Final Report

Energy Conservation Strategies for Air Supported Structures

May 2002

Prepared For:

Minnesota Department of Commerce, State Energy Office

Prepared By:

Eugene A. Scales & Associates, Inc.

This report was prepared as part of an account of work sponsored under U.S. Department of Energy grant number DE-FG45-96R530335 to the Minnesota Department of Commerce, Energy Division. However, any opinions, findings, conclusions, or recommendations are those of the authors and do not necessarily reflect the views of the U.S. Department of Energy.

Customer Information Page

Customer:	Minnesota Department of Commerce, State Energy Office 85 7th Place East, Suite 500 St. Paul, Minnesota 55101-2198
Contract Number:	A26687
Contact	Bruce Nelson Phone (651) 297-2313 Bruce.Nelson@state.mn.us Minnesota Department of Commerce Energy Information Center Phone 651-296-5175 or 1-800-657-3710
Engineering Firm:	Eugene A. Scales & Associates, Inc. Gene Scales 33101 Old Highway 8, Suite 100 Roseville, Minnesota 55113 Phone (651) 636-9928 EAScale@aol.com

Table Of Contents

Disclaimer

Estimated energy savings and implementation costs for energy conservation strategies are based on inputs from air-supported structures owner, operators and suppliers along with experience with similar applications. While the energy conservation opportunities contained in this report have been reviewed for technical accuracy, neither the **Minnesota Department of Commerce, State Energy Office** nor **Eugene A. Scales & Associates Inc.** guarantee the cost savings or reduction in total energy use presented in the recommendations. Neither the **Minnesota Department of Commerce, State Energy Office** nor **Eugene A. Scales & Associates Inc.** shall be liable in any event including but not limited to an event that predicted energy savings are not achieved.

Specific manufacturers of lighting, motors, adjustable speed drives, and other equipment, are identified in the body of this report. The report uses equipment models and costs to develop representative paybacks on energy saving opportunities. Manufacturers identified in the report are provided for informational purposes only and are not to be construed as recommendations. These identifications do not constitute an approval, warranty, guarantee or endorsement by the **Minnesota Department of Commerce, State Energy Office** or **Eugene A. Scales & Associates Inc**.

All utility rebates cited are subject to revision.

Section 1

Introduction & Overview

This report identifies energy conservation strategies for air-supported structures; both new and retrofit opportunities.

The primary objective of this analysis was to determine conservation strategies providing paybacks of less than 10 years that would facilitate compliance with the Minnesota State Energy Code for new air-supported structures (Minnesota Rules, Part 7676.0900, Subpart 1, Item B).

A secondary objective was to provide a resource for suppliers, owners and operators of new and existing structures to identify and understand the value of energy conservation opportunities applicable to air-supported structures.

A simulation was developed to analyze conservation strategies. This approach was used to understand the interactions of the strategies. The simulation considered lighting, occupants, motors, heating and cooling systems, structure operating schedules and Minneapolis, St. Paul, Minnesota weather conditions.

Three baseline air-supported structures were analyzed as part of the analysis:

- Air-supported structure, un-insulated and used primarily during the winter months. This is typical of many air-supported structures currently found in the Minneapolis, St. Paul, Minnesota Metropolitan area. Many are taken down during the summer months so that facilities such as tennis courts can be used out doors.

- Air-supported structure, insulated and used mainly during the winter months. There are a few, (i.e. estimated at 4 – 6) in the Minneapolis, St. Paul, Minnesota Metropolitan area. Insulated structures must remain inflated because of the insulation bulk.

- Air-supported structure, insulated and cooled and used year around. This modification of the basic structure is expected to be common in the future as they offer year around. These structures will have both heating and cooling systems.

Section 2

Executive Summary

Energy conservation strategies for air-supported structures were analyzed separately and in selected combinations. Results are summarized in Tables 2-1, 2 – 1a and 2 – 1b.

<u>General Conservation Strategy Focus</u>

The analysis indicated that there is a general conservation strategy applicable for air-supported structures. The initial focus should be on those strategies that reduce leakage, control pressurization and provide temperature control that can significantly reduce energy use and operating costs with minimal costs.

Night Setback

There can be significant heating and ventilation savings (i.e. up to 50%) by establishing a deep night setback strategy. Most manufacturers suggest turning off heating during the nighttime hours, even during the coldest part of the winter. Makeup air units have the capacity to return the structure to occupied conditions in 30-45 minutes.

Leak Control & Structure Pressurization

Air supported structures can have significant air leaks. The amount of leakage is a function of structure pressurization. Repairing leaks and controlling structure pressurization, either manually or through the use of wind sensor controls and/or adjustable speed fan drives (ASD's) saves energy required to condition (i.e. heat and cool) outside air brought into the structure. Ventilation energy savings up to 25% can be achieved by reducing leakage. ASD's can save up to 25% of the fan motor energy. If the structure is air conditioned, the size of the cooling system can be reduced.

Installation of ASD's should be coordinated with the supplier. ASD's require burner systems that have high or continuous modulation and high temperature limit controls on the burners.

One manufacturer installs s smaller separate fan system for use during the summer months and during periods when no space conditioning is required (e.g., night setback periods).

Analysis of Individual Conservation Strategies

Lighting

Pulse start metal halide technology is available to reduce lighting costs. This technology, about 4-5 years old, has lamps with 30 – 40% less lumen depreciation. Therefore, new fixtures ordered with 750 to 875 watt lamps and ballasts will provide about the same or more light than the standard 1,000-watt lamp used in these structures. Unfortunately, direct replacement lamps are currently available with base up (i.e., lamp hangs down) configurations. Lamp sizes of 400 and 750-watts are available in horizontal configurations, but may require a spot light enclosure.

Premium Efficiency Motors

Premium efficiency motors can be ordered as an option for a small incremental cost and will provide a payback of 2 – 3 years. Retrofitting existing standard efficiency motors is an option that should be pursued when replacing a burned out motor since the incremental costs are low.

Insulation

Installing insulation can reduce heating energy use up to 75%. When insulated, the structure fabric becomes opaque and additional lighting energy is required. Insulating a structure that is used only during the winter months and continuing to operate the structure all year long as opposed to leaving the structure un-insulated and deflating the structure during the summer months provides energy and cost savings that provide a payback on the insulation costs of 4 – 5 years.

Energy Efficient Heating and Cooling Systems

Existing indirect fired makeup air system, typically the standard of the air-supported structure industry, are 80% efficient. Energy efficient heating system options such as condensing boilers and ground source heat pumps systems have much higher first costs, but lower operational costs. However, for air-supported structures, paybacks become very poor, especially when heating and ventilation energy use is reduced by more cost effective strategies such as night setback, leak reduction and pressurization control.

Air-cooled condensing systems used for cooling tend to have similar efficiencies. Efficiencies of available systems vary between 1.20 kw/ton to 1.25 kw/ton and depend on the selected vendor. Selecting a unit that has better efficiency can provide benefits. A difference of .1 kw/ton on the baseline building system of 90 tons would provide about 8% savings. Building owners and operators should consider cooling system with better efficiencies on new or retrofit structures.

Standby Propane Systems

Standby propane systems were found not to be cost effective. Heating and ventilation energy use can be reduced by more cost effective strategies such as night setback and leak reduction. After these strategies are implemented, standby propane systems are not economical unless the air-supported structure in part of a larger complex of buildings.

Mixed Conservation Strategies

Mixed strategies are combinations of individual strategies. Conservation strategy combinations should be selected and combined to reflect those that provide maximum benefits while minimizing implementation costs. The analysis performed on selected combinations confirms that the initial focus should be on strategies that provide night setback, leak reduction and pressurization control. Cost savings will help provide shorter paybacks for higher cost strategies when included in the mix of strategies.

Table 2 - 1, Conservation Strategy Summary Energy & Cost Savings

Conservation Strategy	Heat Energy (MMBTU)	Vent Energy (MMBTU)	Lighting Kw	Lighting Kwh	Motors Kw	Motors Kwh	Cooling Kw	Cooling Kwh	Annual Save ($)	Strategy Cost ($)	Simple Payback
875 Watt Pulse Start Fixtures (New)											
Un-insulated	-32		5.40	7,671					$655	$3,250	5.0
Insulated	-51		5.40	11,975					$750	$3,250	4.3
Insulated & Cooled	-51		5.40	11,975			1.90	3,370	$983	$3,250	3.3
750 Watt Pulse Start Fixtures (New)											
Un-insulated	-64		10.60	15,059					$1,284	$3,000	2.3
Insulated	-100		10.60	23,506					$1,473	$3,000	2.0
Insulated & Cooled	-100		10.60	23,506			3.70	6,615	$1,929	$3,000	1.6
875 Watt Pulse Start Fixtures (Retrofit 1000W)											
Un-insulated	-32		5.40	7,671					$655	$8,250	12.6
Insulated	-51		5.40	11,975					$750	$8,250	11.0
Insulated & Cooled	-51		5.40	11,975			1.90	3,370	$1,176	$8,250	7.0
750 Watt Pulse Start Fixtures (Retrofit 1000W)											
Un-insulated	-64		10.60	15,059					$1,284	$8,000	6.2
Insulated	-100		10.60	23,506					$1,473	$8,000	5.4
Insulated & Cooled	-100		10.60	23,506			3.70	6,615	$1,929	$8,000	4.1
Replace 1000 W with 750 W Spot Light Fixt											
Un-insulated	-64		10.60	15,059					$1,284	$13,750	10.7
Insulated	-100		10.60	23,506					$1,473	$13,750	9.3
Insulated & Cooled	-100		10.60	23,506			3.70	6,615	$1,926	$13,750	7.1
Replace 1000 W with Two 400 W Spot Light Fixt											
Un-insulated	-38		6.40	9,092					$776	$21,250	27.4
Insulated	-60		6.40	14,192					$890	$21,250	23.9
Insulated & Cooled	-60		6.40	14,192			2.30	3,994	$1,166	$21,250	18.2
Premium Efficient Motors (New)											
Un-insulated	-5		0.30	2,629					$120	$333	2.8
Insulated	-5		0.30	2,629					$120	$333	2.8
Insulated & Cooled	-5		0.30	2,629			0.1	385	$142	$333	2.3

Table 2 - 1a, Conservation Strategy Summary Energy & Cost Savings (Conti)

Conservation Strategy	Heat Energy (MMBTU)	Vent Energy (MMBTU)	Lighting Kw	Lighting Kwh	Motors Kw	Motors Kwh	Cooling Kw	Cooling Kwh	Annual Save ($)	Strategy Cost ($)	Simple Payback
Premium Efficient Motors (Retrofit)											
Un-insulated	-5		0.30	2,629					$120	$2,965	24.7
Insulated	-5		0.30	2,629					$120	$2,965	24.7
Insulated & Cooled	-5		0.30	2,629			0.1	385	$142	$2,965	20.9
Standard Efficient Motors (Retrofit)											
Un-insulated	-21		1.15	10,124					$459	$2,965	6.5
Insulated	-21		1.15	10,124					$459	$2,965	6.5
Insulated & Cooled	-21		1.15	10,124			0.1	385	$542	$2,965	5.5
Insulation											
Uninsulated											
R - 12.2	2,756			-34,428					$20,675	$60,750	2.9
R - 13.2	2,815			-34,428			0.90	313	$21,162	$60,750	2.9
R - 14.2	2,865			-34,428			1.70	583	$21,577	$60,750	2.8
Insulate & Operate vs Un-insulate & Deflate	2,756						-25.70	-112,430	$14,138	$60,750	4.3
Night Setback (Shut Off at Night)											
Un-insulated	1,589	679							$17,010	$5,500	0.3
Insulated	262	679							$7,056	$5,500	0.8
Insulated & Cooled	262	679							$7,056	$5,500	0.8
Pressurization Control											
Manual Control											
Uninsulated		123				14,897			$1,758	$5,000	2.8
Insulated		123				14,897			$1,758	$5,000	2.8
Insulated & Cooled		123				14,897	4.30	3,272	$2,077	$5,000	2.4
Automatic Control (Wind Sensor)											
Uninsulated		217				30,025			$3,074	$5,500	1.8
Insulated		217				30,025			$3,074	$5,500	1.8
Insulated & Controlled		217				30,025	4.30	16,358	$3,671	$5,500	1.5
Automatic Control (ASD & Wind Sensor)											
Uninsulated		188				47,502			$3,687	$9,350	2.5
Insulated		188				47,502			$3,687	$9,350	2.5
Insulated & Controlled		188				47,502	7.80	8,793	$4,400	$9,350	2.1

Table 2 - 1b, Conservation Strategy Summary Energy & Cost Savings (Conti)

Conservation Strategy	Heat Energy (MMBTU)	Vent Energy (MMBTU)	Lighting Kw	Lighting Kwh	Motors Kw	Motors Kwh	Cooling Kw	Cooling Kwh	Annual Save ($)	Strategy Cost ($)	Simple Payback
Leakage Control (50% Reduction)											
Uninsulated		328							$2,462	$3,462	1.4
Insulated		328							$2,462	$3,462	1.4
Insulated & Cooled		328					9.6	2636	$2,914	$3,462	1.2
Reduce Leakage Through Holes											
1 " Sq Hole at Ave Structure Pressure		2.02							$15	$15	1.0
Modify Clamping System											
Uninsulated		385							$2,895	$40,400	14.0
Insulated		385							$2,895	$40,400	14.0
Insulated & Cooled		385					11.3	3098	$3,464	$40,400	11.7
Energy Efficient Heating System											
95% Condensing Boiler											
Uninsulated	622	287							$4,508	$91,325	20.3
Insulated	78	287							$2,188	$91,325	41.7
Insulated & Cooled	78	287							$2,188	$91,325	41.7
Select Energy Efficient Condensing Units											
(Each .05 Kw/ton or EER = .38 increase)							4.5	3300	$325	N/A	N/A
Ground Source Heat Pump System											
Un-insulated									N/A	N/A	N/A
Insulated									N/A	N/A	N/A
Insulated & Cooled	-386	-1451				(Cooling)	36	22,543	$3,348	$205,000	61.2
						(Heating)	-65.5	-158090			
Standby Propane System											
Uninsulated									$7,590	$47,500	6.3
Insulated									$698	$47,500	68.1
Insulated & Cooled									$698	$47,500	68.1

Section 3

Baseline Air-Supported Structure Description & Energy Use

Baseline Air-Supported Structure

Three baseline air-supported structures were analyzed as part of the analysis:

- Air-supported structure, un-insulated and used only during the winter months. This is typical of many air-supported structures currently found in the Minneapolis, St. Paul Metropolitan area. Many, such as sports and health facilities are deflated during the summer months.

- Air-supported structure, insulated and used only during the winter months. There are a few, (i.e. estimated at 4 – 6) in the Minneapolis, St. Paul Metropolitan area. Once insulated, structures are kept inflated because of the additional bulk created by the insulation.

- Air-supported structure, insulated and cooled and used year around. This modification of the basic facility is expected to be common in the future as they offer year around use. These structures will be insulated and have both heating and cooling systems.

Typical Structure Description

The baseline structure, components, controls and operation is described in detail in Appendixes A through E. A summary of that description is:

- 270' long by 180' wide by 54' high and orientated such that the long length is east west. Surface area is 64,000 sq ft.

- Multipurpose recreational uses (e.g. soccer, tennis, athletic training, and golf).

- Lighting system consisting of fifty (50) 1,000 watt metal halide fixtures mounted on mobile stands. Lights are aimed at and reflect off the ceiling. Un-insulated structures allow a significant amount of diffuse light to enter and thus lighting fixture operation can be greatly reduced during daylight hours. In insulated structures, additional lighting energy is required since the structure ceiling becomes opaque. Lighting is manually controlled by the building operator and depends on the amount and type of activity.

- Heating and ventilation system that consists of:

  - Indirect fired makeup air unit (i.e. 80% efficiency) with return duct.
  - High efficiency primary (40 HP) and backup (10 HP) fan motors.
  - Manual structure static pressure control (i.e. up to 1.5" water column) to provide sufficient outdoor air ventilation to maintain building pressurization, compensate for structure leakage and structure stability during high wind conditions.
  - Manual space temperature and building pressurization controls.
  - Backup fan system powered by electric (1 st stage backup) and natural gas fired generator set (2 nd stage backup). The back up fan motor powers a separate fan.
  - High cfm (36,000) primary fan system consisting of 2-3 fans operating in parallel and single electrically driven fan motor to provide good air distribution and mixing for the large structure.
  - Air cooled condenser with DX coils in makeup air unit.

Note that variations of the baseline system with respect to size, operation and controls are further discussed in the Appendix A.

Baseline System Energy Use

Energy use was determined through a simulation of air-supported structures considering local Minneapolis/St. Paul temperature, humidity, solar conditions and operational schedules that define indoor lighting, temperatures and occupancy. Energy costs used to evaluate operational costs and conservation opportunities are:

• Natural gas	=$ 6.00/MCF
• Electric	
Demand (Kw)	=$ 7.00/Kw
Energy Use	=$ 0.045/Kwh

Note that the analysis of each opportunity identifies energy savings and electric and gas costs. Local utility rates can be used for customization of the analysis.

Baseline Structure Energy Use

Tables 3 – 1 (un-insulated), 3 – 2 (insulated) and 3 – 3 (insulated and cooled) illustrate energy use for lighting, motors, heating, ventilation and cooling for each of the three baseline structures. Sources of and annual energy costs are included. The primary use of energy (i.e. based on a BTU basis) is heating and ventilation which accounts for:

Structure Type	Heating	Ventilation	Lighting	Motors	Cooling
Un-insulated Structure	51.5%	23.7%	3.4%	6.2%	
Insulated Structure	15.2%	55.7%	12.5%	14.6%	
Insulated & Cooled	11.0%	40.3%	9.1%	10.6%	27.7%

Table 3 - 1, Baseline Air Supported Structure (Uninsulated), Energy Use, Sources & Costs

Energy Use

	Kw	Kwh	MMBTU
Electric			
Motors	25.67	224,859	381
Lights	43.2	61,372	209
Heating			
Envelop			3,152
Ventilation			1,451
Totals	69	286,231	5,193

Energy Sources & Costs

Source	MMBTU	%	Kw	Kwh	Costs ($)
Solar	876	14.3%	0.00	0	$0
Heating	3,152	51.5%	0.00	0	$23,642
Ventilation	1,451	23.7%	0.00	0	$10,886
Lights	209	3.4%	43.20	61,372	$6,806
People	51	0.8%	0.00	0	$0
Motors	381	6.2%	25.67	224,859	$13,073
Totals	6,120	100%	69	286,231	$54,407

Table 3 - 2, Baseline Air Supported Structure (Insulated), Energy Use, Sources & Costs

Energy Use

	Kw	Kwh	MMBTU
Electric			
Motors	25.67	224,859	381
Lights	43.2	95,800	327
Heating			
Envelop			396
Ventilation			1,451
Totals	69	320,659	2,555

Energy Sources & Costs

Source	MMBTU	%	Kw	Kwh	Costs ($)
Solar	0	0.0%	0.00	0	$0
Heating	396	15.2%	0.00	0	$2,967
Ventilation	1,451	55.7%	0.00	0	$10,886
Lights	327	12.5%	43.20	95,800	$8,456
People	51	1.9%	0.00	0	$0
Motors	381	14.6%	25.67	224,859	$13,073
Totals	2,606	100%	69	320,659	$35,382

Table 3 - 3, Baseline Air Supported Structure (Insulated & Cooled), Energy Use, Sources & Costs

Energy Use

	Kw	Kwh	MMBTU
Electric			
Motors	25.67	224,859	381
Lights	43.2	95,800	327
Heating			
Envelop			396
Ventilation			1,451
Totals			2,555

Heating Energy Sources & Costs

Source	MMBTU	%	Costs ($)
Solar	0	0.0%	$0
Heating	396	15.2%	$2,967
Ventilation	1,451	55.7%	$10,886
Lights	327	12.5%	$8,456
People	51	2.0%	$0
Motors	381	14.6%	$13,073
Totals	2,606	100%	35,382

Cooling Energy Sources & Costs

Source	Kw	Kwh	Costs($)
Demand	111		
Energy		82,298	
Totals	111	82,298	$8,082

Section 4

Analysis of Energy Saving Opportunities

Introduction

This section identifies and analyzes feasible energy saving opportunities, both for new and retrofit on existing air-supported structures.

Energy saving opportunities are evaluated individually with respect to a baseline structure and for selected combinations. A fixed energy cost structure - $6.00/MCF natural gas, $7.00/KW electric demand and $0.045/KWH electric energy use is used to determine paybacks. Sales tax of 6.5% is included in the payback analysis of electric cost savings. Energy savings are identified for each opportunity such that the analysis can be customized for different rate structures.

Detailed data on opportunities such as lighting levels, motor efficiencies and costs are contained in the attached appendixes.

Lighting Opportunities

Pulse Start Metal Halide Fixtures and Retrofits

Air supported structures are sold with standard 1,000 watt metal halide fixtures. An option that is available is a pulse start metal halide fixture. This lighting technology, a variation of standard metal halide technology, has been available for about 4 – 5 years. Recent additions to the product line have included larger wattage 750, 875, 1000 and 2000-watt fixtures.

Pulse start fixtures offer many features (Appendix B), including lower lumen depreciation. This provides an opportunity to use lower wattage lamps that provide equal or greater lighting levels with less energy use. Use of a pulse start fixture also provides the opportunity to design a lighting system that requires fewer fixtures. The latter was not covered in the analysis.

Unfortunately, large wattage pulse start metal halide lamps are limited to base up configurations (e.g. light must hang down) at the current time. One manufacturer, Sylvania, manufacturers a 750 watt pulse start lamp for horizontal configuration. Large pulse start metal halide lamps for universal and/or horizontal configuration are expected to be available in the near future (i.e. 1-15 years) as the market matures.

Pulse start metal halide fixtures for new structures and retrofit applications and are currently limited to three options:

- Replacement or retrofit for the current fixtures if base up lamps are used.
- Use of two lighting fixtures (e.g. 2 – 400 watt pulse start fixtures) replacing one 1,000 watt fixture
- Use of one 750 watt pulse start fixture replacing one 1,000 watt fixture

Note that the latter two options would use a horizontal lamp configuration and thus would be housed in a spot light type enclosure. Incremental costs (Appendix B) are estimated at $425 and $275 respectively.

Options analyzed in this report include:

- Future new fixtures or existing fixtures with base up lamps using 875 and 750-watt pulse start metal halide lamps that would use universal position lamps.
- Use of existing 750 watt lamps in a horizontal configuration and spot light type enclosure for new applications.
- Use of existing 400 watt lamps in a horizontal configuration and spot light type enclosure for new applications.

Optional New Fixtures (Base Up Configurations Only)

New pulse start fixtures (Appendix B) are expected to cost about 20% more than standard metal halide fixtures, about $380 for 750 and 875 watt fixtures. Standard metal halide fixtures cost about $310.

875 Watt Pulse Start Metal Fixture

Fixtures having 875-watt pulse start metal halide lamps consume 945 watts and have an initial lumen rating about that of the 1000-watt standard metal halide lamps. However, given the lower lumen depreciation, lighting levels will be higher. As indicated in Table 4 – 1, paybacks range from 3.3 (insulated structure with cooling) to 5.0 years (un-insulated structure). Energy savings are primarily achieved through reduced fixture energy use. Savings in insulated and cooled buildings is greater since higher lighting levels and greater lighting energy use from extended operational hours are required. Structures with cooling save additional energy because internal heat loads are reduced.

750 Watt Pulse Start Metal Halide Fixture

Fixtures having 750-watt pulse start metal halide lamps consume 815 watts and have about 80,000 initial lumens. However, given lumen depreciation savings of 30% to 40%, lighting levels would be about the same as standard 1000-watt metal halide fixtures. Optional fixtures using 750-watt pulse start metal halide lamps (Table 4 – 2) provide paybacks ranging from 1.6 years (insulated and cooled structure) to 2.3 years (un-insulated structure).

Retrofit of Existing Fixtures

Pulse start lamps and ballasts can be retrofitted on existing metal halide fixtures having base up lamp configurations. A retrofit requires that both the lamp and ballast be replaced. The analysis assumes that existing fixtures are mounted on poles and mobile stands and thus minimize conversion labor. Retrofit costs are contained in Appendix B and are $160 for a 750-watt lamp and ballast and $165 for an 875-watt lamp and ballast.

875 Watt Lamp & Ballast Retrofit

Paybacks (Table 4 – 3) range from 7.0 years (insulated structures) to 12.6 years (insulated, cooled structures).

750 Watt Lamp & Ballast Retrofit

Paybacks (Table 4 – 4) range from 4.1 years (insulated structures) to 6.2 years (insulated, cooled structures).

Pulse Start Lamps in Horizontal Configurations (Base Up Configurations)

750-watt lamp & ballast in spot light enclosure - Paybacks (Table 4-5) range from 7.1 years (insulated and cooled) to 10.7 years (non-insulated)

Two 400-watt lamps & ballasts in spot light enclosures - Paybacks (Table 4-6) are greater than 20 years for all structures

Utility Rebates

It should be noted that utility rebates could reduce paybacks for purchasing optional new fixtures and retrofitting existing fixtures. Xcel Energy, for example, provides rebates up to $12/fixture new and up to $65/fixture for retrofit of lamp and ballast. This rebate level would reduce the cost of retrofitting existing fixtures and lower paybacks. As an example, the payback for an 875-watt lamp and ballast retrofit would range from 6.1 to 9.2 years. Similarly, the paybacks for a 750-watt lamp and ballast rebate would be lowered to 2.1 to 3.6 years

Light Emitting Diode (LED) Retrofits of Exit Signs

LED exits signs consume about 2 watts of power as opposed to exit signs having incandescent (two 15 – 20 watt) or fluorescent (two 5 – 7 watt) lamps. Since they also have an expected life of 25 years plus, they provide on-going maintenance savings.

The existing state of Minnesota Energy Code limits exit sign power to 5 watts per side.

LED kits can be retrofit on existing exit signs. Two typical scenarios are analyzed; an existing fixture having two 7-watt lamps and one having two 15-watt lamps.

Common Assumptions

- Six exit doors in baseline structure.
- One revolving entrance door.
- 8,760 hours per year operation.

Existing Fixture with Two 7 Watt Lamps

Demand Savings

7 Fixtures x (14 – 2) watts per fixture	= .084 Kw

Energy Use Savings

.084 Kw x 8,760 hrs/yr	= 736 Kwh

Annual Cost Savings

.084 Kw x $7.00/Kw x 12 months	=$ 7.06
736 Kwh x $0.045/Kwh	=$ 33.12
Sales Tax at 6.5%	=$ 2.61
Total	=$ 42.79

Initial Cost

7 Conversion Kits @ $50 each	=$ 350
7 Installations @ $20 each	=$ 140
Totals	=$ 490
Simple Payback	= 11.5 Yrs

Existing fixture with Two 15 watt lamps

Demand Savings

7 Fixtures x (30 – 2) watts per fixture	= .196 Kw

Energy Use Savings

.196 Kw x 8,760 hrs/yr	= 1,717 Kwh

Annual Cost Savings

.196 Kw x $7.00/Kw x 12 months	=$ 16.46
1717 Kwh x $0.045/Kwh	=$ 77.26
Sales Tax at 6.5%	=$ 6.09
Total	=$ 99.81

Initial Cost

7 Conversion Kits @ $50 each	=$ 350
7 Installations @ $20 each	=$ 140
Totals	=$ 490
Simple Payback	= 4.9 Yrs

Rebates

Most electric utilities in Minnesota provide rebates for new and retrofit LED exit sign retrofits. Xcel Energy, for example, provides $6 per retrofit. Note that rebates amounts were not considered in the analysis.

Table 4 - 1, 875 Watt Pulse Start Metal Halide Fixtures (New Fixture with Structure)

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MCF)	Cost ($) Heating	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	43.2	61,372	$6,806	5,755	$34,528						
Base + 875 Watt Pulse Start	37.8	53,701	$5,955	5,787	$34,724						
Savings	5.4	7,671	$851	-32	-$196				$655	3250	5.0
Insulated											
Base	43.2	95,800	$8,456	2,309	$13,853						
Base + 875 Watt Pulse Start	37.8	83,825	$7,399	2,360	$14,160						
Savings	5.4	11,975	$1,057	-51	-$307				$750	3250	4.3
Insulated & Cooled											
Base	43.2	95,800	$8,456	2,309	$13,853	111.00	82,298	$8,082			
Base + 875 Watt Pulse Start	37.8	83,825	$7,399	2,360	$14,160	109.10	78,928	$7,849			
	5.4	11,975	$1,057	-51	-$307	1.90	3,370	$233	$983	3250	3.3

Note: Ave incremental cost is $65 per fixture x 50 Fixtures = $3,250.

Table 4 - 2, 750 Watt Pulse Start Metal Halide Fixtures (New Fixture with Structure)

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MCF)	Cost ($) Heating	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	43.2	61,372	$6,806	5,755	$34,528						
Base + 750 Watt Pulse Start	32.6	46,313	$5,136	5,819	$34,914						
Savings	10.6	15,059	$1,670	-64	-$386				$1,284	3000	2.3
Insulated											
Base	43.2	95,800	$8,456	2,309	$13,853						
Base + 750 Watt Pulse Start	32.6	72,294	$6,381	2,409	$14,455						
Savings	10.6	23,506	$2,075	-100	-$602				$1,473	3000	2.0
Insulated & Cooled											
Base	43.2	95,800	$8,456	2,309	$13,853	111.00	82,298	$8,082			
Base + 750 Watt Pulse Start	32.6	72,294	$6,381	2,409	$14,455	107.30	75,683	$7,626			
	10.6	23,506	$2,075	-100	-$602	3.70	6,615	$456	$1,929	3000	1.6

Note: Ave incremental cost is $60 per fixture x 50 Fixtures = $3,000.

Table 4 - 3, Retrofit 1000 Watt Fixture with 875 Watt Pulse Start Lamps & Ballast

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MCF)	Cost ($) Heating	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	43.2	61,372	$6,806	5,755	$34,528						
Base + 875 Watt Pulse Start	37.8	53,701	$5,955	5,787	$34,724						
Savings	5.4	7,671	$851	-32	-$196				$655	$8,250	12.6
Insulated											
Base	43.2	95,800	$8,456	2,309	$13,853						
Base + 875 Watt Pulse Start	37.8	83,825	$7,399	2,360	$14,160						
Savings	5.4	11,975	$1,057	-51	-$307				$750	$8,250	11.0
Insulated & Cooled											
Base	43.2	95,800	$8,456	2,309	$13,853	111.00	82,298	$8,082			
Base + 875 Watt Pulse Start	37.8	83,825	$7,399	2,360	$13,967	109.10	78,928	$7,849			
	5.4	11,975	$1,057	-51	-$114	1.90	3,370	$233	$1,176	$8,250	7.0

Note: Ave retrofit cost is $165 per fixture x 50 Fixtures = $8,250.

Table 4 - 4, Retrofit Existing 1000 Watt Fixtures with 750 Watt Pulse Start Lamps & Ballasts

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MCF)	Cost ($) Heating	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	43.2	61,372	$6,806	5,755	$34,528						
Base + 750 Watt Pulse Start	32.6	46,313	$5,136	5,819	$34,914						
Savings	10.6	15,059	$1,670	-64	-$386				$1,284	$8,000	6.2
Insulated											
Base	43.2	95,800	$8,456	2,309	$13,853						
Base + 750 Watt Pulse Start	32.6	72,294	$6,381	2,409	$14,455						
Savings	10.6	23,506	$2,075	-100	-$602				$1,473	$8,000	5.4
Insulated & Cooled											
Base	43.2	95,800	$8,456	2,309	$13,853	111.00	82,298	$8,082			
Base + 750 Watt Pulse Start	32.6	72,294	$6,381	2,409	$14,455	107.30	75,683	$7,626			
	10.6	23,506	$2,075	-100	-$602	3.70	6,615	$456	$1,929	$8,000	4.1

Note: Ave incremental cost is $160 per fixture x 50 Fixtures = $8,000.

Table 4 - 5, Replace 1000 Watt Lamps with 750 Watt Lamps (Spot Light Enclosure)

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MCF)	Cost ($) Heating	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	43.2	61,372	$6,806	5,755	$34,528						
Base + 750 Watt Pulse Start	32.6	46,313	$5,136	5,819	$34,914						
Savings	10.6	15,059	$1,670	-64	-$386				$1,284	$13,750	10.7
Insulated											
Base	43.2	95,800	$8,456	2,309	$13,853						
Base + 750 Watt Pulse Start	32.6	72,294	$6,381	2,409	$14,455						
Savings	10.6	23,506	$2,075	-100	-$602				$1,473	$13,750	9.3
Insulated & Cooled											
Base	43.2	95,800	$8,456	2,309	$13,853	111.00	82,298	$8,082			
Base + 750 Watt Pulse Start	32.6	72,294	$6,381	2,409	$14,455	107.30	75,683	$7,626			
	10.6	23,506	$2,075	-100	-$602	3.70	6,615	$456	$1,929	$13,750	7.1

Note: Ave retrofit cost is $275 per fixture x 50 Fixtures = $13,750.

Table 4 - 6, 2 - 400 Watt Pulse Start Metal Halide Fixtures (Spot Light Enclosure)

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MCF)	Cost ($) Heating	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	43.2	61,372	$6,806	5,755	$34,528						
Base + 750 Watt Pulse Start	36.8	52,280	$5,798	5,793	$34,760						
Savings	6.4	9,092	$1,008	-38	-$232				$776	$21,250	27.4
Insulated											
Base	43.2	95,800	$8,456	2,309	$13,853						
Base + 750 Watt Pulse Start	36.8	81,608	$7,203	2,369	$14,216						
Savings	6.4	14,192	$1,253	-60	-$363				$890	$21,250	23.9
Insulated & Cooled											
Base	43.2	95,800	$8,456	2,309	$13,853	111.00	82,298	$8,082			
Base + 750 Watt Pulse Start	36.8	81,608	$7,203	2,369	$14,216	108.70	78,304	$7,806			
	6.4	14,192	$1,253	-60	-$363	2.30	3,994	$276	$1,166	$21,250	18.2

Note: Ave incremental cost is $425 per fixture x 50 Fixtures = $21,250.

Motor Opportunities

Premium Efficiency Motors

Heating and ventilating units on air-supported structures are sold with energy efficient motors. The units can be ordered with premium efficient motors for an incremental cost (Appendix C), depending on the size of the motor.

Premium efficient motors can also be retrofit on existing heating and ventilating systems having either older standard efficient or newer energy efficient motors.

Optional Premium Efficient Motors on New Heating and Ventilation System

The baseline air-supported structure has an energy efficient 40 HP motor. The average incremental list cost of a premium efficient motor is about $333. As indicated in Table 4 – 7, the major contribution from energy savings is related to motor energy, paybacks ranging from 2.3 (i.e., insulated and cooled structure) to 2.8 (i.e., non insulated structure) years.

Retrofit Premium Efficiency Motor on Existing Heating and Ventilation System.

A premium efficiency motor can be retrofit on an existing heating and ventilation system having a standard efficiency motor.

- Existing Standard Efficiency Motor = 90.0%
- Existing Energy Efficient Motor = 93.0%
- Retrofit Costs

Motor	=$ 2,485
Installation (Estimate $12/HP)	=$ 480
Total Cost	=$ 2,965

Retrofit Existing Energy Efficient Motor with Premium Efficient Motor

The analysis in Table 4 – 8 indicates paybacks that range from 20.9 years (insulated and cooled structure) to 24.7 years (un-insulated).

Retrofit Existing Standard Efficient Motor with Premium Efficient Motor

The analysis in Table 4 – 9 indicates paybacks that range from 5.5 years (insulated and cooled structure) to 6.5 years (un-insulated). Utility rebates (e.g. Xcel Energy) of $660 would reduce paybacks to 4.2 to 5.2 years.

Table 4 - 7, Premium Efficienct Motors (New Installation)

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MCF)	Cost ($) Heating	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	25.67	224,859	$13,073	5,755	$34,528						
Base + Prem Eff Motor	25.37	222,230	$12,920	5,760	$34,561						
Savings	0.3	2,629	$153	-5	-$33				$120	333	2.8
Insulated											
Base	25.67	224,859	$13,073	2,309	$13,853						
Base + Prem Eff Motor	25.37	222,230	$12,920	2,314	$13,886						
Savings	0.3	2,629	$153	-5	-$33				$120	333	2.8
Insulated & Cooled											
Base	25.67	224,859	$13,073	2,309	$13,853	111.00	82,298	$8,082			
Base + Prem Eff Motor	25.37	222,230	$12,920	2,314	$13,886	110.90	81,913	$8,060			
	0.3	2,629	$153	-5	-$33	0.10	385	$22	$142	333	2.3

Table 4 - 8, Retrofit Energy Efficient Motors with Premium Efficienct Motors

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MMBTU)	Cost ($)	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base	25.67	224,859	$13,073	5,755	$34,528						
Base + Prem Eff Motor	25.37	222,230	$12,920	5,760	$34,561						
Savings	0.3	2,629	$153	-5	-$33				$120	$2,965	24.7
Insulated											
Base	25.67	224,859	$13,073	2,309	$13,853						
Base + Prem Eff Motor	25.37	222,230	$12,920	2,314	$13,886						
Savings	0.3	2,629	$153	-5	-$33				$120	$2,965	24.7
Insulated & Cooled											
Base	25.67	224,859	$13,073	2,309	$13,853	111.00	82,298	$8,082			
Base + Prem Eff Motor	25.37	222,230	$12,920	2,314	$13,886	110.90	81,913	$8,060			
	0.3	2,629	$153	-5	-$33	0.10	385	$22	$142	$2,965	20.9

Table 4 - 9, Retrofit Existing Standard Efficient Motors with Premium Efficienct Motors

Structure Description	Demand (Kw)	Energy (Kwh)	Cost ($)	Heating (MMBTU)	Cost ($)	Cooling (Kw)	Cooling (Kwh)	Cost ($)	Net Save ($)	Initial Cost ($)	Simple Payback (Years)
Un-insulated											
Base + Standard Eff Motor	26.52	232,354	$13,508	5,739	$34,432						
Base + Prem Eff Motor	25.37	222,230	$12,920	5,760	$34,561						
Savings	1.15	10,124	$588	-21	-$129				$459	$2,965	6.5
Insulated											
Base + Standard Eff Motor	26.52	232,354	$13,508	2,293	$13,757						
Base + Prem Eff Motor	25.37	222,230	$12,920	2,314	$13,886						
Savings	1.15	10,124	$588	-21	-$129				$459	$2,965	6.5
Insulated & Cooled											
Base + Standard Eff Motor	26.52	232,354	$13,508	2,293	$13,757	111.30	83,345	$8,143			
Base + Prem Eff Motor	25.37	222,230	$12,920	2,314	$13,886	110.90	81,913	$8,060			
	1.15	10,124	$588	-21	-$129	0.40	1,432	$83	$542	$2,965	5.5

Note: Utility Rebates would reduce paybacks by about 1.3 Years

Insulation Opportunities

Air supported structures can be insulated to reduce energy use and operating costs. Whether purchased new with insulation or retrofit at a latter date, air supported structures are insulated at the owners site and thus the costs are about the same. Insulation is inserted between the inner and outer fabric panels. As a consequence of the insulation, the surface becomes opaque and more lighting energy is required.

Insulation Costs

Insulation costs are quoted on a square foot basis of the structure footprint. The footprint of the baseline structure is 48,600 sq ft. Conversations with air supported structure manufacturers indicated installed insulation costs vary from about $1.00 to $1.50/sq ft.

Three insulation scenarios were analyzed; one with R = 12.2, R = 13.2 and R = 14.2. Insulation material varies and this range was mentioned in conversations with manufacturers.

Heating energy required is heat loss through the fabric less internal lighting, people, motors loads and solar gain. Heating costs are based on the baseline makeup air unit efficiency of 80%.

Heating Energy & Cost Savings

Insulation Value	Heat Energy (MMBTU)	Ventilation (MMBTU)	Annual Cost ($)	Cost Save ($)
Un-insulated (Base)	3,152	1,451	34,528	
R - 12.2	396	1,451	13,853	20,675
R - 13.2	337	1,451	13,414	21,114
R - 14.2	287	1,451	13,039	21,489

Cooling Energy & Cost Savings

Insulation Value	Cooling Energy (Kwh)	Annual Cost ($)	Cost Save ($)
R - 12.2(Base Case)	82,298	8,082	
R - 13.2	81,985	8,034	48
R - 14.2	81,715	7,994	88

The above analysis indicates the cost savings associated with incremental increases of insulation materials.

Insulation Costs & Paybacks

Because the cost and insulation values vary, the analysis is presented parametrically with respect to required heating energy. Paybacks are based on average savings of $22,074 and a footprint area of 48,600 sq ft.

Insulation Costs ($) Installed Sq Ft	Total Cost ($)	Simple Payback (Yrs)
1.00	48,600	2.2
1.25	60,750	2.8
1.50	72,900	3.3
1.75	85,050	3.9
2.00	97,200	4.4

Based on an expected range of installed costs, insulation should provide a payback ranging from 2.2 to 4.4 years.

Insulate & Operate versus Un-insulate and Deflate Structure

Many un-insulated air-supported structures operate about 6 months and are deflated during the summer months. The following illustrates the annual energy costs and savings for those operators who have a choice of:

- Deflating the un-insulated air-supported structure during the six summer months.
- Insulating the air-supported structure and keeping the structure inflated during the six summer months.

Annual Energy Savings

Heating

Space	= 2,756 MMBTU
Ventilation	= 0 MMBTU

Motor

Demand (Kw)	= -25.67 (6 months)
Energy use (Kwh)	= -112,430 (6 months)

Strategy	Annual Heating Cost ($)	Annual Electric Cost ($)
Un-insulate & Deflate for 6 Months	34,528	6,536
Insulate & Operate all Year	13,583	13,073
Savings	20,675	-6,537

When the annual savings are evaluated with respect to insulation costs, the following paybacks are achieved based on annual cost savings of $14,138.

Insulation Costs ($) Installed Sq Ft	Total Cost ($)	Simple Payback (Yrs)
1.00	48,600	3.4
1.25	60,750	4.3
1.50	72,900	5.2
1.75	85,050	6.0
2.00	97,200	6.9

Utility Rebates

Gas utilities may provide rebates for insulation retrofits and should be contacted if this strategy is pursued on a retrofit basis.

Night Setback Opportunities

The baseline building operates at 60 F during both occupied and unoccupied hours. Implementing a night setback strategy can reduce both space heating and ventilating energy use during un-occupied hours (i.e. 8-10 hrs/day). No setback in the baseline structure is assumed. However, most operators adjust space temperatures manually and/or can switch off heating.

The amount of setback can depend on many factors. Some manufacturers recommend very deep setbacks (i.e. down to 0 F) or turning the heat off at night, even on sub zero days.

Note that recovery times are short 30-45 minutes because of the capacity of the makeup air units and large air flows. Operators sometimes turn down temperatures during daytime hours when the structure is not being used.

Energy & Costs Savings from Setback Strategies

A parametric analysis was performed to analyze energy savings from a number of setback scenarios for each of the three baseline structures. Temperature control set-point for the baseline structure was assumed to be 60 F during both occupied and un-occupied periods. The scenarios assume that an automatic control system would be installed. The results, based on setbacks of 30F, 60F, 90F (i.e., night shut off) are summarized in Table 4 – 10 and indicate savings can be substantial. It should also be noted that significant energy and cost savings could be achieved by manual temperature setback. However, no attempt was made to analyze this scenario.

Costs

Space temperature control can be automated by installing a number of types of controllers:

- Simple night setback thermostat
- 7 day/24 hour timer
- Digital controller

The analysis assumes that a digital controller would be used since an upgraded version could provide additional capability such as remote site monitoring and control and pressurization control. Thus, a precise cost for the setback function could not be determined. However, controller costs range from $5,500 to $11,000. Cost estimates for a controller with basic control capability including automated night setback is estimated at $5,500.

Paybacks on this cost range from .3 to 1.1 years.

Table 4 - 10, Energy & Cost Savings with Setback Strategies

Air Inflated Structure	Base Energy (MCF)	Energy Use (MCF) with Setback Strategy 30 F	60 F	Shut Off
Un-insulated				
Heating	3,940	2,518	1,994	1,954
Ventilation	1,814	1,206	983	965
Total	5,754	3,724	2,977	2,919
Energy Savings (From Base)	0	2,030	2,777	2,835
Costs Savings		$12,180	$16,662	$17,010
Insulated				
Heating	463	238	144	136
Ventilation	1,814	1,206	983	965
Total	2,277	1,444	1,127	1,101
Energy Savings (From Base)	0	833	1,150	1,176
Costs Savings		$4,998	$6,900	$7,056
Insulated & Cooled (Same as Insulated)				

Note: Gas Cost of $6.00/MCF

Leakage Reduction Opportunities

There are areas in air-supported structures where leakage (Appendix D) can be reduced through a combination of:

- Patching Holes – Small holes in the fabric near exit doors, vehicle exit doors and structure walls near perimeter. Observations indicate that structures that are taken down during the summer months have more leakage because of the additional handling and leaks that develop over time.

- Caulking/Foam – Small seams in makeup air unit panels, around exit and vehicle entry doors. Note that most seams, especially on makeup air units can be caulked or foamed from the inside.

- Adjusting Doors – Adjust exit door latches and seals to insure minimum leakage. Standard industry practice is to use spring loaded hinges to minimize leakage.

- Install Door Covers – Install clear, overlapping plastic covers over exit and vehicle entry doors. The pressure will keep the material tight against the door and further minimize leakage. An alternate approach over vehicle access doors could be an opaque multi-layer cover, held in place by velcro strips. This approach may present problematic issues (e.g., how to close door with strips hanging out the door) unless techniques such as "breakaway covers" are used. This type of cover would provide the additional benefit of some insulation. Local building codes should be checked.

- Modify Perimeter Clamping System – Modify the existing structure perimeter clamping system (e.g. angle clamp) to accept a very low leak clamping system.

Baseline Structure Leakage

Total leakage in the baseline structure (Appendix A) is estimated at:

Leakage Area	Cfm
Exit Doors (6 at 366 cfm)	2,196
Entry Revolving Door	366
Vehicle Entry Door	732
Makeup Air Unit	
Panels Seams	530
Ducts	300
Total	4,124

Other leakage from general structure pressurization through the surface and perimeter is about 7,385 cfm. It is assumed that this leakage is an on-going constant related to the structure type and construction. Further, the leakage is spread uniformly around the entire structure surface and perimeter, which makes a reduction approach, other than pressure control, un-economical.

Costs

Cost estimates for caulking, foaming, patching holes and door covers includes:

Item	Cost/Item	Total Cost
Door Covers (w x h)		
6 each 4' x 7'	=$ 109	$1,614
1 each 8' x 10'	=$ 408	$ 568
Labor & Material (Caulking/Patching)	=$ 80/hr	$ 1,280
Totals		$3,462

Notes:

1 - Door cover costs are for vinyl strip doors (Granger Catalog).
2 - Labor estimates for installing vinyl on doors at 2 hours.
3 - Labor costs for caulking of doors, holes and makeup air unit for a new structure is estimated at 16 hrs at a cost of $80/hr

Energy & Cost Savings from Reduced Air Leakage

The amount of leakage reduction that can be achieved is difficult to estimate and is therefore analyzed on a parametric basis based on simulation results on ventilation at 1.5" w.c.

Leaking Reduction (%)	Cfm Reduction
25%	1,031
50%	2,062
75%	3,093

Annual energy and cost savings are summarized in Table 4 – 11 for three levels of leak reduction; 25%, 50% and 75%.

Table 4 - 11, Air Leakage Reduction - Energy & Cost Savings

Air Supported Structure	Baseline Structure				25% Leak Reduction				50% Leak Reduction				75% Leak Reduction			
	Heat Energy (MMBTU)	Kw	Kwh	Costs ($)	Heat Energy (MMBTU)	Kw	Kwh	Costs($)	Heat Energy (MMBTU)	Kw	Kwh	Costs($)	Heat Energy (MMBTU)	Kw	Kwh	Costs($)
Un-insulated																
Heating	3,152			$23,642	3,152			$23,642	3,152			$23,642	3,152			$23,642
Ventilation	1,451			$10,886	1,287			$9,665	1,123			$8,424	959			$7,193
Total				**$34,528**				**$33,307**				**$32,066**				**$30,835**
Save w/r Baseline								**$1,221**				**$2,462**				**$3,693**
Insulated																
Heating	396			$2,967	396			$2,967	396			$2,967	396			$2,967
Ventilation	1,451			$10,886	1,287			$9,665	1,123			$8,424	959			$7,193
Total				**$13,853**				**$12,632**				**$11,391**				**$10,160**
Save w/r Baseline								**$1,221**				**$2,462**				**$3,693**
Insulated & Cooled																
Heating	396			$2,967	396			$2,967	396			$2,967	396			$2,967
Ventilation	1,451			$10,886	1,287			$7,991	1,123			$8,456	959			$7,193
Cooling		111	82,298	$8,082		106.2	80,980	$7,840		101.4	79,662	$7,598		96.6	78,345	$7,356
Total				**$21,935**				**$18,798**				**$19,021**				**$17,516**
Save w/r Baseline								**$3,137**				**$2,914**				**$4,419**

Paybacks

Paybacks for a new baseline building are:

Leak Reduction	$ Save	Simple Payback (Yrs)
25%	$1,231 - $1,473	2.4 – 2.8
50%	$2,462 - $2,914	1.2 – 1.4
75%	$3,692 - $4,419	0.8 – 0.9

Reduction of Leaks Through Holes

Site observations indicated that there are holes in the structure; especially near the lower wall areas. Often these holes can be simply patched by structure operators by gluing a patch on the inside surface.

Leakage through a hole is a function of structure pressurization and can be estimated from Figure D -1, Appendix D. Leakage for a hole of 1.0 sq inch is:

Pressure	Velocity (Feet/Min)	Hole Leakage (CFM)	Annual Energy Loss (MMBTU)	Annual Cost ($)
0.75	1,750	12.2	1.54	11.55
1.00	2,200	15.3	1.93	14.48
1.25	2,500	17.4	2.19	16.42
1.50	2,750	19.1	2.41	18.08
		Average	2.02	15.13

Paybacks

Paybacks on holes patched by structure operators are estimated to provide paybacks of one year or less.

Modify Clamping System

Modifying the clamping system (e.g. Angle Clamp) to reduce perimeter leakage. Perimeter leakage with an angle clamping system is about 3 cfm per lineal foot per the Air Structure Design and Standards Manual, 1977 Edition.

The baseline air-supported structure has a perimeter of 808 feet and design leakage with an angle clamping system of 2,424 cfm.

Modification Costs

Cost estimates provided by one manufacturer are estimated at $50 per lineal foot or about $40,400.

Energy, Cost Savings and Simple Payback

Retrofit energy and cost savings and simple paybacks are illustrated in Table 4 – 12.

Table 4 - 12, Perimeter Air Leakage Reduction - Energy & Cost Savings

Air Supported Structure	Baseline Structure Heat Energy (MMBTU)	Baseline Kw	Baseline Kwh	Baseline Costs ($)	3 cfm Per Lineal Foot Leak Reduction Heat Energy (MMBTU)	Kw	Kwh	Costs($)	Installed Cost ($)	Simple Payback (Yrs)
Un-insulated										
Heating	3,152			$23,642	3,152			$23,642		
Ventilation	1,451			$10,886	1,066			$7,991		
Total				**$34,528**				**$31,633**		
Save w/r Baseline								**$2,895**	$40,400	14.0
Insulated										
Heating	396			$2,967	396			$2,967		
Ventilation	1,451			$10,886	1,066			$7,991		
Total				**$13,853**				**$10,958**		
Save w/r Baseline								**$2,895**	$40,400	14.0
Insulated & Cooled										
Heating	396			$2,967	396			$2,967		
Ventilation	1,451			$10,886	1,066			$7,991		
Cooling		111	82,298	$8,082		99.7	79,200	$7,513		
Total				**$21,935**				**$18,471**		
Save w/r Baseline								**$3,464**	$40,400	11.7

Structure Pressurization Control Opportunities

Air-supported structure pressurization is typically controlled by one of three approaches:

- Fixed at a set point that typically is a “worst condition” case (i.e. 1.5” W.C.). This was assumed to be the baseline.
- Manually varied during the day by the building operator between .75” W.C. (calm periods) and 1.5 “ W.C. (windy periods, snowing).
- Automatically controlled by an exterior wind sensor. Note that some manufacturers don’t recommend wind sensors because of rapidly changing conditions due to wind gusts.
- Automatically controlled by an Adjustable Speed Drive (ASD) using the signal from an exterior wind sensor. Note that this approach has many features which address rapid pressurization control using direct wind sensor inputs.

The analysis evaluates three options for pressurization control:

- Manual Pressurization Control by Operator.
- Automatic Pressurization Control using a Wind Sensor
- Automatic Pressurization Control using a Wind Sensor and Adjustable Speed Drive

Manual Pressurization Control

The basic assumption is that manual control of pressurization by the operator would be sporadic. The following time distribution assumes that the operator would periodically adjust pressures during occupied hours, but seldom during un-occupied hours.

Pressurization (Inches W.C.	% of Time
1.50	62.5
1.25	12.5
1.00	12.5
.75	12.5

Energy savings result from less ventilation air that needs to be conditioned and reduced fan power. An estimate of reduced fan power can be determined from the theoretical relationship between break horsepower (BHP) and total fan static pressure.

BHP = (cfm x TSP)/(6,344 x Fan Efficiency)

If fan efficiency is assumed to be constant at 75%, then

TSP	CFM	BHP	HP
2.85	36,000	21.563	23.2
2.60	36,000	19.67	21.2
2.35	36,000	17.78	19.1
2.10	36,000	15.89	17.1

Table 4 – 13 summarizes the energy savings from manual pressurization control, given the assumed percentage of time that pressure would be controlled to expected pressure. The table illustrates that annual savings up to $2,077 or more using aggressive manual operator pressure controls can be achieved without additional expense.

Automatic Pressurization Using Wind Sensor

Pressurization control using a sensor input (e.g. wind sensor) to control return air dampers varies total static pressure (TSP). Airflow remains constant. Energy savings result from less ventilation air that needs to be conditioned and reduced fan power. An estimate of reduced fan power can also be determined from the theoretical relationship between break horsepower (BHP) and total fan static pressure, The following pressurization schedule is assumed.

Pressurization (Inches W.C.	% of Time
1.51	12.5
1.26	37.5
1.00	37.5
.75	12.5

Energy and costs savings are summarized in Table 4 – 14 and indicate that annual savings up to $3,761 can be achieved by installing wind senor control.

Costs

Manual control of pressurization uses operator inputs or inputs from an exterior wind sensor connected to a basic control system. The existing controller with wind sensor is $10,500.

Simple Payback

Paybacks range from 1.4 to 1.6 years with respect to the baseline system of constant pressure control.

Automatic Pressurization Control using an Adjustable Speed Drive (ASD)

Pressurization control using a wind speed sensor to adjust the speed of the fan requires an ASD. Energy savings are maximized with this approach because of the exponential relationship between power and fan speed (Appendix E).

The following pressurization schedule is assumed.

Pressurization (Inches W.C.	% of Time
1.50	12.5
1.25	37.5
1.00	37.5
.75	12.5

The relationship between fan static pressure, RPM's and cfm's were derived from the combined fan curve for the makeup air unit (Appendix E).

Energy and cost savings are summarized in Table 4 – 15.

Note that makeup air must have modulating burners and high temperature limit controllers on the burners.

Costs

Detailed costs for an ASD are illustrated in Appendix E. Cost estimates for an installed 40 HP ASD (460V) with bypass are $9,350. It is assumed that the controller would not have to be updated with additional input and output channel.

Paybacks

Paybacks range from 2.1 to 2.5 years when compared to the baseline structure with constant pressure control.

Note that the incremental cost savings associated with the ASD control as opposed to the direct wind control are:

Structure Type	Incremental Cost Save ($)	Simple Payback (Yrs)
Un-insulated	613	15.3
Insulated	613	15.3
Insulated & Cooled	729	12.8

This would indicate that simple pressurization control using a wind sensor to directly control dampers could be sufficient. However, pressurization control using an ASD offers additional benefits, primarily in the area of control integrity, reliability and safety. The latter is of great importance to air-supported structure suppliers and operators since costly structure damage can be avoided.

In this control strategy, the wind sensor would be connected to the digital controller. The signal would be checked for limits and use standard control strategies such as proportional plus integral (PI) or proportional integral derivative (PID) to smooth out the damper control signal. The approach addresses concerns about continual and rapid pressure changes. Other benefits include:

- Backup control for the wind sensor
- Alarming for out of tolerance sensors
- Call in/out alarm feature for monitoring/problem reporting

Table 4 - 13, Energy & Cost Savings with Manual Pressurization Control

Air Supported Structure	Baseline Structure Heat Energy (MMBTU)	Baseline Structure Kw	Baseline Structure Kwh	Baseline Structure Costs ($)	Manual Pressurization Heat Energy (MMBTU)	Manual Pressurization Kw	Manual Pressurization Kwh	Manual Pressurization Costs($)	Annual Cost Save ($)
Un-insulated									
Heating	3,152			$23,642	3,152			$23,642	$0
Ventilation	1,451			$10,886	1,328			$9,963	$923
Fan Motor		25.67	224,859	$13,073		25.67	209,962	$12,238	$835
Total									**$1,758**
Insulated									
Heating	396			$2,967	396			$2,967	$0
Ventilation	1,451			$10,886	1,328			$9,963	$923
Fan Motor		25.67	224,859	$13,073		25.67	209,962	$12,238	$835
Total									**$1,758**
Insulated & Cooled									
Heating	396			$2,967	396			$2,967	$0
Ventilation	1,451			$10,886	1,328			$9,963	$923
Fan Motor		25.67	224,859	$13,073		25.67	209,962	$12,238	$835
Cooling		111	82,298	$8,082		106.7	79,026	$7,763	$319
Total									**$2,077**

Table 4 - 14, Energy & Cost Savings with Automatic Pressurization Control with Wind Sensor

Air Supported Structure	Baseline Structure Heat Energy (MMBTU)	Baseline Structure Kw	Baseline Structure Kwh	Baseline Structure Costs ($)	Automatic Pressurization Control with Wind Sensor Heat Energy (MMBTU)	Automatic Pressurization Control with Wind Sensor Kw	Automatic Pressurization Control with Wind Sensor Kwh	Automatic Pressurization Control with Wind Sensor Costs($)	Annual Cost Save ($)
Un-insulated									
Heating	3,152			$23,642	3,152			$23,642	$0
Ventilation	1,451			$10,886	1,234			$9,254	$1,632
Fan Motor		25.67	224,859	$13,073		25.67	194,784	$11,631	$1,442
Total									**$3,074**
Insulated									
Heating	396			$2,967	396			$2,967	$0
Ventilation	1,451			$10,886	1,234			$9,254	$1,632
Fan Motor		25.67	224,859	$13,073		25.67	194,784	$11,631	$1,442
Total									**$3,074**
Insulated & Cooled									
Heating	396			$2,967	396			$2,967	$0
Ventilation	1,451			$10,886	1,234			$9,254	$1,632
Fan Motor		25.67	224,859	$13,073		25.67	194,784	$11,631	$1,442
Cooling		111	82,298	$8,082		106.7	75,940	$7,485	$597
Total									**$3,671**

Table 4 - 15, Energy & Cost Savings with Automatic Pressurization Control with ASD

Air Supported Structure	Baseline Structure Heat Energy (MMBTU)	Baseline Structure Kw	Baseline Structure Kwh	Baseline Structure Costs ($)	Automatic Pressurization Control with ASD Heat Energy (MMBTU)	Automatic Pressurization Control with ASD Kw	Automatic Pressurization Control with ASD Kwh	Automatic Pressurization Control with ASD Costs($)	Annual Cost Save ($)
Un-insulated									
Heating	3,152			$23,642	3,152			$23,642	$0
Ventilation	1,451			$10,886	1,263			$9,476	$1,410
Fan Motor		25.67	224,859	$13,073		25.67	177,357	$10,796	$2,277
Total									**$3,687**
Insulated									
Heating	396			$2,967	396			$2,967	$0
Ventilation	1,451			$10,886	1,263			$9,476	$1,410
Fan Motor		25.67	224,859	$13,073		25.67	177,357	$10,796	$2,277
Total									**$3,687**
Insulated & Cooled									
Heating	396			$2,967	396			$2,967	$0
Ventilation	1,451			$10,886	1,263			$9,476	$1,410
Fan Motor		25.67	224,859	$13,073		25.67	177,357	$10,796	$2,277
Cooling		111	82,298	$8,082		103.2	73,505	$7,369	$713
Total									**$4,400**

Energy Efficient Heating System Opportunities

Air supported structures typically use indirect fired makeup air units to provide space heating and makeup air heating. These units typically have an efficiency of 80%.

Other types of heating systems are available to provide space and ventilation air heating that have higher efficiencies, but with higher first costs.

High Efficiency Boiler System

This option would use a high efficiency condensing boiler for space and ventilation air heating. The makeup air unit would be configured with hot water coils instead of a gas furnace.

Costs Estimates

• Two each condensing hot water boilers, 95% Efficiency, 4 MMBTU Input, installation, piping and pumps	=$ 96,000
• Structure for boilers	=$ 16,000
• Makeup air unit with hot water coils (Credit)	(=$ 21,000)
• Pumping Energy Costs	=$ 325
Totals	=$ 91,325

Operating Costs

Structure Type	Baseline Energy & Costs Heating (MMBTU)	Costs ($)	Eff Boiler Heating Costs($)	Annual Cost Save ($)
Un-insulated				
Space Heat	3,152			
Ventilation	1,451	34,528	29076	5,452
Insulated				
Space Heat	396			
Ventilation	1,451	13,853	11,665	2,188
Insulated & Cooled				
Space Heat	396			
Ventilation	1,451	13,853	11,665	2,188

Simple Paybacks

Savings range from $2,188 to $4,508. Paybacks range from 20.3 to 41.7 years.

Ground Source Heat Pump System

Another option for space heating and cooling is a ground source heat pump system. These systems provide both space heating and cooling and, thus, would be applicable to insulated structures.

Because of the heating capability of the heat pumps, a small boiler may have to be installed to augment heating during cold weather.

The analysis assumes the following efficiencies:

Cooling Efficiency	EER = 16 (.75 KW/ton)
Heating COP	4.5
Design Peak Cooling Load	90 tons

Baseline System (Insulated & Cooled)

Heating Load (Space & Ventilation)		= 1,847 MMBTU
Cooling Load (Peak)		= 90 Tons
Heating Costs		=$13,853
Cooling Costs		=$ 8,082
	Total Costs	=$21,935

Ground Source Heat Pump System

Heating Costs		
Demand (58 KW)		=$ 2,030
Energy Use (148,235 Kwh)		=$ 7,104
Cooling Costs		
Demand (67.5 KW)		=$ 2,362
Energy Use (49,900 KWH)		=$ 2,391
Additional Pumping Costs		=$ 4,700
	Total Costs	=$18,587

Cost Savings	=$ 3,348

Costs

Costs provided by one equipment vendor are:

90 Wells with pipe, connected to header and back filled at $1,100/well	=$ 99,000
90 Tons Heat Pump System @ $1300/ton	=$117,000
Enclosure	=$ 30,000
1 MMBTU Boiler & Installation	=$ 22,000
Additional Installation Costs	=$ 20,000
Makeup Air Unit with coils	(=$ 21,000)
Air Cooled Condenser (Credit)	(=$ 42,000)
Total	=$205,000

Note that the costs represent difference between the baseline system of an indirect fired makeup air unit with DX coils and a heat pump system. Installed costs of a heat pump system are higher and therefore some incremental installation costs have been included.

Payback

The payback would be greater than 20 years.

Note that operational costs for the heat pump system are high given the energy use costs adopted for the analysis. However, to achieve a payback less than 10 years, savings would have to be about $20,000 annually, which appears unlikely.

Standby Propane Systems

An option for air-supported structure owner operators is a standby propane system, which would qualify the facility for interruptible gas rates. Typically standby or interruptible gas rates are about 66% of firm rates (i.e., Small volume Dual Fuel and Firm Rates from Reliant Energy (Minnegasco) and Xcel Energy).

Year	Small Vol Dual ($ per MCF)	Firm ($/MCF)	% Dual/Firm
98	2.86	4.32	66
99	3.00	4.58	65
00	4.60	6.21	74

Interruptible customers are typically on propane for 8 – 10 days per year. The additional cost of propane, also a volatile fuel, must be factored into the analysis.

On peak heating days, it is estimated that the baseline structure would use about 500 gallons of propane (475 therms) daily. Over ten days, the owner would use about 5,000 gallons. Using an average cost of $0.90 per gallon ($9.95/MMBTU at 90,500 BTU/gal), total annual propane cost is $ 4,500.

Rate Comparisons

Utility customers pay a monthly service charge. Natural gas customers considering dual fuel rates must consider the monthly customer charge in the analysis. Dual Fuel Small Volume Customers pay monthly service charges of $125 per month as opposed to $15 per month for Firm Rate Customers.

Cost Estimate of Standby Propane System

The following quote obtained for a standby propane system is:

Standby Propane System including two 1,000 gallon tanks, mixer, heater, pad, piping, electrical and installation	=$47,500

Cost Analysis

Customer on Firm Rate

• Annual Customer Charge	=$ 180
• Annual Gas Charge (5,755 MMBTU x $6.00/MMBTU)	=$ 34,528
Total	=$ 34,708

Customer on Dual Fuel Rate

• Annual Customer Charge	=$	1,500
• Annual Propane charges	=$	4,500
• Annual Gas Charge (5,755 – 475) MMBTU x $4.00/MMBTU	=$	21,120
Total	=$	27,120
Annual Cost Savings	=$	7,590
Simple Payback	=	6.3 Years

The above analysis was for the baseline system. However, if the less costly conservation strategies (e.g. night heating shut off, leak control and manual pressurization) are implemented first, then the overall energy use is greatly reduced and the simple payback on this strategy would be greater than 10 years. For example, implementing a night heating shut off strategy would reduce annual heating costs for an un-insulated structure by about 50% to $17,518. The simple payback on a backup propane system would then be 24.7 years.

The analysis was not performed for an insulated air supported structure since energy use is significantly reduced (i.e., to about 2,309 MMBTU/Yr). This would reduce savings considerably (i.e., to about $698 annually) and the opportunity would not be economically justified.

Dual fuel capability may be applicable in situations where an air-supported structure is one of a number of combined and/or connected structures (e.g. community center, hockey rink). In these situations, costs and benefits can be spread among a number of buildings.

Cooling System Strategy Opportunities

<u>Energy Efficient Condenser Units</u>

Cooling systems used in air-supported structures are typically large air-cooled condensing units having efficiencies ranging from 1.20 Kw/ton (EER = 10.0) and 1.25 Kw/ton (EER = 9.6). This efficiency range is indicative of currently available air-cooled units available from all commercial cooling suppliers.

As cooling systems become more efficient in the near term or as air-supported structure owners can influence equipment choices, additional energy and operating cost savings can be achieved. For example, a cooling system having an efficiency of 1.15 KW/ton (EER = 10.43) will reduce electric demand by .05 to .10 Kw/ton and result in annual energy and cost savings of:

.05 Kw/ton Reduction for a 90 Ton System

Total Peak Electric Demand Savings	= 4.5 Kw
Total Annual Electric Energy Use Savings	= 3,300 Kwh
Total Annual Operating Cost Reduction	=$ 325

.10 Kw/ton Reduction for a 90 Ton System

Total Peak Electric Demand Savings	= 9.0 Kw
Total Annual Electric Energy Use Savings	= 6,600 Kwh
Total Annual Operating Cost Reduction	=$ 650

<u>Evaporative Cooled Condenser Units</u>

Evaporative cooled condensing units may be available in this capacity range, although a brief survey was able to identify only one manufacturer. These particular units have integral supply fans.

Evaporative cooled condensing units in this capacity range have efficiencies have efficiencies ranging from .85 Kw/ton to .95 Kw/ton and could reduce annual cooling cost by about $1,950 to $2,600 per year. However, water, chemical and spray pump costs are estimated at $1500 to $1750 per year, assuming that a sewer rebate is available. Thus cost savings will range from $450 to $1,150 annual. Incremental costs are unknown, but estimated at $9,000 to $10,000 for a 90 ton unit. Given the expected cost savings, paybacks would range from about 9 to 20 years.

Mixed Strategy Opportunities

Combinations of individual energy saving opportunities can be analyzed to determine the benefits of mixed or integrated conservation strategies. Since the number of combinations are large, combinations were selected based on those that were most likely to be adopted by structure operators. These include:

- Baseline Structure + Fixing Leaks (50% Reduction)
- Baseline Structure + Fixing Leaks + Night Setback (i.e., Night Shut Off)
- Baseline Structure + Fixing Leaks + Night Setback + Manually Controlling Structure Pressure
- Baseline Structure + Fixing Leaks + Night Setback + Manually Controlling Structure Pressure + Purchasing Premium Efficient Motors
- Baseline Structure + Fixing Leaks + Night Setback + Manually Controlling Structure Pressure + Purchasing Premium Efficient Motors + Purchasing 875 Watt Pulse Start Metal Halide Fixtures
- Baseline Structure + Fixing Leaks + Night Setback + Manually Controlling Structure Pressure + Purchasing Premium Efficient Motors + Purchasing 750 Watt Pulse Start Metal Halide Fixtures
- Baseline Structure + Fixing Leaks + Night Setback + Manually Controlling Structure Pressure + Purchasing Premium Efficient Motors + Purchasing 875 Watt Pulse Start Metal Halide Fixtures + Installing an Adjustable Speed Drive on the Fan Motor
- Baseline Structure + Fixing Leaks + Night Setback + Manually Controlling Structure Pressure + Purchasing Premium Efficient Motors + Purchasing 875 Watt Pulse Start Metal Halide Fixtures + Installing an Adjustable Speed Drive on the Fan Motor + Installing Insulation (Un-insulated Structure Only, R = 12.2)

These basic combinations were analyzed for each of the three baseline air supported structure types using the following methodology:

- Combined costs associated with each strategy were determine based on individual strategy analysis.
- Cost savings were based on differences in energy costs between the baseline structure and selected mixed strategy

The results of the analysis are contained in Tables 4 – 16 (Un-insulated Structure), 4 – 17 (Insulated Structure) and 4 – 18 (Insulated & Cooled Structure).

In most cases, the resulting mixed strategy simple paybacks that were less than the paybacks illustrated in the individual strategy analysis. This reflects strategy combinations and those most likely to be implemented by structure owner and operators because of first costs and low paybacks such as night setback temperature control.

Table 4 - 16, Mixed Strategies - Un-insulated Structures

Conservation Strategy	Heat Energy (MMBTU)	Vent Energy (MMBTU)	Lighting Kw	Lighting Kwh	Motors Kw	Motors Kwh	Annual Costs ($)	Annual Save ($)	Strategy Costs ($)	Combined Strategy Cost ($)	Simple Payback
Baseline Structure	3152	1451	43.20	61,372	25.67	224,859	$54,406				
Baseline + Fix Leaks	3,152	1,123	43.20	61,372	25.67	224,859	$51,944	$2,462	$3,462	$3,462	1.41
Baseline + Fix Leaks + Night Setback	1,563	566	43.20	61,372	25.67	224,859	$35,840	$18,566	$5,500	$8,962	0.48
Baseline + Fix Leaks + Night Setback + Manual Pressure	1,563	514	43.20	61,372	25.67	209,962	$34,740	$19,666	$5,000	$13,962	0.71
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors	1,563	518	43.20	61,372	25.37	207,508	$34,627	$19,779	$333	$14,295	0.72
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 875 W Pulse Start	1,589	518	37.80	53,701	25.37	207,508	$33,973	$20,433	$3,250	$17,545	0.86
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 750 W Pulse Start	1,614	518	32.60	46,313	25.37	207,508	$33,342	$21,064	$3,000	$17,295	0.82
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 875 W Pulse Start + Insulation	189	518	37.80	53,701	25.37	207,508	$23,901	$23,463	$60,750	$78,045	3.33
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 875 W Pulse Start + ASD + Insulation	150	511	37.8	53,701	25.37	175,284	$23,024	$20,585	$9,350	$87,395	4.25

Notes:

1 - Leak Rduction of 50%
2 - Night Setback Strategy is Shut Off
3 - Insulation Costs of $1.25/Sq Ft

Table 4 - 17, Mixed Strategies - Insulated Structures

Conservation Strategy	Heat Energy (MMBTU)	Vent Energy (MMBTU)	Lighting Kw	Lighting Kwh	Motors Kw	Motors Kwh	Annual Costs ($)	Annual Save ($)	Strategy Cost ($)	Combined Strategy Costs ($)	Simple Payback
Baseline Structure	396	1,451	43.20	95,800	25.67	224,859	$35,381				
Baseline + Fix Leaks	396	1,123	43.20	95,800	25.67	224,859	$32,919	$2,462	$3,462	$3,462	1.41
Baseline + Fix Leaks + Night Setback	109	566	43.20	95,800	25.67	224,859	$26,587	$8,794	$5,500	$8,962	1.02
Baseline + Fix Leaks + Night Setback + Manual Pressure	109	514	43.20	95,800	25.67	209,962	$25,488	$9,893	$5,000	$13,962	1.41
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors	109	518	43.20	95,800	25.37	207,508	$25,375	$10,006	$333	$14,295	1.43
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 875 W Pulse Start	150	518	37.80	83,825	25.37	207,508	$24,624	$10,757	$3,250	$17,545	1.63
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 750 W Pulse Start	189	518	32.60	72,294	25.37	207,508	$23,901	$11,480	$3,000	$17,295	1.51
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 875 W Pulse Start + ASD	150	511	37.80	83,825	25.37	175,284	$23,024	$12,357	$9,350	$26,645	2.16

Table 4 - 18, Mixed Strategies - Insulated & Cooled Structures

Conservation Strategy	Heat Energy (MMBTU)	Vent Energy (MMBTU)	Lighting Kw	Lighting Kwh	Motors Kw	Motors Kwh	Cooling Kw	Cooling Kwh	Annual Costs ($)	Annual Save ($)	Strategy Cost ($)	Combined Strategy Costs ($)	Simple Payback
Baseline Structure	396	1,451	43.20	95,800	25.67	224,859	111.00	82,298	$43,383				
Baseline + Fix Leaks	396	1,123	43.20	95,800	25.67	224,859	101.40	79,662	$40,518	$2,865	$3,142	$3,142	1.10
Baseline + Fix Leaks + Night Setback	109	566	43.20	95,800	25.67	224,859	101.40	79,662	$34,186	$9,197	$5,500	$8,642	0.94
Baseline + Fix Leaks + Night Setback + Manual Pressure	109	514	43.20	95,800	25.67	209,962	97.90	76,603	$32,800	$10,583	$5,000	$13,642	1.29
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors	109	518	43.20	95,800	25.37	207,508	97.90	76,260	$32,674	$10,709	$333	$13,975	1.30
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 875 W Pulse Start	150	518	37.80	83,825	25.37	207,508	95.90	72,891	$31,691	$11,692	$3,250	$17,225	1.47
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 750 W Pulse Start	189	518	32.60	72,294	25.37	207,508	94.10	69,646	$30,744	$12,639	$3,000	$16,975	1.34
Baseline + Fix Leaks + Night Setback + Manual Pressure + Prem Eff Motors + 875 W Pulse Start + ASD	150	511	37.80	83,825	25.37	175,284	93.00	67,596	$29,730	$13,653	$9,350	$26,325	1.93

Appendix A

Baseline Description of Air-Supported Structures

Baseline Air-Supported Structure Description

Three baseline system descriptions for an air-supported structure were developed as the basis for analyzing energy and cost savings strategies

- Un-insulated, winter only operation
- Insulated, Potential Year around operation
- Insulated & Cooled, Year around operation

Air Supported Structure (Figure A – 1)

Dimensions	270' long x 180' wide x 54' high
Surface Area	64,000 sq ft (48,600 sq ft footprint)

Insulation Value of Structure

- R = 2.20 (sq ft hr F/BTU) for un-insulated structure
- R = 12.2 (sq ft hr F/BTU) for insulated structure

Solar Transmittance	.142 %
Doors	
Exit	6
Revolving Entry	1
Vehicle	1 at 12' height
Occupancy	60 Maximum
Occupancy % During Occupied Hours	
Ave % During Day	50%
Ave % During Night	90%
Occupant Heat Gain	
Sensible	500 BTU/Occupant
Latent	105 BTU/Occupant

Lighting

Total Number of Fixtures	50
Fixture Type	Metal halide
Lamp Wattage	1,000
Fixture Wattage	1,080
Controls	Manual (5 – 6 Lighting Circuit Breakers)
Location	Ground Stands

Lighting System Operation

Un-insulated Structure

Winter	
Day 8 am to 4 pm	50% On (46 hrs/wk)
Night 4 pm to 10 pm	80% On (42 hrs/wk)
Summer	
Day 8 am to 8 pm	50% on (74 hrs/wk)
Night 8 pm to 10 pm	80% On (14 hrs/wk)

Insulated Structure

Winter & Summer	80% On (88 hrs/wk)

Heating/Ventilation/Cooling System

Type	Indirect Fired Makeup Air
Heating Efficiency	80%
Cooling System Efficiency (Condenser Unit)	EER = 9.7 (90 tons)
Heat Input	5,0000,000 BTUH
Supply Static	1.5' w.c.
Design Supply Fan Volume	38,000 at 848 RPM
Total Static	3' w.c.
Primary Fan System	3 Parallel Fans On Common Shaft
Fan Motor	40 HP, 1,800 RPM 93 % Efficiency
Backup Fan	10 HP, 1,800 RPM 90.2 % Efficiency
Backup Power Source	Natural Gas Engine Driven Generator Set

Control

Manual Return Air Damper Control for Pressurization
Space Temperature Control (Manual Set point)
Heat System On/Off
Cooling System On/Off
Note that newer structures tend have small digital controllers

Backup Fan Control

1 st Stage Electric Backup on Pressurization Drop
2 nd Stage Backup with Gas Generator Set

There are a number of variations in construction, materials, systems and operation of air supported structures used by and recommended by various manufacturers. Those that impact energy use are described below:

Clamp Systems – The clamping system used to hold the fabric dome to the concrete footings can be a major source of air leakage. Two typical clamping systems are angle clamp system and channel clamps system (Figure A – 2). Air leakage for the angle clamping system can be up to 3 cfm per lineal foot. Air leakage for the channel clamp system is very low to none. Three cfm per lineal foot leakage for the baseline structure results in total leakage of 2,424 cfm.

Fan Systems – Variation in the fan systems supplied with structures can vary by size and type.

- Summer Fan – A smaller separate fan system used during the summer months. During these periods, a smaller fan (e.g. 10 HP on the baseline structure) can be used if there is no heating or cooling.

- Re-circulation Fan – Installation of a smaller fan system, typically located at the opposite side of the structure from the main heating cooling systems to promote air circulation. This strategy also can be used to reduce the fan size of the main heating/cooling system.

Digital Control System – Small digital control system to replace or expand the functionality of the manual control system and offer:

- Automatic structure pressurization control from a external wind sensor.

- Automatic temperature control as a function of time of day schedules.

- Snow/moisture sensor to provide warm-up temperatures to promote snow melts.

- Automatic fault detection and alarming (e.g., auto call out when structure pressurization fails).

Exit Door System – Spring loaded door hinges to minimize leakage when exit doors are used.

Figure A – 1, Air-Supported Structure Geometry

Figure A – 2, Channel Clamp System

Appendix B

Lighting Systems

Specific manufacturers of lighting equipment are identified in this Appendix. Manufacturers are identified for informational purposes only and are not to be construed as recommendations. These identifications do not constitute an approval, warranty, guarantee or endorsement of this product by the State.

Existing Lighting Systems

Lighting systems within air supported structures are typically provided by metal halide fixtures (i.e., typical is 1,000 watt) pointed upward to reflect off the inner surface of the structure. Most manufacturers mount the light fixtures on semi-mobile stands and or poles to accommodate differing activities in the facility.

Fixtures are also mounted from the ceiling of the structure and point down or can be pointed upward to reflect off the inner surface of the structure.

Because of the thin translucent material used on un-insulated surfaces of the structures, a significant amount of diffuse day lighting is available. Thus fixture use can be greatly minimized during these periods. If the structure is insulated, the benefits of natural day lighting are greatly diminished since the surface material of the structure becomes opaque. This must be considered in the overall evaluation of installing insulation.

The building operator manually controls lighting according to occupancy and activity.

Pulse Start Metal Halide Fixtures

Pulse start metal halide lamps and ballasts are one emerging technology that can reduce energy use and costs. Pulse start metal halide fixtures represent lighting technology that has been available over the last 3 – 5 years with an expanding lamp size availability that now includes 750, 875, 1,000 and 2,000 watts. The technology offers the potential for significant energy and cost savings.

They provide superior performance compared to standard metal halide lamps including:

- Higher Efficacy or lumens/watt (Up to 50%).
- Better Color Uniformity.
- Faster Warm-up and Re-strike (Up to 60% less time).
- Longer Life (up to 50% due to reduced lumen depreciation).
- Less Lumen Depreciation (Up to 40%).
- Lower Temperature Starting.

Unfortunately, large wattage pulse start metal halide lamps are limited primarily to base up configurations (e.g. lamp must hang down). If existing light fixtures use a lamp that has a base up configuration, pulse start options are current available.

If base up configurations are not currently used, options are limited and customers may have to wait a period of time for solutions. One manufacturer, Sylvania, manufactures a 750-watt pulse start lamp for horizontal use (e.g. spot light fixture type). Other configurations such as universal position (i.e., any position) are expected as the market matures. Conversations with one manufacturer have indicated that this may occur within the next 12 – 18 months.

These benefits are achieved through formed body arc tubes, pulse start igniter and low current crest ballast factors. The combined benefits result in energy savings with increased light levels and color rendering index.

Available Pulse Start Lamps & Ballasts

The following illustrates comparable data for the standard 1,000, 875 and 750-watt lamps and ballasts. Additional data sheets are included at the end of this Appendix.

Item	1,000 Watt	875 Watt		750 Watt
	Lamp	CWA Ballast	Reactor Ballast	
Lamp wattage	1,000	875	875	750
Lamp Lumens (Initial)	105 – 110,000	100,600	100,600	80,000
Fixture Wattage	1,080	945	925	815

Note that initial lumens are nearly the same. With less lumen depreciation, the 875 watt pulse start fixture provides higher lighting levels during the life of the lamp.

Pulse start fixtures with 750 watt lamps have an 80,000 initial lumens. However, with lumen depreciation savings of 30 – 40%, they can provide about the same amount of light as standard 1,000 watt fixtures.

Incremental Costs

Pulse Start Metal Halide fixtures cost about 20% - 25% more than standard metal halide fixtures, as indicated in the cost data provided by one lighting vendor (Table B – 1). However, cost increments of 100% have been reported. As the technology for large metal halide fixtures and configurations matures, costs are expected to stabilize. Therefore, a 20% cost increment is used in the analysis.

Table B – 1, Pulse Start Metal Halide Costs

New Fixtures (Includes Lamp + Ballast)

Fixture (Watt)	List Cost ($)
1,000	315 (Standard Metal Halide)
875	380
750	375 (Est)

Component Cost

Wattage	Lamp	Ballast
1,000	60	65 (Standard Metal Halide)
750	85	100
875	85	100

Retrofit Labor

$80/hr x 1.25 hrs/Fixture =$ 100

Existing Retrofit Options

As indicated above, existing fixtures having lamps with base up configurations can use existing pulse start metal halide technology. Otherwise current retrofit options are to limited to the following two options.

Use of two fixtures (e.g. two 350 – 400 watt pulse start fixtures) replacing one 1,000-watt fixture.

Use of one 750-watt pulse start fixture replacing one 1,000-watt fixture.

Note that both would use a horizontal lamp configuration and thus would use a spot light fixture type enclosure. Estimated costs (including lamp) are:

Fixture Type	List ($)	Incremental Cost ($)
Standard 1,000 Watt Fixture	500	
750 Watt Pulse Start (Hor)	750	275
400 Watt Pulse Start (Hor)	450	425

Note that two 400-watt fixtures are required and the cost difference is $400. Note also that an additional $25 per fixtures was added for mounting modifications.

350-Watt Pulse Start Metal Halide Fixtures

Pulse start lighting fixtures that are currently available in base down and or horizontal configurations include 320 and 350-watt fixtures. However, two fixtures would be required for each 1,000-watt standard metal halide fixture.

Light Emitting Diodes (LED's) Exit Signs

Many installed exit sign fixtures have been installed with one to two 5 or 7-watt fluorescent lamps or one to two 15 to 20 incandescent watt lamps.

Newer exit sign fixtures are available with 2-watt LED lamps. In addition to the energy savings, LED lamps have a expected life of 25 plus years and can provide additional maintenance savings. Most new energy codes require low wattage exit signs.

LED exit signs can be retrofitted into existing structures to provide on-going energy, maintenance and cost savings. Retrofit costs are:

Retrofit Kit Costs	=$ 50
Installation Labor (15 min x $80/hr)	=$ 20
Total	=$ 70

Suppliers

Sylvania
Venture

Utility Rebates

Most electric utilities in Minnesota provide rebates for pulse start metal halide fixtures that offset initial costs of either new or retrofit fixtures. Rebates are also available for LED retrofits. Rebates were not considered in the analysis. Examples include:

Xcel Energy

Pulse Start Retrofit

$12/Fixture (New)

Up to $65/Fixture for Retrofit of Ballast and Lamp

Exit Sign Retrofit

$6.00

OtterTail Power Co.

$0.20/watt Saved on Retrofit (e.g. up to $27/Fixture on retrofit of 875 watt lamp and ballast).

Minnesota Power

Up to $200/Kw Saved on retrofit (e.g. up to $27/Fixture on retrofit of 875 watt lamp and ballast).

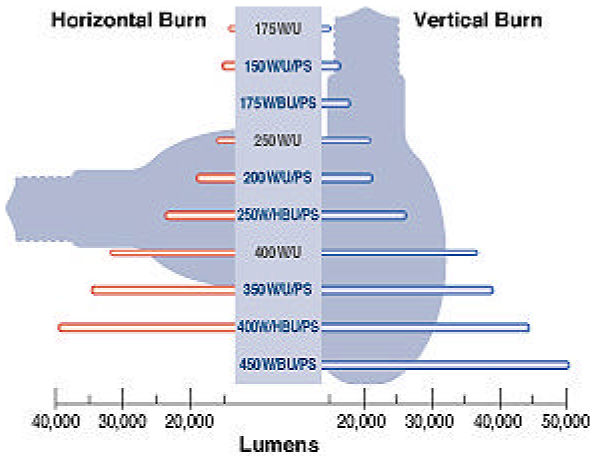
The reader is cautioned to check with their utility representative for current rebate information.

Attached Data

Lamp Data (875, 1,000 Watt Lamps, Base Up Configuration).
Ballast Data (750, 875, 1,000 Watts)
Description and benefits of Pulse Start Lighting Systems

The Uni-Form® Pulse Start Advantage

More Light

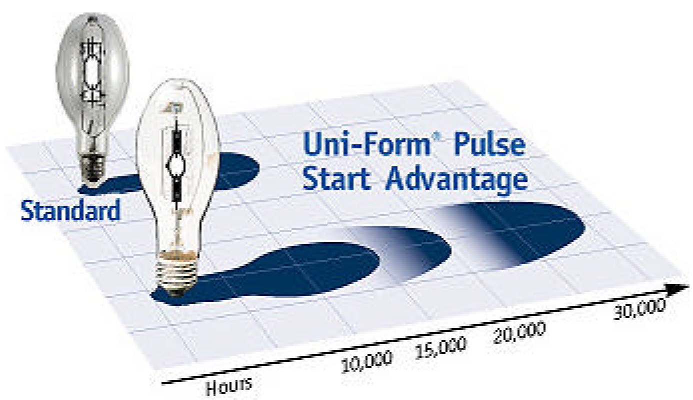


The *Uni-Form* pulse start formed-body arc tube combined with new, more efficient low current crest factor ballasts using high voltage ignitors provides higher light levels initially (20% more) and significantly more maintained light over time (40% more) than today's standard metal halide.

A Bright Insight

Many of Venture's *Uni-Form* pulse start lamps can be used horizontally, too, giving 20% more initial lumens than standard, universal technology.

Longer Life



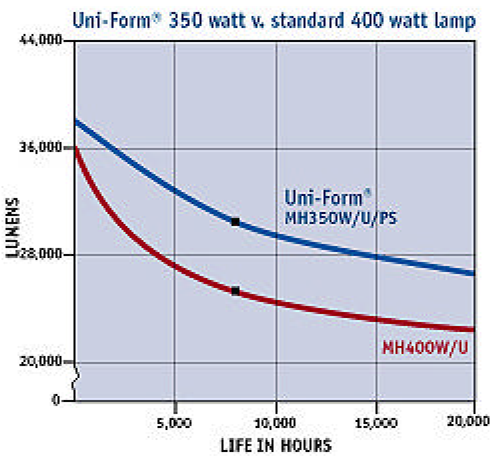
The *Uni-Form* pulse start system offers up to 50% longer lamp life because of less electrode damage, reduced arc tube darkening, and improved lumen maintenance. The direct benefits are lower replacement costs and reduced lifetime operating cost.

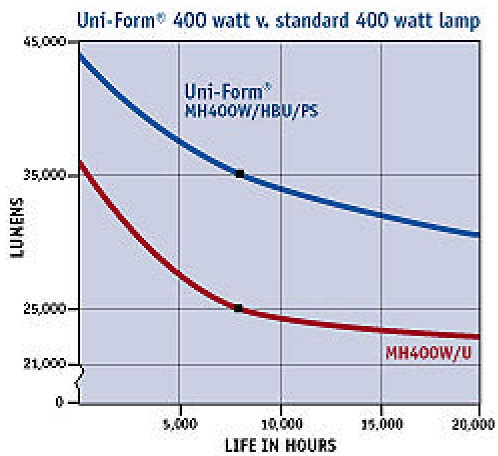
A Light Word

Using Venture's 15,000 hour *Uni-Form* pulse start lamps (150, 175, 200 or 250 W) means relamping less often - labor savings pay for lamp replacement over system life.

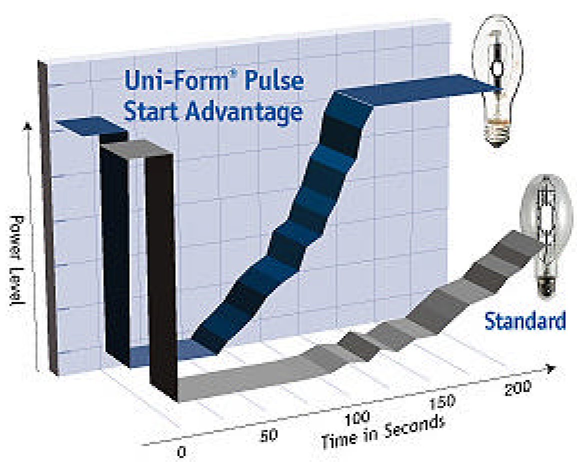
Superior Lumen Maintenance

The combination of the *Uni-Form* formed body arc tube, pulse start ignitor, and low current crest factor ballast results in higher maintained lumens over the entire life of the lamp. The end result is a dramatic improvement in design or mean lumens. The light output stays bright even after thousands of hours!



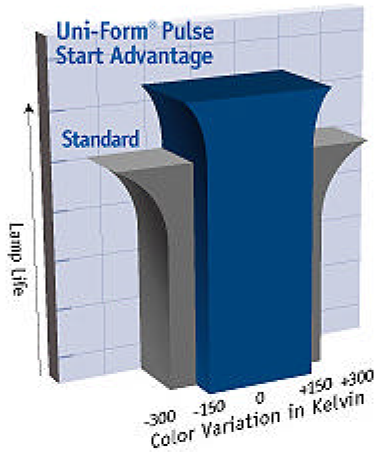


Faster Warm-up/ Hot Restrike



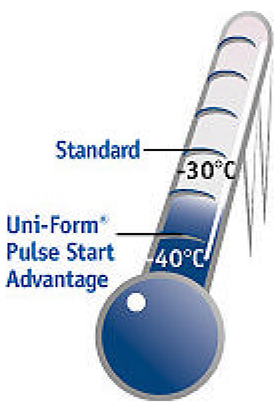
The *Uni-Form* pulse start system combines ignitor starting and improved arc tube design with higher gas fill pressures to provide initial warm up and hot restrike in 60% less time.

Color Uniformity



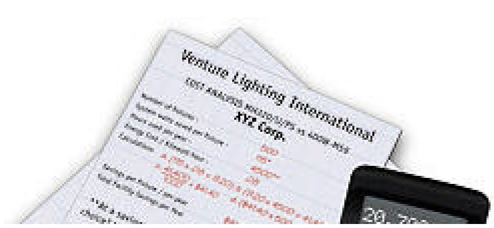
Because of the uniform wall thickness and the consistency of shape obtained with Venture's unique quartz sculpting process, all arc tube chambers are identical in thermal characteristics, resulting in consistent halide temperatures. This ensures minimal variation in lamp color as well as higher light output.

Cold Starting



The external ignitor and the *Uni-Form* formed body arc tube combine to allow better starting in colder conditions, down to -40°C. Quicker breakdown of gases and higher fill pressures result in reliable starting, even in cold weather applications such as cold storage or freezer warehouses.

Saves Energy



The *Uni-Form* pulse start system delivers more light with lower energy usage. When compared to standard metal halide technology, *Uni-Form* pulse start offers up to 50% improvement in system lumens per watt. In addition, the use of *Uni-Form* pulse start reactor ballasts reduces energy losses by more than 50%.

Appendix C

Energy Efficient Motors

Specific manufacturers of motor equipment are identified in this Appendix. Manufacturers are identified for informational purposes only and are not to be construed as recommendations. These identifications do not constitute an approval, warranty, guarantee or endorsement of this product by the State.

Energy Efficient Motors

The Energy Pact Policy Act of 1992 (EPACT) requires that most general purpose motors manufactured for sale in the United States after 10/24/97 meet minimum efficiency standards. These efficiency standards are known as EPACT or Energy Efficient Motors and apply to all single speed, T Frame, Open Drip Proof and Totally Enclosed Fan Powered general purpose motors between 1 and 200 HP. These types of motors are supplied in heating, cooling and ventilation systems. Efficiency levels and typical list prices for two major vendors are illustrated in Table C – 1.

Premium Efficient Motors

Motors efficiency levels have increased and now premium efficiency motors are available. Premium efficiency levels were established by NEMA and thus have a “recognized and consistent efficiency standard”. They can be ordered as option on new fan systems or retrofit on existing fans systems. Table C – 1 illustrates premium efficient motor catalog efficiency and list prices for open drip proof motors.

Incremental Costs

Incremental list prices are illustrated in Table C – 1 for two major vendors, General Electric and Baldor. List price differentials range from 12 to 20%.

Known Suppliers

Premium efficient motors are manufactured by most motors vendors including:

General Electric
Baldor
U.S. Motor
Marathon
Lincoln

Utility Rebates

Most electric utilities in Minnesota provide rebates for premium efficient motors that offset initial costs of either new or retrofit fixtures. Rebates were not considered in the analysis. Examples include:

Xcel Energy

$5/ Hp for New Motor
Up to $16.50/HP for Retrofit of Working Motor

OtterTail Power Co.

Rebate for Premium Efficient Motors is Unknown.
Current Rebates Provided for Energy efficient Motors

Minnesota Power

Up to $200/Kw Saved on retrofit
Or
$.0025/Kwh saved x Life
Example – 40 Hp Premium Efficient Motor
New vs Energy Efficient (.93), .281 Kw Saved, Rebate = $$56.20
Retrofit of Standard (.90), 1.155 Kw Saved, Rebate of $231.00

The reader is cautioned to check with their utility representative for current rebate information
.

Table C-1, Energy Efficient & Premium Efficient Motors,Efficiencies & Costs

Open Drip Proof, 1800 RPM, 230/460V, SF 1.15, T - Frame

HP	Volts	Energy Efficient	List Price Price ($)	Premium Efficient	List Price ($)	Cost Diff ($)
General Electric						
3	230/460	86.5	$311	88.5	376	$65
5	230/460	87.5	$377	89.5	$515	$138
7.5	230/460	88.5	$518	91	$641	$123
10	230/460	90.2	$626	91.7	$775	$149
15	230/460	90.2	$829	93	$1,030	$201
20	230/460	91.0	$1,015	93.0	$1,260	$245
25	230/460	91.7	$1,179	93.6	$1,464	$285
30	230/460	92.4	$1,374	94.1	$1,703	$329
40	230/460	93.0	$2,332	94.1	$2,603	$271
50	230/460	93.0	$2,646	94.5	$2,954	$308
Baldor						
3	230/460	86.5	$297	89.5	$391	$94
5	230/460	87.5	$329	89.5	$428	$99
7.5	230/460	88.5	$467	91	$630	$163
10	230/460	89.5	$573	91.7	$764	$191
15	230/460	91	$867	93	$1,083	$216
20	230/460	91.0	$1,092	93.0	$1,361	$269
25	230/460	91.7	$1,324	94.1	$1,659	$335
30	230/460	92.4	$1,548	94.1	$1,815	$267
40	230/460	93.0	$1,974	94.5	$2,368	$394
50	230/460	93.0	$2,318	94.5	$2,614	$296

Average List Cost Differences (Premium vs Energy Efficient)

3	$80
5	$119
7.5	$143
10	$170
15	$209
20	$257
25	$310
30	$298
40	$333
50	$302

Appendix D

Air Leakage & Ventilation Data

Introduction

Air losses from air supported structures are large. It is important to understand the losses; areas where they occur, what can be done to reduce them and what effects inflation pressure controls strategies have on air losses.

Design Air Losses (Leakage)

Design air losses from air supported structures are published in the Air Structures Design and Standards Manual, 1977 Edition, Publication ASI-77 and are itemized in Table D -1. Although the standard dates back 25 years, it is still used as the industry guidelines. Conversations with manufacturers have indicated that major advances have been made to reduce air losses through better perimeter clamping systems, door seals, door hinges, etc.

Air losses specified in Table D – 1 are based on a pressure of 1.00 inch water column. Air losses in structures operating at different pressures can be re-calculated based on Bernoulli's or conservation laws. Simply stated, at any two points in the air stream or duct, the total pressure is constant except for the friction losses (i.e., the static regain factor). Thus, total pressure = static pressure (SP) + velocity pressure (VP) or

- Inside dome SP +VP = 1.5" + 0 (no air) = 1.5"
- Outside Dome (Across Opening) SP + VP = 0 (atmospheric pressure) + VP
  = VP
  = (V/4005)**2

Thus for any one condition:

SP1 = (CFM1/Area x 4005)**2

And the results for two conditions is:

SP2/SP1 = (CFM2/CFM1)**2

Pressure	Multiplication Factor
1.50	1.22
1.25	1.12
1.00	1.00
.75	.86

Doors

1 Revolving door	@ 300 cfm (1" w.c)	= 300 cfm
6 Exit doors	@ 300 cfm (1" w.c.)	= 1,800 cfm
1 Vehicle air lock	@ 600 cfm (1" w.c.)	= 600 cfm
	Total (1' w.c.)	= 2,700 cfm
	Total corrected to 1.5" w.c.	= 3,294 cfm

Note that the vehicle air lock has roll up doors although panel types (i.e. reduce air leakage) have been used. Site observations indicated leaks far in excess of 300 cfm. Therefore, the guideline was doubled.

Structure Perimeter

Losses through the base perimeter are dependent on the type of clamping mechanism and/or skirt. Conversation with air supported structure manufacturers indicate that major advances in clamping techniques have been developed that have reduced perimeter leakage to near zero using channel clamping systems. The simulation uses 1 cfm/linear foot

808 ft x 1 cfm (1" w.c.) = 808 cfm

Corrected to 1.5" w.c. = 985 cfm

Fabric Seams & Material

Leakage through the fabric and many seams is dependent on the size and construction of the structure and the many seam lengths. Based on conversations with one manufacturer, .1 cfm/sq ft of surface area is used in the simulation.

64,000 sq ft x .1 cfm/ sq ft (1.5" w.c.) = 6,400 sq ft

Mechanical Equipment

Air is lost through mechanical equipment panel seams, ducts and curbs. The following assumptions are based on design guidelines, conversations with manufacturers and observed conditions.

Design guidelines indicate about 150 cfm for each of the blower and heater ducts.

Site observations and subsequent conversations with one manufacturer indicate additional leakage through panel seams on the air handler unit. The following is used in the simulation:

- Control Panel, 3 seams @ 80" = 240" length

If the average seam is about 1/32", total area is about .05 sq ft and leakage at 1.5" w.c. is about 140 cfm. It should be noted that a major portion of this leakage could be reduced by caulking of the seams.

Additional seams on the makeup air unit corners and top panels can similarly be estimated at about .15 sq ft (1/64" seams) and leakage at 1.50 " w.c. is about 390 cfm.

Total estimated losses from the makeup air/heating unit are 830 cfm.

Leakage Summary Estimates

The simulation assumes the following baseline leakage estimates:

Leakage	cfm (at 1.50" w.c.)
Exit/Entry/Vehicle Doors	3,295 cfm
Structure Perimeter	985 cfm
Makeup Air Handler Unit	830 cfm
Fabric & Seams	6,400 cfm
Total	11,510 cfm

Exit Doors

Leakage around exit doors occurs at the base perimeter, door interface to structure and door seals. Newer structures have better flap seals and spring loaded door hinges to control and minimize leakage.

Leakage around doors in existing structures can vary significantly, depending on age and maintenance. Site observations also confirmed these trends.

Leakage around exit doors can be reduced by a combination of patching holes, caulking seams and small leaks and adjusting door latches and locks. One approach for leaky doors could be an overlapping clear plastic strip curtain hung on the inside of the exit door and vehicle exit doors (i.e. building codes permitting). Air leakage and structure pressurization would hold the plastic in place and reduce leakage.

Revolving Entry Doors

Entry revolving doors use thick rubber flaps seals on door edges to minimize leakage. If properly maintained, leakage is minimal.

Vehicle Entry Door/Air Lock

Vehicle entry doors and air locks leak around door edges. Most vehicle doors are roll up types where seals are difficult to maintain. The approach of using clear plastic overlapping strips or a multi-layer blanket fastened with velcro are two methods for minimizing leakage. However, there may be problematic issues associated with this approach since the plastic may blow out if the door is opened and thus prevent or hinder door closure. A breakaway cover may be one answer.

Simulation Assumptions

New Structures – Air losses are assumed to be at design conditions (i.e., 3,295 cfm) and can be reduced by 50% (i.e., 1,648 cfm) with additional caulking and covers such as those described above.

Fabric Seams & Material - Leakage through the fabric and many seams are assumed to be constant at 6,400 cfm, but can be reduced by controlling building pressurization.

Air Flow Through Openings

Airflow through openings of various sizes and pressures is illustrated in Figure D-1 (Air Structures Design and Standards Manual. 1977). This approach is useful for developing estimates of leakage through openings of various sizes. Normal values used in the simulation are:

Structure Pressurization (inches w.c.)	Velocity (fpm)
.75	1,650
1.0	2,200
1.25	2,500
1.50	2,750

For example, an opening of approximately 1 sq inch at 1.5" w.c. would be 1/144 sq ft x 2,750 ft/min = 19.1 cfm. Over an average heating season of 5,200 hours per year at an average outdoor temperature of 30 F and an average interior temperature of 60 F, this represents about 3.2 MMBTU. At a gas cost of $6.00/MMBTU and 80% heating efficiency, this would cost about $24.00 annually.

Building Ventilation

Building codes require that 15 – 20 cfm of outdoors air per occupant be brought into the building. Because of the many leakage points, significant amount of outdoor air are continually brought into the structure. Thus leakage, while using excess energy, also satisfies structure ventilation requirements.

Note that a leakage rate of 11,510 cfm (i.e. baseline building) will provide ventilation for 575 people at 20 cfm per occupant. The simulation uses a maximum occupancy of 60 people.

Utility Rebates

Many gas utilities in Minnesota provide custom solutions rebates for gas savings resulting from leak reduction or elimination. Rebates were not considered in the analysis. Examples include:

Xcel Energy

Custom Solution Rebate of up to $2.00/MMBTU Saved (i.e. First Year).

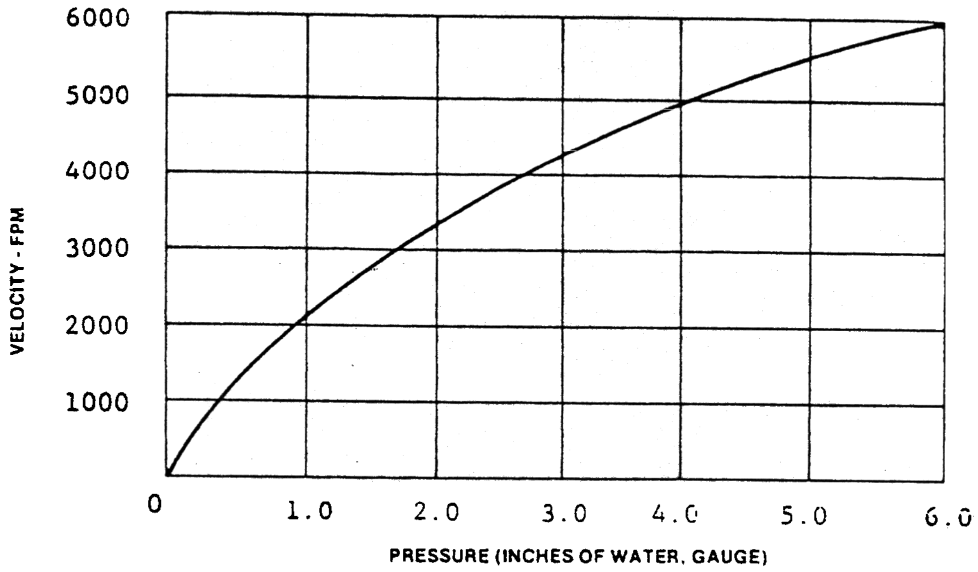
Note that the rebate must pass a cost benefit test.

The reader is cautioned to check with the local utility representative for current rebates that may be applicable.

Table D – 1, Design Air Leakage Rates

ITEM	CFM	UNIT
Base Perimeter		
Clamped Hem	3	Lin Ft.
Burried Skirt	4	Lin Ft.
Skirt on Concrete	6	Lin Ft.
Skirt on Earth	12	Lin Ft.
Field Junctions		
Clamped	3	Lin. Ft.
Roped	6	Lin. Ft.
Toggled	6	Lin. Ft.
Seams		
Sewn	0.1	Lin. Ft
Welded or Cemented	0	Lin. Ft
Doors		
Hatch	100	Each
Emergency Exit	300	Each
Revolving Door	300	Each
Personnel Air Lock	200	Each
Vehicle Air Lock (8' x 8')	200	Each
Vehicle Air Lock (12' x 12')	400	Each
Vehicle Air Lock (16' x 16')	600	Each
Mechanical Equipment		
Blower Duct	100	Each
Heater Duct	150	Each
Air Conditioning Duct	150	Each
Vents		
Diameter 4"	200	Each
Diameter 6"	450	Each
Diameter 12"	1700	Each
Diameter 16"	3100	Each

Figure D – 1, Air Flow Through Opening



Appendix E

Structure Pressurization

&

Adjustable Speed Drives

Specific manufacturers of equipment are identified in this Appendix. Manufacturers are identified for informational purposes only and are not to be construed as recommendations. These identifications do not constitute an approval, warranty, guarantee or endorsement of this product by the State.

Introduction

Pressurization withinair-supported structures is maintained by controlling return air dampers through:

- A wind sensor which varies pressure between 1.5” w.c. (windy, snow periods) to .75” w.c. (calm days).
- Manually controlled by structure operator.

Reducing or increasing structure pressurization reduces or increases leakage and energy use.

Adjustable Speed Drives

Installing an Adjustable Speed Drive (ASD) on the main fan motor to control structure pressurization by modulating fan speed using an input from a wind sensor is an acceptable method. The advantage of using an ASD is that it provides a way to vary fan speed and hence fan power. The result is energy and operational cost savings.

Fan Curves

A typical (i.e. forward curved) fan curve is used in the makeup air unit for the baseline inflatable structure. It should be noted that the recommended type of fan for large built up air handlers is the backward inclined B1 type fan with airfoil blades.

A common fan system arrangement on the makeup air unit is two to three fans operating in parallel. This provides equal air distribution across the large heat transfer surface and minimizes corrosion of the heat exchanger. However, in some applications, parallel fans present other issues that must be considered.

- Parallel fans discharging into a common duct or plenum should be selected to produce the same fan static pressure.
- Operating points must be carefully selected such that fan operation does not become unstable (i.e. unbalanced fan operation that may damage the motors). This can occur with fans that have a “positive” slope in the pressure-volume curve to the left of the peak pressure point. Efficient operating points are typically to the right of this “positive” slope in the fan curve for the combined fans.

The attached information for the baseline system illustrates a combined fan curve for three identical fans operating in parallel, the baseline primary fan system. This baseline fan system is designed to provide 38,000 cfm at 848 RPM with a single 40 HP motor driving the three fans mounted on a common shaft. Total static pressure (TSP) for the unit is about 3.0" w.c.

The information also illustrates fan operation at four static pressures from .75" w.c. to 1.5" w.c. As indicated, the fan system will operate within an efficient operating range (i.e. to the right of the system curve).

Wind Speed Control of Structure Pressurization

Fan speed will vary as a function of wind speeds. Average wind speed distribution data for Minneapolis/St. Paul is fairly constant on a monthly basis varying from a low of 9.2 MPH during August to a high of 12.0 MPH during April, with an average monthly speed of 10.4 MPH. However, there are periods of wind gusts that far exceed these averages. A typical design consideration for the structure is the ability to withstand wind gusts in the prevailing location, but at least to 80 mph.

Manual Control of Baseline Structure Pressurization

Structure pressurization by manual controls will reduce leakage but also slightly reduce break horsepower (BHP). This can be estimated by using theoretical calculations of BHP = (CFM x TSP)/(6344 x Fan Efficiency). The following pressure/power time distribution is used for the baseline structure:

Structure Pressure (Inches w.c.)	Percentage of Time
1.50	62.5
1.25	12.5
1.00	12.5
.75	12.5

Automatic Control of Structure Pressurization Using a Adjustable Speed Drive (ASD)

Use of automatic structure pressurization control using an adjustable speed drive uses the following assumptions:

Structure Pressure (inches w.c.)	Percentage of Time	Fan (cfm)	Fan (RPM)	% Full Speed
1.50	12.5	36,000	760	100
1.25	37.5	33,000	700	92
1.00	37.5	28,000	600	79
.75	12.5	23,000	500	66

The relationship between fan static pressure, RPM's and CFM's were derived from the combined fan curve for the makeup air unit.

Pressurization control using a wind sensor to adjust the speed of the fan requires an ASD. Energy savings are maximized with this approach because of the relationship between power and fan speed. It is assumed that power savings will be similar to those of a variable air volume system with inlet guide vanes. This application has been evaluated by the Electric Power Research Institute (EPRI) and summarized as:

% Flow	% Full load Energy Consumption		% Save
	Inlet Guide Vanes	ASD	
100	109	105	0
95	100	86	
90	93	73	20
85	86	64	
80	82	57	25
75	78	50	
70	75	44	
65	72	38	34
60	69	32	

Note that the air-supported structure industry has been slow to adopt adjustable speed drives; citing additional costs and reliability reasons. Inflatable structure owners/operators should check with their structure supplier to ensure that:

- Existing warrantees are not voided.
- Burners supplied with the makeup air unit have modulation capability.
- Burners are protected by a high temperature limit switches.

Adjustable speed drives installed with a bypass switch provide capability to manually bypass the controlling electronics in case of failure. This feature was included with the costs of an ASD to maintain fan operation and structure pressurization in case of electronics failure.

Backup Fan Motors

Inflatable structure building codes require a backup fan powered by an alternate fuel and capable of providing sufficient airflow to maintain building pressurization. The baseline system has the following backup fan system

- Powered by natural gas engine
- 10 HP, 1800 RPM
- Energy Efficiency Motor (90.2 %)
- 13,000 cfm at 2" w.c.
- 938 RPM Electric, 2,938 RPM engine

The backup fan system is automatically controlled using the following strategy. First stage backup is an electrically driven motor when low structure pressurization is detected. Second stage backup is through the use of a natural gas driven generator set when a power failure is detected

"Summer Fan"

The "summer fan" concept employed by one manufacturer uses a separate fan and motor to provide structure pressurization during the summer months when no heating or cooling is required. A 10 HP supply fan similar to the backup fan is typically used.

Cost Data

Table E – 1 below includes list costs for adjustable speed drives, by-pass switches and estimates for installation costs. Costs are based on an average of two manufacturers.

Table E – 1, Cost of Installed ASD's ($)

HP	230V	460V
20	7,370	7,310
25	8,100	7,660
30	8,970	8,460
40	9,800	9,350

Known Suppliers

ASD's are available from a number of manufacturers including:

General Electric	Graham
Baldor	Magnatek

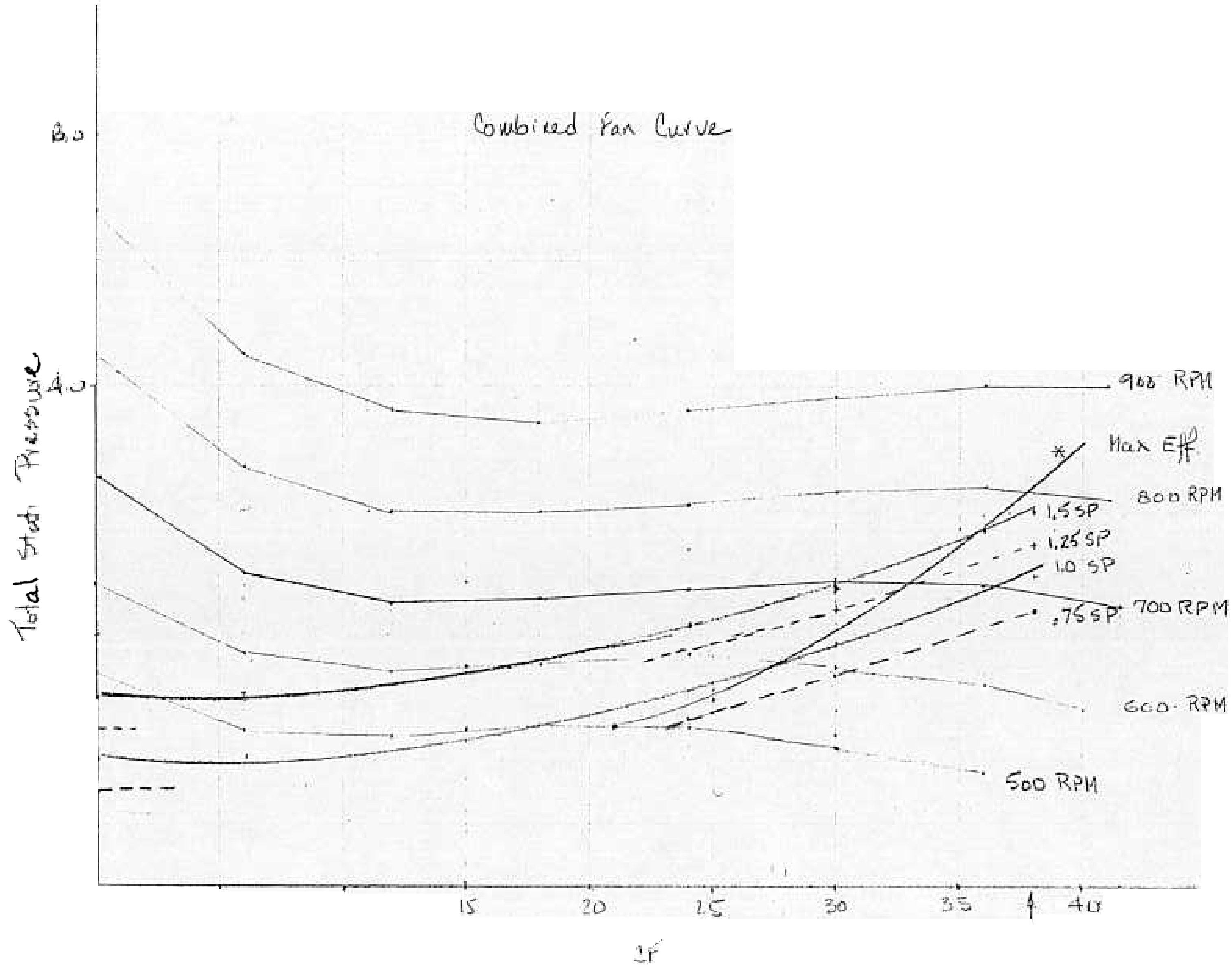
Utility Rebates

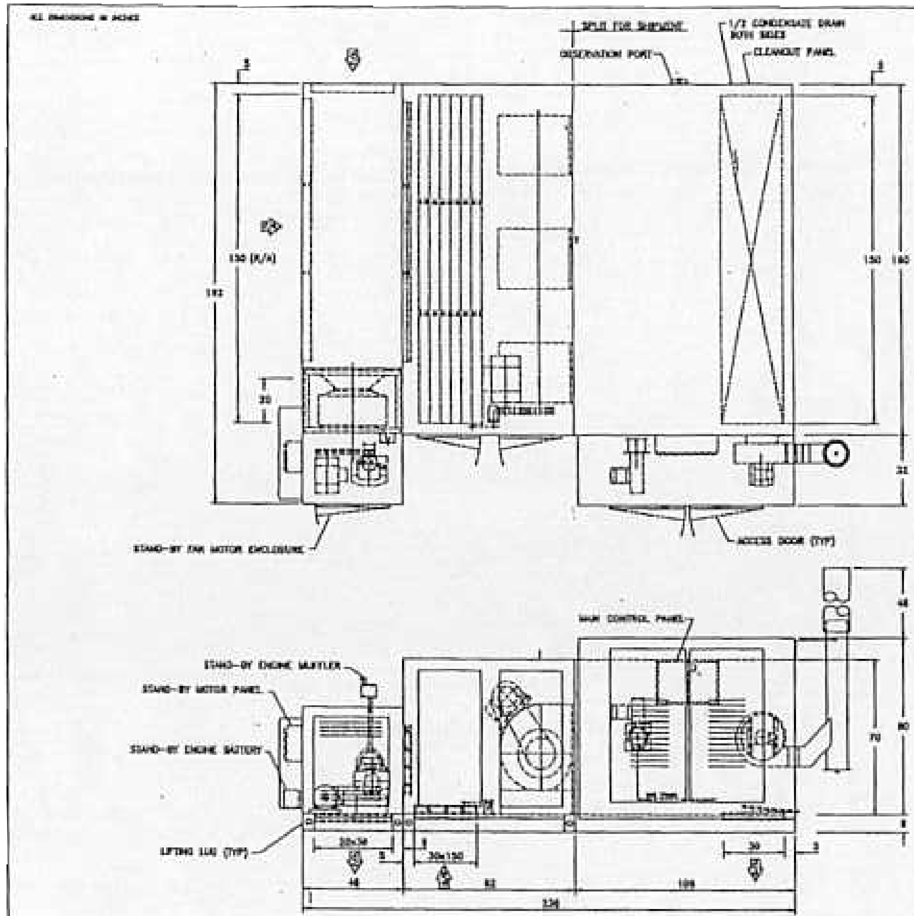
Most electric utilities in Minnesota provide rebates for adjustable speed drives. Rebates were not considered in the analysis. Examples include:

Xcel Energy

$30/HP (Motor must operate 4,000 hours per year).

The reader is cautioned to check with their local utility representative for current rebate availability and amounts.


Combined Fan Curve
8.0
4.0
Total Stat. Pressure
900 RPM
Max Eff
800 RPM
1.5 SP
1.25 SP
1.0 SP
700 RPM
.75 SP
600 RPM
500 RPM
15
20
25
30
35
40



UNIT SPECIFICATIONS

1 MODEL NUMBER	GTGM400-CBHM-S
2 UNIT QUANTITY	1 (ONE)
3 ARRANGEMENT	AS SHOWN
4 HEAT INPUT (MAX)	5,000,000 BTU/HR
5 HEAT OUTPUT (MAX)	4,000,000 BTU/HR
6 HEAT SOURCE	NATURAL GAS
7 FUEL PRESSURE	7" WC
8 TYPE OF FIRING	FULL MODULATION
9 TEMPERATURE RISE	103F
10 SUPPLY AIR VOLUME	36,000 CFM
11 SUPPLY STATIC PRESSURE	1-1/2" W.C.
12 SUPPLY FAN MOTOR	1-40HP 1800 RPM ODP (P-EFF.)
13 SUPPLY FANS SPEED	848 RPM
14 STAND-BY FAN AIR VOLUME	13,000 CFM
15 STAND-BY STATIC PRESSURE	2" W.C. MAX.
16 STAND-BY ENGINE	1 - 16 HP KOHLER W/8 ENGINE
17 STAND-BY FAN MOTOR	1-10HP 1800 RPM ODP (P-EFF.)
18 STAND-BY FAN SPEED	1,138 (ELEC. MTR.), 1,434 (ENGINE)
19 PIPE SIZE	3" DIA. AT APPLIANCE
20 POWER SUPPLY	460/3/60
• 21 EXHAUST STACK	TYPE "C" STACK
22 INSTALLATION	-40F OUTDOOR SUPPORTED
23 ALTITUDE	UNDER 3,000 FT
24 UNIT WEIGHT	14,300 LBS. APPROX.
25 APPROVAL REQUIRED	CGA, ETL
26 WIRING DIAGRAM NO.:	BW12014
27 PIPING DIAGRAM NO.:	BW12014 SHT.4
• 28 REMOTE STATION DWG. NO.:	B15481/B
29	
30	
31	

ACCESSORIES AND OPTIONS

32 1" INTERNAL INSULATION
33 INTAKE LOUVRES AND BIRDSCREEN
34 GRAVITY BACKDRAFT DAMPER FOR STAND-BY FAN
35 GRAVITY BACKDRAFT DAMPER FOR FRESH AIR INLET
36 MOTORIZED R/A OPPOSED BLADE DAMPER
37 MAGNEHELIC PRESSURE GAUGE ON FACE OF REMOTE STATION
38 HASPS ON HINGED ACCESS DOORS FOR CUSTOMERS PADLOCKS
39 PHOTOHELIC PRESSURE CONTROL FOR STAND-BY SET
40

NOTES:

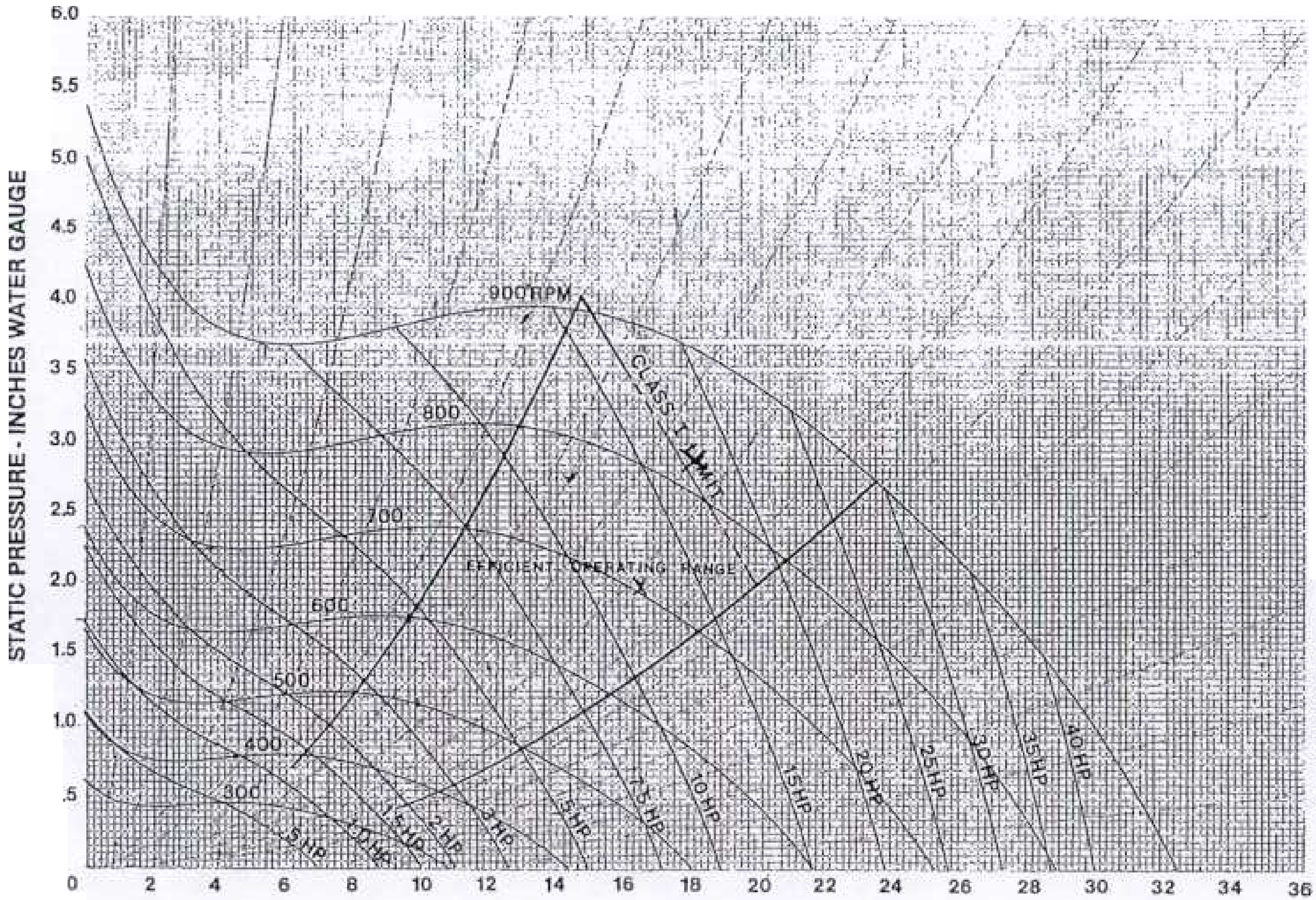
1) • DENOTES ITEMS SHIPPED LOOSE FOR INSTALLATION BY OTHERS
2) PAINT FINISH: LIGHT BLUE ALKYD ENAMEL
3) THIS UNIT TO BE ASSEMBLED AND TESTED IN THE SHOP, THEN SPLIT AS NOTED FOR SHIPPING. ANY FIELD ASSEMBLY REQUIRED FOR INSTALLATION OF THIS EQUIPMENT IS THE RESPONSIBILITY OF THE INSTALLATION CONTRACTOR.

YEADON FABRIC STRUCTURES
WOODBURY
02704
NTS
13APR05

TEMPRITE

TEMPRITE INDIRECT GAS FIRED HEATER
MODEL: GTGM400-CBHM-S
WD BG12014
12014
0

MODEL A22-22H
CLASS I



PHILIPS INDUSTRIES INC.

LAU DIVISION
2027 Home Avenue
Dayton, Ohio 45417
(513) 253-3561

GRAPH NO.	G4582-4
DATE	5-26-87
WHEEL DIA.	22.38
WHEEL WIDTH	22.00
OUTLET AREA	5.1

Performance curves based on test made in accordance with ASHRAE 51-1985, AMCA 210-85. Tested without inlet duct and with discharge duct. Brake horsepower does not include drive losses. Standard Air Density 0.075 lb./cu. ft.

$$SE = \frac{CFM \times SP}{6362 \times BHP}$$

$$BHP = \frac{RPM \times (oz.\ ft.)}{84034}$$

SEE SPECIFICATION DATA SHEET 304 FOR OPERATIONAL LIMITS.