	120.819
11/29/2015	Sunday	4.275	4.275	36.291	39.178	75.469	6.888	36.723	43.611	123.355
11/30/2015	Monday	4.844	4.844	64.569	38.553	103.122	37.743	29.892	67.635	175.600
12/1/2015	Tuesday	2.769	2.769	52.375	38.183	90.558	31.219	28.065	59.284	152.611
12/2/2015	Wednesday	2.980	2.980	48.534	38.339	86.873	27.055	29.788	56.843	146.696
12/3/2015	Thursday	2.958	2.958	51.766	38.848	90.615	31.240	31.337	62.577	156.150
12/4/2015	Friday	3.105	3.105	42.563	39.026	81.589	24.468	25.647	50.115	134.809
12/5/2015	Saturday	5.804	5.804	49.665	38.910	88.575	40.706	36.995	77.701	172.080
12/6/2015	Sunday	5.356	5.356	50.833	38.676	89.509	29.422	36.389	65.811	160.676
12/7/2015	Monday	2.549	2.549	30.698	38.591	69.288	17.487	21.432	38.920	110.758
12/8/2015	Tuesday	2.333	2.333	38.922	38.185	77.107	22.264	26.545	48.810	128.249
12/9/2015	Wednesday	2.149	2.149	36.087	38.233	74.321	19.035	24.370	43.405	119.874
12/10/2015	Thursday	1.833	1.833	39.878	38.485	78.362	20.721	25.564	46.285	126.480
12/11/2015	Friday	1.799	1.799	33.453	38.785	72.237	17.728	21.605	39.333	113.369

Muscatine Armed Forces Reserve Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
12/26/2015	Saturday	3.821	3.821	33.655	39.595	73.249	0.000	0.000	0.000	77.071
12/27/2015	Sunday	3.955	3.955	35.157	39.938	75.095	0.000	0.000	0.000	79.050
12/28/2015	Monday	5.505	5.505	63.842	39.215	103.057	0.000	0.000	0.000	108.563
12/29/2015	Tuesday	2.900	2.900	46.736	39.392	86.127	0.000	0.000	0.000	89.028
12/30/2015	Wednesday	3.120	3.120	51.597	39.687	91.284	0.000	0.000	0.000	94.404
12/31/2015	Thursday	2.781	2.781	53.660	39.755	93.416	0.000	0.000	0.000	96.197
1/1/2016	Friday	3.600	3.600	33.589	39.612	73.201	0.000	0.000	0.000	76.801
							RTU-4 shut down for most of week			
1/2/2016	Saturday	4.151	4.151	34.150	39.927	74.077	0.000	0.000	0.000	78.228
1/3/2016	Sunday	3.727	3.727	36.299	40.145	76.444	0.000	0.000	0.000	80.171
1/4/2016	Monday	4.840	4.840	72.166	40.126	112.292	0.000	0.000	0.000	117.132
1/5/2016	Tuesday	3.505	3.505	60.801	39.972	100.773	0.000	0.000	0.000	104.278
1/6/2016	Wednesday	2.354	2.354	55.045	39.590	94.636	0.000	0.000	0.000	96.990
1/7/2016	Thursday	2.614	2.614	56.638	39.096	95.734	0.000	0.000	0.000	98.348
1/8/2016	Friday	5.306	5.306	56.887	38.627	95.514	0.000	0.000	0.000	100.819
1/23/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/24/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/25/2016	Monday	4.350	4.350	63.110	22.655	85.765	0.000	0.000	0.000	90.115
1/26/2016	Tuesday	2.396	2.396	55.513	23.053	78.565	0.000	0.000	0.000	80.961
1/27/2016	Wednesday	2.441	2.441	48.333	22.908	71.241	0.000	0.000	0.000	73.682
1/28/2016	Thursday	2.491	2.491	48.507	26.205	74.712	0.000	0.000	0.000	77.202
1/29/2016	Friday	2.292	2.292	42.052	22.721	64.773	0.000	0.000	0.000	67.066
1/30/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1/31/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2/1/2016	Monday	3.372	3.372	54.288	22.883	77.171	0.000	0.000	0.000	80.544
2/2/2016	Tuesday	3.026	3.026	46.330	22.721	69.052	0.000	0.000	0.000	72.078
2/3/2016	Wednesday	2.426	2.426	38.329	22.854	61.183	27.533	13.357	40.890	104.499
2/4/2016	Thursday	1.560	1.560	49.194	23.593	72.787	41.551	23.131	64.682	139.029
2/5/2016	Friday	1.608	1.608	37.333	20.261	57.594	30.543	19.224	49.767	108.969
2/20/2016	Saturday	5.547	5.547	55.262	38.601	93.863	33.125	36.865	69.990	169.400
2/21/2016	Sunday	5.114	5.114	43.013	38.857	81.871	29.499	36.942	66.440	153.425
2/22/2016	Monday	2.133	2.133	25.428	19.561	44.989	17.707	18.685	36.392	83.514
2/23/2016	Tuesday	1.403	1.403	28.527	19.513	48.040	20.166	18.557	38.724	88.167
2/24/2016	Wednesday	1.446	1.446	32.559	19.316	51.875	22.481	18.378	40.860	94.181
2/25/2016	Thursday	1.451	1.451	38.365	23.450	61.814	28.812	22.884	51.696	114.961
2/26/2016	Friday	6.043	6.043	53.661	39.156	92.818	40.566	37.289	77.854	176.715
2/27/2016	Saturday	5.579	5.579	48.515	38.358	86.873	32.543	36.523	69.066	161.518
2/28/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.716
2/29/2016	Monday	2.196	2.196	36.633	19.302	55.935	19.474	18.473	37.947	96.078
3/1/2016	Tuesday	1.989	1.989	44.771	19.108	63.879	21.297	18.284	39.581	105.449
3/2/2016	Wednesday	2.118	2.118	47.550	19.699	67.249	25.427	18.552	43.978	113.345
3/3/2016	Thursday	2.188	2.188	56.534	23.229	79.763	30.805	22.614	53.419	135.371
3/4/2016	Friday	2.239	2.239	48.634	19.593	68.227	25.990	18.591	44.581	115.046

Muscatine Armed Forces Reserve Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond										
Date		RTU-1 Supply Fan	RTU-1	RTU-3 Supply Fan	RTU-3 Exhaust Fan	RTU-3	RTU-4 Supply Fan	RTU-4 Exhaust Fan	RTU-4	Total Fan Energy
mm/dd/yy	day	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
3/19/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/20/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/21/2016	Monday	2.472	2.472	35.943	19.585	55.528	22.585	18.658	41.243	99.243
3/22/2016	Tuesday	1.249	1.249	35.529	19.085	54.614	19.424	18.299	37.723	93.585
3/23/2016	Wednesday	1.192	1.192	26.898	19.196	46.094	18.227	17.880	36.107	83.393
3/24/2016	Thursday	1.602	1.602	34.496	22.690	57.186	26.302	22.206	48.507	107.295
3/25/2016	Friday	1.487	1.487	29.372	19.514	48.886	20.877	18.378	39.256	89.628
3/26/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/27/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/28/2016	Monday	2.045	2.045	39.527	19.489	59.016	23.574	18.575	42.149	103.210
3/29/2016	Tuesday	1.266	1.266	34.117	19.429	53.546	19.003	18.545	37.547	92.360
3/30/2016	Wednesday	1.283	1.283	29.310	19.086	48.396	16.661	18.007	34.668	84.348
3/31/2016	Thursday	1.301	1.301	28.512	22.956	51.467	16.734	22.270	39.004	91.772
4/1/2016	Friday	4.960	4.960	48.272	38.811	87.083	37.408	36.686	74.094	166.138
4/16/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4/17/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4/18/2016	Monday	2.121	2.121	22.270	19.372	41.642	14.449	18.375	32.824	76.587
4/19/2016	Tuesday	1.309	1.309	20.002	19.376	39.378	13.354	18.423	31.778	72.465
4/20/2016	Wednesday	1.126	1.126	20.123	19.312	39.436	13.156	15.605	28.761	69.323
4/21/2016	Thursday	1.143	1.143	24.538	22.794	47.332	14.586	20.369	34.955	83.430
4/22/2016	Friday	1.165	1.165	24.578	19.340	43.918	14.364	18.445	32.810	77.893
4/23/2016	Saturday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4/24/2016	Sunday	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4/25/2016	Monday	2.312	2.312	23.280	18.943	42.223	14.930	18.039	32.969	77.504
4/26/2016	Tuesday	1.214	1.214	25.558	19.019	44.577	16.220	18.290	34.510	80.301
4/27/2016	Wednesday	1.130	1.130	23.043	19.009	42.052	12.060	17.657	29.717	72.899
4/28/2016	Thursday	1.133	1.133	29.535	22.668	52.204	14.409	22.143	36.553	89.890
4/29/2016	Friday	1.106	1.106	22.391	19.358	41.750	11.626	18.477	30.102	72.957
5/14/2016	Saturday	5.141	5.141	54.930	38.387	93.316	21.843	36.921	58.764	157.221
5/15/2016	Sunday	4.785	4.785	42.039	38.106	80.145	21.342	36.405	57.747	142.678
5/16/2016	Monday	1.905	1.905	21.048	19.141	40.189	11.880	18.253	30.132	72.227
5/17/2016	Tuesday	1.096	1.096	21.623	19.331	40.953	11.673	18.377	30.050	72.100
5/18/2016	Wednesday	1.122	1.122	22.562	19.321	41.884	11.149	18.300	29.449	72.454
5/19/2016	Thursday	1.228	1.228	23.812	22.837	46.649	13.241	22.196	35.438	83.315
5/20/2016	Friday	1.257	1.257	20.591	19.208	39.799	12.098	18.321	30.418	71.474

Waterloo Readiness Center – Fixed Static Pressure

Fixed Static Pressure				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
7/5/2015	Sunday	26.231	28.501	54.733
7/6/2015	Monday	28.235	30.041	58.276
7/7/2015	Tuesday	20.006	23.461	43.467
7/8/2015	Wednesday	20.157	23.701	43.858
7/9/2015	Thursday	21.271	24.425	45.696
7/10/2015	Friday	23.892	8.167	32.058
7/11/2015	Saturday	31.447	0.000	31.447
7/12/2015	Sunday	36.421	0.000	36.421
7/13/2015	Monday	46.492	0.000	46.492
7/14/2015	Tuesday	53.665	0.000	53.665
7/15/2015	Wednesday	44.520	0.000	44.520

8/2/2015	Sunday	44.621	0.000	44.621
8/3/2015	Monday	43.408	0.000	43.408
8/4/2015	Tuesday	43.024	0.000	43.024
8/5/2015	Wednesday	42.629	0.000	42.629
8/6/2015	Thursday	42.151	0.000	42.151
8/7/2015	Friday	41.242	0.000	41.242
8/8/2015	Saturday	40.365	0.000	40.365

8/9/2015	Sunday	40.832	0.000	40.832
8/10/2015	Monday	40.650	0.000	40.650
8/11/2015	Tuesday	38.680	0.000	38.680
8/12/2015	Wednesday	40.444	0.000	40.444
8/13/2015	Thursday	39.266	0.000	39.266
8/14/2015	Friday	44.876	0.000	44.876
8/15/2015	Saturday	41.288	0.000	41.288

8/30/2015	Sunday	25.375	27.449	52.824
8/31/2015	Monday	27.975	29.595	57.571
9/1/2015	Tuesday	34.814	20.885	55.700
9/2/2015	Wednesday	40.487	0.000	40.487
9/3/2015	Thursday	44.296	0.000	44.296
9/4/2015	Friday	46.414	0.000	46.414
9/5/2015	Saturday	45.580	0.000	45.580

Waterloo Readiness Center – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
9/6/2015	Sunday	48.169	0.000	48.169
9/7/2015	Monday	42.170	0.000	42.170
9/8/2015	Tuesday	39.874	0.000	39.874
9/9/2015	Wednesday	35.001	0.000	35.001
9/10/2015	Thursday	34.004	0.000	34.004
9/11/2015	Friday	38.755	0.000	38.755
9/12/2015	Saturday	33.607	0.000	33.607
9/27/2015	Sunday	34.315	0.000	34.315
9/28/2015	Monday	35.832	0.000	35.832
9/29/2015	Tuesday	34.045	0.000	34.045
9/30/2015	Wednesday	35.861	0.000	35.861
10/1/2015	Thursday	35.925	0.000	35.925
10/2/2015	Friday	41.687	0.000	41.687
10/3/2015	Saturday	38.677	0.000	38.677
10/4/2015	Sunday	39.888	0.000	39.888
10/5/2015	Monday	37.821	0.000	37.821
10/6/2015	Tuesday	37.306	0.000	37.306
10/7/2015	Wednesday	35.903	0.000	35.903
10/8/2015	Thursday	37.105	0.000	37.105
10/9/2015	Friday	37.117	0.000	37.117
10/10/2015	Saturday	36.071	0.000	36.071
10/25/2015	Sunday	36.722	0.000	36.722
10/26/2015	Monday	38.029	0.000	38.029
10/27/2015	Tuesday	39.991	0.000	39.991
10/28/2015	Wednesday	37.571	0.000	37.571
10/29/2015	Thursday	36.824	0.000	36.824
10/30/2015	Friday	36.033	0.000	36.033
10/31/2015	Saturday	37.586	0.000	37.586
11/1/2015	Sunday	35.409	0.000	35.409
11/2/2015	Monday	32.794	0.000	32.794
11/3/2015	Tuesday	38.108	0.000	38.108
11/4/2015	Wednesday	38.802	0.000	38.802
11/5/2015	Thursday	36.785	0.000	36.785
11/6/2015	Friday	37.356	0.000	37.356
11/7/2015	Saturday	34.000	0.000	34.000

Waterloo Readiness Center – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
11/22/2015	Sunday	33.561	0.000	33.561
11/23/2015	Monday	34.649	0.000	34.649
11/24/2015	Tuesday	43.128	0.000	43.128
11/25/2015	Wednesday	41.058	0.000	41.058
11/26/2015	Thursday	40.939	0.000	40.939
11/27/2015	Friday	38.286	0.000	38.286
11/28/2015	Saturday	44.072	0.000	44.072
11/29/2015	Sunday	45.572	0.000	45.572
11/30/2015	Monday	-	-	-
12/1/2015	Tuesday	37.686	0.000	37.686
12/2/2015	Wednesday	40.583	0.000	40.583
12/3/2015	Thursday	41.447	0.000	41.447
12/4/2015	Friday	38.774	0.000	38.774
12/5/2015	Saturday	36.008	0.000	36.008
12/20/2015	Sunday	39.679	0.000	39.679
12/21/2015	Monday	39.995	0.000	39.995
12/22/2015	Tuesday	38.410	0.000	38.410
12/23/2015	Wednesday	40.882	0.000	40.882
12/24/2015	Thursday	38.944	0.000	38.944
12/25/2015	Friday	37.401	0.000	37.401
12/26/2015	Saturday	41.170	0.000	41.170
12/27/2015	Sunday	41.027	0.000	41.027
12/28/2015	Monday	39.220	0.000	39.220
12/29/2015	Tuesday	40.660	0.000	40.660
12/30/2015	Wednesday	38.740	0.000	38.740
12/31/2015	Thursday	39.919	0.000	39.919
1/1/2016	Friday	41.619	0.000	41.619
1/2/2016	Saturday	41.195	0.000	41.195
1/17/2016	Sunday	3.079	0.294	3.374
1/18/2016	Monday	0.087	0.246	0.332
1/19/2016	Tuesday	0.106	0.247	0.353
1/20/2016	Wednesday	21.880	8.853	30.733
1/21/2016	Thursday	39.582	1.573	41.155
1/22/2016	Friday	41.885	0.000	41.885
1/23/2016	Saturday	42.710	0.000	42.710

Waterloo Readiness Center – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
1/24/2016	Sunday	42.304	0.000	42.304
1/25/2016	Monday	42.519	0.000	42.519
1/26/2016	Tuesday	42.968	0.000	42.968
1/27/2016	Wednesday	40.767	0.000	40.767
1/28/2016	Thursday	40.961	0.000	40.961
1/29/2016	Friday	41.869	0.000	41.869
1/30/2016	Saturday	42.471	0.000	42.471
2/14/2016	Sunday	50.271	0.000	50.271
2/15/2016	Monday	44.525	0.000	44.525
2/16/2016	Tuesday	40.784	0.000	40.784
2/17/2016	Wednesday	33.747	0.000	33.747
2/18/2016	Thursday	37.436	0.000	37.436
2/19/2016	Friday	40.729	0.000	40.729
2/20/2016	Saturday	38.025	0.000	38.025
2/21/2016	Sunday	37.210	0.000	37.210
2/22/2016	Monday	37.758	5.465	43.222
2/23/2016	Tuesday	39.493	0.000	39.493
2/24/2016	Wednesday	38.030	0.000	38.030
2/25/2016	Thursday	39.286	0.000	39.286
2/26/2016	Friday	42.498	0.000	42.498
2/27/2016	Saturday	37.935	0.000	37.935
3/13/2016	Sunday	30.522	32.414	62.936
3/14/2016	Monday	32.347	9.283	41.630
3/15/2016	Tuesday	36.087	0.000	36.087
3/16/2016	Wednesday	35.135	0.000	35.135
3/17/2016	Thursday	37.711	0.000	37.711
3/18/2016	Friday	42.103	0.000	42.103
3/19/2016	Saturday	41.375	0.000	41.375
3/20/2016	Sunday	41.462	0.000	41.462
3/21/2016	Monday	39.928	0.000	39.928
3/22/2016	Tuesday	37.629	0.000	37.629
3/23/2016	Wednesday	39.957	0.000	39.957
3/24/2016	Thursday	42.805	0.000	42.805
3/25/2016	Friday	41.802	0.000	41.802
3/26/2016	Saturday	42.114	0.000	42.114

Waterloo Readiness Center – Fixed Static Pressure (Continued)

Fixed Static Pressure				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
4/10/2016	Sunday	40.059	0.000	40.059
4/11/2016	Monday	39.767	0.000	39.767
4/12/2016	Tuesday	38.053	0.000	38.053
4/13/2016	Wednesday	34.750	0.000	34.750
4/14/2016	Thursday	30.845	0.000	30.845
4/15/2016	Friday	30.145	0.000	30.145
4/16/2016	Saturday	29.833	0.000	29.833
4/17/2016	Sunday	32.839	0.000	32.839
4/18/2016	Monday	32.214	0.000	32.214
4/19/2016	Tuesday	33.644	0.000	33.644
4/20/2016	Wednesday	32.780	0.000	32.780
4/21/2016	Thursday	31.606	0.000	31.606
4/22/2016	Friday	33.114	0.000	33.114
4/23/2016	Saturday	32.463	0.000	32.463

Waterloo Readiness Center – Tiered Trim and Respond

Tiered Trim and Respond				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
7/16/2015	Thursday	26.778	0.000	26.778
7/17/2015	Friday	32.670	0.000	32.670
7/18/2015	Saturday	49.854	0.000	49.854
7/19/2015	Sunday	39.088	0.000	39.088
7/20/2015	Monday	30.591	0.000	30.591
7/21/2015	Tuesday	26.098	0.000	26.098
7/22/2015	Wednesday	25.481	0.000	25.481
7/23/2015	Thursday	28.164	0.000	28.164
7/24/2015	Friday	19.154	0.000	19.154
7/25/2015	Saturday	25.347	0.000	25.347
7/26/2015	Sunday	25.081	0.000	25.081
7/27/2015	Monday	36.775	0.000	36.775
7/28/2015	Tuesday	29.694	0.000	29.694
7/29/2015	Wednesday	26.650	0.000	26.650
7/30/2015	Thursday	31.002	0.000	31.002
7/31/2015	Friday	31.946	0.000	31.946
8/1/2015	Saturday	29.992	0.000	29.992
8/16/2015	Sunday	25.220	0.000	25.220
8/17/2015	Monday	24.973	0.000	24.973
8/18/2015	Tuesday	19.426	0.000	19.426
8/19/2015	Wednesday	25.084	0.000	25.084
8/20/2015	Thursday	21.197	0.000	21.197
8/21/2015	Friday	19.842	0.000	19.842
8/22/2015	Saturday	21.978	0.000	21.978
8/23/2015	Sunday	19.097	0.000	19.097
8/24/2015	Monday	12.282	3.874	16.157
8/25/2015	Tuesday	10.848	10.665	21.513
8/26/2015	Wednesday	11.432	11.238	22.670
8/27/2015	Thursday	11.482	11.359	22.841
8/28/2015	Friday	14.943	14.858	29.801
8/29/2015	Saturday	12.691	12.520	25.211

Waterloo Readiness Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
9/13/2015	Sunday	18.091	0.000	18.091
9/14/2015	Monday	16.703	0.000	16.703
9/15/2015	Tuesday	17.504	0.000	17.504
9/16/2015	Wednesday	21.611	0.000	21.611
9/17/2015	Thursday	22.496	0.000	22.496
9/18/2015	Friday	23.143	0.000	23.143
9/19/2015	Saturday	19.938	0.000	19.938
9/20/2015	Sunday	19.451	0.000	19.451
9/21/2015	Monday	20.767	0.000	20.767
9/22/2015	Tuesday	19.401	0.000	19.401
9/23/2015	Wednesday	20.674	0.000	20.674
9/24/2015	Thursday	20.227	0.000	20.227
9/25/2015	Friday	22.433	0.000	22.433
9/26/2015	Saturday	20.374	0.000	20.374
10/11/2015	Sunday	18.193	0.000	18.193
10/12/2015	Monday	20.017	0.000	20.017
10/13/2015	Tuesday	24.965	0.000	24.965
10/14/2015	Wednesday	22.807	0.000	22.807
10/15/2015	Thursday	26.624	0.000	26.624
10/16/2015	Friday	26.651	0.000	26.651
10/17/2015	Saturday	25.988	0.000	25.988
10/18/2015	Sunday	22.266	0.000	22.266
10/19/2015	Monday	20.751	0.000	20.751
10/20/2015	Tuesday	17.422	0.000	17.422
10/21/2015	Wednesday	19.691	0.000	19.691
10/22/2015	Thursday	23.192	0.000	23.192
10/23/2015	Friday	23.386	0.000	23.386
10/24/2015	Saturday	21.826	0.000	21.826
11/8/2015	Sunday	21.897	0.000	21.897
11/9/2015	Monday	23.130	0.000	23.130
11/10/2015	Tuesday	21.979	0.000	21.979
11/11/2015	Wednesday	20.142	0.000	20.142
11/12/2015	Thursday	20.864	0.000	20.864
11/13/2015	Friday	23.228	0.000	23.228
11/14/2015	Saturday	22.021	0.000	22.021

Waterloo Readiness Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
11/15/2015	Sunday	24.822	0.000	24.822
11/16/2015	Monday	22.558	0.000	22.558
11/17/2015	Tuesday	25.381	0.000	25.381
11/18/2015	Wednesday	26.157	0.000	26.157
11/19/2015	Thursday	22.431	0.000	22.431
11/20/2015	Friday	23.487	0.000	23.487
11/21/2015	Saturday	24.064	0.000	24.064
12/6/2015	Sunday	24.121	0.000	24.121
12/7/2015	Monday	23.480	9.851	33.330
12/8/2015	Tuesday	21.496	21.723	43.219
12/9/2015	Wednesday	21.282	21.452	42.734
12/10/2015	Thursday	22.926	7.338	30.264
12/11/2015	Friday	24.933	0.000	24.933
12/12/2015	Saturday	25.368	0.000	25.368
12/13/2015	Sunday	25.924	0.000	25.924
12/14/2015	Monday	25.487	0.000	25.487
12/15/2015	Tuesday	26.673	0.000	26.673
12/16/2015	Wednesday	25.952	0.000	25.952
12/17/2015	Thursday	25.467	0.000	25.467
12/18/2015	Friday	22.282	0.000	22.282
12/19/2015	Saturday	28.713	0.000	28.713
1/3/2016	Sunday	24.059	0.000	24.059
1/4/2016	Monday	20.557	0.000	20.557
1/5/2016	Tuesday	26.768	0.000	26.768
1/6/2016	Wednesday	31.808	0.000	31.808
1/7/2016	Thursday	22.523	0.000	22.523
1/8/2016	Friday	27.868	0.000	27.868
1/9/2016	Saturday	27.732	0.000	27.732
1/10/2016	Sunday	40.282	0.000	40.282
1/11/2016	Monday	35.203	0.000	35.203
1/12/2016	Tuesday	27.565	0.000	27.565
1/13/2016	Wednesday	27.509	0.000	27.509
1/14/2016	Thursday	29.070	0.000	29.070
1/15/2016	Friday	30.185	0.000	30.185
1/16/2016	Saturday	28.619	0.000	28.619

Waterloo Readiness Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
1/31/2016	Sunday	28.281	0.000	28.281
2/1/2016	Monday	27.690	0.000	27.690
2/2/2016	Tuesday	28.911	0.000	28.911
2/3/2016	Wednesday	26.981	0.000	26.981
2/4/2016	Thursday	27.771	0.000	27.771
2/5/2016	Friday	28.357	0.000	28.357
2/6/2016	Saturday	25.321	0.000	25.321
2/7/2016	Sunday	24.133	0.000	24.133
2/8/2016	Monday	24.044	0.000	24.044
2/9/2016	Tuesday	27.894	0.000	27.894
2/10/2016	Wednesday	22.305	0.000	22.305
2/11/2016	Thursday	27.081	0.000	27.081
2/12/2016	Friday	32.376	0.000	32.376
2/13/2016	Saturday	36.832	0.000	36.832
2/28/2016	Sunday	26.202	0.000	26.202
2/29/2016	Monday	23.805	12.618	36.423
3/1/2016	Tuesday	24.784	24.905	49.689
3/2/2016	Wednesday	23.588	23.696	47.284
3/3/2016	Thursday	21.807	21.956	43.764
3/4/2016	Friday	23.480	23.804	47.284
3/5/2016	Saturday	23.749	23.966	47.714
*RTU-1 Exhaust Fan turned on				
3/6/2016	Sunday	22.011	22.335	44.345
3/7/2016	Monday	18.664	19.019	37.682
3/8/2016	Tuesday	15.588	15.892	31.480
3/9/2016	Wednesday	14.817	15.007	29.824
3/10/2016	Thursday	21.066	21.466	42.532
3/11/2016	Friday	21.021	21.348	42.369
3/12/2016	Saturday	17.384	17.642	35.026
*RTU-1 Exhaust Fan turned on				
3/27/2016	Sunday	28.820	0.000	28.820
3/28/2016	Monday	24.356	0.000	24.356
3/29/2016	Tuesday	21.706	0.000	21.706
3/30/2016	Wednesday	19.987	0.000	19.987
3/31/2016	Thursday	23.552	0.000	23.552
4/1/2016	Friday	26.137	0.000	26.137
4/2/2016	Saturday	26.440	0.000	26.440

Waterloo Readiness Center – Tiered Trim and Respond (Continued)

Tiered Trim and Respond				
Date		RTU-1 Supply Fan	RTU-1 Exhaust Fan	RTU-1
mm/dd/yy	day	kWh	kWh	kWh
4/3/2016	Sunday	23.055	0.000	23.055
4/4/2016	Monday	23.414	0.000	23.414
4/5/2016	Tuesday	28.497	0.000	28.497
4/6/2016	Wednesday	23.056	0.000	23.056
4/7/2016	Thursday	24.210	0.000	24.210
4/8/2016	Friday	24.049	0.000	24.049
4/9/2016	Saturday	29.481	0.000	29.481
4/24/2016	Sunday	17.176	0.000	17.176
4/25/2016	Monday	14.398	0.000	14.398
4/26/2016	Tuesday	17.460	0.000	17.460
4/27/2016	Wednesday	21.324	0.000	21.324
4/28/2016	Thursday	19.106	0.000	19.106
4/29/2016	Friday	24.127	0.000	24.127
4/30/2016	Saturday	29.492	0.000	29.492
5/1/2016	Sunday	29.950	0.000	29.950
5/2/2016	Monday	21.960	0.000	21.960
5/3/2016	Tuesday	18.382	0.000	18.382
5/4/2016	Wednesday	19.276	0.000	19.276
5/5/2016	Thursday	20.718	0.000	20.718
5/6/2016	Friday	16.802	0.000	16.802
5/7/2016	Saturday	28.097	0.000	28.097

APPENDIX B

TEMPERATURE CONTROL PERFORAMNCE RESULTS

The following tables provide the results of the temperature control comparison.

Joint Forces Headquarters AHU-2 – Trim and Respond

Trim and Respond					
Average % of occupied hours outside of setpoints per week					
VAV Box	Total	> ± 0.5°F to 1.0°F	> ± 1.0°F to 2.0°F	> ± 2.0°F to 5.0°F	> ± 5.0°F
VAV-128A	62.20%	9.37%	18.45%	33.92%	0.45%
VAV-130A	80.29%	4.94%	8.16%	47.27%	19.92%
VAV-131	69.51%	16.13%	27.37%	25.71%	0.30%
VAV-134	1.28%	0.47%	0.67%	0.14%	0.00%
VAV-135B	36.89%	17.33%	17.49%	2.07%	0.00%
VAV-153	60.36%	11.91%	36.36%	12.08%	0.00%
VAV-154	91.91%	7.97%	30.09%	52.11%	1.73%
VAV-154A	75.20%	17.97%	30.00%	27.23%	0.00%
VAV-154B	16.44%	3.61%	9.44%	3.39%	0.00%
VAV-154C	11.91%	5.87%	5.39%	0.64%	0.00%
VAV-154D	92.27%	4.09%	10.02%	61.47%	16.69%
VAV-154E	84.89%	4.14%	13.63%	52.48%	14.64%
VAV-154F	35.75%	11.51%	11.76%	12.49%	0.00%
VAV-154G	-	-	-	-	-
VAV-154H	14.51%	4.57%	9.65%	0.29%	0.00%
VAV-155C	56.34%	2.68%	6.09%	14.97%	32.60%
VAV-155G	50.00%	6.85%	19.20%	23.89%	0.07%
VAV-158	7.11%	3.68%	3.38%	0.05%	0.00%
VAV-159	71.61%	8.45%	17.27%	31.93%	13.97%
VAV-159A	18.41%	8.42%	7.35%	2.63%	0.00%
VAV-159B	38.05%	10.15%	19.48%	8.40%	0.01%
VAV-159C	27.12%	4.15%	11.85%	11.12%	0.00%
VAV-159D	66.59%	5.00%	12.50%	31.14%	17.94%
VAV-160	1.52%	0.24%	0.39%	0.89%	0.00%
VAV-160C	2.03%	1.80%	0.19%	0.03%	0.00%
VAV-160D	12.34%	8.82%	3.52%	0.00%	0.00%
VAV-160E	10.95%	7.03%	3.74%	0.18%	0.00%
VAV-160F	0.20%	0.06%	0.12%	0.02%	0.00%
VAV-160G	15.80%	5.29%	9.71%	0.80%	0.00%
VAV-160J	9.93%	4.99%	4.36%	0.57%	0.00%
VAV-163	70.58%	16.72%	27.57%	7.84%	18.45%
VAV-166	70.78%	10.30%	28.53%	31.63%	0.31%

Joint Forces Headquarters AHU-2 – Trim and Respond

VAV-209	60.77%	10.18%	15.24%	32.58%	2.77%
VAV-209A	26.07%	7.56%	14.00%	4.47%	0.04%
VAV-211	2.49%	1.08%	0.72%	0.65%	0.02%
VAV-212	28.81%	15.63%	10.85%	2.20%	0.13%
VAV-213	5.68%	2.81%	2.41%	0.43%	0.04%
VAV-215	30.67%	6.14%	11.28%	13.07%	0.18%
VAV-215A	46.91%	11.15%	17.03%	16.47%	2.26%
VAV-215B	28.94%	6.01%	8.32%	12.47%	2.13%
VAV-215D	61.15%	7.31%	16.02%	29.89%	7.93%
VAV-215E	30.58%	4.89%	9.42%	14.85%	1.41%
VAV-215F	29.29%	6.46%	7.39%	13.11%	2.32%
VAV-215G	34.22%	8.35%	9.91%	13.36%	2.59%
VAV-215H	29.38%	6.65%	8.50%	12.55%	1.68%
VAV-215J	64.56%	5.97%	12.19%	37.72%	8.68%
VAV-215K	16.08%	3.20%	2.40%	8.68%	1.80%
VAV-219A	9.87%	2.88%	2.26%	4.74%	0.00%
VAV-222	7.46%	3.66%	2.41%	1.32%	0.06%
VAV-225	22.72%	5.37%	7.28%	8.07%	2.00%

Joint Forces Headquarters AHU-2 – Tiered Trim and Respond

Tiered Trim and Respond					
Average % of occupied hours outside of setpoints per week					
VAV Box	Total	> ± 0.5°F to 1.0°F	> ± 1.0°F to 2.0°F	> ± 2.0°F to 5.0°F	> ± 5.0°F
VAV-128A	62.40%	11.48%	21.04%	27.35%	2.54%
VAV-130A	73.45%	1.71%	6.94%	40.85%	23.96%
VAV-131	62.43%	11.96%	23.82%	22.04%	4.62%
VAV-134	9.24%	2.82%	3.71%	2.71%	0.00%
VAV-135B	40.93%	17.08%	19.38%	4.47%	0.00%
VAV-153	50.91%	9.92%	31.60%	9.38%	0.00%
VAV-154	91.64%	10.62%	29.50%	49.55%	1.98%
VAV-154A	79.29%	18.10%	40.90%	20.28%	0.00%
VAV-154B	12.97%	4.09%	6.86%	2.02%	0.00%
VAV-154C	8.19%	3.64%	3.67%	0.88%	0.00%
VAV-154D	89.89%	5.13%	13.48%	60.42%	10.87%
VAV-154E	72.67%	3.66%	11.93%	45.27%	11.81%
VAV-154F	28.23%	10.98%	10.07%	7.18%	0.00%
VAV-154G	-	-	-	-	-
VAV-154H	10.65%	5.21%	5.01%	0.43%	0.00%
VAV-155C	52.34%	0.62%	5.97%	22.37%	23.39%
VAV-155G	43.21%	8.92%	16.42%	17.36%	0.50%
VAV-158	6.33%	2.08%	1.95%	2.28%	0.02%
VAV-159	77.67%	7.94%	21.03%	42.11%	6.60%
VAV-159A	11.07%	5.34%	4.36%	1.37%	0.00%
VAV-159B	26.76%	8.52%	10.72%	7.52%	0.00%
VAV-159C	17.81%	6.43%	6.39%	5.00%	0.00%
VAV-159D	60.91%	3.68%	6.12%	28.93%	22.17%
VAV-160	4.48%	2.45%	1.49%	0.54%	0.00%
VAV-160C	1.03%	0.96%	0.05%	0.03%	0.00%
VAV-160D	7.24%	3.85%	3.40%	0.00%	0.00%
VAV-160E	8.08%	4.52%	3.29%	0.27%	0.00%
VAV-160F	0.97%	0.77%	0.12%	0.08%	0.00%
VAV-160G	13.31%	7.87%	4.37%	1.07%	0.00%
VAV-160J	7.97%	3.66%	2.92%	1.39%	0.00%
VAV-163	66.83%	14.79%	24.16%	10.85%	17.03%
VAV-166	67.12%	8.35%	35.40%	23.17%	0.21%

Joint Forces Headquarters AHU-2 – Tiered Trim and Respond

VAV-209	54.85%	10.54%	16.54%	26.21%	1.56%
VAV-209A	23.20%	6.69%	10.36%	5.75%	0.41%
VAV-211	4.11%	2.41%	1.17%	0.49%	0.04%
VAV-212	29.27%	16.56%	8.42%	4.13%	0.15%
VAV-213	9.63%	5.93%	2.64%	1.00%	0.05%
VAV-215	41.79%	8.75%	11.72%	18.65%	2.67%
VAV-215A	50.09%	9.01%	19.07%	19.23%	2.79%
VAV-215B	40.09%	9.42%	14.60%	14.74%	1.33%
VAV-215D	52.24%	5.77%	13.60%	23.65%	9.23%
VAV-215E	35.95%	6.35%	11.13%	15.91%	2.57%
VAV-215F	34.04%	9.05%	12.12%	11.56%	1.31%
VAV-215G	35.48%	9.49%	16.37%	8.34%	1.28%
VAV-215H	34.99%	7.30%	11.92%	13.73%	2.05%
VAV-215J	62.50%	6.34%	15.71%	34.02%	6.42%
VAV-215K	18.58%	7.55%	6.13%	3.31%	1.59%
VAV-219A	1.81%	1.00%	0.81%	0.00%	0.00%
VAV-222	8.95%	3.46%	3.38%	2.04%	0.08%
VAV-225	28.41%	4.10%	6.59%	11.16%	6.56%

Joint Forces Headquarters AHU-3 – Trim and Respond

Trim and Respond					
Average % of occupied hours outside of setpoints per week					
VAV Box	Total	> ± 0.5°F to 1.0°F	> ± 1.0°F to 2.0°F	> ± 2.0°F to 5.0°F	> ± 5.0°F
VAV-110	12.00%	3.36%	6.70%	1.95%	0.00%
VAV-114D	55.08%	9.08%	9.04%	31.71%	5.25%
VAV-115	26.95%	11.47%	11.13%	4.36%	0.00%
VAV-175	8.21%	5.46%	2.18%	0.57%	0.00%
VAV-176A	91.38%	9.60%	35.88%	45.90%	0.00%
VAV-176B	38.00%	13.63%	18.22%	6.14%	0.00%
VAV-176C	10.79%	1.72%	1.88%	5.34%	1.84%
VAV-176D	7.15%	2.69%	2.27%	2.16%	0.03%
VAV-176E	13.51%	5.70%	5.70%	2.10%	0.00%
VAV-176F	14.12%	8.14%	5.98%	0.00%	0.00%
VAV-176G	29.17%	5.55%	15.25%	8.38%	0.00%
VAV-176H	22.44%	7.36%	11.25%	3.83%	0.00%
VAV-176-1	8.65%	3.77%	2.89%	1.99%	0.00%
VAV-176-2	18.27%	0.00%	18.24%	0.03%	0.00%
VAV-177	25.47%	12.31%	12.51%	0.65%	0.00%
VAV-178A	49.85%	11.88%	17.07%	18.89%	2.02%
VAV-178B-1	73.10%	3.66%	28.98%	27.12%	13.34%
VAV-178B-2	11.14%	4.15%	3.24%	3.70%	0.04%
VAV-181	31.57%	3.99%	21.18%	6.40%	0.00%
VAV-181A	36.47%	4.15%	14.32%	18.00%	0.00%
VAV-231	51.33%	14.69%	16.08%	19.36%	1.20%
VAV-231A	11.04%	3.73%	4.44%	2.84%	0.03%
VAV-231B	44.07%	6.90%	14.98%	21.60%	0.60%
VAV-231C	6.76%	3.31%	1.46%	1.60%	0.39%
VAV-231D	10.26%	3.69%	2.07%	4.50%	0.00%
VAV-237A	65.40%	5.64%	11.37%	42.45%	5.95%
VAV-239A-1	43.46%	6.59%	11.83%	18.37%	6.67%
VAV-239A-2	-	-	-	-	-
VAV-239A-3	6.75%	3.75%	0.70%	1.96%	0.34%
VAV-239A-4	-	-	-	-	-
VAV-239B	12.63%	5.20%	3.53%	3.08%	0.81%
VAV-239C	37.04%	5.26%	7.14%	23.81%	0.83%
VAV-239E	13.83%	8.23%	3.70%	1.81%	0.09%
VAV-239-1	44.35%	0.00%	39.12%	3.71%	1.51%
VAV-239-2	14.34%	5.26%	4.95%	2.47%	1.67%
VAV-241	10.26%	3.32%	3.56%	3.33%	0.05%
VAV-242	25.86%	5.10%	6.84%	13.92%	0.00%
VAV-242B	28.29%	9.09%	16.73%	2.47%	0.00%
VAV-242C	54.68%	11.79%	25.44%	17.32%	0.13%

Joint Forces Headquarters AHU-3 – Tiered Trim and Respond

Tiered Trim and Respond					
Average % of occupied hours outside of setpoints per week					
VAV Box	Total	> ± 0.5°F to 1.0°F	> ± 1.0°F to 2.0°F	> ± 2.0°F to 5.0°F	> ± 5.0°F
VAV-110	13.02%	3.61%	5.48%	3.91%	0.01%
VAV-114D	51.00%	11.85%	8.85%	24.65%	5.65%
VAV-115	27.91%	10.13%	11.61%	6.17%	0.00%
VAV-175	10.60%	3.00%	2.92%	4.05%	0.63%
VAV-176A	87.28%	9.87%	27.48%	49.93%	0.00%
VAV-176B	41.09%	16.74%	17.13%	7.21%	0.00%
VAV-176C	11.71%	2.34%	3.80%	4.78%	0.79%
VAV-176D	12.64%	5.39%	3.74%	3.24%	0.28%
VAV-176E	19.79%	5.45%	11.37%	2.97%	0.00%
VAV-176F	12.92%	6.77%	6.13%	0.02%	0.00%
VAV-176G	21.50%	3.20%	10.94%	7.36%	0.00%
VAV-176H	17.73%	4.53%	10.07%	3.13%	0.00%
VAV-176-1	12.08%	3.10%	4.68%	4.12%	0.18%
VAV-176-2	15.17%	0.00%	15.14%	0.03%	0.00%
VAV-177	14.23%	5.96%	6.84%	1.42%	0.00%
VAV-178A	52.11%	13.28%	22.08%	13.15%	3.60%
VAV-178B-1	71.64%	5.66%	34.35%	20.15%	11.48%
VAV-178B-2	11.71%	4.37%	3.07%	4.14%	0.13%
VAV-181	25.96%	6.32%	13.18%	6.46%	0.00%
VAV-181A	35.31%	10.30%	11.83%	13.18%	0.00%
VAV-231	45.12%	12.29%	11.52%	18.44%	2.87%
VAV-231A	9.56%	3.22%	3.66%	2.62%	0.06%
VAV-231B	27.75%	7.75%	9.76%	10.14%	0.11%
VAV-231C	6.70%	2.57%	2.00%	2.03%	0.09%
VAV-231D	10.79%	2.34%	6.80%	1.65%	0.00%
VAV-237A	55.46%	2.59%	8.79%	33.98%	10.10%
VAV-239A-1	42.37%	7.05%	12.96%	16.55%	5.81%
VAV-239A-2	-	-	-	-	-
VAV-239A-3	8.31%	1.33%	2.31%	3.96%	0.70%
VAV-239A-4	-	-	-	-	-
VAV-239B	19.35%	4.83%	5.80%	6.53%	2.18%
VAV-239C	39.76%	6.06%	7.55%	25.45%	0.69%
VAV-239E	12.65%	5.02%	4.67%	2.69%	0.27%
VAV-239-1	39.93%	0.00%	31.64%	6.71%	1.58%
VAV-239-2	12.84%	3.89%	2.66%	4.47%	1.83%
VAV-241	10.97%	3.03%	3.78%	3.63%	0.52%
VAV-242	22.57%	5.63%	5.80%	11.13%	0.00%
VAV-242B	17.74%	6.33%	8.91%	2.50%	0.00%
VAV-242C	35.76%	7.47%	10.99%	15.99%	1.30%

APPENDIX C

OCCURRENCE LOGS

This log lists the issues observed that affected the performance of the TTR strategy, were caused by the TTR strategy or affected the progress of the study.

Boone Readiness Center

7/20/2015
Boiler operation is disabled. AHU-1 operating as expected. AHU-2 TTR program needs investigating. Program seems to reset static pressure setpoint to maximum every 30 minutes during early morning hours. First observance of hi-static pressure alarm faults.

7/28/2015
AHU-1
- Reset occurred on 7/25 at 11:47 PM to SPmax
- Reset occurred on 7/27 at 2:28 PM to SPmax

AHU-2
- Reset occurred on 7/21 at 7:27 AM to SPmin
- Reset occurred on 7/24 at 5:00 PM to SPmax
  - Unit appears to have shut down and restarted
- Reset occurred on 7/24 at 11:47 PM to SPmax
  - TTR mode switched off and then on, causing the setpoint reset
- Reset occurred on 7/25 at 11:47 PM to SPmax
  - TTR mode switched off and then on, causing the setpoint reset
- Reset occurred on 7/27 at 2:28 PM to SPmin
  - Unit appears to have shut down and restarted

8/10/2015
Both units seem to have tripped on July 27th at 2:27 PM, causing the TTR program to reset. Supply air temperature for both units failed to meet setpoints from July 29th to Aug. 2nd. Chiller failed, and was fixed by the following Monday (8/3).

8/16/2015 to 9/2/2015
DDC export utility error occurred at 10:36 AM. No data recorded until 9/2

9/7/2015 through 9/30/2015
Drill schedule change caused 24/7 operations by both AHUs, invalid test days
AHU-1 reset on 9/15 at 8:23 AM, both AHU-1 and AHU-2 tripped on 9/15 at 4:28 PM
Static pressure at max for AHU-2 since 9/14 due to stuck open dampers (TAB 235)

10/9/2015
TAB-235 still remains wide open at 100%, even in cooling and heating modes. Max cfm setpoint was reverted back to 500 cfm.

10/30/2015
Occupancy schedule has been fixed and after 10/13 TAB-235 no longer sits at 100% damper position. TAB-235 was trimmed back to a setpoint of 450 cfm (previously 500 cfm).
TAB-231 is sitting at 100% damper position during TTR days.

11/6/2015
TAB-231 now sits at 100% damper position for most of occupied hours. Calls for heating at max airflow but reheat stays at 30%.

11/18/2015
DDC export utility error on 11/15 at approx. 3:00 AM, lost data from 11/15 to 11/18. AHU-2 was shutdown on 11/10 and 11/11. AHU-1 was still on during these days. TAB-227 has space temperature failure. However this doesn't seem to be affecting the TTR program.
TAB-233 continues to stick at 100% sometimes. Calls for 100% reheat with air valve position at 100%. Most rooms calling for reheat, though boiler is shut down. Outside air temperature setpoint to enable boiler is set to 120°F.

11/25/2015
DDC export utility encountered an error on 11/18 at 1:45 pm. Lost previous week of data.

12/09/2015
Missing data from 11/15 to 11/22
Starting from 11/22 through 12/5, AHU-2 supply air regularly hovers around 68°F while setpoint calls for 60°F.
TAB-231 was at 100% most of the day on 11/26.

1/11/2016
TAB-109 and TAB-225 both have space temperature failures, no temperature data recorded.
AHU-2 supply air temperature (~70°F) is constantly above the supply air setpoint (60°F)
TAB's 235 and 231 seem to still be driving max damper position.
TAB-231 was at 100% damper position, in heating mode with space temperature at 69.9°F and the heating setpoint at 70.0°F. Reheat output was at 18% with the discharge air at 75.6°F.

1/21/2016
AHU-2 Alarm and Discharge Air Temperature issues
AHU-2 typically has two alarms causing unit to trip during startup hours between 4 and 5 AM, HiPressure and FreezeStat alarms. Likely cause of FreezeStat is cold, outside air being heavily pulled in AHU due to negative pressure resulting from low return fan speed.
Discharge temperature is also repeatedly above setpoint due to request for chiller operation.
As the mixed air temperature is usually above setpoint (64°F to 60°F), AHU requests cooling from chiller, though current loop section is within the building and remains at 65°F to 70°F,

thus warming the mixed air. Tied the chiller pump operation status to the disabling of the chiller.

1/3 to 1/9 TTR
Both AHU's operating during normally unoccupied hours 1/7 and 1/8
AHU-2 supply air temperature well above setpoint. TAB-231 at 100% open from 1/7 to 1/9

1/10 to 1/16 TTR
AHU-2 suffered multiple trips for reasons stated above on 1/11 and 1/12
Both AHU's operating during normally unoccupied hours 1/13 and 1/14
AHU-1 supply air temperature setpoint adjusted from 60°F to 65°F on 1/12
Supply air temperature broke away from setpoint on 1/13 to ~72°F

2/10/2016
Lost the control board in the BCU. No data from 1/17 and on.

Des Moines Military Entrance Processing Station

7/15/2015
Functional mode is not currently set to automatically switch between fixed and TTR, one must manually switch between methods. The static was set for 1.40" WC for TTR method. No control over the boilers or chiller as this equipment is controlled by a different controls vendor. Difficult to determine exactly what was going on with the VAV boxes. The fact the building was overridden to fixed method at a 1.00" WC setpoint could have also contributed to the VAV issues.

8/8/2015
Data missing on 8/8 from 2:00 AM till 9:00 PM

9/4/2015
Found the schedule to switch TTR & FSP was not effective due to contractor programming error. It was "fixed" mode in the past several weeks.

9/28/2015
Missing 1 hour of data on 9/11 from 7:25 PM to 8:25 PM
Some VAV boxes heating setpoints have been altered (changed from 68°F to 71.5°F). However this doesn't seem to affect damper position.
TAB-131 oscillates constantly between 60% - 100% during occupied hours
TAB-134 can widely oscillate in damper position and space temperature
TAB-103 damper position oscillate during days when heating setpoint was adjusted

10/9/2015
TAB-101 remains 90% to 100 % open, cooling room well past setpoints, needs to be looked at. Missing data during 9/29 (5 hours) and from 9/30 to 10/2. Mode switch to TTR on 10/4 as scheduled.

10/28/2015
Data trends resumed on 10/21 but still had missing trends during the day, have data up to 10/26.

11/23/2015
Hitting 2.40" WC at the graphic and tripping. Checked the high static and it is set for 3.50" WC and is working. Lowered the high static graphic setpoint to 1.50" WC.

3/16/2016
Reverted the SPmax limit to 1.40" WC for TTR strategy.

3/28/2016
Supply Air deviated from setpoint on 3/23 and 3/24. VAV-101 is usually the most open damper. AHU operated as expected.

4/4/2016
Most notable issue is the supply air temperature failing to reach the setpoint for extended periods throughout the week. VAV-101 continues to be the most open damper. Missing trends for VAV-112.

4/24 to 4/30 TTR
Max damper position driven by VAV-101
VAV-101 is not stuck, however supply air temperature from VAV is not adequate to heat room to heating setpoint.

Joint Forces Headquarters

7/23/2016
AHU-1: Supply fan has loud noise. Found the VFD speed control signal was wrongly setup as 4~20mA. It should be 0-10 VDC.

AHU-2: Changed SPmin from 0.50" WC to 0.10" WC
For fixed static pressure method the static pressure setpoints are not set at designed value or test and balancing recommended value – due to noise or high pressure limit switch trip frequently. Boiler/chiller run manually based on outside air conditions. All may impact TTR method effectiveness and energy savings demonstrations.

AHU-12 Static pressure is controlled around minimum setpoint of 0.80" WC. This AHU runs 24 hours/day.

9/4/2016
Missing 12 hours of data for AHU-9, not a valid test day.

10/28/2016
Noticed during unoccupied hours, AHU-12 regularly fails to meet supply air setpoint. This might be the cause of the static pressure setpoint driving to max at night due to VAV boxes' demand for warm/cool air during TTR days.

11/2/2016
VAV-163 continues to be 100% open during TTR days. Airflow setpoint is at 200 cfm, while design is at 150 cfm. AHU-12 experiences failures in supply air temperature during TTR days, causing static pressure setpoint to climb and hold at max static pressure. Otherwise, rest of units are operating as expected.

11/11/2016
AHU-12 suffered a trip on 11/3 3:50 PM to 7:20 PM. Has since resumed normal operation. Supply air temperature reached setpoint on 11/4, max damper position dropped from 100% to 70% on 11/4

Still fixing issues with AHU-2 and AHU-3 VAV boxes.

11/17/2016
AHU-2 supply air temperature reset strategy was changed from based on OA-Temperature to fixed temperature of 55°F. AHU-3 supply air temperature reset strategy was changed from based on OA-Temperature to base on "cooling request".

11/18/2016
AHU-12 supply fan 3 & 4 has been shut down. Last week, AHU-12 suffered a trip. Afterwards, only AHU-12 supply fan 1 & 2 recovered, supply fans 3 & 4 remained shut down.

11/19/2016
IAARNG facility engineer changed AHU-2 temperature reset to base on OA-Temperature again, due to complaints from occupants the temperature were below 68°F in the morning, while the floor radiant heat was still not on.
AHU-1 Static pressure max setpoint adjusted to 1.50” WC from 2.40” WC.

11/30/2015
All AHU’s had normal occupancy hours during holidays of 11/26 and 11/27
AHU-1 kept constant pressure entire week, though max damper position dipped below 90% during occupied hours. Functional mode should be TTR, may be due to SPmax limit override of 1.50” WC. TTR static pressure setpoint is changing (previous limit is 2.40” WC) but occurs above 1.50” WC so the trend isn’t observable.
AHU-2 is ok. VAV-163 and VAV-209 drive TTR static pressure setpoint, both VAV boxes cannot meet cooling setpoint. Temperature reset strategy is being used instead of a fixed temperature setpoint.
AHU-12
  Supply air temperature failed to meet setpoint on 11/25.
  Supply fans 3 and 4 still remain offline.

12/7/2016
AHU-1 Static pressure limit changed from 1.50” WC to 1.80” WC on 12/3
Max damper position at 100% throughout most of the week, even after the static pressure limit was changed on 12/3
VAV-207E stuck at 100% Damper Position for most of the week

AHU-2
VAV-209 stuck at 100% Damper Position for most of the week
AHU-3
VAV-178A stuck at 100% Damper Position for most of the week. Cannot cool room down to cooling setpoint of 71°F
VAV-239E stuck at 100% Damper Position for most of the week. Cannot cool room down to cooling setpoint of 71°F
AHU-12 Supply air setpoint drove down to 58°F on 12/4 and 12/5
Supply fans 3 and 4 still remain shutdown

12/29/2016
AHU-1 TTR SPset seems to be ignoring max damper position, stuck at SPmax of 1.80” WC. Damper position will drop below 85% and static pressure setpoint will not drop.
AHU-2 max damper position at 100% entire week. VAV boxes 209 and 212 at 100% needing cooling.
AHU-12 Supply fans 3 and 4 are still shut down.

1/13/2016
AHU-2, TR mode. Max damper position at 100%, supply air setpoint at 68°F

AHU-3, TR mode. Max damper position at 100%
Both AHU 2 and 3 have heating and cooling demands from VAV boxes
AHU-12, FSP
Supply fans 3 and 4 are still shutdown

2/5/2016
AHU-2 1/17 to 1/23 TTR, max damper position at 100% most of week
VAV-225 damper at 100%, heating and cooling setpoints increased two weeks ago, 72°F & 76°F
Airflow at 300 cfm, max heating airflow setpoint listed at 90 cfm.
VAV-209 damper at 100%, heating and cooling setpoints were decreased, 67°F & 69°F
AHU-3 VAV-178A damper at 100%, struggles to cool room during TTR and TR days
AHU-12 Max damper position at 100% for both TTR 1/17 to 1/23 to FSP 1/24 to 1/30
VAV-24-2B 100% open these days, missing space temperature trend

2/18/2016
AHU-1 Trouble meeting SA setpoint 2/1, SA setpoint increased 65°F to 70°F late 2/1
Supply air temperature setpoint decreased 70°F to 65°F on 2/10 midday
AHU-2 Max damper position at 100% most of TR and TTR days
VAV-163, VAV-209, VAV-212, VAV-225 all at 100% open
AHU-3 Data loss starting 2/5. Max damper at 100% from VAV-178A and VAV-114D
AHU-12
VAV-24-2B at 100% open most days

2/19/2016
Design values for max airflow were switched on VAV boxes 24-2A and 24-2B on AHU-12.

3/3/2016
From 2/14 to 2/20 TTR Mode

AHU-2
Max damper position at 100%
VAV-163 cannot cool room
VAV-209 cannot cool room
VAV-225 cannot heat room
AHU-3 Offline
AHU-12
Max damper position at 100% most of week

2/21 to 2/27 FSP and TR Mode
AHU-2
Static Pressure Max limit was adjusted from 1.25” WC to 1.50” WC on 2/23
Max Damper Position at 100% entire week
VAV-209 cannot cool room
VAV-212 cannot cool room
AHU-3

Most points back online with the installation of new controller
Lost the following points:
AHU-3 SP-SPT
AHU-3 SA-Temp-SPT
AHU-3 SF-KWH
Max Damper Position at 100%
VAV-178A cannot cool room
VAV-178B-2 cannot cool room

AHU-12
Max Damper Position at 100%
VAV-25C, damper position feedback 100% open, airflow ~20 cfm

3/16/2016
From 2/28 to 3/5 FSP or TR
AHU-2
Max damper at 100%
VAV-209 cannot cool room
VAV-225 cannot heat room

AHU-3
Still missing points
VAV-178A cannot cool room

AHU-12
Max damper at 100%
VAV-25C airflow still ~20 cfm with 100% damper position

From 3-6 to 3-12 TTR
AHU-1
Max damper at 100%
VAV-207E cannot cool room

AHU-2
Max Damper at 100%
Supply air temperature setpoint failed to reach setpoint 3/7 and 3/8
VAV-209 cannot cool room
VAV-225 cannot heat room
AHU-4 Supply air temperature failed to reach setpoint 3/7 and 3/8
AHU-12 Max damper position at 100%
VAV-25C damper 100% open, airflow at ~20 cfm
VAV-11 damper 100% open

3/18/2016
Looked into VAV-25C damper being fully open. Looks like VAV actuator must have slipped on shaft or something as it will not allow the VAV box to open. Corrected VAV actuator mounting. Airflow was running about 15 cfm and now is about 215 cfm. This is still about 75 cfm low - this is probably due to AHU-12 only having a 1.50” WC duct static pressure setpoint - it was originally allowed to run up to +2” WC.

3/31/2016
AHU-2
From 3/13 to 3/19 TTR
Max damper position at 100% most of week
VAV-163 cannot cool room
VAV-225 cannot heat room
VAV-209 cannot heat room

From 3/20 to 3/26 TR
Max damper position at 100% most of week
VAV-163 cannot cool room
VAV-209 cannot heat room

AHU-3
From 3/13 to 3/19 TTR
Lost connection with Network 52 VAV boxes, values are locked up through 3/26

From 3/20 to 3/26 TR
Lost AHU trends starting 3/26 at 2:00 AM

AHU-12
From 3/13 to 3/19 TTR
Unit tripped 3/16 at 2:17 PM
Max damper position at 100%
VAV-10J cannot cool room, missing data for temperature setpoints
VAV-25C, missing data for temperature setpoints

From 3/20 to 3/26
Max damper at 100%
VAV-10J cannot cool room, missing data for temperature setpoints
VAV-25C, looks fixed but airflow data doesn't seem right

4/6/2016
AHU-3 still missing trends for AHU and VAV boxes
AHU-1 down 4/1, VAV boxes went into occupied mode
AHU-12 max damper position at 100% entire week

AHU-1
Max damper trend is incorrect starting 4/1 at 5:00 AM
Network 22 reverted from 1 minute to 5 minute trending starting 4/1 at 1:55 AM
Still missing AHU-12 VAV files

4/11/2016
Discovered network "switch" tied to AHU-1 controller went down 4/1, causing interval changes. Values recorded were stuck from previous records. Logs showed the network came back 4/3.

Corrected max static pressure for TTR mode on AHU-1
Issues with AHU-1 in TTR mode due to quick ramp resulting in static pressure tripping internal AHU alarms at 3.00” WC

AHU-3 network still down, IP address is lost

4/14/2016
AHU-1 max damper position at 100% open, difficulties cooling Network 23 VAV boxes
SPmax changed from 1.80” WC to 1.50” WC

AHU-2 max damper position at 100% open, mix of VAV boxes going to 100%, many cannot cool zones

AHU-3 no data

AHU-4 max damper position at 100% for much of week, mix of zones going to and from 100%
SPmax changed from 2.00” WC to 1.50” WC for TTR mode (FSP at 1.05” WC)

AHU-12 max damper position at 100% entire week
VAV-10J Bad supply air temp trend (all 0’s)
VAV-25C damper stuck at 100% open entire week, space temperature within heating and cooling setpoints

4/27/2016
AHU-1 FSP
Max damper position @ 100% throughout week
VAV-207C damper at 100%, can’t reach cooling setpoint
VAV-207E damper at 100%, space temp within setpoints
VAV-208M damper at 100%, can’t reach cooling setpoint
VAV-208P damper at 100%, can’t reach cooling setpoint
VAV-144, cannot heat room

AHU-2 TR
Max damper position @ 100% throughout week
VAV-235B damper at 100%, can’t reach cooling setpoint
VAV-163 damper at 100%, can’t reach cooling setpoint

AHU-3 FSP
No data

AHU-4 FSP
FSP SPmax adjusted to 1.30” WC

AHU-12 FSP

OK, max damper position at 100%
VAV-25C 100% open, No trends for heating and cooling setpoints

5/3/2016
AHU-1 FSP
Max damper position @ 100% most of week
VAV-207C can't reach cooling setpoint
VAV-207E Heating airflow setpoint matches max airflow setpoint
VAV-208M can't reach cooling setpoint
VAV-208P can't reach cooling setpoint
AHU Supply air temperature very near VAV cooling setpoints

AHU-2 TR
Max damper position @ 100% entire week
Mix of zones that cannot reach cooling setpoint
AHU supply air ~65°F whole week

AHU-3 TR (no data)

AHU-12 FSP
Max damper position @ 100% entire week
VAV-25C stuck at 100%

5/11/2016
AHU-1
Max damper position at 100% entire week
Many VAV's wide open, cannot reach cooling setpoint
VAV-207E 100% open when temperature is within setpoints

AHU-3
No data

AHU-4
TTR mode not operating correctly, SPset at max while max damper position @ 80%

AHU-12
Max damper position at 100%
VAV-25C still wide open entire week

5/16/2016
AHU-1
Max damper position @ 100% entire week
VAV-207C 100% open, cannot cool room (69°F cooling setpoint)
VAV-207E 100% open, temperature within setpoints
VAV-208M 100% open, cannot cool room (69°F cooling setpoint)

AHU-2
Max damper position @ 100% most of week
VAV-135B
VAV-163

AHU-3 No data

AHU-4
Static pressure setpoint at max
Max damper position ~80% open

AHU-12
Max damper position @ 100% open
VAV-25C 100% open entire week

5/23/2016
All units in occupied mode starting 5/16
Penthouse units supply air temperature failed 5/18 and 5/19

AHU-1 FSP
VAV-207E damper position at 100%
VAV-207C damper position at 100%

AHU-2 TR
Max damper position at 100% entire week
Static pressure showed heavy oscillation

AHU-3 TR
Returned online 5/17
Static pressure is constant at 1.5” WC

AHU-12 FSP
Max damper position at 100%
VAV-25C damper position open 100% entire week

5/26/2016
Resolved issues with AHU-3
AHU-3 is tied to controller #5, however TTR/TR schedule is on controller #1

AHU-4 static pressure setpoint was overridden to 1.5” WC on April 6, overriding TTR setpoint
TTR SPmax adjusted to 1.5” WC, FSP SPmax at 1.3”

AHU-12 VAV-25C has issues with damper command signal

Muscatine Armed Forces Reserve Center

7/17/2016
It seems that RTU-4 is ignoring the pressure setpoint value. For July 14th (TTR mode should be enabled), the pressure setpoint was constant at the minimum static pressure of 0.40” WC, which makes sense as the max damper value was around 50%. However, the actual pressure stayed constant at 1.20” WC. The TTR program seems to be working, but is being overridden by a higher priority command.

7/22/2016
RTU-4:
Pressure setpoint at 0.40” WC
Actual pressure at 1.20” WC (High pressure warning to due 0.80” WC difference between real and setpoint)
Duct pressure setpoint might be overwritten by:
Outside Air Ventilation minimum setpoint (60% outside air needed)
Return Fan is causing increase of duct pressure? (rated for 1.20” WC at 100% speed)
Changed all “Default State” values to current values

8/5/2016
Adjusted RTU-4 minimum speed to 6 Hz

8/14/2016
RTU-3 was again late switching functional modes to TTR (about 3 days late). Also, during the last week of Fixed Static Pressure (8/4 to 8/8), the RTU doesn't start with the pressure setpoint at the maximum. However, during TTR mode it'll start the day at it's maximum pressure setpoint.

8/18/2015
RTU-4 “unoccupied” mode problems seems disappeared.

9/14/2015
RTU-3 switched to TTR “Off”, though pressure setpoint is not fixed. Pressure setpoint is not determined by TTR method, but changes frequently during occupied hours.
RTU-4 runs 24/7 from 8/22 to 8/29

9/15/2015
Fixed RTU-3 problem (AHU static pressure setpoint vary in the “fixed” mode”.) Problem is due to control contractor error in programming RTU-3.

9/16/2015
RTU-4 exhaust fan turned back on 9/10

10/2/2015
All RTU’s are operating as expected.
Functional mode switch on 9/19 to FSP as scheduled.

RTU-4 continues to run during unoccupied hours, at the minimum static pressure limit.

10/23/2015
All RTU's operating as expected. Functional modes swtiches were on schedule.
RTU-3 ran intermittently during normally unoccupied hours on 10/14 and 10/15. Seems to be ok now.

11/16/2015
During FSP days from 10/24 to 10/30, RTU-3 has odd occupancy hours. Unit seems to shut off and turn on intermittently. Resumes normal operation during TTR week from 10/31 to 11/6.

12/7/2015
11/11 and 11/26 Both RTU-1 and RTU-4 were shut down.
RTU-1 static pressure oscillates wildly on 11/22nd, 23rd and 27th. Supply air temperature oscillates wildly these same days.
RTU-3 started running during normally unoccupied hours on 11/7.
RTU-4 on 11/17th, 18th, 21st, ran just before and just after normally occupied hours.

1/7/2016
RTU-4 resumed operation during unoccupied hours of 12/23
Unit shutdown after 12/23, most likely tripped during startup on 12/24.

1/15/2016
RTU-4 is back online. Unit suffered trip due to high static pressure trip.

2/3/2016
RTU-4 trip is still caused by high static pressure sensor was tripped. The pressure went to ~4.00" WC during initial start. Technician changed (slowed down) VFD ramp up rate to about half of the original rate. Tested twice to restart it, seems ok now.

Another issue is with why RTU-3 and RTU-4 sometime starts at 4:00am in the morning when the occupancy schedule says the occupied starting time is 6:00am. After looking into it, all these RTU units and VAV boxes also have "optimal start" enabled, which calls for around 4:00am to start.

Disabled the optimal start for RTU-1,3,4.

2/5/2016
12/24 RTU-4 trip, max damper at 0%
1/19 RTU-4 trip, max damper position at 50% (2 minute interval), average damper position at ~40%

2/25/2016
RTU-4 back online 2/3

Waterloo Readiness Center

7/13/2015
Waterloo RC RTU-1 Return Fan found to have shut down on July 10th.

7/16/2015
Make sure “fall back default” values for TTR parameters and Zone temperature setpoint are the same – so in case of future power outage, the program will restore to the expected values.
Change VA1 (classroom/library) zone common temperature setpoint from 77°F to 72°F. (Effective 68.5°F to 72.5°F)
Found exhaust fan VFD showed “ou” - Over Current fault and stopped. Changed acceleration/deceleration time from 10 to 5, and manually restarted the exhaust fan by reset the RTU-1 power.

7/17/2015
The FSP static pressure limit was set back to 1.60” WC.

8/25/2015
RTU-1 exhaust fan restarted.

9/1/2015
Exhaust fan appears to have shut down around noon on 9/1

10/14/2015
TAB-101 cannot reach temperature setpoints (69.5°F and 65.5°F) during both TTR and FSP days.

12/9/2015
Exhaust fan has kicked on again.

APPENDIX D

POWER VERIFICATION RESULTS

Boone Readiness Center

AHU-1 SF		Input	Output	VS
VFD Speed	VFD Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.41	0.37	10.81%
50.00%	30	1.11	1	11.00%
66.67%	40	2.38	2.25	5.78%
83.33%	50	4.4	4.1	7.32%
100.00%	60	6.9	6.7	2.99%

AHU-1 RF		Input	Output	VS
VFD Speed	VFD Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.57	0.488	16.80%
50.00%	30	1.2	1.14	5.26%
66.67%	40	2.3	2.32	0.86%
83.33%	50	4.3	4.21	2.14%
100.00%	60	6.95	6.87	1.16%

AHU-2 SF		Input	Output	VS
VFD Speed	VFD Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.53	0.36	47.22%
50.00%	30	1.09	0.865	26.01%
66.67%	40	2.3	2.1	9.52%
83.33%	50	4.5	4	12.50%
100.00%	60	7.45	6.7	11.19%

AHU-2 RF		Input	Output	VS
VFD Speed	VFD Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.43	0.35	22.86%
50.00%	30	0.68	0.59	15.25%
66.67%	40	1.515	1.39	8.99%
83.33%	50	2.8	2.75	1.82%
100.00%	60	4.8	4.72	1.69%

Joint Forces Headquarters

AHU-1 SF		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.75	0.6	25.00%
50.00%	30	2.2	2	10.00%
66.67%	40	3.8	3.2	18.75%
83.33%	50	6.4	5.6	14.29%
100.00%	60	9.7	8.1	19.75%

AHU-2 SF		Input		Output	Error	
Speed	Frequency	Power Meter	Data Logger	VFD Display	Data Logger	Reading
%	Hz	kW	kW	kW	%	%
30.00%	18	0.465	0.519	0.41	11.61%	21.00%
45.00%	27	1.33	1.38	1.3	3.76%	5.80%
60.00%	36	2.6	2.77	2.65	6.54%	4.33%
75.00%	45	3.85	3.98	3.8	3.38%	4.52%
90.00%	54.2	5.95	5.54	5.9	6.89%	6.50%
100.00%	60	-	-	-	-	-

AHU-3 SF		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.77	0.6	28.33%
50.00%	30	2.2	2	10.00%
66.67%	40	4.6	3.9	17.95%
83.33%	50	7.7	6.4	20.31%
100.00%	60	10.2	8.8	15.91%

AHU-4 SF		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.75	0.6	25.00%
50.00%	30	2.2	2	10.00%
66.67%	40	4.6	3.9	17.95%
83.33%	50	7.5	6.1	22.95%
100.00%	60	-	-	-

AHU-9 SF		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.19	0.1	90.00%
50.00%	30	0.37	0.3	23.33%
66.67%	40	0.64	0.5	28.00%
83.33%	50	1.01	0.8	26.25%
100.00%	60	1.58	1.3	21.54%

AHU-12 ES 1 & 2		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	1.7	2.3	26.09%
50.00%	30	2.7	3.55	23.94%
66.67%	40	12.3	13.3	7.52%
83.33%	50	22.7	23.15	1.94%
100.00%	60	-	-	-

AHU-12 ES 3 & 4		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	1.5	2.2	31.82%
50.00%	30	2.6	3.4	23.53%
66.67%	40	12.2	13.25	7.92%
83.33%	50	22.4	23.2	3.45%
100.00%	60	-	-	-

AHU-12 ER 1 & 2		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.49	0.4	22.50%
50.00%	30	1.38	1.1	25.45%
66.67%	40	2.9	2.5	16.00%
83.33%	50	5.4	4.7	14.89%
100.00%	60	8.8	7.8	12.82%

AHU-12 ER 3 & 4		Input	Output	VS
Speed	Frequency	Power Meter	VFD Display	VFD Efficiency
%	Hz	kW	kW	%
16.67%	10	-	-	-
33.33%	20	0.56	0.4	40.00%
50.00%	30	1.53	1.3	17.69%
66.67%	40	3.2	2.8	14.29%
83.33%	50	6	5.2	15.38%
100.00%	60	-	-	-