Senior Thesis Final Report

Ground-source Gymnasiums and Satisfactory Stages

Altoona Area Junior High School
Altoona, PA

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Mechanical Option
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April 9, 2008

Thesis Abstract

ALTOONA AREA JUNIOR HIGH SCHOOL · ALTOONA, PA

BUILDING STATISTICS

Building Occupant:	**Altoona Area School District**
Occupancy Type:	**Secondary Education**
Size:	**292,066 SF**
Number of Stories:	**Academic/Fine Arts Building - 4** **Physical Education Building - 2**
Dates of Construction:	**April 2006 - August 2008**
Cost:	**$48 Million**
Project Delivery Method:	**Design-Bid-Build**

DESIGN & CONSTRUCTION TEAM

Owner:	**Altoona Area School District**
Architects:	**L. Robert Kimball and Associates**
General Contractor:	**Leonard S. Fiore, Inc.**
HVAC:	**D. C. Goodman and Sons, Inc.**
Plumbing:	**S. P. McCarl and Company, Inc.**
Fire Protection:	**Interstate Fire Protection Co.**
Electrical:	**G. M. McCrossin, Inc.**
Food Service:	**Commercial Appliance Contracts**
Auditorium Seating:	**Maffei Strayer Furnishings, Inc.**

ARCHITECTURAL SUMMARY

The new Altoona Area Junior High School consists of a 239,434 SF Academic and Fine Arts Building and a 52,632 SF Physical Education Building. The Academic Building houses two cafeterias, an enclosed courtyard, an auditorium, offices, and classrooms. The Physical Education Building houses two gymnasiums, an indoor running track, and locker room facilities. The entire structure is clad in red brick accented with tinted pre-cast concrete elements. The windows and doors are aluminum with decorative pre-cast panels.

STRUCTURAL OVERVIEW

12-26" Reinforced Concrete Footings
8-12" Reinforced CMU Foundation
5" Slab-on-grade with W2.9xW2.9 WWF
5.25" Concrete Floor Slabs on 9/16" Steel Deck
Single Steel Joists on Load-bearing CMU Walls
Single and Double Joists on Steel Columns
1.5" Galvanized Steel Roof Deck

MECHANICAL OVERVIEW

Modular Indoor and Outdoor CW/HW AHUs
(2) 225-ton Rotary Screw Water Chillers
(2) 3,322-MBH Gas Boilers
(11) Air-cooled Condensing Units
(8) VAV Boxes with Electric Reheat Coil
(1) 41.5-MBH Split-system A/C Unit
(6) Rooftop A/C Units
(12) 14.5-MBH Hydronic Cabinet Unit Heaters
(6) 6,825-BTUH Electrical Wall Heaters
(130) Room Unit Ventilators
(3) 500-BTU/ft Radiant Ceiling Panel Heaters

LIGHTING/ELECTRICAL OVERVIEW

4000 A, 480/277V Service
Voice and Data Communications
Security Cameras/Alarms
Closed-circuit Television
Auditorium and Gymnasium Sound
Fire Detection and Pumping
600 kW Emergency Generator
Interior Fluorescent Pendant Luminaires
Exterior HID Luminaires
Auditorium Dimming
Theatrical Lighting

CHRISTOPHER G. CONRAD · MECHANICAL OPTION
http://www.engr.psu.edu/ae/thesis/portfolios/2008/cgc129/

Acknowledgements

First and foremost, I would like to acknowledge the assistance and cooperation of the Altoona Area School District and their representatives, notably Dr. George Cardone, Assistant Superintendent, and Mr. Tom Bradley, Public Relations Director. Their assistance in granting the go-ahead for this project as well as providing information and photographs of the building construction have been most helpful in the development of the following studies.

Furthermore, much of the accompanying analyses would not have been possible without the construction documents and answers provided by the engineers, designers and contractors involved in the project. Mr. Earl Wong and Mr. Brad Palmisiano of L. Robert Kimball & Associates, Inc. have been of immense help in clarifying the objectives and operation of the existing mechanical systems in the new junior high school. Mr. David Goodman and Mr. Mike Humphreys of D. C. Goodman & Sons, Inc. have also been instrumental in providing a complete set of construction drawings and specifications, much of which provided the inspiration for the following report.

The assistance of my course instructors, faculty advisors, and fellow classmates must also be acknowledged. I would like to give a special thank you to Dr. Jim Freihaut, whose knowledge and constructive criticism over the past school year have most certainly affected the outcome of this report. I would also like to thank Prof. Kevin Parfitt and Prof. Bob Holland for the excellent job they have done in organizing and administrating the Penn State AE Senior Thesis course. I must also give thanks to my fellow peers whose diverse experiences have provided a wealth of knowledge that has enhanced this report.

Finally, I would like to thank my family and friends, whose support over the past five years have made my time at Penn State successful and enjoyable: my mother, Linda; my father, Randy; my sister, Lana; my grandparents, aunts, uncles, and cousins; my roommates, Tom Chirdon, David Miller, and Scott Earley; my bandmates, Thom Fronauer, Ryan Furry, and Michael Furry; and my friends, Paul Conway, Mike Johnson, Jon Reynolds, Andrew Collins, Chris DeStefano, Doug Conrad, Scott Davis and Nick Kutchi.

Dedicated to my grandmother, Althea M. Chilcote,
who passed away during the compilation of this report.

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Executive Summary

The primary purpose of the following report is to examine the potential for a proposed HVAC system redesign to reduce energy costs and consumption at the Altoona Area Junior High School. The scope has been reduced to include an examination of seven direct-expansion/gas air handling units that serve the school's athletic facility. Based off of an anticipated high level of efficiency offered by ground source heat pump systems, this option was critically analyzed and selected to serve as the redesign featured in this study.

It has been found that the use of a GSHP system has the potential to reduce annual maintenance and operating costs by as much as 57% in this instance. It was also determined that while a GSHP system figured to increase annual electricity consumption by an estimated 33%, it totally eliminated the need for natural gas. The main drawback for the proposed GSHP system is its high initial cost, costing an estimated $95,000 more than the traditional existing design.

Furthermore, a proposed gymnasium daylighting system utilizing skylights has been found to increase the thermal loads for the system redesign, as expected, but has demonstrated a potential in decreasing electric lighting costs by as much as 67%.

The conclusions made by this report indicate that a GSHP system with integrated daylighting has the potential to significantly reduce energy costs and consumption and should therefore be considered as a feasible and adequate alternative to the original design.

Additionally, this report has verified the feasibility of diverting outdoor air from an air handling unit serving the school's band room to the school's auditorium, where deficiencies have been noted through previous analysis. This report has also concluded that the use of additional air diffusers to accommodate this diverted outdoor air will not have an adverse effect on background noise if the proper diffuser size is specified. If a diversion of outdoor air meeting the requirements of ASHRAE Std. 62.1 were to be carried out to improve the original design, it is the finding of this report that the acoustic considerations, while critical, are minimal.

1. Existing Conditions

Main aspects of the Altoona Area Junior High School are discussed below. The discussion focuses on the building's mechanical systems and related items. This study's scope is also defined, highlighting which aspects will be further discussed later in this report.

1.1 Building Statistics

The Altoona Area Junior High School building located in Altoona, Pennsylvania is a 292,000 ft^2, $48 million educational facility with a variety of mixed-use and single-use spaces. The school will accommodate an estimated 1800 students in grades 7-9. School construction began in the spring of 2006 and will open in time for the 2008-09 school year.

The Altoona Area School District, one of the largest school districts in Pennsylvania, is the owner of the project and will oversee the management and construction of the building. L. Robert Kimball and Associates, of Ebensburg are the architects for the school. L.S. Fiore, Inc., of Altoona will construct this design-bid-build project. For more information on building details including an in-depth listing of the project's subcontractors, please visit the Capstone Project Electronic Portfolio website at http://www.engr.psu.edu/ae/thesis/portfolios/2008/cgc129.

Main systems and features of the building are described in detail below. Please note that a mechanical system description has been omitted from this section. A more detailed description of the building's existing mechanical system can be found in **Section 1.2**.

Architecture

The new facility consists of a four-story 239,434 ft^2 academic and fine arts building and a two-story 52,632 ft^2 physical education building. The academic building houses two cafeterias, an enclosed courtyard, an auditorium, administrative offices, and classrooms. The physical education building houses two gymnasiums, an indoor running track, and locker room facilities. The entire structure is clad in red brick accented with tinted pre-cast concrete elements. The windows and doors are aluminum with decorative pre-cast panels.

Figure 1-A. *A rendered elevation of the Altoona Area Junior High School.*

Lighting/Electrical

The Building is fed with 4000A, 480/277V service. The building's backup power is provided by a 600 kW emergency generator. The school features fluorescent pendant luminaires in most of the interior spaces with HID luminaires on the exterior. An auditorium dimming system and theatrical lighting are also included in the overall system.

Structural

The building is supported by reinforced concrete footings ranging from 12-26 inches in size with a foundation of concrete masonry units. The main floor slab is 5-inch slab on grade with W2.9xW2.9 reinforcing steel. The upper floors are 5.25-inch concrete floor slabs on top of 9/16" steel decking. Load-bearing CMU walls are reinforced by steel columns with single steel floor joists. The roof system uses 1.5-inch steel decking as a base.

Fire Protection

Smoke detectors and emergency pull stations are connected to a centralized alert center within the building. Sprinklers are provided throughout the building as is stipulated by the International Building Code. Ceiling-mounted luminaries and exit signs are powered by the backup generator in case of an emergency.

Telecommunications

The building features a voice and data communications system as well as a closed-circuit television system which is accessible in all classrooms and throughout all major assembly spaces in the building. Interior and exterior security cameras providing real-time and recordable video will also be installed throughout the school campus. The auditorium and gymnasiums feature public address systems and interactive scoreboards where needed.

1.2 Existing Mechanical Systems Summary

The Altoona Area Junior High School is served by several different HVAC systems. A two-pipe change over chilled water/hot water system serves a majority of the air handlers and classroom unit ventilators in the building. Several prepackaged rooftop units and DX/gas units were also utilized, mainly in the school's athletic area.

Due to the building's size, it would be too tedious to list each space and the system by which it is served. Instead, **Table 1-A**, provided below, makes a listing of the types of spaces in the building and by which type of system these spaces are generally served.

Table 1-A *Building System Summary Organized by Type*

Unit	Space
DX/gas AHUs	Gymnasiums/Athletics
CW/HW AHUs	Library/Auditorium/Cafeteria
VAV Box System	Office Suite
Individual Unit Ventilators	Classrooms/Lounges

The Two-Pipe Change Over System

The obvious characteristic of this system is that only two sets of pipes (one for supply and one for return) serve the units in the building. Chilled water is provided by two 225-ton air-cooled chillers and hot water is provided by two 3,322-MBH natural gas boilers. A three-way mixing valve provides a controlled mixture of return and supply water. Change-over valves control the operation of the system based on seasonal requirements. The chilled water supply temperature is 45°F and the hot water supply temperature is 180°F. Chilled water is returned at 55°F, while hot water is returned at 160°F.

Direct Expansion (DX) Air Handlers

A large portion of the building also uses DX/gas air handling units. These large pre-packaged units utilize direct expansion cooling and gas-fired heating. These single-zone constant air volume (CAV) units are not fed from a centralized boiler/chiller plant and thus operate independently from one another. This offers a high level of controllability for the occupant, and ease of installation for the contractor. The drawback to this system is its inefficiency, which can lead to relatively high electricity costs in the summer and relatively high natural gas costs in the winter. The replacement of this system will serve as the main focus of this report. For further information, please see the following note on scope reduction and **Section 2** of the report.

1.3 Reduction of Scope

Because of the sheer size of the project and the invitation to improve certain aspects of the existing base design, the scope of this study has been reduced significantly. The split-pipe changeover system that occupies a majority of the academic building remains unchanged. Other major systems that have been considered in this report will be discussed below.

Figure 1-B. *A majority of the depth study occurs in the building's athletic facility.*

In the athletic facility, seven pre-packaged DX/gas air handling units have been replaced by a more energy efficient ground-source heat pump network. This study occupies the majority of the depth work presented in this report. In the academic facility, the delivery of outdoor air has been improved in the auditorium's stage area. Breadth topic selection, and more importantly, their integration with depth topic items are provided in their respective sections in this report. The results of these studies, in detail, have been provided below.

2. Project Depth Study

The project's depth study is separated into two different sub-projects, each with its own implications which have come to define the non-mechanical breadth studies presented in this report. The first is a redesign of the current systems in the building's athletic facilities to include a ground-source heat pump network which has been influenced by an accompanying lighting system redesign. The second involves the diversion of outdoor air delivery to the building's auditorium, where the acoustic effects of such a diversion will be examined. Further breadth study details can be found in **Section 3** and **Section 4** of this report.

The design suggestions provided within these studies are presented as if they had been implemented in the building's original design and are presented in an "A vs. B" format. Had the building been finished at the time of this study's conception, a retrofit analysis may have been more effective.

2A.1 Existing Athletic Building Systems Analysis

As part of the preliminary analysis that was conducted before the conception of this report, an annual energy use and cost simulation was performed using Carrier's *Hourly Analysis Program* (HAP). Without diverging from the primary focus of this report, several tables and screenshots from this program are provided below to give the reader an understanding of how the system was simulated and how the resulting figures will influence the conclusions made by this report. The figures provide a step-by-step progression through the simulation process and aim to logically condense its results.

For purposes of brevity, design parameters and sizing data from *HAP* will not be provided in this report. It is confirmed (from previous observation) that the systems sized using *HAP* closely match those in the design documents and should provide similar simulated results. Therefore, this section of the report will focus on schedules, fuel and electricity rates, and other parameters that will specifically affect the annual simulation. Please reference **Table 2-A**, provided below for design values for mechanical systems in the AAJHS athletic complex.

Table 2-A ***Athletic Building Equipment Schedule***

Mark	Total CFM	Min. O.A. CFM	Cooling (DX)			Heating (Gas)		
			MBH	EAT	LAT	MBH	EAT	LAT
AHU A-1	7400	3875	306.3	82.3	55	560	35.3	100
AHU A-2	7400	3875	306.3	82.3	55	560	35.3	100
AHU A-3	3200	1440	122.6	81.1	55	200	40.5	100
AHU A-4	3200	1440	122.6	81.1	55	200	40.5	100
AHU A-5	13150	1500	378.5	76.6	55	560	63.8	100
AHU A-6	2250	1475	102.7	84.2	55	200	27	100
AHU A-7	3650	1040	122	79	55	200	51.5	100

Fractional and Thermostat Schedules

The following screen shots indicate how occupancy schedules were assigned using *HAP*. The schedules were created based off of assumed occupancy over a standard 180-day school year.

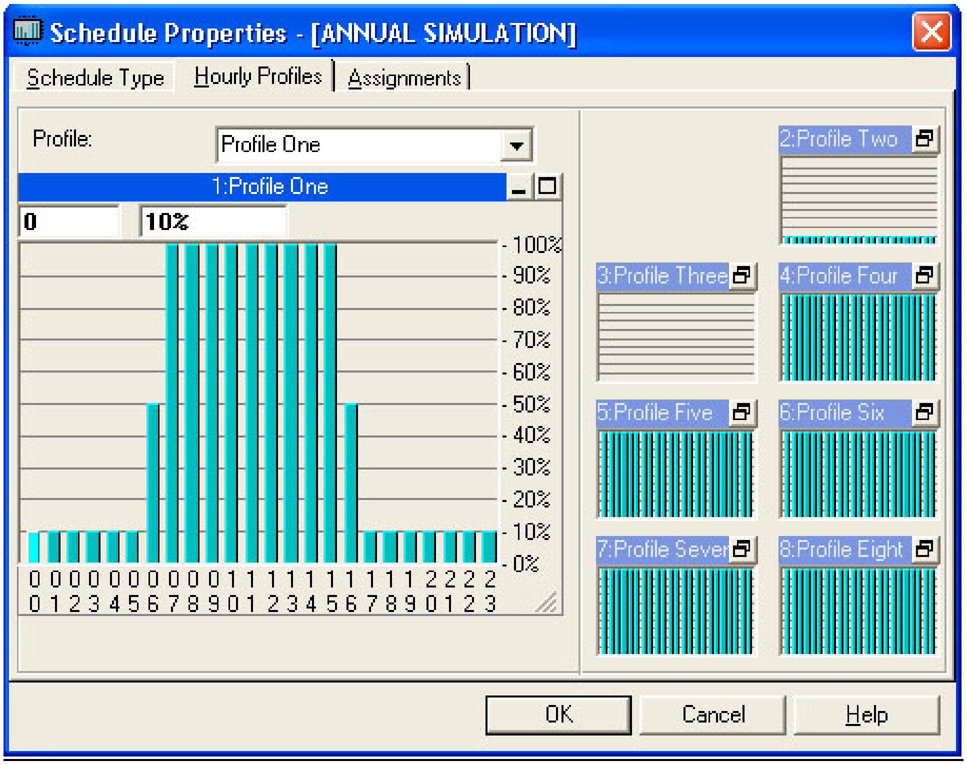


Figure 2-A. *Occupancy schedule profile 1 used by HAP.*

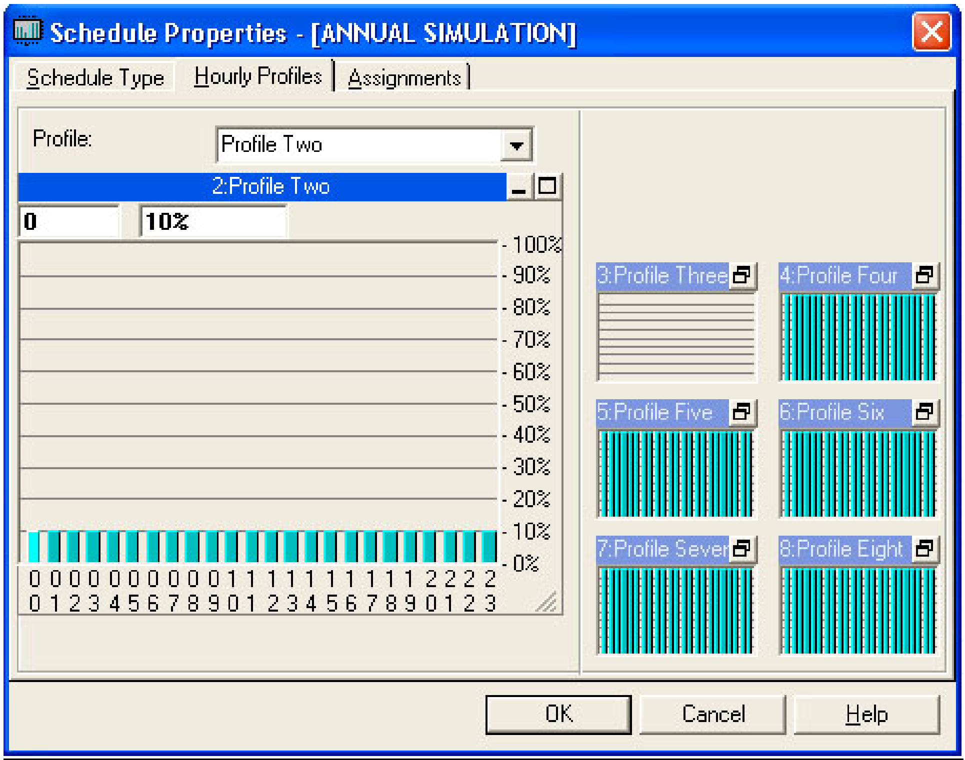


Figure 2-B. *Occupancy schedule profile 2 used by HAP.*

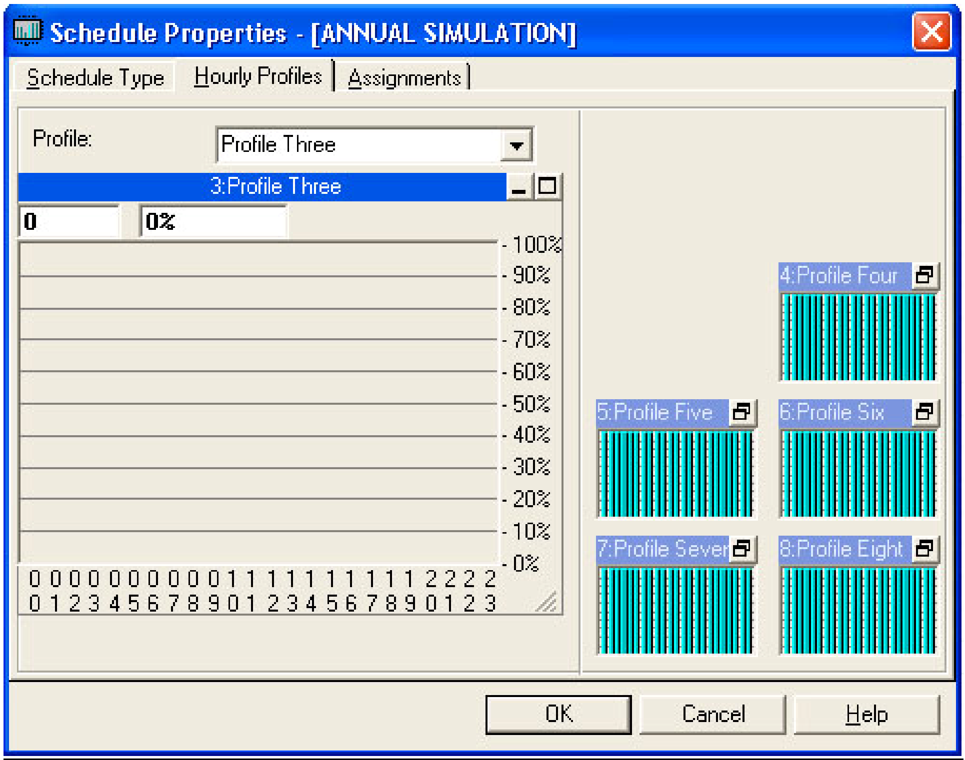


Figure 2-C. *Occupancy schedule profile 3 used by HAP.*

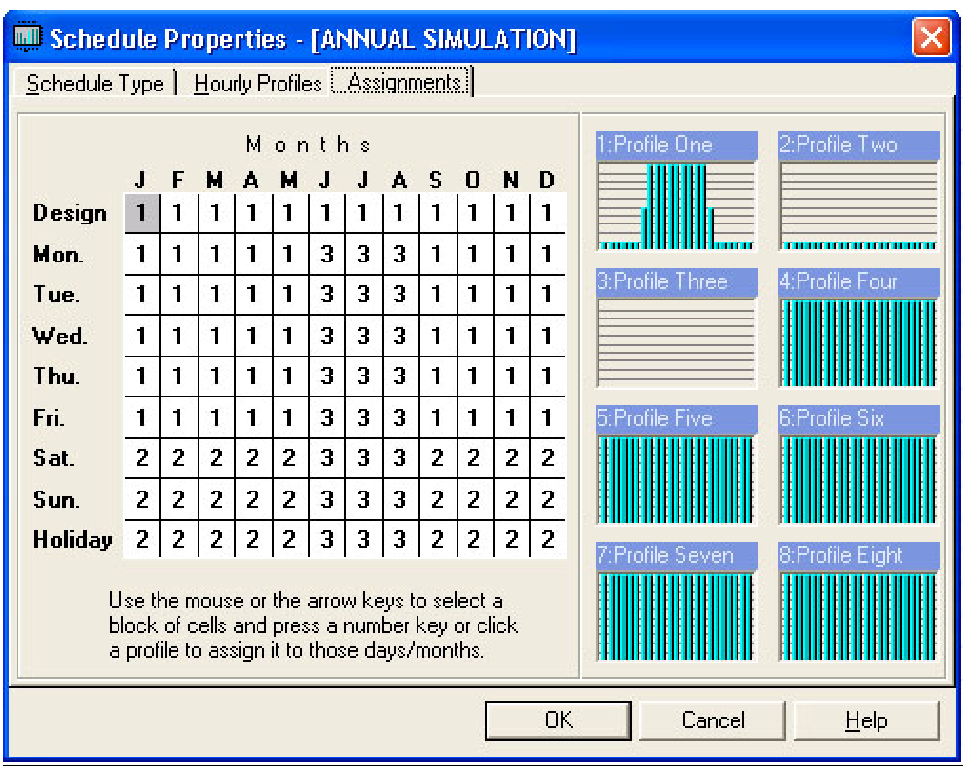


Figure 2-D. *Occupancy schedule annual assignments used by HAP.*

The following screen shots indicate how thermostat schedules were assigned using *HAP*. The schedules were created based off of assumed occupancy over a standard 180-day school year.

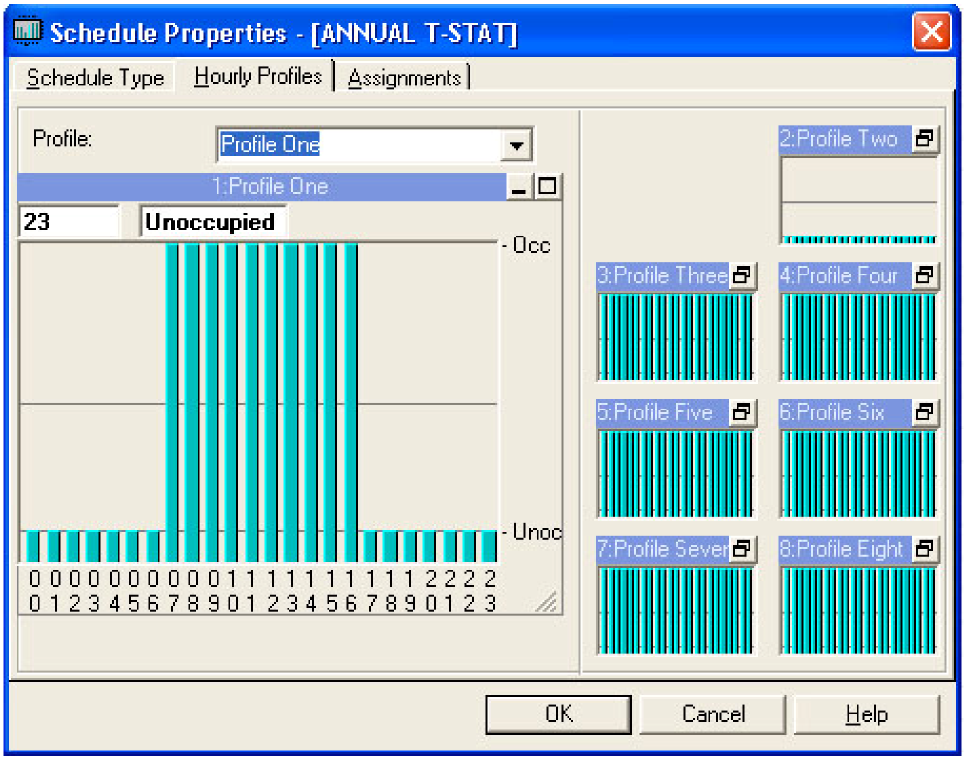


Figure 2-E. *Thermostat schedule profile 1 used by HAP.*

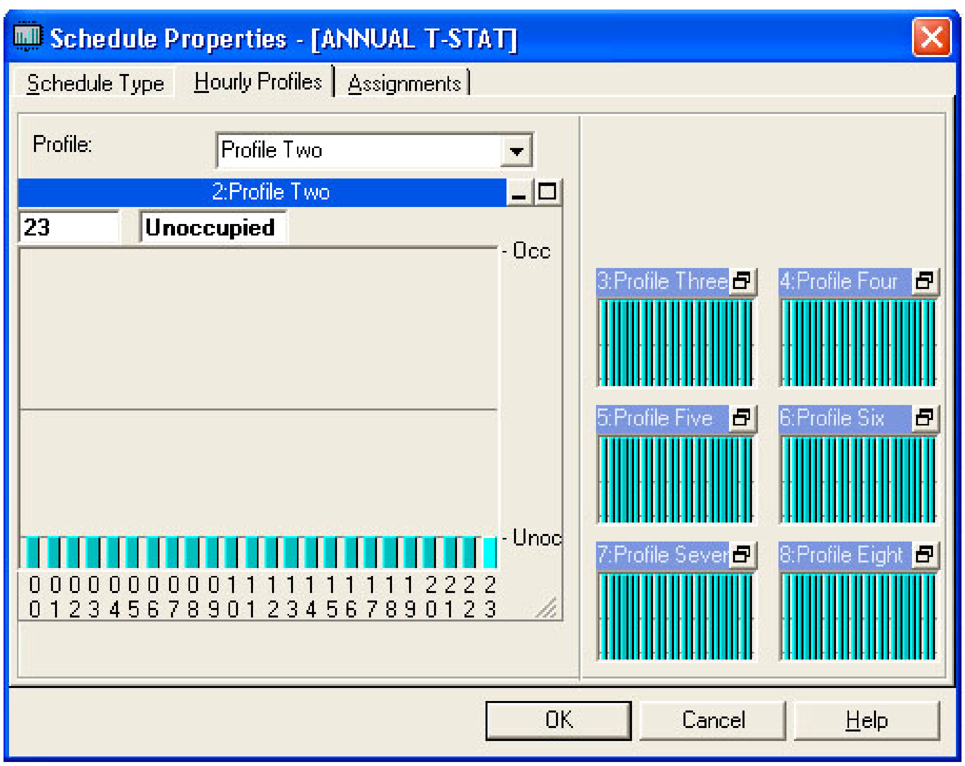


Figure 2-F. *Thermostat schedule profile 2 used by HAP.*

Fuel and Electric Rates

The fuel and electric rates used in the *HAP* simulation are based off of local electricity and natural gas supplier rate tariffs. Please see Schedules A1 and A2 in **Appendix A** for a detailed break-down of the rates used in the simulation.

System Simulation

Because the project scope has been reduced for this report, a total building simulation has not been performed. Instead, each of the systems located in the AAJHS athletic wing has been simulated independently. This is possible due to the fact that each of the DX/gas single-zone CAV air handling units operate independently of each other and are not supplied by a central boiler or chiller. The following tables present the results of each system's simulation.

AHUs A-1 and A-2

These air handling units split the load in the larger of two gymnasiums, a zone that occupies approximately 11,200 ft^2 of floor space. The result of each system's simulation is identical and is thereby only shown once.

Table 2-B *Yearly Simulation for AHUs A-1 & A-2*

Cooling	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Load (kBTU)	0	0	126	3633	16507	0	0	0	25871	2918	497	44
Load (kWh)	0	0	37	1064	4833	0	0	0	7575	854	146	13
Power (kWh)	0	0	43	1245	5655	0	0	0	8863	999	171	15
Heating	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Load (kBTU)	17121	13140	5674	2524	95	0	0	0	0	1017	4168	13149
Load (Therms)	171	131	57	25	1	0	0	0	0	10	42	131
Energy (Therms)	214	164	71	31	1	0	0	0	0	13	53	164

AHUs A-3 and A-4

These air handling units split the load in the smaller of the two gymnasiums, a zone that occupies approximately 7,420 ft^2 of floor space. The result of each system's simulation is identical and is thereby only shown once.

Table 2-C *Yearly Simulation for AHUs A-3 & A-4*

Cooling	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Load (kBTU)	0	0	22	1163	5570	0	0	0	8916	564	75	0
Load (kWh)	0	0	6	341	1631	0	0	0	2611	165	22	0
Power (kWh)	0	0	7	399	1908	0	0	0	3055	193	26	0
Heating	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Load (kBTU)	7720	5765	2896	897	0	0	0	0	0	512	1934	5581
Load (Therms)	77	58	29	9	0	0	0	0	0	5	19	56
Energy (Therms)	96	73	36	11	0	0	0	0	0	6	24	70

AHU A-5

This air handling unit serves the concourse of the building's athletic wing, a zone that occupies approximately 4,280 ft^2 of floor space.

Table 2-D *Yearly Simulation for AHU A-5*

Cooling	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Load (kBTU)	0	0	460	2233	8627	0	0	0	12544	1698	13	0
Load (kWh)	0	0	135	654	2526	0	0	0	3673	497	4	0
Power (kWh)	0	0	158	765	2955	0	0	0	4297	581	5	0
Heating	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Load (kBTU)	13730	6512	1286	556	14	0	0	0	0	136	2324	12764
Load (Therms)	137	65	13	6	0	0	0	0	0	1	23	128
Energy (Therms)	171	81	16	8	0	0	0	0	0	1	29	160

AHU A-6

This air handling unit serves the locker rooms in the building's athletic wing, a zone that occupies approximately 3,550 ft^2 of floor space.

Table 2-E *Yearly Simulation for AHU A-6*

Cooling	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Load (kBTU)	0	0	0	296	1688	0	0	0	2813	31	0	0
Load (kWh)	0	0	0	87	494	0	0	0	824	9	0	0
Power (kWh)	0	0	0	102	578	0	0	0	964	11	0	0
Heating	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Load (kBTU)	7771	5946	3661	1792	155	0	0	0	14	1524	3008	6041
Load (Therms)	78	59	37	18	2	0	0	0	0	15	30	60
Energy (Therms)	98	74	46	23	3	0	0	0	0	19	38	75

AHU A-7

This air handling unit serves the fitness rooms in the building's athletic wing, a zone that occupies approximately 7,250 ft^2 of floor space.

Table 2-F *Yearly Simulation for AHU A-7*

Cooling	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Load (kBTU)	0	0	9	1139	5378	0	0	0	7581	208	30	0
Load (kWh)	0	0	3	333	1575	0	0	0	2220	61	9	0
Power (kWh)	0	0	4	390	1843	0	0	0	2597	71	11	0
Heating	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Load (kBTU)	8758	5939	1258	285	0	0	0	0	0	0	968	6178
Load (Therms)	88	59	13	3	0	0	0	0	0	0	10	62
Energy (Therms)	110	74	16	4	0	0	0	0	0	0	13	78

Estimated Annual Energy Consumption

The total estimated annual energy consumption has been itemized and is provided below.

Table 2-G *Estimated Annual Energy Consumption*	
HVAC Components	
Electric	60,490 kWh
Natural Gas	3,190 Therms
Non-HVAC Components	
Electric	88,310 kWh
Totals	
Electric	**148,800 kWh**
Natural Gas	**3,190 Therms**

These estimated grand totals will be used in the overall economic analysis in **Section 5**.

Estimated Annual Energy Costs

The total estimated annual costs have been itemized and are provided below.

Table 2-H *Estimated Annual Energy Costs*	
HVAC Components	
Cooling	$7,420
Heating	$12,970
Subtotal	**$20,390**
Non-HVAC Components	
Lights	$11,620
Subtotal	**$11,620**
Totals	
Grand Total	**$32,010**

Therefore the estimated grand total for annual cost, including cooling, heating, and lights, is $32,010. The totals presented here will be used in the overall economic project analysis in **Section 5**.

2A.2 Considered Alternative Solution

As a result of preliminary studies and analysis, an alternative solution including a radiant floor system was explored before the final proposal had been prepared. The details of this consideration and its ultimate rejection are provided below.

Radiant Floor Heating/Cooling

Upon initial inspection, a radiant floor system may have provided a feasible solution to the project's money- and energy-saving goals. In the case of the Altoona Area Junior High School, such a system installed in the athletic wing of the building could utilize the existing boiler and chiller plants to provide hot and chilled water to the piping network. Furthermore, based on initial assumptions, this system had the potential to eliminate the need for existing DX/gas units and their relatively high energy and fuel consumption. By sharing centrally-supplied hot and chilled water, a radiant floor system had the potential to significantly reduce cost and energy consumption, as well as fundamentally simplifying the design and its implications.

Figure 2-G. *A Radiant floor system provided an attractive solution for the project.*

2A.3 The Ground-source Heat Pump System

In order to familiarize the reader with GSHP systems and their design process, a brief introduction is provided below. The remainder of this report uses terminology that assumes the reader has some level of familiarity with GSHP systems. If a word or phrase is not familiar, it is likely that it has been discussed here.

The Vertical Closed-loop System

A vertical closed-loop system has been selected for this project because land area available for loop field placement is limited at the Altoona Area Junior High School site. If more land were available, a horizontal closed loop system, which requires more available land area, may have been selected. "Vertical", in this application, indicates that the bores drilled into the ground extend vertically down into the ground, usually between 100-400 feet. "Closed loop" indicates that the piping loops are not open to an outside thermal source, such as well or surface body water. A visual depiction of a vertical, closed-loop system is provided below in **Figure 2-H**.

The basic operation of a ground-source heat pump is similar to that of a traditional air-source heat pump, except heat exchange occurs between the earth (soil) and a water or antifreeze solution pumped through a loop manifold installed therein. Several bores can be included on a parallel loop which connects to a central vault which supplies the main feed lines entering the building. The heat pump units installed inside the building work with traditional duct delivery methods to provide conditioned air to the spaces within the building.

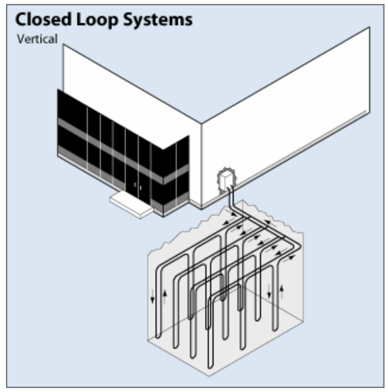


Figure 2-H. *A visual explanation of a vertical closed-loop GSHP system.*

GSHP Advantages

Besides the fundamental advantages of a GSHP system, which include reduced energy consumption and operating costs, there are also some significant architectural advantages:

- Users report a higher level of thermal comfort
- The units are very quiet
- System offers greater level of humidity control
- Low system maintenance
- No externally-mounted equipment

A ground-source heat pump system can also be used for a variety of buildings, ranging from small residential to very large commercial projects. The disadvantage is that the initial equipment and installation costs are typically higher than most traditional HVAC systems. These high initial costs can be offset by low operating and maintenance costs and typically have a fast payback period.

To read about how a GSHP system could potentially reduce energy consumption and operating costs for the Altoona Area Junior High School, please see the several following report sections.

2A.4 Initial Considerations

Before embarking on the actual design of the GSHP system for this project, one must consider several limiting considerations: most notably, the location and size of the loop field and soil conditions. In most practical applications, budget considerations may also limit design variables. In this case, where specific variables are known, they are given. Otherwise, industry standards and program defaults are used.

GSHP Loop Field Site Selection

Upon initial inspection of the site surrounding the Altoona Area Junior High School (see **Figure 2-B)**, one may notice that a significant amount of space is occupied by parking lots for the building. This would seem to indicate that the placement of a GSHP loop field would be an easy undertaking: simply excavate a sufficient area of parking lot, drill bores, install pipe network, and replace the parking lot surface. This is often an easy and affordable method of implementation in many projects, but further examination of the AAJHS master plan, presents an even more logical solution.

A rather large amount of land adjacent to the AAJHS site is currently occupied by Roosevelt Junior High School, one of the schools that will be replaced by the new junior high school. As a part of the new school's master plan, the Roosevelt school building is to be demolished to facilitate the construction of a soccer field at its current site. Because of the ease offered by utilizing this site, it has been selected as the location for the GSHP loop field for this project.

Figure 2-I. *The Roosevelt school site offers 112,600 square feet of land that could be utilized for a GSHP loop field.*

Figure 2-I, provided above, shows the location of the Roosevelt school site, its adjacency to the Altoona Area Junior High building, and its relative size. An examination of design documents indicates that Roosevelt Junior High School and its athletic field occupy approximately 112,600 square feet, an attractive parcel of land for GSHP loop field selection. With some construction phasing considerations that go beyond the scope of this report, it would seem entirely feasible to construct a GSHP loop field after Roosevelt school's demolition, especially considering the Altoona Area School District already owns the site.

Load Increase due to Daylighting

The proposed addition of daylighting to the school's gymnasiums has altered the design loads for which the GSHP system will be designed. **Table 2-I**, provided below, summarizes these increases in both cooling and heating loads for the system. Please see **Section 3** for further details.

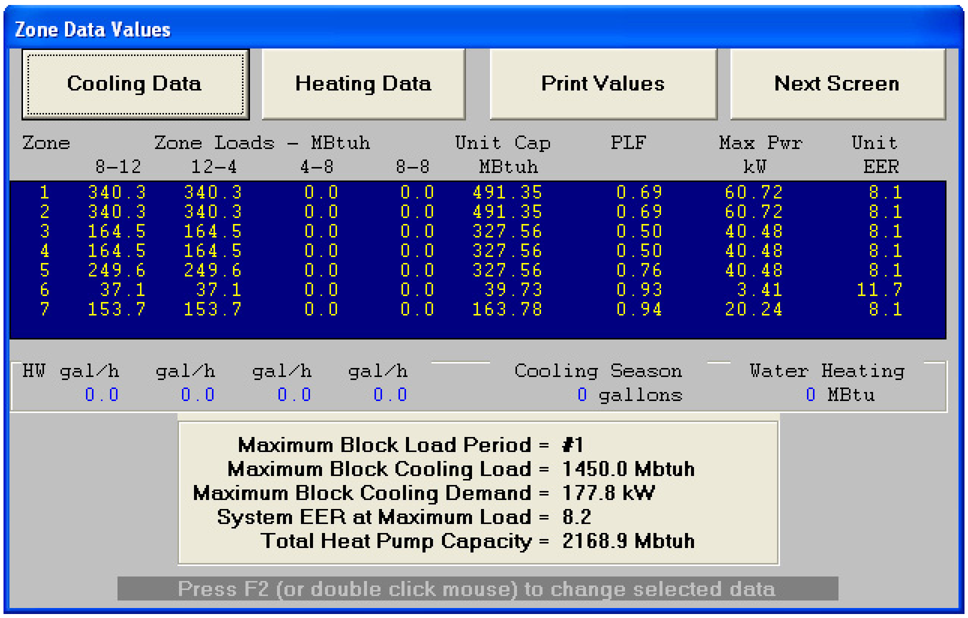
Table 2-I ***Increased Loading due to Daylighting***

Space	Cooling	Heating
Gym #1	50.4 MBH	77.4 MBH
Gym #2	21.3 MBH	29.1 MBH

2A.5 Designing the System

With design loads (including the effects of daylighting) provided by the *Carrier HAP* software and an available 112,600 square feet of land for loop field placement, it was time to begin designing the ground-source heat pump system that replaces the existing DX/gas air handlers in the school's athletic wing. A free and easy-to-use program offered by practitioners at the University of Alabama called *GCHPCalc* proved to be an excellent design tool during the progression of this study. Several screen shots and tables from the program appear in this section, aiding the reader's understanding by condensing important parameters in one location. If interested, the software may be obtained at http://www.geokiss.com/index.htm.

Updated Loading Information



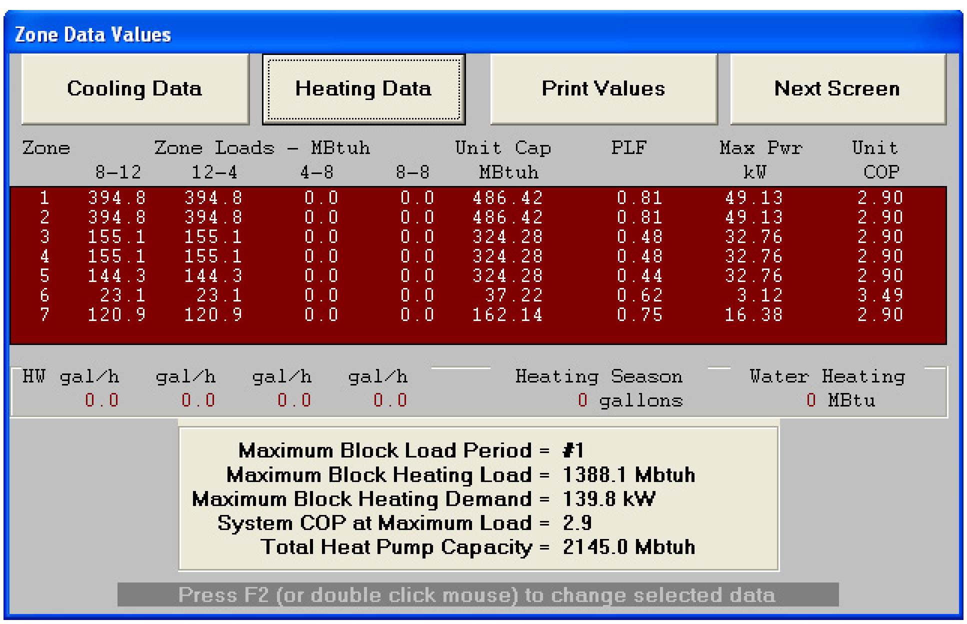
Zone	Zone Loads – MBtuh 8-12	12-4	4-8	8-8	Unit Cap MBtuh	PLF	Max Pwr kW	Unit EER
1	340.3	340.3	0.0	0.0	491.35	0.69	60.72	8.1
2	340.3	340.3	0.0	0.0	491.35	0.69	60.72	8.1
3	164.5	164.5	0.0	0.0	327.56	0.50	40.48	8.1
4	164.5	164.5	0.0	0.0	327.56	0.50	40.48	8.1
5	249.6	249.6	0.0	0.0	327.56	0.76	40.48	8.1
6	37.1	37.1	0.0	0.0	39.73	0.93	3.41	11.7
7	153.7	153.7	0.0	0.0	163.78	0.94	20.24	8.1

HW gal/h	gal/h	gal/h	gal/h	Cooling Season	Water Heating
0.0	0.0	0.0	0.0	0 gallons	0 MBtu

Maximum Block Load Period = #1
Maximum Block Cooling Load = 1450.0 Mbtuh
Maximum Block Cooling Demand = 177.8 kW
System EER at Maximum Load = 8.2
Total Heat Pump Capacity = 2168.9 Mbtuh

Press F2 (or double click mouse) to change selected data

Figure 2-J. *Zone cooling data provided by the GCHPCalc program.*



Zone	Zone Loads – MBtuh 8-12	12-4	4-8	8-8	Unit Cap MBtuh	PLF	Max Pwr kW	Unit COP
1	394.8	394.8	0.0	0.0	486.42	0.81	49.13	2.90
2	394.8	394.8	0.0	0.0	486.42	0.81	49.13	2.90
3	155.1	155.1	0.0	0.0	324.28	0.48	32.76	2.90
4	155.1	155.1	0.0	0.0	324.28	0.48	32.76	2.90
5	144.3	144.3	0.0	0.0	324.28	0.44	32.76	2.90
6	23.1	23.1	0.0	0.0	37.22	0.62	3.12	3.49
7	120.9	120.9	0.0	0.0	162.14	0.75	16.38	2.90

HW gal/h	gal/h	gal/h	gal/h	Heating Season	Water Heating
0.0	0.0	0.0	0.0	0 gallons	0 MBtu

Maximum Block Load Period = #1
Maximum Block Heating Load = 1388.1 Mbtuh
Maximum Block Heating Demand = 139.8 kW
System COP at Maximum Load = 2.9
Total Heat Pump Capacity = 2145.0 Mbtuh

Press F2 (or double click mouse) to change selected data

Figure 2-K. *Zone heating data provided by the GCHPCalc program.*

With loads provided by the *Carrier HAP* program (including the additional loads from utilizing daylighting) and an estimated occupancy schedule, the loading inputs for the *GCHPCalc* program are provided above in **Figure 2-J** and **Figure 2-K**.

Design Water Temperatures/Flow Rates

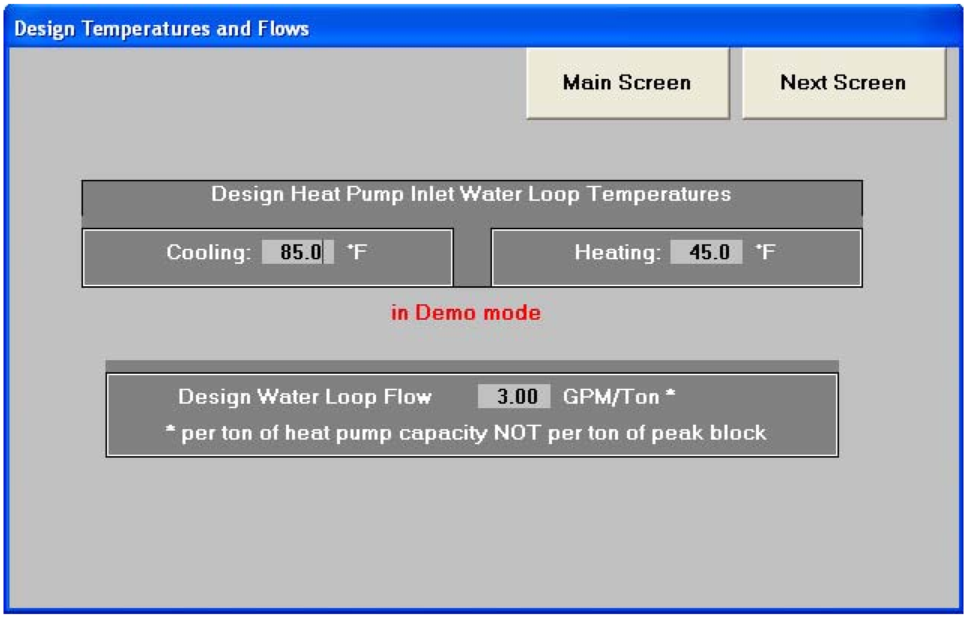


Figure 2-L. *Design temperatures and flow rates provided by the GCHPCalc program.*

Ground Temperatures and Properties

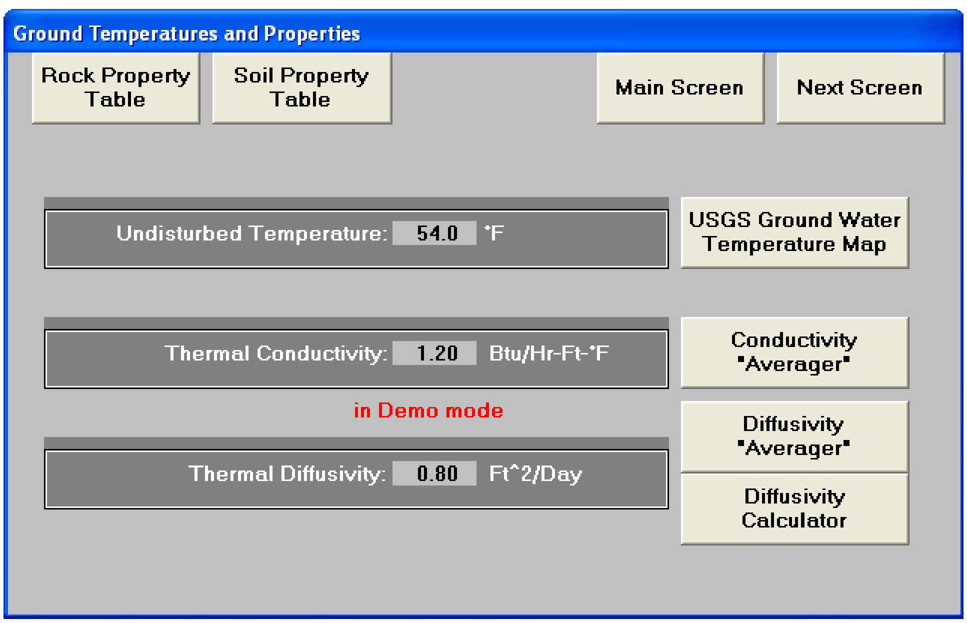


Figure 2-M. *Ground properties used by the GCHPCalc program.*

Please note that undisturbed ground temperature was obtained using the US Geological Survey ground water temperature map, which is provided in Figure 1 of **Appendix A**. Also note that values for thermal conductivity and diffusivity are based on program defaults. It is assumed that if a ground-source heat pump system were to be actually installed, a detailed study would be conducted on-site, providing the designer with more accurate soil property data. While no such study has been conducted for this report, the estimated cost of this procedure has been factored into the economic analysis provided later in this section.

Bore Hole/Pipe Resistance

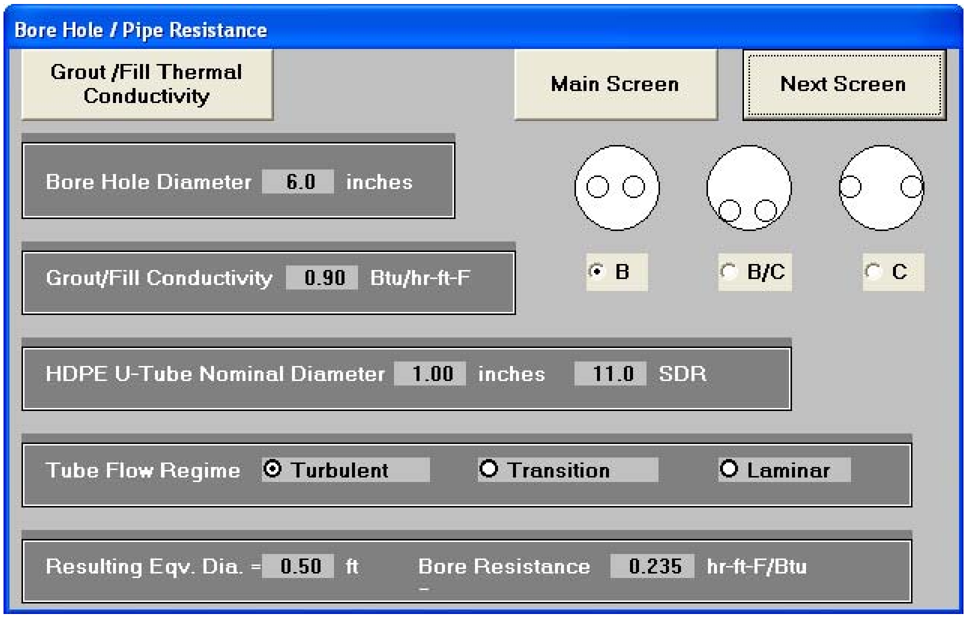


Figure 2-N. *Bore hole and pipe data used by the GCHPCalc program.*

Please note that most data used in this area is based off of program defaults and industry standards. It is also worth noting that, if they were to change, any of these values may be easily changed and its influence on the final result can be determined quickly.

Loop Field Configuration

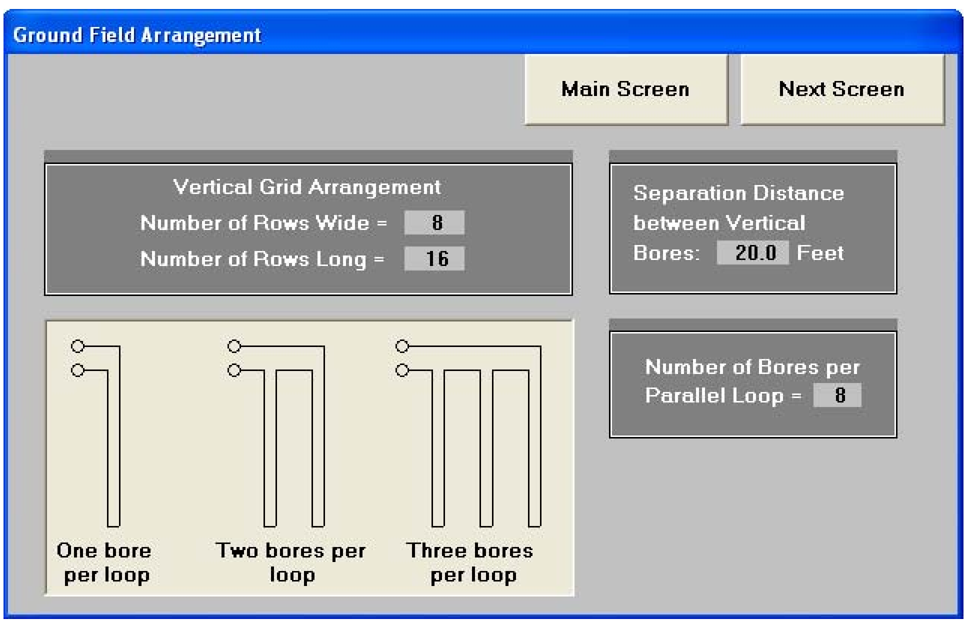


Figure 2-O. *The loop field arrangement used by the GCHPCalc program.*

An eight by sixteen vertical grid arrangement has been selected for this design, based on the space available at the site. This gives a total of 128 bores, whose depth will be determined by the *GCHPCalc* program.

Figure 2-P. *A visual depiction of the 8x16 loop field arrangement and its relation to the school.*

Figure 2-P, while not to scale, allows the reader to visualize how an 8x16 loop field fits into the Roosevelt Junior High School site. It also shows the position of the vault, its proximity to the new school, and a possible location for pipeline access.

Required Bore Lengths

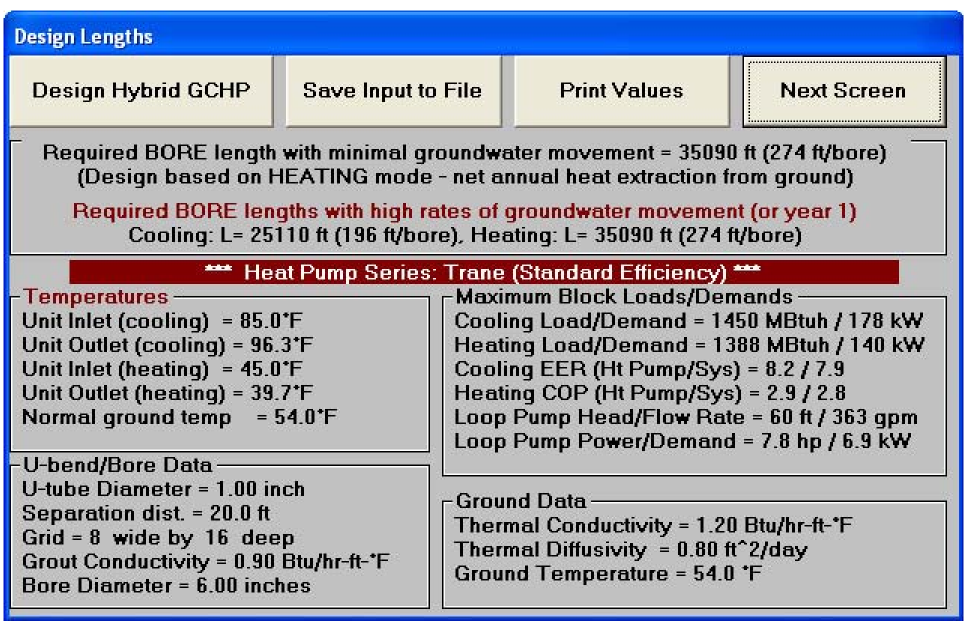


Figure 2-Q. *The required bore length provided by the GCHPCalc program.*

As is indicated by the program outputs, a minimum depth of 274 feet is required for each bore. The total equivalent length is given as 35,090 feet, which can be verified by multiplying 128 bores times 274 ft/bore, which gives 35,072 feet, a figure very close to the program output.

Equipment Selection and Integration

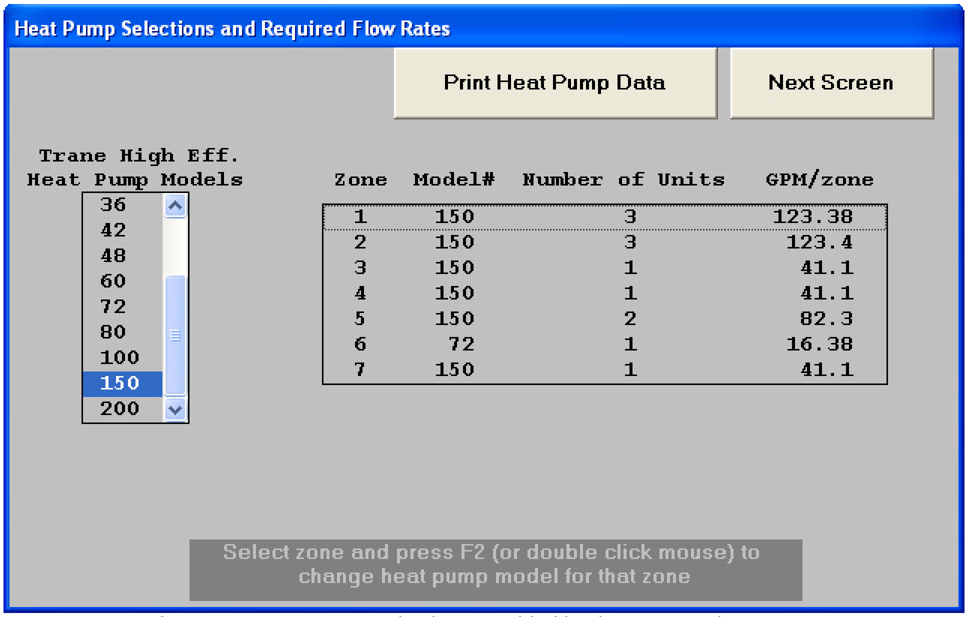


Figure 2-R. *Heat pump selections provided by the GCHPCalc program.*

The *GCHPCalc* program also offers the designer a choice of generic heat pump models and suggests sizes and quantities based on the selected system. The program indicates that a total of eleven #150 and one #72 Trane high efficiency heat pumps should be selected for this project. The generic model numbers, in this case, indicate the nominal size for each unit. Here, #150 corresponds to a 12.5-ton vertical water-source heat pump (WSHP), and #72 corresponds to a 6-ton vertical WSHP. These units are part of the 6-25 ton GEV commercial WSHP product series. Please view the equipment literature located in **Appendix B** for further general information and specification data.

2A.6 Modeling the System

With data provided by the *GCHPCalc* program and known design parameters, a cost and energy consumption simulation could be conducted. For this part of the study, *RETScreen International*, a sustainable energy modeling program provided free from the government of Canada, was utilized. Several screen shots and tables provided by the program are used in the following section to clarify the modeling procedure and the outputs that have been calculated. If interested, the software may be obtained at http://www.retscreen.net/.

Climate Data

The *RETScreen International* software contained climate data for Altoona, PA in its database. In this case, the data had been collected at the Blair County Airport, as can be seen below in **Figure 2-S**. Values have been changed to English units to assist the reader in interpreting the data. This data will assist the software when running its algorithm for providing energy consumption and cost figures for the project.

RETScreen

Country		United States of America	
Province / State		Pennsylvania	
Climate data location		Altoona Blair Co Arpt	
Latitude	°N	40.3	
Longitude	°E	-78.3	Source
Elevation	ft	1,479.7	Ground
Heating design temperature	°F	9.5	Ground
Cooling design temperature	°F	85.8	Ground
Earth temperature amplitude	°F	36.4	NASA

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°F	%	kWh/m²/d	kPa	mph	°F	°F-d	°F-d
Jan	27.9	67.4%	1.72	96.9	9.2	24.4	1,133	0
Feb	30.9	65.3%	2.48	96.9	8.7	28.0	937	0
Mar	37.9	63.6%	3.32	96.8	9.2	36.7	820	0
Apr	49.3	61.9%	4.33	96.7	8.7	48.7	454	0
May	59.2	67.3%	4.96	96.8	7.2	59.5	162	285
Jun	68.0	71.2%	5.60	96.8	6.3	68.7	0	540
Jul	71.8	72.6%	5.45	96.9	5.6	72.3	0	675
Aug	69.6	74.7%	4.90	97.0	4.9	70.5	0	608
Sep	62.4	74.5%	3.94	97.1	5.6	62.8	59	373
Oct	52.3	69.7%	2.83	97.1	6.7	50.5	374	73
Nov	42.3	68.0%	1.79	97.0	8.3	39.7	664	0
Dec	32.2	69.5%	1.46	96.9	8.5	28.8	999	0
Annual	50.4	68.8%	3.57	96.9	7.4	49.3	5,602	2,553
Source	Ground	Ground	NASA	NASA	Ground	NASA	Ground	Ground
			Measured at	ft	32.8	0		

Figure 2-S. *Climate data for Altoona, PA provided by RETScreen International.*

Load Inputs

Building Heating and Cooling Load		Estimate	Notes/Range
Type of building	-	Commercial	
Available information	-	Descriptive data	
Building floor area	m²	3,130	
Number of floors	floor	1	1 to 6
Window area	-	Standard	
Insulation level	-	High	
Occupancy type	-	Daytime	
Equipment and lighting usage	-	Moderate	
Building design heating load	kW	70.9	
	million Btu/h	0.242	
Building heating energy demand	MWh	140.7	
	million Btu	479.9	
Building design cooling load	kW	209.6	
	ton (cooling)	59.6	
Building cooling energy demand	MWh	310.6	
	million Btu	1,059.7	Return to Energy Model sheet

Figure 2-T. *Load inputs for the RETScreen International software.*

Please note that several parameters had to be converted to metric units for compatibility with the program. In this case, building floor area has been converted from 33,680 square feet to 3,130 square meters. Also note that the loads calculated by the *RETScreen* software are imprecise and have been used only in estimating the costs associated with the GSHP system. For a more complete and accurate breakdown of system loads, please see **Section 2A.1**.

Site Conditions

Site Conditions		Estimate	Notes/Range
Project name		AAJHS	See Online Manual
Project location		Altoona, PA	
Available land area	m²	4,760	
Soil type	-	Light rock	
Design heating load	kW	70.9	Complete H&CLC sheet
Design cooling load	kW	209.6	

Figure 2-U. *Site condition parameters for the RETScreen International software*

System Characteristics

System Characteristics		Estimate	Notes/Range
Base Case HVAC System			
Building has air-conditioning?	yes/no	Yes	
Heating fuel type	-	**Natural gas**	
Heating system seasonal efficiency	%	80%	55% to 350%
Air-conditioner seasonal COP	-	3.0	2.4 to 5.0
Ground Heat Exchanger System			
System type	-	Vertical closed-loop	
Design criteria	-	Cooling	
Typical land area required	m²	1,051	
Ground heat exchanger layout	-	Standard	
Total borehole length	m	3,621	
Heat Pump System			
Average heat pump efficiency	-	Standard	
Standard cooling COP	-	3.50	
Standard heating COP	-	2.80	
Total standard heating capacity	kW	176.6	
	million Btu/h	0.603	
Total standard cooling capacity	kW	201.3	
	ton (cooling)	57.3	
Supplemental Heating and Heat Rejection System			
Suggested supplemental heating capacity	kW	0.0	
	million Btu/h	0.000	
Suggested supplemental heat rejection	kW	0.0	
	million Btu/h	0.000	

Figure 2-V. *System characteristics for the RETScreen International software*

Annual Energy Production

Annual Energy Production		Estimate	Notes/Range
Heating			
Electricity used	MWh	66.0	
Supplemental energy delivered	MWh	0.0	
GSHP heating energy delivered	MWh	**140.7**	
	million Btu	479.9	
Seasonal heating COP	-	2.1	2.0 to 5.0
Cooling			
Electricity used	MWh	87.0	
GSHP cooling energy delivered	MWh	**310.6**	
	million Btu	1,059.7	
Seasonal cooling COP	-	3.6	2.0 to 5.5
Seasonal cooling EER	(Btu/h)/W	12.2	7.0 to 19.0
			Complete Cost Analysis sheet

Figure 2-W. *Annual energy production estimated by RETScreen International.*

2A.7 Results

With the outputs provided by the *RETScreen International* software, one may begin to assemble a feasibility study: namely, cost and energy consumption figures. While *RETScreen International* provides a detailed breakdown of the associated costs for the GSHP system, many of the parameters are program defaults and are not editable. Therefore many of the cost outputs provided by the program have been altered to more accurately reflect the considerations of this particular project.

Initial costs

Much of the cost for the proposed GSHP system will come from initial costs: preliminary studies, development, engineering fees, equipment costs, system balance, and other miscellaneous costs. Each of these items has been estimated by detailed break-down and is provided in the tables below.

Table 2-J *Estimated Feasibility Study Costs*		
Site Investigation	$	650
Soil/hydrology Assessment	$	1,625
Preliminary Design	$	1,050
Detailed Cost Estimate	$	975
Report Preparation	$	1,200
Travel and Accommodation	$	0
Feasibility Study Credit	$	(3,000)
Total	$	2,500

Table 2-K *Estimated Development Costs*		
Permits and Approvals	$	650
Land Survey	$	650
Project Financing	$	1,260
Project Management	$	1,875
Travel and Accommodation	$	0
Development Credit	$	(2,500)
Total	$	1,935

Table 2-L *Estimated Engineering Costs*		
GSHP System Design	$	2,625
Tenders and Contracting	$	1,625
Construction Supervision	$	1,875
Engineering Credit	$	(4,500)
Total	$	1,625

Table 2-M *Estimated Equipment Costs*		
Heat Pumps	$	66,442
Circulating Pumps	$	2,909
Circulating Fluid	$	1,664
Drilling and Grouting	$	43,451
Ground HX loop pipes	$	18,105
Fittings and Valves	$	2,416
ECHS Credit	$	(20,000)
Total	$	114,986

Table 2-N *Estimated System Balance Costs*		
Supplemental Heating System	$	0
Supplemental Heat Rejection	$	0
Internal Piping and Insulation	$	12,080
Balance of System Credit	$	(1,000)
Total	$	11,080

Table 2-O *Estimated Miscellaneous Costs*		
Training	$	980
Contingencies	$	19,946
Total	$	20,946

Total Estimated Initial Cost

The total estimated initial costs have been itemized and are provided below. The overall total will be used in the overall economic project analysis in **Section 5**.

Table 2-P *Total Estimated Initial Costs*		
Feasibility Study	$	2,500
Development	$	1,935
Engineering	$	1,625
Equipment	$	114,986
System Balance	$	11,080
Miscellaneous	$	20,946
Total	$	153,072

Therefore the estimated grand total for initial cost, including feasibility studies, development, engineering, equipment, system balance, and miscellaneous costs, is $153,072.

Annual Costs

Annual costs estimated by *RETScreen International* include operation and maintenance costs and fuel and electricity costs. Each of these items has been itemized and is provided in tabular form below.

Table 2-Q *Estimated O&M Costs*		
O&M Labor	$	2,500
Travel and Accommodations	$	(3,500)
Contingencies	$	6,606
Total	$	5,606

Table 2-R *Estimated Fuel and Electricity Costs*		
Electricity	$	9,182
Incremental Electricity Load	$	1,275
	$	10,457

Total Estimated Annual Cost

The total estimated annual costs have been itemized and are provided below.

Table 2-S *Total Estimated Annual Costs*	
Operation and Maintenance	$ 5,606
Fuel and Electricity	$ 10,457
Total	$ 16,063

The estimated grand total for annual cost, including operation and maintenance, and fuel and electricity, is $16,063. The totals presented here will be used in the overall economic project analysis in **Section 5**.

Total Estimated Annual Energy Consumption

Table 2-T *Total Est. Energy Consumption*	
Cooling	87,000 kWh
Heating	66,000 kWh
Total	153,000 kWh

The estimated grand total for annual energy consumption is 153,000 kWh. This total will be used in the overall economic project analysis in **Section 5**. Note that no natural gas figure is given here because this GSHP system does not consume any.

2B.1 Stage Analysis Summary

Preliminary analysis indicated that the Altoona Area Junior High School auditorium stage would experience a deficiency of outdoor air delivery, given the current HVAC system design. A comparison with ASHRAE Std. 62-1 provisions indicates that the stage is deficient by approximately 1190 CFM of outdoor air as designed. This comparison also confirmed that the band room, a space directly adjacent to the stage, would experience a surplus of 1230 CFM of outdoor air. These spaces are served by two roof-mounted CW/HW air handling units, given the marks AHU C-2 and AHU C-3, respectively. A summary of these findings is provided below in **Table 2-U**.

Table 2-U *Actual and Calculated OA Requirement Comparison*

System	Space	Min OA Actual	Min OA Calculated	Difference
AHU C-2	Stage	200 CFM	1390 CFM	-1190 CFM
AHU C-3	Band Room	2305 CFM	1075 CFM	+1230 CFM

These findings invite the prospect of improving air quality for the auditorium by diverting outdoor air delivery from the band room to the stage. That is, AHU C-3 would potentially serve multiple zones: the stage and the band room. Successfully doing so would mandate the redesign of duct work in this area of the building and perhaps some minor equipment resizing. This procedure is not explored in this report. Instead, these findings serve as justification for examining acoustic considerations brought on by this proposed air diversion scheme. For more information, please see **Section 4** of this report.

3. Lighting Breadth Study

Among the topics available to explore in a breadth study relevant to this report, lighting seemed a logical choice. More precisely, this is an exploration of the use of daylighting with the use of skylights, and its impact on HVAC considerations. Therefore the design of a daylighting system in the gymnasiums and its impact on the overall project analysis is presented here.

The objective of this study is to further reduce energy consumption by limiting the use of a traditional lighting system. The intent is not to replace the lighting system in the AAJHS gymnasiums, but to use a daylighting system in tandem with the existing design. It is useful to note that in most practical applications, a control system would be implemented when daylighting is utilized, but the design and configuration of such a system is quite sophisticated. While the use of such a control system is considered in the following simulation data, the operational details have been omitted.

3A. Designing and Modeling the System

Like many pieces of engineering software, the program *SkyCalc Skylight Design Assistant*, allows the engineer to form a design by adjusting parameters based on simulated results. The *SkyCalc* program was utilized for both the design and simulation of the daylighting-only system. Several of the following tables and screenshots were taken directly from the program and present a condensed summary of input parameters and simulation outcomes.

Note that climate data utilized by the program is from Albany, NY, the closest geographically available data to Altoona, PA. Target lighting level is set to 30 fc, the standard for gymnasium playing surfaces.

Input Parameters

Gymnasium #1

Building		
Building type	Class, K-12 9 mo	
Bldg area	19,000	ft^2
Ceiling height	35	ft
Wall color	Off-white paint	

Figure 3-A. *Building inputs for Gymnasium #1 used in the SkyCalc program.*

Building	Default	User Revisions	Design Input
Building width (ft)	97	100	100
Building length (ft)	195	Change width or area	190
Wall reflectance	70%	60%	60%
Ceiling reflectance	70%	70%	70%
Floor reflectance	20%	20%	20%
Shelving reflectance	40%		40%
Roof U-value (Btu/h•°F•ft^2)	0.063		0.063

Figure 3-B. *Additional building inputs for Gymnasium #1 used in the SkyCalc program.*

Electric Lighting	Default	User Revisions	Design Input
Lighting setpoint (fc)	50	30	30
Task height (ft)	2.50	0.00	0.00
Lighting power density (W/ft^2)	0.73	1.10	1.10
Fraction lighting uncontrolled	10%		0.10
Lighting schedule	Classroom, K-12	Default	Classroom, K-12
Room and luminaire depreciation	80%		80%

Figure 3-C. *Electric lighting inputs for Gymnasium #1 used in the SkyCalc program.*

Skylights:		
Number of skylights	30	
Skylight width	6	ft
Skylight length	8	ft
Max skylight spacing = 52.5 ft (1.5 x ceiling ht)		
Skylight Description		
Glazing type	Polycarbonate	
Glazing layers	Triple glazed	
Glazing color	Clear prismatic	
Skylight Well		
Light well height	1	feet
Well color	Off-white paint	
Safety grate or screen	(•) Yes, ( ) No	

Figure 3-D. *Selected skylight inputs for Gymnasium #1 used in the SkyCalc program.*

Please note that the skylight dimensions and quantities given here are based on review of the simulation results and geometric considerations. At any time, these values may be changed to attain desired simulation results.

Gymnasium #2

Building		
Building type	Class, K-12 9 mo	
Bldg area	7,400	ft^2
Ceiling height	35	ft
Wall color	Off-white paint	

Figure 3-E. *Building inputs for Gymnasium #2 used in the SkyCalc program.*

Building	Default	User Revisions	Design Input
Building width (ft)	61	74	74
Building length (ft)	122	Change width or area	100
Wall reflectance	70%	60%	60%
Ceiling reflectance	70%	70%	70%
Floor reflectance	20%	20%	20%
Shelving reflectance	40%		40%
Roof U-value (Btu/h•°F•ft^2)	0.063		0.063

Figure 3-F. *Additional building inputs for Gymnasium #2 used in the SkyCalc program.*

Electric Lighting	Default	User Revisions	Design Input
Lighting setpoint (fc)	50	30	30
Task height (ft)	2.50	0.00	0.00
Lighting power density (W/ft^2)	0.83	1.10	1.10
Fraction lighting uncontrolled	10%		0.10
Lighting schedule	Classroom, K-12	Default	Classroom, K-12
Room and luminaire depreciation	80%		80%

Figure 3-G. *Electric lighting inputs for Gymnasium #2 used in the SkyCalc program.*

Skylights:		
Number of skylights	12	
Skylight width	6	ft
Skylight length	8	ft

Max skylight spacing = 52.5 ft (1.5 x ceiling ht)

Skylight Description	
Glazing type	Polycarbonate
Glazing layers	Triple glazed
Glazing color	Clear prismatic

Skylight Well		
Light well height	1	feet
Well color	Off-white paint	
Safety grate or screen	(•) Yes,	( ) No

Figure 3-H. *Selected skylight inputs for Gymnasium #2 used in the SkyCalc program.*

Again, note that the skylight dimensions and quantities given here are based on review of simulation results and geometric considerations.

Simulation Outputs

Gymnasium #1

Dome Skylight Effective Aperture = 2.43%, Skylight to Floor Ratio (SFR) = 7.58%

Average daylight footcandles (fc)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	4	19	41	59	72	73	62	45	22	6	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	1	11	38	67	91	97	103	93	71	46	18	3	0	0	0	0	0	0
Mar	0	0	0	0	0	0	7	30	61	90	109	117	117	112	94	62	34	10	0	0	0	0	0	0
Apr	0	0	0	0	0	5	24	56	89	113	140	146	138	136	116	80	52	22	4	0	0	0	0	0
May	0	0	0	0	2	14	42	75	110	134	152	170	166	160	141	107	71	36	10	0	0	0	0	0
Jun	0	0	0	0	4	20	50	87	112	149	158	169	165	159	137	108	79	46	16	3	0	0	0	0
Jul	0	0	0	0	2	15	42	80	116	151	169	180	179	165	148	110	81	45	17	3	0	0	0	0
Aug	0	0	0	0	0	7	30	68	104	131	157	167	166	152	133	98	64	32	7	0	0	0	0	0
Sep	0	0	0	0	0	2	17	48	80	107	130	136	141	128	101	72	37	11	1	0	0	0	0	0
Oct	0	0	0	0	0	0	6	27	54	81	103	104	100	88	65	39	13	1	0	0	0	0	0	0
Nov	0	0	0	0	0	0	1	10	30	46	64	66	65	56	40	18	4	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	4	19	39	54	63	60	49	32	14	2	0	0	0	0	0	0	0

Design Illuminance = 30 fc

< 1 fc; < 15 fc; < 30 fc; > 30 fc;

Figure 3-I. *A graphic spread of footcandle values over a one-year period for Gymnasium #1.*

Gymnasium #2

Dome Skylight Effective Aperture = 2.50%, Skylight to Floor Ratio (SFR) = 7.78%

Average daylight footcandles (fc)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	4	17	36	52	63	64	54	39	19	5	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	1	10	34	58	80	85	90	81	62	40	16	3	0	0	0	0	0	0
Mar	0	0	0	0	0	0	7	26	53	79	95	102	102	98	83	54	30	9	0	0	0	0	0	0
Apr	0	0	0	0	0	4	21	49	78	99	123	128	121	119	101	70	46	19	4	0	0	0	0	0
May	0	0	0	0	2	13	37	66	97	117	133	149	145	140	123	94	62	32	9	0	0	0	0	0
Jun	0	0	0	0	3	18	44	76	98	131	138	148	145	139	120	94	70	40	14	2	0	0	0	0
Jul	0	0	0	0	2	14	37	70	102	132	148	158	156	144	130	96	71	39	15	2	0	0	0	0
Aug	0	0	0	0	0	7	26	60	91	115	138	147	145	133	116	86	56	28	6	0	0	0	0	0
Sep	0	0	0	0	0	2	15	42	70	94	114	119	123	112	88	63	32	10	1	0	0	0	0	0
Oct	0	0	0	0	0	0	6	24	47	71	90	91	88	77	57	34	12	1	0	0	0	0	0	0
Nov	0	0	0	0	0	0	1	9	26	41	56	57	57	49	35	16	3	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	4	17	34	47	55	53	42	28	12	2	0	0	0	0	0	0	0

Design Illuminance = 30 fc

< 1 fc; < 15 fc; < 30 fc; > 30 fc;

Figure 3-J. *A graphic spread of footcandle values over a one-year period for Gymnasium #2.*

From these results it is apparent that skylights will provide either over-abundance or a deficiency of light. Using the existing lighting system and diffuse bezels over the skylights will solve this problem, without sacrificing the comfort of the occupant.

3B. Results

Space Renderings

To examine the success of an installed daylighting system, it is often useful to utilize a light-rendering program to provide a visualization of the target space. In this instance, the program

AGI was used to make basic renderings of the gymnasiums. The design visualization time and date was set to noon during the winter solstice to provide a worst-case scenario depiction.

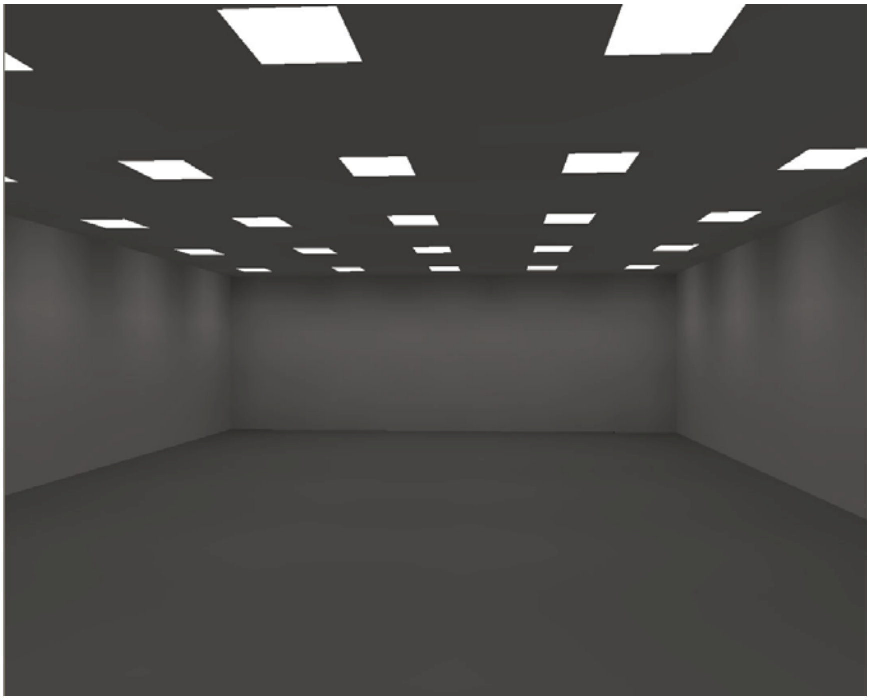


Figure 3-K. *A winter solstice interior rendering for daylight only in Gymnasium #1 by AGI.*

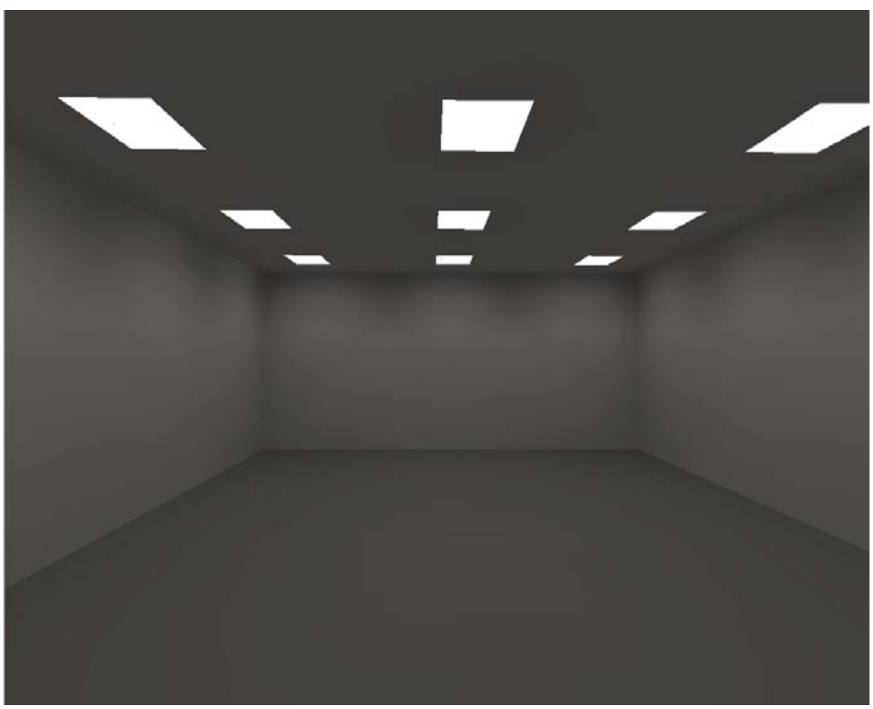


Figure 3-L. *A winter solstice interior rendering for daylight only in Gymnasium #2 by AGI.*

Estimated Annual Cost and Energy Savings

The final results from the *SkyCalc* simulation are presented in tabular form below.

Table 3-A ***Estimated Annual Energy Savings***	
Gymnasium #1	
Lights (kWh)	30,911
Gymnasium #2	
Lights (kWh)	11,778
Total (kWh)	42,689

Table 3-B ***Estimated Annual Cost Savings***	
Gymnasium #1	
Lights	$2,782
Gymnasium #2	
Lights	$1,060
Total	$3,842

The estimated grand total for annual energy savings is 42,689 kWh. The estimated grand total for annual cost savings is $3,842. These totals will be used in the overall economic project analysis in **Section 5**.

4. Acoustics Breadth Study

As indicated by the analysis provided in **Section 2B.1**, the Altoona Area Junior High School auditorium would experience a deficiency in outdoor air delivery given the current system design. Given that the system is reworked to address this deficiency, certain acoustical issues are raised, namely, the sound level effects of placing new diffusers in a space where sound attenuation is critical. The objective of this study is to explore the sound level ratings of the current design, the impact of the redesign, and possible improvements to be made to both systems.

4.1 The Current Design

An examination of the design documents for the project indicates that the building's stage is served by a large roof-mounted CW/HW air handling unit (AHU C-2) which distributes air to the space through five 14-inch round diffusers. **Table 4-A**, provided below, summarizes the characteristics of this air flow.

Table 4-A *Stage Diffuser Characteristics*		
Neck Size	**Air Flow**	**NC Rating**
14"	500 CFM	<20

Note that the diffuser air flow was obtained directly from the project design documentation. The noise criteria level (NC) was found using a reference chart provided by Krueger HVAC. Please see Schedule B2 in **Appendix B** for more information.

4.2 The Redesign

The proposed redesign would stipulate that at least 1190 CFM of additional air would have to be delivered to the stage space. An examination of the current design in **Section 4.1** indicates that the diffusers serving the stage already deliver 500 CFM, nominally. Pragmatism dictates that two additional diffusers of the same size could deliver 1000 CFM, nominally, without affecting the NC rating or other architectural concerns. This would reduce the stage's outdoor air deficiency to a virtually negligible amount.

4.3 Possible Improvements

Acoustics standards dictate that NC ratings must fall below a certain values to adequately eliminate background noise in performance-critical spaces. This value is generally accepted to be below 20. The characteristics of a typical air diffuser provided in **Table 4-A** indicate that 500 CFM of air flowing through a 14" neck size will result in a noise criteria rating that is below 20. Therefore, diverting outdoor air to the stage area would not result in any major acoustic concerns as long as the diffuser size is kept at 14" or greater. Typically, the larger the diffuser is sized, the lower the background noise will be. Diffusers are typically designed large in performance spaces for this reason.

Please see **Appendix B** for more information on diffuser sizing and noise criteria determination.

5. Project Summary

This section is included to indicate the success of the stated project goals in a concise, organized format. They address both depth study aspects as well as affected breadth studies. The procedures used to obtain the following facts and figures are detailed in the previous sections of this report.

Ground Source Heat Pump System (Mechanical Depth)

The HVAC system featuring seven single-zone CAV DX/gas air handling units that occupy the Altoona Area Junior High School athletic building as originally designed have been redesigned to feature a ground source heat pump (GSHP) system. The GSHP system was considered due to an anticipation of lowered energy consumption and cost. The results of this system redesign are presented below.

The GSHP system has been designed to feature an eight by sixteen (128 bores total) loop field configuration that will occupy a parcel of land currently occupied by Roosevelt Junior High School, a building slated to be demolished and replaced with a soccer field as a part of the AAJHS master plan. The design process was carried out with the aid of a computer program called *GCHPCalc*. The program stipulated that vertical bores for the GSHP system should be drilled to 274 feet below the earth surface. The program also suggested that eleven 12.5-ton and one 6-ton vertical high efficiency water-source heat pumps be selected and integrated into a traditional duct network, much like the one that currently exists as designed.

In order to gage the success of the GSHP system, a first and annual cost simulation was performed using the aid of a program called *RETScreen International*. The results of this simulation are presented below in comparison to the original design values.

Table 5-A *Estimated System First Cost*

Original	Redesign
$57,850	$153,070

Table 5-B *Estimated Annual Energy Consumption*

Original		Redesign	
Electricity	148,800 kWh	Electricity	198,620 kWh
Natural Gas	3,190 Therms	Natural Gas	0 Therms

Table 5-C *Estimated Annual Energy Costs*

Original		Redesign	
Cooling	$7,420	Energy	$10,460
Heating	$12,970		
Lights	$11,620	Lights	$7,780
Total	$32,010	**Total**	$18,240

Please note that the reduction in lighting costs can be attributed to the implementation of a daylighting system in the AAJHS gymnasiums. A summary of this breadth study is provided below.

Daylighting System (Lighting Breadth)

The existing lighting system in the AAJHS gymnasiums was not redesigned, but rather enhanced through the use of daylighting in the form of skylights. A program called *SkyCalc* aided in the design and simulation of the system. The program indicated that satisfactory daytime lighting levels could be achieved year-round by utilizing a number of 8x6-ft. triple-glazed polycarbonate skylights. Outcomes indicated that thirty skylights should be used in gymnasium #1, while twelve skylights would be sufficient in gymnasium #2. A program called *AGI* was used to make some simple renderings of the gymnasium spaces, which graphically enhanced the system's effectiveness.

Auditorium Increased Indoor Air Quality (Mechanical Depth)

Noted outdoor air deficiencies in the school's auditorium invited the prospect of correction through the diversion of air delivery from the air handling unit serving the band room. It was determined that an additional 1190 CFM of outdoor air was required to satisfy the provisions of ASHRAE Std. 62.1 – 2004. To correct this problem, the addition of two 500 CFM diffusers to the school stage space was considered. This correction invited the prospect of exploring acoustic considerations as a subsequent breadth study.

Air Diffuser Selection (Acoustics Breadth)

After determining that the proposed diversion of outdoor air to the school's auditorium was feasible, acoustic considerations were explored. An analysis of the existing air diffusers indicated that the noise criteria (NC) rating was adequate given their current 14-inch neck size and nominal air flow of 500 CFM. By diverting an additional 1000 CFM of outdoor air through the space and utilizing the same diffusers already specified in the design, the outdoor air requirement as well as an adequate NC rating has been achieved.

6. Conclusions

This section is provided to summarize the results of the studies conducted for this report and offer conclusions based on these results. As with the project summary in **Section 5**, these conclusions aim to integrate the main depth studies with subsequent breadth studies and present an overall project whose aspects intertwine in a relevant and interesting fashion.

Ground Source Heat Pump System and Gymnasium Daylighting System

This report has verified that the use of a ground source heat pump (GSHP) system has the potential to reduce annual maintenance and operating costs by as much as 57%, at the expense of a higher initial first cost. It was estimated that a GSHP system could cost as much as $95,000 more than the original design. Also it was determined that annual electricity consumption could increase by as much as 33%, while totally eliminating the need for natural gas usage in the system. Furthermore, while a proposed gymnasium daylighting system utilizing skylights increased the thermal loads for the system redesign, their potential in decreasing electric lighting costs as much as 67% has been demonstrated.

The findings of this report indicate that a GSHP system with integrated daylighting have the theoretical potential to significantly reduce energy costs and consumption. Therefore, this system should be considered as an adequate alternative to the original design.

Auditorium Increased Indoor Air Quality and Air Diffuser Selection

This report has verified the feasibility of diverting outdoor air from a space with a surplus to a space with noted deficiencies. The use of additional air diffusers will not have an adverse effect on background noise if the proper diffuser size is selected. If a diversion of outdoor air to meet the requirements of ASHRAE Std. 62.1 was carried out to improve the original design, it is the finding of this report that the acoustic considerations, while critical, are minimal.

References & Photo Credits

Altoona Area School District
http://www.aasdcat.com/aasd/

ANSI/ASA Std. 12.60 – 2002

ASHRAE Std. 62.1 – 2004

Ground Source Heat Pump Design
http://www.geokiss.com/

International Ground Source Heat Pump Association
http://www.igshpa.okstate.edu/

Krueger – Excellence in Air Distribution
http://www.krueger-hvac.com/

Performance Engineering Group
http://www.performanceengineering.com/

RETScreen International
http://www.retscreen.net/ang/home.php

Trane Commercial & Residential Air Solutions
http://www.trane.com/Default.asp

US Department of Energy
http://www.energy.gov/

Appendix A
Useful Schedules and Figures

Schedule A1. *Natural Gas Rate Tariffs*

THE PEOPLES NATURAL GAS COMPANY
d/b/a DOMINION PEOPLES

SUPPLEMENT NO. 93 TO GAS PA—PUC NO. 43
FIFTIETH REVISED PAGE NO. 39
CANCELING FORTY-NINTH REVISED PAGE NO. 39

RATE CS-L
COMMERCIAL SERVICE - LARGE

AVAILABILITY

This rate is available to commercial ratepayers consuming 1,000 Mcf or greater annually (other than those that the Company determines shall acquire service under Rate GS-SB or those that use natural gas as a motor vehicle fuel), located throughout the territory described in the "Description of Territory" in this tariff, and shall be applied to consumption for each month determined in accordance with Rule 10.

The Company shall determine the annual consumption of each CS-L ratepayer in order to assess the appropriate customer charge.
This rate will be used for provision of supplier of last resort service to commercial ratepayers.

RATE TABLE

Customer Charge per meter per month:		
For ratepayers with annual consumption equal to or greater than 1,000 Mcf but less than 2,500 Mcf	$34.20	
For ratepayers with annual consumption equal to or greater than 2,500 Mcf but less than 25,000 Mcf	$52.25	
For ratepayers with annual consumption equal to or greater than 25,000 Mcf	$332.50	
Delivery Charges:		
Delivery Charge per 1,000 cubic feet (Mcf)	$1.9506	
Capacity Charge per 1,000 cubic feet (Mcf)	$0.5236	(D)
Gas Cost Adjustment Charge per 1,000 cubic feet (Mcf)	$1.6971	(I)
Commodity Charge:		
Natural Gas Supply Charge per 1,000 cubic feet (Mcf)	$10.2183	(I)

MARKET BASED COMMODITY CHARGE ADJUSTMENT (CCA)

This adjustment will be applicable to Non-Priority One ratepayers that previously had been receiving transportation service from the Company for at least twelve consecutive months and transfers to service under this rate schedule. Once applied, the CCA will be applicable for twelve consecutive months of service under this rate schedule. The Gas Cost Adjustment Charge shall not be applicable if the CCA is being charged.

The CCA shall be determined monthly and shall equal the difference between the Company's city gate price and the currently effective commodity charge under this rate schedule. The CCA shall never be less than zero. The Company's city gate price shall be based on the first of the month Dominion Transmission Inc. Appalachia Index price as published in *Inside FERC's Gas Market Report* plus applicable Dominion Transmission, Inc. transportation charges and retainage.

MINIMUM MONTHLY BILL

The minimum monthly bill per meter shall be the customer charge per ratepayer per month. In the event of an emergency curtailment in the delivery of gas by the Company to a ratepayer pursuant to Rule 17, or complete or partial suspension of operation by the ratepayer due to fire, flood, explosion, or other similar acts of God, the minimum monthly bill may be reduced in direct proportion to the ratio of the number of days of curtailed service or complete or substantial suspension of operation to the number of days in the billing period.

ISSUED: March 31, 2008 EFFECTIVE: April 1, 2008

Schedule A1. *Natural Gas Rate Tariffs (continued)*

THE PEOPLES NATURAL GAS COMPANY

GAS PA—PUC NO. 43
ORIGINAL PAGE NO. 40

RATE CS-L
COMMERCIAL SERVICE - LARGE

SURCHARGES

All applicable riders to this tariff.

LATE-PAYMENT CHARGE

A late-payment charge of 1.50 percent per month shall be applied for failure to make payment in full for all charges billed by the Company by the due date shown on the bill. This charge is to be calculated on the overdue portion of the bill, excluding any unpaid late-payment charges.

RULES AND REGULATIONS

The Company's Rules and Regulations in effect from time to time, where not inconsistent with any specific provision hereof, are a part of this rate schedule.

WAIVER

The Company reserves the right to waive the ratepayer customer charge per meter for additional meters. An example of when this charge may be waived is if the Company determines that such meters have been installed principally and primarily for the Company's convenience and not due to the load characteristics of the ratepayer.

ISSUED: March 2, 2000

EFFECTIVE: March 3, 2000

Schedule A2. *Electricity Rate Tariffs*

PENNSYLVANIA ELECTRIC COMPANY

Electric Pa. P.U.C. No. 79
Original Page 100

RATE SCHEDULES

RATE GS-LARGE
GENERAL SERVICE SECONDARY - TIME-OF-DAY RATE

AVAILABILITY:

This Rate is available to Full Service and Delivery Service Customers using electric service through a single delivery location for lighting, heating and/or power service whose registered demand is equal to or greater than 400 KW in two (2) consecutive months and Off-peak Thermal Storage Customers whose registered demand is equal to or greater than 100 KW in two (2) consecutive months. THE OFF-PEAK THERMAL STORAGE PROVISION SHALL BE RESTRICTED TO EXISTING CUSTOMERS AT EXISTING LOCATIONS AS OF JANUARY 11, 2007. Secondary voltage shall be supplied to Customers at a single transformer location when load does not require transformer capacity in excess of 2,500 KVA. Upon a Customer's request, the Company may, at its option, provide transformers having a capacity of greater than 2,500 KVA.

New Customers requiring transformer capacity in excess 2,500 KVA and existing Customers whose load increases such that a transformer change is required (over 2,500 KVA) shall be required to take untransformed service.

All of the following charges are applicable to Full Service Customers. All of the following charges, excluding the Generation Charge and the Transmission Charge, are applicable to Delivery Service Customers.

GENERAL MONTHLY CHARGES:

Distribution Charge

$41.29 per month, plus
$4.70 per kW for all billed kW
$0.254 per KVAR

Competitive Transition Charge

$1.75 per kW for all billed kW

Issued: January 17, 2007 Effective: January 11, 2007

Schedule A2. *Electricity Rate Tariffs (continued)*

PENNSYLVANIA ELECTRIC COMPANY

Electric Pa. P.U.C. No. 79
Original Page 101

RATE SCHEDULES

Rate GS-Large (continued)

Generation Charge

4.827 cents per kWh for all kWh

Transmission Service Charge (Per Rider D – Transmission Service Charge Rider)

0.616 cents per kWh for all kWh (January 11, 2007 through May 31, 2008)

From June 1, 2008 forward, the Company will provide and charge for Transmission Service to Customers taking Full-Service in accordance with the provisions of Rider D - Transmission Service Charge Rider, which charge shall apply to all kWh billed under this Rate Schedule.

Issued: January 17, 2007

Effective: January 11, 2007

Schedule A2. *Electricity Rate Tariffs (continued)*

PENNSYLVANIA ELECTRIC COMPANY

Electric Pa. P.U.C. No. 79
Original Page 102

RATE SCHEDULES

Rate GS-Large (continued)

DETERMINATION OF BILLING DEMAND:

The monthly billing demand shall be the higher of:

1. The maximum 15-minute integrated demand registered during the On-peak hours during the month.
2. Forty percent (40%) of the maximum 15-minute integrated demand registering at any time during the month.

KVAR DEMAND

The monthly reactive billing demand shall be the maximum 15-minute integrated reactive demand registered at any time during the month.

The On-peak hours shall be from 8:00 a.m. to 8:00 p.m., prevailing time, Monday through Friday excluding holidays. All other hours shall be Off-peak. The Off-peak holidays are: New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day and Christmas Day. On-peak hours are subject to change from time to time by the Company after giving notice of such changes to Customers.

MINIMUM CHARGE:

No bill shall be rendered by the Company for less than,

$41.29 per month, plus

one-half (1/2) of the demand charge at current rate levels for the highest kilowatt demand billed during the current and preceding eleven (11) months.

Issued: January 17, 2007 Effective: January 11, 2007

Schedule A2. *Electricity Rate Tariffs (continued)*

PENNSYLVANIA ELECTRIC COMPANY

Electric Pa. P.U.C. No. 79
Original Page 103

RATE SCHEDULES

Rate GS-Large (continued)

PAYMENT TERMS:

As per Rule 13, Payment of Bills.

TERM OF CONTRACT:

Each Customer shall be required to enter into a service/supply contract with the Company for a minimum one (1) year term. The supply portion of the contract ("supply contract") applies to Generation Supply and is suspended when a Customer takes Delivery Service only and resumes with a new anniversary date when a Customer returns to Full Service. If the service/supply contract is terminated by the Customer prior to its expiration, the Minimum Charge provisions of this Rate Schedule shall apply. If the Customer's capacity or service requirements increase, the Company, in its sole and exclusive judgment, may at any time require the Customer to enter into a new service/supply contract.

GENERAL PROVISIONS:

A. COMBINED BILLING: This Provision is restricted as of June 18, 1976, to existing loads at existing locations. Combined Billing shall be permitted for three-phase multi-metered points at secondary voltages established prior to June 18, 1976. The billing demand shall be the sum of the individual demands of each metered service. Customer locations and loads may not continue to be billed under this General Provision A: (i) if the Customer increases the capacity of either service entrance wiring, or (ii) the Customer increases the electrical load in the facility necessitating a change in the Company's facilities.

Issued: January 17, 2007 Effective: January 11, 2007

Schedule A2. *Electricity Rate Tariffs (continued)*

PENNSYLVANIA ELECTRIC COMPANY

Electric Pa. P.U.C. No. 79
Original Page 104

RATE SCHEDULES

Rate GS-Large (continued)

B. SERVICE AT PRIMARY VOLTAGE: Customers served at Primary Voltage may be billed under this Rate GS-Large, at the Company's sole and exclusive discretion, when a Customer requires Primary Service at a voltage less than the nearest available Primary Voltage, if the Company agrees to provide the Primary Voltage requested by the Customer.

C. OFF-PEAK THERMAL STORAGE SERVICE: THIS PROVISION SHALL BE RESTRICTED TO EXISTING CUSTOMERS AT EXISTING LOCATIONS AS OF JANUARY 11, 2007 NO CUSTOMERS WILL BE PERMITTED TO TAKE SERVICE UNDER THIS PROVISION AFTER JANUARY 11, 2007. Available to Customers whose primary heating and/or cooling system is electric thermal storage. Electric thermal storage systems are those heating and cooling systems where the space conditioning of a building is provided by a system that uses energy primarily during Off-peak periods. On-peak hours for demand and energy billing shall be from 8:00 a.m. to 6:00 p.m., prevailing time, Monday through Friday during the billing months of October through May and 10:00 a.m. to 8:00 p.m., prevailing time, Monday through Friday during the billing months of June through September. All other hours shall be Off-peak.

D. MARKET BASED BILLING: All billing under the Standard Pricing Adjustment ("SPA") shall be in accordance with Rider L.

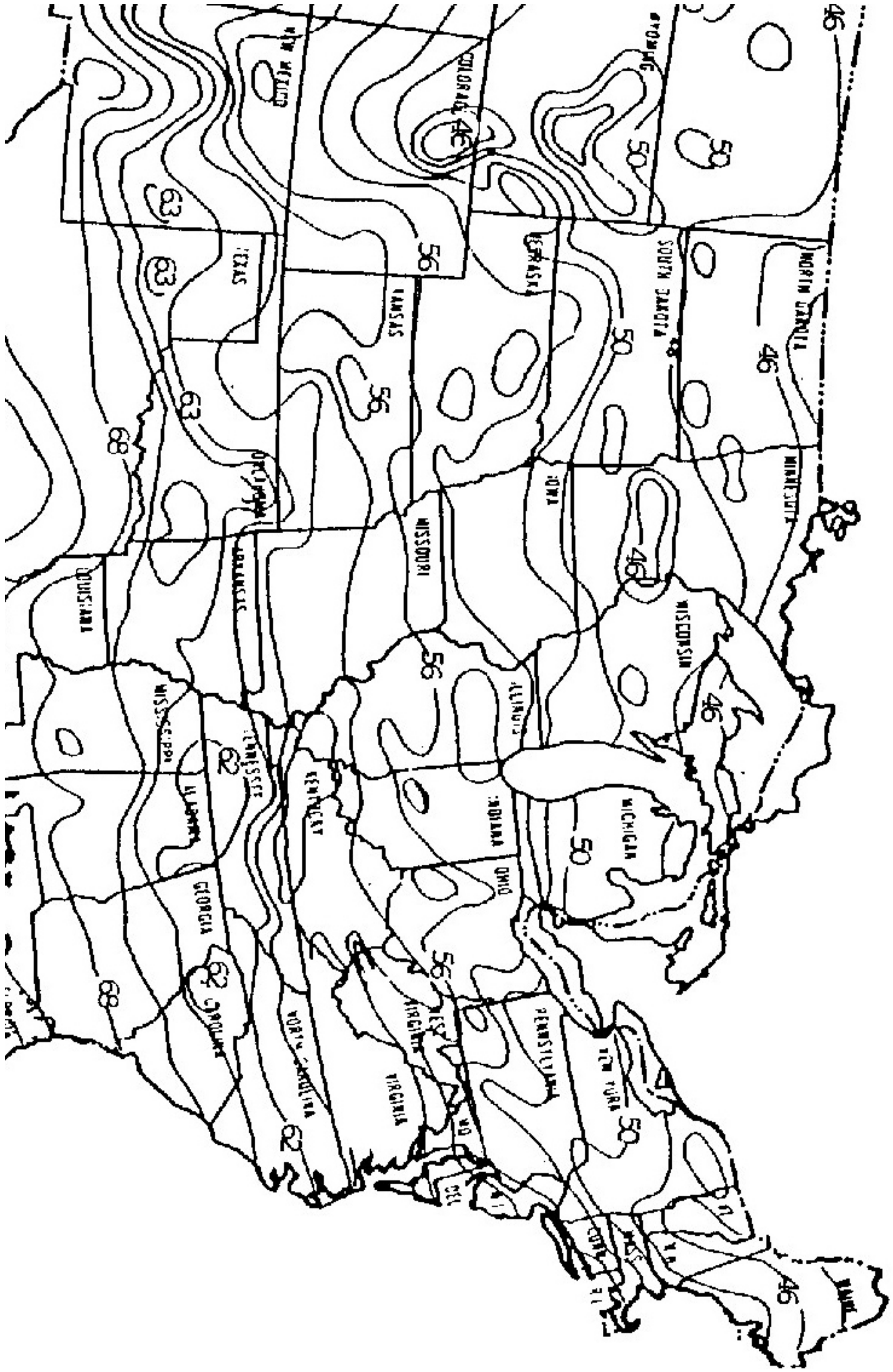
RIDERS:

Bills rendered by the Company under this Rate Schedule shall include the charges stated in or calculated by any applicable Rider.

Issued: January 17, 2007

Effective: January 11, 2007

Figure A1. *USGS Ground Water Temperature Map*



Appendix B
Equipment Literature

Schedule B1. *Trane WSHP Cut Sheets*

TRANE

High Efficiency Horizontal/Vertical Water-Source Heat Pump

Models GEHB/GEVB

6 to 25 Tons - 60 Hz

April 2006

WSHP-PRC014-EN

Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Introduction

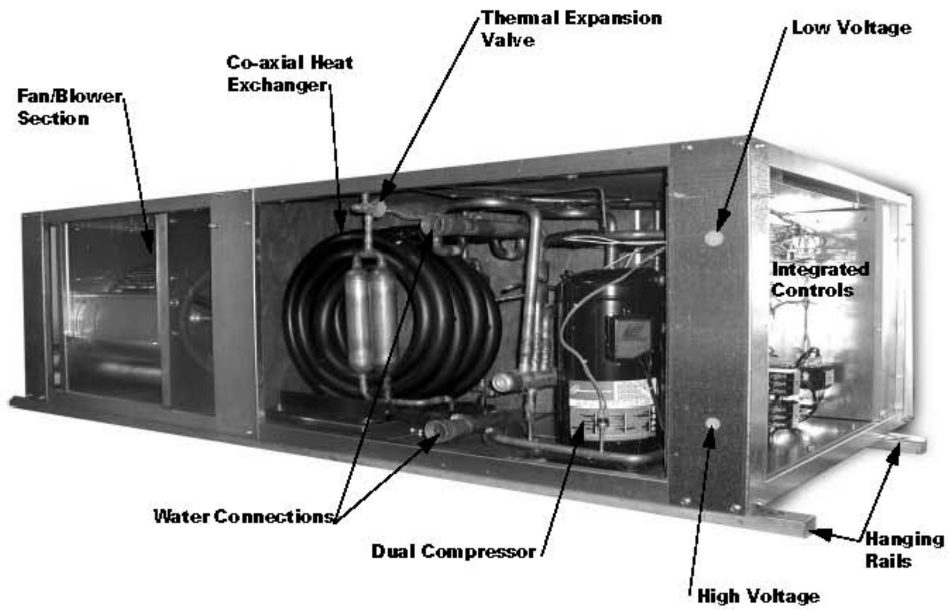
Feature Highlights

The 6 through 25 ton horizontal and vertical water-source heat pump is used in a broad range of applications. Schools, office buildings, health care/rehabilitation facilities, condominiums and retirement facilities are just a few of the types of buildings utilizing the energy conscious water-source design.

Model GEH *(pictured below)* is a ceiling hung product that provides a serviceability to maintenance components; indoor air quality standards; sound attenuation; and best of all, higher efficiencies rated in accordance to ARI-ISO 13256-1 performance and ASHRAE 90.1 standards.

Trane's new design incorporates system advantages such as:

1. Maximum return-air and supply-air flexibility
2. Superior maintenance accessibility
3. Dual-sloped, plastic drain pan
4. Multiple fan speed motor packages
5. Quiet unit design
6. Integrated controls
7. Dual circuit design
8. High and low pressure safeties as standard
9. Dehumidification option
10. Waterside economizing option
11. Supplemental electric heat option



 WSHP-PRC014-EN

Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Features and Benefits

Cabinet Description

The cabinet design incorporates sturdy (non painted) galvanized metal form maximum durability and corrosive resistive exterior. The equipment offers superior installation flexibility with service accessibility.

The cabinet front allows service access for the controls. The new horizontal and vertical design offers *four* product variations of return-air and supply-air combinations. All combinations are order specific and may not be modified at the job site. See *Figure 1* for air side combinations.

Hanging the horizontal configuration is accomplished through the robust metal stiffeners located beneath the unit. Optional vibration isolators are available to help decrease sound vibration during equipment operation.

Airflow Combinations

The 6 through 15-ton horizontal's airflow flexibility includes the following combinations to aid in applications where the equipment is required to hug a corridor or wall.

The four configurations are:

1. Left return-air with back supply-air combination
2. Left return-air with right supply-air combination
3. Right return-air with back supply-air combination
4. Right return-air with left supply-air combination

The sleek, narrow cabinet of the 6 to 25-ton vertical is designed to fit through a standard 36"doorway for installation during new or retrofit construction. The equipment is available in four supply-air/return-air combinations. These combinations are order specific via the unit model number.

The *four combinations* include:

1. Front return-air with back supply-air combination
2. Front return-air with top supply-air combination
3. Back return-air with front supply-air combination
4. Back return-air with top supply-air combination

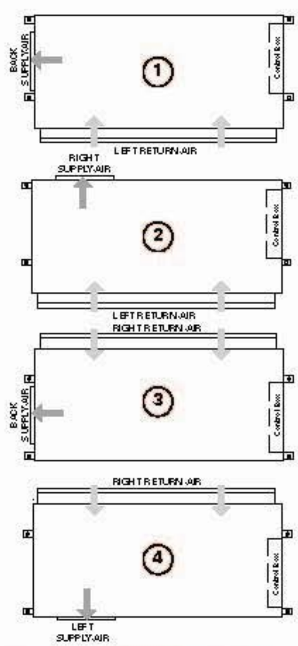


Figure 1. GEH Airflow Options

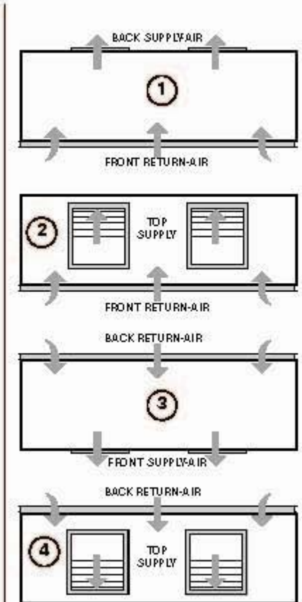


Figure 2. GEV Airflow Options

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Features and Benefits

Figure 3. GEV Panel Design

Figure 4. Plastic Drain Pan

Figure 5. Reciprocating Compr.

Figure 6. Co-axial Heat Exchanger

Access Panels

The upper panels of the 12 1/2 through 25-ton verticals feature a key hole hanging design for ease of maintenance of the unit, allowing the panel to be hooked into place when attaching the panel to the unit. The panels are also sealed with a rubber gasket at all four edges to help eliminate air from escaping around the panel's edge. See *Figure 3* for GEV panel design.

Hanging Device

The hanging channel for the horizontal unit runs the length of the equipment. The structural integrity of the design helps assure no bracket deflection or unit bowing from the unit's weight.

Optional isolation for the hanging bracket is provided with a rubber grommet design. This isolation device helps prevent sound vibration from reaching the structural support members of the building during compressor start and stop.

Drain Pan

The unit drain pan is composed of plastic, corrosive resistive material. The pan is positively sloped to comply with ASHRAE 62 for (IAQ) indoor air quality conformity.

Access to the drain pan is provided through two access panels for cleaning purposes for all models. See *Figure 3* for plastic drain pan.

Cabinet Insulation

The cabinet insulation design meets UL 181 requirements. The air stream surface of the insulation is fabricated of a non-biodegradable source.

Refrigeration Piping

The unit's copper tubing is created from a 99% pure copper formation that conforms to the American Society of Testing (ASTM) B743 for seamless, light-annealed processing.

The unit's copper refrigeration system is designed to be free from contaminants and conditions such as drilling fragments, dirt, or oil. This excludes the possibility of these contaminants from damaging the compressor motor.

Compressor

Dual circuit designs of the GEH and GEV models feature reciprocating compressors in the 6 and 7 1/2 ton sizes, while the 10 through 25 ton units include scroll compressors. The compressors are highly efficient, and incorporate external vibration isolators and thermal overload protection. See *Figure 5* for reciprocating compressor.

Co-axial Water-to-Refrigerant Coil

The unit's internal heat exchanging water coil is engineered for maximum heat transfer.

The copper or cupro-nickel seamless tubing is a tube within a tube design. The inner-water tube contains a deep fluted curve to enhance heat transfer and minimize fouling and scaling. It is available in either copper or cupro-nickel (selectable option) coil.The outer refrigerant gas tube is made from steel material. The coil is leak tested to assure there is no cross leakage between the water tube and the refrigerant gas (steel tube) coil. *Co-axial heat exchangers are more tolerant to freeze rupture.* See *Figure 8* for co-axial water coil.

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Features and Benefits

Water Connections

Water hookups for the 6 through 25 ton units are located internal to the equipment to help alleviate damage to the water copper during shipment or job storage of units prior to installation. Each unit (although dual circuit) contains a single supply and return water connection. See *Figure 7* for large tonnage water hook-up, model GEV. Fittings for the supply and return are internally threaded.

Expansion Valve

The refrigerant flow metering is made through the thermal expansion valve (TXV). It allows the unit to operate with an entering fluid temperature from 25 F to 110 F, and entering air temperatures from 40 F to 90 F. The valve is designed to meter refrigerant flow through the circuitry to achieve desired heating or cooling.

Unlike cap-tube assemblies, the expansion valve device allows the exact amount of refrigerant required to meet the coil load demands. This precise metering by the TXV increases the efficiency of the unit. See *Figure 15* for thermal expansion valve.

Reversing Valve

A system reversing valve (4-way valve) is included with all heating/cooling units. This valve is piped to be *energized* in the cooling mode to allow the system to provide heat if valve failure were to occur. Once the valve is energized for cooling, it will remain energized until the control system is turned to the OFF position, or a heating cycle is initiated.

Units with the cooling only option will not receive a reversing valve. See *Figure 9* for reversing valve.

Blower Motor

A belt driven motor selection powers the fan for the 6 through 25 ton dual circuit units. The 6 through 15 ton units include a single fan assembly, while the 20 and 25-ton units include dual fan assemblies. Because the motor sheave and the motor base are adjustable in the field, a greater variation in external static pressures are available. The large tonnage units are capable of providing 0 ESP to 3.0 ESP allowing a higher static ductwork to be applied on the mechanical system when the application requires extensive ductwork design. This is a low cost alternative to purchasing, installing, and maintaining multiple smaller tonnage units to meet the required air flow demand for the space.

Access to the 6 through 25 ton units is made through the back of unit by way of two panels, and/or through a side access panel if adjustment to the motor belt or motor base are needed. See *Figure 10* for motor accessibility.

Blower Housing

The blower housing is constructed of non-corrosive galvanized steel. It is a double wide/double inlet, forward curved wheel moved by an integral horsepower motor with sealed bearings.

Air-Side Filter

The air-side filter incorporates a 1-inch thick (nominal) or 2-inch thick (nominal) disposable fiberglass option. These filters include an average synthetic dust weight arrestance of approximately 75%. This dust holding capability includes a colorless, odorless adhesive to retain dirt particles within the filter media after fiber contact.

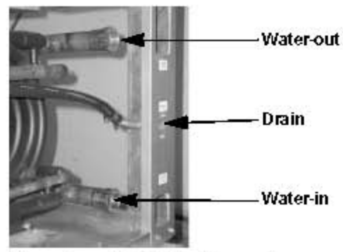

Figure 7. GEV Water Connections

Figure 8. Thermal Expansion Valve

Figure 9. Reversing Valve

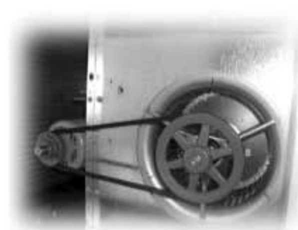

Figure 10. Belt Driven Motor (GEH)

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Features and Benefits

Boilerless Control/Electric Heat

Boilerless Control/Electric Heat *(option)*

In cooling dominant regions where heat may be used 15 to 30 days out of the winter season, eliminating the boiler may be an economical advantage to the building owner. Eliminating a boiler from the system reduces costs associated with the mechanical system installation, as well as the maintenance and service of the boiler.

How can heat be provided for the few days of the year when heat is necessary? Through the water-source heat pump of course. The advantage of the water-source heat pump is it's ability to provide heat recovery within the closed water-loop. While some WSHPs may be extracting heat from the closed water loop, other WSHPs may be adding heat to the closed water loop. This creates a perfect system balance for heat sharing or movement from one space to another.

But when water temperatures fall in a boilerless system, and no further heat recovery may be made via the closed loop, heat may be added to the space through a boilerless control electric heat option. See *Figure 11* for the boilerless control, electric heat system diagram.

With the boilerless electric heat option, the 6 through 25-ton models will contain boilerless controls ONLY to interface for a field provided supplemental electric heat selection. The heater for this model shall be placed external to the equipment by the contractor for ease of installation. All power connections for the electric heater will be completely separate from the unit for field supplied electric heat.

How it Works

In heating mode, when the water temperature falls below 55 F (factory setting), the electric heater is energized, locking out the compressor. The systems electric heat source will continue to be utilized for primary heating until the loop temperature rises above 60 F. Once the entering water temperature rises above 60 F, the boilerless controller returns the unit to normal compressor heating operation and locks out the electric heater. This maximizes efficiency from the unit during the few days requiring heat from the mechanical system.

If the unit employs a cooling only unit design, the electric heat contactor is wired directly to the thermostat for primary heating, and the compressor contactor for cooling.

Note: For geothermal applications, the boilerless controller has an adjustable setting of 25, 35, 45, 55 and 60 degrees.

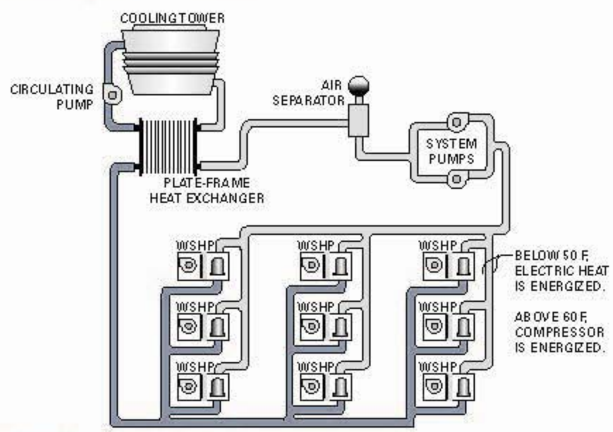

Figure 11. Electric Heat System

What is NOT available with the boilerless electric heat option?

1. Hot gas reheat
2. Basic 24 volt controls
3. Tracer™ ZN510 controls
4. 115 and 575 volt ratings
5. Supplemental or emergency heat applications
6. A factory installed heater

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

Waterside Economizer *(option)*

The beauty of the waterside economizer is it's ability to take advantage of any loop condition that results in cool water temperatures. A prime example would be during fall, winter and spring when cooling towers have more capacity than required and could be controlled to lower temperatures for economizer support.

Another more common inexpensive means of free comfort cooling includes buildings systems where perimeter heating and core cooling are needed. In this system, the perimeter units extract heat from the building loop while in the heating mode, forcing the building loop temperature to drop. Where as, the core are of a building may require cooling in summer or in winter based upon lighting, people and equipment.

If the water-source system design contained an economizing coil option, the moderate temperature loop water circulated through a core water-source system can provide an inexpensive means to satisfy room comfort without operating the water-source heat pump's compressor.

During economizer mode, fluid enters the unit, and passes by a water temperature sensing bulb. This temperature sensing bulb determines whether the two position, three-way valve will direct the water through the waterside economizing coil, and to the heat pump condenser, or through the condenser only. If the water temperature is 55 F or less, fluid will flow into the economizing coil, while simultaneously halting mechanical operation of the compressor. Mechanical cooling will continue on a call for second stage from the thermostat.

The factory built waterside economizer is available on all 6 to 15 ton GEH models and 6 to 25 GEV models.

Note: *The condensate overflow option is not available with the waterside economizer option.*

Hot Gas Reheat *(option)*

For space conditioning and climate control, Trane provides an accurate and cost effective dehumidification control through a hot gas reheat option. This option is designed to accommodate unit sizes 072 through 240.

With this reheat option, the return air from the space is conditioned by the air-to-refrigerant coil, then reheated by the reheat coil to control not only the space temperature, but to also reduce the relative humidity of the space. The moisture removal capability of a specific heat pump is determined by the units latent capacity rating.

When operating in the reheat mode (meaning the sensible temperature has been met in the space), the humidistat signals the reheat relay coil to energize, allowing the high pressure refrigerant gas to flow from the compressor, through the reheat valve, into the reversing valve, or through the reheat coil for dehumidification.

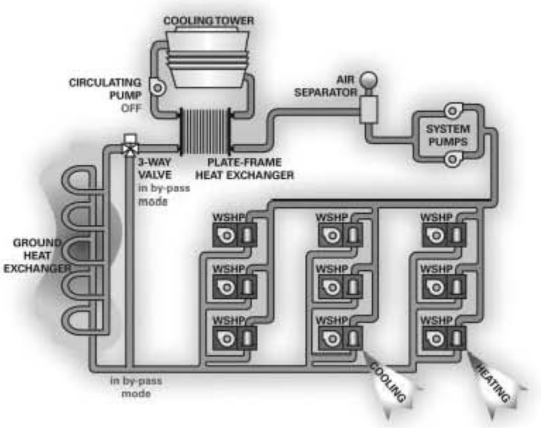


Figure 12. Waterside Economizer System

Note: *Trane places an air separation space between the air-to-refrigerant coil, and the reheat coil to allow for maximum moisture removal.*

Common Reheat Applications

The hot gas reheat option is designed to support building applications requiring fresh-air ventilation units delivering unconditioned-air directly to the space. It also provides dehumidification to large latent load spaces such as auditoriums, theaters and classrooms, or anywhere humidity control is a problem.

Do's and Don'ts in Design

The factory installed hot gas reheat option is only available with Deluxe or ZN524 controls packages.

The water-source heat pumps with hot gas reheat should not be used as a make-up air unit.

Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Selection Procedure

The performance standard ARI/ISO 13256-1 became effective Jan. 1, 2000. It replaces ARI standards 320, 325 and 330. This new standard has three major categories: Water Loop (ARI 320), Ground Water (ARI 325), Ground Loop (ARI 330). Although these standards are similar there are some differences.

The cooling efficiency is measured in EER but includes a Watt-per-Watt unit of measure similar to the traditional COP measurement.

The entering water temperature has changed to reflect the centigrade temperature scale. For instance the water loop heating test is performed with 68-degree F (20-degree C) water instead of 70-degree F. The cooling tests are performed with 80.6-degree F (27-degree C) dry bulb and 66.2-degree F (19-degree C) wet bulb entering air instead of the traditional 80-degree F dry bulb, and 67-degree F wet bulb entering air temperatures. This data (80.6/66.2) may be converted to 80/67 by using the entering air correction table.

A pump power correction has been added onto the existing power consumption. Within each model, only one water flow rate is specified for each performance category, and pumping watts are calculated utilizing the pump power correction formula: (gpm x 0.0631) x press drop x 2990) / 300.

Note: *GPM relates to water flow, and press drop relates to the drop through the unit heat exchanger at rated water flow in feet of head. The fan power is corrected to zero external static pressure. The nominal airflow is rated at a specific external static pressure. This effectively reduces the power consumption of the unit, and increases cooling capacity but decreases heating capacity. These watts are significant enough in most cases to increase EER and COP over ARI 320, 325, and 330 ratings.*

Cooling Dominated Applications

If humidity levels are moderate to high in a cooling dominated application, the heat pump should be selected to meet or exceed the calculated sensible load. Also, the unit's sensible capacity should be no more than 115% of the total cooling load (sensible + latent), unless the calculated latent load is less than the latent capacity of the unit.

The sensible-to-total cooling ratio can be adjusted with airflow. If the airflow is lowered, the unit latent capacity will increase. When less air is pulled across the DX coil, more moisture will condense from the air.

Heating Dominated Applications

Unit sizing in heating dominated applications is based upon humidity levels for the climate, and goals for operating cost and installation costs.

If humidity levels are moderate, the heat pump should be selected with the heating capacity equal to 125% of the cooling load.

If humidity levels are low in the application and low operating cost is important, the heat pump and ground loop should be sized for 90% to 100% of the heating load.

If humidity levels are low and lower initial cost is important, then the heat pump and ground loop should be sized for 70% to 85% of the heating load, with the remaining load to be treated with electric resistance heat.

Installation cost will be reduced in this approach because of the smaller heat pump selection and less loop materials.

In general, the system will not use enough electric heat to offset the higher installation costs associated with a fully sized or oversized system.

Finally, a unit sized for the entire heating load in a heating dominated application will be oversized in cooling. Comfort is reduced from increased room humidity caused by short-run times. Short cycling will also shorten the life expectancy of the equipment and increase power consumption and operating cost.

Many rebate incentives require the heat pump and ground loop to be sized for the entire heating load. Check with you local utility for their requirements.

Selection Program

All WSHP products should be selected through the Trane Official Product Selection System, ***TOPSS***.

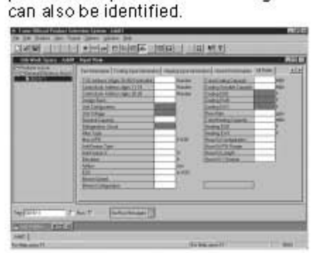
If this program has not been made available, ask a local Trane sales engineer to supply the desired selections or provide a copy of the program.

Required Fields

The first step in the selection is to determine either:

- Total cooling capacity
- Sensible capacity
- Heating capacity

The maximum allowable water pressure drop and selection ranges can also be identified.



Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Selection Procedure

Model Number

G E H B 072 1 1 D 0 A B 0 D L D 0 1 0 N 0 0 1 1 0 0 0 1 0 0 0 0 000

5 10 15 20 25 30

DIGITS 1-3: UNIT CONFIGURATION

GEH = High Efficiency Horizontal

GEV = High Efficiency Vertical

DIGIT 4: DEVELOPMENT SEQUENCE B

DIGITS 5-7: NOMINAL CAPACITY

072 = 6 Ton

090 = 7 1/2 Ton

120 = 10 Ton

150 = 12 1/2 Ton

180 = 15 Ton

240 = 20 Ton

300 = 25 Ton

DIGIT 8: VOLTAGE (Volts/Hz/Phase)

1 = 208/60/1 6 = 220-240/50/1

2 = 230/60/1 7 = 265/60/1

3 = 208/60/3 8 = 230/60/3

4 = 460/60/3 9 = 380-415/50/3

5 = 575/60/3

DIGITS 9: HEAT EXCHANGER

1 = Copper-Water Coil

2 = Cupro-Nickel Water Coil

DIGITS 10: CURRENT DESIGN SEQUENCE

DIGITS 11: REFRIGERATION CIRCUIT

0 = Heating and Cooling Circuit

2 = Heating and Cooling Circuit with Hot Gas Reheat

3 = Heating and Cooling Circuit with Waterside Economizer

4 = Heating and Cooling Circuit with HGR and WSE

A = Cooling ONLY Circuit

C = Cooling ONLY Circuit with Hot Gas Reheat

D = Cooling ONLY Circuit with Waterside Economizer

E = Cooling ONLY Circuit with HGR and WSE

DIGITS 12: BLOWER CONFIGURATION

A = Drive Package A (GEH/GEV)

B = Drive Package B (GEH/GEV)

C = Drive Package C (GEH/GEV)

D = Drive Package D (GEH/GEV)

E = Drive Package E (GEH/GEV)

F = Drive Package F (GEH/GEV)

G = Drive Package G (GEH/GEV)

H = Drive Package H (GEH/GEV)

J = Drive Package J (GEV)

DIGIT 13: FREEZE PROTECTION

A = 20 Degree F Freezestat

B = 35 Degree F Freezestat

DIGIT 14: OPEN DIGIT = 0

DIGIT 15: SUPPLY-AIR ARRANGEMENT

B = Back Supply-Air Arrangement

F = Front Supply-Air Arrangement

L = Left Supply-Air Arrangement

R = Right Supply-Air Arrangement

T = Top Supply-Air Arrangement

DIGIT 16: RETURN-AIR ARRANGEMENT

B = Back Return-Air Arrangement

F = Front Return-Air Arrangement

L = Left Return-Air Arrangement

R = Right Return-Air Arrangement

DIGIT 17: CONTROL TYPES

D = Deluxe 24 V Controls

C = Tracer ZN510 Controls

B = Tracer ZN524 Controls

DIGITS 18: TSTAT/SENSOR LOCATION

0 = Wall Mounted Location

DIGITS 19: FAULT SENSORS

0 = No Fault Sensor

1 = Condensate Overflow Sensor

2 = Filter Maintenance Timer

3 = Condensate Overflow and Filter Maintenance Timer

4 = Fan Status Sensor

6 = Condensate Overflow and Fan Status

H = Fan Status and Filter Maintenance Timer

J = Fan Status, Filter Maintenance Timer and Condensate Overflow Sensor

DIGITS 20: TEMPERATURE SENSOR

0 = No Additional Temperature Sensor

1 = Entering Water Sensor

DIGITS 21: NIGHT SETBACK CONTROL

0 = No Night Setback Relay

N = Night Setback Relay

DIGITS 22: ELECTRIC HEAT

0 = No Electric Heat

4 = External Boilerless Electric Heat

5 = External Supplemental Electric Heat

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Selection Procedure

Model Number - Continued

DIGITS 23: UNIT MOUNTED DISCONNECT

0 = No Unit Mounted Disconnect

DIGITS 24: FILTER TYPE

1 = 1" Throwaway Filter

2 = 2" Throwaway Filter

DIGITS 25: ACOUSTIC ARRANGEMENT

0 = Enhanced Sound Attenuation

1 = Deluxe Sound Attenuation

DIGITS 26: FACTORY CONFIGURATION

0 = Standard Factory Configuration

DIGITS 27: PAINT COLOR

0 = No Paint Selection Available

DIGITS 28: OUTSIDE AIR

0 = No Outside Air Option Available

DIGITS 29: PIPING ARRANGEMENT

0 = Standard Piping Arrangement

DIGITS 30-36: DOES NOT APPLY TO GEH or GEV

0000000 = Digits 30-36 are not applicable to the GEH or GEV products

Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

General Data

Table 1. General Unit Information

Model GEH		072	090	120	150	180
Unit Size	Length (in)	40 3/4	40 3/4	40 3/4	46 3/4	46 3/4
	Height (in)	21	21	21	28	28
	Width (in)	79	79	79	85	85
Compressor Type		Reciprocating	Reciprocating	Scroll	Scroll	Scroll
Approximate Weight	with Pallet (lb)	701	714	831	907	999
Approximate Weight	without Pallet (lb)	652	666	789	865	957
Filter Size	Actual (in)	19 5/8 x 24 5/8 (3)	19 5/8 x 24 5/8 (3)	19 5/8 x 24 5/8 (3)	24 5/8 x 24 5/8 (3)	24 5/8 x 24 5/8 (3)
Water in/out size (FPT)	inches	1 1/4	1 1/4	1 1/2	1 1/2	1 1/2
Condensate size (NPTI)	inches	3/4	3/4	3/4	3/4	3/4
Blower Wheel Size	Belt Drive (in)	12.62 x 12.62	12.62 x 12.62	12.62 x 12.62	15.00 x 15.00	15.00 x 15.00

Model GEV		072	090	120	150	180
Unit Size	Length (in)	42	42	42	81 5/8	81 5/8
	Height (in)	62 5/8	62 5/8	62 5/8	68	68
	Width (in)	36 1/4	36 1/4	36 1/4	36 1/4	36 1/4
Compressor Type		Recip (2)	Recip (2)	Scroll (2)	Scroll (2)	Scroll (2)
Approximate Weight	with Pallet (lb)	617	648	861	1215	1225
Approximate Weight	without Pallet (lb)	577	608	821	1170	1180
Filter Size	Actual (in)	19 5/8 x 19 5/8 (4)	19 5/8 x 19 5/8 (4)	19 5/8 x 19 5/8 (4)	19 5/8 x 24 5/8 (6)	19 5/8 x 24 5/8 (6)
Water in/out size	inches	1 1/4 FPT	1 1/4 FPT	1 1/2 FPT	1 1/2 FPT	1 1/2 FPT
Condensate size (NPTI)	inches	3/4	3/4	3/4	3/4	3/4
Blower Wheel Size and quantity		12.62 x 12.62	12.62 x 12.62	12.62 x 12.62	15.00 x 15.00	15.00 x 15.00

Model GEV		240	300
Unit Size	Length (in)	81 5/8	81 5/8
	Height (in)	68	68
	Width (in)	36 1/4	36 1/4
Compressor Type		Scroll (2)	Scroll (2)
Approximate Weight	with Pallet (lb)	1615	1665
Approximate Weight	without Pallet (lb)	1580	1640
Filter Size	Actual (in)	19 5/8 x 24 5/8 (6)	19 5/8 x 24 5/8 (6)
Water in/out size (sweat)	inches	2 FPT	2 FPT
Condensate size (NPTI)	inches	3/4	3/4
Blower Wheel Size and quantity (regular-low static/high static)		(2) 12.62 x 12.62	(2) 15.00 x 11.00 / (2) 12.62 x 12.62

Table 2. General Informatioin on Air-to-Refrigerant Coil (2-compressor circuit)

Unit Size	072	090	120	150	180	240
Working Pressure	425	425	425	425	425	425
Tubes High	(GEH) 18 (GEV) 24	(GEH) 18 (GEV) 28	(GEH) 18 (GEV) 36	(GEH) 24 (GEV) 28	(GEH) 24 (GEV) 32	36
Tubes Deep	4	4	4	(GEH) 4 (GEV) 2	(GEH) 4 (GEV) 3	4
No. of Circuits	6 refrig flow paths (2X)	(GEH) 6 refrig flow paths-2X (GEV) 7 refrig flow paths-2X	9 refrig flow paths (2X)	(GEH) 8 refrig flow paths-2X (GEV) 7 refrig flow paths-2X	(GEH) 8 refrig flow paths-2X (GEV) 9 refrig flow paths-2X	18 refrig flow paths (2X)
Finned vol. (h,w,d)	(GEH) 18 x 48 x 3.464 (GEV) 24 x 34 x 3.464	(GEH) 18 x 54 x 3.464 (GEV) 28 x 34 x 3.464	(GEH) 18 x 73 x 3.464 (GEV) 36 x 34 x 3.464	(GEH) 24 x 73 x 3.464 (GEV) 28 x 73 x 1.734	(GEH) 24 x 73 x 3.464 (GEV) 32 x 73 x 2.598	36x 73 x 3.464
Coil Surface Area (Ft^2)	(GEH) 6.00 (GEV) 5.67	(GEH) 6.75 (GEV) 6.61	(GEH) 9.125 (GEV) 8.50	(GEH) 12.167 (GEV) 14.19	(GEH) 12.167 (GEV) 16.22	18.25
Fins Per Inch	14	14	14	14	14	14
Tube Material	Copper	Copper	Copper	Copper	Copper	Copper
Tube OD (in)	3/8	3/8	3/8	3/8	3/8	3/8
Wall Thickness	0.014	0.014	0.014	0.014	0.014	0.014
Return Bends	Copper	Copper	Copper	Copper	Copper	Copper

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

Table 3. ARI-ISO WLHP and GLHP Performance

Unit Size	Rated Water Flow (GPM)	Rated Air Flow (SCFM)	Cooling Capacity WLHP (BTUH)	EER WLHP	Heating Capacity WLHP (BTUH)	COP WLHP	Cooling Capacity GLHP (BTUH)	EER GLHP	Heating Capacity GLHP (BTUH)	COP GLHP
GEH 072	18.0	2400	74900	14.4	84600	4.6	74300	15.4	48500	3.3
GEH 090	22.5	3000	90500	12.7	106300	4.2	90200	13.4	62700	3.1
GEH 120	30.0	4000	120900	12.4	148500	4.4	119700	13.4	90800	3.1
GEH 150	37.5	5000	143100	14.4	170300	5.0	141600	15.3	105700	3.4
GEH 180	45.0	6000	174500	12.8	204100	4.5	170700	13.6	122900	3.1
GEV 072	18.0	2400	72900	13.7	85100	4.8	72600	14.8	51600	3.5
GEV 090	22.5	3000	90300	13.0	104300	4.5	89800	14.0	63200	3.2
GEV 120	30.0	4000	120200	12.7	142800	4.4	118000	13.5	86400	3.2
GEV 150	37.5	5000	144000	15.5	171400	5.5	148100	17.3	105400	3.9
GEV 180	45.0	6000	173600	13.0	209800	4.8	178900	14.5	128700	3.5
GEV 240	60.0	8000	250300	13.1	276800	4.3	257200	14.5	186600	3.4
GEV 300	75.0	10000	282900	12.1	339400	4.2	291700	13.2	220900	3.3

1. Rated in accordance with ISO Standard 13256-1: 1998 (Water Loop Heat Pumps and Ground Loop Heat Pumps).
2. Models with capacities greater than 135,000 BTUH are not included in the ARI water-to-air and brine-to-air heat pump certification program.

Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

GEV 072 Cooling Performance

Table 19. GEV 072 Cooling Performance

RATED GPM: 18.0 **MINIMUM CFM:** 1920 **RATED ESP** (in. H20): 0.25
RATED CFM: 2400 **MAXIMUM CFM:** 2880

EWT	GPM	Total Mbtuh	Sen Mbtuh	SHR	Power kW	EER	Reject Mbtuh	LWT	Feet Head
45	9.0	84.5	61.8	0.73	3.83	22.05	97.6	66.7	3.9
45	12.0	85.8	62.3	0.73	3.62	23.68	98.1	61.4	6.4
45	15.0	86.6	62.7	0.72	3.48	24.93	98.5	58.1	9.4
45	18.0	87.3	63.0	0.72	3.37	25.90	98.8	56.0	12.8
45	21.0	87.7	63.2	0.72	3.29	26.68	99.0	54.4	16.6
55	9.0	80.9	60.2	0.74	4.37	18.50	95.8	76.3	3.9
55	12.0	82.2	60.8	0.74	4.16	19.75	96.4	71.1	6.4
55	15.0	83.1	61.2	0.74	4.02	20.69	96.8	67.9	9.4
55	18.0	83.8	61.5	0.73	3.91	21.42	97.2	65.8	12.8
55	21.0	84.3	61.7	0.73	3.83	22.00	97.4	64.3	16.6
68	9.0	75.9	58.1	0.77	5.01	15.17	93.0	88.7	3.9
68	12.0	77.3	58.7	0.76	4.81	16.09	93.7	83.6	6.4
68	15.0	78.3	59.1	0.75	4.67	16.77	94.2	80.6	9.3
68	18.0	79.0	59.4	0.75	4.57	17.30	94.6	78.5	12.7
68	21.0	79.6	59.6	0.75	4.49	17.72	94.9	77.0	16.5
77	9.0	72.4	56.7	0.78	5.42	13.37	90.9	97.2	3.9
77	12.0	73.9	57.3	0.78	5.22	14.14	91.7	92.3	6.4
77	15.0	74.9	57.7	0.77	5.09	14.71	92.2	89.3	9.3
GLHP 77	**18.0**	**75.6**	**58.0**	**0.77**	**4.99**	**15.15**	**92.6**	**87.3**	**12.7**
77	21.0	76.1	58.2	0.76	4.91	15.49	92.9	85.8	16.5
86	9.0	68.9	55.2	0.80	5.81	11.87	88.7	105.7	3.9
86	12.0	70.4	55.8	0.79	5.62	12.52	89.5	100.9	6.4
86	15.0	71.3	56.2	0.79	5.49	13.00	90.1	98.0	9.3
WLHP 86	**18.0**	**72.1**	**56.5**	**0.78**	**5.39**	**13.36**	**90.5**	**96.1**	**12.7**
86	21.0	72.6	56.7	0.78	5.32	13.65	90.7	94.6	16.5
95	9.0	65.3	53.8	0.82	6.18	10.58	86.4	114.2	3.9
95	12.0	66.8	54.3	0.81	6.00	11.14	87.3	109.5	6.4
95	15.0	67.8	54.7	0.81	5.87	11.55	87.8	106.7	9.3
95	18.0	68.5	55.0	0.80	5.78	11.86	88.2	104.8	12.6
95	21.0	69.0	55.2	0.80	5.70	12.09	88.5	103.4	16.4
105	9.0	61.3	52.1	0.85	6.56	9.35	83.7	123.6	3.9
105	12.0	62.8	52.7	0.84	6.39	9.82	84.6	119.1	6.3
105	15.0	63.7	53.1	0.83	6.27	10.17	85.1	116.3	9.3
105	18.0	64.4	53.4	0.83	6.18	10.42	85.5	114.5	12.6
105	21.0	64.9	53.6	0.83	6.11	10.62	85.8	113.2	16.4
115	9.0	57.2	50.5	0.88	6.92	8.27	80.9	133.0	3.9
115	12.0	58.7	51.1	0.87	6.76	8.68	81.7	128.6	6.3
115	15.0	59.6	51.4	0.86	6.65	8.96	82.3	126.0	9.2
115	18.0	60.2	51.7	0.86	6.56	9.18	82.6	124.2	12.6
115	21.0	60.7	51.9	0.85	6.50	9.34	82.9	122.9	16.3
120	9.0	55.2	49.7	0.90	7.09	7.78	79.4	137.6	3.9
120	12.0	56.6	50.2	0.89	6.94	8.15	80.2	133.4	6.3
120	15.0	57.5	50.6	0.88	6.83	8.42	80.8	130.8	9.2
120	18.0	58.1	50.9	0.88	6.75	8.61	81.1	129.0	12.5
120	21.0	58.6	51.0	0.87	6.69	8.75	81.4	127.8	16.3

1. Performance data is tabulated for cooling at 80.6 F DB/66.2 F WB entering air at ARI/ISO 13256-1 rated CFM.
2. For conditions other than what is tabulated, multipliers must be used to correct performance. See the *fan correction factors Table* for CFM other than rated and the *cooling correction factors* for variations in entering air temperature. WLHP data shown in bold type is performance data at ARI/ISO 13256-1. The bold type for GLHP is a rating point only. For ARI 13256-1 GLHP conditions, apply 15% methanol by volume per the antifreeze correction factors found on Page 69.

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

GEV 072 Heating Performance

Table 20. GEV 072 Heating Performance

RATED GPM: 18.0
RATED CFM: 2400
MINIMUM CFM: 1920
MAXIMUM CFM: 2880
RATED ESP (in. H20): 0.25

EWT	GPM	Htg Cap Mbtuh	Absorb Mbtuh	Power kW	COP	LWT	Feet Head
25	9.0	45.5	31.5	4.09	3.26	18.0	5.0
25	12.0	46.9	32.7	4.15	3.31	19.5	7.7
25	15.0	47.9	33.6	4.18	3.35	20.5	10.8
25	18.0	48.6	34.3	4.21	3.39	21.2	14.2
25	21.0	49.0	34.6	4.21	3.41	21.7	17.9
32	9.0	51.6	36.8	4.32	3.50	23.8	5.0
32	12.0	53.1	38.2	4.38	3.56	25.6	7.7
32	15.0	54.3	39.3	4.42	3.60	26.8	10.8
GLHP 32	**18.0**	**55.2**	**40.0**	**4.44**	**3.64**	**27.6**	**14.2**
32	21.0	55.6	40.4	4.45	3.66	28.1	18.0
45	9.0	62.4	46.4	4.69	3.90	34.7	5.0
45	12.0	64.3	48.1	4.75	3.96	37.0	7.7
45	15.0	65.7	49.4	4.80	4.01	38.4	10.8
45	18.0	66.7	50.3	4.82	4.05	39.4	14.2
45	21.0	67.3	50.8	4.83	4.08	40.2	18.0
55	9.0	70.3	53.4	4.93	4.17	43.1	5.0
55	12.0	72.4	55.3	5.00	4.24	45.8	7.7
55	15.0	74.0	56.8	5.05	4.30	47.4	10.8
55	18.0	75.1	57.8	5.08	4.34	48.6	14.2
55	21.0	75.7	58.4	5.08	4.37	49.4	17.9
68	9.0	80.4	62.7	5.18	4.54	54.1	5.0
68	12.0	82.8	64.9	5.25	4.62	57.2	7.7
68	15.0	84.7	66.6	5.30	4.68	59.1	10.8
WLHP 68	**18.0**	**85.9**	**67.8**	**5.33**	**4.72**	**60.5**	**14.2**
68	21.0	86.6	68.4	5.34	4.75	61.5	17.9
75	9.0	84.8	66.6	5.31	4.68	60.2	5.0
75	12.0	87.3	69.0	5.38	4.76	63.5	7.7
75	15.0	89.3	70.8	5.43	4.82	65.6	10.7
75	18.0	90.7	72.0	5.46	4.87	67.0	14.2
75	21.0	91.4	72.7	5.47	4.90	68.1	17.9
86	9.0	92.0	73.5	5.45	4.95	69.7	4.9
86	12.0	94.9	76.0	5.52	5.03	73.3	7.6
86	15.0	97.0	78.0	5.58	5.10	75.6	10.7
86	18.0	98.4	79.3	5.60	5.15	77.2	14.1
86	21.0	99.2	80.1	5.61	5.18	78.4	17.8

1. Performance data is tabulated for heating at 68 F DB entering air at ARI/ISO 13256-1 rated CFM.
2. For conditions other than what is tabulated, multipliers must be used to correct performance. See the *fan correction factors Table* for CFM other than rated and the *heating correction factors* for variations in entering air temperature. WLHP data shown in bold type is performance data at ARI/ISO 13256-1. The bold type for GLHP is a rating point only. For ARI 13256-1 GLHP conditions, apply 15% methanol by volume per the antifreeze correction factors found on Page 69.

Table 21. 072 Fan Correction Factors

Entering CFM	Cooling Capacity	Sensible Capacity	Cooling Input Watts	Heating Capacity	Heating Input Watts
1920	0.961	0.891	0.992	0.973	1.044
2160	0.982	0.947	0.997	0.988	1.020
2400	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
2640	1.015	1.052	1.003	1.010	0.983
2880	1.029	1.102	1.005	1.018	0.969

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

GEV 150 Cooling Performance

Table 28. GEV 150 Cooling Performance

RATED GPM: 37.5 **MINIMUM CFM:** 4000 **RATED ESP** (in. H20): 0.35
RATED CFM: 5000 **MAXIMUM CFM:** 6000

EWT	GPM	Total Mbtuh	Sen Mbtuh	SHR	Power kW	EER	Reject Mbtuh	LWT	Feet Head
45	18.8	155.8	118.5	0.76	7.31	21.33	175.7	63.7	4.4
45	25.0	155.9	118.6	0.76	7.27	21.43	175.7	59.0	7.1
45	31.3	156.0	118.6	0.76	7.25	21.53	175.8	56.2	10.2
45	37.5	156.2	118.7	0.76	7.22	21.62	175.8	54.4	13.8
45	43.8	156.2	118.7	0.76	7.21	21.66	175.9	53.5	17.8
55	18.8	153.7	117.6	0.77	7.70	19.96	174.7	73.6	4.4
55	25.0	153.7	117.7	0.77	7.63	20.14	174.6	68.9	7.1
55	31.3	154.0	117.7	0.76	7.58	20.31	174.6	66.2	10.2
55	37.5	154.2	117.8	0.76	7.53	20.47	174.7	64.3	13.8
55	43.8	154.4	117.9	0.76	7.49	20.62	174.8	63.0	17.7
68	18.8	149.1	115.6	0.78	8.48	17.58	172.6	86.4	4.4
68	25.0	149.2	115.6	0.78	8.37	17.82	172.3	81.8	7.0
68	31.3	149.5	115.7	0.77	8.28	18.04	172.4	79.1	10.2
68	37.5	149.8	115.9	0.77	8.21	18.26	172.4	77.2	13.7
68	43.8	150.2	116.0	0.77	8.13	18.47	172.6	75.9	17.7
77	18.8	145.0	113.9	0.78	9.19	15.78	170.8	95.3	4.4
77	25.0	145.2	113.9	0.78	9.05	16.04	170.5	90.7	7.0
77	31.3	145.6	114.1	0.78	8.94	16.28	170.5	88.0	10.2
GLHP 77	**37.5**	**146.0**	**114.3**	**0.78**	**8.84**	**16.51**	**170.6**	**86.1**	**13.7**
77	43.8	146.4	114.4	0.78	8.75	16.73	170.7	84.8	17.7
86	18.8	140.6	112.0	0.80	10.05	13.99	169.1	104.1	4.4
86	25.0	140.8	112.1	0.80	9.88	14.25	168.8	99.6	7.0
86	31.3	141.2	112.2	0.79	9.75	14.49	168.8	96.9	10.1
WLHP 86	**37.5**	**141.7**	**112.4**	**0.79**	**9.63**	**14.71**	**168.8**	**95.1**	**13.7**
86	43.8	142.1	112.6	0.79	9.51	14.94	168.9	93.8	17.6
95	18.8	135.7	109.9	0.81	11.06	12.27	167.5	113.0	4.3
95	25.0	136.0	110.0	0.81	10.86	12.52	167.1	108.5	7.0
95	31.3	136.4	110.2	0.81	10.70	12.75	167.0	105.8	10.1
95	37.5	136.9	110.4	0.81	10.56	12.97	167.0	104.0	13.6
95	43.8	137.3	110.6	0.81	10.42	13.18	167.1	102.7	17.6
105	18.8	129.7	107.4	0.83	12.34	10.51	165.8	122.9	4.3
105	25.0	130.0	107.5	0.83	12.11	10.73	165.3	118.4	7.0
105	31.3	130.5	107.7	0.83	11.93	10.94	165.2	115.7	10.1
105	37.5	131.0	108.0	0.82	11.76	11.14	165.2	113.9	13.6
105	43.8	131.5	108.2	0.82	11.60	11.34	165.2	112.6	17.5
115	18.8	123.2	104.7	0.85	13.80	8.93	164.2	132.7	4.3
115	25.0	123.5	104.9	0.85	13.54	9.13	163.7	128.2	6.9
115	31.3	124.1	105.1	0.85	13.33	9.31	163.5	125.6	10.0
115	37.5	124.6	105.3	0.84	13.14	9.49	163.4	123.8	13.5
115	43.8	125.2	105.5	0.84	12.96	9.66	163.3	122.6	17.5
120	18.8	119.8	103.3	0.86	14.60	8.20	163.5	137.7	4.3
120	25.0	120.2	103.5	0.86	14.32	8.39	162.9	133.2	6.9
120	31.3	120.7	103.7	0.86	14.10	8.56	162.7	130.6	10.0
120	37.5	121.3	103.9	0.86	13.90	8.73	162.6	128.8	13.5
120	43.8	121.8	104.1	0.85	13.71	8.89	162.5	127.5	17.4

1. Performance data is tabulated for cooling at 80.6 F DB/66.2 F WB entering air at ARI/ISO 13256-1 rated CFM.
2. For conditions other than what is tabulated, multipliers must be used to correct performance. See the *fan correction factors Table* for CFM other than rated and the *cooling correction factors* for variations in entering air temperature. WLHP data shown in bold type is performance data at ARI/ISO 13256-1. The bold type for GLHP is a rating point only. For ARI 13256-1 GLHP conditions, apply 15% methanol by volume per the antifreeze correction factors found on Page 69.

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

GEV 150 Heating Performance

Table 29. GEV 150 Heating Performance

RATED GPM: 37.5
RATED CFM: 5000
MINIMUM CFM: 4000
MAXIMUM CFM: 6000
RATED ESP (in. H20): 0.35

EWT	GPM	Htg Cap Mbtuh	Absorb Mbtuh	Power kW	COP	LWT	Feet Head
25	18.8	92.4	68.3	7.97	3.40	18.1	4.9
25	25.0	95.0	70.8	8.02	3.47	19.7	7.7
25	31.3	96.6	72.4	8.05	3.52	20.7	11.1
25	37.5	97.8	73.6	8.07	3.55	21.4	14.8
25	43.8	98.6	74.4	8.09	3.57	21.9	19.0
32	18.8	102.2	77.9	8.15	3.67	24.0	4.9
32	25.0	105.4	81.0	8.21	3.76	25.9	7.7
32	31.3	107.4	83.0	8.24	3.82	27.0	11.1
GLHP 32	**37.5**	**108.8**	**84.4**	**8.27**	**3.86**	**27.8**	**14.8**
32	43.8	109.9	85.5	8.28	3.89	28.4	19.0
45	18.8	121.6	97.1	8.48	4.20	34.7	4.9
45	25.0	125.6	100.9	8.55	4.30	37.0	7.7
45	31.3	129.2	104.6	8.61	4.40	38.9	11.1
45	37.5	131.6	106.9	8.65	4.46	39.8	14.8
45	43.8	132.4	107.7	8.66	4.48	40.1	19.0
55	18.8	138.2	113.4	8.76	4.62	43.0	4.9
55	25.0	142.3	117.6	8.83	4.72	45.6	7.7
55	31.3	145.8	121.0	8.89	4.81	47.3	11.1
55	37.5	148.8	123.9	8.94	4.87	48.4	14.8
55	43.8	151.2	126.3	8.99	4.93	49.3	19.0
68	18.8	160.4	135.4	9.15	5.14	53.6	4.9
68	25.0	165.5	140.5	9.24	5.25	56.8	7.7
68	31.3	170.0	144.9	9.33	5.34	58.7	11.0
WLHP 68	**37.5**	**173.7**	**148.6**	**9.40**	**5.42**	**60.1**	**14.8**
68	43.8	176.8	151.6	9.46	5.48	61.1	19.0
75	18.8	172.8	147.7	9.38	5.40	59.2	4.9
75	25.0	178.5	153.3	9.49	5.51	62.7	7.7
75	31.3	183.5	158.3	9.59	5.61	64.9	11.0
75	37.5	187.8	162.5	9.68	5.68	66.3	14.8
75	43.8	191.3	165.9	9.75	5.75	67.4	19.0
86	18.8	192.9	167.6	9.79	5.78	68.1	4.8
86	25.0	199.7	174.2	9.93	5.89	72.0	7.7
86	31.3	205.6	180.0	10.06	5.99	74.4	11.0
86	37.5	210.6	184.9	10.17	6.07	76.1	14.8
86	43.8	214.7	189.0	10.26	6.13	77.3	18.9

1. Performance data is tabulated for heating at 68 F DB entering air at ARI/ISO 13256-1 rated CFM.
2. For conditions other than what is tabulated, multipliers must be used to correct performance. See the *fan correction factors Table* for CFM other than rated and the *heating correction factors* for variations in entering air temperature. WLHP data shown in bold type is performance data at ARI/ISO 13256-1. The bold type for GLHP is a rating point only. For ARI 13256-1 GLHP conditions, apply 15% methanol by volume per the antifreeze correction factors found on Page 69.

Table 30. 150 Fan Correction Factors

Entering SCFM	Cooling Capacity	Sensible Capacity	Cooling Input Watts	Heating Capacity	Heating Input Watts
4000	0.968	0.898	0.997	0.987	1.065
4500	0.986	0.951	0.999	0.994	1.028
5000	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
5500	1.013	1.049	1.001	1.005	0.978
6000	1.025	1.096	1.002	1.009	0.960

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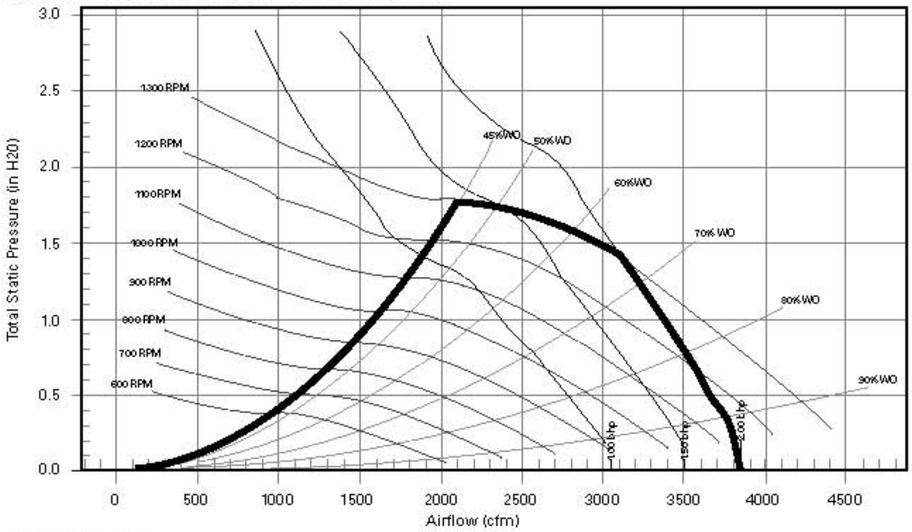
Schedule B1. *Trane WSHP Cut Sheets (continued)*

Figure 19. GEV 072 Top Supply Fan Performance Curve



Includes wet coil, no filter

Table 62 GEV 072 - Top Supply - Fan Performance (includes wet coil, no filter)

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, No Drive Loss Included & No Return Air Filter) 0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1920	595[A]	0.27[A]	649[A]	0.32[A]	698[A]	0.36[A]	744[A]	0.40[A]	788[A]	0.45[A]	830[A]	0.50[A]	871[A]	0.55[A]	912[B]	0.60[B]	953[B]	0.65[B]
2160	655[A]	0.37[A]	705[A]	0.42[A]	751[A]	0.47[A]	794[A]	0.52[A]	835[A]	0.57[A]	874[A]	0.63[A]	912[B]	0.68[B]	949[B]	0.74[B]	985[B]	0.79[B]
2400	717[A]	0.50[A]	763[A]	0.56[A]	806[A]	0.61[A]	846[A]	0.67[A]	884[A]	0.72[A]	921[B]	0.78[B]	957[B]	0.83[B]	991[B]	0.89[B]	1024[B]	0.96[B]
2640	780[A]	0.65[A]	822[A]	0.71[A]	862[A]	0.78[A]	900[B]	0.84[B]	937[B]	0.90[B]	971[B]	0.96[B]	1005[C]	1.02[C]	1038[C]	1.08[C]	1069[C]	1.15[C]
2880	844[A]	0.84[A]	882[A]	0.90[A]	920[B]	0.97[B]	956[C]	1.04[C]	990[C]	1.10[C]	1023[C]	1.17[C]	1055[C]	1.23[C]	1086[C]	1.30[C]	1116[C]	1.36[C]

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter) 1.0		1.1		1.2		1.3	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1920	993[B]	0.70[B]	1034[B]	0.76[B]	1072[B]	0.84[B]	1111[B]	0.92[B]
2160	1021[B]	0.85[B]	1058[B]	0.90[B]	1094[B]	0.95[B]	1129[C]	1.02[C]
2400	1057[C]	1.02[C]	1091[C]	1.08[C]	1123[C]	1.14[C]	1157[C]	1.20[C]
2640	1100[C]	1.21[C]	1130[C]	1.28[C]	1161[C]	1.35[C]	1191[C]	1.42[C]
2880	1145[C]	1.43[C]	1175[D]	1.51[D]	1203[D]	1.58[D]	1231[D]	1.66[D]

1. [A] = Package A
2. [B] = Package B
3. [C] = Package C
4. [D] = Package D

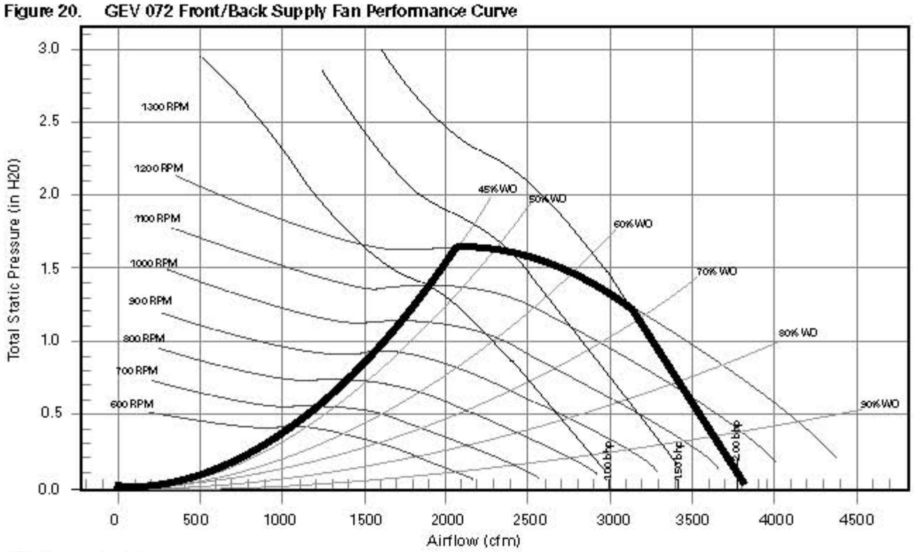
Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

Fan Performance

Figure 20. GEV 072 Front/Back Supply Fan Performance Curve



Includes wet coil, no filter

Table 63 GEV 072 - Front/Back Supply - Fan Performance (includes wet coil, no filter)

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, No Drive Loss Included & No Return Air Filter)																	
	0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1920	559[A]	0.30[A]	611[A]	0.34[A]	660[A]	0.39[A]	706[A]	0.44[A]	749[A]	0.48[A]	790[A]	0.53[A]	831[A]	0.59[A]	869[A]	0.64[A]	907[B]	0.70[B]
2160	616[A]	0.41[A]	663[A]	0.46[A]	708[A]	0.51[A]	751[A]	0.56[A]	792[A]	0.62[A]	830[A]	0.67[A]	867[A]	0.73[A]	904[B]	0.78[B]	939[B]	0.84[B]
2400	674[A]	0.55[A]	717[A]	0.60[A]	759[A]	0.66[A]	799[A]	0.72[A]	837[A]	0.78[A]	873[A]	0.84[A]	909[B]	0.90[B]	943[B]	0.96[B]	975[C]	1.02[C]
2640	733[A]	0.71[A]	773[A]	0.78[A]	811[A]	0.84[A]	849[A]	0.90[A]	884[A]	0.97[A]	919[C]	1.03[C]	953[C]	1.10[C]	985[C]	1.16[C]	1016[C]	1.23[C]
2880	793[A]	0.91[A]	830[A]	0.98[A]	865[C]	1.05[C]	900[C]	1.12[C]	934[C]	1.19[C]	966[C]	1.26[C]	998[C]	1.33[C]	1029[C]	1.40[C]	1060[C]	1.47[C]

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter)							
	1.0		1.1		1.2		1.3	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1920	947[B]	0.76[B]	988[B]	0.83[B]	1030[B]	0.90[B]	1068[B]	0.97[B]
2160	974[B]	0.91[B]	1008[B]	0.97[B]	1042[C]	1.04[C]	1079[C]	1.11[C]
2400	1007[C]	1.08[C]	1040[C]	1.15[C]	1071[C]	1.22[C]	1102[C]	1.29[C]
2640	1046[C]	1.29[C]	1076[C]	1.36[C]	1106[C]	1.43[C]	1135[D]	1.51[D]
2880	1088[D]	1.54[D]	1116[D]	1.61[D]	1144[D]	1.69[D]	1172[D]	1.77[D]

1. [A] = Package A
2. [B] = Package B
3. [C] = Package C
4. [D] = Package D

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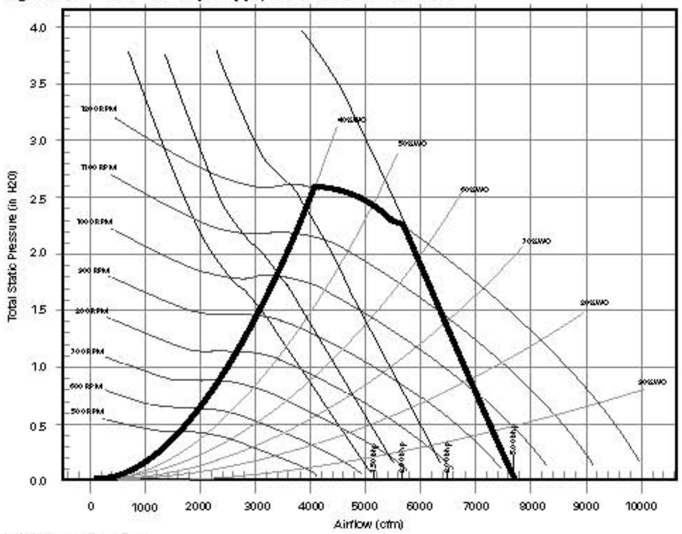
Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

Fan Performance

Figure 25. GEV 150 Top Supply Fan Performance Curve



Includes wet coil, no filter

Table 68. GEV 150 - Top Supply - Fan Performance (includes wet coil, no filter)

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter)																	
	0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
4000							626[A]	1.07[A]	660[A]	1.16[A]	692[A]	1.25[A]	724[A]	1.34[A]	754[A]	1.43[A]	783[A]	1.52[A]
4500			607[A]	1.22[A]	639[A]	1.31[A]	671[A]	1.41[A]	702[A]	1.52[A]	733[A]	1.62[A]	762[A]	1.72[A]	791[A]	1.82[A]	818[A]	1.92[A]
5000	630[A]	1.50[A]	661[A]	1.62[A]	690[A]	1.72[A]	718[A]	1.83[A]	747[A]	1.94[A]	776[B]	2.06[B]	803[B]	2.17[B]	830[B]	2.29[B]	856[B]	2.40[B]
5500	686[A]	1.96[A]	716[B]	2.10[B]	742[B]	2.22[B]	768[B]	2.33[B]	794[B]	2.45[B]	820[B]	2.58[B]	847[B]	2.71[B]	872[B]	2.83[B]	897[B]	2.96[B]
6000	743[B]	2.52[B]	771[B]	2.68[B]	796[B]	2.81[B]	820[B]	2.94[B]					892[D]	3.33[D]	916[D]	3.47[D]	939[D]	3.61[D]

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter)																	
	1.0		1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
4000	810[A]	1.62[A]	837[A]	1.72[A]	864[A]	1.81[A]	890[A]	1.90[A]	915[C]	1.99[C]	939[C]	2.09[C]	963[C]	2.19[C]	987[C]	2.29[C]	1010[C]	2.39[C]
4500	845[A]	2.02[A]	871[B]	2.12[B]	896[B]	2.23[B]	920[B]	2.34[B]	943[C]	2.45[C]	967[C]	2.56[C]	991[C]	2.19[C]	1013[C]	2.76[C]	1035[C]	2.87[C]
5000	882[B]	2.51[B]	906[B]	2.62[B]	931[B]	2.73[B]	954[C]	2.84[C]	977[C]	2.96[C]	999[D]	3.08[D]	1021[D]	3.21[D]	1043[D]	3.33[D]	1065[D]	3.45[D]
5500	921[D]	3.08[D]	944[D]	3.21[D]	967[D]	3.33[D]	990[D]	3.45[D]	1013[D]	3.57[D]	1034[D]	3.69[D]	1056[D]	3.82[D]	1076[D]	3.95[D]	1097[D]	4.09[D]
6000	962[D]	3.75[D]	985[D]	3.88[D]	1007[D]	4.02[D]	1028[D]	4.15[D]	1050[D]	4.29[D]	1070[D]	4.42[D]	1091[D]	4.55[D]	1111[D]	4.68[D]	1131[D]	4.81[D]

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter)			
	1.9		2.0	
CFM	RPM	BHP	RPM	BHP
4000	1034[C]	2.50[C]	1059[C]	2.61[C]
4500	1057[C]	2.98[C]	1077[D]	3.09[D]
5000	1085[D]	3.56[D]	1106[D]	3.68[D]
5500	1117[D]	4.22[D]	1136[D]	4.35[D]
6000				

1. [A] = Package A
2. [B] = Package B
3. [C] = Package C
4. [D] = Package D

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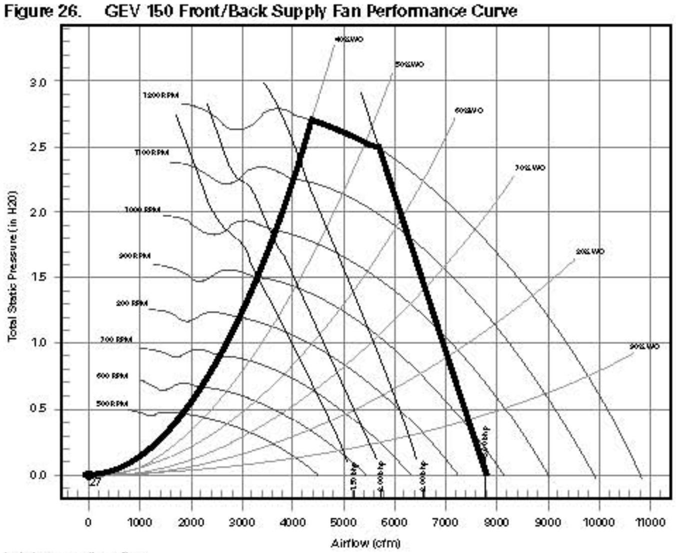
Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Performance Data

Fan Performance

Figure 26. GEV 150 Front/Back Supply Fan Performance Curve



Includes wet coil, no filter

Table 69. GEV 150 - Front/Back Supply - Fan Performance (includes wet coil, no filter)

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter)																			
	0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
4000									626[A]	1.11[A]	658[A]	1.20[A]	689[A]	1.28[A]	719[A]	1.36[A]	749[A]	1.45[A]	778[A]	1.54[A]
4500					606[A]	1.28[A]	636[A]	1.37[A]	666[A]	1.46[A]	695[A]	1.55[A]	723[A]	1.64[A]	751[A]	1.74[A]	779[A]	1.84[A]	806[A]	1.93[A]
5000			626[A]	1.58[A]	654[A]	1.68[A]	681[A]	1.78[A]	708[A]	1.88[A]	735[A]	1.98[A]	761[B]	2.08[B]	787[B]	2.19[B]	812[B]	2.29[B]	838[B]	2.40[B]
5500	652[A]	1.95[A]	677[B]	2.06[B]	703[B]	2.17[B]	728[B]	2.28[B]	753[B]	2.39[B]	778[B]	2.50[B]	802[B]	2.61[B]	826[B]	2.72[B]	850[B]	2.83[B]	873[B]	2.95[B]
6000	707[B]	2.51[B]	730[B]	2.63[B]	753[B]	2.75[B]	777[B]	2.87[B]	800[B]	2.99[B]							890[D]	3.46[D]	912[D]	3.59[D]

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter)															
	1.1		1.2		1.3		1.4		1.5		1.6		1.7		1.8	
CFM	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
4000	805[A]	1.62[A]	832[A]	1.71[A]	858[A]	1.80[A]	884[A]	1.89[A]	910[C]	1.98[C]	936[C]	2.08[C]	962[C]	2.18[C]	987[C]	2.29[C]
4500	833[B]	2.03[B]	858[B]	2.12[B]	884[B]	2.22[B]	908[C]	2.32[C]	932[C]	2.42[C]	955[C]	2.51[C]	978[C]	2.61[C]	1002[C]	2.72[C]
5000	863[B]	2.51[B]	888[C]	2.62[C]	911[C]	2.72[C]	935[C]	2.83[C]	958[C]	2.93[C]	980[D]	3.04[D]	1002[D]	3.15[D]	1024[D]	3.25[D]
5500	897[D]	3.07[D]	919[D]	3.18[D]	942[D]	3.30[D]	965[D]	3.42[D]	987[D]	3.54[D]	1009[D]	3.65[D]	1030[D]	3.77[D]	1050[D]	3.88[D]
6000	933[D]	3.71[D]	955[D]	3.84[D]	976[D]	3.97[D]	997[D]	4.10[D]	1017[D]	4.22[D]	1038[D]	4.35[D]	1059[D]	4.48[D]	1078[D]	4.60[D]

Std Airfow	Unit External Static Pressure inches W.G. (Wet Coil, 3% Drive Loss Included & No Return Air Filter)			
	1.9		2.0	
CFM	RPM	BHP	RPM	BHP
4000	1011[C]	2.39[C]	1035[C]	2.49[C]
4500	1025[C]	2.83[C]	1048[C]	2.94[C]
5000	1046[D]	3.37[D]	1067[D]	3.48[D]
5500	1071[D]	4.00[D]	1091[D]	4.12[D]
6000	1099[D]	4.73[D]	1118[D]	4.86[D]

1. [A] = Package A
2. [B] = Package B
3. [C] = Package C
4. [D] = Package D

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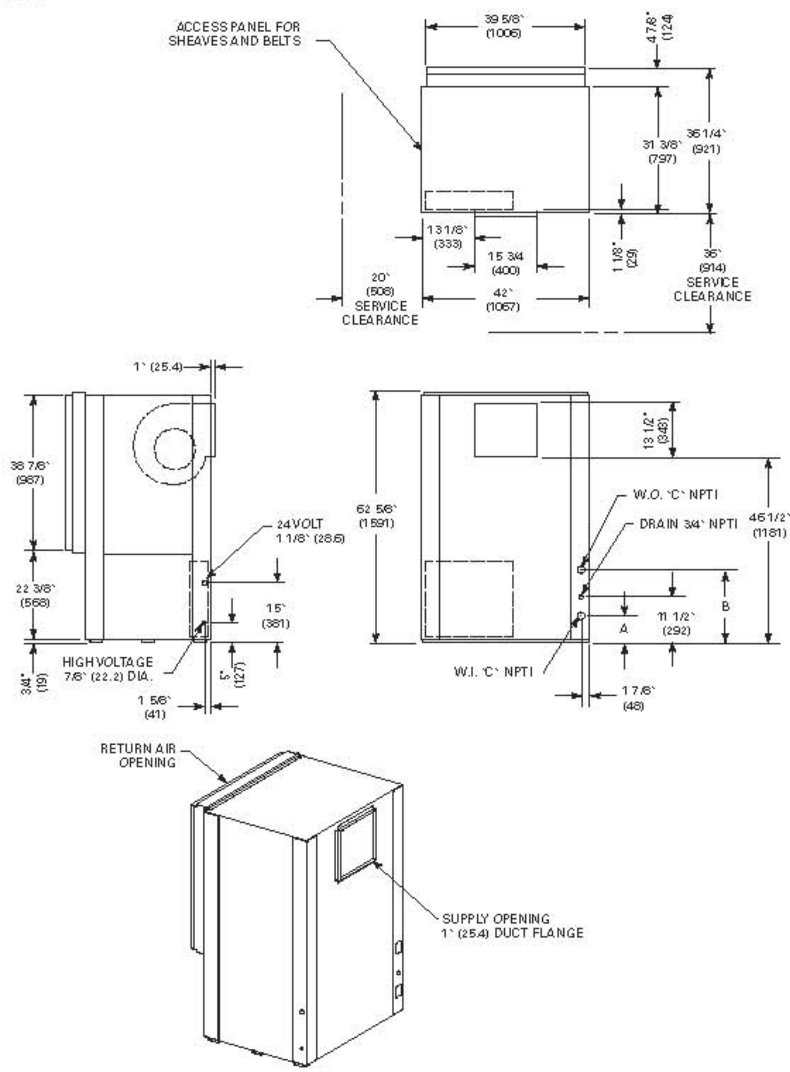
Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Dimensional Data

GEV - Back Return/Front Supply

GEV 072-120



Unit GEV	A	B	C
072	6 5/8" (168)	18 3/8" (467)	1 1/4"
090	6 5/8" (168)	18 3/8" (467)	1 1/4"
120	6 1/2" (165)	18 1/2" (470)	1 1/2"

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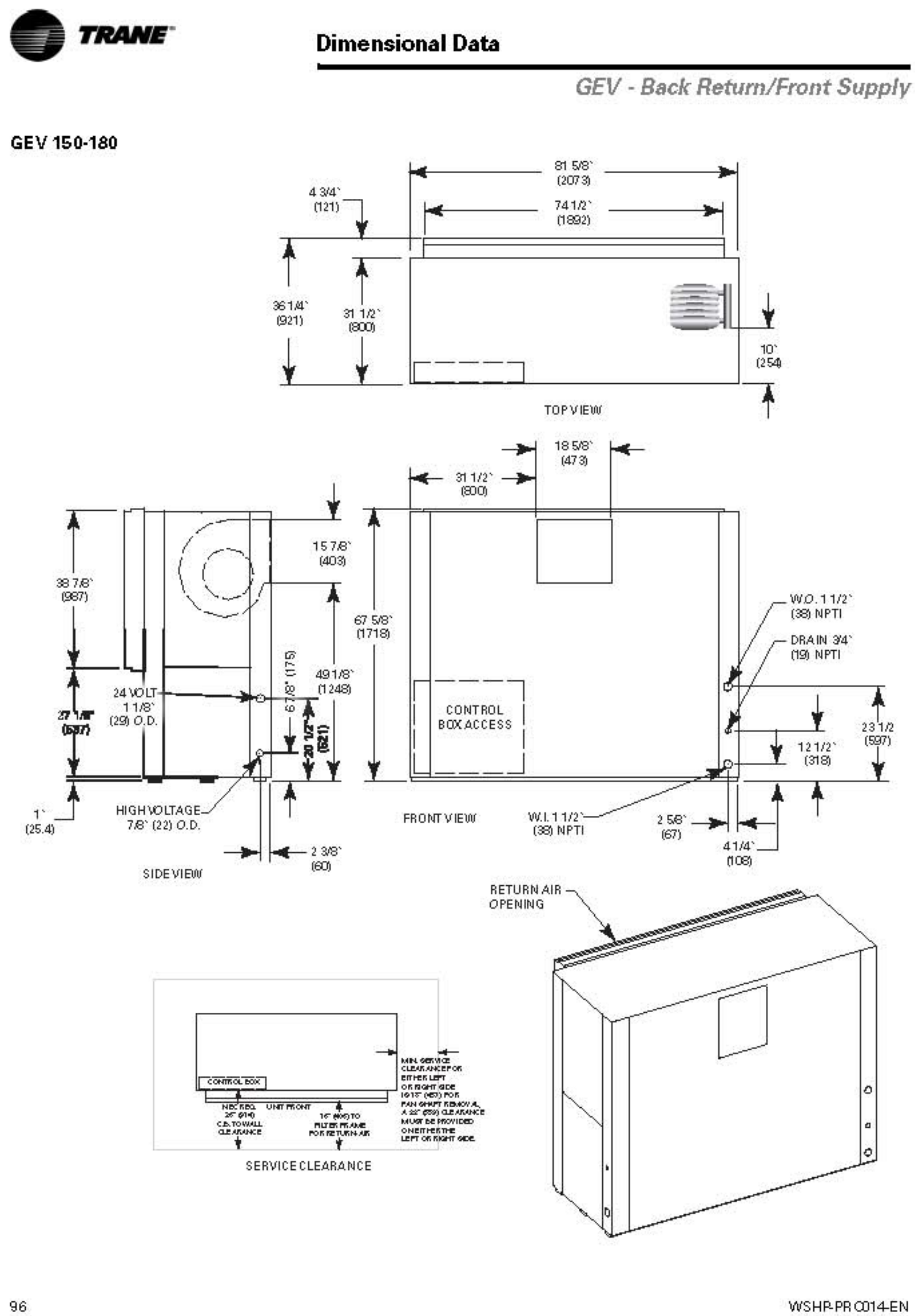
Schedule B1. *Trane WSHP Cut Sheets (continued)*



Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Mechanical Specifications

General

Equipment is completely assembled, piped, internally wired, fully charged with HCFC-22 and test operated at the factory. Filters, thermostat field interface terminal strip, and all safety controls are furnished and factory installed.

The system water inlet and outlet connections are female NPT composed of either a copper or a bronze option.

The 6 through 10-ton equipment contain ETL, CETL and ISO-ARI 13256-1 listings and labels prior to leaving the factory. Larger units are rated in accordance with ISO-ARI 13256-1. Service and caution area labels are placed on the unit in their appropriate locations.

Cabinet

Unit casing is constructed of zinc coated, heavy gauge, galvanized steel.

Access to the refrigerant and controls is provided through the front and side access panels.

All panels are insulated with 1/2-inch thick dual density bonded glass fiber. The exposed side is a high density erosion proof material suitable for use in air streams up to 3600 feet per minute (FPM). The insulation meets the erosion requirements of UL 181. It has a flame spread of less than 25 and a smoke developed classification of less than 50 per ASTM E-84 and UL 723.

Access for inspection and cleaning of the unit drain pan, coils and fan section are provided. The unit shall be installed for proper access.

Filters

One inch or two inch, throwaway filters are standard and factory installed. The filters have an average resistance of 76-percent and dust holding capacity of 26-grams per square foot.

Sound Attenuation

Sound attenuation is applied as a standard feature in the product design.

All units are tested and rated in accordance with ARI 260.

Compressors

The unit contains a high efficiency reciprocating or scroll compressor. External vibration isolation is provided by rubber mounting devices located underneath the mounting base of the compressor. A second isolation of the refrigeration assembly is supported under the compressor mounting base.

Internal thermal overload protection is provided. Protection against excessive discharge pressure is provided by means of a high pressure switch. A loss of charge is provided by a low pressure safety.

Refrigerant Tubing

The refrigerant tubing is of 99% pure copper. This system shall be free from contaminants and conditions such as drilling fragments, dirt and oil. All refrigerant and water lines are insulated with an elastomeric insulation that has a 3/8-inch thick wall in the air-side section of the unit.

Refrigerant Circuits

The refrigerant circuit contains a thermal expansion device. Service pressure ports are factory supplied on the high and low pressure sides for easy refrigerant pressure or temperature testing.

Air-to-Refrigerant Coil

Internally finned, 3/8-inch copper tubes mechanically bonded to a configured aluminum plate fin are standard. Coils are leak tested at the factory to ensure the pressure integrity. The coil is leak tested to 200 psig and pressure tested to 450 psig. The tubes are to be completely evacuated of air and correctly charged with proper volume of refrigerant prior to shipment.

The refrigerant coil distributor assembly is of orifice style with round copper distributor tubes. The tubes are sized consistently with the capacity of the coil. Suction header is fabricated from rounded copper pipe.

A thermostatic expansion valve is factory selected and installed for a wide range of control.

Drain Pan

The condensate pan is constructed of corrosion resistant material and insulated to prevent sweating. The bottom of the drain pan is sloped on two planes which pitches the condensate to the drain connection. The drain pan is flame rated per UL945V-B. When the unit is installed and trapped per the manufacturers installation manual, and local city specifications, the drain pan shall be designed to leave puddles no more than 2-inch in diameter, no more than 1/8-inch deep, no longer than 3-minutes following the step 3 of the following test.

- Temporarily plug the drain pan.
- Fill the drain pan with 1/2-inch of water or the maximum allowed by the drain pan depth, whichever is smaller.
- Remove the temporary plug.

Water-to-Refrigerant Heat Exchanger

The water-to-refrigerant heat exchanger is of a high quality co-axial coil for maximum heat transfer. The copper or optional cupro-nickel coil shall be deeply fluted to enhance heat transfer and minimize fouling and scaling. The coil has a working pressure of 400 psig on both the refrigerant and water sides.

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Schedule B1. *Trane WSHP Cut Sheets (continued)*

TRANE

Mechanical Specifications

Indoor Fan

The blower has nine blower motor/ sheave combinations available.

Options of the blower motor/fan packages are selected and wired from the factory to match performance criteria suggested in the performance section.

The fan(s) are placed in a draw-through configuration. They are constructed of corrosion resistant galvanized material.

Electrical

The unit control box contains all necessary devices to allow heating and cooling operation to occur from a remote wall thermostat. These devices are as follows:

- 24 VAC energy limiting class II 75 VA (minimum) transformer.
- 24 VAC blower motor relay.
- 24 VAC compressor contactor for compressor control.
- Field thermostat connections shall be provided for ease of hook-up to a terminal strip located in the unit's control box.
- Lockout relay which controls cycling of the compressor shall be provided to protect the compressor during adverse operating conditions. The device may be reset by interrupting power to the 24 VAC control circuit. Reset may be done either at a remote thermostat or through a momentary main power interruption.
- A high pressure switch shall protect the compressor against operation at refrigerant system pressures exceeding 395 psig.
- The low-water temperature switch or sensor shall prevent the compressor operation with leaving water temperatures below 20 F.
- Factory installed wire harness shall be available for the Deluxe, ZN510 and ZN524 control packages.

Nameplate information shall be provided for the application of either time-delay fuses or HACR circuit breakers for branch circuit protection from the primary source of power.

Deluxe Controls *(option)*

The deluxe control package provides a 75 VA transformer with circuit breaker. The controller includes a lockout relay, anti-short cycle compressor protection, random start delay, brown-out protection, low pressure time delay, compressor delay on start and an open relay for night setback or pump request. Optional wiring from the factory for night setback, condensate overflow, hot gas reheat, electric heat, and compressor enable is also provided. Three LEDs (light emitting diodes) are included for diagnostics of the equipment.

Tracer ZN510 Controller *(option)*

This system utilizes factory furnished and mounted DDC controls for operation of up to 120 units on a Comm 5 (LonMark) link. The Tracer ZN510 control package includes a 75 VA transformer. The controller provides random start delay, heating/ cooling status, occupied/unoccupied mode, fan status and filter maintenance options. Optional wiring from the factory for condensate overflow is available. Three LEDs (light emitting diodes) are included for diagnostics of the equipment.

The ZN510 is capable of a standalone application, or as applied to a full building automation installation.

Tracer ZN524 Controller *(option)*

The ZN524 controller utilizes factory furnished and mounted DDC controls for operation of up to 120 units on a Comm 5 (LonMark) link. The Tracer ZN524 control package includes a 75 VA (minimum) transformer. The controller provides random start delay, heating/cooling status, occupied/unoccupied mode, fan status and filter maintenance options. Optional wiring from the factory for condensate overflow is available. Three LEDs (light emitting diodes) are included for diagnostics of the equipment.

The ZN524 is capable of a standalone application, or as applied to a full building automation installation.

With this controller, the unit is capable of a hot gas reheat (for dehumidification), boilerless control for electric heat, waterside economizing, and support of variable speed pump control applications.

Economizing Coil *(option)*

The waterside economizing package is an external unit accessory piping kit and wiring ready for turn-key installation to the unit. The economizing coil is designed to perform with the WSHP at unit measured flow rate of 80.6 F DB/66.2 F WB with 45 F EWT.

All hydronic coils are of 3/8" (6-20 ton units), 1/2" (25 ton unit) copper and aluminum plate fin combination. All coils are proof and leak tested from the manufacturer.

The proof test is performed at 1.5 times the maximum operating pressure and the leak test at the maximum operating pressure.

A dual sloped non corrosive drain pan is easily accessible and cleanable for the hydronic economizing coil.

An electronic two-position, 3-way valve meters water flow to the economizing coil during the economizing mode. It is factory set to energize the economizing mode at 55 F, while simultaneously halting mechanical operation of the compressor.

The economizer is field attached to the equipment.

Electric Heat *(option)*

Boilerless control electric heat is factory wired and tested.

The boilerless control option is composed of a controls interface for a field provided boilerless or supplemental electric heat selection. The heater for this model is placed external to the equipment by the contractor for ease of installation. All power connections for the electric heater will be completely separate from the unit for field supplied electric heat.

Schedule B1. *Trane WSHP Cut Sheets (continued)*

Mechanical Specifications

Hot Gas Reheat *(option)*

Dehumidification is provided through a hot gas reheat option. The coil consists of 3/8"/1/2" copper tubes mechanically expanded into evenly spaced aluminum fins. All coils are proof and leak tested. The proof test must be performed at 1.5 time the maximum operating pressure and the leak test performed at the maximum operating pressure.

Ball Valves *(option)*

Ball valves are field installed between the unit and the supply and return lines of the loop to stop water flow to the unit in a maintenance or service situation.

Motorized Water Valve *(option)*

When extreme fluid temperature conditions do not exist with an open loop system, a motorized water valve may be applied to each water-source heat pump. The motorized valve shall stop flow to the unit, causing pressures to rise. This rise in pressure will halt pump operation to provide greater energy savings of the entire system.

Hoses *(option)*

Hoses consists of a stainless steel outer braid with an inner core of tube made of a nontoxic synthetic polymer material. The hoses are suitable for water temperatures ranging between 33 F and 211 F without the use of glycol.

Automatic Flow Devices *(option)*

The automatic flow kit contains a Hays Mesurflo® automatic flow control valve, two ball valves, two flexible hoses, a high flow Y-strainer, and may include a strainer blow-down and various other accessories.

The automatic flow control valve is factory set to a rated flow, and shall automatically control the flow to within 10% of the rated value over a 40 to 1 differential pressure, operating range (2 to 80 PSID). Operational temperature is rated from fluid freezing, to 225-degrees F. The valve body shall be constructed from hot forged brass UNS C37700 per ASTM B-283 latest revision. For more information pertaining to the automatic balancing hose kits, see literature documentation WSHP-SLB005-EN.

ARI Standard 13256-1

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Literature Order Number	WSHP-PRC014-EN
File Number	PL-UN-000-WSHP-PRC014-EN
Date	April 2006r
Supersedes	PL-UN-000-WSHP-PRC014-EN (0104)
Stocking Location	Inland

Trane has a policy of continuous product and product data improvement and reserves the right to change design and specifications without notice.

Schedule B2. *Krueger Air Diffuser Cut Sheets*

KRUEGER
Excellence in Air Distribution

SUPPLY | ROUND DIFFUSERS

RM2/RM4/RA2/RA4 SERIES | FOUR-CONES

RM2/5RM2/RM4/5RM4/RA2/RA4 PERFORMANCE DATA: HORIZONTAL/VERTICAL THROW

▼ IP/METRIC DATA: RM2/5RM2/RM4/5RM4/RA2/RA4 (NO DAMPER)

	IP Data													Metric Data										
	Neck Vel	Air Flow	Horizontal Ps	Horizontal Pt	Vertical Ps	Vertical Pt	Horizontal Throw	Vertical Projection 10°F	20°F	30°F	40°F	HZ	VT	Neck Vel	Air Flow	Horizontal Ps	Horizontal Pv	Vertical Pt	Vertical Pt	Horizontal Throw	Vertical Projection 5°C	11°C	17°C	22°C
	FPM	CFM	"WG	"WG	"WG	"WG	ft	ft	ft	ft	ft	NC	NC	m/s	L/s	Pa	Pa	Pa	Pa	m	m	m	m	m
6" Dia.	200	39	0.00	0.01	0.00	0.01	1 - 1 - 2	0	0	0	0	-	-	1.0	19	1	1	1	1	0.2 - 0.3 - 0.7	0.1	0.1	0.1	0.1
	400	79	0.01	0.02	0.02	0.03	1 - 2 - 4	2	1	1	1	-	-	2.0	37	3	5	5	2	0.5 - 0.7 - 1.4	0.5	0.4	0.3	0.3
	600	118	0.02	0.05	0.04	0.06	2 - 3 - 7	4	3	3	2	**20**	**21**	3.0	56	6	12	12	6	0.7 - 1.0 - 2.0	1.1	0.8	0.8	0.6
	800	157	0.04	0.08	0.07	0.11	3 - 4 - 8	6	5	4	4	**29**	**30**	4.1	74	11	21	21	10	0.9 - 1.4 - 2.3	1.9	1.4	1.4	1.1
	900	177	0.06	0.11	0.09	0.14	3 - 5 - 8	8	6	6	5	**32**	**33**	4.6	83	14	26	26	13	1.0 - 1.5 - 2.5	2.4	1.8	1.7	1.4
	1000	196	0.07	0.13	0.11	0.17	4 - 6 - 9	10	7	7	6	**35**	**36**	5.1	93	17	33	33	16	1.1 - 1.7 - 2.6	3.0	2.2	2.1	1.8
	1100	216	0.08	0.16	0.13	0.21	4 - 6 - 9	12	9	8	7	**38**	**39**	5.6	102	21	39	39	19	1.2 - 1.9 - 2.7	3.6	2.7	2.5	2.1
	1200	236	0.10	0.19	0.16	0.25	4 - 7 - 9	13	11	9	8	**41**	**42**	6.1	111	25	47	47	22	1.4 - 2.0 - 2.8	4.1	3.2	2.7	2.5
	1300	255	0.12	0.22	0.18	0.29	5 - 7 - 10	15	12	10	9	**43**	**44**	6.6	120	29	55	55	26	1.5 - 2.1 - 3.0	4.4	3.6	2.9	2.8
8" Dia.	200	70	0.00	0.01	0.00	0.01	1 - 1 - 3	1	1	1	1	-	-	1.0	33	1	1	1	1	0.3 - 0.5 - 0.9	0.3	0.2	0.2	0.2
	400	140	0.01	0.02	0.02	0.03	2 - 3 - 6	4	3	3	2	-	-	2.0	66	3	5	5	2	0.6 - 0.9 - 1.8	1.1	0.8	0.8	0.7
	600	209	0.02	0.05	0.04	0.06	3 - 4 - 9	8	6	6	5	**21**	**22**	3.0	99	6	12	12	6	0.9 - 1.4 - 2.7	2.5	1.9	1.8	1.5
	800	279	0.04	0.08	0.07	0.11	4 - 6 - 10	14	11	10	9	**30**	**31**	4.1	132	11	21	21	10	1.2 - 1.8 - 3.1	4.4	3.3	2.9	2.6
	900	314	0.06	0.11	0.09	0.14	4 - 7 - 11	16	13	11	10	**33**	**34**	4.6	148	14	26	26	13	1.4 - 2.0 - 3.3	4.9	4.0	3.3	3.1
	1000	349	0.07	0.13	0.11	0.17	5 - 7 - 11	18	15	12	11	**36**	**37**	5.1	165	17	33	33	16	1.5 - 2.3 - 3.5	5.5	4.4	3.6	3.4
	1100	384	0.08	0.16	0.13	0.21	5 - 8 - 12	20	16	13	12	**39**	**40**	5.6	181	21	39	39	19	1.7 - 2.5 - 3.6	6.0	4.9	4.0	3.8
	1200	419	0.10	0.19	0.16	0.25	6 - 9 - 12	22	17	14	13	**42**	**43**	6.1	198	25	47	47	22	1.8 - 2.7 - 3.8	6.6	5.3	4.4	4.1
	1300	454	0.12	0.22	0.18	0.29	6 - 9 - 13	23	19	16	15	**44**	**45**	6.6	214	29	55	55	26	2.0 - 2.8 - 3.9	7.1	5.7	4.7	4.4
10" Dia.	200	109	0.00	0.01	0.00	0.01	1 - 2 - 4	2	1	1	1	-	-	1.0	51	1	1	1	1	0.4 - 0.6 - 1.1	0.5	0.4	0.3	0.3
	400	218	0.01	0.02	0.02	0.03	2 - 4 - 7	7	5	5	4	-	**11**	2.0	103	3	5	5	2	0.8 - 1.1 - 2.3	2.0	1.5	1.4	1.2
	600	327	0.02	0.05	0.04	0.06	4 - 6 - 11	15	11	10	9	**22**	**23**	3.0	154	6	12	12	6	1.1 - 1.7 - 3.3	4.5	3.3	3.1	2.6
	800	436	0.04	0.08	0.07	0.11	5 - 7 - 13	20	16	13	13	**31**	**32**	4.1	206	11	21	21	10	1.5 - 2.3 - 3.9	6.2	5.0	4.1	3.8
	900	491	0.06	0.11	0.09	0.14	6 - 8 - 13	23	18	15	14	**34**	**35**	4.6	232	14	26	26	13	1.7 - 2.5 - 4.1	6.9	5.6	4.6	4.3
	1000	545	0.07	0.13	0.11	0.17	6 - 9 - 14	25	20	17	16	**37**	**38**	5.1	257	17	33	33	16	1.9 - 2.8 - 4.3	7.7	6.2	5.1	4.8
	1100	600	0.08	0.16	0.13	0.21	7 - 10 - 15	28	22	18	17	**40**	**41**	5.6	283	21	39	39	19	2.1 - 3.1 - 4.5	8.5	6.8	5.6	5.3
	1200	654	0.10	0.19	0.16	0.25	7 - 11 - 16	30	24	20	19	**43**	**44**	6.1	309	25	47	47	22	2.3 - 3.3 - 4.7	9.2	7.3	6.1	5.8
	1300	709	0.12	0.22	0.18	0.29	8 - 11 - 16	32	25	22	21	**45**	**46**	6.6	335	29	55	55	26	2.5 - 3.5 - 4.9	9.8	7.6	6.6	6.2
12" Dia.	200	157	0.00	0.01	0.00	0.01	1 - 2 - 4	2	2	2	1	-	-	1.0	74	1	1	1	1	0.5 - 0.7 - 1.4	0.7	0.6	0.5	0.4
	400	314	0.01	0.02	0.02	0.03	3 - 4 - 9	10	7	7	6	**11**	**12**	2.0	148	3	5	5	2	0.9 - 1.4 - 2.7	3.0	2.2	2.1	1.7
	600	471	0.02	0.05	0.04	0.06	4 - 7 - 13	20	16	13	12	**23**	**24**	3.0	222	6	12	12	6	1.4 - 2.0 - 4.0	6.0	4.8	4.0	3.7
	800	628	0.04	0.08	0.07	0.11	6 - 9 - 15	26	21	17	16	**31**	**32**	4.1	297	11	21	21	10	1.8 - 2.7 - 4.6	8.0	6.4	5.3	5.0
	900	707	0.06	0.11	0.09	0.14	7 - 10 - 16	29	24	20	18	**35**	**36**	4.6	334	14	26	26	13	2.0 - 3.1 - 4.9	9.0	7.2	5.9	5.6
	1000	785	0.07	0.13	0.11	0.17	7 - 11 - 17	33	26	22	20	**38**	**39**	5.1	371	17	33	33	16	2.3 - 3.4 - 5.2	10.0	8.0	6.6	6.2
	1100	864	0.08	0.16	0.13	0.21	8 - 12 - 18	35	28	24	22	**41**	**42**	5.6	408	21	39	39	19	2.5 - 3.7 - 5.4	10.8	8.4	7.3	6.8
	1200	942	0.10	0.19	0.16	0.25	9 - 13 - 19	37	29	26	24	**43**	**44**	6.1	445	25	47	47	22	2.7 - 4.0 - 5.7	11.3	8.8	7.9	7.3
	1300	1021	0.12	0.22	0.18	0.29	10 - 14 - 19	39	30	28	25	**46**	**47**	6.6	482	29	55	55	26	2.9 - 4.2 - 5.9	11.7	9.1	8.6	7.6
14" Dia.	200	214	0.00	0.01	0.00	0.01	2 - 3 - 5	3	2	2	2	-	-	1.0	101	1	1	1	1	0.5 - 0.8 - 1.6	1.0	0.8	0.7	0.6
	400	428	0.01	0.02	0.02	0.03	3 - 5 - 10	13	10	9	8	**11**	**12**	2.0	202	3	5	5	2	1.1 - 1.6 - 3.2	4.1	3.0	2.9	2.4
	600	641	0.02	0.05	0.04	0.06	5 - 8 - 15	24	19	16	15	**23**	**24**	3.0	303	6	12	12	6	1.6 - 2.4 - 4.7	7.4	5.9	4.9	4.6
	800	855	0.04	0.08	0.07	0.11	7 - 10 - 18	32	26	21	20	**32**	**33**	4.1	404	11	21	21	10	2.1 - 3.2 - 5.4	9.8	7.9	6.5	6.1
	900	962	0.06	0.11	0.09	0.14	8 - 12 - 19	36	29	24	23	**35**	**36**	4.6	454	14	26	26	13	2.4 - 3.6 - 5.7	11.0	8.9	7.3	6.9
	1000	1069	0.07	0.13	0.11	0.17	9 - 13 - 20	39	31	27	25	**39**	**40**	5.1	505	17	33	33	16	2.6 - 4.0 - 6.0	12.0	9.3	8.1	7.6
	1100	1176	0.08	0.16	0.13	0.21	10 - 14 - 21	41	32	29	27	**41**	**42**	5.6	555	21	39	39	19	2.9 - 4.4 - 6.3	12.6	9.8	8.9	8.1
	1200	1283	0.10	0.19	0.16	0.25	10 - 15 - 22	43	34	32	28	**44**	**45**	6.1	605	25	47	47	22	3.2 - 4.7 - 6.6	13.1	10.2	9.7	8.5
	1300	1390	0.12	0.22	0.18	0.29	11 - 16 - 23	45	35	35	29	**46**	**47**	6.6	656	29	55	55	26	3.4 - 4.9 - 6.9	13.7	10.6	10.6	8.8
16" Dia.	200	279	0.00	0.01	0.00	0.01	2 - 3 - 6	4	3	3	3	-	-	1.0	132	1	1	1	1	0.6 - 0.9 - 1.8	1.3	1.0	0.9	0.8
	400	559	0.01	0.02	0.02	0.03	4 - 6 - 12	17	13	12	10	**12**	**13**	2.0	264	3	5	5	2	1.2 - 1.8 - 3.6	5.2	3.9	3.7	3.0
	600	838	0.02	0.05	0.04	0.06	6 - 9 - 18	29	23	19	18	**24**	**25**	3.0	395	6	12	12	6	1.8 - 2.7 - 5.4	8.7	7.0	5.8	5.4
	800	1117	0.04	0.08	0.07	0.11	8 - 12 - 20	38	31	25	24	**32**	**33**	4.1	527	11	21	21	10	2.4 - 3.6 - 6.2	11.6	9.4	7.7	7.3
	900	1257	0.06	0.11	0.09	0.14	9 - 13 - 22	43	33	29	27	**36**	**37**	4.6	593	14	26	26	13	2.7 - 4.1 - 6.6	13.0	10.1	8.7	8.2
	1000	1396	0.07	0.13	0.11	0.17	10 - 15 - 23	45	35	32	29	**39**	**40**	5.1	659	17	33	33	16	3.0 - 4.5 - 6.9	13.7	10.7	9.6	8.8
	1100	1536	0.08	0.16	0.13	0.21	11 - 16 - 24	47	37	35	31	**42**	**43**	5.6	725	21	39	39	19	3.3 - 5.0 - 7.2	14.4	11.2	10.6	9.3
	1200	1676	0.10	0.19	0.16	0.25	12 - 18 - 25	49	38	38	32	**45**	**46**	6.1	791	25	47	47	22	3.6 - 5.4 - 7.6	15.0	11.7	11.6	9.7
	1300	1815	0.12	0.22	0.18	0.29	13 - 18 - 26	51	40	41	33	**47**	**48**	6.6	857	29	55	55	26	3.9 - 5.6 - 7.9	15.6	12.2	12.3	10.1

► *Throw values are given terminal velocities of 150, 100, and 50 FPM (0.75, 0.50, and 0.25 m/s). Horizontal throw values are given for isothermal conditions. Vertical throw values are for a terminal velocity of 50 FPM at the temperature differences shown. NC values are based on octave band 2 - 7 sound power levels minus a room absorption of 10dB, re 10^{-12} watts. Dash (-) in space denotes a NC value of less than 10. Data was obtained from tests conducted in accordance with ANSI/ASHRAE Standard 70, ISO Standard 5219, and ISO Standard 3741. See K-Select program for performance data not shown, including octave band data.*

ROUND DIFFUSERS

RM2 - RM4 - RA2 - RA4

Schedule B2. *Krueger Air Diffuser Cut Sheets (cont'd.)*

SUPPLY | ROUND DIFFUSERS

RM2/RM4/RA2/RA4 SERIES | FOUR-CONES

KRUEGER
Excellence in Air Distribution

RM2/5RM2/RM4/5RM4/RA2/RA4 PERFORMANCE DATA: HORIZONTAL/VERTICAL THROW

▼ IP/METRIC DATA: RM2/5RM2/RM4/5RM4/RA2/RA4 (NO DAMPER)

	IP Data													Metric Data											
	Neck Vel	Air Flow	Horizontal Ps	Horizontal Pt	Vertical Ps	Vertical Pt	Horizontal Throw	Vertical Projection 10°F	20°F	30°F	40°F	HZ	VT	Neck Vel	Air Flow	Horizontal Ps	Horizontal Pv	Vertical Pt	Vertical Pt	Horizontal Throw	Vertical Projection 5°C	11°C	17°C	22°C
	FPM	CFM	"WG	"WG	"WG	"WG	ft	ft	ft	ft	ft	NC	NC	m/s	L/s	Pa	Pa	Pa	Pa	m	m	m	m	m
	200	353	0.00	0.01	0.00	0.01	2 - 3 - 7	5	4	4	3	-	-	1.0	167	1	1	1	1	0.7 - 1.0 - 2.0	1.6	1.2	1.1	0.9
	400	707	0.01	0.02	0.02	0.03	4 - 7 - 13	21	16	15	12	**12**	**13**	2.0	334	3	5	5	2	1.4 - 2.0 - 4.1	6.4	4.7	4.5	3.7
	600	1060	0.02	0.05	0.04	0.06	7 - 10 - 20	33	27	22	21	**24**	**25**	3.0	500	6	12	12	6	2.0 - 3.1 - 6.0	10.1	8.1	6.7	6.3
18"	800	1414	0.04	0.08	0.07	0.11	9 - 13 - 23	44	35	29	28	**33**	**34**	4.1	667	11	21	21	10	2.7 - 4.1 - 7.0	13.4	10.7	8.9	8.4
Dia.	900	1590	0.06	0.11	0.09	0.14	10 - 15 - 24	48	37	33	31	**36**	**37**	4.6	751	14	26	26	13	3.1 - 4.6 - 7.4	14.6	11.4	10.0	9.4
	1000	1767	0.07	0.13	0.11	0.17	11 - 17 - 26	51	39	37	33	**40**	**41**	5.1	834	17	33	33	16	3.4 - 5.1 - 7.8	15.4	12.0	11.1	9.9
	1100	1944	0.08	0.16	0.13	0.21	12 - 18 - 27	53	41	40	34	**42**	**43**	5.6	917	21	39	39	19	3.7 - 5.6 - 8.2	16.2	12.6	12.3	10.4
	1200	2121	0.10	0.19	0.16	0.25	13 - 20 - 28	56	43	44	36	**45**	**46**	6.1	1001	25	47	47	22	4.1 - 6.0 - 8.5	16.9	13.1	13.3	10.9
	1300	2297	0.12	0.22	0.18	0.29	15 - 21 - 29	58	45	46	37	**47**	**48**	6.6	1084	29	55	55	26	4.4 - 6.3 - 8.9	17.6	13.7	13.9	11.3
	200	436	0.00	0.01	0.00	0.01	2 - 4 - 7	6	5	4	4	-	-	1.0	206	1	1	1	1	0.8 - 1.1 - 2.3	1.9	1.4	1.3	1.1
	400	873	0.01	0.02	0.02	0.03	5 - 7 - 15	25	18	17	14	**13**	**14**	2.0	412	3	5	5	2	1.5 - 2.3 - 4.5	7.5	5.6	5.1	4.4
	600	1309	0.02	0.05	0.04	0.06	7 - 11 - 22	38	30	25	23	**25**	**26**	3.0	618	6	12	12	6	2.3 - 3.4 - 6.7	11.4	9.2	7.6	7.1
20"	800	1745	0.04	0.08	0.07	0.11	10 - 15 - 25	50	39	33	31	**33**	**34**	4.1	824	11	21	21	10	3.0 - 4.5 - 7.7	15.2	11.9	10.1	9.5
Dia.	900	1963	0.06	0.11	0.09	0.14	11 - 17 - 27	53	42	37	34	**37**	**38**	4.6	927	14	26	26	13	3.4 - 5.1 - 8.2	16.3	12.6	11.4	10.5
	1000	2182	0.07	0.13	0.11	0.17	12 - 19 - 28	56	44	42	36	**40**	**41**	5.1	1030	17	33	33	16	3.8 - 5.7 - 8.6	17.1	13.3	12.6	11.1
	1100	2400	0.08	0.16	0.13	0.21	14 - 20 - 30	59	46	46	38	**43**	**44**	5.6	1133	21	39	39	19	4.1 - 6.2 - 9.1	18.0	14.0	13.9	11.6
	1200	2618	0.10	0.19	0.16	0.25	15 - 22 - 31	62	48	49	40	**45**	**46**	6.1	1236	25	47	47	22	4.5 - 6.7 - 9.5	18.8	14.6	14.8	12.1
	1300	2836	0.12	0.22	0.18	0.29	16 - 23 - 32	64	50	51	41	**48**	**49**	6.6	1339	29	55	55	26	4.9 - 7.0 - 9.8	19.5	15.2	15.4	12.6
	200	628	0.00	0.01	0.00	0.01	3 - 4 - 9	8	6	6	5	-	-	1.0	297	1	1	1	1	0.9 - 1.4 - 2.7	2.5	1.8	1.7	1.4
	400	1257	0.01	0.02	0.02	0.03	6 - 9 - 18	31	24	21	19	**13**	**14**	2.0	593	3	5	5	2	1.8 - 2.7 - 5.4	9.4	7.3	6.2	5.7
	600	1885	0.02	0.05	0.04	0.06	9 - 13 - 26	46	37	31	29	**25**	**26**	3.0	890	6	12	12	6	2.7 - 4.1 - 8.0	14.1	11.4	9.4	8.8
24"	800	2513	0.04	0.08	0.07	0.11	12 - 18 - 30	61	47	41	39	**34**	**35**	4.1	1186	11	21	21	10	3.6 - 5.4 - 9.3	18.4	14.3	12.5	11.7
Dia.	900	2827	0.06	0.11	0.09	0.14	13 - 20 - 32	64	50	46	41	**38**	**39**	4.6	1334	14	26	26	13	4.1 - 6.1 - 9.8	19.5	15.2	14.0	12.6
	1000	3142	0.07	0.13	0.11	0.17	15 - 22 - 34	68	53	51	44	**41**	**42**	5.1	1483	17	33	33	16	4.5 - 6.8 - 10.4	20.6	16.0	15.6	13.3
	1100	3456	0.08	0.16	0.13	0.21	16 - 25 - 36	71	55	56	46	**44**	**45**	5.6	1631	21	39	39	19	5.0 - 7.5 - 10.9	21.6	16.8	17.0	13.9
	1200	3770	0.10	0.19	0.16	0.25	18 - 26 - 37	74	58	58	48	**46**	**47**	6.1	1779	25	47	47	22	5.4 - 8.0 - 11.4	22.5	17.5	17.8	14.5
	1300	4084	0.12	0.22	0.18	0.29	19 - 27 - 39	77	60	61	50	**49**	**50**	6.6	1927	29	55	55	26	5.9 - 8.4 - 11.8	23.5	18.2	18.5	15.1
	200	982	0.00	0.01	0.00	0.01	4 - 6 - 11	11	8	8	6	-	-	1.0	463	1	1	1	1	1.1 - 1.7 - 3.4	3.3	2.5	2.3	1.9
	400	1963	0.01	0.02	0.02	0.03	7 - 11 - 22	40	32	26	25	**14**	**15**	2.0	927	3	5	5	2	2.3 - 3.4 - 6.8	12.1	9.7	8.0	7.5
	600	2945	0.02	0.05	0.04	0.06	11 - 17 - 33	59	48	39	37	**26**	**27**	3.0	1390	6	12	12	6	3.4 - 5.1 - 10.0	18.1	14.6	12.0	11.3
30"	800	3927	0.04	0.08	0.07	0.11	15 - 22 - 38	76	59	53	49	**35**	**36**	4.1	1853	11	21	21	10	4.5 - 6.8 - 11.6	23.0	17.9	16.0	14.8
Dia.	900	4418	0.06	0.11	0.09	0.14	17 - 25 - 40	80	62	59	52	**38**	**39**	4.6	2085	14	26	26	13	5.1 - 7.6 - 12.3	24.4	19.0	18.0	15.7
	1000	4909	0.07	0.13	0.11	0.17	19 - 28 - 43	85	66	66	55	**42**	**43**	5.1	2317	17	33	33	16	5.7 - 8.5 - 13.0	25.7	20.0	20.0	16.6
	1100	5400	0.08	0.16	0.13	0.21	20 - 31 - 45	89	69	70	57	**44**	**45**	5.6	2548	21	39	39	19	6.2 - 9.3 - 13.6	27.0	21.0	21.3	17.4
	1200	5890	0.10	0.19	0.16	0.25	22 - 33 - 47	93	72	73	60	**47**	**48**	6.1	2780	25	47	47	22	6.8 - 10.0 - 14.2	28.2	21.9	22.2	18.2
	1300	6381	0.12	0.22	0.18	0.29	24 - 34 - 49	96	75	76	62	**49**	**50**	6.6	3012	29	55	55	26	7.4 - 10.4 - 14.8	29.3	22.8	23.1	18.9
	200	1414	0.00	0.01	0.00	0.01	4 - 7 - 13	14	10	10	8	-	-	1.0	667	1	1	1	1	1.4 - 2.0 - 4.1	4.1	3.1	2.9	2.4
	400	2827	0.01	0.02	0.02	0.03	9 - 13 - 27	48	39	32	30	**15**	**16**	2.0	1334	3	5	5	2	2.7 - 4.1 - 8.1	14.7	11.8	9.7	9.1
	600	4241	0.02	0.05	0.04	0.06	13 - 20 - 40	72	58	48	45	**27**	**28**	3.0	2002	6	12	12	6	4.1 - 6.1 - 12.0	22.0	17.7	14.6	13.7
36"	800	5655	0.04	0.08	0.07	0.11	18 - 27 - 46	91	71	64	59	**36**	**37**	4.1	2669	11	21	21	10	5.4 - 8.1 - 13.9	27.6	21.5	19.4	17.8
Dia.	900	6362	0.06	0.11	0.09	0.14	20 - 30 - 49	96	75	72	62	**39**	**40**	4.6	3002	14	26	26	13	6.1 - 9.2 - 14.7	29.3	22.8	21.9	18.9
	1000	7069	0.07	0.13	0.11	0.17	22 - 33 - 51	101	79	80	65	**42**	**43**	5.1	3336	17	33	33	16	6.8 - 10.2 - 15.5	30.9	24.0	24.3	19.9
	1100	7775	0.08	0.16	0.13	0.21	25 - 37 - 54	106	83	84	69	**45**	**46**	5.6	3670	21	39	39	19	7.5 - 11.2 - 16.3	32.4	25.2	25.5	20.9
	1200	8482	0.10	0.19	0.16	0.25	27 - 40 - 56	111	86	88	72	**48**	**49**	6.1	4003	25	47	47	22	8.1 - 12.0 - 17.0	33.8	26.3	26.6	21.8
	1300	9189	0.12	0.22	0.18	0.29	29 - 41 - 58	116	90	91	75	**50**	**51**	6.6	4337	29	55	55	26	8.8 - 12.5 - 17.7	35.2	27.4	27.7	22.7

► *Throw values are given terminal velocities of 150, 100, and 50 FPM (0.75, 0.50, and 0.25 m/s). Horizontal throw values are given for isothermal conditions. Vertical throw values are for a terminal velocity of 50 FPM at the temperature differences shown. NC values are based on octave band 2 - 7 sound power levels minus a room absorption of 10dB, re 10^{-12} watts. Dash (-) in space denotes a NC value of less than 10. Data was obtained from tests conducted in accordance with ANSI/ASHRAE Standard 70, ISO Standard 5219, and ISO Standard 3741. See K-Select program for performance data not shown, including octave band data.*

ROUND DIFFUSERS

RM2 - RM4 - RA2 - RA4

Schedule B2. *Krueger Air Diffuser Cut Sheets (cont'd.)*

KRUEGER
Excellence in Air Distribution

SUPPLY | ROUND DIFFUSERS

RM/RA SERIES | CONE DIFFUSERS

INTRODUCTION: RM/RA SERIES

Krueger's RM/RA round ceiling diffusers provide excellent performance in variable air volume systems. The round ceiling diffusers have three or four cones depending on model selected to provide a uniform appearance regardless of design specifications. Krueger's round ceiling diffusers come in three styles.

The first style, RM1/5RM1, is used when vertical throw is not needed, but the consumer needs to adjust the room air induction. This is accomplished by utilizing the two position inner cones. At position one, capacity is maximized. In position two, room air induction is increased.

The second style, RM2/5RM2/RM4/5RM4, is used when horizontal and vertical discharge is required. This is accomplished by utilizing the three position inner cones. At position one, capacity is maximized and throw is horizontal. In position two, room air induction is increased and the throw remains horizontal. When set in position three, the air projects vertically from the diffuser.

The third style, RA2/RA4, is used when horizontal and vertical discharge is required with infinite adjustability between horizontal and vertical. In the full open setting, capacity is maximized and throw is horizontal. In the full closed setting, air projects vertically from the diffuser.

Krueger's round ceiling diffusers come with a safety cable to secure the inner cones after removal. (Safety cable is optional for 12" inlet size or smaller.)

MODELS

MODEL RM1 - Steel, 3-Cones, 2-Position Adjustments
MODEL 5RM1 - Aluminum, 3-Cones, 2-Position Adjustments
MODEL RM2 - Steel, 4-Cones, 3-Position Adjustments
MODEL 5RM2 - Aluminum, 4-Cones, 3-Position Adjustments
MODEL RM4 - Steel, 4-Cones, 3-Position Adjustments with Large Outer Anti-smudge Cone
MODEL 5RM4 - Aluminum, 4-Cones, 3-Position Adjustments with Large Outer Anti-smudge Cone
MODEL RA2 - Steel, 4-Cones, Fully Adjustable
MODEL RA4 - Aluminum, 4-Cones, Fully Adjustable, with Large Outer Anti-smudge Cone

FEATURES

- Horizontal Only (RM1/5RM1) Air Distribution
- Horizontal/Vertical (RM2/5RM2/RM4/5RM4/RA2/RA4) Air Distribution
- Designed for Heating and Cooling Applications
- 360° Discharge Air Pattern
- Excellent Performance in Variable Air Volume Systems
- Designed for Exposed Duct or Hard Ceiling Applications

RM1 ►

RM2 ►

RA4 ►

ROUND DIFFUSERS

RM-RA SERIES

ACCESSORIES

- Optional Safety Cable (12" Inlets or Smaller)
- Optional Round Straightening Grid

FINISHES

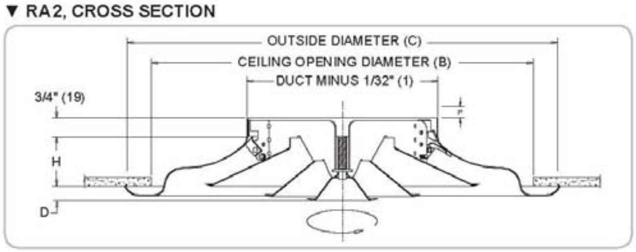
- Standard Finish is British White
- Optional Finishes Available

Schedule B2. *Krueger Air Diffuser Cut Sheets (cont'd.)*

ROUND DIFFUSERS

RA2 DIMENSIONAL INFORMATION

▼ RA2, CROSS SECTION



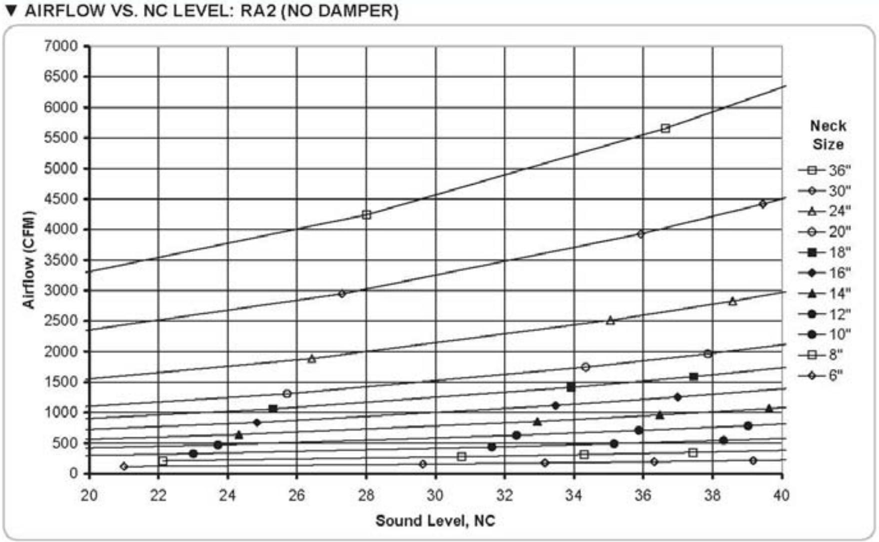
▼ RA2, AVAILABLE NECK SIZES

Nominal Round Duct Size	Ceiling Opening Diameter B	Outside Diameter C	Position 1 (Horizontal) D	Position 3 (Vertical) D	H	P
6"	12" (305)	13 1/2" (343)	1 7/16" (37)	11/16" (17)	1 5/8" (41)	-
8"	16" (406)	18" (457)	1 13/16" (46)	7/8" (19)	2 1/8" (54)	-
10"	20" (508)	22 1/2" (572)	2 1/4" (57)	1 1/8" (29)	2 5/8" (67)	-
12"	24" (635)	27" (686)	2 11/16" (68)	1 1/4" (32)	3 1/4" (83)	-
14"	28" (711)	31 1/2" (800)	3 1/8" (79)	1 3/16" (30)	3 3/4" (95)	2 1/2" (64)
16"	32" (813)	36" (914)	3 5/16" (84)	1 5/16" (33)	4 1/4" (108)	2 5/8" (67)
18"	36" (914)	40 1/2" (1029)	3 3/4" (95)	1 1/2" (38)	4 7/8" (124)	2 3/4" (70)
20"	40" (1016)	45" (1143)	4 1/8 (105)	1 5/8" (41)	5 3/8" (137)	3" (76)
24"	48" (1219)	54" (1372)	4 7/8" (121)	1 7/8" (48)	6 1/2" (165)	3 1/8" (79)
30"	60" (1524)	67 1/2" (1715)	5 9/16" (141)	1 7/8" (48)	8" (203)	4 3/8" (111)
36"	60" (1524)	67 1/2" (1715)	5 9/16" (141)	1 7/8" (48)	8" (203)	4 3/8" (111)

► *Dimensions in () are mm.*

RA2 REFERENCE CHART

▼ AIRFLOW VS. NC LEVEL: RA2 (NO DAMPER)



R A 2

Schedule B2. *Krueger Air Diffuser Cut Sheets (cont'd.)*

SUPPLY | ROUND DIFFUSERS

RM2/RM4/RA2/RA4 SERIES | FOUR-CONES

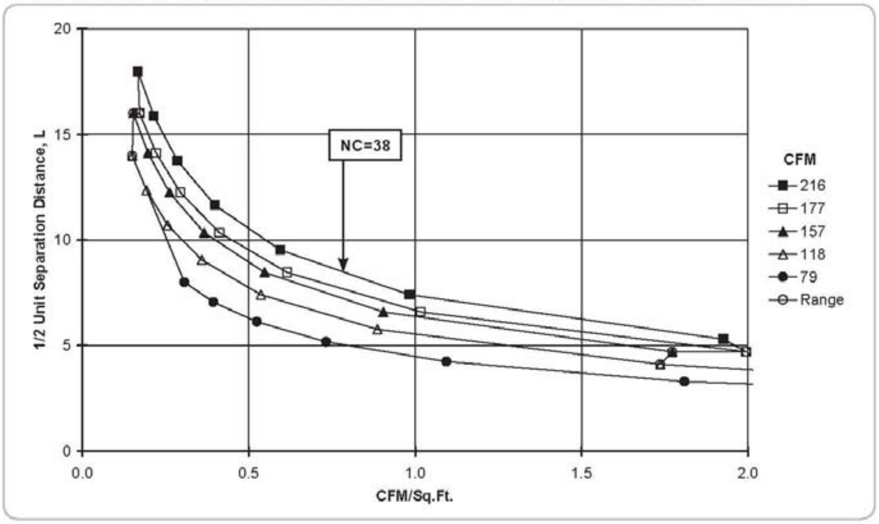
KRUEGER Excellence in Air Distribution

ROUND DIFFUSERS

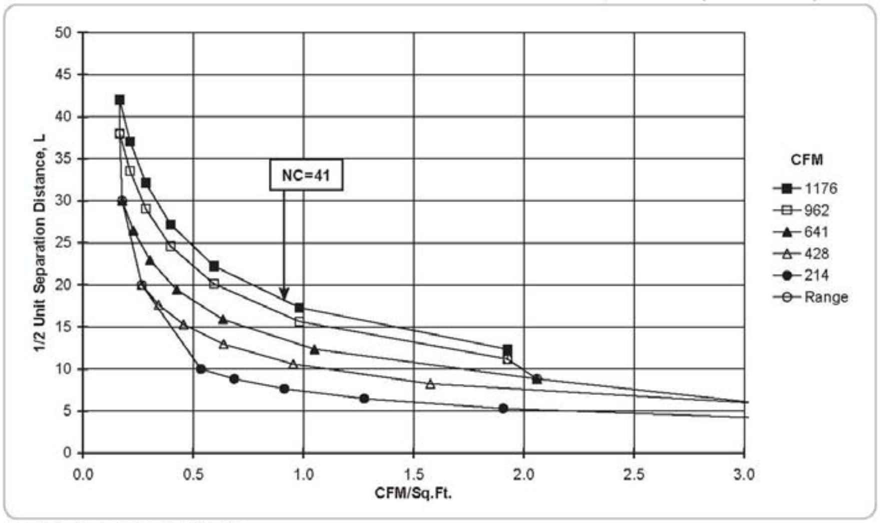
RM2-RM4-RA2-RA4

RM2/5RM2/RM4/5RM4/RA2/RA4 REFERENCE CHARTS: HORIZONTAL THROW

▼ DIFFUSER SPACING FOR 80% ADPI: RM2/5RM2/RM4/5RM4/RA2/RA4, 6" NECK (NO DAMPER)



▼ DIFFUSER SPACING FOR 80% ADPI: RM2/5RM2/RM4/5RM4/RA2/RA4, 14" NECK (NO DAMPER)



► *Charts are at 20 BTUH/ft² loads.*
See the Engineering section of this catalog for instructions on how to read these charts and additional ADPI information.

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